Governor's Office of the Capital City

INTEGRATED PROJECT MANAGEMENT OFFICE

CSCEC AECOM Consultants Co., Ltd

FEASIBILITY STUDY & CONCEPT DESIGN

"FIRST RING ROAD" project

Engineering report Volume I-I

Ulaanbaatar
2025

Foreword

Rationale:

- Government Resolution No. 476 of 2022 of Mongolia on the construction of the "New Ring Road" in Ulaanbaatar City
- Order No. A/1311 dated November 6, 2024, of the Governor's office of the Capital City of Ulaanbaatar
- Concept of the General Development Plan of Ulaanbaatar City until 2040

Terms of Reference for the preparation of the Feasibility Study of the "First Ring Road" Project of Ulaanbaatar City

- Government Resolution No. 173 dated April 9, 2025, of Mongolia on the approval of the start, end, and turning points and coordinates of the First Ring Road of Ulaanbaatar City

The Feasibility Study (FS) and Concept Design of the "First Ring Road" Project of Ulaanbaatar City were prepared between January 9, 2025, and August 31, 2025, under Contract No. UT2402804435, commissioned by the Governor's office of the Capital City of Ulaanbaatar and the Unified Project Management Department SOE. The main objective of the project is to determine the optimal option for the FS and concept design of the "First Ring Road," aimed at reducing traffic congestion in Ulaanbaatar, decreasing road load, and enhancing traffic safety. Within the project framework, three route alignment options were developed, evaluated based on social, economic, environmental, and technical criteria, and the most cost-effective option was proposed to the Client.

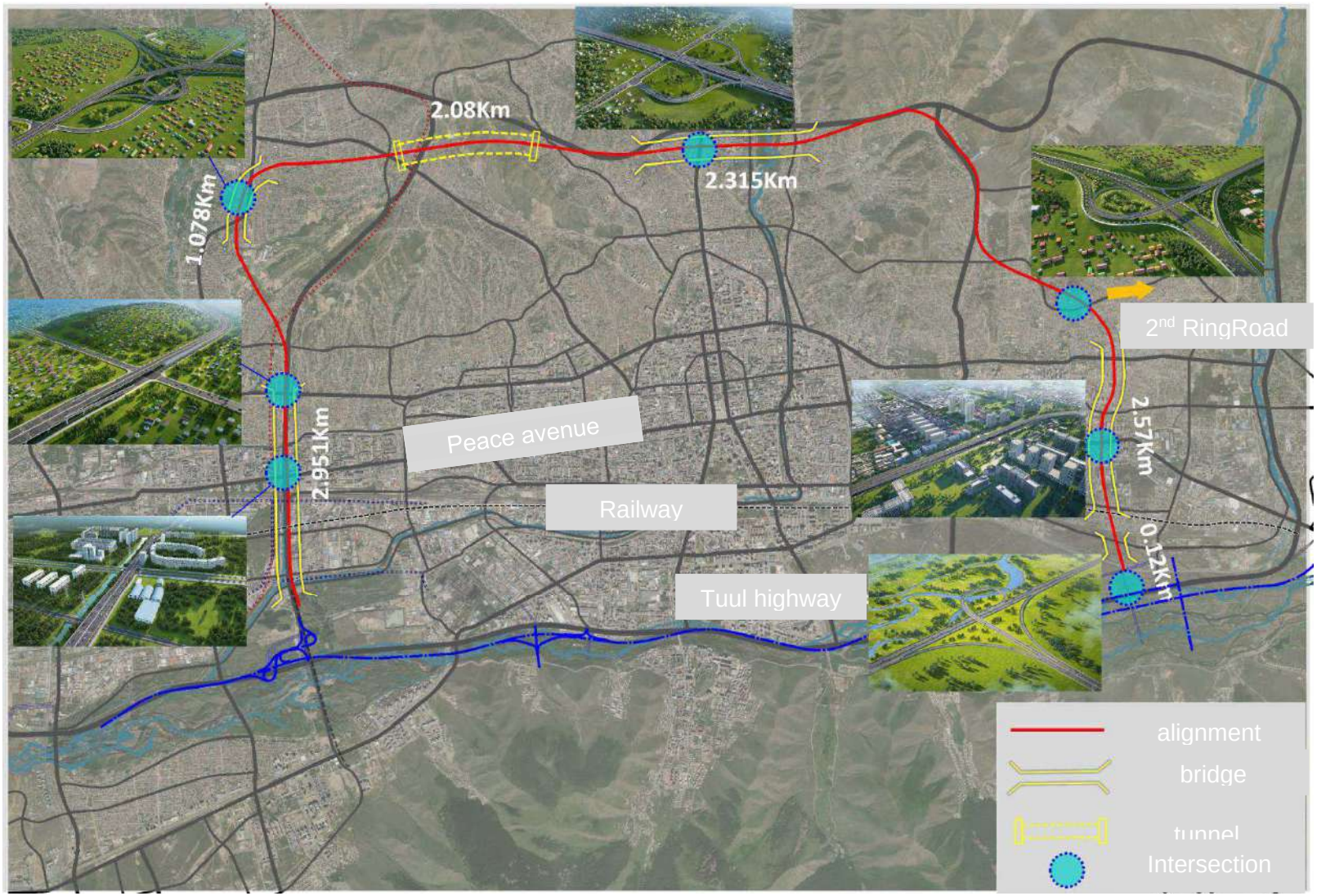
Among the three options developed based on the forecast of road traffic volume and traffic intensity of Ulaanbaatar City up to 2044, technical key indicators, cost estimation, and investment return analysis, Option 1 was identified as having the least adverse environmental and social impacts, being in line with the long-term planning vision of Ulaanbaatar City, and offering the most cost-efficient solution. The alignment of this option circumvents the central settlement area and has been planned in coordination with the existing and planned road network, with all necessary calculations performed.

The proposed Option 1 comprises a total length of 24.793 km, consisting of a combination of bridges, tunnels, and road sections with six lanes, including six bridges, a 2.08 km-long tunnel, seven entry interchanges, 13 transfer interchanges, and 15 access points. According to the study, dividing the construction works into three packages would enable the road to be built in the shortest possible time with the highest efficiency. The total estimated cost of the First Ring Road Project construction is MNT 3.35 trillion, with a construction duration of 24 months. As part of this feasibility study and concept design work, a total of 5 volumes of main reports, 10 reports as annexes, 23 albums, and a 3-minute animation video were prepared.

This complete feasibility study serves as a foundational document for project decision-making and implementation planning, and we are confident it will contribute significantly to the socio-economic development of Ulaanbaatar City.

August, 2025

QING CHU
Representative office in Mongolia of
CSCEC AECOM Consultants Co., Ltd


2.08Km
2.315Km
1.078Km
2.951Km
2.57Km
0.12Km
2nd RingRoad
Peace avenue
Railway
Tuul highway
alignment
bridge
tunnel
Intersection

LIST OF ABBREVIATIONS

EBA	Environmental Baseline Assessment
ESIA	Environmental and Social Impact Assessment (ESIA)
UPRI	Urban Planning and Research Institute
OSNAAUG	Local Government-Owned Enterprise with Independent Accounting
TCP	Toll Collection Point
V	Vehicle
MRT	Ministry of Roads and Transport
RTDC	Road and Transport Development Centre
Gov	Government
STC	Science and Technology Council
MUDCH	Ministry of Urban Development, Construction, and Housing
TMC	Traffic Management Centre
WSSA	Water Supply and Sewerage Authority
UR	Ulaanbaatar Railway
UBEDN	Ulaanbaatar Electricity Distribution Network
UB	Ulaanbaatar
UDHN	Ulaanbaatar District Heating Network
NEMA	National Emergency Management Agency
NEDN	National Electricity Distribution Network
UBEDN	Ulaanbaatar Electricity Distribution Network
UBHDN	Ulaanbaatar Heat Distribution Network
GUP	General Urban Planning
CRKCC	Citizens' Representative Khural of the Capital City
GOCCUB	Governor's Office of the Capital City of Ulaanbaatar
IPMO	Integrated Project Management Office
FS	Feasibility Study

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PROJECT OVERVIEW

1. BACKGROUND

Based on the following key documents:

(i) Mongolia's long-term development policy "Vision–2050";

(ii) The General Development Plan of Ulaanbaatar City until 2040;

(iii) Government Resolution No. 476 of 2022 on the construction of the "First Ring Road" in Ulaanbaatar City;

(iv) Order No. A/720 dated June 19, 2024, of the Governor of the Capital City;

(v) Government Resolution No. 173 dated April 9, 2025, approving the start, end, and turning points and coordinates of the First Ring Road of Ulaanbaatar City—

The Feasibility Study (FS) and Concept Design of the "First Ring Road" Project were developed under Contract No. UT2402804435, signed on January 9, 2025. The project aims to implement significant improvements to the public transport and road infrastructure of the capital city and reduce traffic congestion by a considerable margin.

The following essential social needs and demands have arisen about the development of the First Ring Road Project, which can be briefly summarised as follows:

Project location	Year	GDP	Population	Unemployment rate
Ulaanbaatar city	2005	1 ,762 001.3	972 887	1.7
	2010	6,153,936.5	1 158 691	8.7
	2015	14,704,133,69	1 345 500	6.9
	2020	24,187,785.69	1 499 140	6.3
	2024	55,8278 475.2	1 677 872	5.8

Urban Traffic Load and Congestion: The traffic load on Ulaanbaatar's road network has surged sharply in recent years. Over the past decade, the number of registered vehicles in the capital has increased by 80%, while the road network has only expanded by 19%, resulting in a significant shortfall in road capacity. On average, 300,000–400,000 vehicles operate daily in Ulaanbaatar—double the current network's capacity (Capital City Governor's Office, 2024). Consequently, traffic congestion has reached critical levels, with average vehicle speeds during peak hours dropping to just 7–13 km/h, and the linear length of citywide congestion extending to 97 km. In this context, constructing a new ring road system to divert traffic around the city center presents a key solution. A 2022 study by JICA concluded that one of the root causes of Ulaanbaatar's congestion is the lack of road connectivity and an incomplete network.

Currently, Ulaanbaatar lacks a fully enclosed ring expressway, and most major roads intersect at the city center, compounding congestion. The proposed ring road would allow direct connectivity between peripheral districts, significantly reducing central traffic. Studies indicate that network expansion and the introduction of new roads could ease congestion on main roads

by an average of 20%.

Air Pollution: Vehicle emissions are a significant source of air pollution in Ulaanbaatar. According to the World Health Organization, approximately 10% of Mongolia's total air pollution originates from vehicles in Ulaanbaatar. Particularly during winter and summer seasons, in addition to household emissions, idle engine operation caused by traffic congestion worsens air quality. City policies have recognized this issue by linking air quality improvement efforts with traffic congestion mitigation. For instance, since November 2023, new vehicle registrations have been restricted to reduce congestion, air pollution, and traffic accidents. Implementation of the First Ring Road Project is expected to reduce urban congestion and increase average travel speeds, thereby decreasing idle engine time and resulting emissions. Estimates show that average vehicle speed could increase by 23.3%, leading to proportional reductions in fuel consumption and pollutant emissions. The ring road is also expected to shift traffic away from the city centre, improving public transport efficiency and supporting policies aimed at reducing private vehicle use.

Road Traffic Accidents and Safety: High congestion and poor road network capacity contribute to increased traffic accidents. The majority of road accidents nationwide occur in the capital. For example, in the first eight months of 2017, 25,892 traffic accidents were recorded across Mongolia, of which 89.7% (23,248) occurred in Ulaanbaatar (montsame.mn). Slow traffic, driver frustration, and frequent rule violations are all contributing factors, as noted by the Traffic Police Department. The First Ring Road Project is expected to improve road safety significantly. Designed with multiple lanes, limited intersections, and modern standards, the road will allow drivers to bypass narrow inner-city streets and avoid crossing the city center. This will reduce congestion at intersections and improve traffic flow, thereby lowering the risk of accidents.

Infrastructure Deficiency and Network Gaps: Ulaanbaatar's road infrastructure has lagged behind vehicle growth in recent years. While the number of vehicles has grown by 80% in a decade, the road network has only expanded by 19%, revealing a lack of capacity and integration (visitulaanbaatar.net). Although some partial inner ring roads exist in the city center, there is currently no official high-speed ring road. The proposed ring road would serve as a critical infrastructure link to close existing gaps. It will connect the city's eastern, western, and northern districts directly, eliminating the need to pass through the center and improving network balance. Diverting traffic from central roads to the ring road will also extend the lifespan of existing infrastructure and reduce maintenance frequency. Moreover, the project will lay a foundation for infrastructure development in underserved suburban areas.

Regional Development and Urban Expansion: Beyond managing internal traffic, the First Ring Road holds strategic importance for regional development and road network

expansion. By connecting to key national and regional roads—including those leading to Darkhan-Uul Province, Nalaikh, Choir, and the new airport in Khushig Valley—the project will reduce the volume of transit traffic currently passing through the city and causing congestion.

Economic Impact: The new ring road will improve traffic efficiency, saving time and fuel currently lost to congestion—delivering clear economic benefits. This directly enhances labor productivity and reduces the time individuals and businesses lose in traffic. For example, trips currently taking one hour due to congestion could take just 45 minutes or less, freeing up time for work, services, or daily life. Reduced fuel consumption will also positively impact fuel imports and foreign currency spending. Lower direct and indirect economic losses caused by congestion will benefit both the national and city budgets. According to a 2022 study by the Capital City Citizens' Representative Khural, the direct cost of congestion reaches several tens of billions of tugriks per day. With the new ring road, a significant portion of this cost can be saved, improving the business environment and logistics. Additionally, road construction will create new jobs and stimulate demand in the domestic construction and transport sectors, contributing to macroeconomic growth.

Social Impact: The project is not only expected to improve traffic flow and capacity but also introduce modern design solutions with positive social impacts. The "Complete Street" concept will be implemented along the ring road, enabling the safe coexistence of various transport modes and pedestrians. Side roads will include pedestrian walkways, bicycle lanes, landscaping, lighting, and surveillance systems. This will provide alternative transport options for residents in the city's outskirts, encouraging walking and cycling—beneficial to both public health and urban culture.

Environmental Benefits: By easing congestion and increasing traffic flow efficiency, the project will reduce vehicle emissions—a major contributor to Ulaanbaatar's air pollution (transport.ub.gov.mn). During congestion, vehicles emit large amounts of pollutants (e.g., SO_2, NOx, PM2.5) due to extended idling. A smoother flow reduces such emissions. The reduction of heavy vehicle traffic in urban areas will also minimise dust and noise pollution. Specifically, reduced access of heavy trucks near social infrastructure will decrease noise, vibration, and accident risks. Along the planned road, green spaces will be developed with regionally suitable trees and shrubs, increasing green space per capita, improving air filtration, trapping dust, and enhancing the city's aesthetics. This contributes to a healthier, safer, and more inclusive urban environment.

State Policy in Implementation:

In the 2022 State Budget, MNT 420 billion was allocated to reduce traffic congestion in the capital, and MNT 586 billion was approved in the 2023 Budget for the same purpose (Capital City Governor’s Office, 2024). The Governor’s office of the Capital City of Ulaanbaatar

has included this project in a comprehensive policy package titled the “24 Mega Projects,” aligning it with other ongoing development initiatives. The traffic load on Ulaanbaatar’s road network has significantly increased in recent years, and congestion levels have sharply risen. The rapid growth in the number of vehicles highlights the urgent need for new planning and organisational solutions.

2. PROJECT SUMMARY

Project name:	The First Ring Road
Project scope:	22 km – 26 km
Time:	09 Jan, 2025- 31 Aug, 2025
Client:	The Governor’s office of the Capital City of Ulaanbaatar
Contractor:	CSCEC AECOM Consultants Co,.Ltd
Country:	Монгол улс, Улаанбаатар хот
Project location:	The project route will pass through the following areas: TEC-4 Road, Peace Avenue (Enkhtaivani Örgön Chölöö), Tolgoit, Ard Ayush Road, Bayankhoshuu Intersection, the territory of 10 khoroos of Songinokhairkhan District, Denjiin Myanga Road, Khailaast Street, Doloon Buudal Road, West Altan-Ölgii Street, Da Khüree Street, Khilin Street, Police Academy Avenue, and Dunjingarav Street.

3. RESEARCH PRCESS

The project aimed to conduct a complete feasibility study, develop a concept design based on it, and prepare and submit EPC tender documents for an international open tender to select the contractor to build the First Ring Road. This complete study was implemented in 5 phases, as shown in the diagram below.

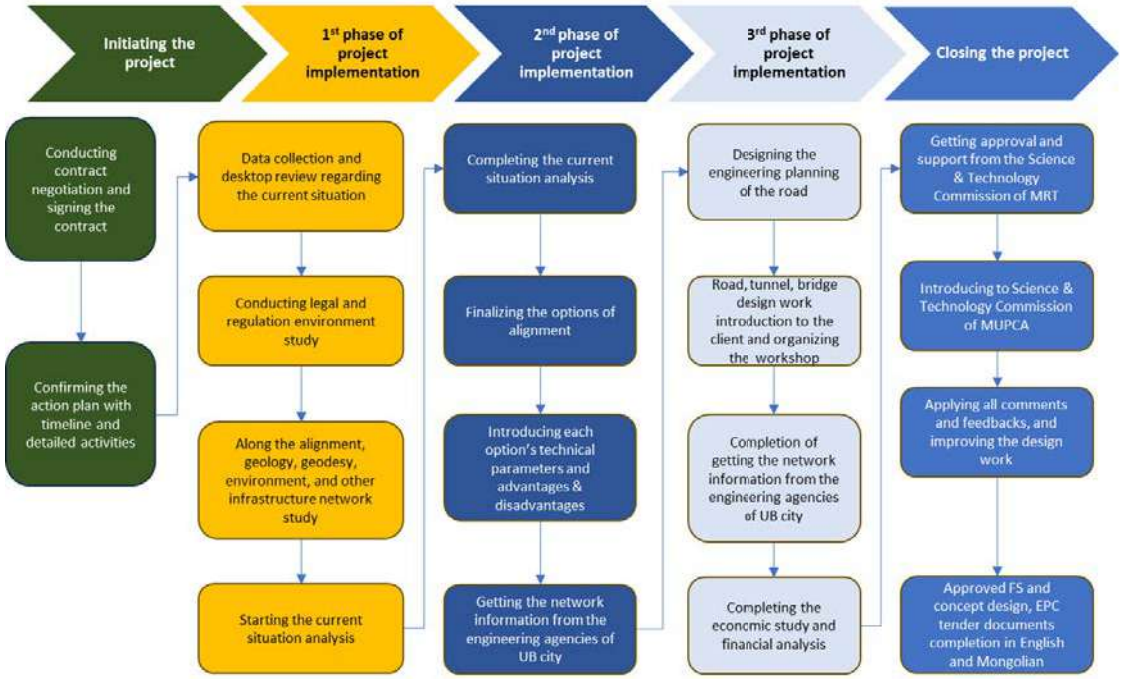


Diagram 1. Consulting service work process

4. CONDUCTED STUDIES

Hydrogeological study: A 24-48 hour drainage test was conducted in a 42 m deep monitoring well, from which the infiltration coefficient and discharge were calculated.

Geotechnical: 3 holes were drilled with a total length of 95 mm and a depth of 25-40 m, and geotechnical documentation of the structure was prepared, from which the rock mass assessment and rock strength and hardness calculations were performed according to JBG standards, and the necessary parameters were determined.

Geodetic and topographic survey: The survey was conducted at a total of 11 geodetic network points, using direct inverse levelling measurements along the road alignment, and produced 1:500 scale topographic maps, orthophotos, and hard point markers.

Historical, ethnographic, archaeological, and paleontological research: No archaeological sites have been identified at the project site, and there are no known signs on the ground. However, it is not ruled out that there may be historical and cultural relics preserved underground. If any historical artifacts are discovered during construction work, it is necessary to notify the relevant organisation, the Institute of Archeology of the Mongolian Academy of Sciences.

Environmental Study: An environmental assessment and an ecological and social impact assessment were conducted within the project. The study concluded that increasing the number of production and service points along the highway route could boost the local budget. By planning green spaces along the road alignment, soil properties will be improved, erosion will be reduced, and the natural landscape will be enhanced.

Research on the deposits of road construction materials: Sand, gravel, stone, cement, reinforcing steel, asphalt, bitumen, crushed stone, gypsum, clay, and power plant ash can be obtained from the vicinity of the capital city.

Legal environment research: More than 10 Mongolian Government resolutions and more than 40 regulations related to road construction are currently being regulated. In Mongolia, there are limited regulations related to highway planning, highway tunnel construction, and route planning. The following rules from China can be registered with the Standardisation and Metrology Administration and reused in the project.

- CJJ 37-2012- Urban Road Engineering Design
- CJJ193-2012- Urban Road and Route Planning Norms
- JTGD60-2015- Highway Bridge Design
- JTG3362-2018- Highway Reinforced Concrete and Concrete Bridge Design
- GB50014-2021- Outdoor Drainage Line Design Standard
- CJJ/T 34-2022- Urban heat supply network planning standards
- GB 50420-2007- Urban green space planning standards

• CJJ 75-97- Urban highway green belt planning standards

• CECA/GC 1-2015- Rules for compiling and reviewing investment estimates for construction projects

• 40-JTG D702-2014- Highway tunnel facility planning

Vehicle Traffic Intensity Study: The transportation study was developed by dividing it into three main parts. These are:

A. Citizen Traffic Study

B. Traffic Intensity and Capacity Study of Highways and Intersections

C. Vehicle speed survey along the highway network and additional vehicle speed survey data along 31.4 km of highway network along five routes. The survey was conducted by installing a “GPS” device on vehicles and collecting vehicle speed data during peak traffic hours or when road congestion is high.

Alignment selection study: Based on the current situation study, urban development, and ongoing project studies, three options were developed with lengths of 24.793 km, 25.8 km, and 26.754 km. These were compared in terms of economics, investment, environmental impact, and technical difficulties.

Calculation of comparison of technological solutions: Option 1, a 24.793 km long route, and Option 2, a 25.8 km long route, were selected, and the three technological solutions were compared in terms of economy and budget costs, and the optimal solution was selected.

Preliminary cost estimate: The estimate was made using China's GLODON Cubicost budgeting software, and then converted to the NormSoft road budgeting software used in Mongolia.

Socio-economic and financial analysis: The economic analysis (EIA) was prepared using the World Bank's "HDM-4 and RED" software. The financial analysis showed that the project could fully recover its initial investment costs within 9 years.- Socio-economic and financial analysis: The economic analysis (EIA) was prepared using the World Bank's "HDM-4 and RED" software. The financial analysis showed that the project could fully recover its initial investment costs within 9 years.

When conducting a risk analysis of the project scenario, NPV =21.603 million. The IRR of $ 12% is expected to decrease. Therefore, when implementing the project, work plans, financing, and preparations for starting construction work will be carefully developed in advance. Also, suppose the relocation activities are organised promptly and the project is implemented within 2 years according to the basic conditions proposed in this economic analysis. In that case, the project will be profitable (IRR = 14%). This research and analysis are unique in that they paid great attention to road safety and made plans to reduce it when developing road design solutions.

Discussion: During the development of the feasibility study, two discussions were held with a total of 75-150 people, including engineers from the client, experts from relevant departments of the Ministry of Land, Infrastructure and Transport, project subcontractors, geodesy team, BONU team, and geology team.

Meetings: 86 working group meetings and meetings were held during the wor

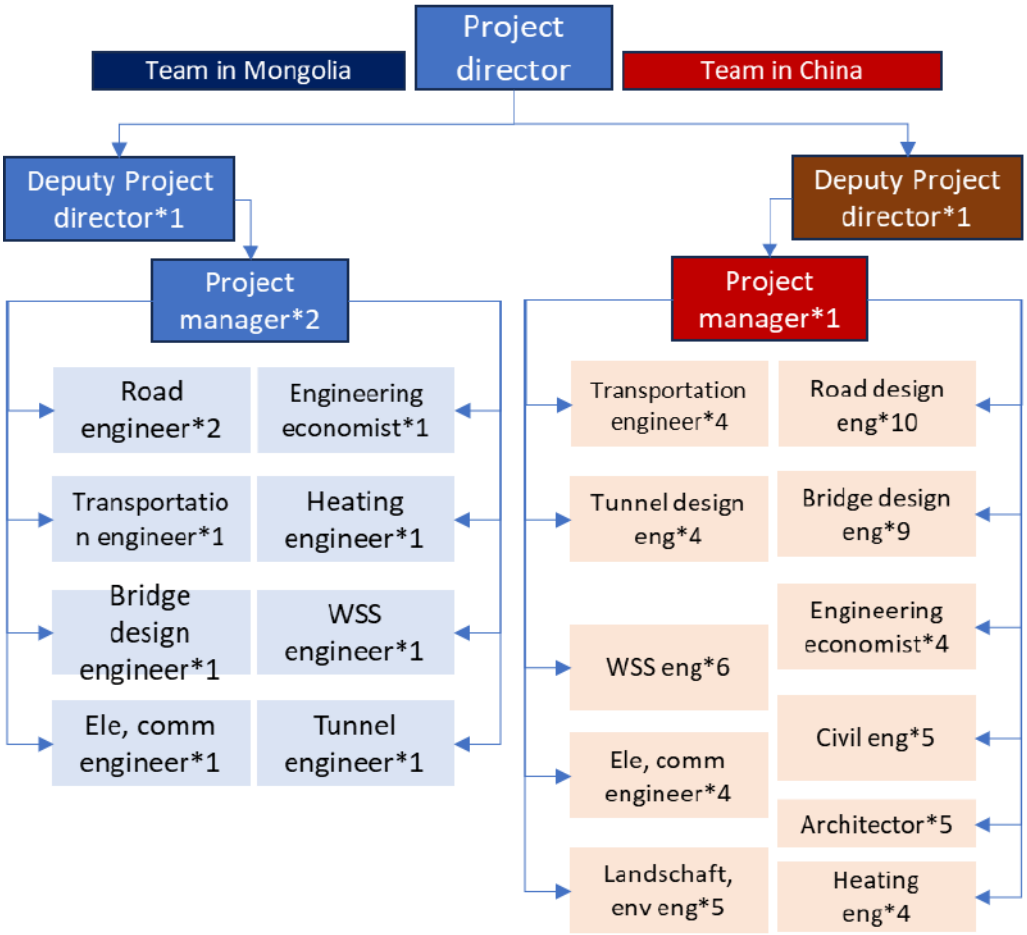
Official number: In developing the plan, clarifications, suggestions, and recommendations were obtained from engineering network providers and relevant state administrative central organisations.

5. TEAM STRUCTURE

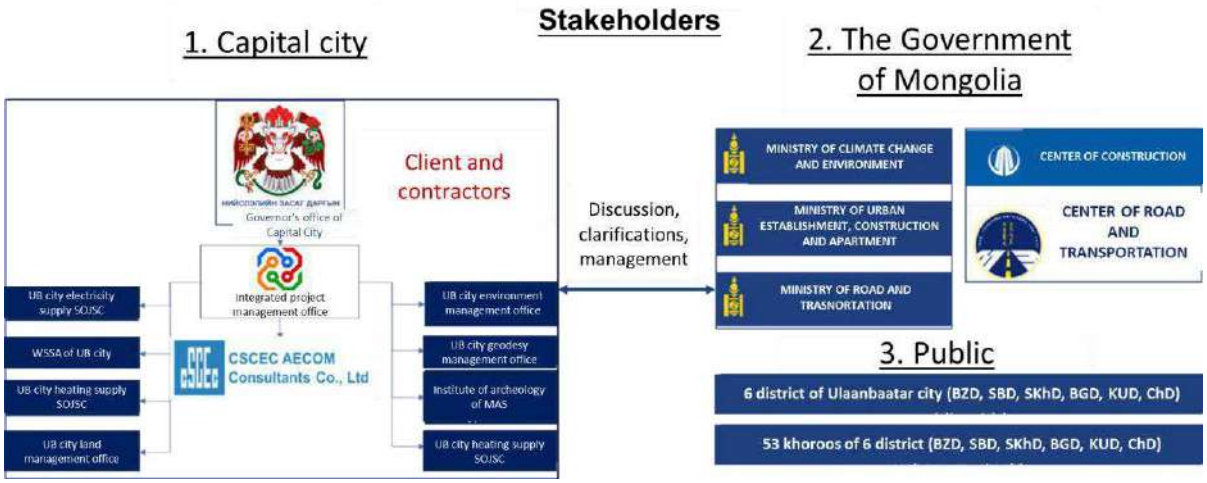
The general contractor is CSCEC AECOM Consultants Co., Ltd. of China. The subcontractors of the project in China were professors from the Chinese Academy of Sciences. The project's external team consists of 75 people, of which 12 experts are based in Ulaanbaatar and 63 experts work remotely from China.

A total of 12 people from the domestic "AUDE" LLC worked as subcontractors. The structure of the team that conducted this major study is shown in the diagram below.

Also, a variety of software and applications were used to conduct the research, and all additional software used is shown in the table below. The stakeholders played a crucial role in ensuring the quality and completeness of the study, with the primary client, the Ministry of Environment, clearly setting out its expectations for the project team and providing guidance on how to comply with domestic laws and regulations. However, the ministry provided exceptional support in activities such as verifying the accuracy of research conducted by departments and obtaining necessary suggestions for improvement through consultation with professional teams.



Research and analysis used	Sogtware names
Geographical information	ArcGIS, QGIS, AutoCAD Map 3D
Traffic simulation and analysis	TransCAD
Engineering solutions and modelling	AutoCAD Civil 3D, EICAD,HintCAD Revit,SketchUp,midas Civil NX, midas Civil Designer, Abaqus ， PKPM、Sap2000、Midas gen、Plaxis
Environmental assessment	ArcGIS, ENVI, Simapro, PRIMAVERA
Financial and economic analysis	Microsoft Excel, HCS, TransCAD, STAN8 Microsoft Excel, HCS, STAN
Project management and planning	Microsoft Project, Primavera P6, AstaPowerproject
Hydrogeological and drainage network analysis	HEC-RAS, SWMM, AutoCAD Civil 3D ,Piping Leader
Geotechnical and structural analysis	PLAXIS, GeoStudio, YJK Architectural Structure Calculation Module, MIDAS GEN, MIDAS GTX NX, Lizheng Geotechnical Engineering Calculation and Analysis Software V7.0PB2
Green infrastructure research	LANDWorks, SketchUp, Photoshop、AutoCAD, 3DS, Lumion
Noise research.	CadnaA,SoundPLAN, NoiseMap, INM (IntegratedNoise Model), ArcGIS, ENVI, Simapro, PRIMAVERA



6. APPROACH AND METHODOLOGIES

This project, which combined feasibility studies and conceptual design, was a highly detailed calculation and research project that required a very short time frame and was also a unique project that required the design of a tunnel structure that had never been seen before in Mongolia. Therefore, the norms and regulations required for the construction of the tunnel structure were calculated and planned according to Chinese norms. However, all calculations for other road and bridge structures were carried out based on the Mongolian Urban Development and Road and Road Construction Norms and Rules "ROAD DESIGN" ZZBNbD 22-004-2016, design standards and regulations (BNbD, MNS, ZTEG instructions), and the specific conditions and requirements of the project. In addition, the following studies were conducted:

- Road transport study
- OD matrix study of public transport
- Vehicle speed study
- Traffic intensity study
- Environmental sustainability assessment
- Environmental and social impact assessment
- Hydrological assessment
- Citizen satisfaction
- Economic and financial analysis
- Widespread deposit survey
- Road damage survey at the intersection with existing roads
- Geological survey
- Geodetic survey, etc., were completed.

All stages of the project study and planning are being carried out step by step, based on the approval of relevant government agencies, the opinions of local stakeholders, and the

actual situation. The results of the study are planned to serve as the basis for the tender documents and technical justification for the selection of the EPC + F contractor.

7. RESEARCH OBJECTIVES

To reduce road congestion in the capital city of Ulaanbaatar, reduce air pollution caused by road congestion, and develop a feasibility study and concept design for the "First Ring Road" project and to prepare the tender documents for the selection of the EPC contractor in English and Mongolian in preparation for an international open tender.

8. KEY RESEARCH RESULTS

To develop a solution for the First Ring Road that would offer high economic and financial benefits, minimal adverse environmental impacts, and a significant positive effect on mitigating traffic's negative consequences, the construction team proposed three route options to the client.

Within the scope of the project, the road alignment was developed in three variants based on the current status study and the provided numerical and data information, and the main technical specifications are shown in the following table.

Option	Total Length (m)	Bridge (m)	Tunnel (m)	Road (m)	Lanes	Environmental Impact	Social Impact	Economic Impact
1	24,793	9,034	2,080	13,679	6	Very Low	Very Low	Very Low
2	25,800	10,005	2,720	13,075	6	Medium	Very High	Medium
3	26,754	8,350	4,710	13,694	6	Very High	Medium	Very High

9. Characteristics of each option

Option 1 is compatible with the planned and existing roads, has the least negative environmental impact, requires the least investment, and is the most feasible option in terms of implementation plan. The advantages of this option include being more aligned with the urban development plan, being closer to the city centre, being able to distribute traffic efficiently and serve sub-centres of the city evenly, having a relatively small number of buildings that will be affected by land acquisition, and not encroaching on the sanitary protection zone of clean water sources. However, in some areas, there are problems related to the relocation of high-voltage overhead line supports.
Option 2 runs through the Bayankhoshuu sub-centre on the flat land on the east side of the river bank in the northwest part of Ulaanbaatar city, with minimal impact from road excavation and land acquisition, and retains space for the development of the city sub-centre on the east side. It is also connected to existing roads, and the construction conditions are favourable. However, this option passes through special needs areas of the city, and there is a risk that the existing roads will be closed entirely during the project implementation, and the transit road will pass through the residential area of Bayankhoshuu sub-centre.
Option 3 is consistent with the road alignment of the Ulaanbaatar City Development Master Plan. Based on this, the road alignment is expanded to the west, north, and east of the city to develop the urban development space of Ulaanbaatar, connecting Bayankhoshuu and Selbe sub-centres in the north. The impact of land acquisition has been reduced by extending the road outwards, away from densely populated urban areas. However, this option has the longest bridges and tunnels, and is associated with significant challenges, such as the amount of investment required and the increased construction time. It also has the disadvantage of having little traffic distribution function, being close to the planned highway that intersects it to the east, and having overlapping functions.

Трассын уг хувилбарууд нь техникийн үзүүлэлтийн хувьд Монгол Улсын авто зам

төлөвлөлтийн норм ба дүрмийн техникийн үзүүлэлтийн шаардлагыг бүрэн хангаж байгаа хэдий ч авто замын хөдөлгөөний замын түгжрэл, хот байгуулалтын орон зайн төлөвлөлт, төслийг хэрэгжүүлэх хөрөнгө оруулалтын хэмжээ, хэрэгжилүүлэх үйл ажиллагааны хүндрэл зэргийн харгалзан Хувилбар 1-ийг санал болгож байна. ТЭЗҮ болон концепт дизайн боловсруулах ажлын хүрээнд нийгэм эдийн засгийн тооцооллыг технологийн 3 шийдлээр хийсэн бөгөөд доорх хүснэгтэд үзүүлэв.

Key parameters of the alignments	Solution 1 (Option 1)	Solution 2 (Option 2)	Solution 3 (Option 1)
Technical parameters			
Maximum Longitudinal Gradient of the Main Road (%)	**4%**	4%	6%
Bridge Length (m)	9,034	10,005	9,310
Tunnel Length (m)	2,080	2,720	0
Embankment Length (m)	13,679	13,075	15,483
Fill Volume (10,000 m³)	337.14	301.84	241.35
Cut Volume (10,000 m³)	420.43	438.93	724.89
Total Length (m)	24,793	25,800	24,793
Construction work (month)	24	28	24
Investment & Operations and maintenance (OM)			
Invetsment (USD)	918,569,840	899,000,000	915,000,000
Cost of the operations and manitenance (USD/km/year)	212,904.3	223,178.5	211,768.1
Negative impact for the environment, socio-economy			
Environmental impact	Low	Medium	High
Social impact	Low	high	Medium
Economic impact	Low	medium	high

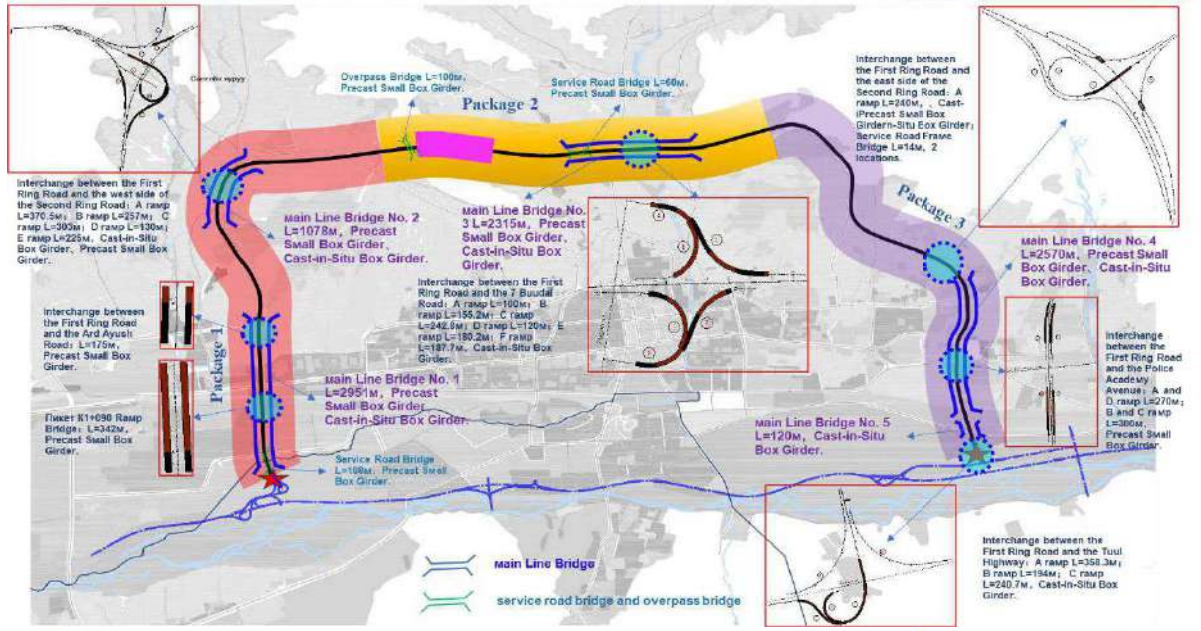
Cost types are divided into three main categories: land acquisition, external engineering infrastructure, and construction, as shown in the table below.

Solution names	Construction (1000 tugrik)	Land acquisition (1000 tugrik)	Engineernig & infrastructure (1000 tugrik)	Total cost (1000 tugrik)
Solution 1 (24.793 км, 4%)	2,622,031,897	510,000,000	219,370,389	3,351,402,286
Solution 2 (25.8 км, 4%)	2,908,157,168	491,300,000	222,092,563	3,621,549,730
Solution 3 (24.793 км, 6%)	2,522,915,111	475,000,000	219,370,389	3,217,285,500

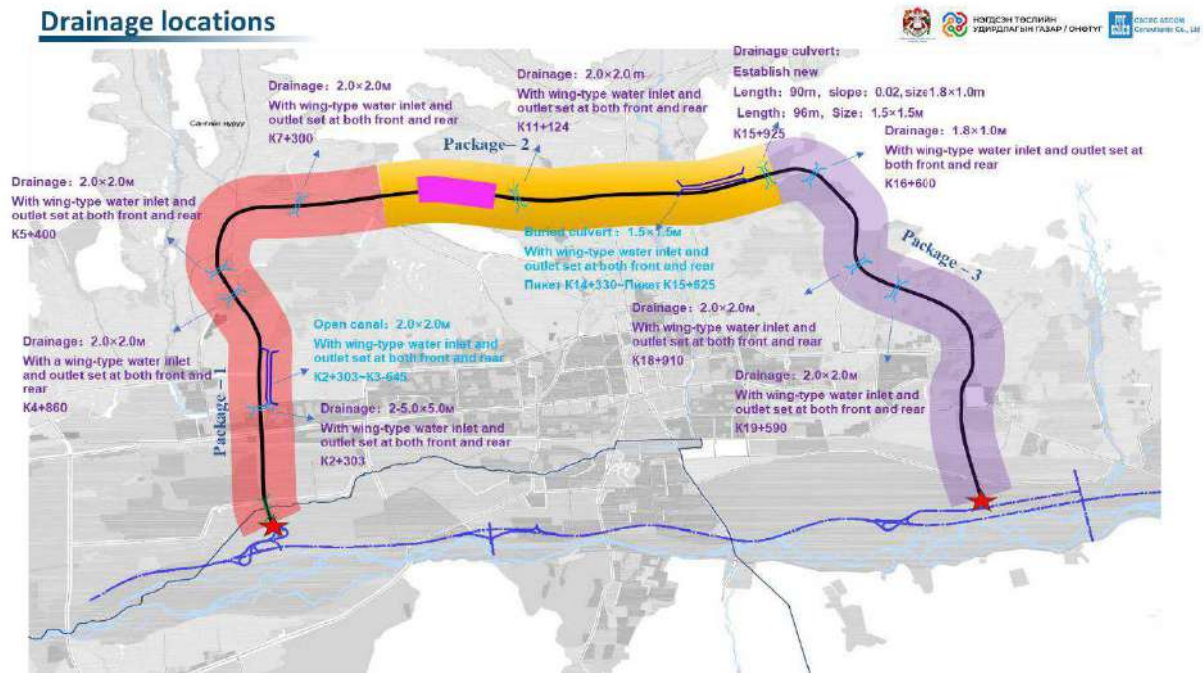
Based on the professional analysis, the study concluded that Solution 1 (Option 1) is the ideal alignment to be implemented. To be more specific, the project can be implemented in a short period, with an estimated time of 2 years or 24 months to put the First Ring Road into operation. It was considered optimal to divide the road alignment into three packages for selecting a construction contractor for each package, and start the three construction projects simultaneously. The following table shows the technical specifications of the package.

Solution 1 (Option 1) 24.793 км, 4%	Bridge length (м)	Tunnel length (м)	Road bed length (м)	Total length (м)
Package 1	4,029	-	4,571	8,600
Package 2	2,315	2,080	2,505	6,900
Package 3	2,690	-	6,603	9,293
Total length (м)				**24,793**

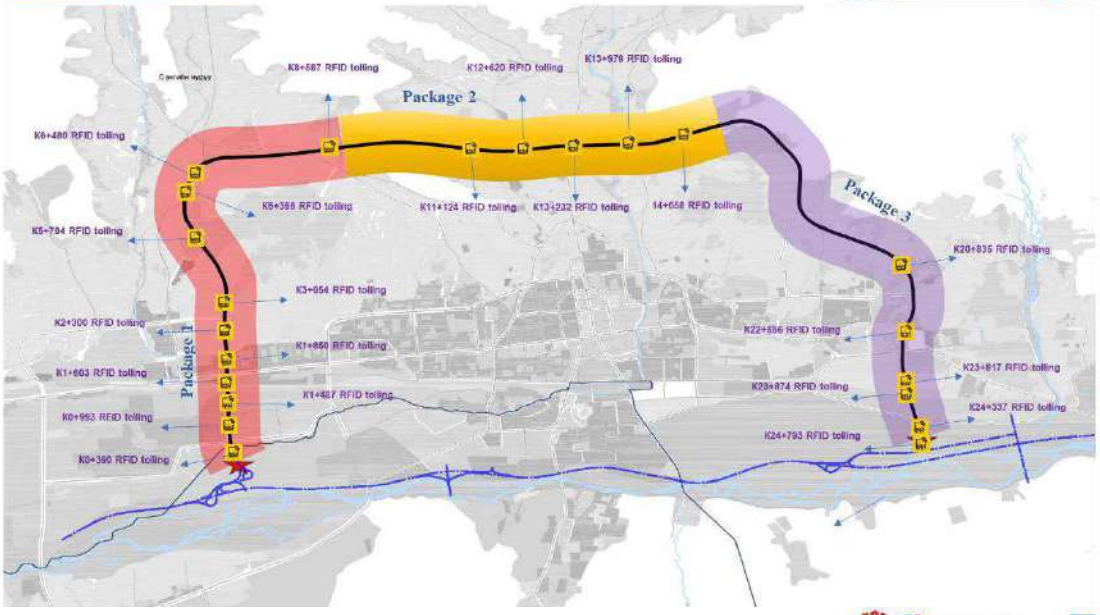
Planned bridge and overpass locations



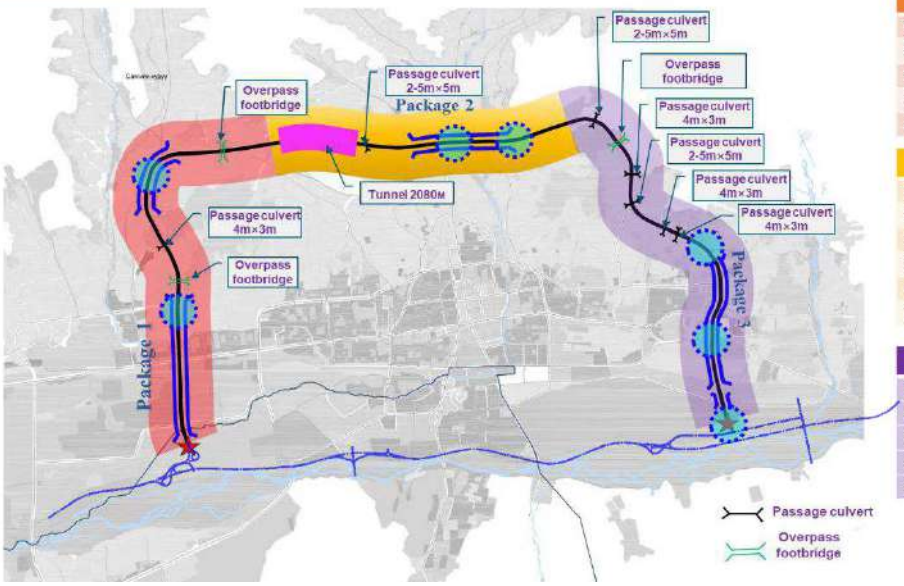
Drainage locations



RFID locations



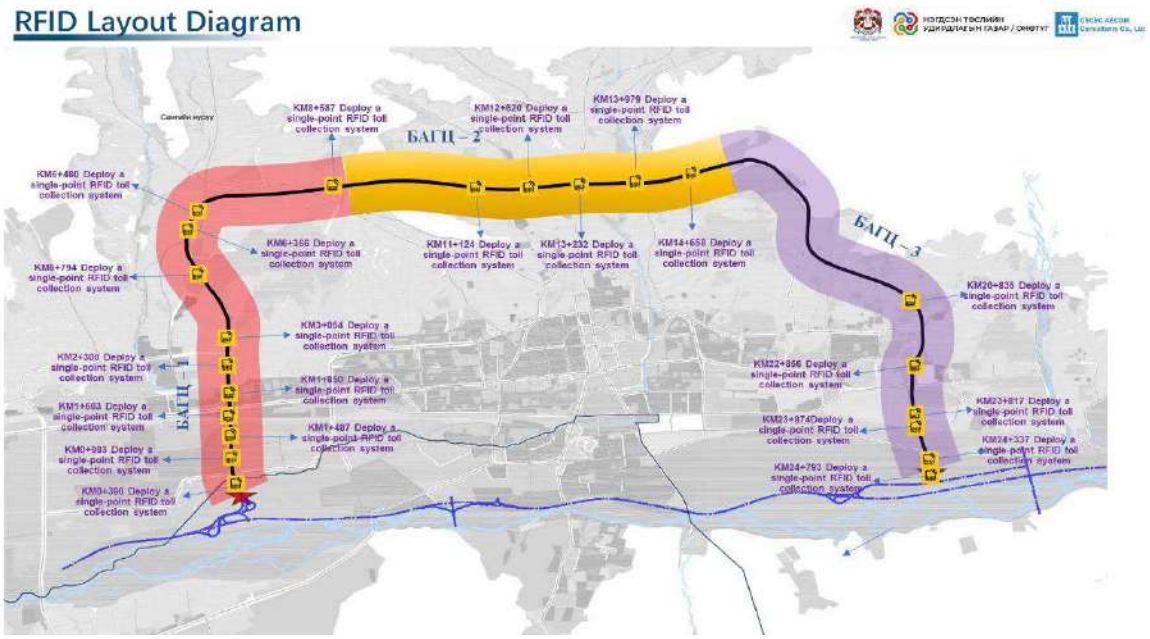
Footbridges and culverts



Package 1	
Total length	8.6 km
Road bed length	4.571 km
Bridge length	4.029 km
Overpass footbridge	2 pcs
Passage culvert	1 pc

Package 2	
Total length	6.9 km
Road bed length	2.505 km
Bridge length	2.315 km
Tunnel length	2.08 km
Overpass footbridge	0
Passage culvert	1 pc

Package 2	
Total length	9.293 km
Road bed length	6.603 km
Bridge length	2.690 km
Overpass footbridge	1 pc
Passage culvert	5 pcs



Average annual daily traffic volume of the planned road - Solution 1 (Option 1) with 4% slope/

Year	2027 он	2030 он	2035 он	2040 он	2044 он
Unit	Veh/day	Veh/day	Veh/day	Veh/day	Veh/day
Number of vehicles	103,223	217,841	263,483	311,648	355,381

Project Evaluation

A. Economic Evaluation of the Total Length

Financial investment cos	918.6 million.$ -Trass 1 (4%)
Modified Rate of Return at 12% Rinvestment Rate	13%
Total Road User Benefits	1001.302 million.$
Net present value (NPV)	217.543 million.$
Internal rate of return (IRR %)	14%
Population served per investment (persons/1000$)	1.9

CHAPTER 1. EXISTING CONDITIONS ANALYSIS

1.1. LEGAL ENVIRONMENT

Purpose of the study

The purpose of the “First Round” project is to determine the legal framework for implementing the project, to create the necessary legal environment for the correct and effective implementation of the project, to assess the current state of legal regulations, to identify potential legal obstacles, conflicts, and regulatory overlaps that may arise during the implementation of the project, and to identify possible ways to resolve them.

More than half of the total population (1.6 million people, 2024) lives in the capital of Mongolia, Ulaanbaatar. In recent years, urbanisation problems such as traffic congestion, road accidents, and air pollution have become serious and have significantly affected the lives of residents. Although Ulaanbaatar accounts for 0.3 per cent of the total territory of Mongolia, it is home to 50 per cent of the total population, 66 per cent of the GDP, 61 per cent of the health services, and 96 per cent of the higher education, which creates many social, economic, transport, and environmental problems. The number of vehicles in the country has been increasing steadily, with an average annual growth rate of 5% since 2015. By 2025, traffic jams will occur at every intersection in Ulaanbaatar. The reasons for this are the underdeveloped road infrastructure, such as roads and parking lots, insufficient enforcement of traffic rules by road users, and inadequate traffic regulation and organisation.

Therefore, to effectively address the above issues, reduce the burden of urban road traffic, and mitigate the adverse effects of traffic congestion, an analysis was conducted of how the Government of Mongolia and relevant organisations reflect short, medium, and long-term policies, strategic directions, and implementation measures in policy documents.

1.1.1. Policy of Mongolia

Mongolia's National Security Concept (2010): It outlines policies in seven primary areas to ensure national security. These are broad policies covering key areas such as Mongolia's independence, social stability, economic security, and foreign relations. The concept states that "In the direction of 'Ensuring the safety of the living environment', the policy of determining the location of satellite cities and implementing the policy of ensuring the safety of the living environment by constructing high-speed highways, energy, and engineering facilities in the vicinity of the city will be implemented." Therefore, the implementation of the "First Ring Road" project is directly related to national security issues, as it is a matter of reducing the concentration and congestion of Ulaanbaatar city and developing infrastructure.

Vision 2050: The Mongolian Parliament adopted the "Vision 2050" long-term development policy of Mongolia by Resolution No. 52 dated May 13, 2020. The policy document proposes nine basic goals and 48 objectives to be organised in three implementation

phases: 2021-2030, 2031-2040, and 2041-2050. The nine basic goals are: (1) National Unified Values, (2) Human Development, (3) Quality of Life and the middle class, (4) Economy, (5) Governance, (6) Green development, (7) Peaceful and safe society, (8) Regional and local development, (9) Ulaanbaatar and satellite cities.

Within the framework of the Ulaanbaatar and satellite city policy, five goals have been set: 1. People-centred city, 2. Environment-centred solutions, 3. Planning-centred development, 4. Good urban governance, and 5. Satellite city. Within the framework of the people-centered development goal (Phase I 2021-2030), a general development plan has been developed for Ulaanbaatar city, taking into account the necessary planning of the expansion and restriction of the settled territory, land organisation, road network, public transportation, and underground space, and linking it to an integrated information system to implement urban development activities.

New Revival Policy: "Strengthening the independence and independence of Mongolia's economy, "Vision-2050" Mongolia's long-term development is a medium-term target program to be implemented over up to 10 years to create the basic conditions for effective implementation of the policy, and to improve the economy, infrastructure, and state productivity. Within the framework of the policy, based on active partnerships between the public-private sector and investors, the implementation of work within the framework of the goals and objectives of solving six sets of problems that limit the development of Mongolia (1. Port revival, 2. Energy revival, 3. Industrial revival, 4. Urban-rural revival, 5. Green development revival) was approved.

Within the framework of the "Urban-rural revival" set of problems, it is specified to implement the project to create a network of "First Ring Road" with a total length of 71.5 km and 11 multi-level intersections connecting the sub-centres of the capital city of Ulaanbaatar. As a result, it is expected that the road congestion index will be reduced by 15-20 per cent.

The three-pillar development policy was developed in line with the Global Sustainable Development Goals (2015-2030), Mongolia's Sustainable Development Vision-2030, the Government's 2016-2020 Action Program, the Economic Recovery Program, and the Development Path Program. Under the concept of "Mongolia with a Unified Purpose," the policy planned three priority areas in an environmentally friendly manner: "Multi-pillar economic development policy", "Just, disciplined, and responsible sustainable governance", and "People-centred social policy", and included 27 goals and detailed project programs to implement them. The 9th goal, "Developing integrated transport, logistics, and infrastructure that supports economic growth and creating a favourable environment for citizens to work and live," includes the expansion and modernisation of the Ulaanbaatar city road network.

1.1.2. Road sector policy

The Vision-2050 long-term development policy stipulates that a total of 16,060 km of paved roads will be constructed within the framework of the goal of expanding and developing a quality and accessible national road, transport and logistics network to ensure the country's economic growth, and providing safe and reliable services that meet the demands and needs of consumers. The five-year development direction of Mongolia for 2021-2025 stipulates that, within the framework of the goal of connecting leading economic regions and sectors with infrastructure, roads connecting strategic deposits with border crossings will be built, and road and transport infrastructure will be expanded to support economic growth and increase exports. The Action Program of the Government of Mongolia for 2020-2024 stipulates that, within the framework of the goal of expanding the road and transport network to ensure economic growth and increase exports, 1,879.65 km of roads connecting border crossings and 920.27 km of roads in tourism areas will be built in 2021-2024. This indicates that the volume of large-scale transport flows passing through Ulaanbaatar will increase in the future.

This action plan also stipulates that major repairs, regular repairs, and maintenance work will be carried out on the 14,918.7 km of international and national road network by norms and standards, and major repairs, renovations, and regular repairs will be carried out on national roads, which will extend the repair and maintenance period of roads, improve their quality, and gradually increase capital resources. The goals and objectives for the development of the road network have been defined in the medium and long-term policy documents of Mongolia, and the "New Revitalization Policy" has set the goal of fully connecting border crossings by rail and road in stages, improving the competitiveness of transport and logistics, improving freight traffic, and creating the basic conditions for becoming a transit country in the future. Within the framework of this goal, it is planned to build a total of 2,954.45 km of paved roads connecting 14 border crossings.

Based on the current traffic situation in UB, urban planning, and socio-economic population analysis, the project plans to build a 13-20 km long, 4-6 lane ring road. This road will be a "full street" combining pedestrian paths, bicycle paths, and green spaces, and will have the characteristics of a multi-functional street. According to preliminary estimates, the implementation of the project can increase the throughput of the city's roads by 7%-23%. In addition, the following projects are planned to be implemented to reduce road congestion in the capital city. These include:

A. High-capacity public transport metro (2024-2030)

B. Tuul Highway and First Ring Road (2024-2030)

C. Under-railway "hole passage" (2022-2025)

D. Pendulum road transport (2023-2026)

D. Special road bus BRT (2024-2028)

E. Light rail "Tram" (2024-2027)

These projects and programs are coherently coordinated and form a comprehensive system that complements each other within the framework of the structure, functions, goals and implementation of the "First Ring Road" project. For example, the main lines of large-capacity public transport, such as metro, BRT, and tram, are planned to be located on the central axes. At the same time, the "First Ring Road" will serve as a line for distributing transport flows in the centralised structure of the capital and regulating cross-regional and inter-regional movements. This will allow the transit points of the above vehicles to be located by the ring road and distribute passenger flows in an open and non-concentrated manner.

57.8 per cent of the standards, norms, and technical documents of Mongolia's roads were approved before 2007, while the remaining 42.2 per cent were approved in the last 10 years. Many issues require the development and coordination of new standards, norms, and technical documents in the road sector.

Within the framework of the above policy and planning, the objectives of implementing major road repairs, maintenance, and modernisation by norms and standards, improving road quality and service life, and gradually increasing investment have been identified. However, 52.9 per cent of the total 308 standards and regulations in the road sector are only testing, inspection, and analysis standards, and due to insufficient regulation of repair, maintenance, and operation (3.9%), there is an urgent need for standard reform and development. Considering the current road load, population growth, and urban planning situation in the capital, the implementation of the "First Ring Road" project with a length of 13–25 km and 4–6 lanes is considered a competent solution to increase the city's traffic capacity by 7–23 percent and a strategically important solution for the proper distribution of transport loads.

The need to study the legal and regulatory environment: The purpose of this sub-group is to guide on eliminating legal conflicts, duplications, and misunderstandings that may arise between the client, contractor, and government agencies during the implementation of the project by studying the applicable laws, regulations, and orders and decisions of the authorized bodies, and to provide guidance on how to expedite and clarify the decision-making process. Although technical and engineering designs, financial calculations, and economic efficiency can be implemented in a coordinated manner, the legal environment is also the basis for ensuring their results and minimising legal disputes and obstacles. The legal framework and issues that protect and properly balance the legitimate interests of citizens, business entities, and government and non-government organizations that will be directly or indirectly affected by this project are mainly addressed, and the legal framework and issues that need to be addressed are primarily related to land acquisition, violation of ownership rights, resettlement, and environmental impact.

1.1.3. Legal framework related to the release of land owned and occupied by citizens affected by the project land acquisition:

Method of land repossession by the state: Within the framework of the above legislation, land repossession and land acquisition activities can be carried out in two ways: voluntary and compulsory. The Law on Land Ownership for Citizens of Mongolia legalises the compulsory repossession of land for disaster prevention activities in the event of a disaster, dangerous phenomenon, accident, or danger that may cause significant damage to the health or life of many people, livestock, or property. In other cases, land acquisition activities are carried out only by mutual agreement with the landowner and by providing compensation. However, there is no issue of giving compensation to the person using the land.

Principles to be followed in land acquisition: Adherence to the following principles is necessary: listening to affected citizens, ensuring full participation, providing fair compensation, and basing all decisions related to land acquisition on the law. Although the current Land Law and the Law on Land Ownership for Mongolian Citizens do not contain detailed regulations on the participation of citizens and legal entities in the planning process and their hearing, Articles 73-81 of the General Administrative Law, which came into effect on July 1, 2016, contain specific regulations on ensuring the participation of persons whose rights and legitimate interests may be affected in large-scale construction, urban and land planning, conducting hearings, and organising discussions. Article 3, Section 3.4 of the General Administrative Law states that "This law shall regulate relations other than those regulated by a specific law that governs the activities of administrative bodies," which is mandatory for the activities of administrative bodies at all levels and is compulsory for land acquisition within the framework of a project.

Legal basis for land acquisition: In Ulaanbaatar, a densely populated city, land is needed to implement development projects that address social issues caused by unplanned urban sprawl, uncoordinated land allocation, and over-concentration. This increases the need to create legal regulations for compulsory land acquisition based on social necessity. Article 10 of the Law on Reducing Traffic Congestion in Ulaanbaatar City and Housing Ger Districts, adopted in 2023, legalises 18 types of sectors in which land can be acquired based on social necessity. Article 10.2.10 of the law includes "highways and railways, bridges, tunnels, and crossings," which is a basis for considering the "First Ring Road" project as a social necessity. However, the law does not specify the criteria and indicators for evaluating a social necessity as a social necessity, and what must be proven, which may lead to human rights violations. Also, Article 10.3 of the law states that "When deciding on compulsory land acquisition, at least 70 per cent of the land owners, persons with the right to land ownership, and citizens and legal entities who are affected by the project or measure must have received support." The initial

criteria for a project to be supported are that the Government considers the project to be a social necessity and officially makes a decision, the decisions and resolutions included in the general and partial plans of Ulaanbaatar City have been approved by the City Council, public discussions have been held, and a consensus process has been implemented. The land affected by the project has been assessed in accordance with the justification and procedures specified in the law. After these requirements are fully met, the legal conditions for compulsory land acquisition will be established.

1.1.4. Differences in legal regulation:

The Law on Reducing Traffic Congestion and Housing in Ger Districts of Ulaanbaatar, the Capital City, stipulates that land acquisition shall be carried out if at least 70 per cent of the citizens affected by the project's facilities have expressed their opinions and accepted them. However, Article 14.7.1 of the Law on Urban Development stipulates that "the project shall be presented to the owners and possessors of land and immovable property in the selected area and at least 80 percent of them shall be given their consent;" which is a legal construct in one sense, but it is possible to resolve the issue within the framework of the method of interpreting the law and applying the norms.

Considering the objectives, regulatory relationships, and chronological order of the above two laws, the objectives of the Urban Redevelopment Law are to redevelop built-up areas of settlements, to plan for the demolition and reconstruction of non-compliant buildings, and to regulate relations related to the new construction and redevelopment of ger districts, while the objectives of the Law on Housing Ger Districts to Reduce Traffic Congestion in Ulaanbaatar City are to increase the conditions for unhindered travel for citizens, improve the types and accessibility of public transportation, and the use of parking lots, and reduce the social and economic impacts of congestion and environmental pollution, or they are different in terms of legal objectives.

According to the type of urban redevelopment activity specified in Article 12 of the Law on Urban Redevelopment, it is the construction of new buildings and structures in the newly planned area of the city, and in turn, creates a favourable environment for people to live and reside in the area. The Law on Housing Ger Districts to Reduce Traffic Congestion in Ulaanbaatar City is characterised by the construction of roads, road structures, and engineering structures based on essential social needs without completely vacating the land and reallocating it to citizens. Therefore, the criteria for implementing the "New Ring Road" project, as specified in the Law on Housing Ger Districts to Reduce Traffic Congestion in Ulaanbaatar City, are that at least 70 per cent of the citizens affected by the project must support it.

Table 1. 1. Legislation related to land acquisition

Law, approved date	Relationships and content that are important to regulate
Constitution of Mongolia 1990.01.13	6.4. The State may impose obligations related to land on the landowner, exchange land with compensation or reclaim it for special state needs. It may confiscate it if it is used contrary to the interests of public health, environmental protection, or national security. 16.3. If the State or its competent authority expropriates private property based on unavoidable public necessity, it shall pay compensation or value. Provision 16.3 of the Constitution expands on the compensation referred to in 6.4, stipulating compensation for the requisitioning of other private property as well.
Law on Land 2002.06.17	The purpose of this Law is to regulate the relations concerning the possession and use of land by citizens, business entities, organisations, and other related entities. It serves as the fundamental law governing land-related legal relations. The Law defines the concept of land clearance, rights and responsibilities of land possessors and owners, powers and functions of competent authorities, special requirements, and procedures for dispute resolution. Specifically: **Government of Mongolia**: The Government shall have the authority to designate land for special needs for implementing nationally significant development and infrastructure projects, establish procedures for land use, and transfer such land to competent authorities. **Citizens' Representative Khural of the Capital City (hereinafter referred to as "CRK")**: Based on the proposal of the respective Governor, the CRK shall have the authority to designate land for special needs within the capital, aimag, or soum, determine its size, boundaries, and usage procedures. In case of special need designation, it shall also decide on the provision of compensation based on the Governor's proposal. **Governor**: The district Governor may participate in the project by providing input on the phased development plan of the city and the annual land management plan. In case of a Government decision to exchange or reclaim land with compensation, the respective Governor shall enter into agreements with citizens or entities and implement the land clearance activities. **Administrative Authority – General Authority for Land Administration and Geodesy (hereinafter "GALAG")**: This authority shall organise the land planning for state special needs, provide land status and quality assessment, monitor and evaluate quality changes at the national level, approve the procedure for maintaining cadastral records, and implement court-ordered land confiscation decisions. **Compensation and Land Clearance Period**: Land clearance may be conducted only **between May 15 and September 15**. The Governor shall provide compensation within 60 days, and the land possessor or owner shall vacate the land within 30 days from the full receipt of compensation. **Dispute Resolution**: Disputes related to the Governor's decision or land clearance and land fees shall be resolved by the Capital City's Land Dispute Resolution Council. If unsatisfied with the Council's decision, parties may appeal to the Administrative Court.
Law on Allocation of Land to Mongolian Citizens for Ownership 2002.06.27	The purpose of this law is to regulate the relations arising from the allocation of land for ownership to Mongolian citizens. It specifies the mandatory procedures to be followed in cases of land exchange or reclamation with compensation due to state special needs. **Government of Mongolia**: The Government may decide to exchange or reclaim land based on state special needs, with compensation, and shall approve the methodology for land-based valuation. **Administrative Authority – GALAG**: Shall provide professional guidance to the Governor, and in cases of land reclamation with compensation, may negotiate with the landowner on behalf of the Government. **Notice Period and Its Consequences**: Decisions to exchange or reclaim privately owned land based on state special needs must be preceded by negotiation with the landowner at least one year in advance. Article 32.5 outlines the conditions for such bargaining. If such notice is provided, the citizen shall not be compensated for any fixed structures or increased land value created after receiving the notice.
Law on Reducing Traffic Congestion and	The purpose of this law is directly aligned with the goals of the "New Ring Road Project" — to improve mobility for citizens and reduce the social and economic impacts of congestion and environmental pollution.

Law, approved date	Relationships and content that are important to regulate
Redeveloping Ger Areas in Ulaanbaatar City 2023.12.07	This law defines the concept of "unavoidable public necessity" as stipulated in the Constitution of Mongolia, and regulates principles for land clearance, forms of compensation, valuation of land and property, and other related matters. **Grounds for Unavoidable Public Necessity**: Roads, railways, bridges, tunnels, and crossings are classified as land subject to clearance based on unavoidable public necessity. **Fundamental Requirements for Land Clearance Decisions**: Implementation must have at least 70% support from affected citizens, comply with general and detailed urban plans, and be based on a Government resolution. **Government of Mongolia**: Shall adopt procedures related to land clearance based on unavoidable public necessity. **Governor**: The Capital City Governor shall have the authority and duty to clear land for the implementation of traffic congestion reduction projects and programs. **Authorised Information Provider**: The Law designates the Capital City Traffic Management Centre as the institution responsible for registering, analysing, monitoring, and studying congestion, and providing information to competent authorities. **Regulation on Land Clearance Based on Unavoidable Public Necessity Government Resolution No. 91, 2024.03.06** By Article 10.1 of the Law on Reducing Traffic Congestion and Redeveloping Ger Areas, this regulation governs relations related to land clearance based on unavoidable public necessity. **Government of Mongolia**: Project locations and boundaries (hereinafter "project area") shall be included in the Capital City's annual land management plan. **Land Clearance Procedure and Implementing Entity**: The Capital City Land Department shall organise land clearance activities. Steps include: • Public consultation, • Asset valuation, • Signing land clearance agreements, • Transferring land possession/ownership rights, • Handover to the project implementer, • Issuance of possession rights to the implementer. **Asset Valuation Entity and Costs**: Valuation shall be carried out by a licensed entity. The Capital City Land Department and the project implementer shall bear the costs. **Dispute Resolution**: All disputes except those related to valuation shall be resolved by the Capital City's Land Dispute Resolution Council by Article 601.1.3 of the Law on Land. Valuation-related disputes shall be resolved exclusively by the court.
Regulation on Land Clearance Based on Unavoidable Public Necessity Government Resolution No. 91, 2024.03.06	By Article 10.1 of the Law on Reducing Traffic Congestion and Redeveloping Ger Areas, this regulation governs relations related to land clearance based on unavoidable public necessity. **Government of Mongolia**: Project locations and boundaries (hereinafter "project area") shall be included in the Capital City's annual land management plan. **Land Clearance Procedure and Implementing Entity**: The Capital City Land Department shall organise land clearance activities. Steps include: • Public consultation, • Asset valuation, • Signing land clearance agreements, • Transferring land possession/ownership rights, • Handover to the project implementer, • Issuance of possession rights to the implementer. **Asset Valuation Entity and Costs**: Valuation shall be carried out by a licensed entity. The Capital City Land Department and the project implementer shall bear the costs. **Dispute Resolution**: All disputes except those related to valuation shall be resolved by the Capital City's Land Dispute Resolution Council by Article 601.1.3 of the Law on Land. Valuation-related disputes shall be resolved exclusively by the court.

Law, approved date	Relationships and content that are important to regulate
Law on Asset Valuation 2022.06.17	The purpose of this Law is to define the legal basis for asset valuation, regulation, supervision, rights and duties of government agencies, legal entities, and individuals involved, and to regulate the establishment of a valuation information system. **Basis for Valuation**: Article 5 sets out the grounds for asset valuation. Specifically, Article 5.2.5 stipulates: "valuation of assets subject to reclamation for state and local needs," which directly applies to the land clearance under the "New Ring Road Project." **Valuation Procedure**: The procedure for valuation related to compensation shall be jointly approved by the Ministry of Construction and Urban Development and the Ministry of Finance. **Dispute Resolution**: If a citizen disagrees with the valuation, they may select another licensed appraiser, submit objections before final approval, and claim damages if the valuation report violates legal requirements.

1.1.5. Recommendations related to land acquisition

This recommendation is based on a study of how the Administrative Court resolved land acquisition disputes between administrative bodies and citizens between 2021 and 2024. According to the results of the study, violation of the basic principles of the General Administrative Law (GALC) during the approval and implementation stages of land management plans is a basis for considering the administrative decision as illegal, and further, for the court to invalidate the land management plan and the part of the project that is relevant to citizens. In this regard, there is a risk that the project, its related design and budget will be changed, and the project implementation will be stalled.

For example, the court considered the following situations to be violations of the law. These include:

- Failure to develop a land management plan based on the grounds of the General Administrative Law;

- Failure to provide citizens with advance information and participation;

- Failure to adhere to the principle of protecting legitimate expectations during the project implementation process.

- Violation of the procedure for delivering the “Hearing Procedure” to a large number of persons as stipulated in Article 27 of the Civil Procedure Code

In some cases, even if the land owned and used by a citizen is not directly affected by the impact of the road, if the court has sufficiently determined whether the entrance and exit are completely blocked, or if there is a situation where health and safety for people to live in it have been lost, it is appropriate to consider it as affected and provide compensation. Furthermore, it was deemed necessary to ensure citizen participation in the project's development stage and accompanying planning documents, to consider the opinions of citizens who have expressed interest in participating, and to plan measures to mitigate potential negative impacts in advance. Based on these grounds, the court's decisions, and the administrative body's decision made in the absence of citizen participation and in circumstances where the issue was ignored, the

administrative body's decision is considered to violate the law or be invalid.

The new ring road project is essential for reducing traffic congestion in Ulaanbaatar and supporting urban development. Still, it is necessary to note that the following multifaceted risks may arise during the land acquisition stage.

1.1.6. Risk factors

Legal risks: Land acquisition related to the relocation of households living in the project-affected areas, and the modification and relocation of energy, engineering networks, and buildings is the most problematic issue. Article 10 of the Law “On Reducing Traffic Congestion in Ulaanbaatar, the Capital City, and Housing in Ger Khorool” approved by the Mongolian Parliament in 2023 defines 18 types of sectors that can be acquired based on social imperatives. Article 10.2.10 of the law states that “highways and railways, bridges, tunnels, and crossings” constitute a basis for the “New Ring Road” project to be considered a social imperative. However, although the name of the law suggests it has detailed regulations, the law does not specify the criteria and indicators for determining “urgent needs of public interest” or social imperatives.

This shows that the main principle of resettlement policy of the World Bank and Asian Development Bank, Article 16.3 of the Constitution of Mongolia, Article 17 of the UN Universal Declaration of Human Rights, and the “least intrusive means” or “last resort” as stated in the resettlement policy, is not entirely consistent with international legal norms, such as “least intrusive means” or “least intrusive means” and “least intrusive means” as stated in the international law. In addition, since the implementation of the law, there have been no recorded cases of administrative bodies, such as governors, filing lawsuits in court and resolving cases of forced land acquisition. Therefore, when making decisions related to land acquisition, it is necessary to strictly adhere to the basic legal principles of prior agreement with citizens, realistic agreement on the time and price of land acquisition, ensuring citizen participation, notification, hearing, and obtaining opinions. The failure of citizens and legal entities to accept administrative decisions, land acquisition assessments, and compensation poses a risk of creating legal disputes and hindering the implementation of decisions. It is important to note that the fact that 70 per cent of affected communities supported land acquisition is only an indicator of support for the project and is not the sole basis for the forced land acquisition of the remaining communities.

Socio-economic risks: There is a risk of a decrease in the standard of living of the displaced communities, loss of income, and other problems. Therefore, it is necessary to fairly assess compensation, ensure adequate employment, carefully plan the resettlement policy, and study the timing issue**.**

Financial risks: The planning route (as indicated in option No. 1) passes through 53

khoroos in 6 districts, and the area within a radius of 300 m from the route and within 600 m covers a total area of 191.7 hectares, 3,799 units, and 6,941 buildings. According to preliminary estimates, the cost of land acquisition is estimated to be 748.5 billion tugriks, and there are risks such as land acquisition costs exceeding the original plan, additional costs due to compensation disputes, and investment interruptions.

Environmental risks: When carrying out work in protected areas such as historical and cultural monuments, green spaces, and water sources, there may be negative environmental impacts, which require careful obtaining of relevant permits and assessments.

Project implementation risks: There are risks such as project delays, work failures, and contractual obligations (on the part of the client). Mongolian regulations are essential for project implementation, and relevant rules are shown in Appendix 1.

Management and organisational risks: Incomprehensible communication with citizens during the planning and implementation stages, lack of information, multiple stages, and poor coordination can cause misunderstandings and negatively affect the reputation of the project.

Technical Risk: Engineering Complexity – Relocating facilities such as substations, high-voltage lines, and central heating mains requires detailed design, calculations, and engineering solutions.

Power outage risk: There is a possibility of service interruption to customers during the renovation. Address any issues that may arise in this regard. Land location conditions – If a new location cannot be selected, the design and planning work will be delayed.

Cost Risk: Additional Cost Increase – There is a risk of exceeding the budget included in the Preliminary Feasibility Study. Tender Requirements – There is a risk of loss of time as a licensed organisation is required for the relocation work. Certification Costs – There will be additional costs such as testing, connection, and certification.

Legal and Regulatory Risks: Ownership Disputes – If an agreement cannot be reached with the owner of the transmission line and substation, disputes related to ownership will arise. Delays in Granting Permits – There is a risk of loss of time as multiple stages of permits are required. Compensation Issues – There may be disputes over the amount of valuation and compensation.

The relocation, modification, and transfer of energy facilities within the framework of the New Ring Road Project is a comprehensive operation that is technically complex, legally complex, and requires organisational coordination. Therefore, to organise the above activities effectively and continuously, it is necessary to calculate the engineering solution from the design stage carefully. This includes creating conditions for temporary connections and an uninterrupted power supply, which are basic measures to prevent technical difficulties.

Secondly, to mitigate legal risks, it is essential to assess ownership disputes and consult with citizens through an external evaluation. Thirdly, it is necessary to estimate the costs and budget increases related to the above activities in advance.

1.1.7. Legal basis for implementation

The process of transferring, re-planning and protecting engineering networks, including telecommunications facilities, is regulated by the following laws. These include:

- Law on Telecommunications
- Law on Construction
- Law on Land
- Law on Highways
- Law on Environmental Impact Assessment
- Law on State and Local Property
- Law on the Construction of the Republic of Kazakhstan, technical instructions and regulations

These documents provide detailed regulations on which organisations to obtain what permits in the case of transferring networks, who will draw up technical conditions, who will bear the costs, and how to confirm the choice of a new location. The stages of implementing telecommunications networks, norms, and rules, as well as the methods commonly used worldwide for setting road tolls, are presented in Appendix 2.

1.1.8. Regarding tolls and travel speed limits

Toll roads in cities serve not only as a revenue-generating means but also as a traffic flow management tool. Many factors influence the successful implementation of a toll road system, and it is necessary to study the legal framework and international experience. This subsection compares standard methods of setting tolls in different countries, their features, and toll rates. It also concludes that there is a legal possibility to make the “First Ring Road” toll-free.

1.1.9. International experience and domestic regulations on setting road tolls:

Toll roads have the following objectives: 1) Reduce traffic congestion, 2) Reduce environmental pollution, 3) Promote public transport, and 4) Generate funding. Within the framework of the objectives of reducing traffic congestion and promoting public transport, the main aim is to change the driving habits and create incentives for using public transport by introducing taxes and fees. In large cities with high population density such as Singapore, London, and Stockholm, Sweden, regulations are implemented in such a way that the toll for that area increases based on road demand, i.e. in the city center or high-traffic areas, and at the beginning and end of work hours (usually during the evening peak hours 07:00–10:00,

16:00–19:00).

However, within the framework of the objective of reducing environmental pollution, regulations are standard in which the toll for using the road increases depending on the age of the vehicle, engine capacity, weight, and category. For example, in 2017, London introduced the Toxicity Charge (T) as part of its efforts to reduce air pollution. This charge is a £10 surcharge for older, non-Euro four vehicles with petrol or diesel engines manufactured before 2006 that are likely to cause air pollution in central London. The following countries were selected for comparison, taking into account the long-standing success of road charging systems, the specific characteristics of the regulations (which will help you choose the most suitable option for your country), and the differences in economic levels. In doing so, the amount of road charges used was compared individually, as a percentage of the average wage of the population living in the country or region. It should be noted that the percentages given below are averages of all indicators and vary depending on the distance travelled, the year of manufacture, the engine capacity of the vehicle, and the start and end times of work.

Table 1. 2. Average road tolls and the ratio of average wages to toll burden

City / Country	Type	Fee ($/day)	Avg. Salary ($/month)	Payment Burden	Notes
Singapore	Intelligent Electronic System	1.5 – 3.5	4,500	0.78%	Rates increase during peak hours and are dynamic, based on zone and time.
London (UK)	Congestion Charge	20	4,900 – 5,200	10.9%	Free of charge from 18:00 to 07:00.
Stockholm (Sweden)	Peak Hour Charge	2 – 4.7	4,020	2.8%	Higher rates during peak hours.
Milan (Italy)	Emission-based Charge	2.3 – 4.6	4,812	3.5%	Depends on vehicle emissions.
Seoul (South Korea)	Tunnel Toll	1.5	2,800	1.6%	Charged per tunnel passage.
Tokyo (Japan)	Expressway Toll	3.5 – 7	4,000	1.7%	Tolls are charged per highway section.
Oslo (Norway)	Road Toll (Ring Toll)	2 – 4	5,812	1.5%	Higher rates during peak hours.
Paris (France)	Climate-based Classification	3.4 – 6	3,500	5.0%	Based on vehicle classification.
Zurich (Switzerland)	Annual Fee	1	7,300	0.6%	Annual payment scheme.
Poland	Planned Congestion Charge	8 – 14	1,700	3.2%	Varies based on total distance travelled.
Note: *The average payment burden for road charges is 3.2% of the monthly salary.* *As of April 2024, the average monthly salary in Ulaanbaatar was* ***2,755,800 MNT****, and* ***3.2% of that is 88,185 MNT****.*					

For road projects financed by international development banks such as the World Bank, ADB, and EIB, it is recommended that the road toll system should not reduce the standard of living (study the cost burden on households), exempt public transport and vulnerable groups

from paying, and have a flexible tariff system. The Law on Roads of Mongolia sets road tolls for different road categories by other authorities. According to Article 30, Clause 30.1 of the Law, the Government, the Capital, and the Citizens' Representatives' Meeting of the respective aimag and capital city shall set the tolls for international, national, and special-purpose roads and road facilities. By the above regulations, the Government and the Citizens' Representatives' Meeting of the respective aimag and capital city shall set and enforce road tolls within their respective territories and jurisdictions. Article 4.1.73 of the Law states that ""capital road" means a road within the territory of Ulaanbaatar city, its satellite cities, and districts;" As stated, the newly constructed New Ring Road belongs to the capital city's quality roads, so the road usage fee is regulated by the Capital City Citizens' Representatives' Meeting. However, no standard sets the fee differently for a specific road route from other roads. However, the Government has approved the "Ulaanbaatar-Khushi Valley New Airport Highway Usage Fee" by Resolution No. 282 of 2019. Although the Capital City Citizens' Representatives' Meeting has the legal possibility to set a special fee for the New Ring Road, it is necessary to improve further the legal regulations (by law and regulatory acts) related to the relevant factors for setting the fee, the form of setting the fee (fixed fee set per month/year, whether it is calculated per kilometer), the grounds, and the methodology.

Speed regulation on highways in Mongolia is regulated by the "Mongolian Road Traffic Rules". Article 12.4 of the Rules states that "It is prohibited to exceed the speed of vehicles in built-up areas by 60 km/h, outside built-up areas by 80 km/h, and on long roads by 100 km/h." The above regulations set the maximum speed limit based on the location of the road, regardless of the category and type of road. The feasibility study for the new ring road envisages a toll road with an estimated speed of 40 km/h for secondary roads and 80 km/h for main roads. This selected version of the road (ZZBNbD 22-004-2016, main road - main road with a demarcated carriageway 1B) conflicts with the speed regulations specified in the Mongolian Road Traffic Regulations.

Table 1. 3. Speed regulation regulations are specified in the Mongolian Road Traffic Regulation

Road Condition / Vehicle Type	Maximum Speed (km/h)
Streets and roads in cities and settlements	30–60 km/h (depending on road markings)
Areas near schools, kindergartens, and hospitals	20–30 km/h
Intercity highways (passenger cars)	80–100 km/h
Rural roads (cargo trucks)	70–80 km/h
Heavy-duty vehicles, vehicles with trailers	60–70 km/h
Wet, slippery, or mountainous roads	30–50 km/h (reduced depending on potential risks)

1.1.10. About EPC contracts and the need to apply them:

The purpose of this sub-section is to provide a brief understanding of EPC (Engineering,

Procurement, Construction) contracts, including the main issues such as the rights and obligations of the client, risks, guarantees, and liability related to construction structures, and to explain further how to comply with domestic laws and regulations when concluding contracts for clients and contractors, and to address issues of concern to the parties, and to develop appropriate recommendations.

A. About EPC contracts: According to the FIDIC model contract, international financial institutions such as the World Bank, the European Bank for Reconstruction and Development, and the Asian Infrastructure Investment Bank, require the mandatory application of the terms of the contract in the projects they finance, while some national companies and investors have expressed their willingness to finance projects implemented according to this model contract, which means that the contract does not apply to national borders and has become widely used. Currently, the Association of Consulting Engineers has developed several model contracts necessary for implementing mega projects in the construction sector, and the 8-colour book or 8 model contracts are widely used worldwide. Among them, FIDIC's Silver Book is a model contract developed for EPC (Engineering, Procurement, Construction) or turnkey contracts, which is a unique contract condition in which one contractor is responsible for all the work including design, construction, procurement of materials and equipment as a complete package and is obliged to hand over the finished product to the customer.

In recent years, due to the intensive construction work in Mongolia and the implementation of projects of high economic importance, the trend of using contracts developed by FIDIC is increasing. The importance of FIDIC's model contract lies in its ability to facilitate the production of work results within agreed time, cost, and quality, while also ensuring the transparent and straightforward distribution of risks and responsibilities among the parties. Since large-scale construction mega projects often involve a variety of relationships, including work execution, sales, procurement, transportation, insurance, and storage, the use of FIDIC model contracts for this mixed relationship will be a significant incentive for the implementation of the “New Ring Road” project (hereinafter referred to as the “project”).

B. Requirements: As mentioned above, international financial institutions such as the World Bank, the European Bank for Reconstruction and Development, and the Asian Infrastructure Investment Bank require the mandatory use of FIDIC model contracts for projects they finance, which is a requirement to attract the necessary investment for the implementation of the project. Choosing the terms of a turnkey contract has many benefits for the contractor and the project customer (the party receiving the results), such as saving costs and time, being free from risks, and using a variety of knowledge and skills.

EPC contract regulations are considered in terms of content, and the following items are considered separately. They include:

a) Rights and obligations of the client and contractor,

b) Guarantees

c) Risks

d) Construction and construction

e) Dispute resolution.

Therefore, this subsection explains the issues raised in the above-mentioned contents and the importance of the regulations related to them.

A) Rights and obligations of the client: In the context of an EPC contract (according to the FIDIC Silver Book turnkey contract model), the client's participation is limited compared to other types of contracts, but it assumes certain rights and obligations that are crucial for the successful implementation of the project. The primary responsibility of the client is to provide the information required to start the project, obtain relevant permits, make payments on time, issue guarantees, clearly establish the criteria for accepting the work within the specified time according to the contract, and provide appropriate support and approvals during the project. In addition, the contractor is responsible for vacating and handing over the site, granting access to the work site, providing accurate technical and environmental information, paying the contract fee on time, and obtaining the necessary permits and licenses. The client should adhere to the principle of not participating in the engineering and technical solution during the project, and should only focus on the results, quality, and implementation of the project. This form of control is manifested in two forms: managerial and technical.

The client must ensure the accuracy of the information provided to the contractor, not violate its payment obligations, and make clear and formal decisions when making amendments to the contract. Since delays and misunderstandings caused by the client's actions risk negatively affecting the results of the entire project, the effective implementation of its rights and obligations is the basis for the successful implementation of the project.

Table 1. 4. Customer management and technical control

Management Control	Technical Control
Section 1.8 “Document retention and handover”	Section 3.4 “Instructions”
Section 1.13 “Individual and Joint Responsibilities”	Section 3.5 “Decision”
Section 1.14 “Instructions”	Section 4.1 “General Obligations of the Contractor”
Section 1.15 “Decision”	Section 4.9 “Quality Management and Compliance Control System”
Section 1.16 “Contractor’s Representative”	Section 4.20 “Progress Report”
Section 8.3 “Detailed Planning”	Section 5.1 “Contractor’s Documents”
Section 8.7 “Progress Indicators”	Section 7.2 “Samples”
Section 13.1 “Right to Make Changes”	Section 7.3 “Inspection and Testing”
Section 13.3 “Procedure for Making Changes”	Section 7.4 “Tests to be Carried Out by the Contractor”
Section 13.4 “Provisional Sum”	Section 8.9 “Suspension of Works by the Client”
Section 14.1 “Interim Payment”	Section 9.2 “Postponed Tests”

Section 14.6 “Final Payment Request”	Section 11.4 “In Case of Failure to Remedy Defects”
Section 15.2 “Termination Due to Contractor’s Default”	Section 11.5 “Exclusion and Repair of Defective Works from Scope”
Section 15.5 “Termination at the Client’s Convenience”	Section 15.1 “Notice to Remedy Breach”

The contractor's rights and obligations: Under the terms of the EPC contract, the contractor shall complete the project design, purchase materials, and complete the construction work in full, within the time specified in the agreement, with guaranteed quality, at the price initially agreed upon by the parties, and transfer it to the customer in a turnkey manner (ready for immediate use after passing specific test criteria).

The contractor shall perform all engineering design work for the project itself, including staged work such as development of the execution design. It shall also be responsible for purchasing all materials and equipment necessary for the implementation of the project itself and supplying them in a quality manner. All materials used in the construction work shall meet the requirements specified in the contract, and the delivery period shall not affect the project period. Another essential duty of the contractor is to perform all construction work, conduct tests and inspections, and finally hand over the project to the customer in a ready-to-use condition. The customer retains the right to conduct quality control and inspection during this execution process, but the primary responsibility for the performance results shall lie with the contractor.

The contractor assumes all risks of the project (soil conditions, weather, material price increases, performance errors, etc.) and is fully responsible for the performance of the contract. The main issue to be considered is that all performance, materials, and work by the contractor must fully comply with the requirements of the agreement, and the customer reserves the right to refuse delivery in case of non-compliance. Also, if the delivery period is exceeded, the customer has the right to demand payment of penalties and deductions from the payment, which is a crucial regulation to ensure project time discipline. Under the EPC contract, the contractor is fully responsible for the technical implementation, economic results, and legal compliance of the entire project. It is crucial for the customer to carefully examine whether the contractor meets the requirements to manage all risks according to the contract.

B) About the guarantee: In the context of EPC contracts, the concept of "guarantee" refers to the contractor's obligation to ensure the performance of the project, complete the project by the contract, perform quality work, as well as the responsibility to repair any damage or defects that may occur during the quality guarantee period of the project. The guarantee is an essential component of the contract to ensure the performance of the obligation and is the primary means of protecting the final results of the project and the interests of the customer. In general, the concept of guarantee in EPC contracts is divided into the following main types:

Performance Guarantee: In an EPC contract, the Performance Guarantee is a guarantee

that the contractor will adequately perform its obligations under the contract and will issue it at its own expense in the amount and currency specified in the special conditions of the contract. It is usually used by the contractor to prevent a breach of the contract, to compensate for economic losses incurred by the client, and to eliminate defects. The contractor is obliged to deliver the performance guarantee to the client within 28 days from the date of signing the contract, and it can be in the amount of 5% - 15% of the total contract price.

The client is obliged to release the performance guarantee within 28 days after the contractor has completed the work specified in the contract and fulfilled its obligations to vacate the site (submitting all relevant documents, successfully conducting tests, and eliminating any defects, if any), or on the date of termination of the contract. If the guarantee is not released within 28 days of the occurrence of the condition for releasing the guarantee, the certificate shall be deemed to have been issued to the contractor.

Advance payment guarantee: When the client makes an advance payment, the contractor provides a financial guarantee to protect against risks such as misuse of the funds, delay in the deadline, and non-performance of the work. The amount of the advance payment guarantee is equal to the amount of the payment made by the contractor, and the guarantee is issued by a legal entity registered in the country where the client has approved the guarantee. The validity period of the guarantee is valid until the advance payment is paid in full, and the amount of the guarantee is regulated so that it can be reduced by the amount of the refund made by the contractor.

Retention money: Retention money is an inevitable part (usually a percentage) that the client retains from the payment due to the contractor after each specific stage of the work. It is an incentive for the contractor to complete the job on time and fulfil its obligations properly. This guarantee shall be void if the warranty period specified in the contract has been completed, all defects and damages have been fully repaired, and the contractor has been issued a Performance Certificate. The amount of the deposit is 5-10 per cent of the construction price.

Parent company guarantee: It is understood as a guarantee by which the parent company of the contractor confirms the financial and legal compliance of its subsidiary company with its contractual obligations and confirms its liability. The general conditions of the 2017 Mungulog Book contract do not stipulate the contractor's responsibility or obligation, but it is provided that the contractor may be required to provide a parent company guarantee. The instructions for preparing special conditions of the contract state that if the customer requires the contractor to provide a parent company guarantee, this should be reflected in the tender documents. The peculiarity of this guarantee is that it is included as an annex to the tender documents if the customer requires it, in which case the contractor shall provide this guarantee before concluding a contract with the contractor, and it shall become effective upon the

conclusion of the main contract.

All of the above guarantees have their functions in the contract conclusion and execution stages and differ in terms of purpose and time of issuance of the guarantee. In the case of an advance payment guarantee, the contractor issues a guarantee before the advance payment is made, while the performance guarantee is issued after the contract is concluded, before the work begins, and the guarantee of the withholding amount is issued in the event of partial payment of the contract during the work.

In terms of the price, the amount of the advance payment guarantee is equal to the advance payment, the performance and withholding amount guarantees are 5-10 per cent, and the guarantee of the parent company is generally liable. However, the common feature is that the validity period of the guarantee expires when the work specified in the contract is fully completed and the customer's obligations to deliver the goods have been fulfilled, the warranty period has expired, and the defects have been eliminated.

C) Risk allocation: The legal system of contracts is based on the principle of fulfilling contractual obligations (pacta sunt servanda). Unforeseen and force majeure events, such as earthquakes, infectious diseases, fires, droughts, floods, etc., natural disasters, inflation, volatile economic changes, and general unrest, may occur due to natural or social factors that are unpredictable and beyond the control of the parties to the contract. Therefore, it is necessary to identify the risks that arise during the contract, how to resolve them, and who is responsible. Risk is defined in legislation and other sources as follows. These include:

- Law on Disaster Protection (2017) - "disaster risk" means the probability of damage to the population, livestock, animals, property, and the environment due to a disaster;
- ISO 31000:2018 – Risk Management – Guidelines- Risk is the effect of uncertainty on objectives.
- FIDIC Contract Guide (2017 Silver Book)- “Risk” – Uncertain circumstances and events beyond the control of the parties are likely to affect the performance of the contract.
- World Bank Environmental and Social Framework (ESF)- Risk refers to the potential for adverse effects on people or the environment arising from project activities or external factors.
- Oxford Dictionary of Law- Risk – The chance of an event occurring which may cause loss or damage.
- PMBOK Guide (Project Management Institute)- Risk – An uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives.

Risks to the Client: In the EPC contract, the Contractor assumes most of the risks related to the design, geological formation risks, and storage of transportation materials associated with the execution of the work specified in the contract, which is a fundamental principle

reflected in the general conditions of the agreement, but it is necessary to note that the following risks may arise for the client.

Design and testing risks: The Contractor will comply with the client's requirements during the design process. If the client's requirements are unclear, the Contractor will proceed as usual. In this case, it is necessary for the client to clearly describe the results of the work in detail, as this may not meet the client's objectives or cause disputes related to defects. In addition, it is necessary to provide detailed information on the acceptance test, its procedures, and standards.

Additional payment and time-related risks: If the client fails to grant the contractor timely access rights, and if archaeological artifacts are discovered at the work site, and if the Contractor incurs additional costs, the client will be responsible for these costs. In addition, if the amount of the performance guarantee is not specified, the right to recover damages based on the guarantee cannot be exercised, so this risk must be taken into account. Also, if the work is delayed or stopped due to the Contractor's actions, the Contractor has the right to extend the contract period and demand additional costs, so this risk must be calculated.

Risks related to testing, suspension, changes, and contract termination: According to the terms of the contract, the customer has the right to stop the work, and in this regard, there is a risk that the customer will demand an extension of the period and additional payments, so it is necessary to pay attention to whether there is a compelling reason to stop the work. Unjustified suspension of work for an extended period (84 days or more) is grounds for the Contractor to terminate the contract. Also, according to the contract, the Contractor has the full right to change and give instructions for the performance of the work, and if such instructions result in costs exceeding 10 percent of the total price agreed upon in the contract, or if the total amount of all changes exceeds 30 percent, the Contractor has the right to demand a guarantee for payment of that amount. If the financial guarantee is not provided, the work may be stopped or the contract may be terminated. In the event of termination by the contracting party, it is prohibited for another party to continue the work until the Contractor has paid for the work performed and other damages, so it is necessary to consider the risk of delay.**Risk of unexpected and force majeure factors:** Clause 19.1 of the contract stipulates that the contracting party is primarily responsible for the risk of unforeseen and force majeure factors, and the Contractor has the right to compensate for any costs incurred and extend the contract period. If the work is stopped for 140 days or more due to the above circumstances, either party has the right to terminate the contract voluntarily.

Clause 19.1 of the contract provides for the following conditions: These include:

War, state of war (declared or undeclared war)

Attack

Hostile action of foreign powers

Insurrection

Terrorism

Revolution

Riot

Military or illegal transfer of power

Civil War

Riots, riots and riots, riots and curfews,

Contamination of munitions, ammunition, explosives, ionising radiation and radioactivity, where this may be related to the use of ammunition, explosives, radioactive substances and radioactivity by the Contractor

Earthquake

Hurricane

Natural disasters such as volcanic activity.

Contractor's Risk: The Contractor is responsible for all risks associated with the design, procurement, transportation, and construction of the project and its delivery to the client by the terms of the contract, and the detailed risks associated with this are set out in the following section. The Contractor's assumption of all the risks related to the above activities means that the Contractor will be able to take into account all risks that may arise from signing the contract and complete the work without changing the total contract price due to unforeseen costs. The main risks include:

- Engineering design
- Risks of subsurface geological formation
- Risks related to the storage and protection of construction materials.

Engineering design: If the design provided by the client is proven to be incorrect and requires an extension of time or additional costs, the client will be responsible for the consequences of this situation. In all other cases, the Contractor is responsible for the risks associated with the design.

Subsurface geological formation risk: Under the EPC contract, the client is obliged to provide the Contractor with a subsurface geological formation or natural formation below the ground, and the Contractor is obliged to ensure that the information is accurate and factual. In addition, the Contractor has obtained all necessary information about risks, contingencies and other unforeseen circumstances and has agreed to enter into a contract at the best possible price, calculating the costs to be incurred in the case.

Construction and construction regulations: EPC contracts are "turnkey" contracts, in which the Contractor assumes all responsibilities until the construction is completed and put

into operation, but the client has certain rights and responsibilities to exercise control over the project requirements during the execution of the work. In particular, the client's failure to fulfil its obligation to inspect and approve the materials and samples to be supplied by the Contractor and notify them of their compliance with the relevant norms and standards can lead to delays in the delivery of the contract, extension of time and reimbursement of costs.

Table 1. 5. Rights and responsibilities of parties related to facilities, materials, and structures

Party	Rights	Obligations	Timeline	Consequences
Contractor	To prepare and submit samples and prototype materials- To request approval of submitted samples	To develop samples in full compliance with the technical specifications and contractual documents- To submit samples within the agreed timeframe- To implement the project works strictly by the approved samples	Within the timeframe specified in the contract and work schedule	If the sample fails to meet requirements, the contractor is obliged to revise or resubmit.- If sample approval is delayed, project timeline extension may be requested
Client	To review or commission the review of submitted samples- To approve, accept, or reject samples	- To review the submitted samples within the contractual period- To provide formal feedback or comments- To monitor implementation based on the approved samples	Within the timeframe stipulated in the contract (e.g., within 14 calendar days from submission)	If no response is provided within the specified period, the sample may be deemed approved (subject to special conditions in the contract)- Subsequent changes may result in additional costs or timeline extensions.
Execution Phase	–	- To execute all materials and works in strict accordance with the approved samples	Commences immediately after sample approval	- If execution deviates from approved samples, the contractor bears full responsibility for rework costs and associated delays

1.1.11. EPC contract model acceptance in Mongolian legislation

To assess and identify in advance how the terms of the EPC (Engineering, Procurement, Construction) contract for the implementation of the First Ring Road project will be consistent with or inconsistent with domestic laws, and what legal risks may arise, and to develop relevant recommendations.

1.1.11.1. Special Licenses:

The EPC contract is based on the design, which is the soul of the contract. According to the EPC contract, the Contractor develops the design based on the customer's technical requirements and prepares and approves the documentation. If the design is approved and verified, the customer and the authorized body will issue an official permit to start construction work. Although this sequence is consistent with the Construction Law and other laws, the contract requires the participation of other authorized organizations in addition to the customer who signed the contract. Their decisions are directly related to the approval of the design and the issuance of a permit to start work, so the participation of other parties needs to be reflected in detail in the contract.

In the case of a foreign legal entity, the Law on Construction, the Law on Highways, and

the Law on Permits require that the person designing buildings and highway structures must be a legal entity registered in Mongolia and have a special design license. Since a branch or representative office of a contractor company does not have the right to be a legal entity or obtain a special permit, it is necessary to establish a subsidiary in Mongolia and get a special license through it to design, or to employ a subcontractor with a relevant special license registered in Mongolia. Therefore, before concluding a contract with the Contractor, it is necessary to notify them in advance and provide information detailing the requirements for obtaining a special license.

1.1.11.2. Regarding guarantees:

As mentioned in the above section, the customer can choose and combine four types of guarantees depending on the scope of the project. In Mongolia, the regulations related to guarantees and warranty periods are regulated by the Law on Sale and Purchase of Goods, Works, and Services with State and Local Property (hereinafter referred to as the "Tender Law") and the Civil Code. The Tender Law legalizes three types of guarantees: Tender Guarantee, Advance Payment Guarantee, and Performance Guarantee.

Tender Guarantee: This guarantee is valid until the contract is signed or for the period specified in the tender documents. It ensures that the Contractor will sign an agreement with the customer and commence work if selected in the tender. Consequently, its validity period is relatively short. The guarantee amount is 0.5 per cent of the budgeted cost. You can choose from a bank guarantee, Mongolian Government securities, or a Mongolian insurer as the form of guarantee. Although this guarantee is not included in the form of guarantee for the EPC contract, it is mandatory to issue it from the parties participating in the tender.

Advance payment guarantee: The advance payment guarantee specified in the Law on Tenders has the same purpose, amount, form of guarantee, and issuance period as the advance payment guarantee specified in the terms of the EPC contract.

Performance guarantee: The performance guarantee specified in the Law on Tenders of Mongolia has similar purposes, validity period, and consequences, but is significantly different in terms of the percentage of the guarantee and the consequences of disposing of the guarantee. For example, while the performance guarantee specified in the Law on Tenders is 3 per cent of the budgeted cost, the amount of the performance guarantee in the EPC contract is 5-15 per cent. Therefore, to comply with the law, it is necessary to urgently submit and approve a draft law amending the Tender Law to set the performance guarantee amount at 3 per cent, or to implement the percentage before the project is implemented or to allow the Government to choose the percentage depending on the scope of the project.

It is necessary to pay special attention to the fact that changing the guarantee in violation of the tender law may result in the Contractor not being able to find a financial institution to

issue a guarantee, or refusing to issue a guarantee, and on the other hand, the state officials involved in the project and event to be implemented during the budget year may face disciplinary and legal liability. According to the Tender Law, the Contractor of projects and events to be implemented during the budget year shall submit a new performance guarantee to the client before the expiration of the performance guarantee period. If the client fails to submit it within this period, the client will be considered to have violated the contract, and the client will have the right to dispose of the performance guarantee directly, or it will become the client's income. Therefore, the Contractor must pay special attention to the expiration date of the guarantee and its consequences

1.1.11.3. Regarding the warranty period:

While the warranty period under the EPC contract is 12-24 months, depending on the scope of the project, the Mongolian Construction Law and the Highway Law stipulate that it is three or more years. Therefore, when concluding the contract, it is necessary to amend the warranty period to 3 years to comply with the above laws. On the other hand, the Contractor must calculate the risks arising to him considering this period. In terms of the time of issuing the guarantee, the tender guarantee specified in the Tender Law is issued before the contract is concluded. At the same time, the EPC contract guarantees (except for the guarantee of the parent company) are issued after the contract is concluded. Therefore, when implementing the EPC contract through the Mongolian procurement process, it is necessary to reflect the above differences and include or combine them as a type of double guarantee by the terms of the contract.

The amount of the performance guarantee for the EPC contract should be set at 3% as specified in the Law on Tenders, or the contracting party should conduct relevant research to the legislator before implementing the project and concluding the contract, such as increasing the amount, and allowing the contracting party to choose the amount of the guarantee depending on the scope of the project, and submit a draft law to the legislator for approval. The Contractor should pay special attention to the fact that if the guarantee is not renewed before the expiration of the performance guarantee period specified in the Law on Tenders, the contracting party has the right to dispose of the guarantee immediately. The draft contract should be amended by the law regarding the right to withdraw and demand from the guarantee to be concluded between the parties. The guarantee period should be specified as 3 years or more to comply with domestic legislation, and this requirement also applies to the performance of work that is partially delivered.

1.1.11.4. Special permits:

The client is obliged to inform, provide information and assist the Contractor about the performance of the work specified in the EPC contract, the special permits required by the

Contractor, their validity periods and conditions, and the following licenses and special permits will be used for road works to be carried out under the EPC contract.

Table 1. 6. Special licenses for EPC contract implementation

License/Permit	Issuing Authority	Legal Basis	Conditions for Issuance	Validity Period
Asset Valuation License	Ministry of Finance	Law on Asset Valuation	Articles 14–21 of the Law on Asset Valuation	3 years; renewable once for another 3 years, or granted with no expiry
Detailed Environmental Impact Assessment (EIA)	Ministry of Environment and Climate Change	Law on Environmental Impact Assessment	Response to be provided within 5 working days	3 years; renewable once for another 3 years upon request
Water Use Permit	District Governor; Environmental Division; River Basin Authority	Articles 26–31 of the Law on Water	As specified in the contract	As per contract
Mineral Resource Utilization Permit	Governor of the Capital City	Law on Commonly Spread Minerals	Articles 12–16 of the relevant law	3 years; renewable once for 2 more years
Subsoil Use Permit	Governor of the Capital City	Law on Subsoil	Based on approved project documentation	No expiry
Construction Work Permit	Ministry of Energy; Energy Regulatory Commission; Ministry of Construction	Law on Construction; Law on Energy	–	Valid for the duration of the project
Communications Network Construction and Operation Permit	Communications Regulatory Commission	Law on Communications	Articles 13–15 of the Law on Communications	10 years (renewable once for same period)
Communications Network Infrastructure Installation, Maintenance License	Communications Regulatory Commission	Law on Communications	Articles 13–15 of the Law on Communications	5 years (renewable once for same period)
Construction and Commissioning of Energy Facilities	Ministry of Energy	Law on Energy; Energy Facility Construction Procedure	Based on approved technical designArticles 21–23 of the Law on Energy	Up to 3 years
Energy Connection Permit	Energy Regulatory Commission	Law on Energy	Subject to technical conditions and approved scheme	Until commissioning is complete
Design, Construction, Maintenance & Testing of Energy Facilities	Ministry of Energy	Articles 21–23 of the Law on Energy	–	3–5 years
Road Construction Permit	Ministry of Road and Transport Development	Law on Roads	Location and design must be approved	1–2 years
Hazardous Waste Transport and Handling Permit	Ministry of Environment and Climate Change	Law on Waste	Transport plan required	Valid for the duration of the project
Fire Safety Clearance	National Emergency Management Agency (NEMA)	Law on Fire Safety	Must comply with approved technical design	Until commissioning is complete

License/Permit	Issuing Authority	Legal Basis	Conditions for Issuance	Validity Period
Employer Registration	Ministry of Labour and Social Protection	Labour Law	Requires labor contract, tax registration, and social insurance compliance	Valid during employment
Work Permit for Foreign Employees	Ministry of Labour and Social Protection; Immigration Agency	Law on the Legal Status of Foreign Nationals	Requires employment contract, official invitation, and visa clearance	1 year

1.1.11.5. Design:

While the EPC contract foresees risks related to design errors (except for those that are unknowable), the Law on Construction and the Law on Highways stipulate that the person who performed the Design is responsible for future risks related to the Design, which is essentially the same as the liability and consequences of the Design in the EPC contract.

Unforeseen and force majeure circumstances: The Civil Code of Mongolia and other laws do not specify in detail what events are considered force majeure circumstances. Therefore, in addition to applying the provisions specified in Chapters 17 and 19 of the EPC contract, it is necessary to include detailed conditions depending on the weather conditions and other features of the project implementation period. It is also essential to specify in detail which authorized organization will finally determine whether the unforeseen and force majeure circumstances specified in the contract have occurred, and which documents will be considered as evidence to prevent disputes related to this.

Dispute resolution mechanism: Given the long-term nature of the construction contract relationship, there is a high likelihood of disagreements, conflicts, and disputes between the parties. Therefore, if the parties do not clearly state in their contract how to resolve their disputes, they must resort to the courts of ordinary jurisdiction. Under the terms of the EPC contract, the parties use the methods of resolving disputes amicably, having them resolved by a dispute resolution commission consisting of 1 to 3 members appointed by the parties, and, as a final step, arbitration.

Figure 1. 1. Dispute resolution sequences

The domestic court system for resolving disputes related to long-term mega projects has the following negative consequences, so the parties are interested in arbitration. It is considered unfair and risky for foreign investors. When resolving international construction

contract disputes in national courts, there are often cases where the judge lacks specialized knowledge and does not understand the case. Forcibly enforcing Mongolian court decisions abroad requires a special legal agreement between the parties, and it is not easy to directly implement the court decision. It is common practice worldwide to include international arbitration clauses in EPC and turnkey contracts, which ensures equality of parties, professional choices, and speedy proceedings. Mongolia acceded to the New York Convention on the Recognition and Enforcement of Foreign Arbitral Awards, adopted in 1958, in 1994, and to the Convention on the Recognition and Enforcement of Foreign Arbitral Awards, adopted in 1985, in 1994, respectively. This indicates that international arbitration awards are legally enforceable in Mongolia, meaning that there is no conflict with domestic law for parties to resolve their disputes through arbitration.

1.2. THE EXISTING ROAD NETWORK CONDITIONS

1.2.1. Road classifications

As of 2024, the capital city of Ulaanbaatar will consist of 1,258.5 km of paved roads, 96 large and small bridges, and bridge structures. According to a study conducted by the Capital City Road Development Department, when calculating the age of the capital city's roads since they were put into operation at a frequency of 5 years, 34 per cent of all roads were built before 1996 and have been in use for more than 25 years. The pavement and curbs of roads over 20 years old in the Ulaanbaatar city area have completely deteriorated and are no longer usable after pothole repairs. Roads that are 10-15 years old account for 11 per cent, and these are in serious condition. If some roads are properly maintained, these roads can be used normally.

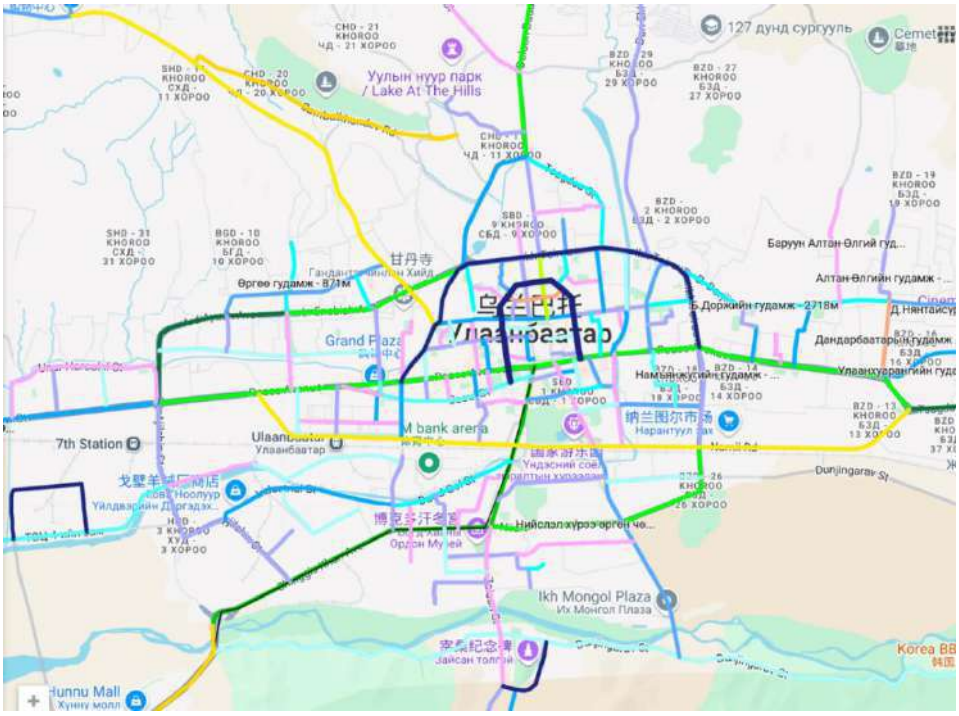


Figure 1. 2. Current distribution map of two-way roads with two or more lanes

1.2.2. Road network model

Ulaanbaatar is a monocentric, linear city stretching along the Tuul River valley, depending on the specific style of the territory, and the road network model has horizontal and vertical axis roads. The majority of the Ulaanbaatar regional road network, or 75 per cent of the total road network, is located in the built-up area of the city. There are two types of roads in the built-up area of Ulaanbaatar city, namely national and capital roads. There are 853.4 km of paved roads and 70 bridges and bridge structures in the city and its suburbs, and the number of Ulaanbaatar city roads has increased by a total of 211.2 km between 2020 and 2024.

The main road is designed to carry the main transport load within the territory of Ulaanbaatar city. As of 2024, there will be 161.60 km of roads with 35 main streets of grades

1 and 2, 423.0 km of auxiliary roads of grades 1 and 2, and 480.0 km of streets and highways of neighborhood quality within the built-up area of the city. As of 2024, the city will have three multi-level intersections and one additional bridge structure.

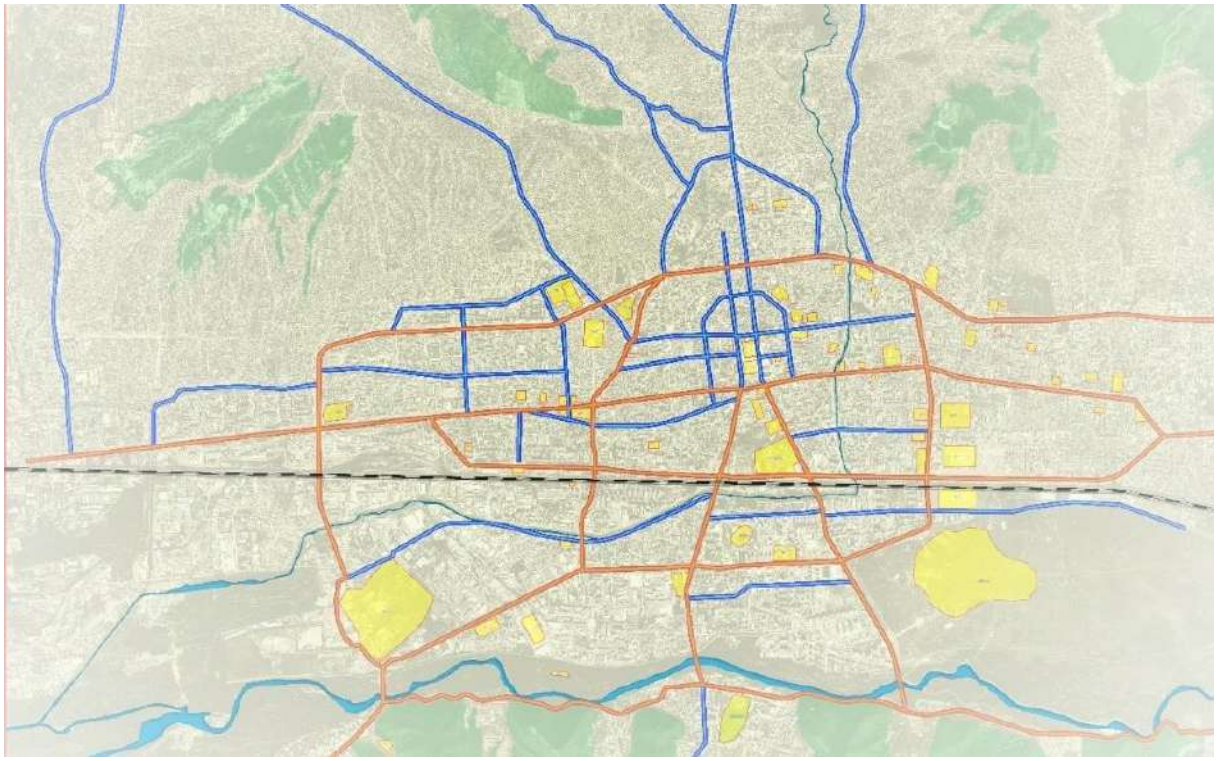


Figure 1. 3. Ulaanbaatar city road network

In addition to the approximately 500-meter-wide secondary road system around the Central Business District (CBD), most residential areas are connected by secondary roads at intervals of 1-2 kilometers, forming a "herringbone" road network. This type of structure makes north-south traffic highly dependent on the intersection of the main road, creating a major congestion intersection in District 21 during peak hours.

The city's newly developed areas exhibit the characteristic of "isolated islands" of development. The Khushi Valley New Hundred Trees City to the west and Amgalan New City to the east are planned to be integrated with an integrated road network. Still, due to the slow pace of construction, the actual roads built only account for 43% of the planned amount and are not well connected to the central area of the city, creating a "disconnected traffic area" in reality.

1.2.3. Structure of road network

The hierarchical road system of Ulaanbaatar city is structurally deficient. The lack of a comprehensive highway system in the town leads to high congestion in intercity transit and urban traffic. According to traffic flow monitoring data, approximately 12,000 freight vehicles pass through the city daily on the national highway A3 (the Sino-Mongolian border with Russia),

accounting for 35% of the traffic on the main road, which further increases the load on the city. The regional road traffic circulation system is seriously flawed, and a study conducted in the three districts of Bayangol, Sukhbaatar, and Khan-Uul revealed that 23% of the auxiliary road network is dead-end and 54% of the street width is less than 6 meters. In Bayanzurkh district, road separation due to land ownership disputes is common, and about 17 km of planned auxiliary roads have not been connected, forcing 40% of the district's traffic to bypass the main road. The current road network in Ulaanbaatar city is mainly connected to the east and west directions, and has a horizontal elongated mesh shape, which meets the current needs of the entire city, but is inefficient. The fact that vehicles travelling from east to west and south to north in the city must pass through the city centre has caused traffic concentration, increasing the traffic load in the central area and causing congestion. The road network's structure is inappropriate, with excessively close distances between main roads and a lack of auxiliary roads. This results in inefficient traffic operations on the main roads in the city centre, where all the load is concentrated.

Implementing relevant measures and policies is necessary to alleviate vehicle congestion and improve traffic flow in the city's central area. It is imperative to improve the management of public transport routes in the city centre, enhance the road network's structure, clearly define the roles and categories of roads, and optimise the organisation of public transport and large-sized freight transport. To balance the population distribution in the suburbs and balance the relationship between residence and employment, it is necessary to neutralise and change the traffic flow from east to west and south to north in the city centre area, expand the city space, intensify the construction of sub-centres, and distribute state and social infrastructure organisations.

A study of the current state of road traffic shows that the main roads of Ulaanbaatar are heavily congested during the morning and evening peak hours. It was found that as the traffic load increases, the impact on the entrances and exits along the secondary roads and streets is intense. This is mainly due to the high traffic volume on the main roads running from east to west through the city centre, such as Enkhtaivan Avenue, Ikh Toiruu, Enebish Avenue, Narny Zham, Chinggis Avenue, and Niislel Hure Avenue, as well as the high traffic volume on the main roads running from south to north. In addition, these roads are densely populated with commercial, tourist, administrative, public, and business areas, and many vehicles are passing through them, so the road width is insufficient, which reduces the efficiency of road traffic and causes congestion. Currently, the following problems are encountered. These include:

The structure of the road network is not fully adequate. The current road network primarily comprises two-lane and and 6-lane main roads, as well as two-lane and 4-lane secondary roads, with a notable lack of and 4-lane roads.

Hospitals, education, business, recreation, and commercial facilities are primarily concentrated in the city centre and west, significantly increasing the flow of citizens and increasing the traffic load. East and west-bound highways pass through the city centre of Ulaanbaatar. By passing the external transportation highway through the city's outskirts, the impact on the traffic load inside the city is reduced. It is necessary to create intersections that seamlessly connect the highways going out of the town with the freight roads outside the city.

In the "Ulaanbaatar City Transport Strategy until 2040", the highway structure is planned

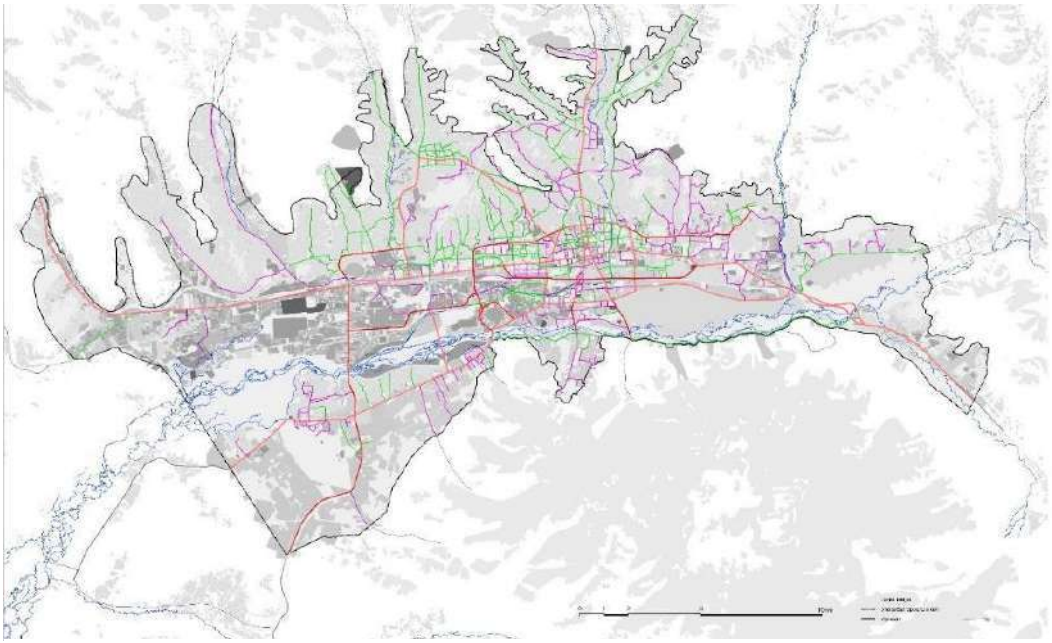


Figure 1. 4.Ulaanbaatar city road network

to have eight sections in the horizontal axis and 2 in the vertical axis. The city's highway network will form a system of horizontal, vertical, and circular main roads, combined with auxiliary roads, connecting improved residential areas, construction zones, industrial zones, mixed-use zones, social structures, and green spaces. In the built-up area of 35,206 hectares of Ulaanbaatar city, there are two types of roads: state-level and capital-level. The city and its suburbs have 853.4 km of paved roads and 70 bridges and bridge structures, and Ulaanbaatar city's roads have increased by a total of 211.7 km between 2020 and 2024. The main roads are designed to carry the main transport load within the territory of Ulaanbaatar city. As of 2024, there are 35 main streets of 1st and 2nd grade, 161.60 km of roads, 423.0 km of auxiliary roads of 1st and 2nd grade, and 480.0 km of residential area roads in the built-up area of the city. As of 2024, there have been three multi-level intersections in the city, and one bridge structure has been added.

Table 1. 7. Ulaanbaatar city road network 2024

Definition					
№	**Legend**	**Classification**	**Length (km) 2020**	**Length (km) 2024**	**Increase (km)**
1		1st class main road	96.4	112	15.6

2		2nd class main road	55.1	49.6	Classification is changed
3		1st class secondary road	112.1	222.0	109.9
4		2nd class secondary road	134.8	201.0	66.2
5		Within a neighborhood	455.0	480.0	25.0
6	Total		853.4	1064.6	211.7

Reference: UPRI, 2024

The roads of Ulaanbaatar city, depending on the road category, have 2-6 lanes, lane widths of 3.5 - 3.75 m, and are paved with asphalt concrete, cement concrete, and stone aggregate. Depending on the spatial planning characteristics of Ulaanbaatar city, the availability of paved roads in built-up areas is 75 per cent, and in ger districts, it is about 25 per cent. Due to the poor quality of road pavement and the lack of access to stormwater drainage lines, the city's roads are easily damaged during the rainy season. The carrying capacity of the Ulaanbaatar city road network is approaching its load limit. According to the 2023 traffic census, the average speed of vehicles on weekdays has decreased to 18.7 km/h, which is a 37% decrease compared to 2015. During the evening peak hours (18:00-19:00), the average vehicle speed on the central road is only 12.3 km/h. The intersection of Chinggis Avenue and Enkhtaiwan Avenue has been included in the "100 Most Congested Intersections in Asia" for three consecutive years.

Traffic density indicators show the system's shortcomings. The road network load in the central part of the city is 0.92 (the normative value is 0.75), and the V/C ratio (traffic flow/capacity) in some areas exceeds 1.3. Most seriously, the road network redundancy is only 0.18, far below the safety standard of 0.4, which means that when a traffic accident occurs at any intersection in the area, it will cause a significant traffic jam. During the winter snowstorm of 2022, 87 per cent of the city's roads were closed due to two traffic accidents. Economic cost estimates show the problem is severe. The World Bank estimates that Ulaanbaatar's traffic congestion costs the city $430 million annually, equivalent to 2.1 per cent of GDP. Commuters spend an average of 74 minutes more per day commuting and use 150,000 litres of fuel per day. The Ulaanbaatar City Development Plan for 2040 aims to increase the road network density to 4.0 kilometres per square kilometre, enhance the traffic capacity of the street network and public transport, and increase public transport usage to 70 per cent, thereby reducing private car use by citizens by 30 per cent. The key to this is to create a comprehensive, well-planned and accessible street network.

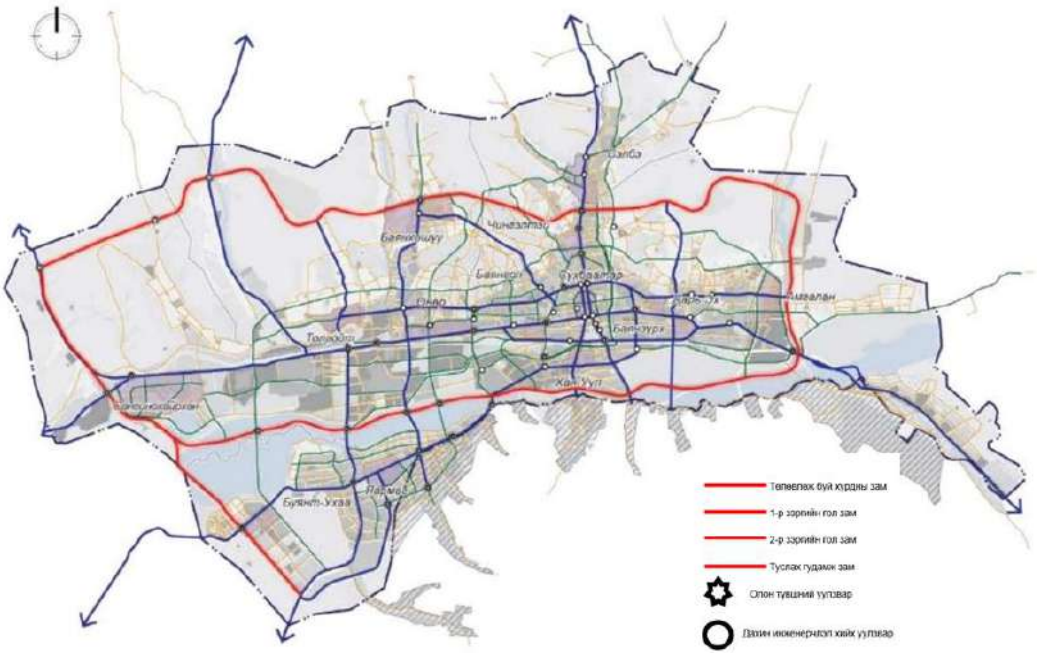


Figure 1. 5. Planned road network of Ulaanbaatar city

The territory along the planned road route is densely populated, with large urban settlements, private real estate enterprises and organisations, high and low voltage power transmission lines, main and auxiliary roads in urban areas, drinking water supply points and other infrastructure and engineering networks.

The terrain along the road route is generally high in the north, low in the south, high in the east, low in the west, with Chingeltei, Sharkhad, and Dari-Ekh mountains in the north, and flat terrain in the southwest and southeast ends. The road route is divided by the existing river channel and the Selbe River. The general condition of each road route plan in the plan is shown in aerial photographs (Collection of Road Accident and Violation Statistics in Mongolia, 2024).

Table 1. 8. Vehicles number

		2022	2023	2024	2024	
						2024/2023
		Nationwide	Nationwide	Nationwide	Ulaanbaatar	
Public transport and vehicles		1,081,212.0	1,192,520.0	1,338,956.0	796,681.0	12%
	Passenger vehicles	716,028.0	788,038.0	896,277.0	580,240.0	14%
	Trucks	183,383.0	195,918.0	270,780.0	92,154.0	8%
	Buses	21,828.0	23,356.0	24,118.0	13,154.0	3%
	Special purpose vehicles	9,631.0	10,517.0	12,051.0	8,097.0	15%
	Water trucks	3,664.0	4,188.0	4,917.0	3,429.0	17%
	Locomotive	42,460.0	48,949.0	53,436.0	29,385.0	9%
	Healvy machineries	15,045.0	16,979.0	21,348.0	15,015.0	26%
	Trailer vehicles	61,230.0	73,055.0	80,426.0	44,808.0	10%
	Motorcycles	27,943.0	31,520.0	35,605.0	10,399.0	13%

Steering wheel position		**977,002.0**	**1,071,015.0**	**1,202,522.0**	**727,209.0**	12%
	Right		690,425.0	792,678.0	507,791.0	15%
	Left		380,590.0	409,844.0	219,418.0	8%
Engine type		**1,017,642.0**	**1,117,125.0**	**1,256,258.0**	**750,535.0**	13%
	Fuel	399,748.0	420,128.0	437,499.0	243,624.0	4%
	Diesel	282,408.0	305,033.0	329,335.0	163,241.0	8%
	Electric	659.0	1,072.0	1,563.0	1,379.0	46%
	Gas	13,033.0	13,711.0	16,542.0	9,304.0	21%
	Hybrid	321,794.0	377,181.0	471,495.0	332,987.0	25%
Aging		**1,081,213.0**	**1,192,521.0**	**1,338,956.0**	**796,681.0**	12%
	0-3	39,503.0	67,027.0	69,819.0	48,733.0	4%
	4-6	47,176.0	51,570.0	65,989.0	36,471.0	28%
	7-9	72,429.0	99,338.0	108,530.0	78,487.0	9%
	10 <	922,105.0	974,586.0	1,094,618.0	632,990.0	12%
Engine capacity		**1,017,546.0**	**1,115,683.0**	**1,252,960.0**	**747,912.0**	12%
	until 1500cm3	334,495.0	351,151.0	362,791.0	190,304.0	-20%
	1501-2500 cm3	394,668.0	451,530.0	543,596.0	344,901.0	55%
	2501-3500 cm3	130,479.0	143,744.0	161,858.0	69,236.0	13%
	3501-4500 cm3	42,297.0	45,361.0	49,001.0	30,917.0	-60%
	4501 cm3<	112,607.0	123,997.0	135,714.0	85,554.0	199%

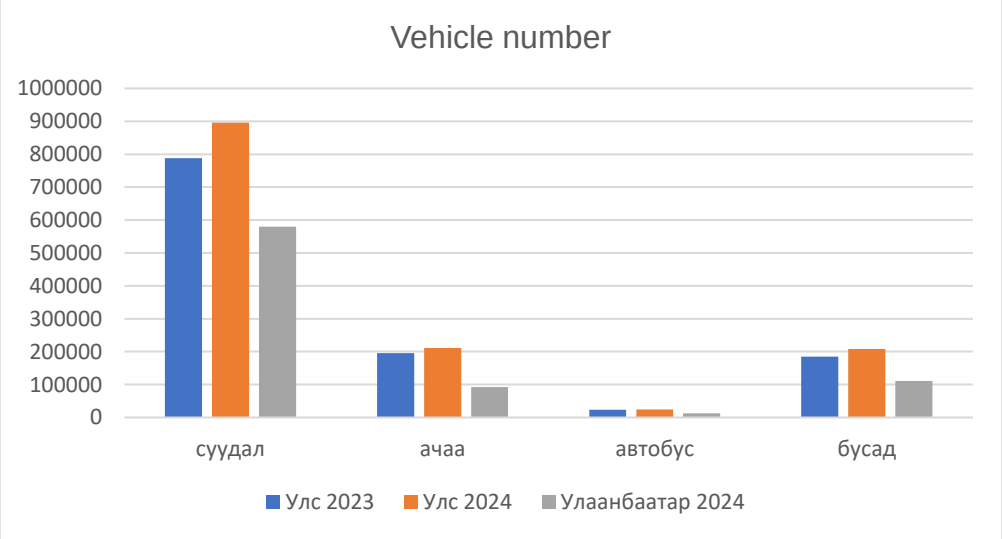


Figure 1. 6. Vehicle growth rate by type

Railway transport: The railway, which divides the Ulaanbaatar region horizontally, carries out the necessary transportation of mining, non-mining, containers, and coal for the economy of the country, region, and city. The railway is single-track and of high age, with freight terminals and warehouses located along the railway station, significantly impacting traffic congestion in Ulaanbaatar. In 2024, a tunnel was built at the intersection with the Tolgoit station crossing.

Air transport: Air freight services are provided from Ulaanbaatar to 135 cities in 45 countries around the world. For air freight, the leading transportation organisation operates from those countries and third countries through the cargo terminals of Beijing and Seoul airports, while export cargo is mainly sent to the United States and European countries. In the southern part of the capital region, in the Khushigti Valley, the Chinggis Khaan International

Airport, jointly developed by the Governments of Mongolia and Japan, was commissioned in 2021.

Freight transport and logistics: Our country's freight transport is mainly provided by rail. Ulaanbaatar city alone accounts for 67 per cent of Mongolia's GDP, and about 80 per cent of imported freight arrives and is distributed in Ulaanbaatar, and more than 70 per cent of transit freight turnover is related to Ulaanbaatar. The integrated transport logistics system is not fully developed, and the capacity of terminals is 5-8 times less than the throughput capacity of the Ulaanbaatar railway. The terminals are located in the city centre, which not only creates an urgent need to transport freight within the city, but also affects the utilisation of roads and road facilities due to the lack of a dedicated road network for freight transport.

1.2.4. Geometric dimensions, technical specifications, and damage studies of existing roads and road structures that overlap with the road alignment

The planned highway intersects with 12 existing highways, and a total of 17 highways were surveyed for damage at 62 points, identifying the damage by the main categories of (i) cracks and (ii) potholes, (iii) sinkholes, and (iv) subsidence, and determining the geometric size, while technical parameters such as road lane width, number of lanes, shoulder width, and pavement type were determined. The figure below shows the existing roads that intersect and overlap with each other, marked with numbers.

Table 1. 9. Intersection with planned alignment

№	Intersecting Roads	№	Parallel/Overlapping Roads
1	Intersection with TES-4 Road	1	Along the Industrial Ring Road
2	Intersection with Moscow Street	2	Along Önör District Street
3	Intersection with Zuunsalaa Road	3	Along Western Altan Ölgii Road (Monel Road)
4	Intersection with Revolutionary Street	4	Along Hilchin Street
5	Intersection with Sambalkhündev Road	5	Along General's Road
6	Intersection with Denjiin 1000 Street		
7	Intersection with Khailaast Street		
8	Intersection with 7 Buudal Road		
9	Intersection with Dari-Ekh Street		
10	Intersection with Gants Khudag Road		
11	Intersection with Eastern Altan Ölgii Road (Tsagaan Davaa Road)		
12	Intersection with Tsagdaagiin Street		

The number of breakdowns, some technical parameters, road usage levels, and intersection points of sections are shown in the table below.

Table 1. 10.Overlapped intersections and existing road with alignment

	Intersection Point (Lat, Long)	Lane Width (m)	Shoulder Width (m)	Pavement Type	Type of Damage	Damage Dimensions	Serviceability (%)
1	47.9109396 106.8311999	3.8	8.35	Asphalt	Hole	40см*35см	78%

	Intersection Point (Lat, Long)	Lane Width (m)	Shoulder Width (m)	Pavement Type	Type of Damage	Damage Dimensions	Serviceability (%)
2	47.9109672 106.8313424	3.8	8	Asphalt	Crack	20.4см*10см	78%
3	47.9109353 106.8306748	3.8	3	Asphalt	Crack	20.4см*15см	65%
4	47.9109214 106.8306775	3.8	3	Asphalt	Crack	20.4см*25см	60%
5	47.9109989 106.8304908	3.8	3	Asphalt	Hole	73см*51см*15см	72%
6	47.9110047 106.8306286	3.8	3	Asphalt	Hole	50см*26см*15см	60%
7	47.9110007 106.8306684	3.8	3	Asphalt	Crack	10см*75см	60%
8	47.9110937 106.830457	3.8	3	Asphalt	Crack	3.8м*100см	60%
9	47.9112268 106.8310805	3.8	3	Asphalt	Crack	24.3м*5см	70%
10	47.9112268 106.8310805	4.4	1.8	Asphalt	Crack	17м*12см	80%
11	47.9113904 106.8309940	4.4	1.8	Asphalt	Crack	8.8м*15см	80%
12	47.9116398 106.8308894	4.4	1.8	Asphalt	Crack	8.8м*20см	75%
13	47.9117868 106.8309511	4.4	1.8	Asphalt	Crack	17м*15см	70%
14	47.9125444 106.8309789	4.4	1.8	Asphalt	Crack	9м*20см	65%
15	47.9135334 106.8309578	4.4	5.3	Asphalt	Crack	17.м*15см	70%
16	47.9138347 106.8309028	4.4	5.3	Asphalt	Crack	16м*23см	70%
17	47.9148124 106.8310540	4.4	5.3	Asphalt	Hole	40см*60см*7см	70%
18	47.9147933 106.8310423	4.4	5.3	Asphalt	Hole	35см*45см*5см	75%
19	47.9147932 106.8310410	4.4	5.3	Asphalt	Crack	30м*5см	70%
20	47.9190895 106.8305353	3	1.1	rock	-	-	90%
21	47.9190890 106.8305354	3	1.7	Asphalt	Hole	65см*60см*3см	75%
22	47.9196114 106.8304294	3	1.8	Asphalt	Settlement	20м*30см	65%
23	47.9196928 106.8303493	3	1.8	Asphalt	Hole	70см*55см*14см	70%
24	47.9197121 106.8303261	3	1.8	Asphalt	Hole	65см*50см*12см	70%
25	47.9197537 106.8303131	3	1.8	Asphalt	Hole	80см*65см*16см	70%
26	47.9250386 106.8306188	3	1.1	rock	-	-	95%
27	47.9255949 106.8314205	3	1.8	Asphalt	-	-	95%
28	47.9450957 106.8219405	4	5	Asphalt	Hole	30см*10см*3см	85%
29	47.9450957 106.8219405	4	5	Asphalt	Crack	8м*3см	85%
30	47.9450957 106.8219405	4	5	Asphalt	Hole	30см*14см*4см	80%
31	47.9507638 106.8255713	3	1.8	Asphalt	Hole	84см*90см*4см	60%
32	47.9507640 106.8255715	3	1.8	Asphalt	Hole	20см*30см*2см	60%

	Intersection Point (Lat, Long)	Lane Width (m)	Shoulder Width (m)	Pavement Type	Type of Damage	Damage Dimensions	Serviceability (%)
33	47.9507638 106.8255713	3	1.8	Asphalt	Hole	20см*20см*2см	65%
34	47.9507642 106.8255717	3	1.8	Asphalt	Hole	20см*25см*2см	65%
35	47.9507645 106.8255719	3	1.8	Asphalt	Hole	110см*50см*3см	65%
36	47.9507649 106.8255722	3	1.8	Asphalt	Hole	20см*25см*4см	65%
37	47.9507650 106.8255722	3	1.8	Asphalt	Hole	50см*30см*4см	65%
38	47.9513459 106.8257032	3	1.8	Asphalt	Depression	12см*70см*13см	65%
39	47.953333 106.852222	3.5	1.4	Asphalt	Crack	7м*2.5см	80%
40	47.953333 106.854722	3.5	1.8	Asphalt		-	80%
41	47.953334 105.853062	3.5	1.7	Asphalt	Crack	14м*2см	80%
42	47.953061 106.906393	3.5	2.2	Asphalt	Crack	7м*3см	80%
43	47.695361 106.886670	3.5	7	Asphalt	Crack	6м*3см	80%
44	47.953060 106.919445	3.5	6	Asphalt	Crack	16м*3см	80%
45	47.95361 106.93389	3.5	2	Asphalt	Crack	6м*2см	80%
46	47.95306 106.91944	3	2	Asphalt	Crack	2.2м*2см	80%
47	47.953333 106.91500	3	2	rock	Crack	9м*2см	80%
48	47.953333 106.91500	4	2	Asphalt	Crack	4м*5см	80%
49	47.95389 106.935	3	17	Asphalt	Crack	7см*3см	70%
50	47.95722 106.95833	3.5	14	Asphalt	Hole	9.5м*70см*12см	50%
51	47.95694 106.95917	3.5	14	Asphalt	-	-	95%
52	47.95194 106.96528	3.5	14	Asphalt	Depression	18м*9м*4см	60%
53	47.94806 106.96833	3.5	14	Asphalt	-	-	95%
54	47.94000 106.96917	3.5	14	Asphalt	Crack	7м*2см	80%
55	47.93639 106.97472	3.5	14	Asphalt	-	-	95%
56	47.93417 106.98194	3.5	14	Asphalt	Crack	6м*2см	80%
57	47.93056 106.99083	3.5	14	Asphalt	-	-	95%
58	47.92389 106.99528	3.5	14	Asphalt	-	-	95%
59	47.92111 106.99528	3.5	14	Asphalt	-	-	95%
60	47.91278 106.99250	3.5	14	Asphalt	-	-	95%
61	47.91222 106.99194	3.5	14	Asphalt	Depression	6м*4м*7см	80%
62	47.89944 106.99499	3.5	14	Asphalt	-	-	95%
The average road conditions of existing roads that are being built and overlap with							75%

1.2.5. The average road conditions of existing roads that are being built and overlap

The planned road layout has been developed based on the road planning norms and rules in force in Mongolia, "Road Planning" ZZ BNbD 22-004-2016 and "Urban Planning and Construction Norms BNbD 32.01.04. According to the task of developing the feasibility study, the planned road falls into the category of Capital Road and Main Street Road of I and II categories (KZT, 2024).

Table 1. 11. Main Street Road Classification

Classification	Definition	Group	The primary purpose of the street/road
Main road	A street designed to carry the main traffic load of a city or village is called a main street.	Class I main street road	Connects the main elements of the city and village, and introduces the main load of transport traffic in the town. Does not intersect with the railway at the same level. Designed for all types of transport within the city.
		Class II main street road	This road often intersects with railways at various levels. It is similar in function to a Class I road, but has a lower traffic volume.

When designing road elements, the estimated traffic speed and basic road design geometry parameters are selected as shown in the table below (RTD, 2024).

Classification	Unit	Class I main street road	Class II main street road
Estimated speed	km/h	100	80
Minimum horizontal radius	M	600	400
Maximum slope	%	5	6
Concave vertical curve minimum radius	M	6000	6000
Concave vertical curve minimum radius	M	1500	1500
Minimum sight distance – when stopping	M	185	130
Minimum sight distance – when overtaking	M	320	245

In mountainous or harsh climatic conditions, as well as in the case of leaving access to buildings on roads undergoing significant repairs, the permissible slope along the main road may be increased by 1%, and along other roads by 2%. The number of traffic lanes on multi-lane roads is determined by the traffic service level based on a study of the traffic intensity. The roadbed and longitudinal and cross-sectional elements are planned in conjunction with each other and the surrounding terrain. In the following planning, it is not allowed to prepare a continuous straight section, and its length limit is selected not more than the following (KZT, 2024).

Radius of concave curve of the cross section (m)	Algebraic difference of the corresponding slopes (%)					
	20	30	40	50	60	80
4000	150	100	50	-	-	-
8000	360	250	200	170	140	110
12000	680	500	400	350	250	200
20000	-	-	850	700	600	550
25000	-	-	-	-	900	800

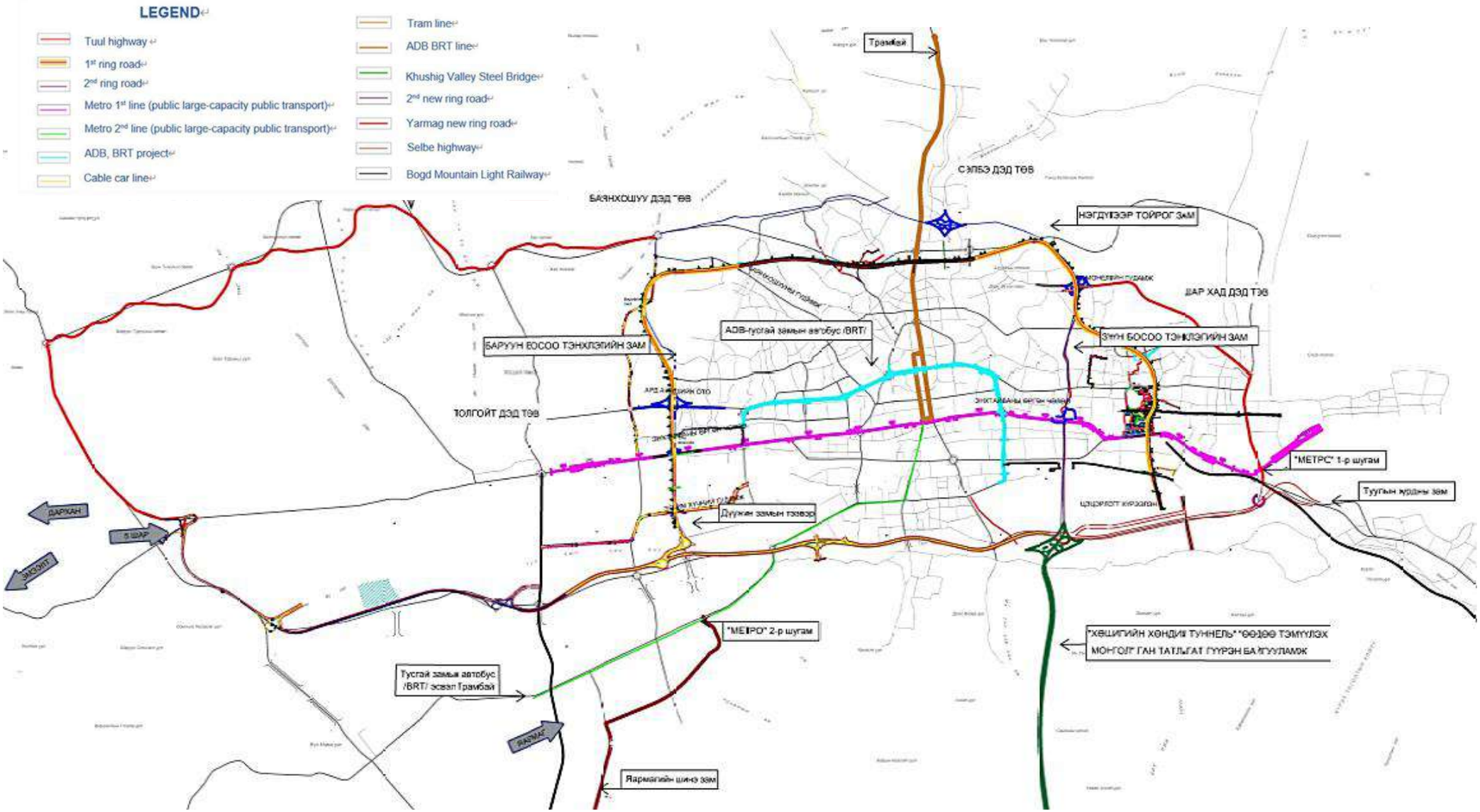
1.3. OTHER PROJECTS AND PROGRAMS BEING IMPLEMENTED NEAR THE PROJECT LOCATION

The following projects are being implemented in Ulaanbaatar in conjunction with the New Ring Road project to reduce traffic congestion in the capital. These include:

- High-capacity public transport metro (2024-2030)
- Tuul Highway and First Ring Road (2024-2030)
- Under-railway "hole" (2022-2025)
- Suspension road transport (2023-2026)
- Bus Rapid Transit (BRT) (2024-2028)
- Light rail "Tram" (2024-2027)
- Khushi Valley Tunnel, Mongolian steel cable-stayed bridge over the Oudeu River
- New Yarma Road
- Selbi Highway, etc.

Many new infrastructure projects are planned along the planned route, and the following image shows the locations of the projects and their intersections with the First Ring Road.

INTEGRATED PROJECT MANAGEMENT OFFICE
CSCEC AECOM Consultants Co., Ltd



Ulaanbaatar Metro

The Ulaanbaatar Metro project, a large-capacity public transport system, is planned to be built on Enkhtaivan Avenue with a length of 19.1 km. Since July 2024, the Korean company "Duhua Engineering" JSC has been conducting the necessary studies for the Ulaanbaatar Metro project. The consulting team has revised the feasibility study to increase the total length of the line from 17.7 km to 19 km. The metro will have one maintenance depot, which will be located at the end of Uliastai. A total of 15 stations will be built, with one additional station at the end of Uliastai. The average speed of the metro from Tolgoi to Amgalan will be 39.2 km/h, and the capacity to transport 17,000-26,000 passengers per hour.

Tuul Highway

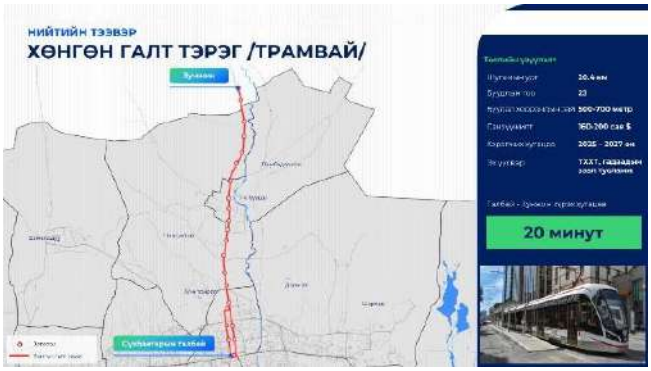
The construction of a 33-km six-lane highway directly connecting Bayanzurkh Bus Station to Bus Station 22 will begin this quarter. This project is a significant initiative that can directly alleviate the traffic congestion on Enkhtaivan Avenue and Yarmagiin Road.

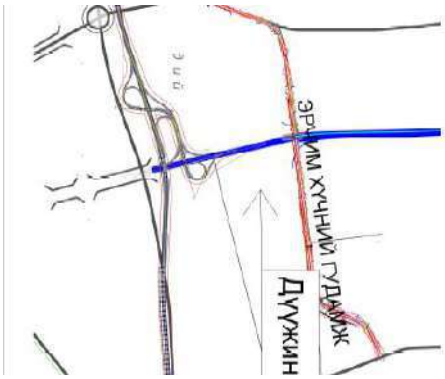
Bus Rapid Transit (BRT)

Two BRT lines will be implemented. One of the lines will run from Buyant-Ukhaa along Yarmagiin Road, cross the bridge, and return to the 120,000-meter camel statue. The Peace Bridge's carriageway has four lanes, with two lanes dedicated to bus rapid transit. If the bus rapid transit starts running on the narrow road, it will significantly impact traffic congestion. Therefore, it is necessary to expand the Peace Bridge and make the entire road from the Camel Statue to the square six lanes.

Cable car

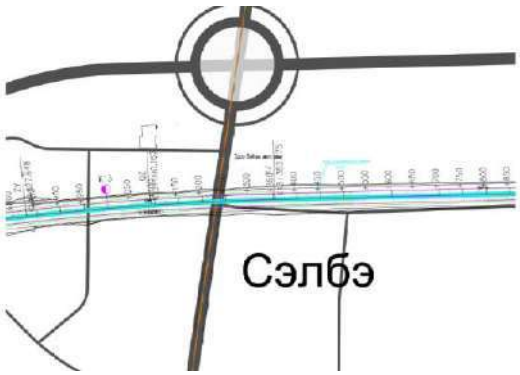
This project has been discussed since 2018. The most important thing is safety. Shuttle transportation equipment and components are manufactured in France and are being tested for shipment. Construction work will begin in the spring of 2025. It is planned to complete the job in 12 months. The length of the route is 4.2 km, and the travel time from Kharkhorin to Yarmag will be 11 minutes. All cabins will be heated from the seats, with a capacity of 10 people, and emergency transportation will operate in the event of a power outage.





LRT, Light Rail or "Tram"

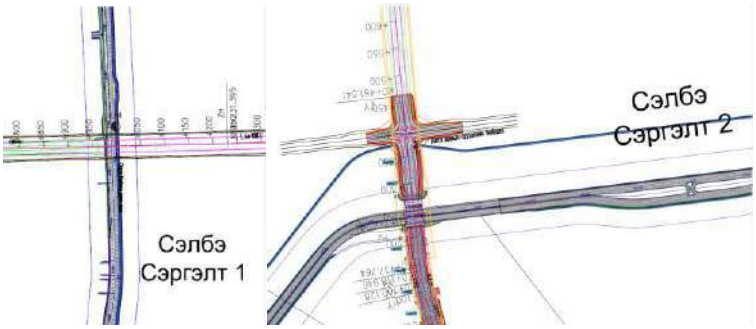
Light rail, LRT, and tram are collectively referred to as one term, and a preliminary feasibility study for the tram is being developed. A single vertical line will be built by the first quarter of 2025. The route of the line is planned to run from Zunjin Shopping Centre to Sukhbaatar Square. The tram will take three years to complete, which is 10 times less than the budget cost of the metro. It is also planned to build all the intersections of the metro, BRT, and tram at the central square. The best solution to reduce traffic congestion is to increase public transport accessibility, so the implementation of the above projects will increase the number of public transport passengers by 850 thousand. In addition, the average speed of buses will be 28 km/h, and the average speed of road traffic will be 18 km/h. (K13-200)



Selbe Sergelt 1 (between K0+150-c K0+300) and Selbe Sergelt 2 (between K13+900-c K14+050)

A comprehensive project with a road and bicycle path along the Dund and Selbe rivers. About 1/3 of the project scope is planned to be implemented in our khoroo. It aims to reduce flood risk and reduce road congestion, increase public transport accessibility, promote bicycle use, increase the city's pedestrian network, develop a cross-road network along the river,

reduce car use, improve amenities along the river, and create conditions for citizens to work and live in a healthy and safe environment.



Information on other road projects: The following projects are currently underway or planned to be implemented along the project route. These are:

Figure 1. 7. Energy street road project

Figure 1. 8. The road connecting the Tolgoit highway to the Ard-Ayushin Avenue.

Figure 1. 9. Road project between Gahain bair and Denjiin 1000

Figure 1. 10. Chingeltei 12th Khoroo Bulgiin Street No. 16, Bayankhoshuu Sub-Centre Road, Denji 1000-n Road Connecting to Hailaast Street, Bayanzurkh District

Figure 1. 11. The Khuree new road

Figure 1. 12. BZD 8th khoroo, Ulaanhuaran, Khilchin Street, Shar Khad-Khilchin Ulaanhuaran Road

Figure 1. 13. Repairement of the Janjin club road

1.4. ROAD AND ROAD FACILITIES

Bridge structures: As of 2024, there will be 85 large and small bridges with a length of 7325.71 m in Ulaanbaatar city. These are classified by size:

- Large /100m or more in length/ 13 in total or 4700.0 m in total;
- Medium /25-100m in length/ 44 in total or 2196.61 m;
- Small /up to 25m in length/ 29 in total or 429.1 m in length.

If the bridges in the city are classified by structure, there are 82 reinforced concrete bridges, two steel bridges, one wooden bridge, and nine road tunnels. The bridge structures in use are 25 years old or more, or 33 bridges built before 1990, and 37 bridges built before 1990. 87% of the bridge structures are rated as having good vibration resistance, 6% as having decreasing vibration resistance, and 7% as having poor vibration resistance. 6-13% of all bridges in the city are at risk during seismic shaking.

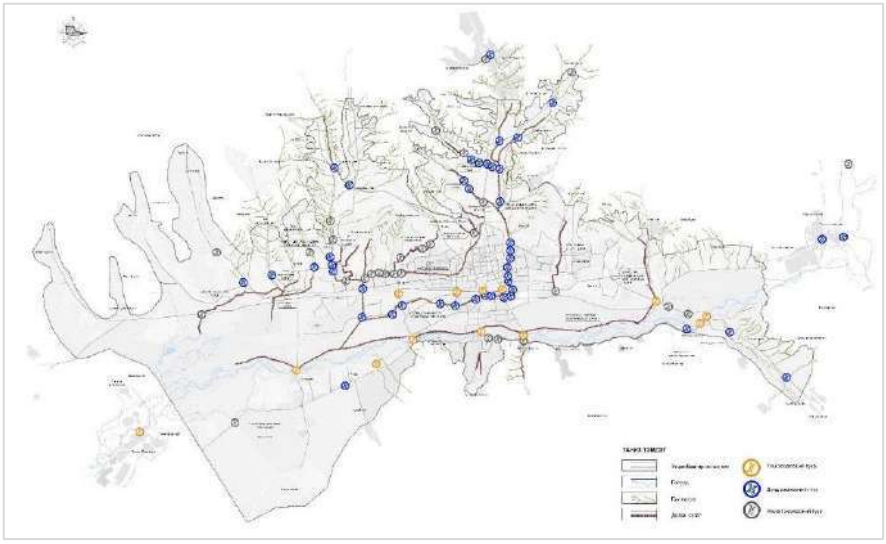


Figure 1. 14. Bridges location

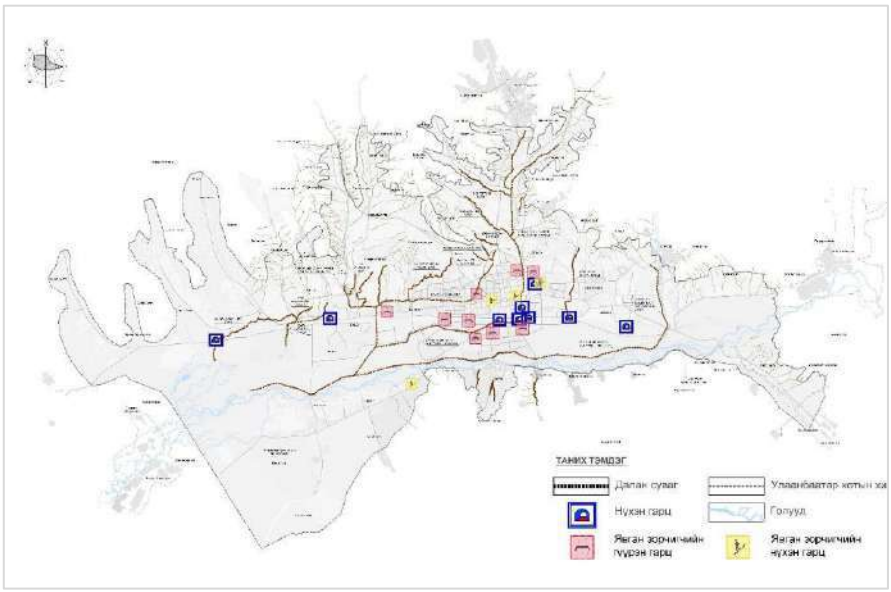


Figure 1. 15. Crosswalk locations

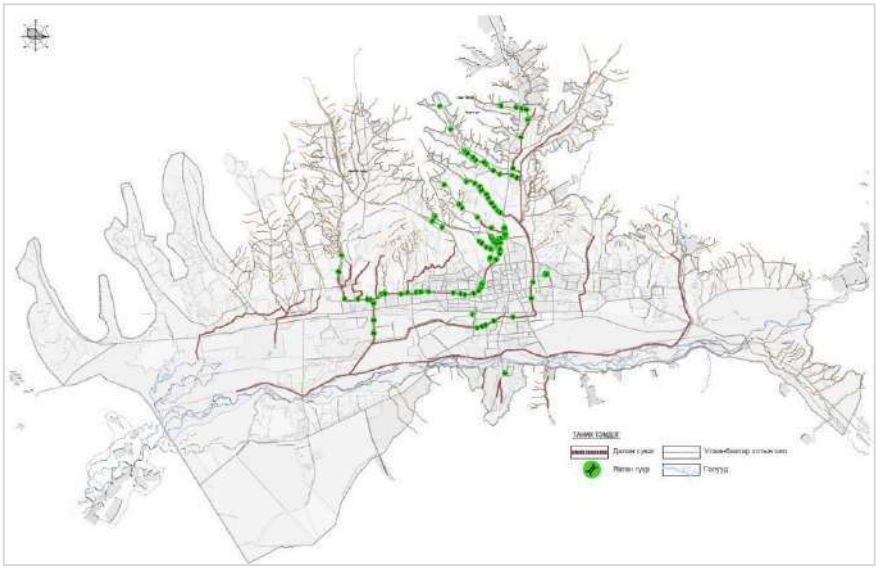


Figure 1. 16. Footbridge locations

In densely populated urban areas, pedestrians are at high risk of traffic accidents, and the lack of pedestrian crossings (overpasses and bridges) increases this risk. Therefore, the following issues need to be addressed urgently. The main bridges in Ulaanbaatar are located along the Tuul River, connecting the eastern and western parts of the city. The Peace Bridge, the Sun Bridge, the Yarma Bridge, the Olympic Bridge, and the Marshal Bridge play an essential role in the city's transportation network, connecting the southern and northern districts and are the main road junctions.

Peace Bridge is located in the city centre, on Chinggis Avenue, and is the main bridge crossing the Tuul River and connecting the southern and northern parts of the city. The Peace Bridge was built in the 1960s and was repaired and reinforced in 2007. The bridge is 378.88 meters long, with a 7×11.4+11.15+6+5×20+6+12×11.4 reinforced concrete transverse T-shaped bridge + Π-shaped rigid structure upper part of the bridge, a low-rise and square-pillared foundation, and a concrete U-shaped bridge deck. The bridge not only plays a vital role in the city's economic and logistics transportation, but also is a historical and cultural structure of the city.

Sun Bridge: Sun Bridge is another vital bridge in Ulaanbaatar, located across the Sun Road. It is an essential component of the transportation network of Ulaanbaatar, connecting the north and south of the city. The bridge is 895 meters long and uses steel plates in the upper part. It was officially opened on October 17, 2012 and is a relatively modern bridge in Ulaanbaatar. **Olympic Bridge:** The Olympic Bridge is a bridge built in the city centre on Ikh Mongol Street, with a total length of 1,167 meters and a two-way, 4-lane road. The bridge was entirely constructed and officially opened on September 22, 2022, and is playing an essential role in reducing traffic congestion.

Figure 1. 17. Peace bridge

Figure 1. 18. Sun bridge

Yarmag Bridge: Yarmag Bridge was commissioned in 2018. It has a total length of 4,312.2 meters, with a total length of 250.2 meters, crossing the Tuul River from the north to the south, and consists of four parts: the main linear bridge, the ring bridge, the ring road foundation, and the old bridge. It is the first intersection bridge in Mongolia.

Other bridges: Other bridges are located in different areas of Ulaanbaatar city and are mainly used for local transportation. The structures are usually simple structures, such as reinforced concrete and slabs, and are relatively short in size. Most were built after the mid-20th century.

Figure 1. 19. Olymp bridge

1.4.1. Crosswalk and footbridges

Figure 1. 20. Yarmag bridge

There are nine multi-level pedestrian overpasses and four underpasses in the built-up area. Still, the number of pedestrian overpasses and underpasses is insufficient in the densely populated areas of the city. Pedestrian bridges in Ulaanbaatar are usually located in high-traffic areas and over floodplains: for example, in the city centre, near schools and large shopping malls. The bridges are generally made of metal, and some new bridges have a modern design. Most pedestrian bridges have anti-slip and rain protection. Some have elevators and dedicated ramps to meet the needs of people with disabilities, which play an essential role in ensuring pedestrian safety.

Figure 1. 21. Other bridges

1.4.2. Issues of the bridges

The main bridges in Ulaanbaatar are mostly made of steel and reinforced concrete and were built from the mid-20th century to the early 21st century. Bridges built in the 21st century are of relatively modern design and construction. Mid-20th-century bridges are aging, poorly maintained, and have high traffic volumes, resulting in several problems.

Bridge aging: Many bridges built between the mid-20th century and the late 20th century have exceeded their useful life, leading to deteriorating structural integrity. Insufficient maintenance: Bridges have not been regularly repaired or replaced, and some are severely damaged, with cracks, corrosion, and broken bridge decks.

Traffic congestion: Almost half of Mongolia's population (about 1.5 million people) lives in Ulaanbaatar. The number of cars has tripled in the past decade, and traffic jams on bridges have become a common occurrence. Most bridges have two lanes, no car lanes, and no pedestrian walkways, making it challenging to change mixed-vehicle traffic. As the number of vehicles increases, bridges are overloaded, which further increases structural damage.

River water risk: In recent years, due to extreme weather changes, river flows have increased beyond historical levels, exceeding the design length of some bridges, putting bridge abutments at risk of severe erosion and damage.

Drainage damage: Bridge drainage structures are outdated, and water easily accumulates and freezes during the winter and rainy seasons when snow melts, increasing the risk of bridge deck damage and traffic accidents.

Climate impact: The extreme climate of Ulaanbaatar seriously affects the strength of bridges. Extreme temperature changes: Extreme cold in winter (up to -40 degrees Celsius) and high temperatures in summer (+35 degrees Celsius) cause bridge materials to expand and contract, freeze, and overheat, accelerating aging and wear. The use of snowmelt and the accumulation of ice and snow in winter can cause corrosion and damage to bridge structures.

Figure 1. 22. Footbridges

1.4.3. The current situation of the tunnels

Underpass under the railway near Narny Road: The underpass is primarily designed to divert vehicles and pedestrians from intersections in the city centre and reduce traffic congestion. It is approximately 200 meters (not approved), has two two-way roads and a pedestrian walkway. It was built in the early 2010s. It is currently in use and has significantly reduced congestion, but it still causes traffic jams during peak hours. During floods, it becomes impassable.

Underpass connecting Chinggis Khaan International Airport: Part of the highway connecting the city centre of Ulaanbaatar to Chinggis Khaan International Airport, reducing travel time from the city centre to the airport. It is 1.5 km long, with two lanes of traffic. It has been built since 2020. The tunnel, which is a key node on the airport highway, has improved the efficiency of traffic between the airport and the city, but is not yet fully connected to the entire highway network.

Tunnels outside the city: Although the tunnels outside Ulaanbaatar are located in a

geographically complex location (e.g., on a mountain plateau), these tunnels are still used to distribute traffic and reduce traffic congestion in the city centre. The tunnels are two-lane, two-way tunnels with a distance of 500 m to 1 km (many sections are separated), and were built in 2015-2020. Some of the tunnels on the outer road allow vehicles to pass through, but they do not have a fully integrated system, so the impact on traffic flow is minimal.

Tunnels along the Tovchoon Road (5-lane): A tunnel was constructed to make the road independent of railway traffic and improve continuous traffic flow. The tunnel length is 169 m underground, 5.8 m high, and 10.2 m wide. It has a complete drainage system. It will be put into operation in September 2024.

1.5. PUBLIC TRANSPORTATION OF THE CITY

The primary type of public transport in Ulaanbaatar is bus transport. Public passenger transport services are mainly provided by large-capacity buses. As of 2024, public transport carried 145.1 million passengers in that year, with a passenger turnover of 2,204.5 million person-km, and a total route length of 4,309.6 km. Public transport services are provided by 19 enterprises on 131 main and suburban routes. One thousand two hundred buses operate on weekdays and 925 on weekends. Public transport services are offered by double-decker buses, as well as large- and medium-capacity buses.

As of 2024, a total of 1,145 stops were used in public transport, of which 68 were final and 1,076 intermediate stops were registered. As of the first quarter of 2025, public transport services were provided on 131 routes and 4,623 stops in duplicate (Appendix 3). Public transport services have three main components: roads, parking lots, and vehicles. Currently, there are 1,280 parking lots in use for public transport, of which 126 are registered, 64 in the city centre, and 62 in the suburbs (Appendix 3). The lack of accessibility to the road network increases the overlap of public transport routes, leading to traffic congestion. According to research, the average speed of public transport is 11 km/h on weekdays and 16 km/h on weekends. Although public transport buses account for less than 5% of the total number of vehicles on the road, 50% of the total population uses public transport.

Table 1. 12. Types of public transport in Ulaanbaatar city

№	Types	2024	
		AANB	Vehicles number
1	Main	19	1278
2	Transit	2	34
3	Taxi	5	252
4	Workers shuttle bus	92	285
5	Children	61	148
6	School shuttle bus	20	43
	Total	199	1980

As of 2024, a total of 1,278 large-capacity buses were registered, of which 1,055 were diesel buses, 80 were electric buses, 10 were double-decker buses, 43 were modular buses, and 68 were medium-capacity buses. Of the 252 vehicles providing taxi services, 226 were

LPG-powered and 26 were gasoline-powered.

As of 2024, the total registration database included 2,145 large-capacity buses, 37 express buses, and 252 qualified taxi drivers.

1.5.1. Routes of public transport

As of 2025, public transport services will be provided daily on 131 routes, with large, medium, and small buses. Of these, 104 will be main routes and 17 will be suburban routes. The total route length is 914.3 km, with a total number of stops of 2,386.

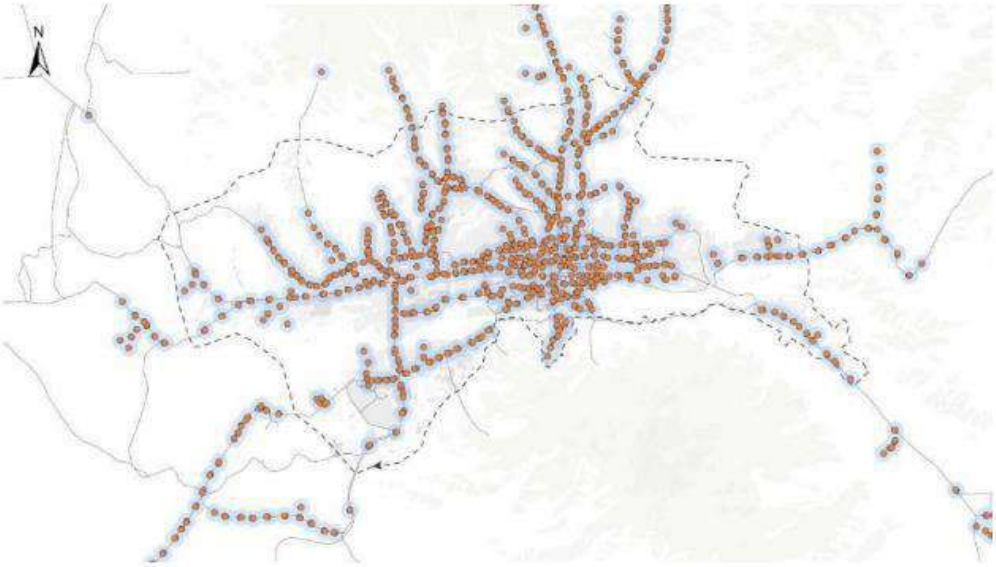


Figure 1. 23. Public transport station in Ulaanbaatar

1.5.2. City logistics

The current logistics situation in Ulaanbaatar involves transporting all local goods directly from the city centre, particularly from large shopping centres like Narantuul and Dunjingarav, as well as from railway stations and select food factories. In addition, goods from large mining projects such as Oyu Tolgoi and Tavan Tolgoi are imported, stored, and transported to Ulaanbaatar. The presence of wholesale trade centres operating throughout the city and large warehouses with freight terminals along the railway is another reason for congestion. Currently, 11 terminals are operating in Zones 1 and 2 of the town along the main railway line.

Pedestrian and bicycle paths: An integral part of the city's road infrastructure is pedestrian paths. Currently, there are 340.0 km of pedestrian paths and 98.3 km of bicycle paths along the highways in Ulaanbaatar. The width of the pedestrian paths is 1.5-3.0 m, and the bicycle paths are distinguished by their colour. The surface of the sidewalk is uneven and damaged, and the guide path for people with disabilities is installed in a way that compromises its basic use. Also, when constructing the bike path, the existing sidewalk strip was divided and distinguished only by colour. Since 2023, electric vehicles such as scooters and eco-bikes have been allowed to travel on the bike path, which hurts the comfort and safety of pedestrians.

1.5.3. Public parking space current situation

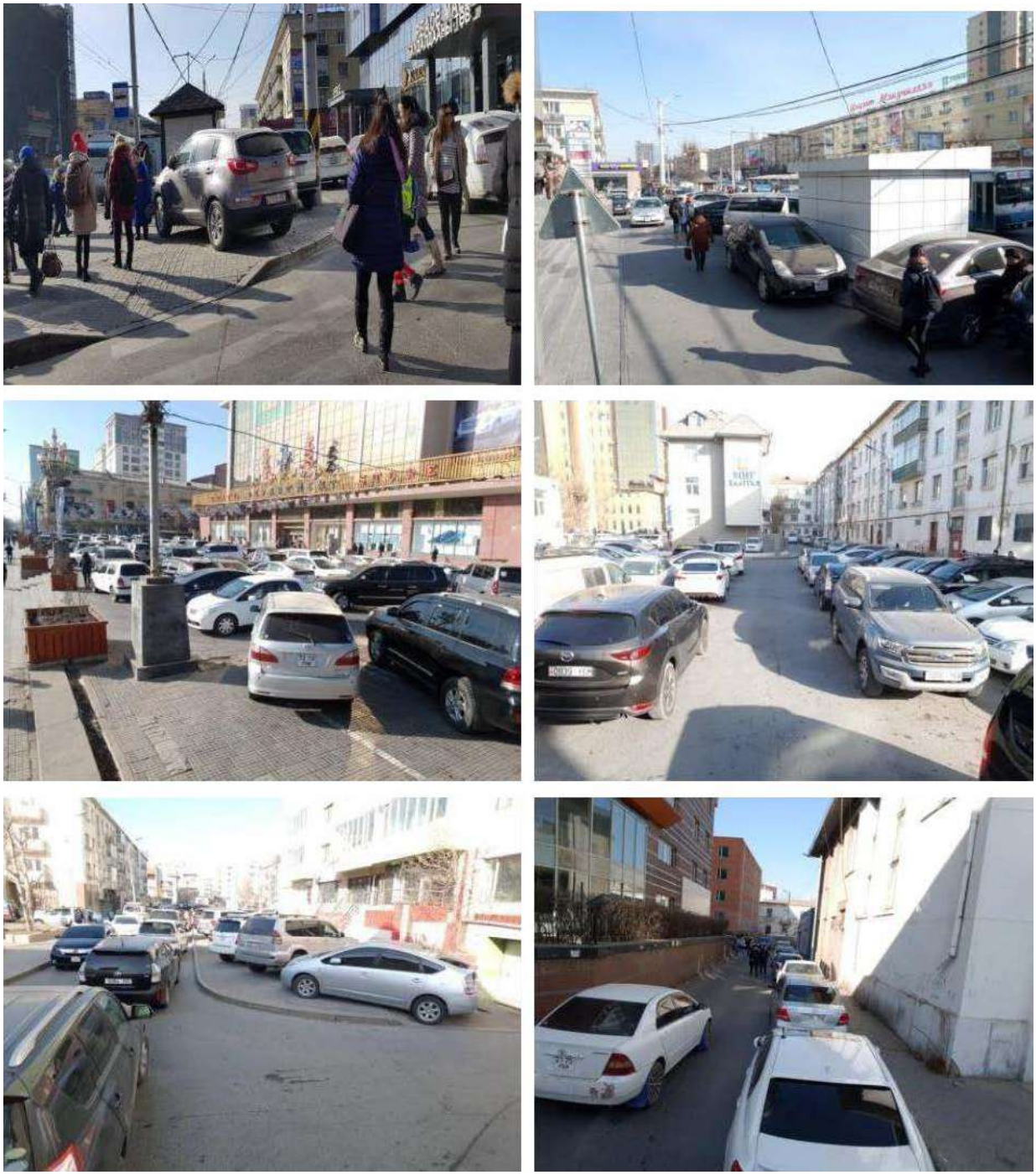


Figure 1. 24. Baga toiruu parking space and pedestrian current conditions

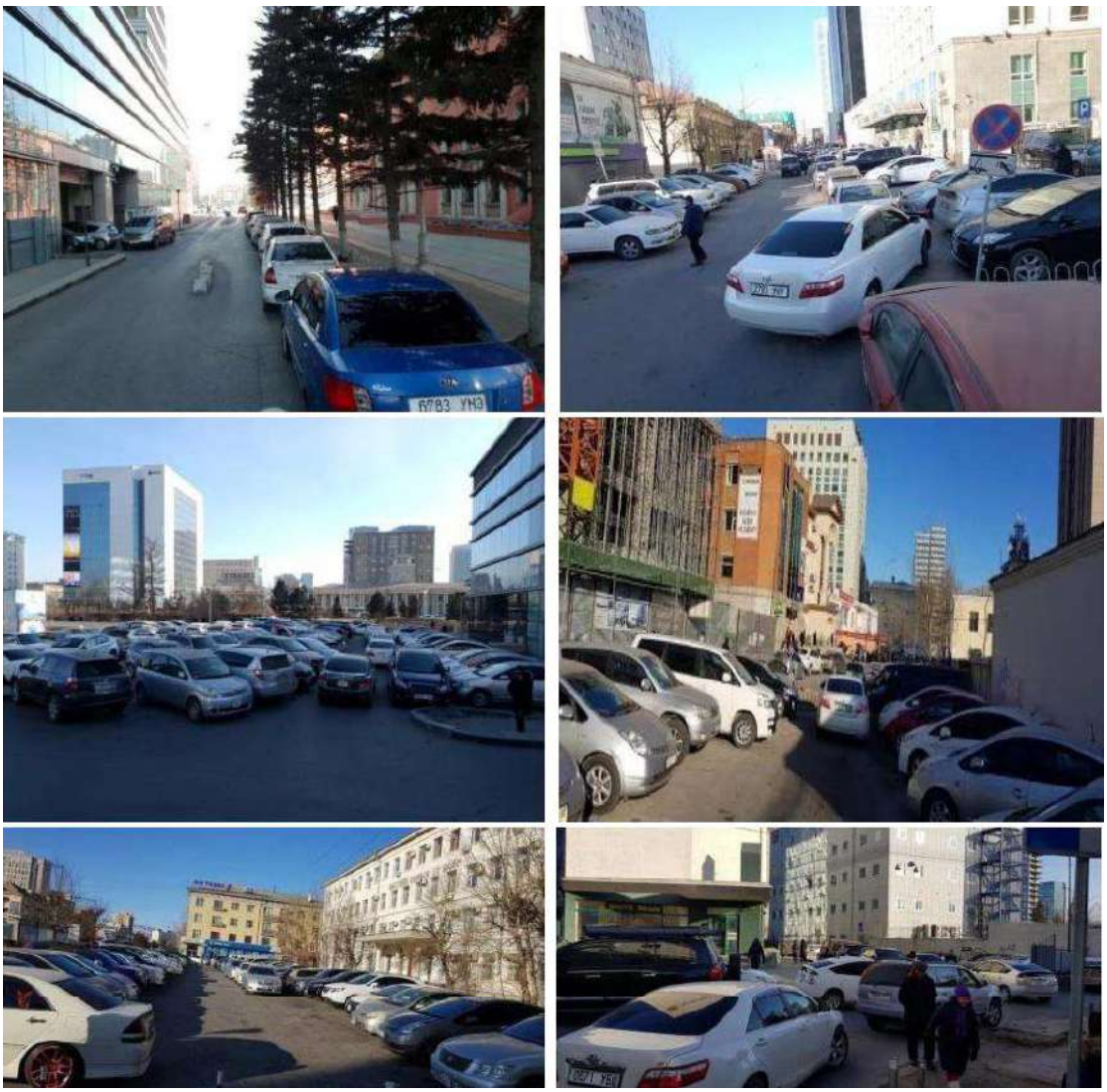


Figure 1. 25. Bayanzurkh tovchoo, Sapporo parking space current conditions

The parking problem in Sukhbaatar District, the current central district, is complicated due to insufficient planning for parking, population growth, and private cars in the original planning of Ulaanbaatar City. Since the parking capacity cannot meet the needs, the city administration is trying to solve this problem by taking management measures. Specifically, Sukhbaatar District is the main concentration area of government agencies and other organisations, and is the area where traffic congestion and parking needs are the most. The table above shows that approximately 70% of offices, entertainment facilities, and government agencies in Ulaanbaatar City are concentrated in Sukhbaatar District.

To build new buildings in Sukhbaatar District, the central business district of Ulaanbaatar, it is necessary to develop a parking planning and management plan according to the standards that are consistent with the characteristics of the location. The city's parking planning should comprehensively consider the following factors:

- Population size and growth trends
- Number of car owners and the percentage of car owners using Public transport services.
- Efficiency of existing parking facilities: Attractive changes for the city's population

- According to a survey on the assessment of the transport situation in Ulaanbaatar, 92% of citizens believe that parking is insufficient. 61% say that the availability of on-street parking has worsened since last year.

- There are approximately 2.4 parking spaces in the city centre.

Figure 1. 26. Pedestrian, green space and parking space current conditions

Table 1. 13. Districts' parking evaluation results.

Districts	Bad	Medium	Good
Bayangol district	92%	6%	1%
Bayanzurkh district	93%	6%	1%
Songinokhairkhan district	91%	7%	2%
Sukhbaatar district	93%	6%	2%

Districts	Bad	Medium	Good
Khan-Uul ditsrict	92%	6%	1%
Chingeltei district	91%	7%	2%

In other words, due to insufficient parking supply, poor parking organisation, and poor management in the capital city, Ulaanbaatar is experiencing a parking chaos, with bike lanes, sidewalks, and car lanes all in one lane, causing traffic congestion as people continue to search for parking spaces.

1.6. ASSESSMENT OF CURRENT PARKING RESOURCES

1.6.1. Planning and management experiences regarding parling

Rationalise the planning of sufficient parking spaces: Based on urban development, traffic changes, construction project locations, and parking needs, develop reasonable parking facility construction standards and public parking plans. Intensify the construction of public parking spaces: Urban public parking spaces are a vital part of the city's infrastructure. It is necessary to improve land planning, financial support, and policy support measures for the planning and construction of public parking spaces, increase the construction of off-street public parking spaces, actively promote the construction of underground parking spaces, double parking spaces, and automatic parking spaces, implement preferential policies, encourage social investment, and build a variety of off-street parking spaces, and increase investment.

Establish an integrated management of parking resources: Strengthen legal supervision and inspection of parking operations, and use a comprehensive approach of law, administration, and economics to manage and organize.

Improve the mechanism for forming public parking prices: Based on the general requirements of scientific resource allocation, rational demand identification, and revenue management, it is necessary to improve the mechanism for forming parking prices, taking into account factors such as resource employment costs, traffic structure adjustment costs, construction costs, operation and management costs, etc.

Improve the management of parking resources: In line with the requirements of convenient use, emphasis on guidance, and quality service provision, accelerate the construction of the identification and payment system of urban parking facilities. It is necessary to make full use of existing resources, combine the construction of the urban digital management system and the urban traffic information system, actively organise the urban parking information service platform, integrate parking resources, and vigorously organise the urban parking information system.

1.6.2. Strategy of parking development

Strategy 1: Zoning strategy. Implement a zoning strategy by dividing the city into three

parts based on the district's parking supply along the main road, public transport development, road network capacity, development trend, and density. Implement a strict parking supply strategy to control parking supply and fees in the I and II urban areas. Additionally, implement a parking supply strategy to comply with the public transport policy of the city centre area. Ensure the availability of parking in the three urban areas.

Strategy 2: Time-limited strategy. Establish time-limited parking management according to the capacity of the road network. Increase the construction of parking lots in the city centre area in the coming years, and focus on parking demand management in the medium and long term, and increase parking construction. For I and II urban areas, prioritise short-term improvements in parking management and expansion of parking supply. In the medium term, focus on parking construction. In the long term, focus on managing parking demand and increasing parking construction. Within the framework of the three categories, parking lot construction and parking demand management should be given equal importance, and parking spaces should be provided in sufficient quantities.

Strategy 3: Multi-faceted strategy. In the context of the coexistence of various types of parking lots, such as underground parking lots, street parking lots, underground garages, parking buildings, automatic and non-automatic parking lots, appropriate parking types should be selected based on the permitted land use conditions in different areas of the city. Actively promote the development and application of new parking technology products.

For parking lot management, the organisation in charge must improve and enforce relevant regulations, gradually reduce illegal parking, and adopt policies to promote orderly parking that meets urban standards.

Parking lot ownership: In addition to the current basic construction methods, such as building parking lots in buildings and government investment, it is also necessary to promote the construction of parking lots by individual entrepreneurs or organisations in various ways. Property rights can be separated to create a parking lot development model.

Strategy 4: Differentiated standard strategies and parking standards should be revised, with different standards applied in other city areas. Specifically, Level I, II, and III vehicles should be balanced with road capacity.

Parking spaces are classified into the following types according to their purpose. These include:

Special-purpose - parking spaces belonging to professional transportation organisations or enterprises, which are only intended to stop internal vehicles of the relevant organisations. For example: public transport bus stops, long-distance freight, passenger transportation centres, etc.

Parking spaces outside service buildings - parking spaces attached to extensive public facilities or buildings, which mainly provide parking services to passengers related to business

activities. The target group of parking services includes vehicles of the main building and cars coming from outside the building.

Public parking spaces - parking spaces that provide public parking services to passengers of all types of activities, and the service scope is the widest, and are usually located near large shopping malls, city entrances and exits, and public transportation interchanges. Specifically, parking spaces outside service buildings and public parking spaces are not entirely different; both serve a specific purpose within the target group of parking services and support each other. Parking spaces outside buildings are used as public parking spaces to some extent.

Regarding the use of parking spaces: Side parking spaces within the carriageway - a space marked with several lanes for parking vehicles on both sides or one side of the red line of a city road. This parking space is suitable for temporary parking and entry, but it significantly obstructs traffic. Therefore, it is necessary to have sufficient width for other vehicles to pass through this parking space or to restrict such parking.

Independent parking: This parking lot is situated outside the city road and is connected to it via an auxiliary road. It has little impact on traffic.

In terms of parking location, it is classified as:

Above-ground and double parking lots are the most commonly used parking lots because they are convenient and low-cost. Currently, such parking lots have been established in the areas of the Ikh Nayyar Shopping Centre and the 1st General Hospital.

Figure 1. 28. Scheme of parling in the road

Figure 1. 27. Individual parking space

Underground parking: This refers to one or more floors of parking built underground. It improves the use of urban land and enhances the value of land use. However, the cost is relatively high because it requires additional lighting, air conditioning, drainage and other system maintenance costs.

Double parking structure: It can be built in the city centre or on a slope, and can be used to automatically move, store, and retrieve vehicles up and down and horizontally, using elevators or lifting machines to park them in the required parking spaces. The parking rack is also a vertical, automatic control, multi-layer steel structure, and uses equipment to load and unload vehicles. Double parking racks can be installed in both above-ground and underground parking lots to increase the number of parking spaces.

Figure 1. 29. Layerd parking spaces

In terms of operations management,

Free parking: refers to on-street parking in residential and commercial areas, temporary parking lots in extensive public facilities and post offices, and parking lots outside shopping malls and restaurants. The turnover rate of free parking lots is high, and the parking time is short.

Time-limited parking: Limiting vehicle parking time and imposing fines for exceeding the specified duration can improve the turnover rate. Traffic police or a duty officer usually monitors time-limited parking lots. The fee varies depending on the time of use.

Paid parking: refers to parking lots where a specific parking fee is charged regardless of the length of time of parking. There are usually two types of fees: hourly and unlimited. There is no time limit, and only one payment is required.

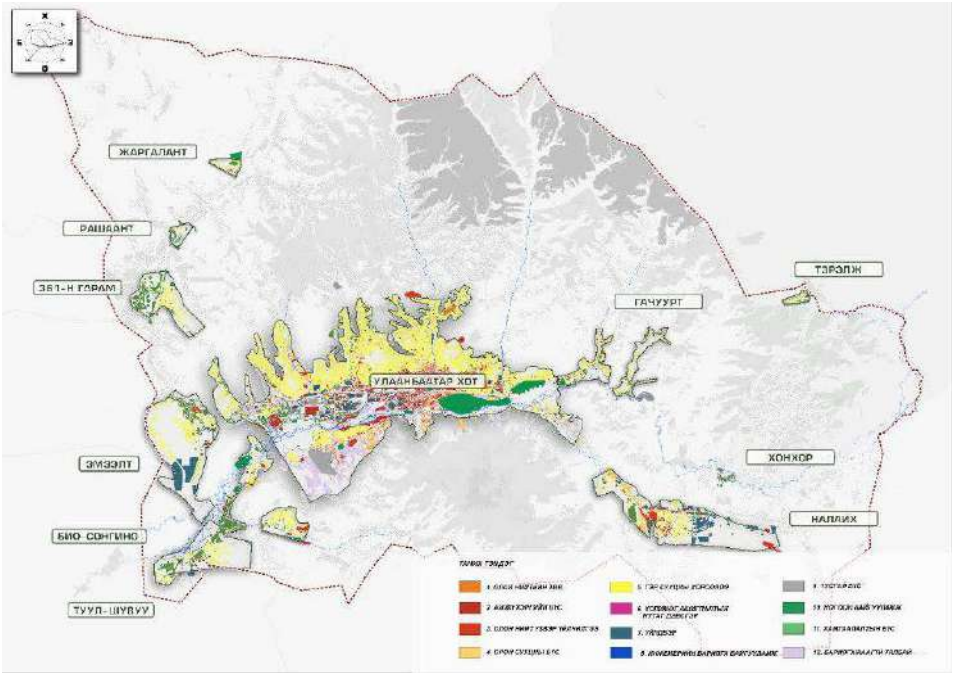
Special-purpose parking: refers to parking lots designated by signs for certain types of people or vehicles. There are temporary parking lots (temporary taxi stops for picking up and dropping off guests, temporary parking lots for loading and unloading goods, or temporary parking lots for delivering mail), parking lots for the disabled, the elderly, and medical personnel.

1.7. CURRENT STATUS OF URBAN ORGANIZATION

1.7.1. Current status of urban organization

The capital of Mongolia, Ulaanbaatar, is a city with a history of 383 years, located in the valley of the Tuul and Selbe rivers, surrounded by the Bogdhan, Songinokhairkhan, Chingeltei, and Bayanzurkh mountains at an altitude of 1,300-1,350 meters above sea level. It has six

Figure 1. 30. Нийслэл Улаанбаатар хот орчмын нутаг



central districts and three remote districts. The total area is 47,035.1 km2. Since 1954, Ulaanbaatar has been expanding in the west and southwest directions with an urban planning structure of residential, industrial, warehouse, engineering infrastructure resources, green areas, specially protected areas, and a public centre area of the city, by six general plans and specifications. Ulaanbaatar is generally elongated to the east and west, with a geographical slope in the east and west directions, and surrounded by mountains and valleys in the south and north. As of 2024, Ulaanbaatar. Ulaanbaatar is the core city of the capital's urban development system. The Ulaanbaatar Urban Development Plan-2020/2030 and Ulaanbaatar Urban Development Plan-2040, respectively, have estimated the area of Ulaanbaatar's urbanisation support at 35,206.0 hectares, while maintaining the existing settlements and taking into account water resources, natural ecology, and land surface slope. As of 2024, the ger settlements in the mountainous and steep northern part of the city will cover a total area of 10,328.2 hectares, with 40% of the city's total population, or 600,000 people from 169,400 households, permanently residing. In the relatively flat and low-lying area, with relatively low surface slope, 6,950 hectares, 898,500 people from 252,300 households, or 60% of the total population, will reside in built-up areas with engineering infrastructure. Over the past 30 years, the process of migration to Ulaanbaatar has increased sharply. Since the majority of citizens migrating from rural areas settle in ger districts, the rapid expansion of these districts and the increase in the number of vehicles have hurt the city's conditions. As a result, Ulaanbaatar is facing the following problems and obstacles. These include:

- Constant traffic congestion
- Loss of urban planning policy

- Air and environmental pollution
- Violation of citizens' rights to a healthy and safe life
- Increased unemployment and poverty
- Insufficient and inconsistent provision of social and engineering infrastructure, etc.

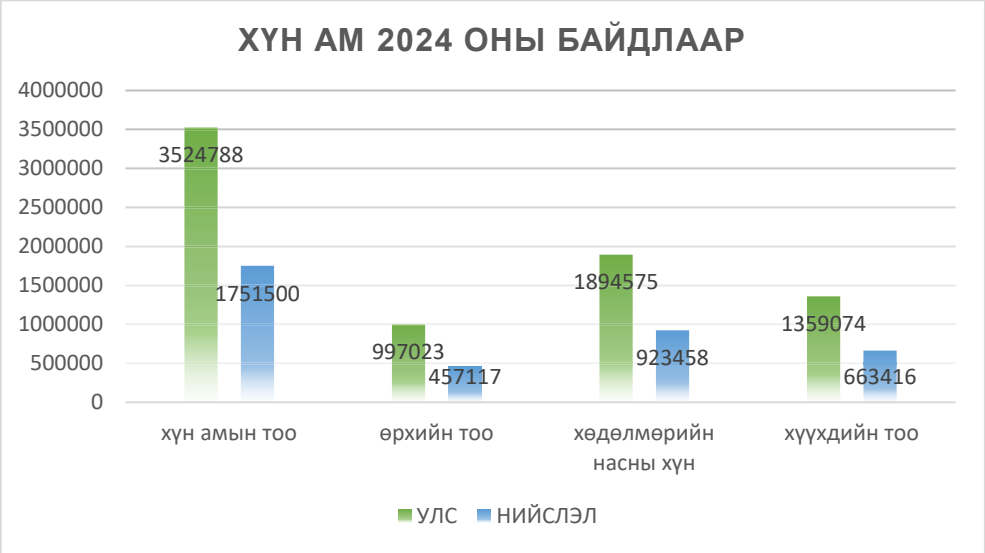


Figure 1. 31. Population growth by country and city

The master plan for the development of Ulaanbaatar until 2040 aims to address issues such as transforming the monocentric city structure into a polycentric one, developing satellite cities, and creating sub-centres to facilitate access to infrastructure, government services, and reduce traffic congestion. The "New Revival Policy" approved by Resolution No. 106 of the Parliament in 2021 is a medium-term target program aimed at strengthening Mongolia's economic independence and self-reliance, reducing the negative impact on the country's socio-economic situation, promptly resolving factors limiting development, creating the basic conditions for implementing the "Vision-2050" long-term development policy, and improving the economy, infrastructure, and state productivity. It includes the construction of 4 ring roads around the city centre, six horizontal and nine vertical main roads, improving the quality and standards of public transport in Ulaanbaatar, introducing new types of public transport with high capacity, expanding and upgrading the network of primary roads and road facilities, and establishing multi-level intersections to increase accessibility.

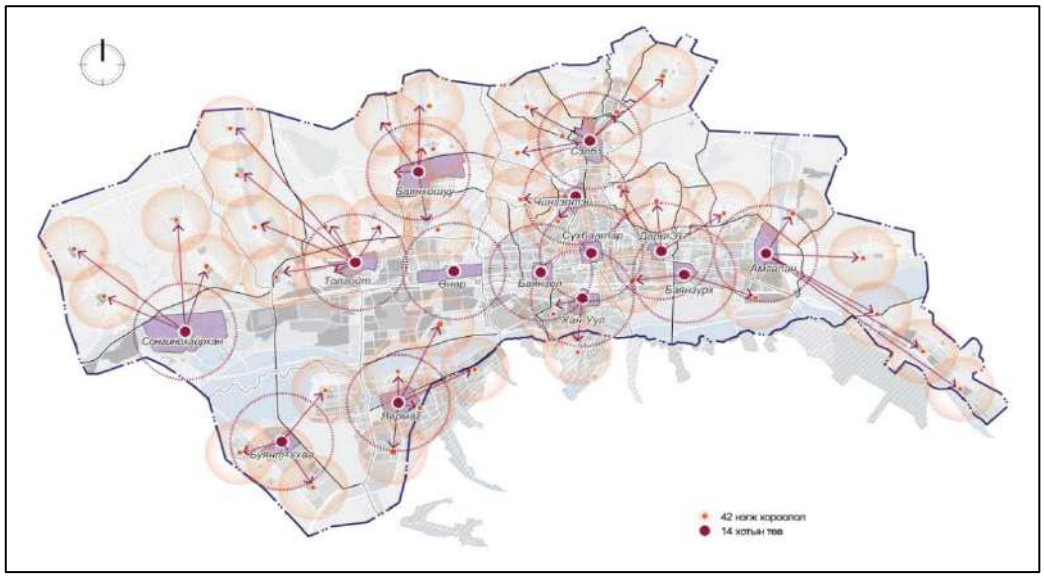


Figure 1. 32. Polycentric city impact

Within the framework of the port revitalisation policy, it is planned to build 2966 km of paved roads, 3358 km of railways, and connect 11 new ports with paved roads and four ports with railways. As of 2024, 1768100 people from 457117 households, or 45.8 per cent of the total population of Mongolia, live in the capital city. The population density is 2.3 people per square mile nationwide and 376.2 people per square mile in the capital city, which is a significant problem.

1.7.2. Land expansion of Ulaanbaatar city

The process of urbanisation is underway in the capital city of Ulaanbaatar. The urbanisation process is mainly developing along the main national roads. According to the classification of cities and towns specified in the "Urban Planning and Construction Norms and Rules of the Mongolian People's Republic of 30.01.04", the urban areas have a metropolitan development and settlement system with urban areas classified as large cities 1 (Ulaanbaatar city), small cities 3 (Nalaikh, Baganuur, Bagahangai), and rural villages 8. Due to the weak development of the links between neighbouring urban areas and the lack of a clear policy, strategy, and plan to support growth, the development of the metropolitan regions and villages is slow.

- Nalaikh, Bagahangai cities and villages are a mixed settlement type with built-up and ger settlements common throughout Mongolia.

- The built-up area will have centralised, partial engineering supply, 1-9 (Nalaikh, Baganuur)-n, two-story residential buildings for public, industrial, and service purposes, and a network of paved streets and roads, and green spaces. The ger district will consist of residential and ger houses with natural dirt roads and cultivated land.

- The villages will have partial, independent engineering supply, ger districts and low-rise buildings for economic purposes, connected by paved roads along the vertical and horizontal

axes. Some villages and settlements have emerged in a flow without specific planning. A clear example of this is 361-garam.

- Settlements such as Tuul-Shuvuu and Bio-Songino have emerged based on agricultural production and services such as chicken and poultry egg production, greenhouse farming, and animal medicine, and have low and medium-rise buildings and partial IDB supply. There are paved entrance roads in some areas.

- Villages and settlements such as Rashaant, Emeelt, and Honkhor have low-rise residential buildings, warehouses, and industrial and ger districts along the railway station.

- Jargalant village, formerly known as Jargalant Sangin, is a dairy farm with 800 cows, and agricultural production is dominant.

- Gatsuurt village was originally developed along the Gatsuurt 800-cow farm, but in recent years, tourism has developed slightly and is developing in the form of camps and ger districts for city residents.

- The chaotic expansion of ger districts has negatively affected the ecological conditions of the Tuul and Gatsuurt rivers.

Due to the unorganised allocation of land in the settlement environment, permitted and unauthorised groups of settlements have been established within the protective strips of land with rivers and forests, polluting the environment. The population figures show that these urban areas have not developed significantly from 2013 to 2020. The following factors have contributed to this situation:

- The capital city has no specific initiatives, policies, or planning strategies for the development of peripheral urban areas, and this work has been neglected

- The state and the capital city have no sources of investment for development, so the construction of road transport and engineering infrastructure has not been carried out

- The land allocation process has been carried out in a chaotic manner, which has legally created conditions for unplanned settlements in the future

- Within the framework of the policy of free land ownership for citizens of the Republic of Mongolia, 52 locations in the capital city have no planning designs

It is necessary to improve the current situation, balance the development of urban areas in the capital city, and break up excessive concentration, as reflected in the 2040 development concept of Ulaanbaatar. These measures need to be reflected in the general development plan of Ulaanbaatar. These are:

- The capital city has no specific initiative, policy, or planning strategy for the development of peripheral urban areas, and this work has been neglected

- The state and the capital city have no sources of investment for development, so the construction of road transport and engineering infrastructure has not been carried out

- The land allocation process has been carried out in a highly chaotic manner, which has

legally created the conditions for unplanned settlements in the future

- Within the framework of the policy of free land ownership for citizens of the Republic of Mongolia, 52 locations in the capital city have no planning designs

To improve the current situation, it is necessary to take the following urban development measures, as reflected in the 2040 development concept of Ulaanbaatar, to balance the development of urban areas in the capital city and to break up excessive concentration. There is a need to reflect these measures in the general development plan of Ulaanbaatar. These include:

- Determining the capacity of the urban area within the territory of the capital city
- Defining the boundaries of the surrounding urban areas
- Determining the direction of production and services in urban areas
- Proposing a proposal to create a sophisticated system for managing urban development policies within the capital city

The assessment of urban development in the existing territory of Ulaanbaatar city, based on four main and 54 sub-indicators, resulted in an overall rating of 2.8 or "limited suitability". Of these, the environmental assessment was 3.5 points or limited suitability, the socio-economic assessment was three or medium, the overall infrastructure assessment was 2.8 or medium, and the architectural space and landscape assessment was 1.9 or unsuitable.

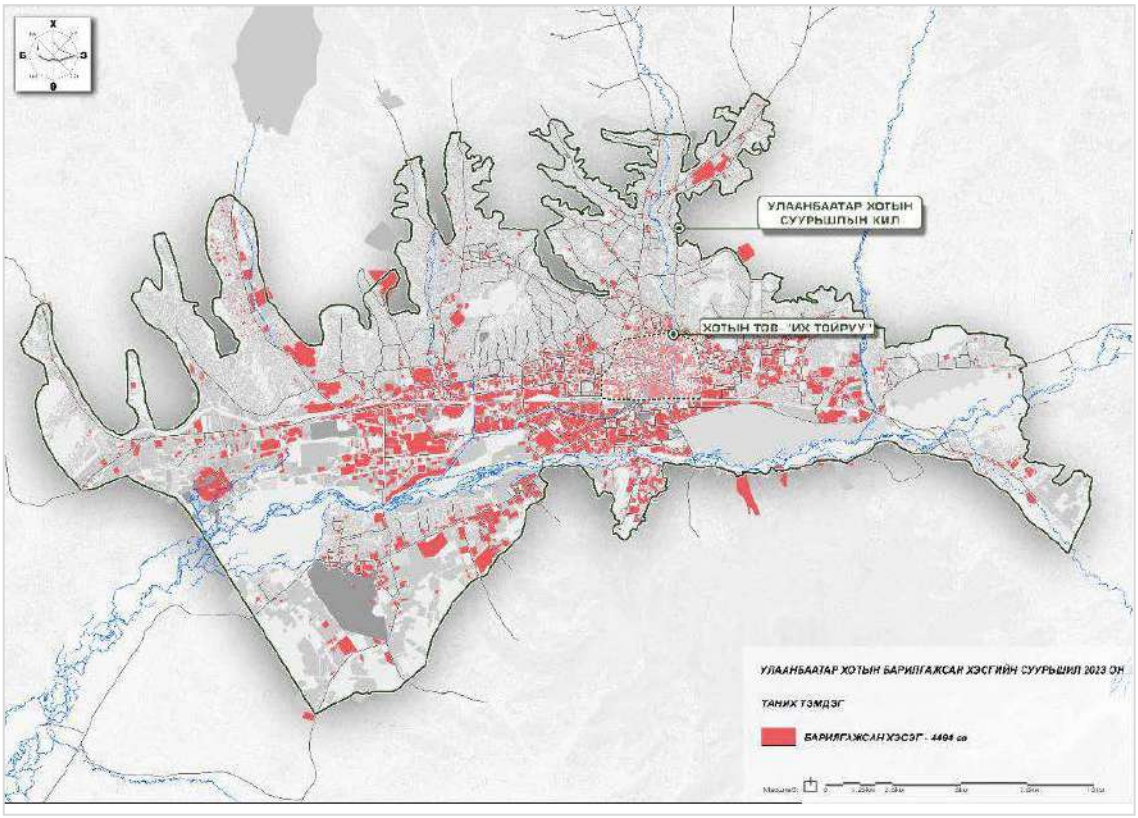


Figure 1. 33. Urbanized area of the city

By 2024, settlements with ger districts in Ulaanbaatar city will have been established on a total area of 10,328.2 hectares in the mountainous and rugged northern part of the city, where

40 per cent of the city's population, or 600,000 people from 169,400 households, will permanently reside. In the relatively flat lowlands, where centralised engineering infrastructure is provided, built-up settlements will be established on an area of 6,950 hectares, where 60 per cent of the city's population, or 898,500 people from 252,300 households, will permanently reside.

1.7.3. Built-up area of Ulaanbaatar city

The built-up area is characterised by the concentration of streets, public housing complexes, and public housing estates. The area varies in size depending on its location. The return on investment in construction is particularly high in the city centre, resulting in a high density of construction and settlement, which is also evident in some other areas. The financing in the construction sector primarily supports the construction of public housing. Meanwhile, the chaotic construction of vacant land without planning is underway, which not only destroys the comfortable living environment of residents but also spoils the city's architectural appearance. Social services such as culture, art, education, physical education, and sports, as well as extensive commercial and industrial services, are concentrated in the built-up area, creating a pull towards the city centre and directing the flow of traffic in one direction.

The built-up area consists mainly of public buildings, public housing estates and micro-districts with centralised engineering infrastructure. The population density in the built-up area is uneven and unbalanced, ranging from 13 people/ha to 1712 people/ha. The built-up area consists mainly of public housing, public and industrial buildings, with centralised engineering infrastructure.

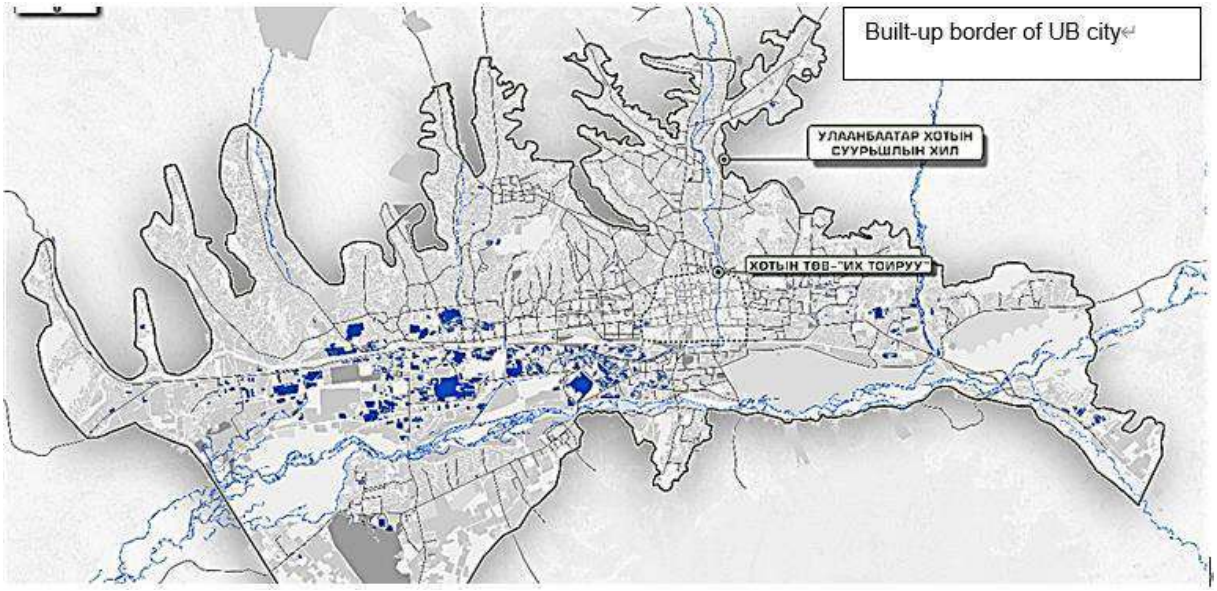


Figure 1. 34. Ulaanbaatar City Factory Zone

An essential component of the built-up area of the city is the industrial and warehouse zone. The industrial and warehouse zone is located in the southwest of Ulaanbaatar city and is home to large state-owned industrial enterprises. In addition to the concentration of

metallurgical enterprises in the region, the engineering network supply sources of Ulaanbaatar city are located. As of 2024, a total of 2341.1 hectares of the territory of Ulaanbaatar city are used for industrial and warehouse purposes. The withdrawal of raw materials and fuel from industrial enterprises is branched off from the railway running through the city. The increasing uncontrolled expansion and settlement of ger districts in unsuitable and dangerous places such as ravines, floodplains, steep slopes, and under high-voltage lines is increasing the risk of endangering the right of citizens to live safely. The city lacks a clear policy and planning for the development of green areas, and a system to control and limit settlement expansion, resulting in inadequate provision of road transportation, engineering and social infrastructure, and access to green spaces, which is reducing the living conditions and quality of life for residents.

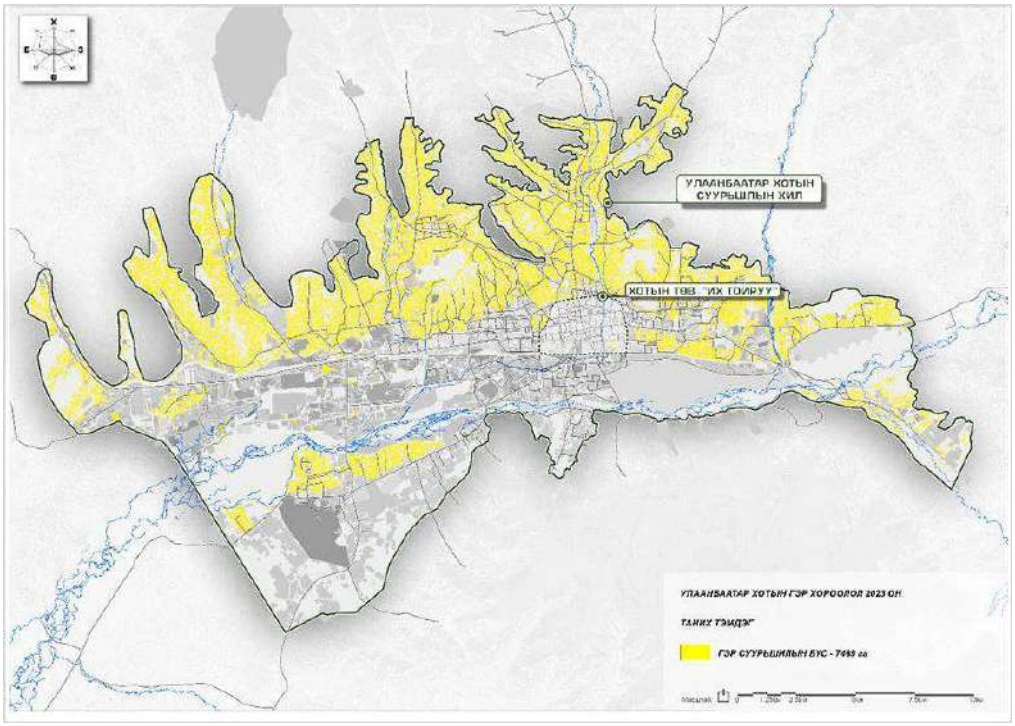


Figure 1. 35. Ger area of UB city

Current status of construction: The construction survey was conducted along the "New Circle" highway route, with a 60m strip and an impact zone, by building type and floor. The impact zone was taken as 600m at the research stage, and as 1000m in the densely populated area. The route of the road passes through 53 khoroos of 5 districts of Ulaanbaatar city, and is planned to merge with the Tuul highway through the Industrial Zone in the southwest, the flood dam and the high-voltage power line protection zone in the west, the "Onur" district in the west, the Bayankhoshuu ger settlement area in the north, the Tsagaan Dawan pass in the east, the Khilchin residential area, and the Janjin ger district. The construction survey was developed by building type and overlap. The types of buildings were studied according to the following general categories:

- residential
- residential

- serviced residential
- trade and various services/shops, auto repair, hotels, hot water/
- educational institutions/universities, general education schools, kindergartens, training centres/
- hospitals, health care
- factories, warehouses, business offices
- public, administrative/cultural centres, sports halls, community centres/
- special-purpose/fire departments, defence, courthouses/
- gas stations
- engineering infrastructure/heating centres, electrical substations, wells, water distribution facilities/.

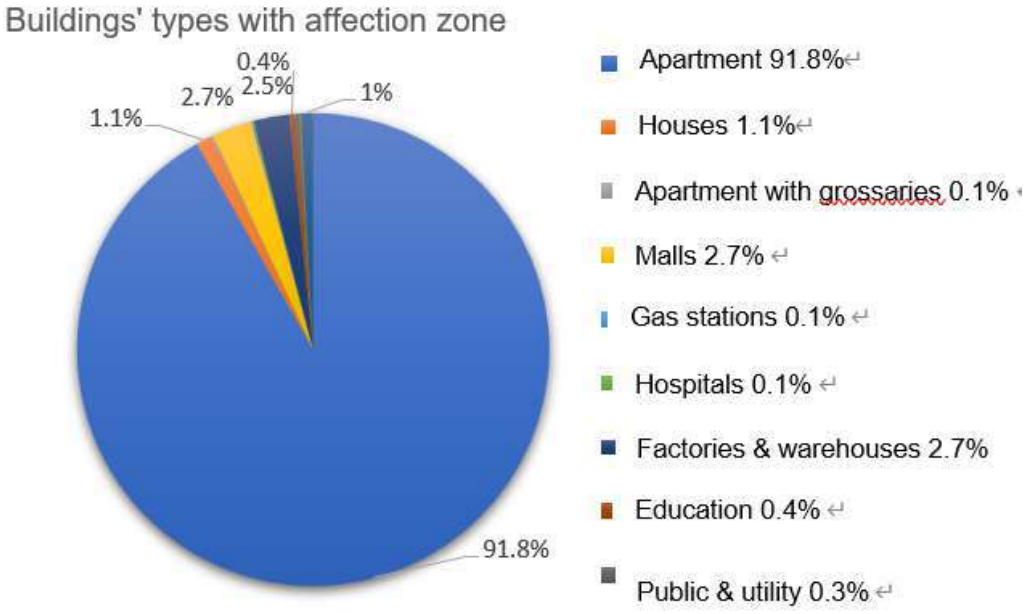


Figure 1. 36. Study of buildings

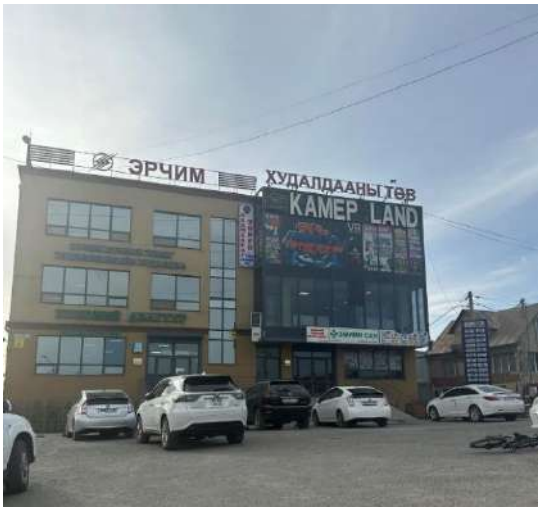
According to the study, there are 11,951 residential buildings, 144 apartments, 15 serviced apartments, 355 commercial and service buildings, 52 educational buildings, 14 hospitals and health facilities, 319 industrial and warehouse buildings, 33 public and administrative buildings, 17 special-purpose buildings, 11 gas stations, and about 108 engineering infrastructure buildings in the 31,121 unit area affected by the road. Of these, 1,191 residential buildings, three serviced apartments, 42 commercial and service buildings, 41 industrial and warehouse buildings, one gas station, four public and administrative buildings (UBBG, Soyombo Sports Hall, Sukhbaatar District 13th Khoroo Building), and 15 electrical substations are affected within a 60-meter strip of the road. In the total area, the majority of residential buildings in ger districts are self-built, with plank fences and pit latrines, while industrial and warehouse buildings built before 1990 are brick, and those built after 1990 have sandwich walls and roofs.

There were many collapsed and unused residential and warehouse buildings in the impact area.

The number of buildings was categorised into three groups: 1-2 floors, 3-6 floors, and seven or more floors. Out of a total of 13,019 buildings, 12,801 or 98.3% of the buildings were 1-2 floors, 117 or 0.93% of the buildings were 3-6 floors, and 101 or 0.77% of the buildings were seven or more floors.

"Soyombo" sport hall (built in 2020, overlapping in the project alignment in SBD)

Apartment with a shopping mall in the planned alignment in BZD, under construction



Shopping centre in the planned alignment, SKhD

Apartment with a shopping mall in the planned alignment in BZD, built in 2024

“Buyan” furniture factory in the alignment, built in 2022, SKhD

13th khoroo building in SBD, built in 2014, in the planned alignment

Factory building (the right side building was built in 2017, and the left side building was built in 2023)

Total motors store in the planned alignment, built in 1990, BZD

“89” car wash, in the alignment and built in 2014

ChD, house in the alignment

Figure 1. 37. Buildings study

1.7.4. Protection of the history, properties, and heritages

Article 7, Section 1 of the Constitution of Mongolia states that "Mongolian people's historical and cultural monuments, scientific and intellectual heritage are under state protection," and Article 1.1.6 of the "National Security Concept of Mongolia" approved by Resolution No. 48 of the State Great Khural of 2010 states that "Preserving, protecting and

developing national history, language, culture, heritage and customs are the foundation and vital immunity of the Mongolian nation." Article 4.3.2 of the "State Policy on Culture" approved by Resolution No. 52 of the State Great Khural of 2012 states that "the ancient and modern cultural heritage shall be kept under state protection as a precious national treasure." No historical monuments under state or capital city protection shall be affected along the route of the First Ring Road.

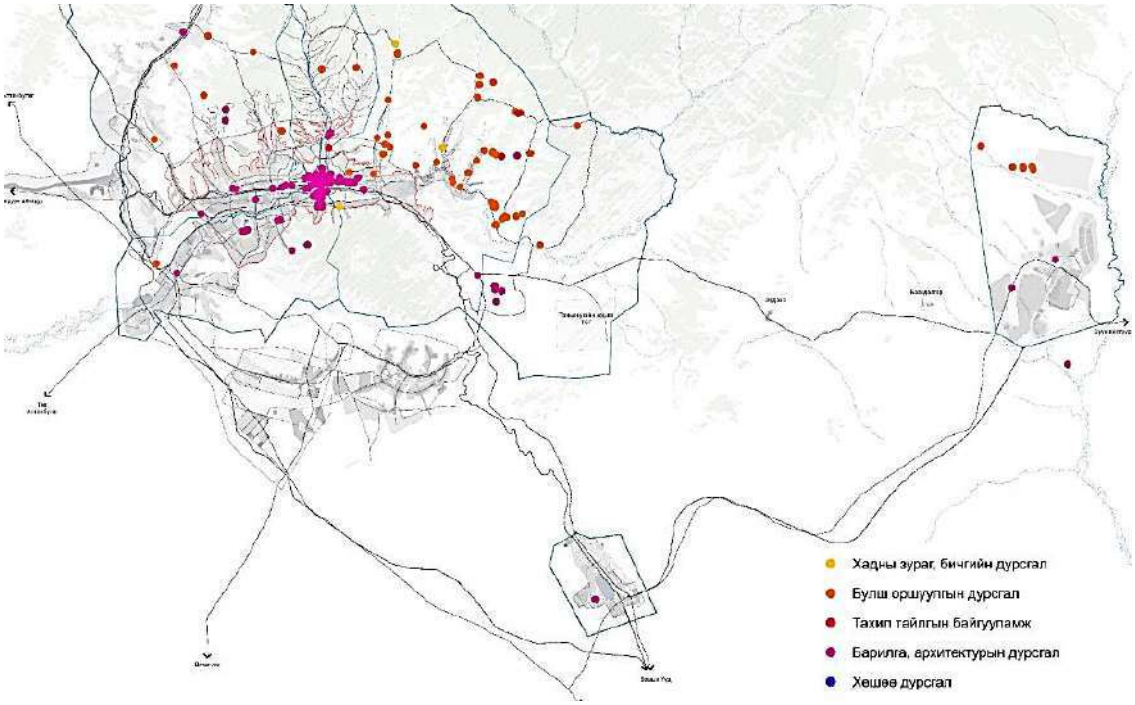


Figure 1. 38. Historical and cultural immovable monuments included in the state inspection and inventory (2015)

Table 1. 14. Valid protection zones approved by Government Resolution in the territory of the capital city of Ulaanbaatar

№	Names of historical buildings	Protected zones approved by the GoM (ha)	Protected zone current area (unit area)
1	Bogd Khan museum	5.7 ha 92001)	3.38 га
2	Dambadarjaa monastry	10.5 ha (2001)	4.51 га
3	Chojin Lama monastry museum	2 ha (2001)	1.35 га
4	Valid protection zones approved by Government Resolution in the territory of the capital city of Ulaanbaatar	1.7 ha (2001)	1.35 га
5,6	Wooden ger-shaped temples of Dashchoilin Monastery	58 ha (2001)	Gandantegchilen monastery is 6.86 ha
			Geser Temple 0.32 ha
7		0.5 ha (2001)	0.86 ha
8	Gandantegchilen Monastery, Geser Temple	6558 ha, (2002)	0.29 ha (the size of the protective fence)
9		0.07 ha (2003)	0.713 ha
10	Chin Van Khanddorj's House	15.6 ha (2003)	165.57 ha
11	Tyub Aimag. Erdene Sum, Tonyukuk Statue	0.27 ha (2009)	0.267 ha
12	2 stone pillars of Dar-Ehiin Temple	0.14 ha (2009)	0.138 ha
Нийт-12		6652.48 га	6652.48 ha

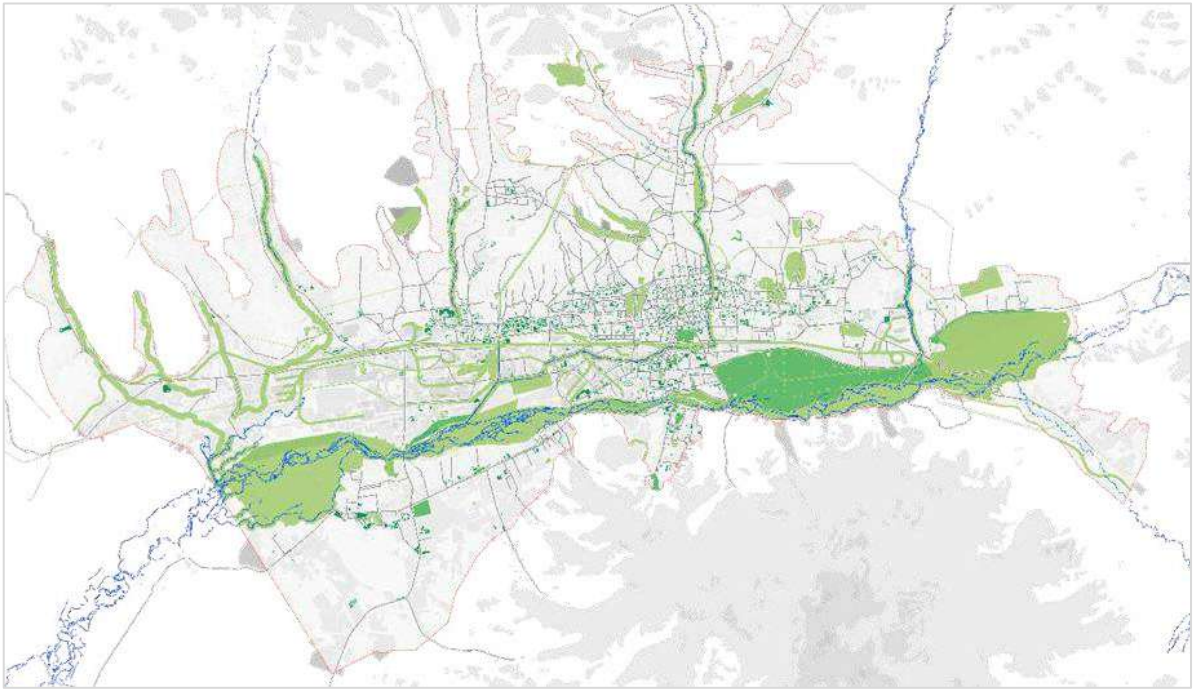
1.7.5. Green space in Ulaanbaatar city

Ulaanbaatar's green spaces are mainly located in the city centre, along the main streets,

and are public gardens, parks, and garden squares established in the 1960s-80s. These green spaces form the basis of the green spaces of Ulaanbaatar today.

Green spaces in Ulaanbaatar are classified as follows by the applicable urban planning norms and rules:

- Public
- Limited use
- Special use



The green areas of the city are classified as public green areas, which are mainly located in the town. The distribution of green areas in the city is uneven and is primarily located in built-up areas. Gardening work is primarily carried out in built-up areas, but in rural areas, gardening and green areas are abandoned. The irrigation and maintenance of green areas in the city are insufficient, resulting in frequent replanting, which not only fails to expand the city's green spaces but also incurs unnecessary costs. As of 2024, the area of green areas in Ulaanbaatar city will be 1336.67 hectares, which is 3.8 times higher than in 2010, and the area of green areas per capita will be

Currently, there are six large-scale parks in Ulaanbaatar, covering a total area of 1,152.18 hectares, including one environmental education center (Misheel Education Park) with an area of 27.97 hectares, one physical education and sports park (National Park) with an area of 972.37 hectares, and one children's playground (National Recreation Center) with an area of 27.67 hectares.

Table 1. 15. Green space are of Ulaanbaatar city

№	Green space classification			Occupied area (ha)	Percentages (%)
1	Public green spaces	Green parks	Nationawide	1,109.41	2.452%

№	Green space classification		Occupied area (ha)	Percentages (%)
		District wide	281.95	0.623%
		Garden Street	99.87	0.221%
2	For limited utility	University	19.01	0.042%
		School	54.88	0.121%
		Kindergarten	44.80	0.099%
		Hospital	26.51	0.059%
		Apartment	107.52	0.238%
		Other	181.75	0.401%
3	For special utility	Botanical Gardens	26.36	0.058%
		Spring Protection	10.97	0.024%
		River Protection	2,744.09	6.066%
		Cemetery	252.52	0.558%
		Railway Protection Zone	711.41	1.573%
		Landfill	33.32	0.074%
		Other	50.97	0.113%
Total amount of the green space			5,754.84	12.722%

Poor road and transport traffic: Ulaanbaatar lacks a developed highway or network of expressways. As a result, Enkhtaivan Avenue, the only east-west central railway, intersects with numerous roads along its route and is not well connected to other city roads. The traffic on the road and transport network is mixed with the daily life activities of citizens. There are many commercial, educational, and public service areas along the main road, which increases the density of road traffic. As a result, this road traffic situation is not well connected to the areas along the road. Many roads in the city centre lack connections to road intersections, making it impossible to use road transport effectively.

1.7.6. Land utility current conditions

The total land area of the capital city is 470,444 hectares. Of which:

- Agricultural land – 265,980.1 hectares or 57%
- Urban, rural and other settlement land – 41,084.5 hectares or 9%
- Road and network land – 5,679.0 hectares or 1%
- Forest land – 76,966.8 hectares or 16%
- Water land – 4,078.1 hectares or 1%
- Special state land – 76,655.4 hectares or 16%

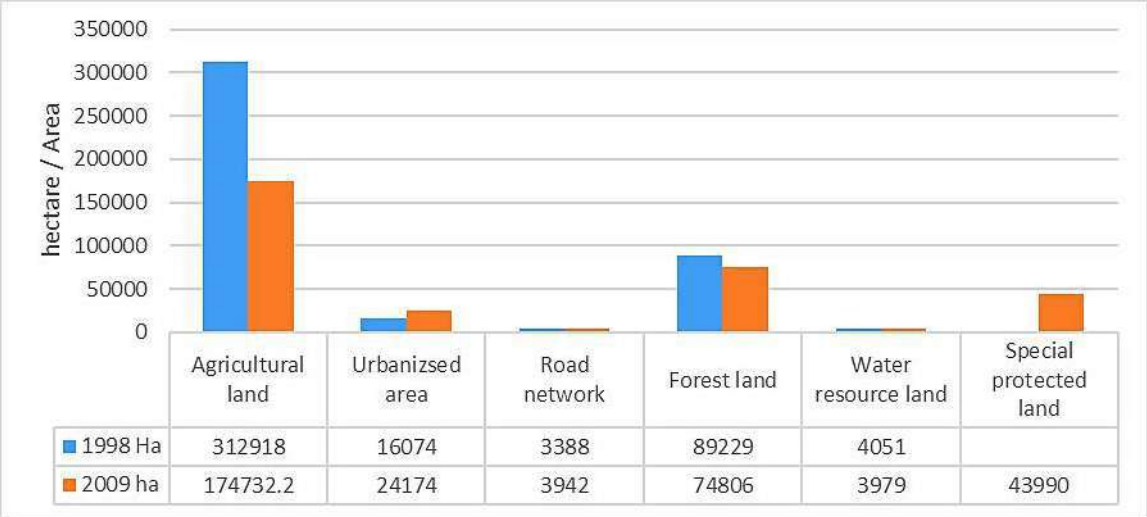


Figure 1. 39. Ulaanbaatar city land utilities

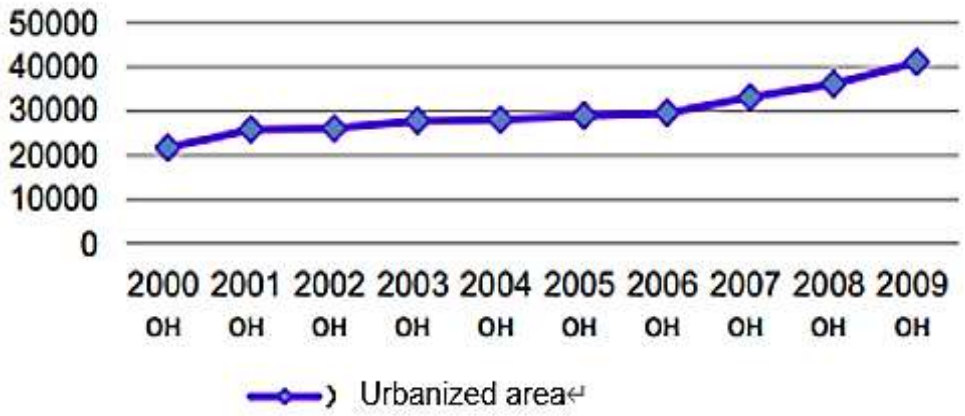


Figure 1. 40. Land utilization changes

Figure 1.39**.** Urban, rural and other settlements Considering the changes in land use in Ulaanbaatar city over the past 10 years, the main reasons for the increase in urban, rural and other settlements in 2009 compared to 2000 and the decrease in different categories of land are that the classification of the unified land fund has changed due to changes in land relations law, some areas have been excluded from the category due to human error, and the demand for land has increased due to land ownership. Considering the territory covered by the 2010 unified land fund classification of Ulaanbaatar city, agricultural land is 6116.7 ha, urban land is 28653.4 ha, road network land is 844.9 ha, forest land is 703.4 ha, and land for special state needs is 8168.7 ha. Considering land use in 6 districts (Bayangol, Bayanzurkh, Songinokhairkhan, Sukhbaatar, Khan-Uul, and Chingeltei), it occupies 69 per cent of the total territory, and 31 per cent falls on three remote districts (Baganuur, Bagahangai, and Nalaikh).

Table 1. 16. Land integrated database classifications

No.	Land Fund Category	Land Area (ha)	Share (%)

		Capital City	Ulaanbaatar
1	Agricultural land	265,980.1	174,732.2
	Pasture land		160,480.2
	Arable land		5,298.3
	Agricultural buildings & facilities		763.1
3	Other settlements	41,084.5	24,174.5
4	Construction land		12,455.67
	Public use land		1,464.38
	Industrial land		1,725.93
	Mining land		792.6
	Residential area		7,735.9
5	Road and utility network land	5,679.0	3,942.4
	Road land		451.5
	Railway land		1,128.9
	Air transport land		860.0
	Utility network land		1,502.1
7	Forest fund land	76,966.8	74,806.6
8	Water fund land	4,078.1	3,977.1
9	Special use land	76,655.4	43,989.6
10	Special protected areas		40,564.0
	State security & defense land		3,358.2
	Foreign diplomatic missions		20.5
	Science, technology, environmental monitoring land		46.9
Total		470,444	325,660

No.	District Name	Land Area (ha)
1	Bayangol	2,949
2	Bayanzurkh	124,412
3	Songinokhairkhan	120,063
4	Sukhbaatar	20,840
5	Khan-Uul	48,466
6	Chingeltei	8,930
Ulaanbaatar city total		**325,660**
7	Baganuur	62,020
8	Bagakhangai	14,000
9	Nalaikh	68,764

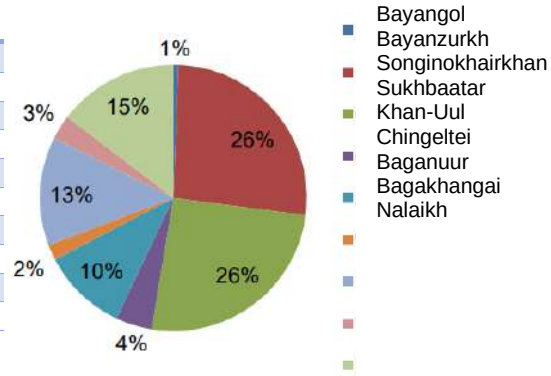


Figure 1. 41. Districts' land of Ulaanbaatar city

Table 1. 17. UB city land changes between 2000-2009

Category (English)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Capital city total land area (ha)	470444	470444	470444	470444	470444	470444	470444	470444	470444	470444
Agricultural land	324725	324725	324490	279922.1	279654	278760.4	278077.4	274478.1	271011.3	265980.1
Other settlements	21684.3	25808.9	26051.9	27776.7	28038.5	28892.6	29529.9	33115.9	36131.6	41084.5
Road and utility network land	9063.7	4939.1	4941.1	5652.2	5652.2	5652.2	5659.6	5668.3	5669.9	5679.1

Category (English)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Forest fund land	110629	110629	110629	76294	76300.3	76339.8	76378.1	76382.7	76891.3	76966.8
Water fund land	4332	4332	4332	4143	4143	4143	4143	4143	4083.9	4078.1
Reserve land	10	10								
Special protected areas				76656	76656	76656	76656	76656		76655.4

Reference: Statistical Bureau of the capital city

In 2000-2009, the land of the capital's unified land fund, Cities, Villages and Other Settlements, increased by 19,400.2 hectares, which is the main reason why other categories of land, such as agricultural land by 58,745 hectares, road and utility network land by 3,184.6 hectares, forest land by 33,622.2 hectares, and water reservoir land by 253.9 hectares, respectively.

Table 1. 18. Capital city land change between 2008-2009 (ha)

No.	Main Category	2008 (ha)	2009 (ha)	Change
1	Agricultural land	271,011.14	265,980.1	−5,031.04
2	Other settlements	46,036.86	41,084.5	+4,952.36 (−4,367.92)
3	Road and utility network land	5,688.04	5,679	+9.04
4	Forest fund land	77,041.95	76,966.8	+75.15
5	Water fund land	NA	4,078.1	–
6	Special use land	NA	76,655.4	–

Reference: Report of the land database

As of 2009, the unified land fund of the capital city compared to 2008:

• Agricultural land decreased by 5,031.04 hectares,

• Urban and rural land increased by 4,952.36 hectares,

• Road and network land increased by 9.04 hectares,

• Forest land increased by 75.15 hectares.

Land status and quality

According to the report of the Unified Land Fund, a total of 5,694.12 hectares of land have undergone some degree of change in status and quality. Including:

• 29 hectares of arable land,

• 5,587.2 hectares of pasture land,

• 23.5 hectares of urban, rural and other settlement land,

• 16.4 hectares of forest land,

• 5.0 hectares of water land.

Of these, 33.0 hectares have been cleared for various reasons and have completely lost their original appearance. The primary source of land quality changes in cities, villages, and other settlements is pollution from domestic and industrial waste.

1.7.7. Land valuation and payment system

In 1995, a legal framework for determining land valuation fees was established in Mongolia, and land owners and users pay fees at the rate established by law. The basic price of land in the capital was set by the Government at 40-440 million tugriks with regional differences, and the resolution of the Capital City People's Representatives Khural No. 4/21 of 2005 was amended and amended by the resolution No. 5/39 of July 16, 2010 "On the temporary determination of land valuation zoning and payment rates in the capital territory" and the coefficients and rates have been changed since July 15. Land payment revenue is almost 9 times higher than in 2010 and 2001 in the capital city budget revenue.

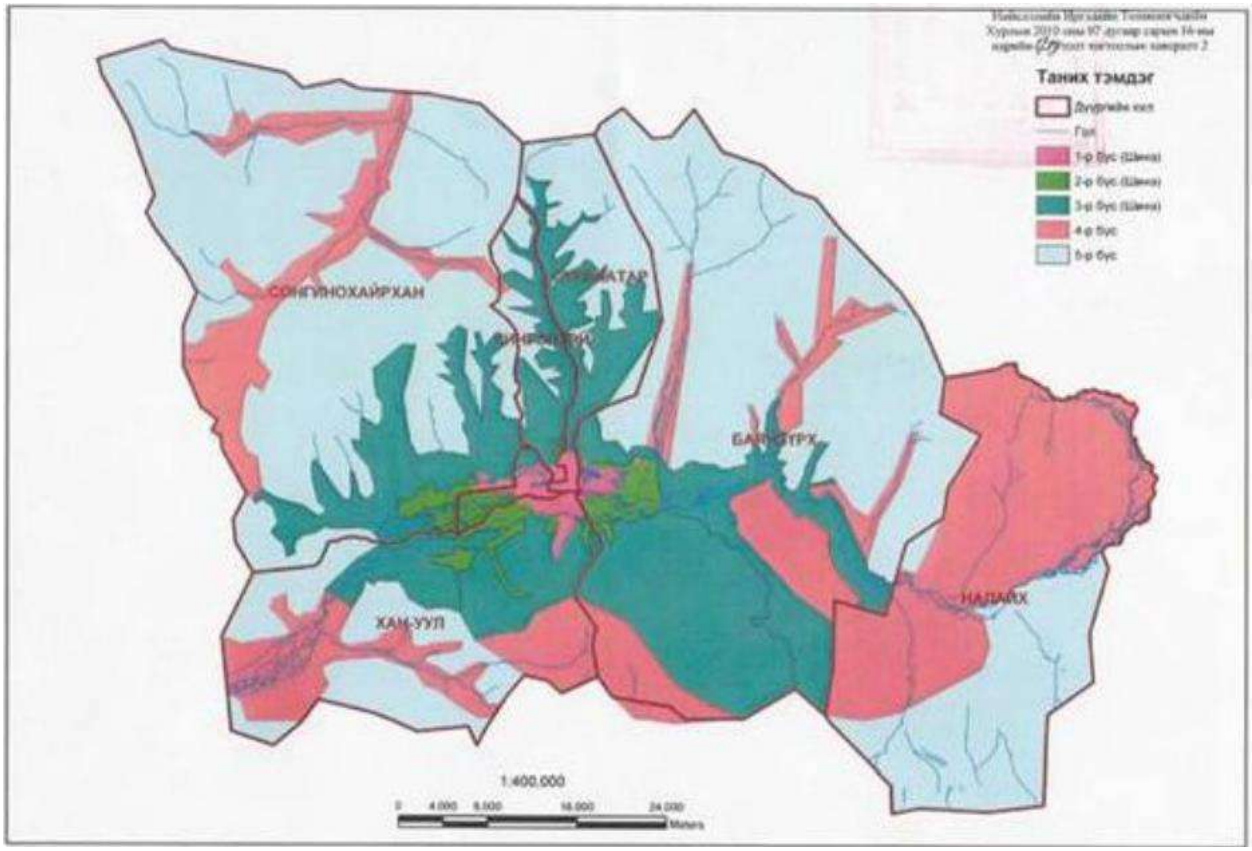


Figure 1. 42. Zone bordering for defining the land payment

Table 1. 19. Income from the land payment

No.	Year	Plan (million MNT)	Actual (million MNT)	Performance (%)
1	2001	1,962.9	2,053.0	104.6
2	2002	2,797.5	3,007.0	107.5
3	2003	3,257.9	3,542.9	108.7
4	2004	3,600.0	3,765.8	104.6
5	2005	5,700.0	5,705.2	100.1
6	2006	6,585.0	6,904.5	104.9
7	2007	11,201.0	11,290.7	100.8
8	2008	15,201.0	15,838.0	104.2
9	2009	17,180.0	17,742.9	103.3
10	2010	17,997.5	18,013.1	100.1

Table 1. 20. Land valuation zoning and payment coefficient and amount

Land Use / Purpose	Zone 1 Coefficient	Zone 1 Price/mÂ²	Zone 2 Coefficient	Zone 2 Price/mÂ²	Zone 3 Coefficient	Zone 3 Price/mÂ²	Zone 4 Coefficient	Zone 4 Price/mÂ²	Zone 5 Coefficient	Zone 5 Price/mÂ²
Residential use	0.2	66	0.1	53	0.1	44	0.3	12	0.2	8
Institutional use (offices, public institutions)	0.2	88	0.15	68	0.1	44	0.4	16	0.3	12
Commercial use	1	440	0.6	264	0.3	132	1	40	0.5	20
Industrial service, wholesale trade, and service facilities	0.8	352	0.5	220	0.2	88	0.8	32	0.4	16
Storage, fuel stations, wholesale trade markets, logistics	1	440	1	440	1	440	1	40	1	40
All types of garages (above/below ground)	1	440	1	440	1	440	1	40	1	40
Public transport	0.2	88	0.15	66	0.1	44	0.5	20	0.4	16
Heating, communications, energy	0.6	264	0.3	132	0.2	88	0.7	28	0.5	20
Railway, airport buildings	0.6	264	0.4	176	0.3	132	0.8	32	0.6	24
Railway, airport protective zones	0.3	132	0.2	88	0.1	44	0.4	16	0.3	12
Political parties, NGOs, international organizations and their representative offices	0.3	132	0.2	88	0.1	44	0.8	32	0.4	16
Monasteries, temples	0.8	352	0.6	264	0.4	176	0.7	28	0.6	24
Manufacturing (excluding agriculture)	0.6	264	0.4	176	0.1	44	0.4	16	0.2	8
Agricultural production	0.4	176	0.15	68	0.1	44	0.4	16	0.2	8
Seasonal agricultural production (5 years)					0.1	4	0.1	4	0.1	4

Appendix No 3. Resolution No. 5/39 of the Khural of Citizens' Representatives of the Capital City.

1.7.8. Land regulation

Since the adoption of the 2020 Ulaanbaatar City Development Plan, the legal regulation of land relations has become increasingly narrow, and the transfer of land to citizens has led to the emergence of state and private land, which has led to a fundamental change in planning methods and principles.

Eighteen per cent of the total 470,444 hectares of land, or 89,303.57 hectares, is owned, used, or occupied by 142,077 citizens, business entities, state organisations, foreign citizens, foreign-invested business entities, and legal entities.

Table 1. 21. Legal status study of the Unified Land Fund of the Capital

Purpose	Area (ha)	Legal owners	Share (%)
Designated for family residential use	4367.92	78452	5%
Leased for residential and agricultural purposes (including ger district areas)	9183.983	55556	10%
Of which: ger district area	4752.1		
Leased to government organizations	10762.15	836	12%
Leased to cooperatives	18800.85	6954	21%
Land leased to Mongolian agricultural cooperatives	882.4	37	1%
Land owned by foreign citizens or stateless persons	31.15	47	1%

Purpose	Area (ha)	Legal owners	Share (%)
Land leased to foreign-invested agricultural cooperatives	779.15	194	1%
Agricultural land leased/used	6116.66		7%
Other settlements leased/used	28653.37		32%
Road land leased/used	844.91		1%
Forest fund land leased/used	703.36		1%
Special use land leased/used	8168.77		9%
Total	89303.57	142077	100%

In 2009, the number of households that owned land was 80,203. Citizens owned 9.9% of the total land (29,529.87 ha) in the six districts of the central part of Ulaanbaatar city, and 0.6% of the total land (470,444.00 ha) in the nine districts, or 4,367.92 ha.

By land use, the following land types are classified:

• A total of 4,367.9 hectares of land were owned by 80,203 citizens for family needs,

• 9,184.0 hectares were owned by citizens for business purposes,

• state organizations owned 10,762.1 hectares,

• enterprises owned 18,800.9 hectares,

• foreign citizens and stateless persons used 31.15 hectares,

• foreign-invested enterprises and foreign legal entities used 779.1551 hectares.

The left side area of the planned alignment

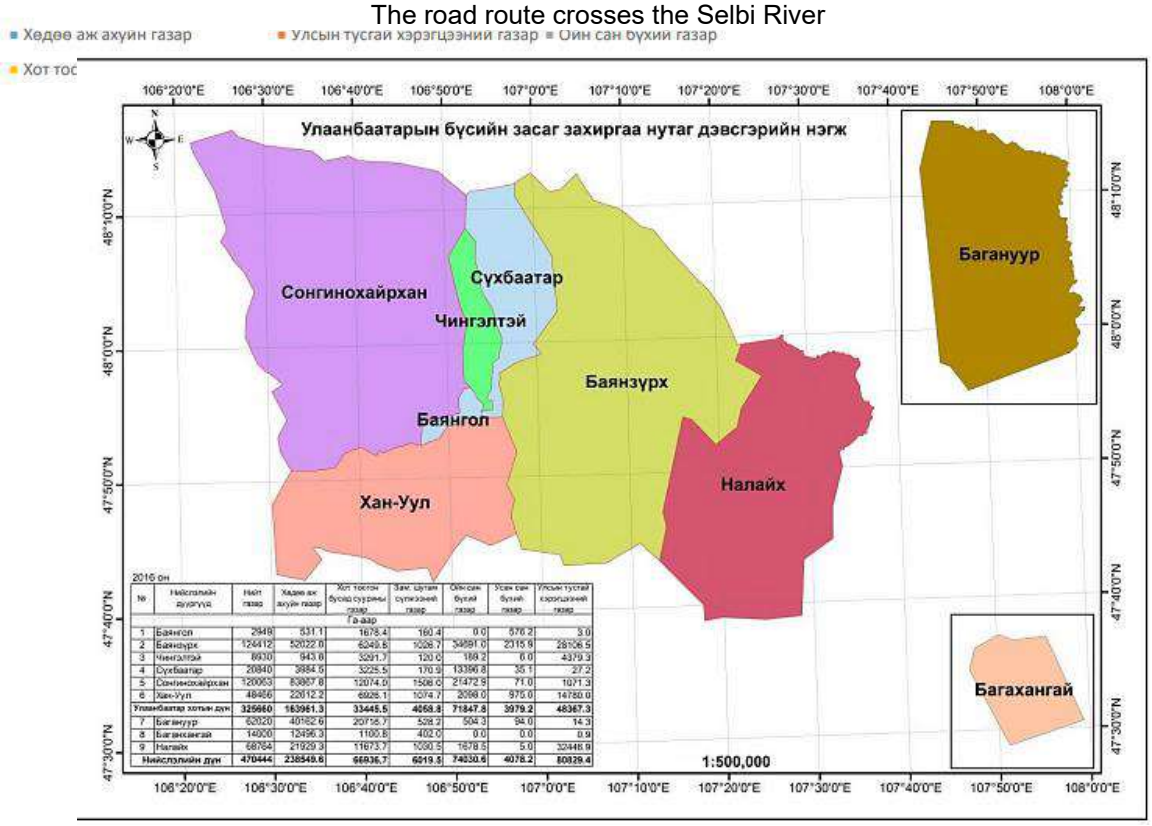
The right side area of the planned alignment

Current status of the settlement area passing through the eastern part of the road route

In general, a total of 44,487.1 hectares of land in the capital city are in active economic circulation.

Current status of the mountain plateau that runs through the northern part of the road route

The road route crosses the Selbi River



List of territorial boundaries of the capital's districts

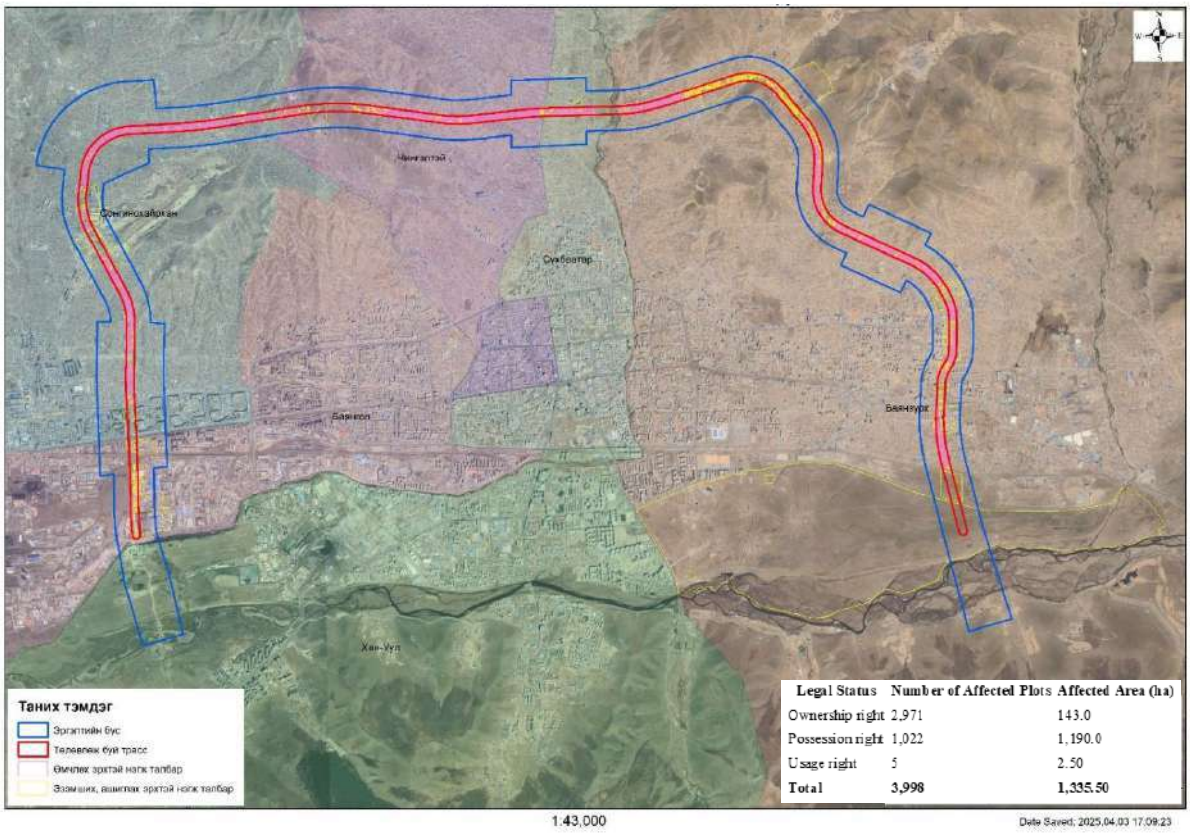
In land law, there are concepts of land ownership, possession, and use, and there are many cases where these concepts are confused among citizens. These concepts differ from each other, and their corresponding legal regulations are distinct. Of these, land ownership is the concept that expresses the broadest authority over land. Land ownership means having the right to dispose of land and use it to produce its beneficial properties. The right to dispose of it means selling it, gifting it, bequeathing it to others, trading it, and pledging it. The right to own land as a subject belongs only to Mongolian citizens and the state. Article 6, Section 6.3 of the Constitution of Mongolia prohibits citizens from transferring their right to dispose of land to stateless persons or foreign citizens.

Land ownership means keeping land in one's possession within the scope permitted by law, by the purpose and conditions specified in the contract. The right to own land is a concept that also includes the right to use land.

Table 1. 22. The capital city land valuation

District Name	Other Settlements (ha)	Construction Land (ha)	Public Land (ha)	Of which: Unallocated Free Land (ha)	Industrial Land (ha)	Mining Land (ha)	Ger District Land (ha)
Bayangol	1,696.57	800.22	270.92	14.56	338.10	0.00	287.33
Bayanzurkh	6619.53	3459.51	1118.04	0.00	373.09	160.05	2512.09
Chingeltei	3444.56	748.57	356.39	73.25	293.00	0.00	2339.60
Sukhbaatar	3716.91	1310.40	286.77	2.20	0.91	20.90	2380.23
Songinokhairkhan	13657.54	3067.02	1525.95	0.00	559.65	537.80	9025.67
Khan-Uul	7239.38	5073.24	207.00	25.51	672.96	79.35	3205.67
Ulaanbaatar City Total	36374.48	14459.48	1240.38	121.48	1944.81	797.85	17931.96
Baganuur	2195.20	1192.47	579.02	0.00	253.20	0.00	1439.39
Bagakhangai	2388.45	0.00	0.00	0.00	376.16	0.00	0.00
Nalaikh	12586.29	8790.47	612.79	366.72	1032.20	775.20	1385.53
Total	73304.42	36442.46	2984.96	1067.22	6470.47	5943.85	21477.68

New Ring Road (First Ring Road) Option 1. Legal condition



Assessment grade: The basic assessment of Land in cities, villages, and other settlements is determined by the land grade, taking into account location, engineering supplies, socio-economic, engineering, geological, and environmental conditions, and intended use.

Assessment district: The division of the unified land fund by natural and territorial complex Land conditions is called an assessment district, and the purpose of use, geographical location, and differential income from land fertility and yield are taken into account when determining the basic assessment. Government Resolution No. 182 dated June 20, 2018, revised the Land Assessment District, grade, basic assessment, and land payment amount. Government Resolution No. 182 of 2018, when determining the basic evaluation of Land in

Ulaanbaatar, analysed the market price data of Land and, based on it, divided it into 17 use purposes and 16 zonings, taking into account the main factors affecting land prices, such as location, engineering supplies, socio-economic, and environmental conditions.

"For family use" means the Land specified in Articles 29.1 and 29.2 of the Land Law

"Trade and all types of services" means schools, kindergartens, hospitals, health institutions, libraries, physical education, sports, cultural and artistic institutions of all levels, their buildings, offices, public housing buildings, Land used for mixed purposes such as production and services, shopping centers, shops, hotels, recreational, physical education, parks, health resorts, gas stations, oil product warehouses, car garages, airports, parking lots, public transportation, warehouses, cellars, Land for travel and tourism services, Land for political parties, non-governmental organizations, religions, and temples, heat, communication, energy stations, Land under antennas, cemeteries, and others.

"Agricultural production" means buildings and structures for intensive animal husbandry and agriculture, greenhouses, and agricultural production land intended for growing potatoes, vegetables, fruits, and cultivated plants in areas exceeding the limits specified in Articles 29.2 and 29.3 of the Land Law.

"Agricultural construction" means: winter and spring sheds, fences, khoroos, veterinary service areas, animal washing and disinfection areas, threshing floors, feed depots, grain storage facilities, agricultural machinery and aggregate enclosures, greenhouses, cellars, all types of farms, beekeeping facilities, etc. "Industry other than agricultural production" includes Land intended for heavy and light industry and mining.

New Ring Road (First Ring Road) Primary Option

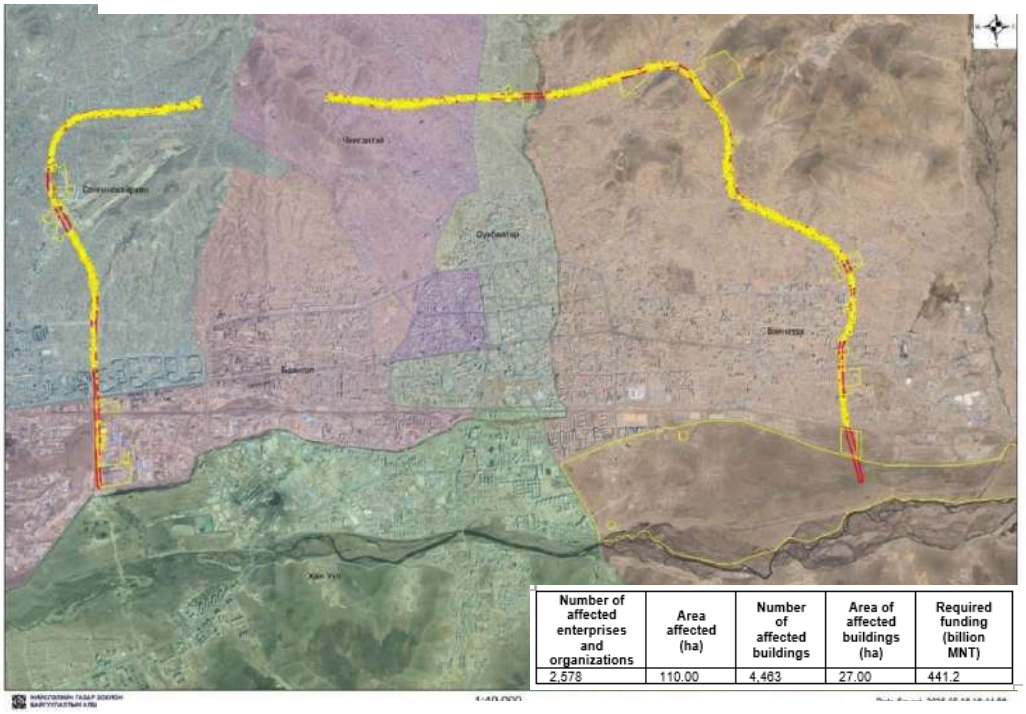
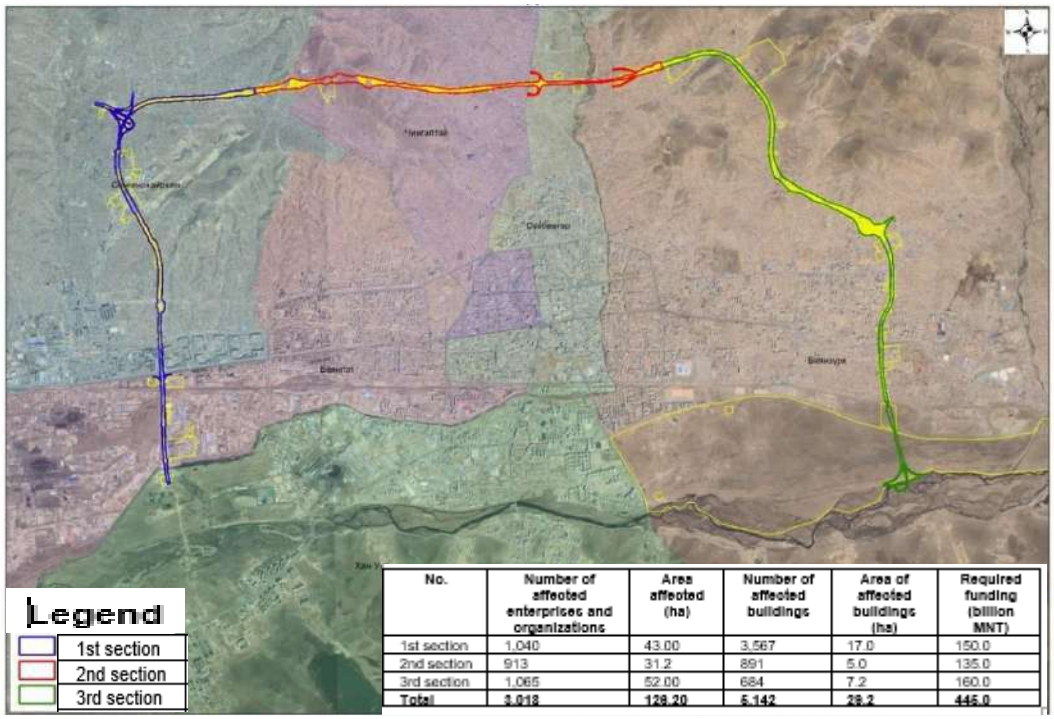


Figure 1. 43. Area affected by the proposed road alignment

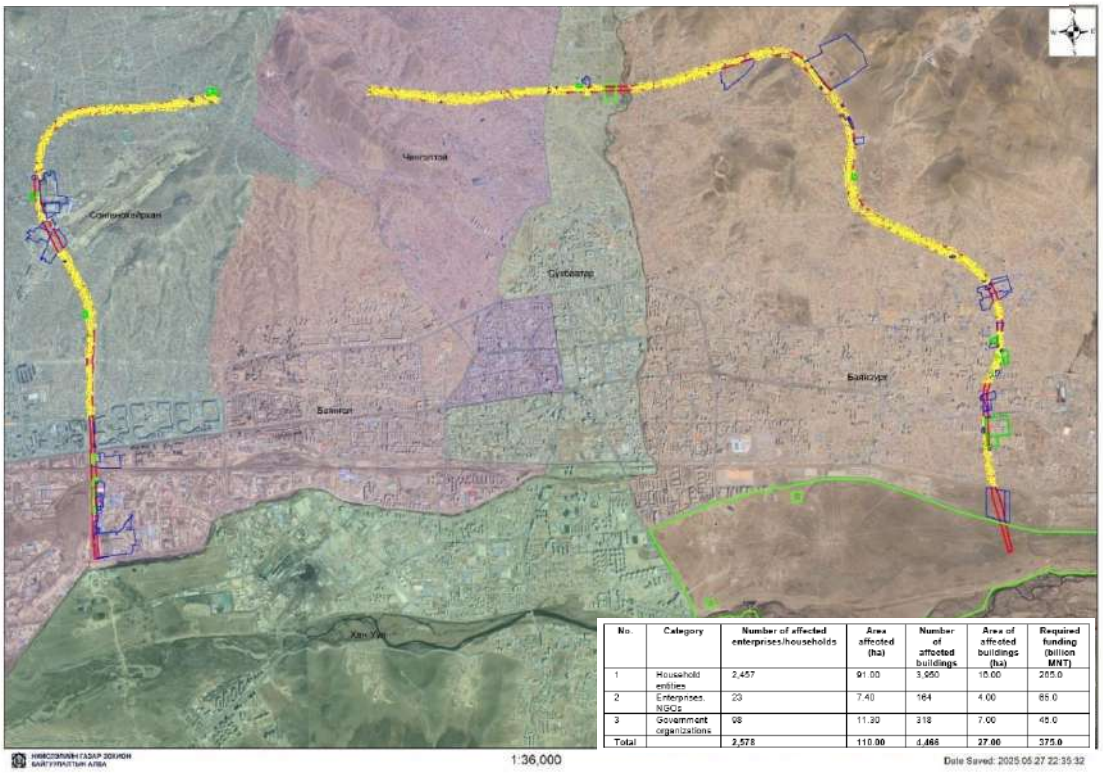
New Ring Road (First Ring Road) Primary Option



No.	Number of affected enterprises and organizations	Area affected (ha)	Number of affected buildings	Area of affected buildings (ha)	Required funding (billion MNT)
1st section	1,040	43.00	3,567	17.0	150.0
2nd section	913	31.2	891	5.0	135.0
3rd section	1,065	52.00	684	7.2	160.0
Total	3,018	128.20	5,142	29.2	445.0

Figure 1. 44. Estimated land acquisition costs for dividing the highway into three sections

New Ring Road (First Ring Road) Primary Option



No.	Category	Number of affected enterprises/households	Area affected (ha)	Number of affected buildings	Area of affected buildings (ha)	Required funding (billion MNT)
1	Household entities	2,457	91.00	3,950	15.00	265.0
2	Enterprises, NGOs	23	7.40	164	4.00	65.0
3	Government organizations	98	11.30	318	7.00	45.0
Total		2,578	110.00	4,466	27.00	375.0

Figure 1. 45. Estimated land acquisition costs, excluding the tunnel sections

1.8. ELEVATION AND SLOPE

Ulaanbaatar city is about 1,600 km from the Pacific Ocean, 5,310 km north of the equator

and 4,690 km south of the North Pole, or at 47 55' north latitude, in the 7th time zone, 7 hours 08 minutes ahead of London. The 00 marker, the starting point of the Mongolian highway network, is located on the southwestern edge of Sukhbaatar Square in Ulaanbaatar. Natural processes, landslides, and temporary runoff have significantly damaged the land surface in the capital. This is especially true along the Chingeltei, Bayanzurkh, and Songinokhairkhan mountains. One of the significant factors in land erosion is the chaotic network of dirt roads in urban and rural areas. In particular, on the slopes of mountains and in areas with very rough terrain, surface runoff is likely to form along the dirt road, resulting in land degradation.

Based on the 1:500 scale topographic map developed by Bayasakh Survey LLC, a professional organization with a special license to provide geodetic production and services, and the 0.5 m height, the following is the assessment of the land surface by the Methodological Guidelines for Comprehensive Assessment of Urban Development in Urban Areas /UBB 30-201-09/, as specified in the terms of reference for the consultancy service for the development of the preliminary technical and economic feasibility study and design budget for the "New Circular Highway" project /Ulaanbaatar/.

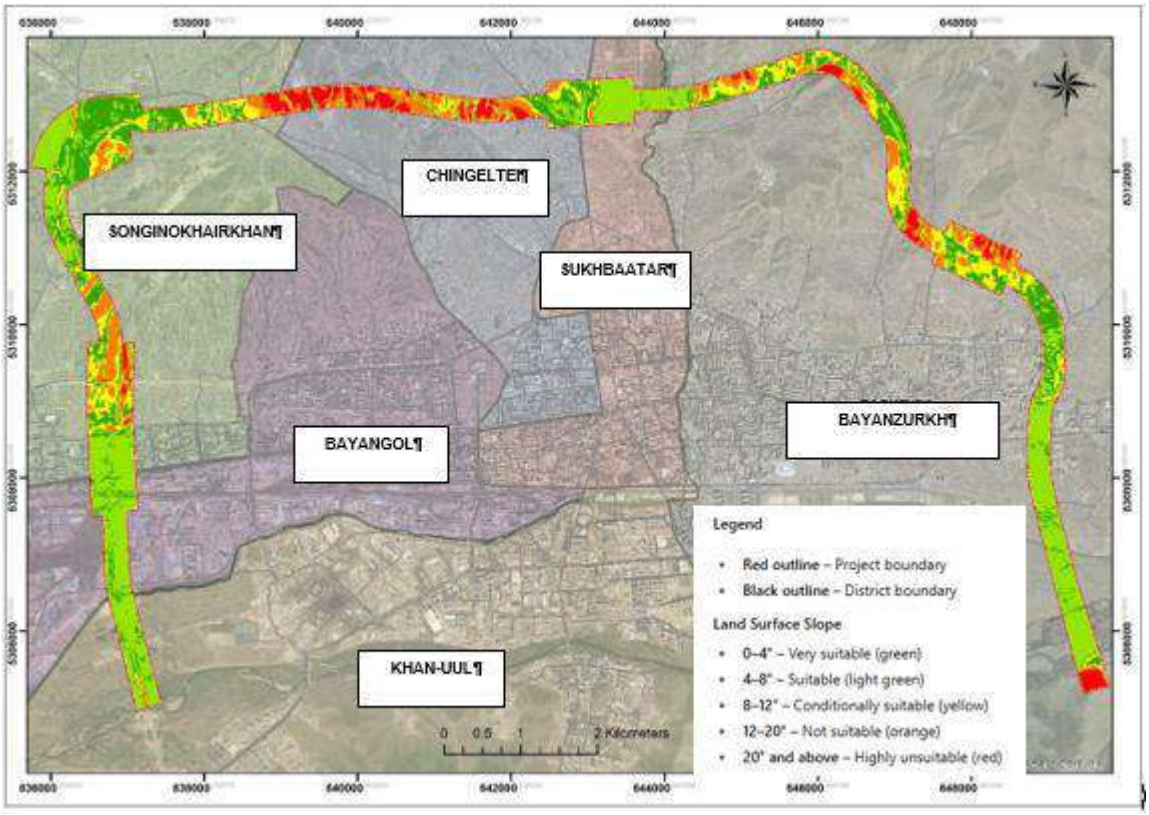


Figure 1. 46. Land surface slope evaluation

The assessment of the ground surface slope along the selected route for the project is shown in the table below.

Table 1. 23. Slope valuation

Indicator	Area (ha)	Percentage (%)

Very suitable (slope 0–4%)	393.90	37.95
Suitable (slope 4–8%)	331.31	31.92
Conditionally suitable (slope 8–12%)	174.97	16.86
Not suitable (slope 12–20%)	108.86	10.49
Highly unsuitable (slope over 20%)	28.96	2.79
Total	1,038.0	100

Bogdhan Mountain, located to the south of Ulaanbaatar, is a mountain range extending about 40 km from east to west. In the central part, it is a high mountain and a medium-altitude mountain, with the highest peak being Tsetse Gun Peak at 2,268 m, as well as peaks such as Tushe Gun, Baruun, and Zuun Shiree, which are 2,256 m high. The built-up and construction areas of the capital, Ulaanbaatar, are 1,260-1,590 m above sea level, and the entire surface of the Land has a slope system that runs from the northern mountains to the Tuul River basin.

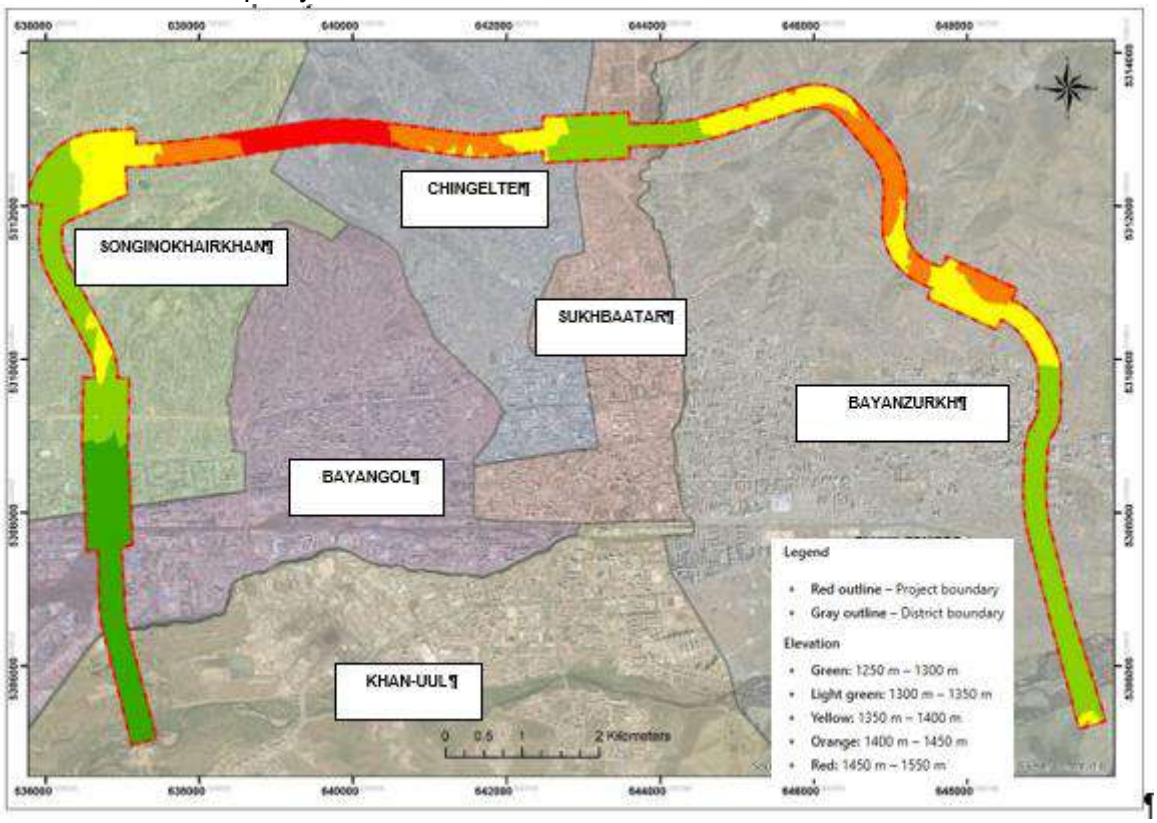


Figure 1. 47. Elevation of the city

The highest point along the route is 1,550 m above sea level, and the lowest point is 1,260 m.

1.9. ENERGY SUPPLY

In the planning area, power supply lines and substations intersect and traverse at 342 points (93 substations, 139 substations, and 110 cable lines).

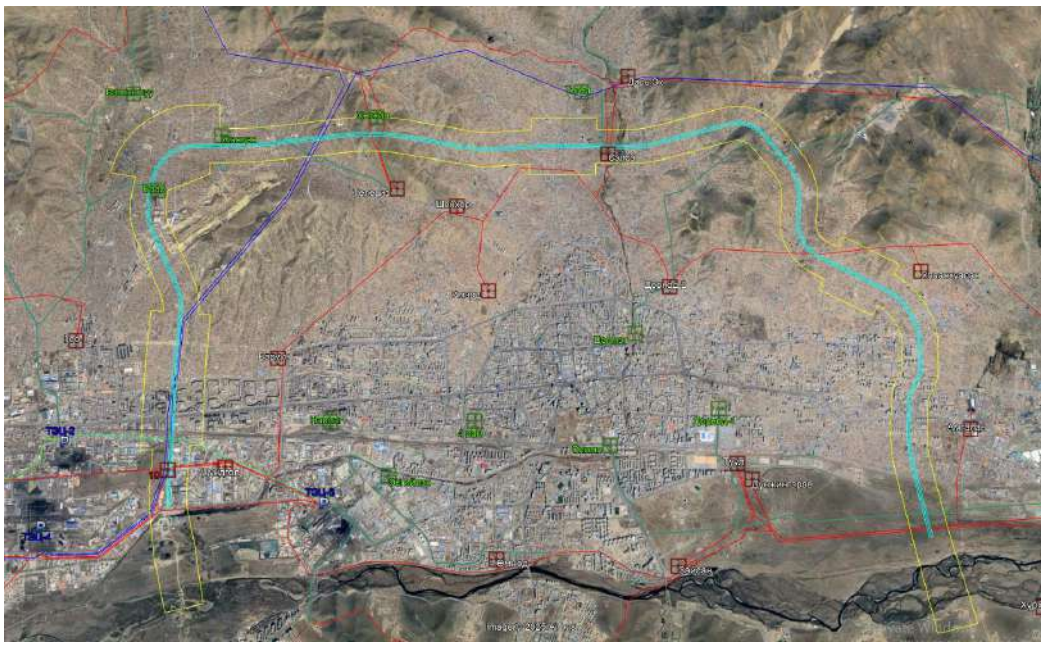


Figure 1. 48. Current conditions of 35-220 power supply

There are 3 220 kV lines, 15 110 kV lines, 13 35 kV lines, 119 6-10 kV lines, 99 0.4 kV lines, and 93 6-10 kV substations.

Table 1. 24. Study of close and crossed lines

No.	Indicator	Approached	Intersected	Total
1	Substation	8	85	93
2	35 kV substation	-	-	-
3	RP (Distribution Point)	-	-	-
Total substations	8	85	93	
1	220 kV overhead power line (OHL)	3		3
2	110 kV OHL		15	15
3	35 kV OHL		7	7
4	6–10 kV OHL	5	45	50
5	0.4 kV OHL	4	60	64
Total 0.4–35 kV OHL	12	127	139	
1	35 kV cable line (CL)	2	4	6
2	10 kV CL	5	64	69
4	0.4 kV CL		35	35
Total 0.4–35 kV CL	7	103	110	
Total points	27	315	342	

Line and substation details:

A section of the road has been entered between the 220 kV IHB-4 and the 205th and 206th TSDASH pillars No. 10-16 connecting the Ulaanbaatar substation.

A section of the road has been approached between the 220 kV IHB-4 and the 208th TSDASH pillars No. 16-20, connecting the Darkhan substation.

The 110 kV high and low circuits have been entered between the 103rd, 104th, 107th, 108th, 110th, 125th, 126th, 133rd, 134th, 135th, 136th, 137th, 138th, 149th, and 150th TSDASHs.

The fence of the 110/35/10 kV Selbe substation is 63m from the planned roadbed.

35 kV Soyozha-A, B, Bayanzurkh-A, B, Gachuurt, Khozhil-A, B, TsDASH, Jantsan-A, B, Togol-A, B, KSH are included in the road route.

Ninety-three substations and 119 lines of 6-10 kV are included in the road route and intersect.

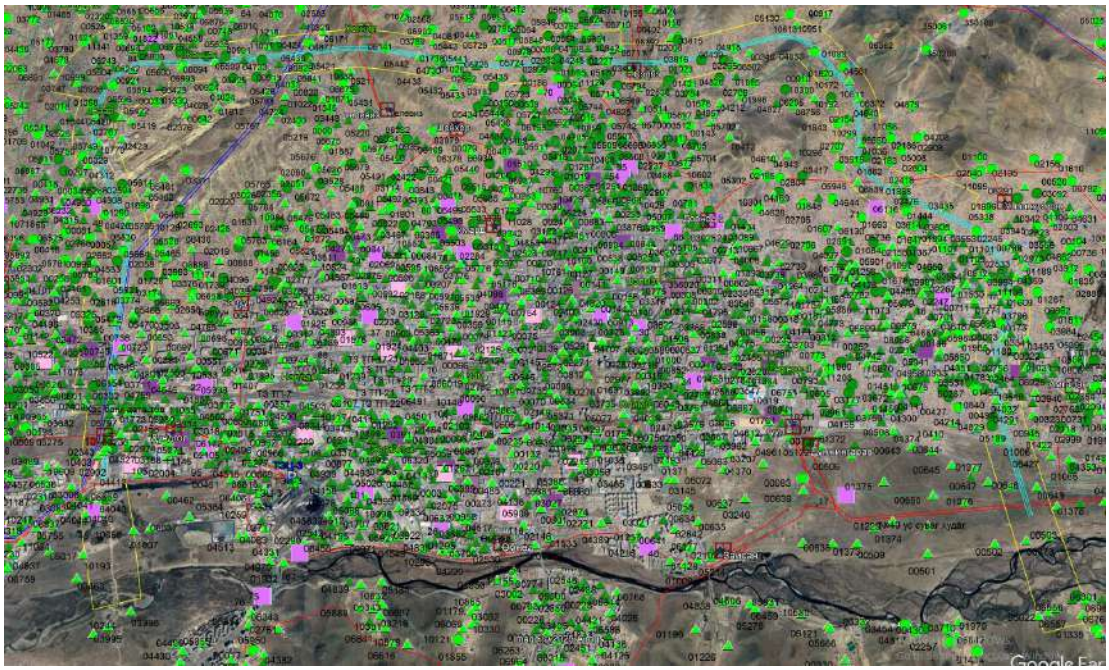


Figure 1. 49. 6-10 electricity supply current conditions

Conclusion: Preliminary clarification of the planned road route has identified 342 points where power supply lines intersect with substations. It is necessary to develop detailed information on lines and substations, and coordinate them with the planned lines, substations in the power supply section of the Ulaanbaatar City Development Master Plan until 2040, as well as other partial and general plans. The planning for the relocation of line equipment at these intersection points needs to be developed in consultation with the user organisations. In particular, since the main line that transmits the power flow of the source power plants, the 220 kV 205, 206, and 208 TSDASH pillars No. 10-20, is included in the planned road route, it is necessary to develop a planning solution in consultation with the Ministry of Energy and the TSDNS.

1.10. COMMUNICATION

Laws in the field of communications and information technology

Law on communications

Law on broadcasting

Law on postal services

Law on cybersecurity

Law on electronic signatures

Law on personal data protection

Law on transparency of public information

Table 1. 25. Laws and regulations related to the telecommunications and information technology sector

No.	Law	Regulation	Approval Date
1	Law on Communications	Regulation on retraining, awarding professional ranks, and accreditation council rules for specialists in the communications and information technology sector	2023.11.78 №A/121
2	Law on Protection of Personal Data	Regulation on technological security requirements for processing sensitive personal data, genetic and biometric data	2023.09.11 №A/90
3	Law on Protection of Personal Data	Regulation on conducting assessments when collecting, processing, and using information using electronic processing technologies	2023.09.01 №A/81
4	Law on Cybersecurity	Regulation on registration of entities conducting information security audits and audit procedures	2023.08.18 №A/74
5	Law on Broadcasting	Regulation on transmitting disaster and emergency alerts through the broadcasting network	2023.01.04 №A/01
6	Law on Public Information Transparency	Regulation on providing services by organizations responsible for the state electronic information database	2022.07.06 №A/35
7	Law on Public Information Transparency	General regulation on operating websites, posting, updating, and monitoring transparent and open information electronically	2022.05.18 №201
8	Law on Public Information Transparency	Regulation on obtaining permission from the information owner to use restricted information, delivering notifications, and keeping records on requests and transfers to third parties	2022.05.31 №211
9	Law on Public Information Transparency	Methodology for calculating, paying, discounting, or exempting costs related to providing information in paper form to legal entities or individuals	2022.05.25 №206
10	Law on Public Information Transparency	Regulation on maintaining a unified registry of e-projects, programs, and activities related to public information infrastructure and state e-operations	2022.05.31 №219
11	Law on Public Information Transparency	List of open data	2022.06.15 №232
12	Law on Public Information Transparency	Regulation on the operation of a non-permanent council responsible for organizing, evaluating, and making recommendations on open data transparency implementation	2022.08.26 №A/288, A/44
13	Law on Electronic Signatures	Revised edition	2021.12.17
14	Law on Electronic Signatures	Regulation on issuing, suspending, restoring, and invalidating certificates for public servants	2022.06.23 №A/28
15	Law on Electronic Signatures	Regulation on creating and using the national repository of digital signature certificates	2022.06.29 №A/30
16	Law on Public Information Transparency	Regulations related to open data	2022.05.18 №200
17	Law on Public Information Transparency	Methodology for open data payment calculations	2022.05.18 №202
18	Law on Public Information Transparency	Regulation on managing core system operations, providing services through the system, and exchanging information	2022.05.11 №196
19	Law on Public Information Transparency	Regulation on providing recommendations and conclusions before establishing a public information system	2022.05.02 №A/18
20	Law on Protection of Personal Data	Regulation on the destruction of unique biological data collected by the data controller	2022.04.13 №55
21	Law on Cybersecurity	List of organizations with critical infrastructure	2022.05.25 №207
22	Law on Cybersecurity	Regulation on establishing and using the state unified information network	2022.05.11 №197

No.	Law	Regulation	Approval Date
23	Law on Communications	Regulation on retraining, awarding professional ranks, and accreditation council rules for specialists in the communications and information technology sector	2020.12.25 №A/148
No.	Law	Regulation	Approval Date

Table 1. 26. Norm and standard of communication

No.	Norms and Regulations
1	Regulation on developing, approving, and conducting expert review of urban development documents, 2011
2	Regulation on designing and evaluating building and facility design projects, 2019
3	BD 11-120-17 Geodetic works for energy and communications engineering facilities
4	BD 13-104-20 Standard service life of buildings, facilities, and engineering networks
5	BNbD 30-01-04 Urban and settlement planning, construction
6	UBB 30-201-09 Methodological guidelines for comprehensive urban development assessment of urban and settlement land
7	BNbD 31-04-03 Administrative and business buildings
8	BNbD 31-03-03*/11 Public and civil buildings
9	BD 81-16-20 Standard prices for design works
10	BNbD 81-31-12 Budget norms for construction and installation works of communication, radio, and television facilities
11	BNbD 81-40-04*/12 Base budget norms for building communication works
12	BNbD 83-40-21 Unit labor time norms for installation works of communication facility cable lines
13	BNbD 83-29-04 Labor norms for installation works of cable TV, alarm, and intercom systems
14	BD 81-106-16 Regulation on using standard valuation of unit capacity of buildings and facilities

Well channelling and cable line facilities: Indicators of well channelling and cable line facilities. Level of readiness of well channelling: The Ulaanbaatar City Network Operation Department, at its own expense, ensures the readiness of well channelling according to the annual plan and restores damaged and filled channels.

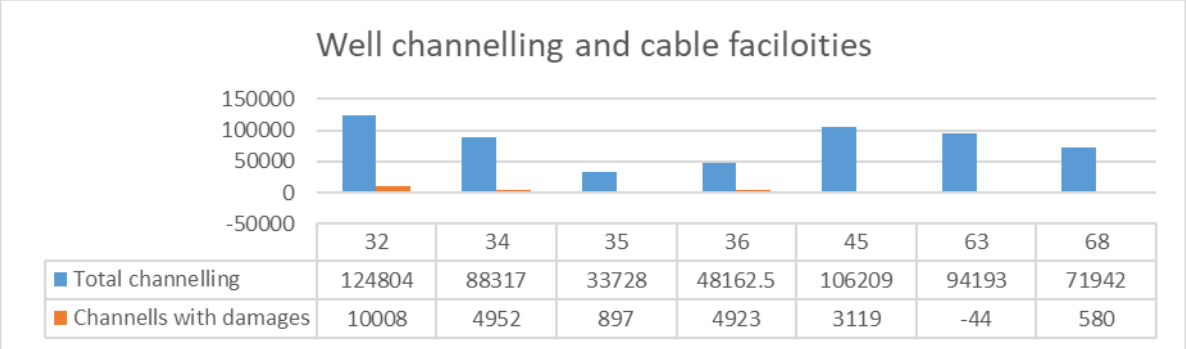


Figure 1. 50. Well channelling readyness

According to the study on the readiness of well canalisation, the number of filled canalizations is relatively small, but up to 14 per cent of the canalisations are damaged. In cooperation with the General Planning Department of the Capital, new well canalisation expansion works are being carried out with state and capital investment. Works carried out with state budget investment: As part of the work to connect wells and canalisations in Ulaanbaatar to the cable network, the following canalisations were newly constructed and expanded between 2021 and 2022. Since the tariff for laying fiber optic cables through wells

and canalisations was cheap, citizens and business entities filled the well canalisations by laying fiber optic cables to build their networks, which hurt the utilisation. Therefore, based on a detailed cost estimate for wells and canalisations, a proposal for changes in the tariff was submitted to the Telecommunications Regulatory Commission and the Department of Fair Competition and Consumer Protection.

The tariff was revised and implemented from June 2015, and a total of 115 tenant contracts were renewed. Well channelling arrangement work: Since 2013, the work of arranging fibre optic cables for operator companies and organisations using well channelling on lease in Ulaanbaatar city has been organised. Additionally, the work of arranging fibre optic cables and non-technological cables for 115 organisations working under contract is being carried out. Protective zone: Article 28 of the Law on Telecommunications states that 28.1.1 is 10 meters on each side from the overhead line, 28.1.7 is 5 meters on each side from the cable line, the space for broadcasting waves between radio relay lines or the ground access station of a satellite communication satellite, and 300 meters on each side from that station, and 28.1.4 is the size of the sanitary protection zone determined depending on the capacity of the radio and television access station and wave generating equipment.

Based on the Resolution No. 102 of the Presidium of the Khural of Citizens' Representatives of the capital city of 2011 "On Approval of the Procedure", the Governor of the capital city issued the following orders: A/653, A/775, A/945 on organising the protection of engineering structures. Accordingly, the engineering network, topographic maps of its protective strips, and other relevant information submitted by the network organisations are registered in the urban development database of the capital city, and appropriate updates and changes are made to the database. Load study of the main well channelling route of Ulaanbaatar city: The channelling load was calculated in 83 directions within the city network stations 32, 34, 35, 36, 45, 63, 68 and substations 352, 361, 362 in Bayanzurkh, Bayangol, Songinokhairkhan, Khan-Uul, and Sukhbaatar districts of Ulaanbaatar. The load on the ducting pipe is calculated as follows, depending on the diameter and quantity of cables that can fit in one pipe.

Figure 1. 51. Alignments of UB city communication lines and network

1.10.1. Approach and methodologies of the well channelling along the main alignments

A total of 1,513 fibre optic cables and 370 physical cables were laid in the 83 routes covered by the study. Of the total physical cables, 32 are 1,200, 1,800, and 2,400 pairs, 205 are 100-600 pairs, and 133 are 10-50 pairs. The length of the 83 routes is 106,637 meters, of which the length of the heavily loaded channels is 41,902 meters. The number of wells passed through these routes is 1,361.

Of the total 83 routes:

- In 38 routes, the channelling load is high (80-100%)%
- In 23 routes, the channelling load is average (50-70)%
- In 22 routes, the channelling load is low or up to 40%.
- Fibre optic cables account for 62% of the heavily loaded channels, and physical cables account for 38%.

Of the 38 busy routes, 30 are canals along the central road and 8 are canals along the suburban road. The scope of the central highway includes wells and canals from Sapporo Ward to Officers' Palace Ward. In terms of the age of the busy canals, 2.6 per cent are under 10 years old, 63.2 per cent are under 30 years old, and 34.2 per cent are under 40 years old.

1.10.2. Loads of the stations and distribution cabins

A study was conducted on the capacity, technical readiness level, and future expansion of Ulaanbaatar city network stations and substations, encompassing a total of 266 distribution cabinets across seven stations and three substations within the Ulaanbaatar city network.

The load of the stations and distribution cabinets is not more than 40 per cent, and the capacity utilisation is low, so there is no need for further expansion, and all stations and distribution cabinets are ready for future planning.

Figure 1. 52. Facilities of channeliing along the road

Lines affected by the planned route

The planned ring road route crosses the existing communication channel structure at 9 points and intersects it at a point 900 meters away. In the Ger district, 2000 meters of overhead lines intersect.

Figure 1. 53. Crossing points over the planned alignment

Table 1. 27. Networks affected by the planned alignment

	Planned Route Crossing Locations
1	Ulaanbaatar BUK
2	Online Distribution LLC

	Planned Route Crossing Locations
3	Bars II Market
4	Moscow Residential Complex
5	Erchim Trade Center
6	Mongol Ceramic LLC
7	Tushig Construction Materials
8	Soyombo Sports Center
9	Monbet Spare Parts Store

Figure 1. 54. Одоо байгаа мэдээлэл холбооны шугам сүлжээний трасс

1.11. HEATING SUPPLY

The heat supply system of Ulaanbaatar is divided into a centralised heat supply, a regional heat supply system, and an independent heating system.

As of today, centralised heat sources with a total installed capacity of 326.35 Gcal/h and an actual heat demand of 157 Gcal/h have been built in Ulaanbaatar. The thermal energy generated by "Amgalan Thermal Power Plant", "DCS-2" DCS, "DCS-3" DCS, and "DCS-4" DCS reliably provides the heating, hot water, and ventilation needs of 2921 business customers connected to the centralised heat supply system of the capital city, 16 Customer Service Centers of 3 distribution centers under OSNAAUG, and 67 companies with private licenses with a total estimated heat load of 3403.3 Gcal/h for more than 12,800 buildings and facilities.

The amount of thermal energy distributed from the stations in the last 5 years (thousands of Gcal) has increased by 5-8% per year, with more than 350-620 buildings and structures with an average annual heat load of 190-240 Gcal/h newly connected to the centralised heat supply.

According to the general development plan for Ulaanbaatar's development until 2040, 136 partial locations are being redeveloped, with a new heat load of 1638 Gcal/h planned for connection. This development highlights the importance of expanding and modernising the primary generator and transmission network shortly. In other words, there is a need to increase the installed capacity of the energy sector equipment in line with the development of the city

and optimally solve the necessary investment issues.

In 2021, a total of 6,858.9 thousand Gcal of thermal energy was purchased from the stations and distributed to consumers, fulfilling the plan by 98.5%. Of the purchased thermal energy, 2.6% was produced by TPP-2, 10.6% by Amgalan Thermal Plant, 31.8% by TPP-3 JSC, and 55% by TPP-4 JSC.

The production and supply of the energy sector are crucial components that form the basis for the country's security, economic, and social development. In recent years, the population concentration and density of the capital city have increased rapidly. Since 2015, as part of the redevelopment of ger districts, new towns and districts have been built and put into operation. In addition, the number of buildings connected to centralised heat supply has been increasing year by year, as well as the organisation of work to reduce air pollution by stopping heating boilers and connecting buildings located close to heat lines to centralised heat supply.

Balance of the central heat supply of the capital city: The installed capacity of the central heat supply system of the capital city is currently 2318 Gcal/h, but the load of connected consumers has reached 3403.3 Gcal/h, exceeding the installed capacity by more than 50 per cent.

Expansion and modernisation works are to be carried out in terms of sources: To ensure and improve the reliable operation of the capital city's central heat supply system, enhance the heat supply to consumers, and meet the normal demand for thermal energy, the following expansion and modernisation works for the sources must be completed by 2025. These include:

Expand the installed capacity of the HPP-2 JSC by 300 MW or 340 Gcal/h. Expand the installed capacity of the HPP-3 JSC by 75 MW or 100 Gcal/h. Expand the Medium Pressure Station of TPP-3 JSC by 250 MW or 400 Gcal/h. Expand the installed capacity of ADS JSC by 100 Gcal/h. Expansion and modernisation work is to be carried out in terms of transmission lines:

In terms of the transmission network, there are a total of 9 networks originating from TPP-2 JSC, TPP-3 JSC, TPP-4 JSC, and ADS JSC, and the connected load of the transmission lines of 6 of these networks is overloaded by about 60% of their capacity, and their capacity is insufficient and overloaded.

Transmission network line capacity: Also, out of the total 15 main lines of the capital city's transmission network with a length of 380 km, 24% or 91 km of lines and equipment are operating in conditions where their service life has expired and damage may occur.

Heat supply pipeline survey

The heating season in Ulaanbaatar city starts on September 17 and lasts until May 8, or a total of 233 days. As of 2024, the total length of the district heating network will be 379 km, of which 27 per cent, or 90.7 kilometres, have been in use for 30 years and have exceeded

their service life. Therefore, since most of the capital's heating network is at high risk, it is urgently necessary to upgrade and expand these lines. Seventy-one per cent of the heating network in Ulaanbaatar city is underground, and 29 per cent is above-ground. Many lines in the heating network of Ulaanbaatar city have exceeded their service life by more than 30 years.

Table 1. 28. Heating supply network current situation

№	Pipeline location	Size	Length
1	Located along the northern side of the Yarma highway	3×Φ1000	3×100 м
2	From the south of the road of the TPP-4 JSC to the Bars-2 market	2×Φ800	2×1500 м
3	From the south of the highway of the TPP-4 JSC to the Bars-2 market	2×Φ1200	2×880 м
4	To the west of the Mongolian Basalt LLC	2×Φ200	2×30 м
5	To the south of the Shini Urguu settlement	2×Φ800	2×240 м
6	From the south of the central highway of the 1st district to the north road of the 1st district	2×Φ700	2×730 м
7	Across the highway to the east of the Moskva district.	2×Φ250	2×100 м
8	Located along the northern side of the central highway of the 1st district.	2×Φ600	2×100 м
9	Located along the northern side of the Shini Urguu settlement	2×Φ700	2×150 м
10	In front of the Iron Works LLC	2×Φ500	2×150 м
11	In front of the Iron Works LLC	2×Φ500	2×150 м
12	Located along the north side of the Enkhtaivan Avenue highway.	2×Φ500	2×200 м
13	In front of the 35th school, along the broad street of the ger district	2×Φ700	2×200 м

1.12. WATER SUPPLY AND SEWAGE SYSTEM

The feasibility study and planning solution for the current status of the water supply and sewage system for the Ulaanbaatar City "New Ring Road" construction project was developed based on the following documents. Including:

Regulation No. A/720 of the Governor of the capital dated June 19, 2024

- Law on Urban Development of Mongolia

- Resolution No. 52 of 2020 on the approval of the "Vision 2050" long-term development document of Mongolia

- General development plan for the development of Ulaanbaatar city until 2020, concept for 2030, 2013

- Concept for the general development plan for the development of Ulaanbaatar city until 2040, 2021

- Partial general plan of Selbe sub-centre, 2015

- Law on the use of water supply and sewage systems in cities and settlements

• "Rules for the development, approval and assessment of construction projects" Resolution No. 204 of 2009 of the State Duma

• "Planning and construction of cities and villages" 30-01-04

• "Water supply. External networks and facilities" BNbD 40-02-16

• "Sewerage. External networks and structures" BNbD 40-01-14

• "Water supply and sewage inside buildings" BNbD 40-05-16

General section: The route of the new ring road project passes through the territories of Khan-Uul district 3, 4, Bayangol district 20, 29, Songinokhairkhan district 6, 7, 8, 9, 10, 16, 23, 28, 30, 39, 40, Chingeltei district 15, 16, 18, 22, Sukhbaatar district 14, 16, 21, 26, 27, 29, 31, 32, 36, Bayanzurkh district. The road axis determines the scope of influence in the 31 districts of Ulaanbaatar city. It is estimated that the total length of the route will be 300 m in two directions, covering 8.4 hectares.

Current status: The current status of the water supply and sewage lines within the project scope has been calculated as a planning area of 150 m in both directions from the planned highway route, and a study of the lines intersecting with the highway and running along the highway has been developed.

The highway is planned to have three lanes of 2 traffic, a total of 6 lanes, and the preliminary planning route length is 28 km.

Water supply: A total of 28.0 km of the highway route is intersected by a water supply network with a diameter of Φ50, Φ100-600mm, and a length of 33,000m at 21 points, transversely and longitudinally.

Since it is located near the Bayankhoshuu sub-centre in the east and close to the western district reservoir after the 1st district, the highway planning route will be coordinated with that section at the working drawing stage, as required. Also, in that section, the Φ225mm diameter plastic pipeline network constructed within the Bayankhoshuu sub-centre is located along the highway route. In the section of the planned highway route that passes through Chingeltei, Hailaast, and Selbe sub-centres, the Φ225 and Φ175mm diameter pipeline networks for supplying and discharging water to the Hailaast reservoir, as well as the Φ150-175mm diameter clean water pipelines for providing water to the water distribution facility, are located across the road.

Figure 1. 55. Water supply system that is crossed by road

Figure 1. 56. Water supply line intersecting with a road

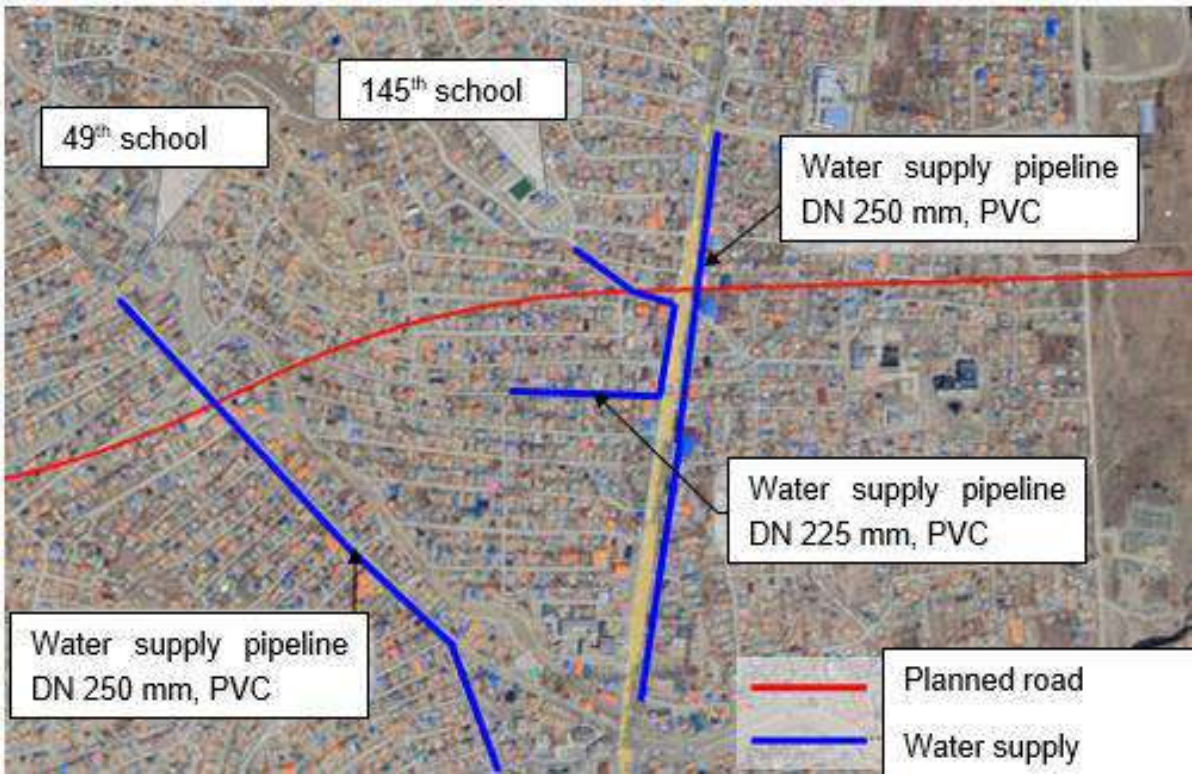


Figure 1. 57. Water supply line intersecting with a road

In the northern part, particularly in the vicinity of Hailaast and Selbe sub-centres, measures are necessary to remove and relocate water distribution lines to areas that can be identified in the future, in a detailed route study. It is essential to consider the fact that the eastern part of the highway route, in the vicinity of Sharkhad, Amgalan, and Ulaankhuran, intersects with the Φ600 and Φ700mm diameter line network that supplies water to the Eastern Region Reservoir at the working drawing stage. Also, the central Φ110-350mm diameter clean water line intersects at 10 points in that section. A protective casing pipe will be planned in the area where it intersects the highway. Sewerage: A total of 28.0 km of water supply, Φ50, Φ100-600mm diameter, 33,000m long line network intersects with the Φ30,000m long line network at 21 points, both horizontally and vertically. (See together with Figure 6-8).

The Φ1200mm diameter ceramic pipe of the central collector located on the north side of Enkhtaivan Avenue intersects with the road, and it is necessary to calculate the level difference at the planning stage carefully. From the 1st district, the Φ150-300mm diameter plastic and cast iron pipeline network constructed within the scope of the planning of the sub-centre near the Bayankhoshuu sub-centre intersects with the road route along and across.

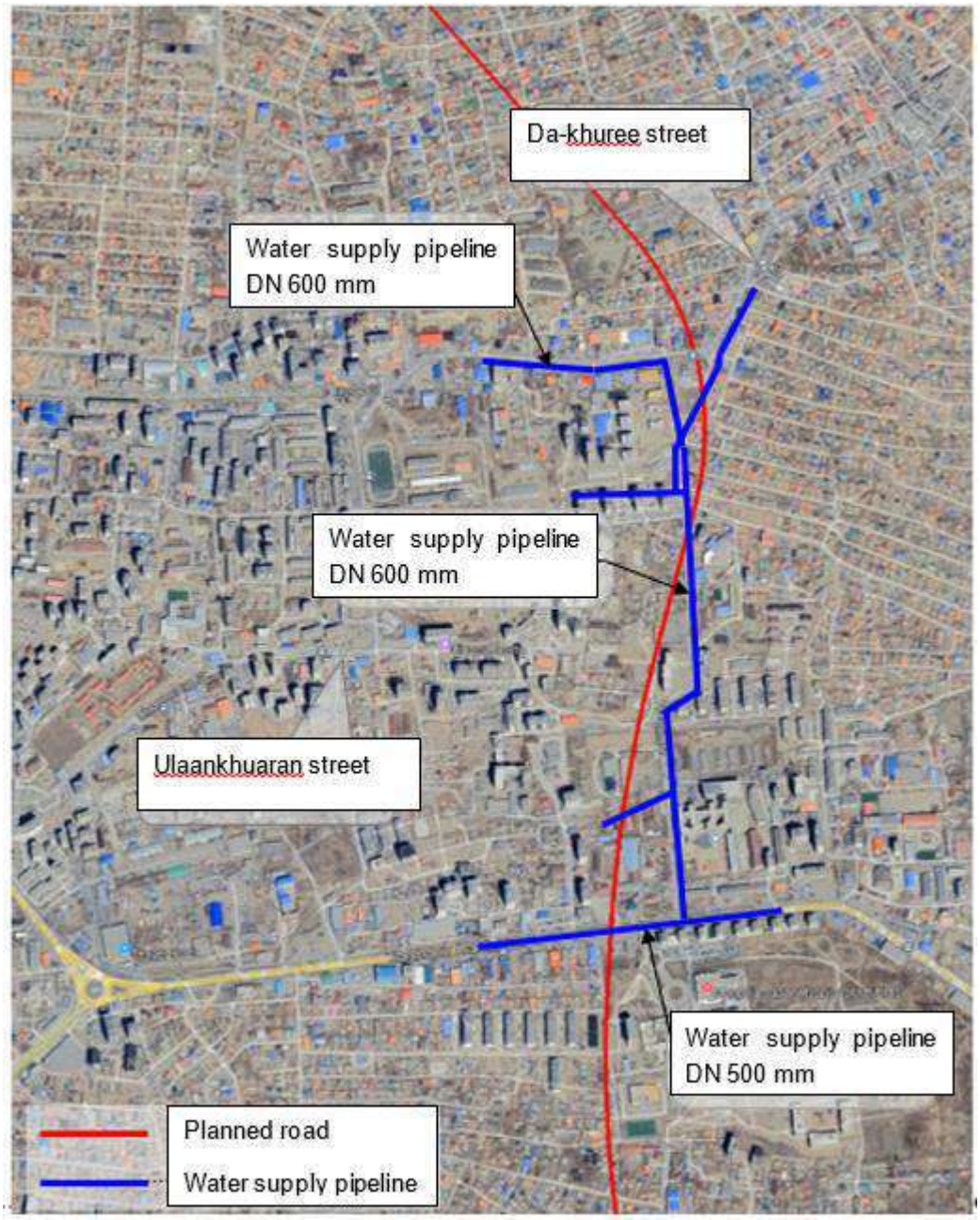


Figure 1. 58. Water supply line intersecting with a road

In the eastern part of the highway, around Sharkhad, Amgalan, and Ulaankhuran, the central sewage line with a diameter of Φ150-350mm is intersected at 5 points. A protective casing pipe will be planned at the intersection with the highway. Since it is challenging to move sewage lines with a diameter of more than Φ350, it is necessary to prepare the deep slope of the sewage line in detail in the design of the highway planning work.

Figure 1. 59. Sewer line crossing a highway

Water supply and sewerage network assessment: The assessment of the water supply and sewerage network in the study area evaluates the conditions intersecting and running along the highway, as well as the general difficulty of transporting and strengthening the network. The valleys of large and small rivers such as Tuul, Selbe, Dund, and Ulyastai have alluvial soil. The surface of the Tatm land is highly undulating, and depending on the conditions of the area, alluvial turf, alluvial dark, and alluvial peat soils are distinguished. Alluvial dark soil

is distributed throughout the region with scattered grass vegetation. The humus layer is about 20-40 cm thick, with coarse humus, alternating sandy and loamy bands downwards, and the soil-forming rocks are sandy-gravelly alluvial sediments. The humus content in the upper part of the soil decreases by 5-10% as it descends. The comprehensive urban development assessment has a combined environmental assessment of 2.9 points, or limited suitability, and the engineering ecological assessment has a score of 2.1 points, or unsuitable.

Water supply network assessment

Table 1. 29. Water supply level

No.	Administrative Unit Covered	Total Pipeline Length, m	Pipeline Location	Evaluation, %	Supply Coverage	Assessment
			Intersecting	Parallel and Overlapping	100.0% (Very High)	75.0–100.0% (High)
1	Selbe Recovery Project, Package I	3420	11	4	50%	

Sewage pipeline network assessment

Table 1. 30. Sewage pipeline network assessment

No.	Administrative Unit Covered	Total Pipeline Length, m	Pipeline Location	Supply Level, %	Supply Coverage	Assessment
			Intersecting	Parallel and Overlapping	100.0% (Very High)	75.0–100.0% (High)
1	Selbe Recovery Project, Package I	14090	8	6	10%	

The water supply and sewage network were rated 2.0 points or Lower. According to the geological engineer's conclusion, there is alluvial soil in the valleys of large and small rivers such as Tuul, Selbe, Dund, and Uliastai. The surface of the Tatmyn land is very hilly and, depending on the conditions of the area, alluvial turf, alluvial dark, and alluvial peat soils are distinguished. Alluvial dark soils are distributed throughout the region with scattered grass vegetation. The humus layer is about 20-40 cm thick, characterised by thick coarse humus, with alternating sandy and loamy bands downwards. The soil-forming rocks are sandy and gravelly alluvial sediments. The humus content in the upper part of the soil decreases by 5-10% as it descends. A total of 22 km of clean water lines and 25 km of sewage networks are located in the area, with a combined environmental assessment of 2.9 points, or limited suitability, and an engineering ecological assessment of 2.1 points, or unsuitable.

1.13. BRIEF STUDY OF COMMON MATERIAL DEPOSIT

Background

The primary construction materials required for the Ulaanbaatar Ring Road project, including sand, gravel, aggregate, crushed stone, cement, reinforcement, steel structures, asphalt, bitumen, water, and other auxiliary materials, are essential for the construction of all primary and auxiliary sections, including road embankments, base courses, pavements, bridge

structures, engineering structures, drainage systems, protective structures, traffic safety equipment, signs, and markings. Most of these materials can be provided by domestic manufacturers, but special-purpose materials, bitumen, and some chemical additives need to be imported from foreign suppliers. Therefore, rational planning of the supply chain, advanced transportation organisation, and ensuring the continuity of supply of all materials are the main conditions for the successful implementation of the project.

1.13.1. Material exploration research

There are abundant deposits of road and building materials in the vicinity of Ulaanbaatar city. In particular, the gravel and stone deposits currently in use at the beginning and end of the study area are fully supplying the materials for the newly constructed road and bridge structures. The planned road is designed to traverse the foothills, slopes, and summits of the Chingeltei mountain range, with some high points to be excavated. The lower-upper Carboniferous sandstone and its weathering in this area are suitable for crushed stone and gravel filling materials for roads, which has the advantage of saving costs. In other words, the stones and gravel from the excavations can be used in the concrete mixture for road embankments and bridges, and the asphalt mixture for roads. The following table shows the location information of the four currently used quarries and two new quarries. Since the materials of the presently used quarries meet the technical requirements, no samples were taken for analysis.

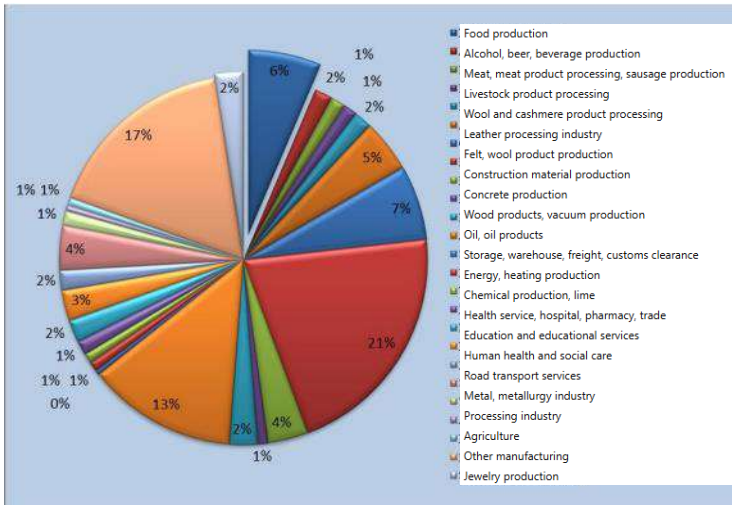


Figure 1. 60. Manufactoring classification

There are a total of 806 organisations producing building materials and raw materials in the industrial zones around Ulaanbaatar, of which 139 are building materials factories and 14 are petroleum products factories.

Table 1. 31. Ulaanbaatar, construction material study in 6 manufactoring zone

No.	Industrial Zone	Number of Enterprises	Number of Factories	Administrative Unit Location	Available Land Area (ha)	Main Business Purpose
1	Western Industrial Zone-1	101	70	Bayangol District, 20th Khoroo	1142.04 ha	37% of the enterprises produce concrete components and construction materials. Other activities include food production, metal products, furniture

No.	Industrial Zone	Number of Enterprises	Number of Factories	Administrative Unit Location	Available Land Area (ha)	Main Business Purpose
						manufacturing, and machinery.
2	Western Industrial Zone	171	150	Bayangol District, 20th Khoroo; Songinokhairkhan District, 20th Khoroo	—	Food production, leather processing, office furniture manufacturing, vehicle maintenance, equipment repair.
3	Western Industrial Zone	193	106	Songinokhairkhan District, 20th Khoroo	—	Manufacturing of construction materials, blocks, concrete components, leather processing, wool processing, textile and sewing factories, food processing, and wholesale trading.
4	Central Zone-1	53	46	Bayangol District, 1st, 3rd, 4th Khoroo	—	Located near Zuun intersection, Zaisan Bridge, and other main roads; includes metal, wood, and furniture manufacturing, food production, and retail.
5	Central Zone-2	132	97	Khan-Uul District, 3rd Khoroo	—	Includes machinery for engineering and construction works, building materials production, wholesale trading, car repair, storage facilities, and food processing.
6	Eastern Industrial Zone	156	71	Bayanzurkh District, 1st, 2nd, 3rd Khoroo	—	Leather and wool processing factories, food production, warehouse facilities, storage yards, and other industrial activities.
Total	806	540	—	—	—	

1.13.2. General information

General information on standard material deposits in and around the capital city of Ulaanbaatar is shown below. These include:

1. Sand

Purpose: Used as a filler in concrete mortar, road base and asphalt concrete mixtures.

Source: Quarries around Nalaikh, Shuvuun Fabrik, Gachuurt

2. Gravel, gravel

Purpose: Used as a filler in road embankments, base courses, and pavements.

Source: Quarries in Tuv aimag, Altanbulag soum (e.g., "Altan Nrezhne" LLC), Emeelt, and Moringiin Davaa.

3. Stone, crushed stone

Purpose: Used as a filler in asphalt concrete mixtures, road pavements, and bridge structures.

Source: Licensed stone crushing plants ("Sum Sunder" LLC, "Arvijih Kar" LLC, other

quarries).

5. Reinforcement, steel structures

Purpose: Reinforced concrete structures, bridge supports, beams, and building structures.

Source: Darkhan Metallurgical Plant, Tumurt Trans, Tumen Metallurgical, Beren Group.

6. Asphalt, bitumen

Purpose: Highway pavement, waterproofing layer.

Source: Domestic factories and the possibility of importing from Russia and China.

7. Water

Purpose: Concrete production, field work.

Source: Local reservoirs, water distribution centres.

8. Construction auxiliary materials

Waterproofing, sealing materials

Adhesives, adhesives

Chemical additives (concrete accelerators, hardening enhancers)

9. Special-purpose materials

Geosynthetic materials (geotextiles, geogrids) - for road base and pavement layers.

Road signs and marking materials - for highway traffic safety.

Types and status of reserves of cement raw materials and additives

Limestone, the primary raw material for cement production, must meet the technical specifications specified in the MNS 963:91 standard. Good quality limestone is widely distributed in our country, and currently, the reserves of the following primary raw materials have been identified and registered. These include:

a) Limestone

b) Gypsum

c) Clay

d) Iron ore

e) Thermal power plant ash

Power plant ash is used as an additional raw material in cement production, and its average chemical composition is shown in the following table:

Table 1. 32. Chemical substances of power plant ash

Name	SiO_2	CaO	Fe_2O_3	Al_2O_3	Na_2O	K_2O	P_2O_5	SO_3
Percentages	55.26%	6.46%	9.93%	20.94%	2.47%	1.17%	0.72%	0.37%

The consolidated register of mineral resources records proven reserves of limestone, the primary raw material for cement, as 592.6 million tons.

Deposits with potential for mining and purchasing construction materials

1. Sand: - Moltsog sand (Nalaikh): ~40-50 years of reserves, with a daily capacity of 400-500 tons of sand. Around Gachuurt, Khujirbulan, Shuvuun factory: Sufficient supply of sand

and gravel.

2. Gravel, gravel: - "Altan Network" LLC (Tyub aimag, Altanbulag soum): 200 t/h quarry. - "Sum Sunder" LLC (Ulaanbaatar, Khan-Uul): 120 t/h capacity. - "Arvizhih Kar" LLC (Ulaanbaatar area): Stone mining and crushing capacity. Around Emeelt, Moringi pass: Potential alluvial deposits.

3. Cement: Limestone reserves: 592.6 million tons. Gypsum reserves: 80 million tons. - Production reserves of domestic industries: 4.23 million tons of cement per year.

4. Reinforcement and steel structures: Iron ore reserves - Total proven reserves: 1.65 billion tons.

- Large deposits - Tumurtei, Bayangol, Tumur Tolgoi: 343 million tons. Tayan Lake: 71.7 million tons. Kharaat Mountain, Ereeni deposit: 71.5 million tons. Bargilt: 23 million tons.

5. Asphalt, bitumen: Capacity of factories operating in the vicinity of Ulaanbaatar. Eco Asphalt LLC: 120 tons/hour. 7 companies including Yalguwat LLC, Bat Zam LLC, Tugs Zam LLC, Nutgiin Zam LLC, Tegsh Plant LLC.

6. Crushed stone and gravel: Around Moringi pass: 38 thousand. m^3/year. Around Ulaanchuluut: ~30 thousand. m^3/year. Other quarries around Takhilt, Barunuturuun, Gachuurt, and Emeelt.

7. Gypsum: Tavan Tolgoi deposit (Umnogovi): 4.6 million tons. Shiree Uul deposit (Dundgovi): 4.44 million tons. Taishir deposit (Gobi-Altai): 240 thousand tons.

8. Clay: Nalaikhin Ikh Bulgiin clay deposit: Proven reserves, can be used for cement production. - Nairamdal clay deposit: Clay deposit suitable for production.

9. Power plant ash: Ulaanbaatar Power Plant No. 4: There are ash reserves that can be used as building materials.

1.13.3. Main materials for road and construction

Cement

Cement consumption in our country is increasing year by year, from 1.9 million tons in 2012 to 2.3 million tons per year in 2024. In 2022, 3.8 trillion tugriks were to be invested in the construction sector, but some projects have been delayed due to border closures, cement shortages, and price increases.

Mongolia began importing ⅔ of its cement in 2013, which had adverse effects such as poor quality, high impurities, and pollution of imported products, which negatively affected the quality of construction mortar. To improve this, additional chemicals were used, increasing costs. In addition, cement that has been stored for a long time has been supplied, which has created conditions that do not meet the requirements for use.

Domestic cement, on the other hand, offers several advantages, including maintaining storage conditions, being cost-effective, and having a responsible manufacturer. Increased cement production in Mongolia has the potential to reduce dependence on imports, limit

exchange rate and inflation growth, and increase tax and fee revenue. In addition, it has a positive effect on stabilising rail freight, reducing seasonal price fluctuations, and lowering market prices through production based on domestic raw materials. In general, producing cement domestically and meeting demand has many benefits.

Most of the 13 major cement plants currently operating in Mongolia use wet process technology. Still, plants such as "Khutul" and "Montcement" have begun to switch to the dry process technology that is widely used internationally in recent years. The dry process uses less water than the wet process (4–5 times less), reduces fuel consumption by half, saves up to 30 per cent of energy, and is more environmentally friendly because it produces less dust and allows waste to be recycled.

Since 2010, Mongolia has established partnerships with European standardisation organisations such as CEN, CENELEC, and ETSI in the fields of construction, railways, and water supply. In this context, many Eastern European countries, such as Kazakhstan and the Czech Republic, have actively implemented the introduction of Euro standards and Euro codes and updated their standard systems. Bulgaria, Latvia, Lithuania, Poland, and Romania have made a complete transition. This is a significant achievement.

There are a total of nine types of Eurocodes in the European Union. Our country has been using them indirectly, through regulated means, or by building codes. Although national standards based on Eurocodes have not yet been fully developed, more than 70 Eurocodes have been directly adopted in areas such as building insulation, mineral wool, and treatment facilities. In the railway sector, more than 100 Eurocodes have been introduced at the national level.

Due to the active implementation of international projects and programs, building materials, especially cement and concrete standards, have become widely used in our country's road construction sector.

To mention the progress in standardisation in recent years, out of a total of 19 standards approved in 2020, 16 were nationalised based on EN standards, and three new standards were approved. However, in 2022, out of a total of 11 standards approved, one was nationalised based on EN standards.

Cement Production Status: 12 potential large cement plants are operating near the project location, and their details are as follows:

1. Ulaanbaatar City

1.1. Central Asian Cement

1.2. MJL Cement

1.3. Erdes Beton

2. Dornogovi Province

2.1. Mon-cement Building Materials Plant

2.2. Teeliin Shonkhor

2.3. Hermes Gahiur

2.4. Mak Euro Cement Plant

3. Selenge Province

3.1. Khotuli Cement Lime Plant

Table 1. 33. Cement standards in force in Mongolia and their compliance

No.	New MNS Standards Based on EN Cement Standards		Existing MNS Cement Standards	
	No.	Name	No.	Name
1	MNS EN 196-5:2020	Cement Testing Method. Part 5: Testing the quality of pozzolanic cement	MNS ISO 836:2000	Quality of pozzolanic cement – Testing method
2	MNS EN 196-2:2020	Cement Testing Method. Part 2: Chemical analysis of cement	MNS 0975:2002	Cement – Chemical analysis method
3	MNS EN 196-1:2020	Cement Testing Method. Part 1: Determination of strength	MNS 0976:2008	Cement – Determination of compressive strength using multi-size standard sand
4	MNS EN 196-3:2020	Cement Testing Method. Part 3: Determination of setting time and soundness	—	—
5	MNS EN 196-6:2020	Cement Testing Method. Part 6: Determination of fineness	—	—
6	MNS EN 196-7:2020	Cement Testing Method. Part 7: Methods for taking and preparing samples	MNS 3091:2008	Cement – General technical requirements, Part 7
7	MNS EN 196-8:2020	Cement Testing Method. Part 8: Determination of heat of hydration by solution method	MNS 3740:1999	Cement – Determination of heat of hydration by solution method
8	MNS EN 196-9:2020	Cement Testing Method. Part 9: Determination of heat of hydration by semi-adiabatic method	—	—
9	MNS EN 196-10:2020	Cement Testing Method. Part 10: Determination of water-soluble hexavalent chromium content in cement	—	—
10	MNS EN 197-1:2020	Cement. Part 1: Composition, specifications, and conformity criteria for common cements	MNS 0974:2008	Portland cement – Technical requirements
11	MNS EN 197-2:2020	Cement. Part 2: Conformity evaluation	—	—

1. Darkhan-Uul aimag

1.1. Erel Cement Plant

2. Khovd aimag

2.1. Khovd Eco Cement Plant

3. Erdenet city

3. Stroy Industrial

4. Tuv aimag

4.1. Monkhin Bayan Gal Plant

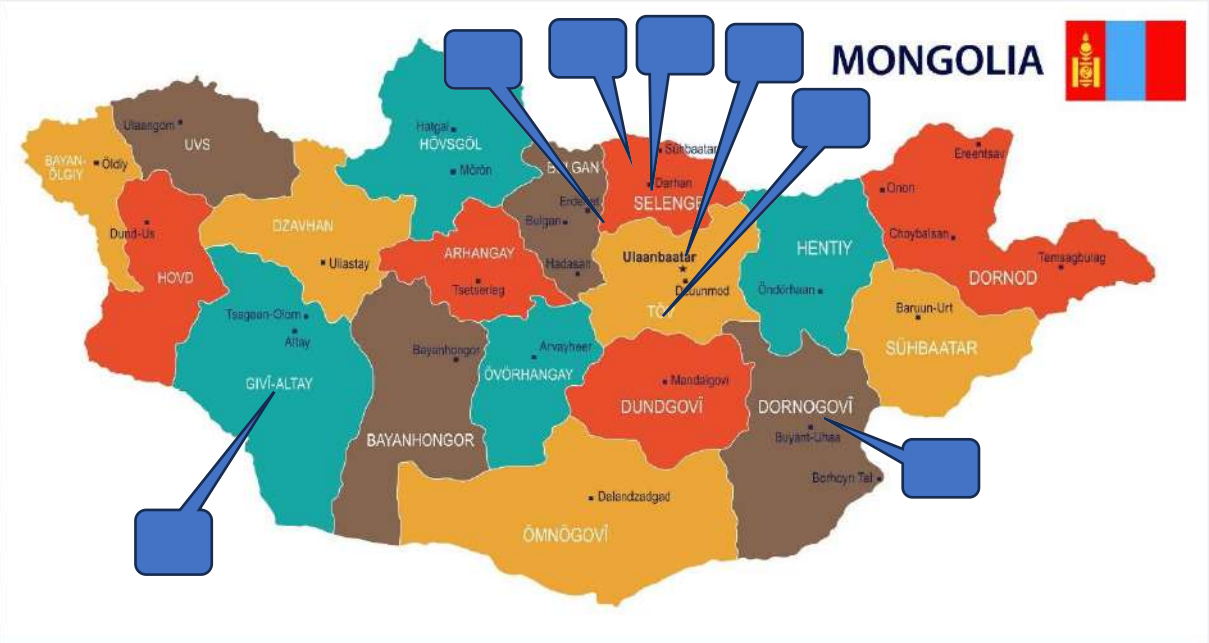


Figure 1. 61. Raw material mining location

In recent years, cement production in Mongolia has been developing rapidly, and many factories with sufficient capacity to meet domestic needs have been established and started operating.

"Khutuli Cement-Khohoi" JSC: By switching to dry process technology, it can produce 3,000 tons of clinker per day, 1 million tons of cement and 65 thousand tons of lime per year. The modernisation test and adjustment began in November 2013 and was put into operation in May 2014.

"Erel" Cement Plant: The first cement plant in Mongolia, established in Darkhan in 1968, produces PC 32.5 and PC 42.5 Portland cement using the wet process.

"Montcement Building Materials" LLC: Started operation in 2015. It uses advanced dry process technology and can produce 3,000 tons of clinker per day and 1 million tons of cement per year. Using eco-technology, 90 per cent of wastewater is reused, and waste discharge meets European standards.

"Monkhin Bayan Gal" LLC: Located in Sergelen soum, Tuv aimag, with a capacity to produce 2,500 tons of clinker per day and 1 million tons of cement per year, a factory with Chinese investment.

"Teeliin Shonkhor" LLC: Located in Sainshand soum, Dornogovi aimag, with a capacity to produce 100 thousand tons of cement per year. Raw materials are obtained from local deposits, connected to the railway, and equipped with fully automated equipment.

"Hermes Gahiur" LLC: The factory, which is being built on the Biluut limestone deposit in Dalanjargalan soum, can produce 240 thousand tons of dry-process cement per year.

"Khovd Eco" Cement Factory: Located in Khovd aimag, with a capacity to produce 100 thousand tons of cement per year.

"Stroy Industrial" LLC: The plant, which has been operating in Erdenet since 2006, produces 30 thousand tons of cement per year. Cement is transported in bulk and supplied to the concrete market of Ulaanbaatar. The raw material warehouse and production area are well organised.

"Central Asian Cement": The feature of this plant is the use of a rotating rail cylinder area to increase the efficiency of raw material reception and production.

"MGL Cement" LLC: Established in 2013 and started operating at full capacity in 2016. It receives its raw materials from "Khotuli Cement Chalk" OJSC. It produces OPC 42.5 cement.

"Erdes Beton" LLC: Can produce 110 thousand tons of OPC 42.5 cement per year. Stone is imported from Khotuli and gypsum from Dundgovi aimag. It makes 8 tons of cement per hour with equipment manufactured in China.

"Nalgar Tushig" LLC – "Nalaikh" Cement Plant: The first plant in Mongolia to operate in the dry process since 2008. It produces OPC 42.5 and PSC 32.5 Portland cement and mineral powder. Raw materials are obtained from the Shokhoyin Mountain in Erdene soum, Tuv aimag.

Results and economic significance

If the above plants operate at full capacity, Mongolia will be able to produce 4.23 million tons of cement per year, which will fully meet domestic needs.

To reduce import dependence, large plants such as "Montcement", "Monkhin Bayan Gal", and "MAK" were put into operation in 2015–2016, and imports of 1.5 million tons in 2014 decreased to 91 thousand tons by 2022, and the amount of foreign exchange loss decreased from 14–97 million US dollars to 5 million US dollars, which had a significant positive impact on the national economy.

Iron rebar

Current status of rebar consumption and supply in Mongolia: Although the demand for rebar in Mongolia is increasing year by year, domestic production is still insufficient. Approximately 90 per cent of our country's total rebar consumption is met by imports from China and Russia. Annual consumption fluctuates around 250,000–350,000 tons and is likely to increase in line with the expansion of the construction sector.

Domestic production situation: There are 15 registered enterprises in Mongolia producing rebar, and the theoretical installed capacity of these factories is about 450 thousand tons per year. However, these capacities are not fully utilised. For example, in 2019, a total of 66.3 thousand tons of rebar were produced, which accounted for up to 30 per cent of the total domestic consumption for that year.

Reasons for production failure: Domestic rebar factories usually process steel bars from scrap iron. However, the production volume is low due to the limited amount of scrap. Many factories struggle to maintain stable and smooth production due to factors such as labour shortages, incomplete infrastructure, and a lack of technology. During the 2020–2021 COVID-

19 pandemic, all factories except the Darkhan Steel Plant completely stopped their operations, and production sharply decreased.

Import dependence and future outlook: Over the past five years, Mongolia has imported a maximum of 534,056 tons of steel products, worth 292.0 million US dollars or 715.4 billion tugriks. These figures show that Mongolia depends on foreign markets for more than 90 per cent of its total steel consumption.

Per capita consumption of iron and steel products: The annual consumption of iron and steel products in our country is only 115 kg per capita, which is ~3 times lower than the world average (~330 kilograms) and ~6 times lower than the example of developed countries (Japan – 640 kg/person).

Future demand projection: If the world average consumption level is calculated, the annual demand for iron and steel products in Mongolia is 1 million tons

In terms of value, it is likely to reach 1 trillion 225 billion tugriks or approximately 500 million US dollars.

Reinforcement is classified according to several basic characteristics as follows:

1. By purpose and location

By operating conditions: Special types are used depending on the external environment, such as humid or chemical environments.

By location within the structure: Main reinforcement (load-bearing), auxiliary reinforcement (responsible for fastening and welding).

2. By shape and elasticity

Rigid elements: Large steel structures such as I-beams, channels, and angle iron.

Flexible elements: Smooth and curved steel bars, woven mesh, and welded frames.

3. By manufacturing material

Iron reinforcement: The most widely used. Heat-resistant, can be bent and welded.

Composite reinforcement: Materials made of glass, basalt, carbon fibre, and wood. The advantages are corrosion resistance, non-conductivity, and light weight.

Table 1. 34. Requirements for steel reinforcement (MNS JIS G 3112:2002)

Grade	Yield Strength (0.2% offset), N/mm²	Tensile Strength, N/mm²	Elongation After Fracture, %	Rebar Type	Required Bending Angle	Bendability	Test Mandrel Radius
SR 235	≤ 235	380 ± 20	N2: ≥ 20% N3: ≥ 24%	180°	For N2: 1.5 × nominal diameter	—	
SR 295	≤ 295	440 ± 600	N2: ≥ 18% N3: ≥ 20%	180°	For N2: 1.5 × nominal diameter if Ø ≤ 16 mm For N3: 2 × nominal diameter if Ø > 16 mm	—	
SD 295A	≤ 294	440 ± 600	Same as N2: ≥ 16% Same as N3: ≥ 18%	180°	For N2: 1.5 × nominal diameter if Ø ≤ 16 mm For N3: 2 × nominal diameter if Ø > 16 mm	—	

Grade	Yield Strength (0.2% offset), N/mm²	Tensile Strength, N/mm²	Elongation After Fracture, %	Rebar Type	Required Bending Angle	Bendability	Test Mandrel Radius
SD 295B	345–440	≥ 440	Same as N2: ≥ 16% Same as N3: ≥ 18%	180°	For N2: 1.5 × nominal diameter if Ø ≤ 16 mm For N3: 2 × nominal diameter if Ø > 16 mm	—	
SD 345	345–440	≥ 490	Same as N2: ≥ 18% Same as N3: ≥ 20%	180°	For N2: 1.5 × nominal diameter if Ø ≤ 16 mm For N3: 2.5 × nominal diameter if Ø ≥ 51 mm	—	
SD 390	390–510	≥ 560	Same as N2: ≥ 16% Same as N3: ≥ 18%	180°	For N2 & N3: 2.5 × nominal diameter	—	
SD 490	490–625	≥ 620	Same as N2: ≥ 12% Same as N3: ≥ 14%	90°	For N2: 2.5 × nominal diameter if Ø ≤ 25 mm For N3: 2.5 × nominal diameter if Ø > 25 mm	—	

About rebar manufacturers and importers in Mongolia

Darkhan Iron and Steel Industry: As the largest rebar manufacturer in Mongolia, the company operates primarily due to its raw material resources. The project capacity of this iron and steel industry is 100 thousand tons per year. However, 20 percent of the project capacity is being produced. The iron and steel industry is capable of producing 10-35 mm diameter construction rebar (rebar), 10-100 mm diameter smooth iron bars, 30x30-65x65 mm angle iron, and 100-140 mm diameter round iron balls, and is supplying them to the domestic market.

To increase the product range, expand its business activities, and meet domestic demand, in 2017, a round iron ball rolling plant with a capacity of 25,000 tons of round iron balls per year was put into operation, equipped with equipment from Germany and Italy.

Tumurtolgoy Mine: The company's first mine, the Tumurtolgoy iron ore open pit, is located 28 km from the Darkhan Metallurgical Plant in Khongor soum, Darkhan-Uul aimag. The deposit has 25 million tons of iron ore reserves. The Tumurtolgoy iron ore mine produces 2 million tons of ore with a 42-45% Fe content per year and processes it in a dry magnetic separation plant equipped with modern mining equipment from the USA, Germany, and China, with a capacity to produce 1.3 million tons of whole and powdered concentrate with 0-10 mm and 10-40 mm particles and 55-58% Fe content.

Tumurtein Iron Ore Mine: The Tumurtein iron ore open pit is located 130 km from the Darkhan Metallurgical Plant in Khuder soum, Selenge aimag. The deposit is a strategic deposit of Mongolia with 229.3 million tons of iron ore reserves. In addition, an open pit mine was established and started operating in the eastern part of the deposit in October 2014. The western and east mines of the east part of the deposit mine produce a total of 2 million tons of ore per year, which is processed in a dry magnetic method plant equipped with modern advanced equipment from a US mining processing plant, and operates with a capacity to produce 1.3 million tons of whole and powdered concentrate with a particle size of 0-10 mm,

10-40 mm, and a Fe content of 58-62%. Currently, the plant produces products that meet the requirements of Mongolian national and international standards, such as rebar and smooth iron bars, angle iron, and iron ingots with various cross-sections, and supplies them to the domestic market. The plant can produce 200-300 tons of billets and products per day. Products are classified by production:

- Iron bars with a cross section of 115x115x1.5- 6000mm according to the Mongolian national standard MNS 4854:99

- D10-35 mm cross-section SD295, SD345, SD390, SD400 type iron bars, as people say, AI - AIV reinforcement according to the Mongolian national standard MNS JIS G 3112:2002

- R10 - 80 mm cross-section SR235, SR295, Ст45, Ст70 type smooth iron bars according to the Mongolian national standard MNS 4239:1994

- SS400 type angle iron with a cross section of L30x30x3 and L45x45x5 mm

- Mongolian national standard MNS 4238:1994.

Within the scope of the metal analysis and testing laboratory:

- Analysis and determination of the composition of iron and cast metal structures.

- Determination of the mechanical properties of all types of rolled products

Perform tests and experiments

Determine the hardness of metal structures and parts.

Perform macro and microstructural analysis of metals.

Within the scope of the material analysis laboratory:

- Crushing, grinding, and sample preparation of ore and rock samples.

- Determination of moisture content and material particle size

- Determination of the specific volume of ore and materials, and the volume and weight of the castings.

- Analysis and determination of the composition of iron ore, other rock ores, concentrates, and direct reduced iron

(DRI).

- Analysis and determination of the composition of all types of refractory powders and structural materials.

- Analysis and determination of the composition of additional iron alloys that improve the properties of iron and cast iron.

- Analysis and determination of the composition of lime, limestone, fluorspar, clay, lining materials, coke, coal, and other materials.

Analysis and determination of the composition of non-ferrous metals.

- Analysis and determination of the composition of iron and cast metal structures and products.

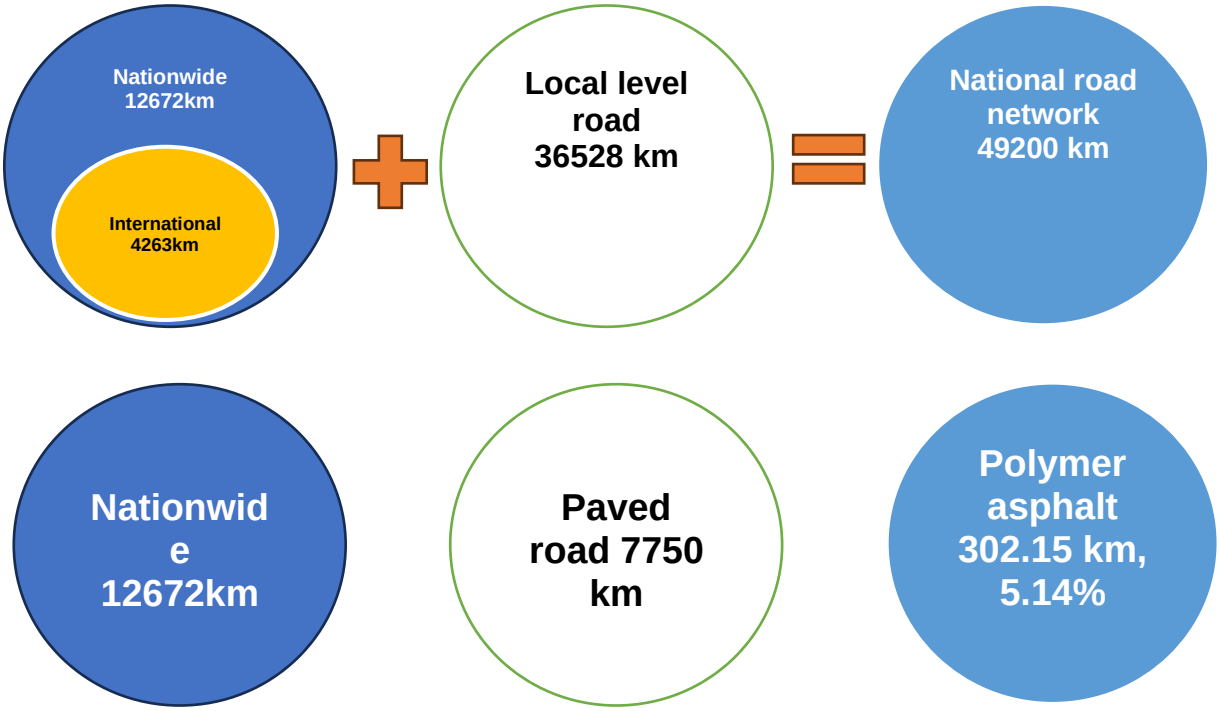
The production of the Darkhan Metallurgical Plant is based on Japanese equipment and

technology, and the product quality standard is based on the JIS standard of the country, which is located in an active earthquake zone.

The MNS JIS G 3112:2002 standard is the main requirement for product production.

Study on the consumption, supply and price of bitumen in Mongolia

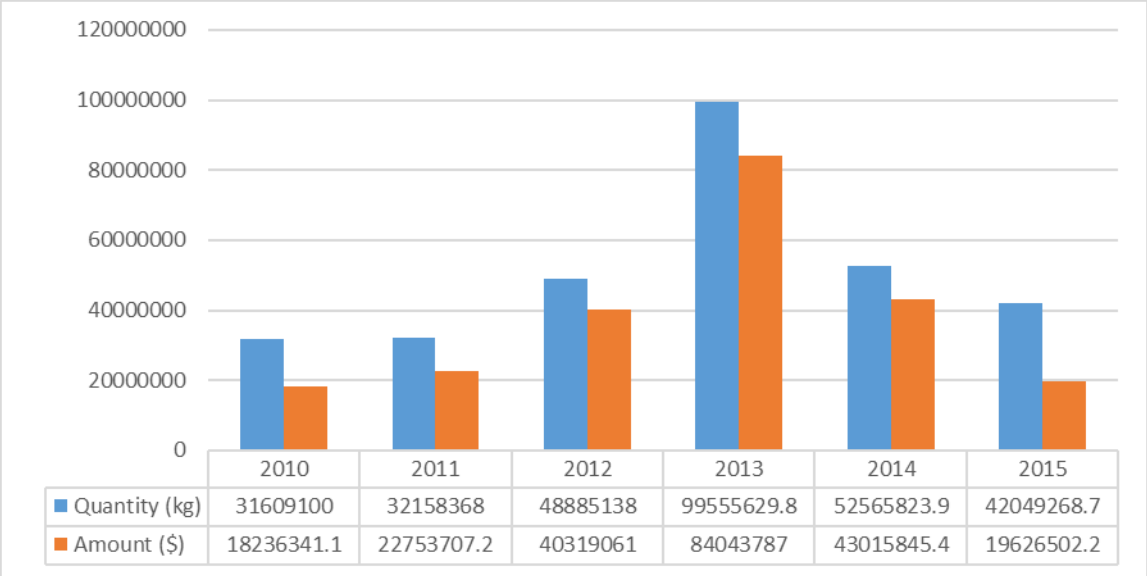
The total length of roads in Mongolia as of October 2022 is estimated to be 49,200.0 km, of which 74.2% or 36,528.0 km are local roads and 25.8% or 12,672.0 km are national roads. 33.6% or 4263.0 km of national roads are international roads. Also, 51.9% or 7744.7 km of national roads are paved roads.



Polymer-added bitumen has been used in Mongolia since 2012. In recent years, to improve the serviceability of pavements, bitumen, which is polymerised in Russian factories and .

The cost of imported construction packaged in 1-ton packages, has been used in several projects with the addition of SBS-type copolymer materials and plasticisers materials is calculated according to the following scheme. The cost of the materials consists of the transaction price of the goods agreed upon with the supplier, customs duties and value-added tax upon entry into Mongolia, transportation costs from the supplier to Ulaanbaatar, loading and unloading expenses related to cargo transportation (depending on the terms of the contract between the seller and the buyer, how both parties are responsible for the transportation costs varies), storage costs, and other costs. The price received by the construction contractor is the cost of the imported materials plus the profit percentage of the importing organisation. Mongolia imports 100% of the following bitumen grades: BND-90/130, BND-60/90, BND-40/60, BND-130/200, BND-200/300 from countries such as the Republic of Korea, China, Iran, Italy, Kazakhstan, Malaysia, Poland, and Japan. Russia alone accounts for

85-90 percent of total imports, and 92% of total bitumen is used in road construction. The volume and value of bitumen products imported into our country from 2012 to 2015 are shown.



	2010	2011	2012	2013	2014	2015
Quantity (kg)	31609100	32158368	48885138	99555629.8	52565823.9	42049268.7
Amount ($)	18236341.1	22753707.2	40319061	84043787	43015845.4	19626502.2

Figure 1. 62. Price and volume of imported bitumen

Each country selects its bitumen and carries out road construction production depending on the temperature and climate of the road construction region. If it heats up to 40 degrees in summer and -40 degrees in winter, it means that it will be used for that purpose. In general, it is beneficial for us to produce and improve bitumen, which is the primary material for asphalt-paved roads, in the future. This will create positive opportunities such as maintaining smooth railway freight traffic across the border, stabilising the seasonal increase in bitumen prices, and reducing market prices based on domestic raw materials. By adding additives to bitumen, the quality is improved and adjusted to the environment of the region. For example, if it is cold in winter, special substances are added to make it very elastic, while in areas where it is very hot in summer, it must also be made more dense with special substances. There are two types of road bitumen: thick and liquid. Petroleum bitumen is extracted from heavy oil residues by reprocessing. The technical conditions of petroleum bitumen are standardised by GOST 22245-90 and are produced in 5 different grades: BND 40/60, BND 60/90, BND 90/130, BND 130/200, BND 200/220. Of these, BND 60/90 and BND 90/130 bitumen are mainly used in road construction in Mongolia.

Concrete characteristics: The main factor affecting the quality assurance of concrete is the use of cement with high technical parameters. There are no special standard technical requirements for cement in the road sector of our country, and cement that meets the requirements of the general "MNS 974: 2008 Portland cement. Technical requirements" is used. However, since 2019, the MNS EN 196 - 1: 2019 standard has been implemented. The requirements for concrete used in the construction of roads, tunnels, bridges, and other types of structures are different from those for concrete used in structural elements. For example, the flowability of concrete in soil water and acidic and alkaline environments, air content, and

the type and size of natural minerals contained in rocks and sand are different.

Concrete classification: From 2017, concrete classification and how to transfer it to the new EN standard MNS EN 206: 2017. According to the 2020 standard, all cement standards will be transferred to the EN standard, bringing it to the international level, making it possible to mutually accept product quality documents, creating favourable conditions for foreign trade.

About concrete engineering solutions: In recent years, with the rapid growth and development of the economy, there has been an urgent need to use high-quality, long-lasting concrete in infrastructure, engineering structures, and large-scale projects. Many factories in our country are fully equipped with equipment and management systems capable of producing 150m³ of high-quality mortar of grades M700–M1000 and introducing innovative technologies.

They value product quality, constantly introduce modern, new, and leading technologies into their operations, and strive to supply the Mongolian construction industry with high-quality products that meet the latest world standards. The primary objective of engineering studies is to enhance the capabilities and applications of concrete materials, thereby creating living conditions that foster peace and confidence for the end user.

Current status of cement concrete production*:* There are more than 140 cement concrete factories registered in Mongolia, of which approximately 90 companies are actively operating. 65 per cent of these concrete production companies are Mongolian, 25 per cent are Chinese, and 7 per cent are Korean-invested. For example, Korean-invested companies such as "Bat Beh Remicon", "H&H Remicon", "JKS Remicon", and "Sam Won Dream Walk" operate, while Japanese-invested "Aizawa" is also operating. The number of concrete production plants is unstable and fluctuating due to the growth of investment in the construction sector. While most concrete producers operate in specialised areas, in recent years, construction companies have increasingly assembled and used portable and stationary concrete production units for their projects. These include companies such as "Bridge Construction", "Koyote", "Ondurbuyant Holding", "NAZU" Group, and "Erel" Group. The quality requirements for each type of concrete application vary. Also, some road construction companies, such as "Ochirnyam", "Ochir Tuv", and "New Progress" groups, have established factories to produce concrete for their use. For example, high-strength, air-enriched concrete produced by "EDT", "Naran Beton Daght" and "Aizawa Mongol" companies was supplied for the construction of the 5.5 km Sonsgolong highway, which was put into operation in 2015. Also, in 2017, "Premium Konkrit" LLC supplied concrete for the construction of the runway of the new airport. As of May 2024, there were a total of 125 companies registered with the Mongolian Association of Building Materials Manufacturers and the Association of Concrete Mixture Manufacturers with the right to produce concrete products and mortar, of which 88 companies actively operating in Ulaanbaatar were included in this study. Distribution of concrete batching plants in the districts of Ulaanbaatar city:

- 26% or 23 plants in Bayangol district
- 43% or 39 plants in Songinokhairkhan district
- 19% or 17 plants in Khan-Uul district
- 9% or seven plants in Bayanzurkh district
- 1% or one plant in Sukhbaatar district
- 1% or one plant in Baganuur district
- 1% or one plant in Nalaikh district

Of these 88 plants, 45% (39) are in Songinokhairkhan district, 26% (23) are in Bayangol, 19% (17) are in Khan-Uul, 9% (8) are in Bayanzurkh, and the remaining 1% (one plant) is in Sukhbaatar district. In terms of supply, 85 out of 88 factories operating in Ulaanbaatar have concrete production plants, and the leading manufacturers include "Suuri" LLC, "Bilguun Trade" LLC, "UB BUK", "Beton Armatur" LLC, "MKAi" LLC, "Bat Bekh Remikon" LLC, and "Erel Beton" LLC. In terms of investment, 70% of concrete production plants are Mongolian companies, while Japanese-invested companies include "Aizawa" and "Suruga Mongol", and Korean-invested companies include "Bat Bekh Remikon", "MKAi", "H&H Remikon", "Samwon Dream Walk", and "JKS Remikon".

In terms of operations, more than 30 concrete production plants operate in specialised areas, and in recent years, construction companies have increasingly used mobile and stationary concrete production plants for projects. For example, large companies such as "Altai Construction", "Buti", "Zag Construction", "Nazu Construction", "Koyoto", "Bridge Group", "Ondurbuyant Holding", "Khurd Group", "Erel Group" are operating in this sector. Twenty-five factories are producing more than 15,000 m³ of concrete per year.

Table 1. 35. Information on concrete batching plants

No.	Factory / Company Name	Location	Capacity & Commissioning Year	Quarry Location (Lat/Long)
1	Arga Baril LLC	Bayanzurkh District, 10th Khoroo, Ulaanbaatar	120 m³/h (2013, 27,031 m³)	47°54′30.83″N / 107°0′53.52″E
2	Bridge Construction LLC	Bayanzurkh District	140 m³/h	47°54′28″N / 107°0′53.52″E
3	Telmen Investment LLC	Bayanzurkh District, 14th Khoroo, Marshal Zhukov Avenue, 55/1	180 m³/h	47°54′8.63″N / 107°5′55.43″E
4	BUUKH LLC	Bayanzurkh District, 11th Khoroo	60 m³/h	47°55′24.29″N / 106°44′48.30″E
5	Ikh Modun LLC	Bayanzurkh District, 14th Khoroo	120 m³/h	—
6	MKI LLC	Songinokhairkhan District, 20th Khoroo, Tev Office, SBD, "UB Mart"	150 m³/h, 1500 m³/day (2013, 38,000 m³)	47°53′4.56″N / 106°44′48.56″E
7	Orgil Zuurgam LLC	Songinokhairkhan District, 20th Khoroo	90 m³/h (2013, 60,537 m³)	47°55′2.85″N / 106°55′37.83″E
8	Karier LLC	Songinokhairkhan District, 20th Khoroo, west of Food Trading	120 m³/h, 1200 m³/day	47°54′23.98″N / 106°55′3.99″E
9	Battuen LLC	Songinokhairkhan District, 20th Khoroo	90 m³/h (2013, 15,000 m³)	47.8848°N / 106.7810°E
10	Standart Remicon LLC	Songinokhairkhan District, 20th Khoroo	1200 m³/day	47.8412°N / 106.7810°E
11	Mereks LLC	Songinokhairkhan District, 20th Khoroo	150 m³/h	—

No.	Factory / Company Name	Location	Capacity & Commissioning Year	Quarry Location (Lat/Long)
12	Avzaga Mezern LLC	Songinokhairkhan District, 20th Khoroo	120 m³/h, 1200 m³/day (2013, 17,000 m³)	—
13	Remicon LLC	Songinokhairkhan District, 20th Khoroo	300 m³/h (2013, 108,420 m³)	47°53′29.57″N / 106°46′7.27″E
14	Tegs Zuurgam LLC	Songinokhairkhan District, 20th Khoroo	180 m³/h, 1800 m³/day (2013, 65,000 m³)	47°54′36.16″N / 106°46′1.93″E
15	New Progress Group	Songinokhairkhan District, 4th Khoroo	120 m³/h (2013, 23,958 m³)	47°54′51.43″N / 106°46′1.85″E
16	Khunnu Concrete LLC	Songinokhairkhan District, 14th Khoroo	90 m³/h, 1200 m³/day	47°54′40.16″N / 106°44′1.88″E
17	Bulgan Gazar LLC	Sukhbaatar District, 20th Khoroo	60 m³/h	—
18	Zev Zuurgam LLC	Songinokhairkhan District, 20th Khoroo	30 m³/h	—
19	Ein & Ei LLC	Songinokhairkhan District, 20th Khoroo	120 m³/h (2013, 20,000 m³)	47°53′15.87″N / 106°45′4.98″E
20	Prosilid Standart LLC	Songinokhairkhan District, 20th Khoroo, Songino Street, 99/1	120 m³/h (2013, 23,000 m³)	47°53′6.9″N / 106°45′8.55″E
21	Aizawa Mongol LLC	Songinokhairkhan District, 20th Khoroo	150 m³/h (2013, 36,000 m³)	47°53′6.9″N / 106°45′8.55″E
22	Yu End Ji LLC /Glass Concrete/	Songinokhairkhan District, 20th Khoroo	120 m³/h (2013, 32,000 m³)	47°53′3.42″N / 106°46′0.32″E
23	Erdem Brothers LLC /EGE LLC/	Songinokhairkhan District, 20th Khoroo, Songino Road, No. 80	80 m³/h	47°53′19.73″N / 106°45′5.94″E
24	Tev Karkas LLC	Songinokhairkhan District, 20th Khoroo	90 m³/h	—
25	Gangar Invest LLC	Bayanzurkh District, 20th Khoroo	60 m³/h (2013, 19,000 m³)	—
26	Koetis LLC	Bayanzurkh District, 20th Khoroo, Tev Office, SBD, 1st Khoroo	45 m³/h	—
27	Premium Concret LLC	Bayanzurkh District, 16th Khoroo, Max Mall Center, Suite 501	7 plants – 6700 m³/day (2013, 136,000 m³)	—
28	Romkon LLC	Bayanzurkh District, 2nd Khoroo	150 m³/h, 1500 m³/day (2013, 27,000 m³)	—
29	Tedmnt LLC	Bayanzurkh District, Ulaanbaatar	180 m³/h (2013, 29,300 m³)	47°53′54.96″N / 106°50′8.01″E
30	Material Impex LLC	Bayanzurkh District, Ulaanbaatar	120 m³/h	47°53′54.96″N / 106°50′8.01″E
31	Ulaanbaatar BUUKH LLC	Bayanzurkh District, 20th Khoroo	180 m³/h (2013, 20,728 m³)	47°53′54.96″N / 106°50′8.01″E
32	Khurd LLC	Bayanzurkh District, 20th Khoroo, Kharkhorin 1st Street	45 m³/h	47°54′24.98″N / 106°50′1.96″E
33	Undur Buyant Holding LLC /UBN/	Bayanzurkh District, 20th Khoroo	80 m³/h (2013, 35,648 m³)	—
34	Oirchirm LLC	Bayanzurkh District, "Romkon Building" Office Center, Suite 604	250,000 m³/year	—
35	Naran Beton Zuurgam LLC	Bayanzurkh District, 18th Khoroo	60 m³/h (2013, 37,490 m³)	47°53′17.27″N / 106°45′4.59″E
36	Uranag LLC	Bayanzurkh District, 3rd Khoroo, Dund Gol Street, Ulaanbaatar 16020	120 m³/h, 1000 m³/day	47°53′15.50″N / 106°53′5.73″E

Current status of crushed stone and stone crushers

Natural stone materials are divided into road, building materials, bridge, underground and water engineering structures, architectural materials and facing slabs. During the production process, the composition, structure and properties of the rock do not change. Therefore, the primary basis of minerals and raw materials for building materials is rock. The natural state of minerals of a more or less constant composition is called rock. Mikhail Vasilyevich Lomonosov

laid down the basic principle of the classification of rock, and in modern times it was developed by Russian scientists F.R. Levinson-Lessing and A.P. Karpinsky. The classification of rock determines the structure and properties of rocks, taking into account the conditions in which they were formed.

- Orgimolite is a primary rock formed during the precipitation of magnesium.
- Sedimentary rocks are secondary

rocks formed by the erosion of primary rocks

- Metamorphic rocks are formed by the recrystallisation of primary and sedimentary rocks on the surface of the Earth due to the physical and chemical conditions.

"Tsee Tsee Impex" LLC stone crusher is located 5 km from the end of Khujirbulan, Ikh Bulag, Bayanzurkh district, UB city, 20th khoroo. The company was founded in 2008 and is engaged in stone crushing and gravel washing. In 2014, a new crushing and grading plant with a capacity of 200 tons of gravel per hour was put into operation at its licensed site in the Republic of Korea. The plant can produce gravel of all sizes, mainly 0-5, 5-10, 10-20, and 0-40 fractions. The above products fully meet the standards of Mongolia MNS 346/2000, MNS 0390/98, and MNS 0392/98. In 2016, the company expanded its operations and put into operation a new plant with a capacity of 200 tons of washed 0-5 gravel (known as SAND in the world) per hour and a wastewater treatment system. The plant is the first plant in Mongolia to produce washed 0-5/SAND/ and use water for water treatment. The plant will bring significant progress to the entire construction industry and will also improve the quality of the final product.

The stone crusher of “Narangol Sooru” LLC is located in the Narang River, Songino Khairkhan District, 1st Khoro, UB City, 1 km from the final asphalt road of the Narang River. Cement and improved dirt roads have been laid from the main road to the factory, providing transport conditions.

The stone crusher of “Yalguusan” LLC is located in Ulaan Khulut, Songino Khairkhan District, UB City, 1 km north of the new road to the Narangol River. It has not yet started operations and has a reserve of crushed stone materials.

“Tegsht Plant” LLC is located in Dashgai Mountain, Tuv aimag, Altanbulag soum, 40 km from UB city. Phone: 99106479, 89029998. It implements national and international standards in its operations, introduces environmentally friendly technologies, and contributes to the development of Mongolia, which has earned the trust of employees and investors. “Tegsht Plant” LLC is a material manufacturer and project contractor in the mining, construction, and highway sectors, supplying products and services such as aggregates, asphalt concrete, road construction, and maintenance to consumers and customers.

The sand and gravel quarry of “Mon-Els” LLC is located in the Hundred-Tree Sands of Nalaikh District (50 meters along the Baganuur road, 60 kilometres from UB) and has two sand

screening and stone crushing plants with a capacity of 120 tons/hour and 60 tons/hour. The plant has not yet started operating, and there is a small amount of sand reserves in the area.

Research on dams and foundation material deposits

Ulaanbaatar city is situated in a temperate zone of the world, within a vast mountainous area that is far from the ocean. It is under the influence of the negative Siberian cycle, resulting in a harsh continental climate characterised by frigid winters and hot summers, along with significant fluctuations in both daily and seasonal air temperatures. The annual air temperature is low, precipitation is minimal, snow cover is scarce, humidity is consistently low, there is no wind in winter, there is much wind in spring, and the duration of sunshine is long. The project area is geomorphologically classified as a strip area belonging to the Tuul River valley transport surface and the mountain foothill accumulation surface. The location and overview of alluvial deposits, sand, and crushed stone deposits used in the capital area are shown in Table 2.40.

Future demand and price study for cement concrete: Mongolia has a growing economy, and at its peak, it consumed 2.0 million tons of concrete per year. In recent years, approximately 1.5 million tons of concrete have been produced, with 50% made by 10 companies and the remaining 50% by other companies. Currently, there are more than 140 concrete plants in Mongolia with a capacity to produce 15,368 m3 of concrete per hour. Of these, there are more than 110 plants in Ulaanbaatar, the leading ones being “Suuri” LLC, “UB BUK”, “Beton Armatur” LLC, and “Erel Beton” LLC. There are about 30 factories in the region—these supply 90 per cent of the domestic market. Industry associations have estimated that by 2030, concrete demand will increase by 1.5-2.5 times, reaching 5.9-9.6 million cubic meters. The demand for housing supply, infrastructure projects, and social construction explains this. A study was conducted on the prices of concrete mix and the prices of the primary concrete materials, cement, sand, and aggregate.

In 2021-2022, cement prices were quite volatile due to the influence of many factors. For example, Monkhin Bayan Gal increased by 16%, Khotul by 24%, Mak by 26%, and Mon Cement by 28%. Let's summarise the reasons for the increase in cement prices in recent years:

- Transportation costs: The issue of importing goods across the border between China and Mongolia has not yet been completely resolved, which has led to a severalfold increase in transportation costs.

- Inflation: In February 2022 alone, inflation was 14.2%, and the increase in the price of all kinds of goods has increased the cost of cement production to a certain extent, just as the increase in the price of goods affects our purchasing power.

- Labour: According to the revised Labour Law, employees who used to work 28 days and rest for 14 days will now work 14 days and rest for 14 days. So, for the organisation to maintain its operations as before, it needs to hire more employees, which has significantly increased labour costs.

- The price of imported cement has also fluctuated due to factors such as customs duties and increased transportation costs.

The price of raw materials, imported materials, and products in the global market has increased, and availability has become scarce. Supply has decreased, and transportation has become difficult due to border restrictions and restrictions in China, a major importer. In other words, during the recent pandemic, the exchange rate increased by 54 per cent, energy tariffs by 92 per cent, coal prices by 130 per cent, railway tariffs by 26 per cent, and transportation prices by 900 per cent. This has become the main reason for the increase in domestic cement prices. Therefore, it is uncertain how this unstable and uncertain cement price situation will continue in the future. Consequently, it is necessary to study the possibilities of making the project challenging, which could put the price at risk, and to pay attention to the project's implementation.

Нийслэл In the capital city area, construction and road companies, including “Yalgvuts” LLC, “Bat Zam” LLC, “Tugs zam” LLC, Nutgiin zam LLC, Tegsh plant LLC, and UVT LLC, produce and supply asphalt concrete mixtures. These plants mainly use BND and BN bitumen. There are more than 10 asphalt concrete plants in the Ulaanbaatar capital area, of which about seven companies are actively operating. The construction of the Mongolian road sector has been rapidly increasing in recent years, and the need for the construction of paved and asphalt concrete roads is likely to increase further. A quantitative study reveals that over the past 10 years, approximately 2 million tons of bitumen have been imported at a cost of about $229 million, leading to the construction of about 5,655 km of paved roads. The primary raw material for asphalt concrete, the most expensive pavement in road construction, is bitumen, and our country imports it 100% from neighbouring and third countries. Mongolia's comprehensive national development policy considers roads as a key driver for supporting regional development.

This is because, in our country, which is rich in mineral resources, the construction of an oil refinery is slow and uncertain. To meet demand, it is necessary to increase the use of natural bitumen or economically efficient, improved bitumen that meets the technical requirements of road construction standards, thereby increasing the service life of the pavement. Additionally, the use of regionally appropriate additives should be improved.

ROAD CONSTRUCTION MATERIAL DEPOSITS SITE RESEARCH

There are abundant deposits of road and construction materials around Ulaanbaatar. In particular, the gravel and stone deposits currently in use at the beginning and end of the study area are fully supplying the newly constructed highway and bridge structures with materials. The planned highway's horizontal direction is designed to traverse the foothills, slopes, and summits of the Chingeltei Mountain Range, with some high points being excavated. The lower-upper Carboniferous sandstone and its weathering in this area are suitable for crushed stone

and gravel filling materials for highways, which has the advantage of saving costs. In other words, the stones and gravel from the excavations can be used in the concrete mixture for highway dams and bridges, and the asphalt mixture for highways. The following table shows the location information of the four currently used quarries and two new quarries.

The technological road routes are planned to transport road construction earth materials from the deposits to the construction site. The road construction contractor will plan the technological route connecting the production bases, such as asphalt concrete and cement concrete plants, stone crushers, crushed stone base plants, etc.

The following is a suggested route for temporary roads that can be used during road construction. According to the numbering shown in Figure II.2.6:

List of temporary roads

• 1 - To the west of the Ulaanbaatar-Darkhan highway toll collection point

• Repair of a temporary road around the mountain with a separate dirt road

• 2 - Use the dirt road between the residential

• quarters west of the Friendship Road at the mouth of Bayangol

• 3,4,5,6 - Use the roads of the West and East branches of Bayankhoshuu ger quarters

• 7,8,9,10 - Use the roads of the Hailaast, Doloon Khokhin, and Dar-Ekhin ger quarters

• 11 - The currently used paved road in Uliastai

• 12 - Improve the road between the ger quarters at the intersection with the Zuragat-Bayankhoshuu highway

• Repair of a temporary road

• 13 - Regulate traffic on the roads within the Unur quarter

• 14 - Use the road within the final quarter of Tolgoyt or from the west to the East

• one-way traffic management

• 15 - Detour traffic on Friendship Road, Orbit, and Takhilt paved roads

• 16 - Temporary road construction by connecting and improving existing roads in the Songgolong industrial and service area.

There are abundant deposits of road and building materials around Ulaanbaatar city. In particular, the currently used gravel and stone deposits at the beginning and end of the study area are fully supplying the materials for the newly constructed road and bridge structures.

CONCLUSION

When studying the road network of Ulaanbaatar, it was found that the city centre’s ring roads are overloaded, and traffic jams occur daily. The city’s population and the number of cars have increased sharply in recent years, which has led to insufficient road capacity, increased road damage and defects, and a risk of reduced traffic safety and quality.

The current roads, built in the 1980s, do not fully meet today’s needs in terms of traffic and technical standards. For example, factors such as road width, limited underpasses, and

bridge capacity hinder traffic flow and cause congestion. In line with the rapid growth of the city's economic development and the creation of new infrastructure areas, increasing traffic congestion at concentrated points creates a need to expand and modernise the capital's road network. It is also considered appropriate to study the possibility of introducing intelligent transportation systems (ITS) and modern traffic control tools.

According to the preliminary transport plan, the number of cars is expected to increase by 30-40 per cent in the next 10-15 years, indicating a tendency to strain the current road network further. Therefore, constructing a new bypass road is an optimal solution to reduce the load on the city centre, shorten travel times, and save fuel and time. In terms of the environment and social environment, the newly constructed bypass road is planned to have a positive impact on reducing noise and air pollution and improving travel safety. In addition, improving the accessibility of housing, businesses, and service areas along the road will yield significant benefits in terms of urban planning.

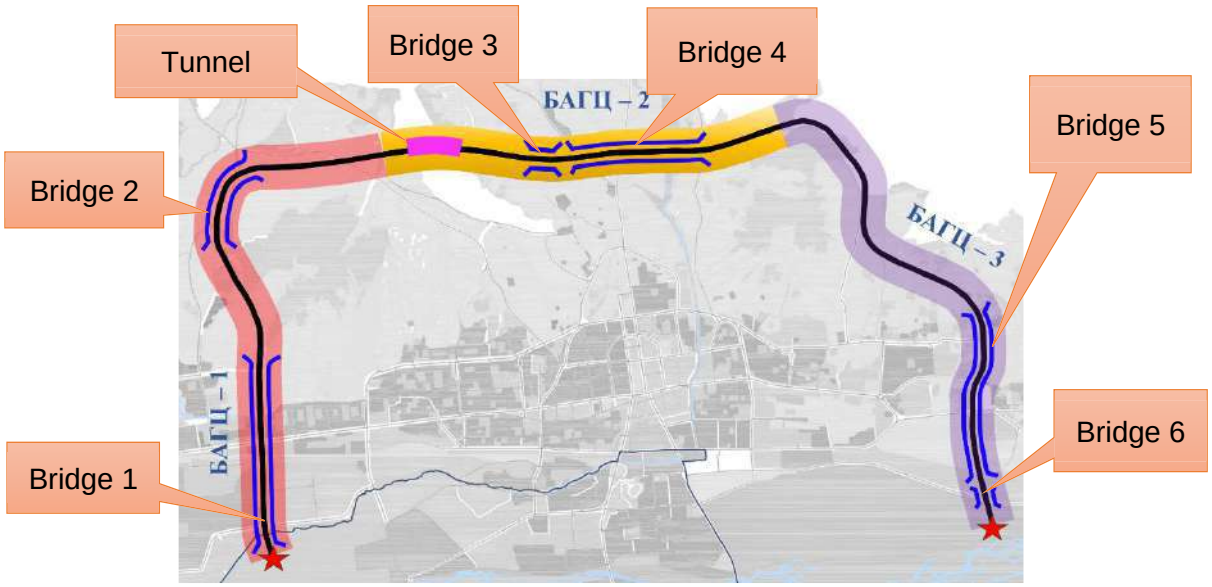
Therefore, the study proves that the newly constructed bypass road will significantly improve the road network of Ulaanbaatar, balance the load, ensure sustainable development of the city, and improve the quality of life of citizens.

CHAPTER 2. GEOGRAPHICAL STUDY OF PROPOSED OPTIONS

2.1. SITE SURVEY

2.1.1. Background

Figure 2. 1. Proposed option



Physical geography along the planned route: A large-scale topographic background map and a 1:500 scale topographic background map were developed within the project using aerial mapping. Location of the planned route: A strip map of the planned road route was created across the territories of 6 districts: HUD, BGD, SHD, CHD, SBD, and BZD. When calculating the percentage of administrative units passing through the planned route, HUD covers 47,932 ha, BGD - 61,813 ha, SHD - 348,572 ha, CHD - 727,888 ha, SBD - 59,965 ha, and BZD - 39,634 ha, with a total area of 1,225,839 ha, as shown in Figure 2.2.

The topographic background map was used to assess the slope and elevation of the land surface. These include:

Watershed. The river crosses the Dund and Tuul rivers in the territory of the HUD and BZD, and in this section, the width of the river and its branches is 465 m. In the territory of the SBD, it crosses the eastern Selbiin River, forming a river basin with many small tributaries, such as the Chingeltei and Tumur Khudgiin rivers, along its course, and is about 220 m wide. The river basin and protective strip are shown in Figure 2.3, with a buffer zone.

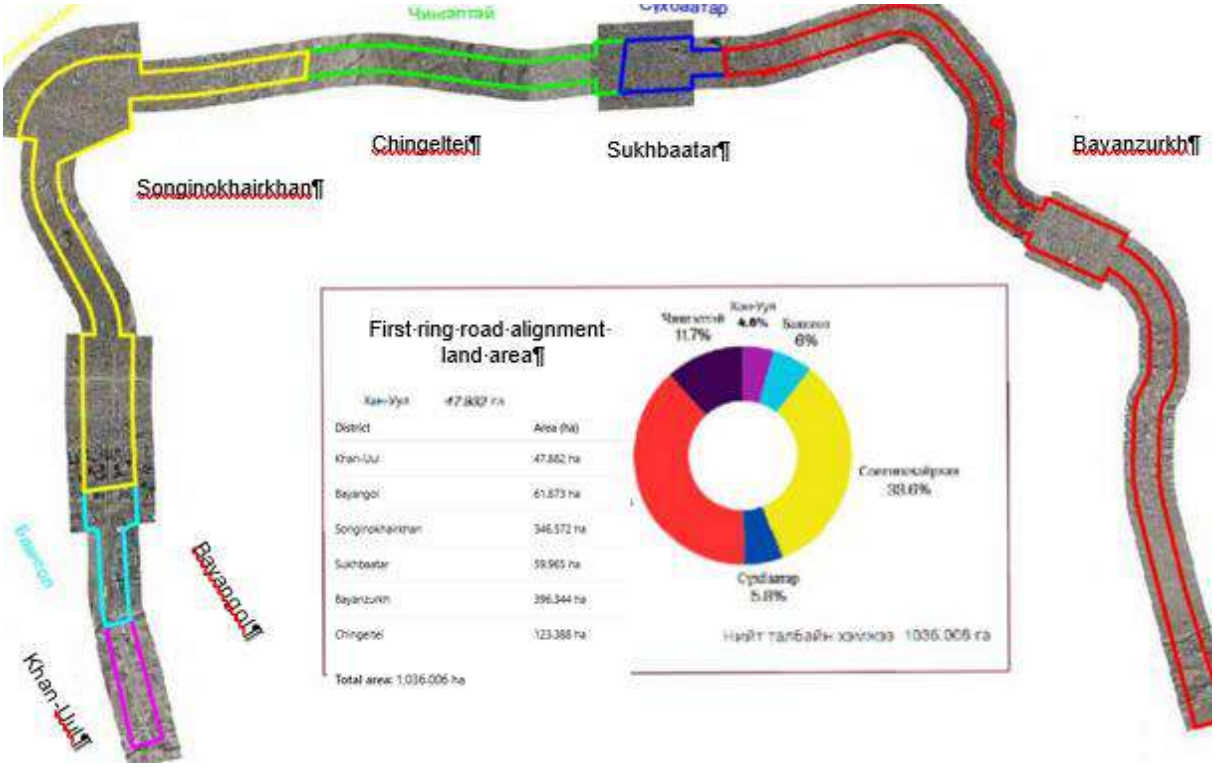


Figure 2. 2. Alignment location

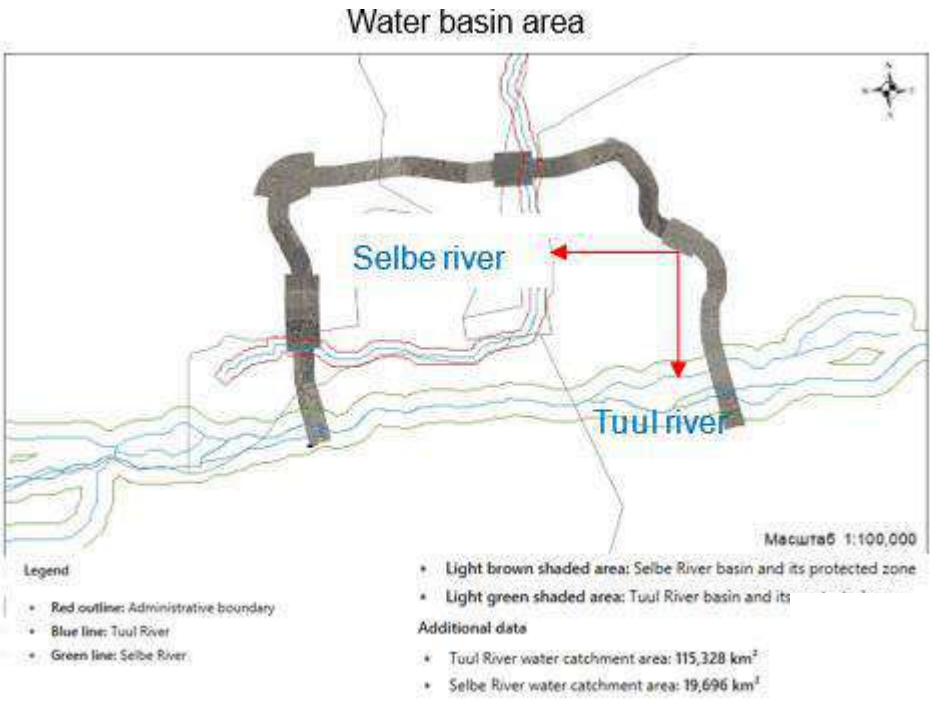


Figure 2. 3. Rivers pass through the planned alignment.

Flood channels through which the trestle passes:

1. Chingeltei Channel, length 2140 m, width 13 m.

2. Hailaast Channel. Length 2485 m, width 10 m, depth 1.6 m.

Land surface. Ulaanbaatar city is located in the Tuul River basin, on the slopes of the Asralt Khairkhan (2799 m), the peak of the Khentii Range, and on the slopes of Bogd Khan

Mountain (average height 1350 m). It is surrounded by Chingeltei Mountain (1949 m), Bayanzurkh Mountain (1834 m), Bogd Khan Mountain (2256 m), and Songinokhairkhan Mountain (1652 m). The built-up and construction area of the capital, Ulaanbaatar, is 1260-1350 m above sea level, and the entire land surface has a system of slopes from the northern mountains to the Tuul River basin. The absolute altitude of the site is 1200-1500 m. Within the framework of the basic research work of UBET-2040, the entire territory of the city was divided into suitable, limited suitable and unsuitable zones for assessment according to the "Comprehensive Assessment of Urban Development". The land along the planned route was classified into 12 levels according to its slope and assessed as follows: the 1st level is 1266.36-1301.59 m high, 1877700.43 sq. m, the 2nd level is 1301.59-1302.68 m high, 105198.04 sq. m, etc., as shown in Figure 2.4 and Table 2.1.

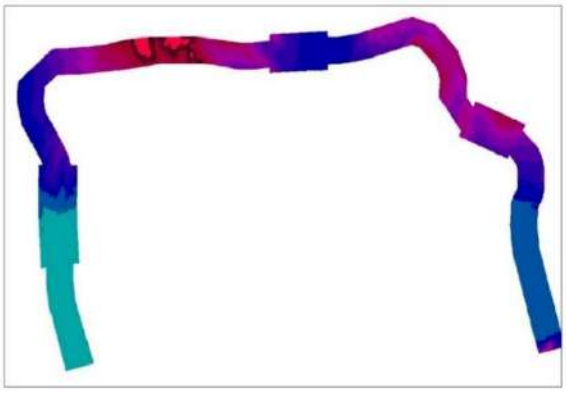


Figure 2. 4. A classification of the elevation of the earth's surface

No.	Lowest Elevation (m)	Highest Elevation (m)	Area (m²)
1	1266.34	1301.59	1,877,700.43
2	1301.59	1302.68	1,051,198.04
3	1302.68	1303.39	162,002.02
4	1303.39	1304.03	2,287,278.48
5	1304.03	1305.65	171,652.89
6	1305.65	1312.31	3,826,474.95
7	1312.31	1324.20	13,934,658.0
8	1324.20	1335.88	1,939,465.08
9	1335.88	1352.22	2,222,142.20
10	1352.22	1377.88	1,186,689.29
11	1377.88	1400.01	1,232,152.57
12	1400.01	1537.12	2,312,503.66

Table 2. 1. The elevation of the ground surface along the route

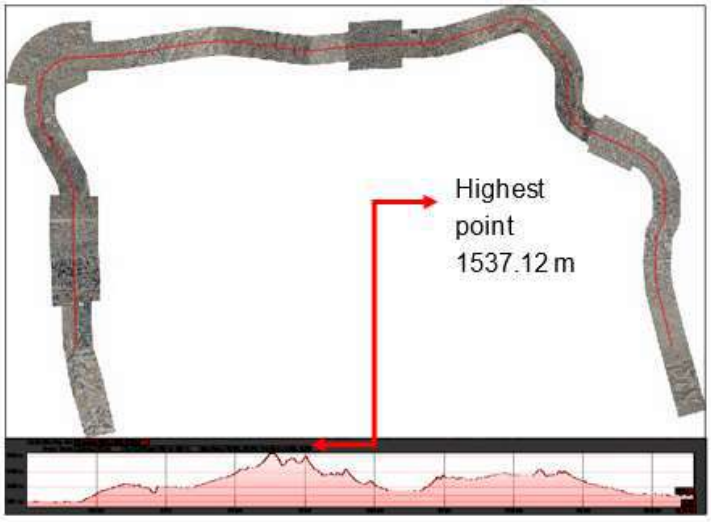


Figure 2. 5. Ground surface elevation along the axis of the alignment

Трассын Land slope and slope direction. The topographic map along the route is divided into 12 levels according to slope when analysed in the “AutoCAD Civil 3D” program. Level 1 shows the area with the lowest slope in yellow, and the area with the highest slope in maroon. Along the Tuul and Selbe river basins, the hill is 0-1.44%, 1318477.32 sq. m, and around the Chingeltey branch mountain, the slope is 34.53 -45.41%, covering an area of

146544.27 sq. m. Arrows show the slope direction, and the direction of the lowest slope is shown in red. The land slope is shown in Figure 2.6, the slope direction is shown in Figure 2.7, and Table 2.2.

Figure 2. 6. Land surface elevations and slope

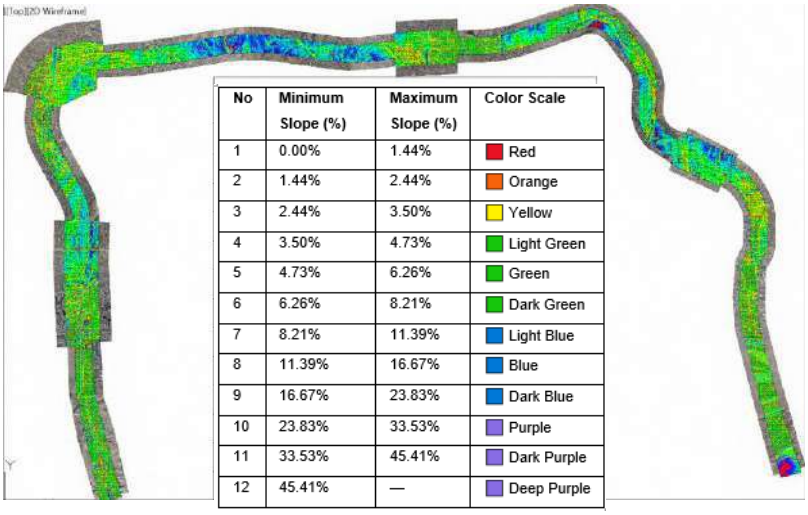


Figure 2. 7. Slope directions

No.	Minimum Slope (%)	Maximum Slope (%)	Area (m²)	Color Scale
1	0.00%	1.44%	1,318,477.32	Yellow
2	1.44%	2.44%	1,059,224.02	Orange
3	2.44%	3.50%	895,045.68	Red
4	3.50%	4.73%	944,446.68	Purple
5	4.73%	6.26%	1,034,147.10	Brown
6	6.26%	8.21%	1,092,182.41	Light Green
7	8.21%	11.36%	1,310,814.70	Dark Red
8	11.36%	16.67%	1,378,168.27	Dark Orange
9	16.67%	23.83%	933,849.35	Dark Purple
10	23.83%	33.53%	5,235,055.53	Dark Brown
11	33.53%	45.41%	1,912,757.59	Orange-Brown
12	45.41%	—	146,544.27	Bright Red

Table 2. 2. Table of land surface slopes

Image load and work level: Geodetic measurement, mapping measurement and processing along the planned route were divided into three work levels. These are: Work level 1 included areas with low traffic load, open areas, and ger districts; work level 2 included areas with moderate traffic density, dams, canals, and engineering networks with moderate load, or areas with buildings and ger districts. However, in work level 3, the industrial area of HUD and the high-rise building area of SHD 1 had high traffic density, high density of factories, buildings, and networks, which made it difficult to measure (the length of the flight path varied, multiple paths were used to take pictures, flight altitude changes, and satellite measurements had many path errors and reduced accuracy), and the map load was high. The work levels are shown in Figure 2.8.

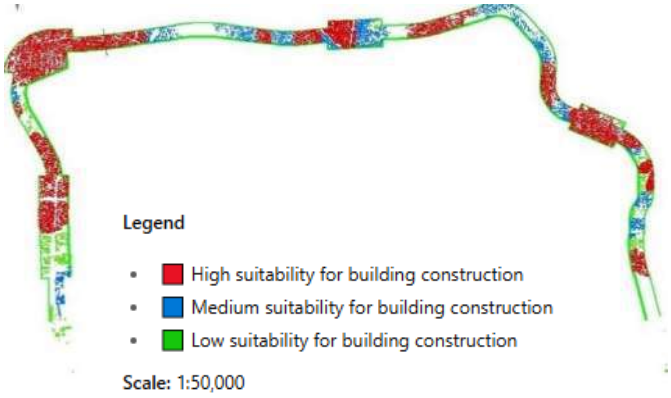


Figure 2. 8. Building areas

2.2. CONDITIONS OF ENGINEERING GEOLOGY

2.2.1. Engineering-geological and geotechnical conditions of the study area and physical-mechanical properties of soil and rocks

The boreholes drilled in the study area revealed brownish-yellow, moist to water-saturated sand-filled gravel of Pleistocene-Holocene age (Q1-2) under the technogenic overburden; brownish-yellow, hard to elastic sandy-filled gravel; brownish-yellow, hard-to-agile clay-containing gravel; brownish-yellow, soft-to-agile gravel-containing gravel; brownish-yellow, hard-to-agile clay-containing gravel; brownish-yellow, hard-to-agile clay-containing gravel; brownish-yellow, hard-to-agile clay-containing gravel; brownish-yellow, hard-to-agile clay-containing gravel; Eluvial-deluvial (edQ) origin, brownish-yellow, greenish-gray, complex flow indicators, weathered to sandy, clayey gravel; Brownish-brown, greenish-gray, complex flow indicators, weathered to sandy, clayey gravel; Carboniferous sandstone of the Altan-Ovoo Formation was found, which was classified into 10 engineering geological elements.

The geological formations along the route of the First Ring Road are distinguished by the rocks of the Gorkhi Formation (S4-D3gr), Altan-Ovoo Formation (C_1ao), Orgioch Formation (C1-2or), and Booroljut Formation (K1br) /Figure II-2/. During the drilling process, greenish-grey sandstone was discovered. These rocks are covered by greenish-grey, sandy-

conglomerate gravel of eluvial origin (eQ), sandstone weathered to clayey-conglomerate gravel, brownish-yellow, reddish-brown, gravelly clay, clayey-conglomerate gravel, brownish-yellow clayey-conglomerate gravel, sandy-conglomerate gravel, gravelly sandstone, gravelly clay, clayey soil, brownish-yellow, sandy-conglomerate gravel, and technogenic (tQ) overburden.

Ulaanbaatar city consists of the following three types of structural formations in terms of tectonics /Figure II-3/. Including:

- Paleozoic structure
- Mesozoic structure
- Cenozoic structure

From March 10 to 30, 2025, the construction engineering and exploration company “Land Test” LLC surveyed with archive number 25/096 based on the customer’s assignment and BNbD-11-03-21 for the preparation of a feasibility study for the road, and from May 15 to June 15, 2025, the construction engineering and geological research company “Terra Benefit” LLC carried out a survey with archive number 21-2025-06 for the feasibility study stage of bridge and tunnel structures. The study area has moderately complex engineering and geological conditions. It is situated across a surface with diverse geomorphological features, and engineering and geological processes are actively developing in the area. In the wells located in the Tuul River valley, groundwater was detected at a depth of 2.5-3.5 m. /As of 2025.03.11/ The groundwater of Ul is hydraulically connected to the Tuul River, and the groundwater level can rise by 1.0-1.5m seasonally. It is located across the 7-8 seismic zone.

Bridge-1. Tuul River I terrace transport and depositional surface,

Gur-2: Mountain foothills and depositional surface,

Tunnel: The Tunnel area is characterised by erosion and a sloping mountain foothills surface.

Gur-3: Mountain foothills and depositional surface,

Gur-4: Mountain foothills depositional surface and Selbe River I terrace transport and depositional surface,

Gur-5: Mountain foothills and depositional surface-Tuul River II terrace transport and depositional surface,

Gur-6: Tuul River I terrace transport and depositional surface. The highest point of the surface along the highway route is 1519.02, and the lowest point is 1271.099.

Groundwater in boreholes drilled as part of bridge and tunnel surveys along the route was found to be between 2.0 and 9.0m. The depth of seasonal freezing is 2.51-3.59m, and no perennial permafrost has been detected. It is located across a 7-8 magnitude seismic zone—байрлаж байна.

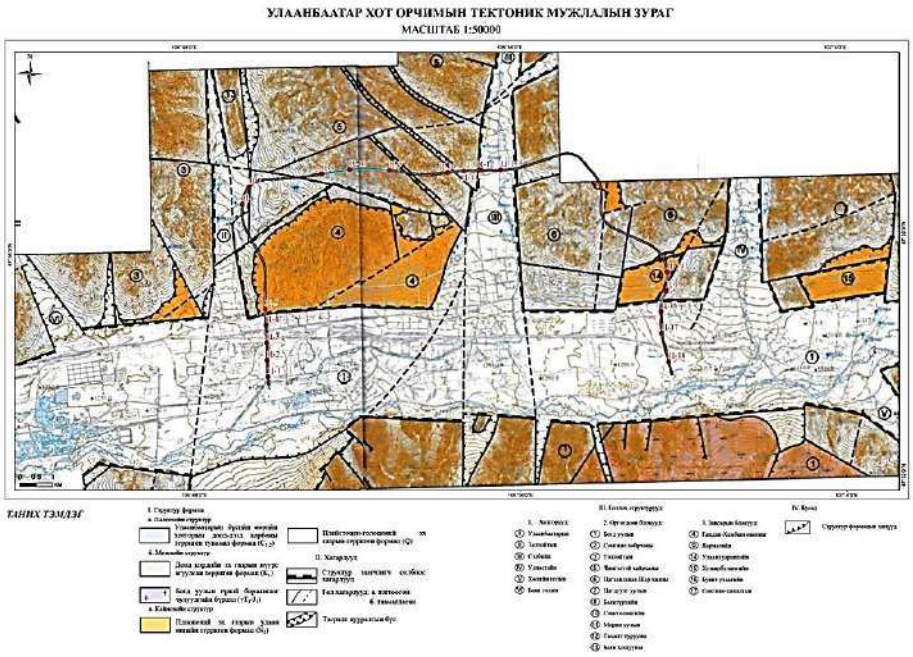


Figure 2. 9. Geology map of UB city

2.3. HYDROLOGY CONDITIONS

The peculiarity of the flow regime of rivers and streams in Mongolia is that after the spring yellow water flood ends, a short dry period continues in May-June, and then the summer rainy season begins. The Tuul River and its tributaries, along with some valleys, are flooded only by summer rains. The catchment areas of small rivers, ravines, and streams originating from the mountains around Ulaanbaatar are covered with gravel and gravel-to-clay sediments, and the region where Mongolia's river floods become severe is included.

Floods, one of the natural disasters, occur every year on the Tuul River and its tributaries. However, predicting when and how much flooding will happen is difficult and requires detailed research. Accurately calculating the maximum flow of a rainy flood is an essential basis for calculating economic and water structures and roads. Therefore, it is necessary to calculate the maximum flow on a scientific basis. The project area crosses the Tolgoit River Valley and the Selbe River Valley (Figure 2.10).

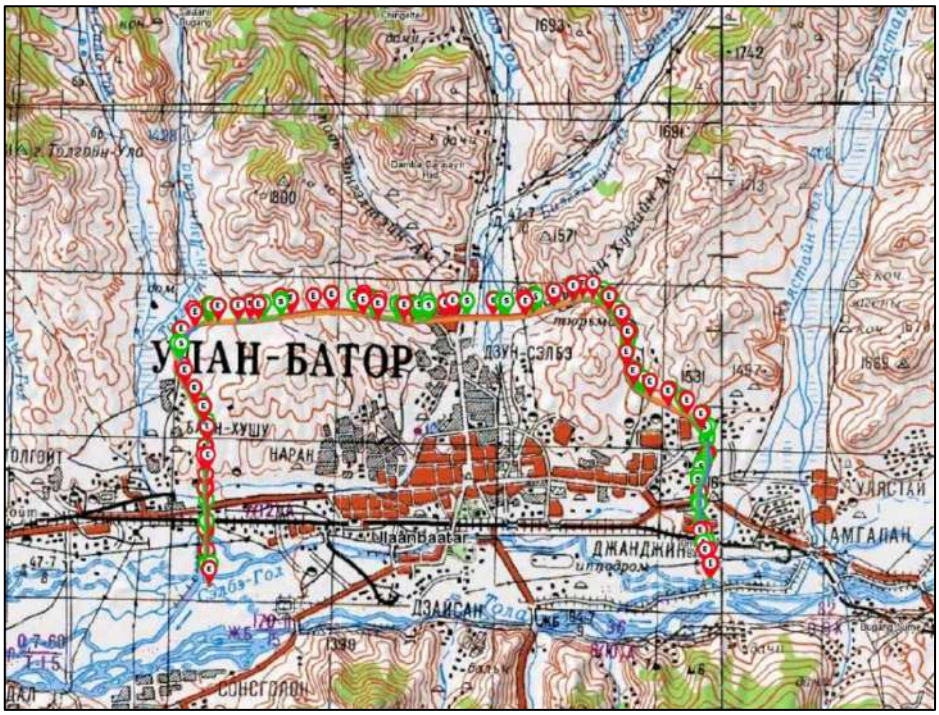


Figure 2. 10. Location of hydrological or surface water networks along the highway route

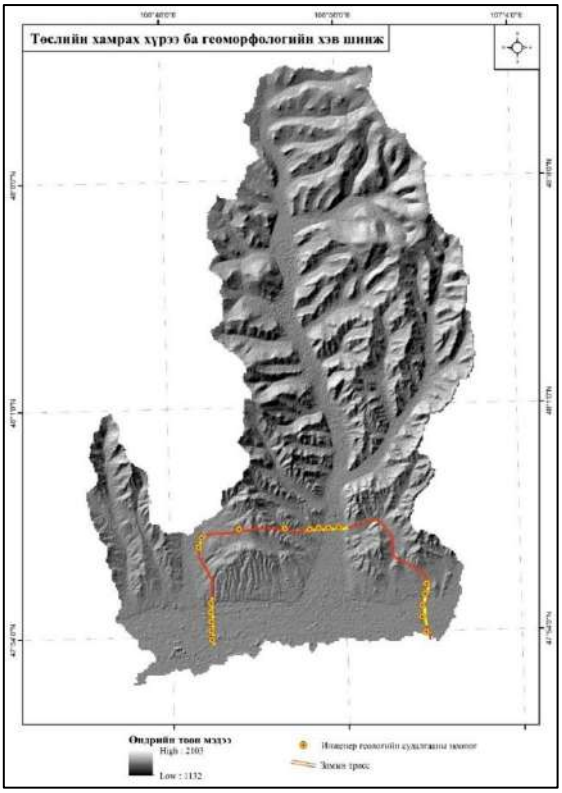


Figure 2. 11. Project scope and geomorphological characteristics

Locations affected by the project construction: 8 places along the highway route where surface water flow intersects or creates flood risk have been identified using satellite data and hydrological calculation software ArcSWAT. The above locations have been divided into 8 and are reflected in the flood calculation section according to the numbering.

Flood calculation: The table below shows the names of the above-mentioned eight flood risk mouths, the location of the intersection with the highway route, and the water catchment area.

Table 2. 3. Catchment area coordinations

No.	Name	Location	Catchment Area (ha)
0		Longitude	Latitude
1	End of Khan Material Valley	5311003	636282
2	Bayankhoshuu Valley 1	5312845	638524
3	Bayankhoshuu Valley 2	5312978	639385
4	Denjiin 1000 Valley	5312909	640871
5	Khailaast Valley	5312891	642422
6	Selbe River	5312959	643809
7	Tumur Khudag Valley	5313466	646031
8	Monel Valley	5311397	647181

2.4. HYDROGEOLOGY CONDITIONS

Seventeen engineering geological survey wells and one hydrogeological survey well were drilled along the project route. The following groundwater was detected in the engineering geological survey wells (Table 2.2). Depth of groundwater detection and occurrence (as of 2025/05/16-2025/05/27).

Table 2. 4. Groundwater is found, and the depth is fixed

Well No.	Well Location	Groundwater Level (m) – Encountered	Groundwater Level (m) – Stabilised
Ts-1	Bridge-1	6.8 m, 27.2 m	6.0 m
Ts-2	Bridge-1	6.2 m	4.5 m
Ts-3	Bridge-1	4.2 m	4.0 m
Ts-4	Bridge-1	2.2 m	2.2 m
Ts-6	Bridge-2	8.4 m	6.0 m
Ts-7	Bridge-2	6.0 m	6.0 m
Ts-10	Bridge-3	3.0 m	2.0 m
Ts-12	Bridge-4	4.4 m	2.0 m
Ts-13	Bridge-4	2.0 m	0.6 m
Ts-14	Bridge-5	2.8 m	2.8 m
Ts-16	Bridge-5	9.0 m	6.0 m
Ts-17	Bridge-5	9.0 m	6.0 m
Ts-18	Bridge-6	9.0 m	9.0 m

Based on the hydrogeological conditions along the route of the new ring road, the wells drilled in the western, eastern and northern parts of Ulaanbaatar city are relatively low in waterlogging and the possibility of relatively low groundwater problems during the construction phase of engineering structures, well No. Ts-1 was planned to conduct hydrogeological testing and drill to the bedrock (Table 2.2). The location is close to the water supply sources of Ulaanbaatar, which are of high yield, such as the former Meat Combine source to the west and the Factory source to the southeast. The location was selected based on the reports of hydrogeological works carried out in Ulaanbaatar, which have the highest infiltration coefficient and thick aquifers. The hydrogeological drilling work of the engineering geology department was carried out in a sequential system, and the following problems were solved. These include:

The depth structure of the geological section at the point where the hydrogeological drilling was carried out, its lithological-petrological composition, the geological formation, stratigraphic state, and the basic natural conditions of the hydrogeological environment of the study area are studied in detail, and the thickness of sediments and rocks of a certain age discovered during the drilling process are classified according to the unique characteristics of their lithological-petrological composition. The well was drilled using a Schramm drilling machine from the United States using the gas percussion method. The research well was designed to be equipped with a 219 mm chimney sweep series and executed as a single drainage well to meet the purpose of collecting information. It is necessary to determine in detail the main parameters of the hydrogeological calculation of the pore watershed in the thickness of the Quaternary alluvial loose sedimentary rocks with relatively high water content discovered during the hydrogeological study phase (seepage coefficient, water conductivity, and water level change transmission coefficient). By accurately determining the basic parameters of the hydrogeological calculation for the above relatively high water table area, the reduction in the level calculation at the end of the operational life of the hydrogeological well or the load-bearing capacity of water extraction operations will be the leading indicators for assessing.

Using the test-strain level measurements, well design, and hydrological data, the infiltration coefficients were calculated using the Aquifer Test Pro software and the following analytical equation by Dupuy.

$$K = \frac{0.73Q \cdot LgR_0/r_0}{(2H - S_0)S_0}$$

K – infiltration coefficient of the irrigated area, m/day.

Q - hydrogeological well parameters determined during sampling and test-strain yield, m3/day /2760 m3/day./

r0 – radius of the hydrogeological well, /0.1 m/

S0 - decrease in water level in the hydrogeological research well, m /1.72 m/

N – thickness of the aquifer detected in the hydrogeological well, m /2760 m/

R0 – transferred radius of the possible depletion effect in the hydrogeological well under the conditions of the steady regime of groundwater infiltration, m. According to reference data, it is taken as 150-200 m for groundwater with a free surface without tides. In our conditions, 150 m was chosen directly.

$$K = \frac{0.73*2760}{(2x22.85-1.72)\times 1.72} lg\frac{150}{0.1} = 84.59 \text{ м/хон.}$$

2.5. HISTORY, ETHNOLOGY, ARCHAEOLOGY, PALEONTOLOGY

In the 1890s, the Russian explorer N.M. Yadrintsev, who visited Urgaug, described, measured and recorded the stone monument. The legend about the settlement of Ulaanbaatar

in its current location in 1778 says that “geologists came across a stone in the valley of the Tuul River and were very impressed” and decided to build Urgaug. It is still known as the “Hollow of the Stone” and the “Altan Tevshiin Valley”.

Since then, the Finnish explorer Gustav Jon Ramstedt and the Polish traveller W. Kotwich, who explored Mongolia in the early 20th century, have observed and recorded various monuments in the Niislel area at that time. In 1925, at the invitation of the then Institute of Scripture, the Soviet archaeologist G.I. Borovka, who had participated in the famous Kozlov research class and excavated the tombs of Hunnu nobles in Noyon Mountain, traveled along the Tuul River from the vicinity of Ulaanbaatar city, conducting archaeological research, discovering and recording numerous monuments, and excavating and analyzing some types of monuments. As a result of his study, a published article4 and a later published photo album5 documented multiple monuments in the areas of Takhilt and Songino Khairkhan Uul, which are now part of the Songinokhairkhan district of Ulaanbaatar city, and mapped and published some monuments with photographs.

In 1948-1949, the “Mongolian-Soviet Historical and Ethnographic Research Department” under the leadership of S.V. Kiselev, a correspondent member of the USSR Academy of Sciences, and H. Perle, a scientist from the Institute of Sciences of the Mongolian People’s Republic, carried out a large-scale study of the ruins of the ancient capital of Mongolia, Kharkhorum. The research department established two branches aimed at studying stone tools, conducting ethnographic research, and creating original materials. The stone tools research department, headed by Soviet archaeologist A.P. Okladnikov, collected old stone tools from the Zaisan and Maahuur Tolgoi areas near Ulaanbaatar. They also discovered several new monuments related to other historical periods. One of them was a bronze sculpture with images of horses, birds, and humans found at the mouth of the Gachuurt River, about 30 km East of Ulaanbaatar. The Gachuurt coins were copied again in 1963 by archaeologist D. Navaan of the archeology department, organised by the State Central Museum, which allowed for the addition of many new elements to the previous copy. 7 Even today, researchers are still analysing and studying this monument and its preservation.

Article 7 of Chapter I of the “Constitution of Mongolia” states that “Historical and cultural monuments, scientific and intellectual heritage of the Mongolian people are under state protection.” Also, Chapter 5 of the Mongolian Law on the Protection of Cultural Heritage, which aims to regulate relations related to the search, registration, study, classification, evaluation, preservation, promotion, restoration, and inheritance of historical and cultural heritage, stipulates in Article 27.8 that “Before allocating land for economic activities such as the construction of urban settlements and buildings, the construction of new roads, the establishment of hydroelectric power plants, and the exploration and exploitation of minerals, a preliminary exploration and study shall be conducted by a paleontological, archaeological,

and ethnological professional research organization and a conclusion shall be drawn", and in Article 27.9, "The customer shall be responsible for the costs required for the preliminary exploration and the preservation of discovered historical and cultural monuments."

Archaeological exploration is a form of research based on its methodology to search for, discover, identify, study, and analyse ancient historical and cultural monuments. Archaeological exploration and research can be categorised into three types: detailed, simple, and simplified.

The route of the "First Ring Road" has passed through the territories of Bayanzurkh, Sukhbaatar, and Songino Khairkhan Khan-Uul districts of Ulaanbaatar city for many years, traversing residential areas and ger districts. The topsoil has been heavily eroded, making it impossible to find visible archaeological relics. The archaeological exploration and research were carried out using simple methods. The photographs were taken in general terms based on the road conditions and are attached to the conclusion. No archaeological relics were found in the area during the archaeological exploration and research.

Although no archaeological relics were found during the exploration and research work and there are no visible signs on the surface, it is not ruled out that there are historical and cultural relics preserved underground, so it is recommended to be cautious when conducting research and construction work, and to immediately notify a professional organization if historical and cultural relics or artifacts are found.

CHAPTER 3. ENGINEERING SOLUTION & PLANNING – ROAD

BACKGROUND

The starting point of this project, which will contribute significantly to improving the road network, expanding the city space and reducing traffic congestion and air pollution in Ulaanbaatar, will start from Energy Street and will pass through Enkhtaivan Avenue, Bayankhoshuu Sub-Centre, Doloon Khulna Road, and Police Academy Avenue to join the planned Tuul Highway.

The planned road route intersects with Tuul Highway to the south and New Ring Road No. 2 to the East and west. This planned road is an essential hub for public transport and freight traffic in the city. Residents of the New Town can travel quickly through the First Ring Road, which also passes through residential areas in the western and eastern parts of the city. This project is expected to have a positive impact on the traffic of the region's residents.

3.1. DESIGN WORK BASIS AND TECHNICAL REQUIREMENTS

3.1.1. Design basis

A. Document preparation basis

1) Work Task Book for New Ring Road (Ulaanbaatar) Feasibility Study Report and Conceptual Design Consulting Service Project;

2) Urban Development Plan of Ulaanbaatar until 2040;

3) Resolution No. 476 of the Mongolian government in 2022, on the construction of the "New Ring Road" in the capital city of Ulaanbaatar, the Mayor's Decree No. A/720 released on June 19, 2024;

4) Resolution No. 173 of the Mongolian government was released on April 9.

(2) Laws and regulations followed

1) Urban Development Law;

2) Highway Law;

3) Land Law;

4) Traffic Safety Law;

5) Law on Surveying and Mapping;

6) Environmental Law;

7) Environmental Impact Assessment Law;

8) Water Law;

9) Mineral Law on "Use of Widely Distributed Minerals";

10) Order No. 295 of the Mongolian Minister of Finance (December 25, 2018);

11) Traffic Regulations;

12) Energy Law; and

13) Other relevant laws and regulations in Mongolia.

B. Specifications & standards used

1) Highway Design ЗЗБНбД 22-004-2016;

2) Norms and Regulations for Urban and Village Planning and Construction БНбД 30-01-04;

3) Standard Prices for Road and Bridge Design and Survey Engineering;

4) Budget Specification for Highway and Road Facility Construction and Maintenance Engineering 33БНбД 81-013-2019;

5) Design of Highway Bridges and Pipes БНбД 32-02-12;

6) Highway and Railway Surveying Engineering БД 11-114-14;

7) Design and Construction Planning in Earthquake Zone Areas БНбД 22.01.21;

8) Standard Prices for Geodetic Surveying and Mapping Work БД 81-103-21;

9) Implementation of Drones, Aerial Photography and Mapping БД 11-124-21;

10) General Principles for Research on Construction Engineering БНбД 11-07-04 Part II Engineering Geodetic Surveying Work;

11) Geodetic Surveying Work БНбД 3.01.03-88;

12) Guidelines for Pedestrian and Disabled Road Planning MNS 5682:2022;

13) Relevant evaluation criteria;

14) Regulations for Mongolian Electrical Equipment and Facilities БД43-101-03;

15) Implementation Rules for Geological Survey of Linear Structures in Mongolia БД 11-107-10;

16) Rules for Electrical Facilities ЭХД-1-13-01-2006;

17) General Technical Requirements for Road and Street Lighting in Cities, Villages and Other Settlements MNS 6846: 2020;

18) Other relevant specification and standard documents; and

19) Relevant Chinese specification and standard documents.

3.1.2. Technical Standards

3.1.2.1 Road engineering

The road design is compiled based on the current Highway Design Specification 22-004-2016 and Urban and Rural Planning and Construction Specification BNbD32.01.24 in Mongolia. According to the requirements of the work task book, the proposed road belongs to the classification categories of Grade I and Grade II capital highways and main roads.

(1) Road grade

Table 3. 1. Classification of Road Grades

Condition of the traffic area	Road classification and rating	XYT	Abbreviation of the classification and road nomenclature	Description
The traffic sections are separated, and	**Main road** Classification - 1A, 1B	**A**	**ӨХу3** High-speed highway	Fully controlled, with no intersections at the same level, direct access from other roads is not allowed, and entry is only through intersections at different levels.

Condition of the traffic area	Road classification and rating	XYT	Abbreviation of the classification and road nomenclature	Description
the opposing flows have separate roads. Main road		**B**	**Xy3** Speed road	Access is limited, and generally, entry is through intersections at different levels. In some cases, an intersection at the same level may exist. Overall, this road is a transitional stage with the potential for further development into a high-speed highway.
	Main road Classification - 1B	**B, C**	**O3Г3 Multi-lane main road**	The road supports the movement of vehicles to a reasonable extent, with direct access from other roads allowed, but it is limited and semi-controlled..
	Collector road Classification - 2A, 2B	**C**	**Xp3** Collector road	The road allows for the passage of vehicles and access to local roads.

(2) Designed speed

Table 3. 2. Designed Speed Chart for Main Roads

Road classification	Road grade	Road nomenclature	Estimated road speed, km/h		
			Flat terrain	Hilly terrain	Mountainous terrain
Main road	**1A**	High-speed highway	130	120	110
	1B	Expressway	120	110	100
	1C	Main road, with marked lane	100-110	90-100	80
	1D	Main road, without a marked lane	80-100	60-70	50
Collector road	**2A**	Rural and urban collector roads	70-80	60	50
	2B	Special-purpose collector roads	60	50	30

According to the requirements of the specifications and work task book, the road grade for this project is classified as Grade I main road. Given the terrain's mix of hills and mountains, and the route's passage through densely built urban areas, the design aims to enhance connectivity with the existing road network. This approach utilises a "differentiated speed limit + intelligent control" strategy. For the two lanes on the inner side of the main road, a designed speed of 100 km/h is adopted. For the outer lane of the main road, a designed speed of 80 km/h is adopted to ensure safe transition to the auxiliary lane for traffic conversion. For the outer auxiliary lane, its primary function is to connect the traffic of surrounding land and the current road network, and a designed speed of 40 km/h is adopted.

For the tunnel section, considering the poor visibility conditions inside the tunnel, the limited tolerance space for drivers and the suppressing environment inside the tunnel, drivers may feel nervous or their perception of speed may be distorted. High-speed driving is prone to scratching or colliding with the side walls. Meanwhile, a higher designed speed will require an increase in the profile size of the tunnel, and the investment in the tunnel will increase by about 10%. The Permanent International Association of Road Congresses (PIARC) believes that the tunnel designed speed for the vast majority of countries is reduced by 10-20 km/h compared with regular road sections, which is beneficial for the economy and safety. Therefore, this design adopts a designed speed of 80 km/h for the tunnel section.

(3) When designing roads, select the traffic calculation speed and geometric fundamental indicators for road planning based on the following table:

Table 3. 3. Minimum Parameters for Plan and Longitudinal Sections

Classification		Unit	Main road	
			Grade-I main road	
Calculation speed		Km/h	100	80
Minimum radius of a horizontal curve		M	450	250
Maximum longitudinal slope (hill)		%	6	7
Minimum radius of a convex curve		M	6000	
Minimum radius of a concave curve		M	1500	
Minimum visible distance	Stopping sight distance	M	200	140
	Overtaking sight distance	M	680	560

In mountainous areas or extremely harsh natural climate conditions, as well as in road facilities undergoing large-scale maintenance, when it is necessary to preserve roads leading to buildings, it is allowed to increase the slope along the main road by 1% and increase the slope along other roads by 2%.

(4) The number of lanes on multi-lane roads is to be determined based on traffic flow prediction research and combined with traffic service levels.

Table 3. 4. Basic Dimensions of a Cross Section

Classification	Unit	Main street	
		Class 1 road	Class 2 road
Number of lanes on the road		4-8	2-6
The width of one lane of the road	M	3.75	3.50
Width of the pedestrian path	M	4.5	3
Standard shoulder width	M	0.75-2.0 (left), 2.4-3.0 (right)	
Width of the shoulder adjacent to the additional traffic lane	M	0.5 (left), 1.5 (right)	
Auxiliary lane width	M	4.5	
Nonmotorway width	M	2.5m	
Sidewalk width	M	3.5-4.5	
Width of a median strip	M	3	6
Lateral slope of a road surface	%	2	2

(5) After determining the radius of the road's horizontal curve, the corresponding designed superelevation is to be selected according to the provisions of Table 2.5 in the Highway Design Specification. For a designed speed of 100 km/h, the minimum circular curve radius for the superelevation is set to 450 m. The minimum circular curve radius for this project is 450 m, which meets the requirements of the designed speed of 100 km/h for the main road.

Table 3. 5. Minimum Radius of a Horizontal Curve for a Main Road

Estimated speed, km/h	Pavement and tire contact coefficient	Minimum radius of the curve applicable to the superelevation, m			
		Maximum superelevation, %			
		4	6	8	10
100	0.12	490	440	400	360
80	0.14	280	250	230	200

(6) When the radius of the curve shown in the base map is less than 1,000 m, each driving lane is to be widened towards the inside of the curve.

Table 3. 6. Widened Dimensions of Each Driving Lane on Small Radius Curves

Radius (m)	Widening amount (meter)				
	Length of an ordinary trailer vehicle				
	≤7 m	7-12	13-20	20-24	≥24
1000			0.4	0.4	0.5
850			0.4	0.5	0.6
700		0.4	0.5	0.6	0.7
600	0.4	0.4	0.5	0.7	0.8
500	0.4	0.4	0.6	0.8	1.0
400	0.6	0.5	0.9	1.2	1.5
300	0.8	0.6	1.2	1.5	2.2
200	1.0	0.8	1.5	1.8	3.0

(7) The widened section gradually changes proportionally from the starting point of the transition curve, the maximum widening is located at the midpoint of the curve, and the transition is completed at the endpoint of the curve.

Table 3. 7. Superelevation Transition Length at a Conventional Turning Point

Length, m	Estimated speed, km/h	e, %						
		0.02	0.03	0.04	0.05	0.06	0.07	0.08
	80	39	39	52	65	91	91	104
	100	39	52	65	78	104	117	130

(8) The design of the base course and various elements along the line and cross-section should be coordinated and adapted to the surrounding surface morphology. Continuous and excessively long straight sections are prohibited in longitudinal design, and the limit of their maximum length is not to exceed the values specified in the table below.

Table 3. 8. Maximum Length of a Straight Section on a Longitudinal Section

Vertical curve radius (m)	Algebraic difference of slope (%)						
	20	30	40	50	60	80	100
	Maximum length of the straight section on the longitudinal section (m)						
Multi-lane road							
4000	150	100	50	0	0	0	
8000	36	250	200	170	140	110	

Vertical curve radius (m)	Algebraic difference of slope (%)						
	20	30	40	50	60	80	100
	Maximum length of the straight section on the longitudinal section (m)						
12000	680	500	400	350	250	200	
20000			850	700	600	550	
25000					900	800	

(9) Values used for the leading technical indicators of the road

Table 3. 9. Values Used for Technical Indicators of Roads

No.	Item	Unit	Standard value	Used value	Remark
1	Road grade	/	Grade-I main road		
2	Designed speed	km/h	60-110	100 (partial 80)	Main road
		km/h	/	40	Side road
3	Road width	м	/	45~60	
4	Number of lanes	ш	4/6	Main road 4-6, Side road 2-4	
5	Driving lane width	м		3.5/3.75	
6	Maximum straight line length	м	2000	1255	
7	Minimum radius of a circular curve	м	250	450	
8	Maximum longitudinal slope	%	6-5	4	Main road
		%	7	6.65	Side road
9	Minimum longitudinal slope	%	0.35	0.38	
10	Minimum slope length	м	/	240	
11	Maximum superelevation	%	6	4.8	
12	Minimum clearance	м	Ordinary road 4.9 Railway 7.06	Ordinary road section 4.9 Railway section 8.4	

(10) Values Used for Technical Indicators of an Interchange

Table 3. 10. Values Used for Technical Indicators of Interchanges

No.	Ramp type	Designed speed (km/h)	Minimum radius (m)	Maximum longitudinal slope (%)	
				Bridge section	Roadbed section
1	Loop ramp	40	55	4	7
2	Directional and semi-directional ramps	60	130	4	6

(11) Pavement type: Asphalt concrete pavement

(12) Standard axle load of pavement design: BZZ-100 kN

(13) Designed lifespan of a pavement structure: 20 years

(14) Seismic requirements: The designed road is located in an area with a basic seismic intensity of 8 degrees and a peak ground acceleration of 0.20 g.

(15) Forecast period of a traffic volume: 20 years

3.2. ROAD ENGINEERING

3.2.1. Road Route Design

3.2.1.1 Design principle

(1) The design principles for the design plan of this project are as follows:

1) Safety and reliability

① Seismic and flood control standards: It is designed with a seismic fortification of 7 degrees, and the bridge foundation design takes into account the erosion depth of a once-in-a-century flood.

② Slope stability: The mountainous section adopts a graded slope + support of an anchor cable frame beam, while the soft foundation section in the plain area is equipped with a loading berm.

③ Traffic safety facilities: Anti-collision guardrails, intelligent lighting, and fog warning systems are arranged throughout the entire road section.

2) Sustainability and low carbon

① Green material application: The use of local stones and recyclable asphalt concrete is prioritised to reduce transportation carbon emissions.

② Stormwater resource utilisation: Water is collected through permeable pavements and reservoirs for greening irrigation along the route.

③ Biodiversity conservation: Animal migration channels (such as soil covering and greening above culverts) are set up to avoid fragmentation of an ecological corridor.

3) Economic efficiency and feasibility

① Earthwork balance optimisation: The excavation of stonework in the northern section of the tunnel is used for roadbed filling in the southern section, reducing the cost of earth disposal and excavation.

② Staged construction strategy: The construction of the main channel is prioritised to ensure the connectivity of the line. For those that are interconnected with the planned road, they can be constructed synchronously as per the construction plan of the planned road.

③ Minimisation of land acquisition and demolition: Avoid densely populated residential areas and use wasteland or current road corridors for routing.

4) Elasticity and adaptability

① Climate Resilience Design: A cold-resistant asphalt and frost-resistant roadbed structure for extreme low temperatures (-40°C) is used.

② Reservation of expansion space: An interchange is reserved with ramp interfaces to adapt to future urban expansion or the need for new expressways.

③ Dynamic adjustment mechanism: Based on the geological exploration results in the construction period, the bridge span or tunnel support scheme is dynamically optimised.

5) Social and cultural coordination

① Integration of ethnic characteristics: Bridge guardrails and sound barriers are

integrated with traditional Mongolian patterns to highlight regional culture.

②Transparency of public participation: The route plan is publicised, and opinions are solicited from communities along the route to reduce social conflicts.

3.2.1.2 Design Ideas

(1) Overall design ideas

1) Under the guidance of the overall plan of Ulaanbaatar City, full considerations are given to the urban development status, ecological environment protection and social environment, and the road alignment scheme is optimised.

2) According to the geological and material characteristics of this project, the analysis of roadbed filling materials and foundation earth properties is strengthened, roadbed schemes are reasonably selected, and systematic design of roadbed cross section, filling treatment and protective drainage is achieved.

3) For pavement design, under the premise of meeting the traffic volume and usage requirements, the principles of adapting to local conditions, selecting materials reasonably, facilitating construction, facilitating maintenance and saving investment are followed. The pavement structure scheme is designed with priority given to the use of locally experienced and mature structural forms in Ulaanbaatar City.

4) Based on the predicted traffic volume and analysis of traffic capacity, taking into account both engineering and social benefits, while meeting transportation needs, and based on the standards of existing and ongoing projects in Ulaanbaatar city, the construction content and scale of the engineering are optimised.

5) The applicability of the scheme, engineering economy, structural safety, aesthetic appearance and progressiveness of technology are taken into comprehensive considerations, and the bridge scheme design, construction technology and method are optimized.

6) Based on the overall plan of Ulaanbaatar City and the actual situations, the pipeline layout of this project is optimised from the short term to the long term, and the feasibility and necessity of constructing comprehensive pipe galleries in some sections are analysed in depth.

7) Adaptation is carried out to local conditions, with ecological greening as the primary focus. The characteristics of Ulaanbaatar city are highlighted, the safety requirements and visual experience of driving are fully considered, the rational allocation of plants and diversity of tree species are optimised, and a high-standard urban road greening landscape system is established.

(2) Specific design ideas

1) Priority given to transportation functions

① Priority for fast passage: Semi-enclosed urban main road standards are adopted, level crossings are reduced, and interchanges and separated interchanges are set up to ensure the continuous traffic capacity of the main line.

② An expressway system + a side road system is adopted, the functions of fast passage and serving the surrounding areas along the route are realised simultaneously, and viaducts and ground side roads in urban sections are used to reduce land occupation.

③ Multi-level connection: A "circular + radial" road network structure is formed with current roads, the proposed Tuul Expressway, and the urban sub-centre (Bayankhoshuu), and long-term expansion interfaces are reserved.

2) Adaptive design to natural conditions

① Terrain matching alignment: The northern mountainous area adopts a combination of tunnels and viaducts to reduce ecological damage caused by mountain excavation; and as the current road network density in the urban built-up areas of the east and west sections is high, elevated and ground auxiliary lanes are used to reduce demolition and effectively eliminate interference with the current roads, thus achieving the effect of fast passage.

② Geological risk avoidance: For problems such as frozen soil and alluvial soft foundation, composite foundation treatment techniques (such as crushed stone piles and geogrids) and frost resistant roadbed structures are adopted.

③ Hydrological disaster prevention and control: In case of crossing the Selenga River and its tributaries, large-span bridges are used to avoid compressing the river channel; and ecologically protective slope and seepage blind ditches are set up to reduce the erosion of the roadbed by runoff.

3) Ecological and urban integration

① Minimisation of ecological disturbance: Sensitive ecological areas (such as wetlands and forests) are avoided, low-noise roads and ecological sound barriers are used, and the habitats of organisms along the line are protected.

② Urban spatial stitching: Through three-dimensional greening and landscape node design (such as a landscape platform of a flyover bridge), the Bayankhoshuu sub-centre is connected with the main urban area, promoting regional coordinated development.

4) Cost control across the full life cycle

① Prefabricated assembly construction: Prefabricated components are used on bridges, retaining walls and the like to shorten the construction period and reduce environmental impact.

② Smart operation and maintenance reservation: Traffic monitoring and structural health monitoring systems are integrated to reserve interfaces for future intelligent transportation management.

3.2.1.3 General layout scheme

(1)Principle of plane design

1) The route position is to comply with the requirements of the Urban Plan of Ulaanbaatar City until 2040.

2) The horizontal alignment is straight, continuous, and smooth, adapted to the terrain and

features, and coordinated with the surrounding environment.

3) Efforts are to be made to avoid immovable cultural relics, water sources, and nature reserves as much as possible.

4) The basic requirements of driving mechanics and the visual and psychological requirements are met.

5) The balance and coherence of the horizontal alignment are ensured.

6) Factors of land development along the route are fully considered.

7) Entrances, exits and overhead crossing nodes are set up reasonably.

(2) Study process

According to the work task, the object of the study has been changed from the small ring road to the large ring road. The small ring road is located in the core area and belongs to the traffic protection zone. The focus is on traffic improvement. Currently, the implementation of the small ring road has a significant impact on traffic and is too difficult to implement; from the perspective of urban planning and transportation improvement, building a large ring road first cannot only effectively divert traffic, but also reconstruct the urban layout, guide the city to develop outward, and alleviate overcrowding in the city center. After the completion of the large ring road, the necessity of constructing the small ring road will be studied as required.

The road survey involved in this project was initially planned using a 1:10 million scale map and Google Earth and EI software. The selection of the road line position corridor was completed from February 15 to April 20, 2025, and the terrain survey and scheme design along the proposed road were carried out within the line position corridor. A total of 4 route schemes were proposed successively, and three comparative schemes were made for the recommended plane line position schemes based on different maximum longitudinal slopes. The route selection is based on the long-term and medium-term development planning framework of the project coverage area. Following the requirements of the New Ring Road Construction Plan of Ulaanbaatar City, it aims to build a continuous traffic flow around Ulaanbaatar City, reduces the traffic load of main roads, connects the city's subcenters, disperses the pressure on the core area, and comprehensively considers the transportation demands of the capital and residents, natural landscape characteristics, current situations of residential areas, infrastructure layout, etc. Finally, the planning schemes for each route direction are selected for route comparison and selection.

(3) Evaluation of project start and end points

Requirements for the project location, route and coverage based on work task book: The project passes through TETS-4 Road, Enkhtaivan Avenue - Tolgoit, Ard Ayush Road, Bayankhoshuu Intersection, 10th residential area in Songinokhairkhan District, Denj Myanga Terminal, Hailaast Street, Doloon Buudal/Station No. 7, West Altan Ulgii Street, Da-Kushee Street, Khilchin Street, Police Academy Avenue and Dunjingarav Street.

Project start point selection: The start point of the project, to some extent, determines the north-south line position of the first ring road in Ulaanbaatar. If it is too close to the west side, it will not effectively alleviate traffic congestion. If it is too close to the east side, it will pass through densely built areas with a large amount of demolition. It is essential to choose a location with minimal demolition and a moderate distance from the city centre. Regarding the selection of the start point of the New Ring Road, the project team conducted multiple on-site surveys. It combined them with urban road network planning for demonstration and analysis. Finally, they chose point 1: the intersection of the current new road and the TETS-4 road. To the south, it can seamlessly connect with the Tuul Expressway and build a rapid transportation system.

Considering that most of the vehicles connecting the Tuul Expressway interchange with the start point of this project are fast passing vehicles, and the current TETS-4 traffic is already saturated, if intersection signals control the start point, it will inevitably form a long queue at the intersection, which is contrary to the original design intention of this project and cannot effectively improve the congestion situation in Ulaanbaatar. Therefore, this design prioritises ensuring fast passing as its first element and considers using a separate interchange to cross the current TETS-4 road. The ground auxiliary lane intersects with it at the same level, ensuring both fast traffic and meeting normal traffic demand.

Figure 3. 1. Schematic Diagram for Selecting the Start Point Position of the Project

Figure 3. 2. Current Status of the Project Start Point

Project endpoint selection: The first choice for the endpoint of the New Ring Road is to connect with the proposed Tuul Expressway, forming a circular rapid transportation system together with the Tuul Expressway. Point 1 avoids the end point of the water source protection area and connects to the Tuul Expressway through a single-horn interchange, and its location is suitable; point 2 is located closer to the central urban area and theoretically has a better effect on alleviating traffic. However, due to the need to pass through national parks and water conservation areas, as well as the densely built north of the railway, lots of demolitions are required, and the implementation conditions are not currently available. Therefore, point 2 will not be considered this time. Point 3 can altogether avoid the water source protection area, but it is too close to the east side, and thus it has a weak effect on alleviating traffic congestion, which will weaken its service function. Through a comprehensive comparison of the above three points, the endpoint of this route scheme is determined as point 1.

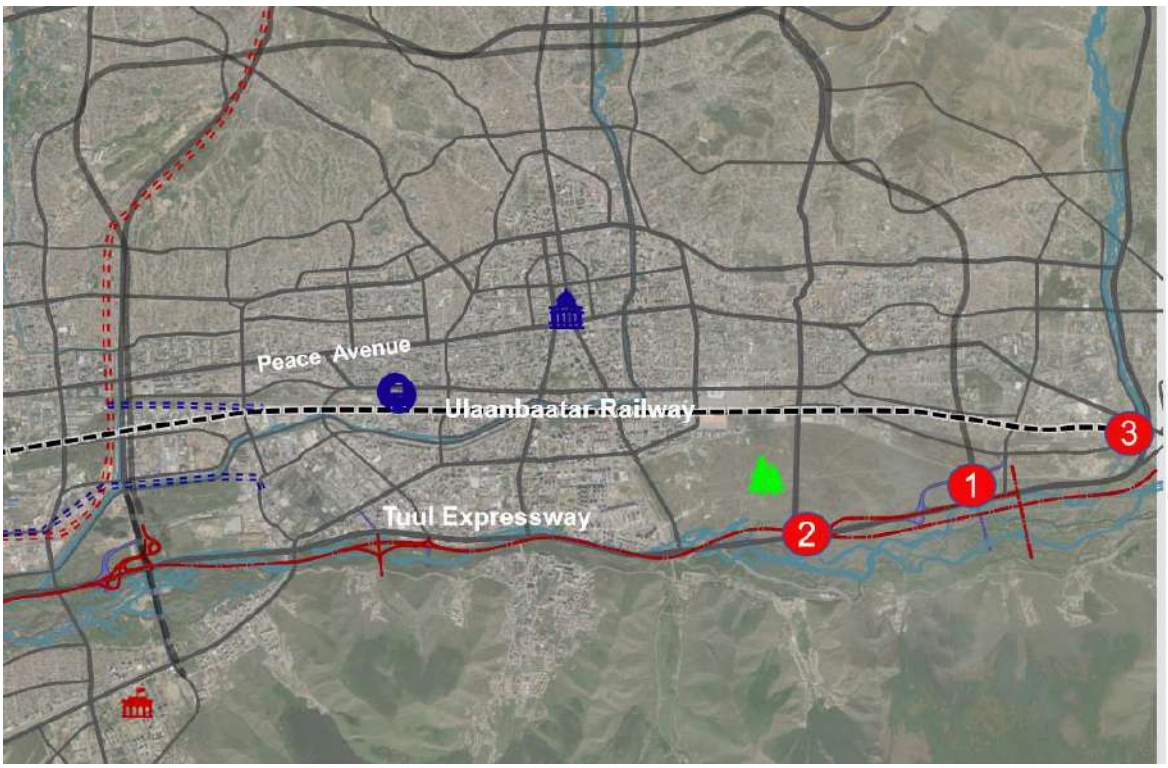


Figure 3. 3. Schematic Diagram of the Project End Point Position

(4) Comparison and selection of an overall route scheme

In terms of route scheme selection, we have made the following three route schemes based on the planning and functional layout for Ulaanbaatar City, traffic demand and the planning of the 2nd Ring Road and Tuul Expressway, combined with factors such as topography, land acquisition and demolition, and engineering construction costs:

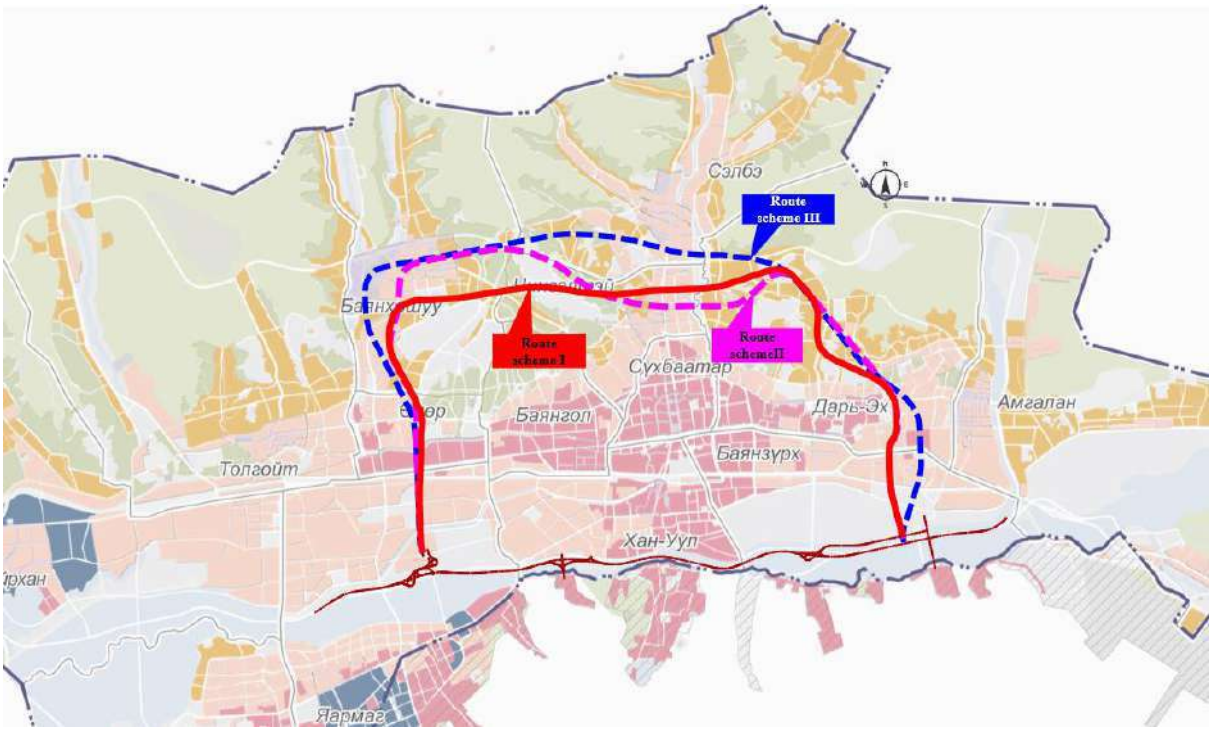


Figure 3. 4. Schematic Plan of the Route Corridor

1) Route scheme I

The starting point of the route for scheme I is connected to the single-horn interchange of Tuul Expressway, and a viaduct is set up along the high-voltage corridor and the east side of the riverbank to cross the railway and existing urban roads. The route extends northward to the northwest subcenter and then turns eastward to cross the Sambalkhundev mountain and the Selbe River, passing between the two subcenters. To the south, it avoids the current high-rise buildings and uses a viaduct to cross the current road. At the end point of the route, an interchange is set up to connect with the Tuul Expressway and the planned passage on the south side. Except for No. 2 and No. 3 bridges that span the Selbe River section and No. 5 bridge that does not have a ground side road system, all other sections of the viaduct adopt a combination of elevated main roads + ground side roads. The ground side road in the western section of the road level intersects with the existing railway, controlled by signals, and the main road crosses over using a viaduct; the east side of the route over-intersects with the railway using a bridge. Due to its proximity to the Tuul Expressway and low demand for surrounding land services, there is no ground system in place.

The route length of this scheme is 24.793 km, the length of the roadbed section is 13.679 km, the length of the bridge section is 9.034 km/5 pcs, the length of the tunnel section is 2.08 km, and the entire line is equipped with seven interchanges, 12 separated interchanges, three footbridges to be implemented in the short term, four footbridges planned for the long term, seven passages. Control factors mainly include the Tuul Expressway, railway, Peace Avenue, high-voltage iron tower, planning of the subcenter urban area, Sambalkhundev Mountain, Selbe River, and water source protection areas. This scheme aligns more closely with urban development planning, situated near the city centre, with strong traffic diversion functions, serving multiple urban subcenters, and connecting smoothly with planned or existing roads. Except for some sections involving the relocation of high-voltage lines, there are no vital building demolitions, avoiding water source protection areas, with minimal environmental impact and low implementation difficulty.

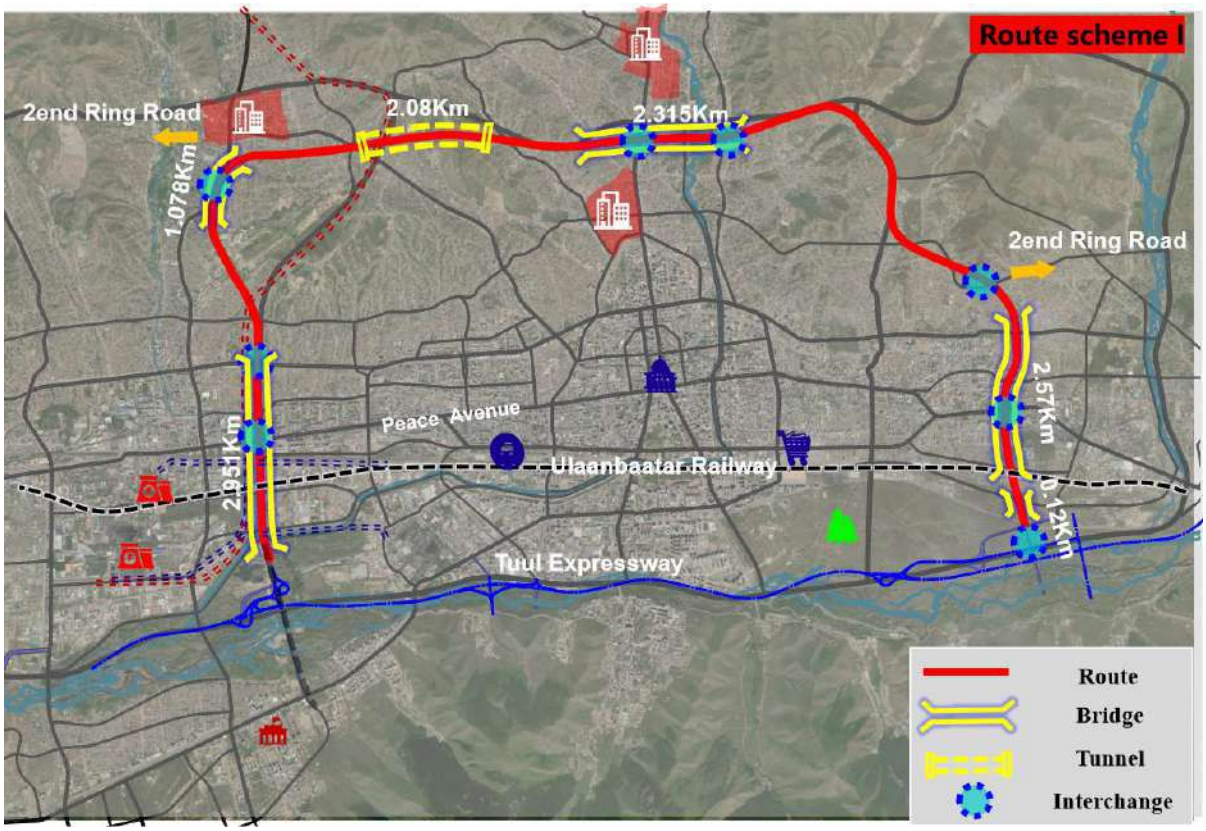


Figure 3. 5. Layout Plan of Scheme I

2) Route scheme II

The starting point of the route for scheme II is connected to the single-horn interchange of the Tuul Expressway. After an interchange is set, it crosses the railway and Peace Avenue in sequence to the north, and then turns northwest and runs along the east side of the riverbank in the subcenter. The route crosses the mountain through the Sambalkhundev Tunnel to the east, and then continues along the current road in the Selbe subcenter. After passing through Ulaanbaatar Prison, the route turns southwest and crosses Peace Avenue and the railway in sequence. The endpoint is connected to the Tuul Expressway (chainage No. K4+800) with an interchange.

The overall route length of this scheme is 25.800 km, the length of the roadbed section is 13.075 km, the length of the bridge section is 10.005 km/5 pcs, the length of the tunnel section is 2.72 km, and the entire line is equipped with seven interchanges, 12 separated interchanges, 4 footbridges to be implemented in the short term, 3 footbridges planned for the long term, seven passages. Control factors mainly include the Tuul Expressway, railway, Peace Avenue, high-voltage iron tower, planning of the subcenter urban area, the Selbe River, and water source protection areas. This scheme is located along the gentle terrain on the east side of the riverbank in the northwest region, reducing excavation and demolition, while reserving space for the development of the urban subcenter on the east side. In addition, current roads can be fully utilised, and the construction conditions are convenient. However, this scheme will interrupt the original road traffic during the construction period.

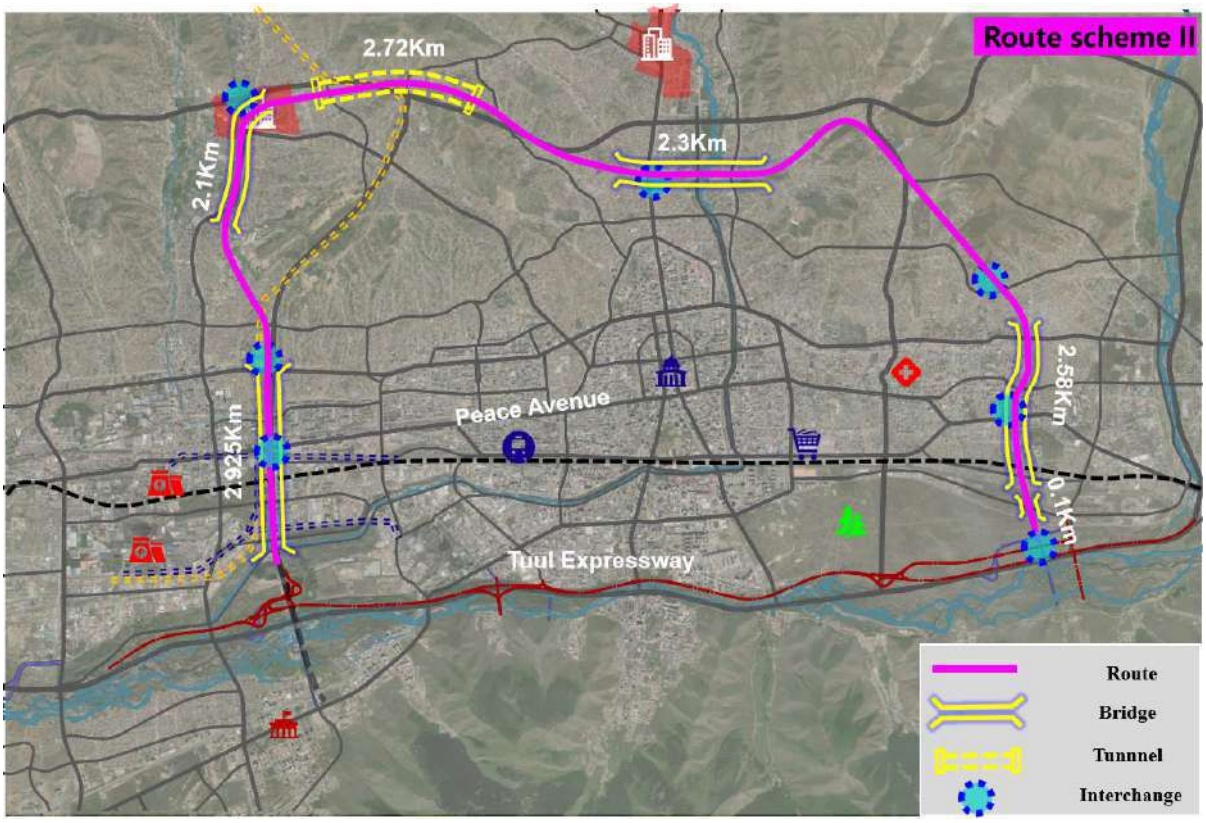


Figure 3. 6. Layout Plan of Scheme II

3) Route scheme III

The starting point of the route is located at the intersection of Energetics St and Үйлдвэрийн тойруу. The route extends northward along the high-voltage corridor and the west side of the river, with bridges set up. After crossing the Ulaanbaatar Railway, it continues northward and passes through the current Unur Horool St before heading northward for about 800 m. The bridge section ends with an interchange. After passing through the interchange, the route turns northwest and crosses the Mongolian yurt area. A bridge is set up to cross the Bayankhoshuu St before heading north, and an interchange is set up to connect with the planned expressway on the northwest side. Then the route turns east and passes through the north side of the Bayankhoshuu subcenter towards the east. A tunnel is set up to pass through the mountain range and continues eastward, and a bridge is set up to pass through the Selbe subcenter. An interchange is set up in the Selbe subcenter to connect with the subcenter road. After crossing the subcenter, the bridge continues eastward and connects with the tunnel to pass through the mountain range. After leaving the tunnel, the route turns southeast after running along the West Altan-ulgii Street for 1 km and continues. The route bypasses the northeast side of the Cemetery and enters the eastern Mongolian yurt area of the city after leaving the tunnel. After passing through a 1.5 km roadbed section, a bridge is set up to cross the east town and then move southwest to the end point interchange.

The total length of the route is 26.754 km, and the length of the roadbed section is 8.35 km. The entire line is equipped with seven bridges of 8.35 km, two tunnels of 4.71 km, seven

interchanges, 12 separated interchanges, four footbridges to be implemented in the short term, three footbridges planned for the long term, and eight underpasses.

The overall direction of this scheme is in line with the planned route, and on this basis, it expands to the west, north, and east sides of the city, maximizing the development space of Ulaanbaatar City; it connects two urban subcenters in the north, expands the route to avoid densely built urban areas, and thus minimizes demolition. However, the longest tunnel and bridge in this scheme have the most extended construction period and the highest difficulty, and the route is far away from the central urban area, has more traffic detours, has poor traffic diversion functions, and is close to the planned expressway on the east side, with redundant functions.

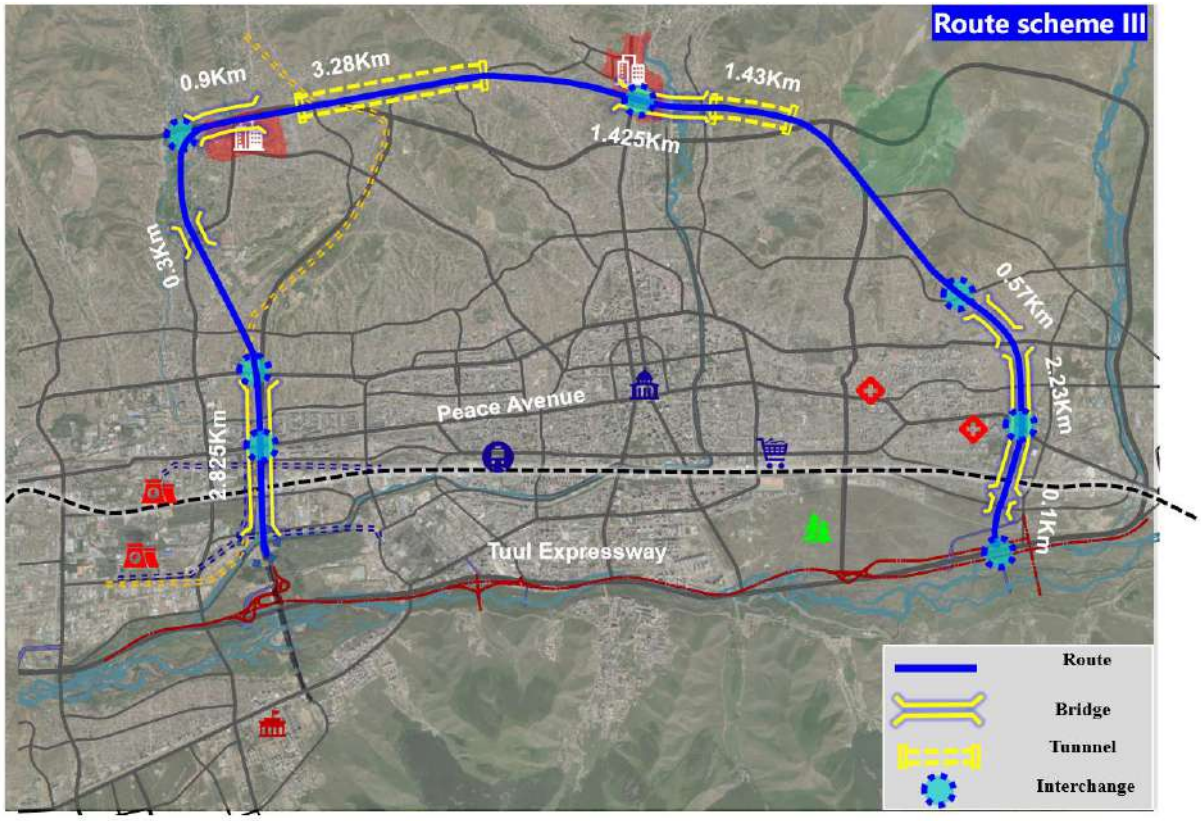


Figure 3. 7. Layout Plan of Scheme III

4) Research on the start point scheme of the route

Comparison of plan schemes for the start point section: The K0+000-K4+000 start section of the route is a difficult point in the design of this project's path. Previously, the design scheme considered relocating the towers of the 220 KV high-voltage transmission overhead lines No. 205, 206, and 208, and also proposed four relocation schemes, including power tunnels, to reduce the demolition of buildings on the east side.

Figure 3. 8. On-site Survey by the Power Department

On May 30, 2025, on-site research was conducted with technical personnel from the National Power Transmission Grid State-Owned Joint Stock Company on the relocation plan. According to the reply letter from the National Power Transmission Grid State Owned Joint Stock Company (02/603), "Due to the relocation of the transmission line involving the adjustment of land use for high-voltage protection zones, it may lead to disputes over land ownership". Given the scarcity of land on both sides of the line, Mongolia lacks relevant construction standards for power tunnels, and their application is not yet established. Consequently, relocating 220 KV power tunnels poses significant challenges. Based on the above reasons, we have adjusted the route within a range of 4 km from the start point, altogether avoiding 220 KV and adjusted the route to the east.

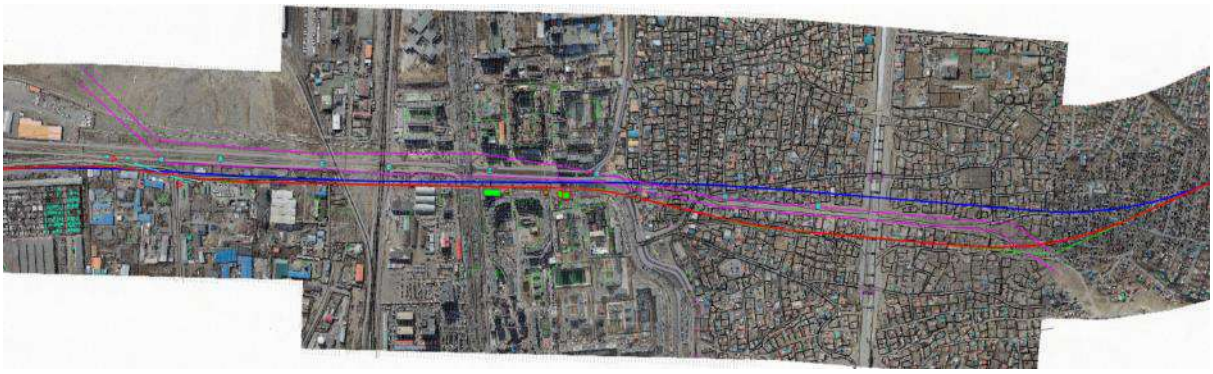


Figure 3. 9. Comparison of Plan Schemes for the Start Point Section

Table 3. 11. Coordinate Table of Intersection Points of the Route in Scheme I

Intersection number	Intersection stake number	Intersection coordinates		Value of the turning angle
		N (X)	E (Y)	
BP	-K0+100	5306133.867	636945.4944	
PI1	K0+067.915	5306294.404	636896.2647	11°17′58″(Y)
PI2	K0+743.890	5306967.785	636828.4698	9°59′11.3″(Y)

Intersection number	Intersection stake number	Intersection coordinates		Value of the turning angle
		N (X)	E (Y)	
PI3	K1+105.526	5307328.884	636855.2243	6°57′35.9″(Z)
PI4	K2+209.139	5308431.565	636802.7879	12°37′23″(Y)
PI5	K2+693.255	5308909.243	636886.1604	8°22′38.4″(Z)
PI6	K3+559.166	5309775.264	636909.1883	29°55′34.9″(Z)
PI7	K5+397.266	5311402.957	636028.9806	34°36′54.9″(Y)
PI8	K6+585.466	5312603.498	636159.657	80°33′31.9″(Y)
PI9	K8+001.811	5312694.749	637777.0626	5°39′23″(Z)
PI10	K10+084.699	5313016.552	639835.4701	16°29′16.6″(Y)
PI11	K11+910.225	5312774.109	641651.8961	14°00′03.7″(Z)
PI12	K13+090.330	5312905.875	642826.8921	5°00′49.1″(Y)
PI13	K14+643.068	5312943.411	644379.5114	16°27′45.2″(Z)
PI14	K16+566.505	5313534.455	646215.1731	67°56′17.1″(Y)
PI15	K17+823.367	5312493.844	647085.5479	43°39′40.8″(Y)
PI16	K18+936.326	5311347.26	647010.357	69°04′57.3″(Z)
PI17	K21+098.304	5310397.947	649077.2179	65°35′47″(Y)
PI18	K22+099.446	5309252.339	649071.9036	30°07′21.8″(Y)
PI19	K22+489.679	5308910.411	648871.3876	32°20′14.8″(Z)
PI20	K23+518.417	5307872.822	648906.6951	12°34′33.7″(Z)
EP	K24+793.006	5306636.805	649226.9251	

Table 3. 12. Coordinate Table of Intersection Points of the Route in Scheme II

Intersection number	Intersection stake number	Intersection coordinates		Value of the turning angle
		N (X)	E (Y)	
BP	K0+000	5306194.212	636926.3756	
PI1	K0+119.357	5306309.307	636894.7643	9°36′31.3″(Y)
PI1	K0+696.724	5306884.1	636836.8951	5°23′04″(Y)
PI2	K1+449.088	5307636.794	636832.105	2°59′02.6″(Z)
PI3	K2+561.688	5308747.612	636767.1086	4°20′30.9″(Y)
PI4	K3+812.184	5309998.137	636788.7891	29°24′27″(Z)
PI5	K5+452.163	5311451.135	636002.6891	45°47′24.7″(Y)
PI6	K6+416.062	5312406.765	636301.725	14°17′40.2″(Z)
PI7	K7+579.613	5313571.815	636364.4437	77°10′00.2″(Y)
PI8	K10+745.920	5314133.967	639635.3504	46°52′58.1″(Y)
PI9	K12+804.484	5312808.535	641385.9171	24°20′44.6″(Z)
PI10	K14+232.520	5312488.179	642797.6522	13°18′02.8″(Z)
PI11	K16+485.148	5312508.465	645052.3318	43°00′08.5″(Z)
PI12	K17+999.267	5313577.083	646177.717	93°02′54.7″(Y)
PI14	K22+217.199	5310179.707	649076.2055	40°44′06.4″(Y)
PI15	K23+106.501	5309252.232	649071.9031	30°07′49.9″(Y)
PI16	K23+496.637	5308910.411	648871.3876	32°20′42.9″(Z)
PI17	K24+525.380	5307872.818	648906.6952	12°34′32.7″(Z)
EP	K25+799.966	5306636.804	649226.9183	

Table 3. 13. Coordinate Table of Intersection Points of the Route in Scheme III

Intersection number	Intersection stake number	Intersection coordinates		Value of the turning angle
		N (X)	E (Y)	
BP	K0+000	5306194.212	636926.3756	
PI1	K0+119.113	5306309.06	636894.7892	9°37′43.1″(Y)
PI2	K0+696.726	5306884.1	636836.8951	5°23′09.9″(Y)
PI3	K1+448.680	5307636.385	636832.1289	3°11′53.1″(Z)
PI4	K3+450.103	5309634.089	636707.8069	23°29′00.3″(Z)
PI5	K6+065.744	5311974.197	635513.173	23°46′20.1″(Y)
PI6	K7+476.749	5313392.073	635432.1081	82°46′38.4″(Y)
PI7	K12+640.677	5314368.065	640700.6985	16°36′44.4″(Y)
PI8	K14+248.711	5314196.043	642305.7331	9°25′13.8″(Y)
PI9	K15+783.514	5313784.6	643785.5437	16°33′14.4″(Z)
PI10	K16+894.563	5313804.41	644902.5402	13°15′54.9″(Y)
PI11	K18+263.356	5313513.12	646244.236	39°18′44.4″(Y)
PI12	K21+455.974	5310976.858	648257.2259	13°33′38.8″(Z)
PI13	K23+243.378	5309875.007	649667.4935	50°17′32.4″(Y)

PI14	K24+823.767	5308221.357	649716.7725	19°09′48.3″(Y)
PI15	K26+464.259	5306650.908	649222.9226	33°16′22.3″(Z)
EP	K26+754.120	5306361.228	649304.9834	

Table 3. 14. Comparison Table of Technical Indicators for Schemes

No.	Indicator	Unit	Technical indicator of roads		
			Scheme -1	Scheme -2	Scheme -3
1	Climate zone	-	II B		
2	Road grade	-	Grade-I main road		
3	Designed speed	км/ц	100/80		
4	Road length	м	24,793	25,800	26,754
5	Number of turns	шир	19	17	15
6	Minimum radius of a curve	м	450	450	600
7	Maximum radius of a curve	м	6,500	10,000	10,000
8	Total length of a turning curve	м	12,685.052	13,378.777	11,605.641
9	Curve proportion	%	50.958	51.856	43.379
10	Minimum radius bulge of a vertical	м	4,000	5,000	3,000
11	Maximum radius of a convex vertical	м	60,000	25,000	40,000
12	Minimum radius of a concave vertical	м	3,000	6,000	2,000
13	Maximum radius of a concave vertical	м	60,000	28,000	25,000
14	Minimum value of slope inclination	%	0.35	0.34	0.47
15	Maximum value of slope inclination	%	4	4.52	3.98
16	Maximum slope length	м	1,910	2,460	2,570
17	Roadway width	м	3.75/3.5		
18	Number of lanes	ш	6		
19	Total number of lanes	ш			
20	Non-motorway width	м	2.5		
21	Sidewalk width	м	4.5		
22	Horizontal slope of pavement	%	2		
23	Coverage type	-	An advanced type of pavement structure		

Table 3. 15. Comparison Table of Economic Indicators

Scheme	Scheme I	Scheme II	Scheme III
I. Technical Feasibility			
Route length m	24793.006	25800.000	26754.120
Bridge length m	9034	10005	8350
Tunnel length m	2080	2720	4710
Roadbed length m	13679.006	13074.966	13694.12
Filling volume 10,000m^3	337.14	301.84	242.30
Excavated earthwork and stonework 10,000 m^3	420.43	438.93	341.13
Demand for a land acquisition area of 1,000 m^2	1653.935	1706.681	1901.406
Construction period (month)	23	28	30
II. Economic and financial feasibility			
Total investment cost USD (Billion)	0.919	0.979	1.131
Operation and maintenance cost USD (million)	5.40	5.76	6.41
III. Environmental and social impact			
Environmental impact	Minimum	General	Maximum

Traffic safety assessment	Good	bad	bad
IV. Evaluation	Good	Fair	bad

Table 3. 16. Investment Comparison Table of Route Comparison and Selection Schemes

Version	Version 1	Version 2	Version3
Length of the route (m)	24793.006	25800.0	26754.12
Road investment	456,498,067,433	475,039,216,292	492,604,619,872
Bridge investment	1,634,656,344,823	1,701,047,388,853	1,763,956,819,441
Tunnel investment	463,712,084,132	606,392,725,403	1,050,040,344,356
Network investment	176,376,940,000	183,540,674,818	190,327,411,398
Green space investment	25,497,826,822	26,533,447,861	27,514,568,375
Relocation of the network	16,227,343,503	16,227,343,503	16,227,343,503
Land acquisition	510,000,000,000	491,300,000,000	511,300,000,000
Total investment, MNT	3,282,968,606,712	3,500,080,796,729	4,051,971,106,944
Total investment, USD	918,569,840	979,317,514	1,133,735,620

Note: The road budget indicators for Scheme II and Scheme III are consistent with those for Scheme I.

Through comparative analysis of the three route corridor zones, it is found that all three route schemes meet the requirements of the specifications in terms of technical indicators. However, in terms of improving traffic congestion, the spatial layout of urban development, engineering investment scale, and implementation difficulty, after comparing the three schemes, it is recommended to adopt Scheme I for this engineering.

3.2.1.4 Selection of temporary road and construction road routes

The New Ring Road project is located in the urban area of Ulaanbaatar, with convenient transportation conditions in the surrounding area. The nearby material yards have convenient transportation to reach around the project area. After on-site investigation, the temporary roads and construction roads involved in this project are mainly temporary access roads that reach the construction site when the road roadbed is not yet constructed, and bridges and tunnels are being constructed, and a total of 11 construction roads are designed. The specific locations are shown in the following drawing.

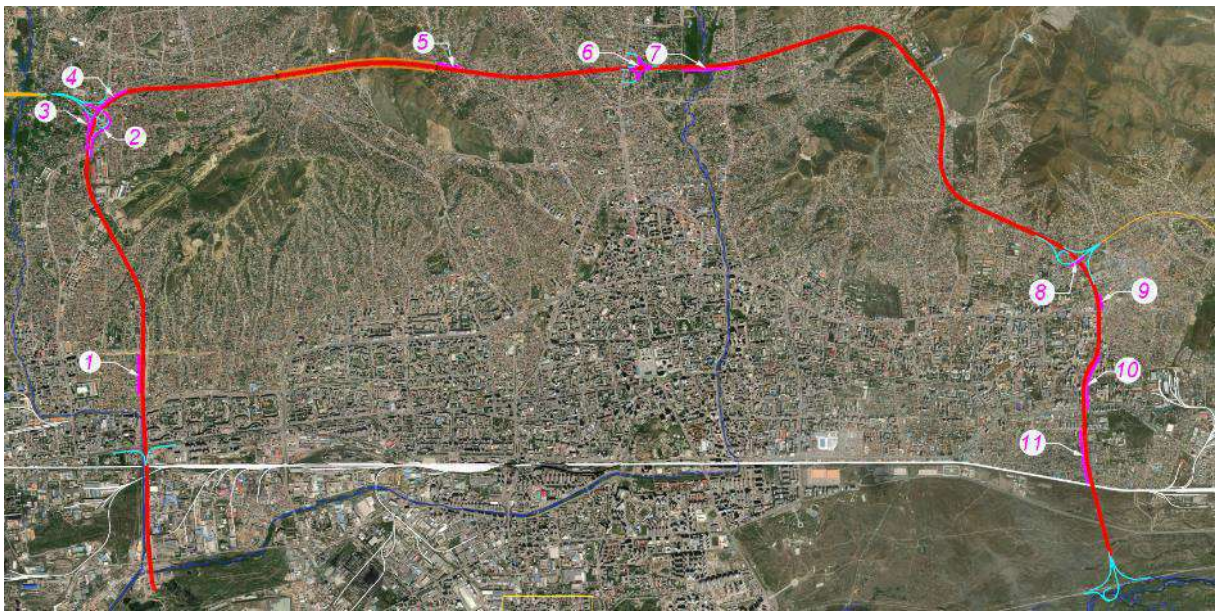


Figure 3. 10. Route Design of Construction Roads

According to the on-site construction operation situations, the numbering of the construction roads in Drawing 3.2.1-8 is explained:

Table 3. 17.Explanations for Conditions of Construction Roads

No.	Construction road No.	Explanations for setting of temporary roads
1	①	Connected to a current road during construction of No. 1 bridge
2	②	Connected to a current road during construction of the interchange between the New Ring Road and the west side of the Second Ring Road
3	③	Connected to a current road during construction of the interchange between the New Ring Road and the west side of the Second Ring Road
4	④	Connected to a current road during construction of the interchange between the New Ring Road and the west side of the Second Ring Road
5	⑤	Connected to a current road during construction of the east entrance of the tunnel on the New Ring Road
6	⑥	Connected to a current road during construction of interchange between the New Ring Road and the Doloon Buudal road and No. 3 bridge
7	⑦	Crossing the Selbe River during construction of No. 3 bridge
8	⑧	Connected to a current road during construction of the interchange between the New Ring Road and the east side of the Second Ring Road
9	⑨	Connected to a current road during the construction of No. 4 bridge
10	⑩	Connected to a current road during construction of No. 4 bridge
11	⑪	Connected to a current road during construction of No. 4 bridge

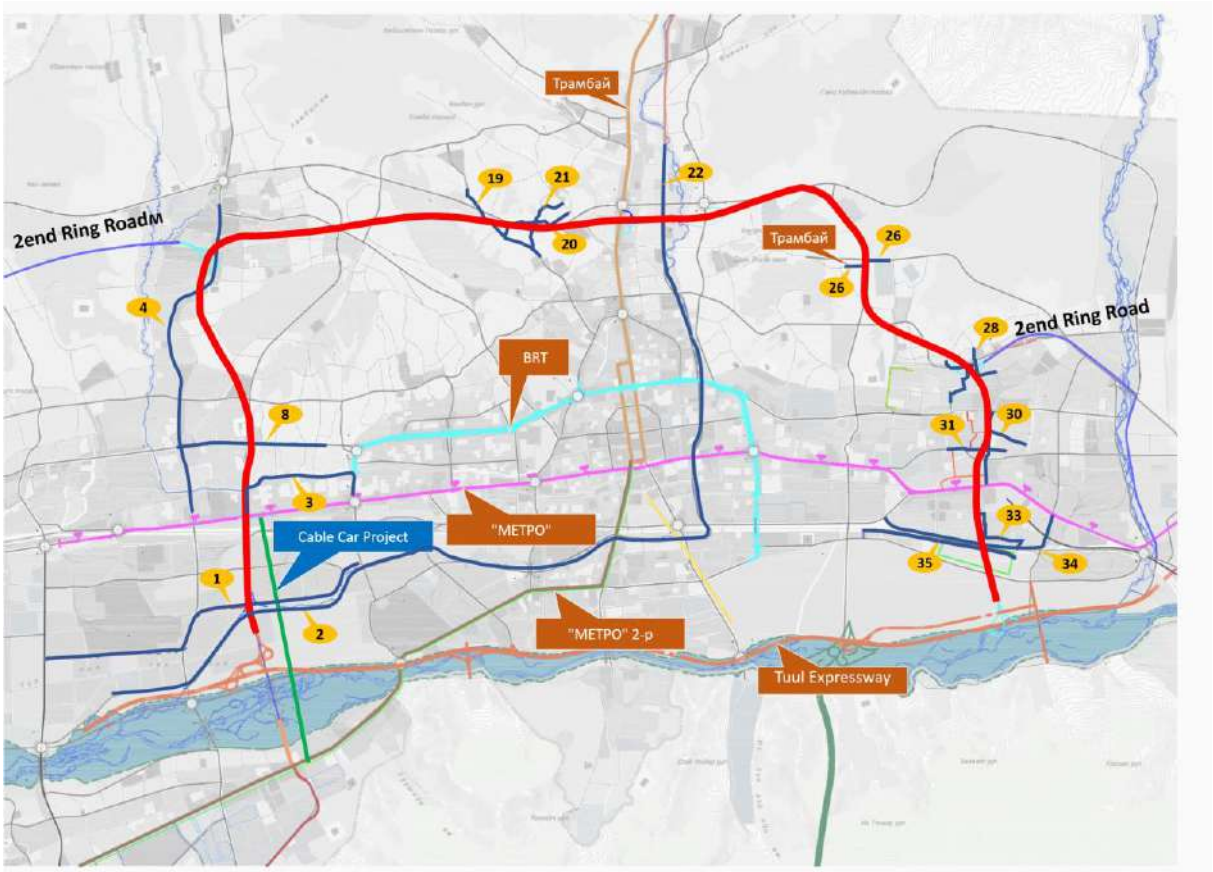


Figure 3. 11. Analysis of Relationship with Related Projects Along the Route

1:Main street: The power street is crossed by a bridge, and the auxiliary street is at the same level.

2:The intersection with the Selbe revitalization road is accessed via a junction， According to the planning scheme, the Selbe project crosses over the current road with a net height of approximately 5.8 m. To meet the increase in traffic volume, it is necessary to ensure that there are no signals along the entire route. Therefore, the Project needs to cross over the road of No. 4 Power Plant, and the net height between the designed road elevation and the Selbe project will be insufficient. Therefore, in the next stage of the Selbe project, the design elevation is to be lifted to meet the net height requirements under the bridge.

3:The route aligns with the Unur Housing Complex street.

4: The main street of the route crosses the Bayankhoshuu street with a bridge, and the auxiliary road is at the same level.

8: The main street of the route crosses the Ardy-Ayushi street with a bridge, and the auxiliary road is at the same level.

19: The main street of the route crosses the Denzhiny Myangan Pig Housing area and extends to the residential area with a bridge, and the auxiliary road is at the same level

20: The route aligns with the 16th street of the Bulgin, 12th district in Chingeltei.

21:The auxiliary road from the Denzhiny Myangan highway intersects with the Khailaast street at the same level.

22: The main street of the route crosses the Selbe revitalization road with a bridge, and the auxiliary road is at the same level.

26: The auxiliary road is at the same level with the 5th street of the Green Square in SBD, 13th district.

28: The route aligns with the Da Khuree street.

30: The route aligns with the intersection of Erdenetolgoi street from Khilchni street.

31: The main street of the route is aligned at the same level with the Ulaan Khuaran road.

33: The route aligns with the road around the Jangjin Club residential area.

34: The main street of the route crosses the Narni street to Amgalan with a bridge, and the auxiliary road is at the same level.

35: The intersection at the Dunjinggarav junction aligns with the Amgalan direction road, with entry via the planned junctions.

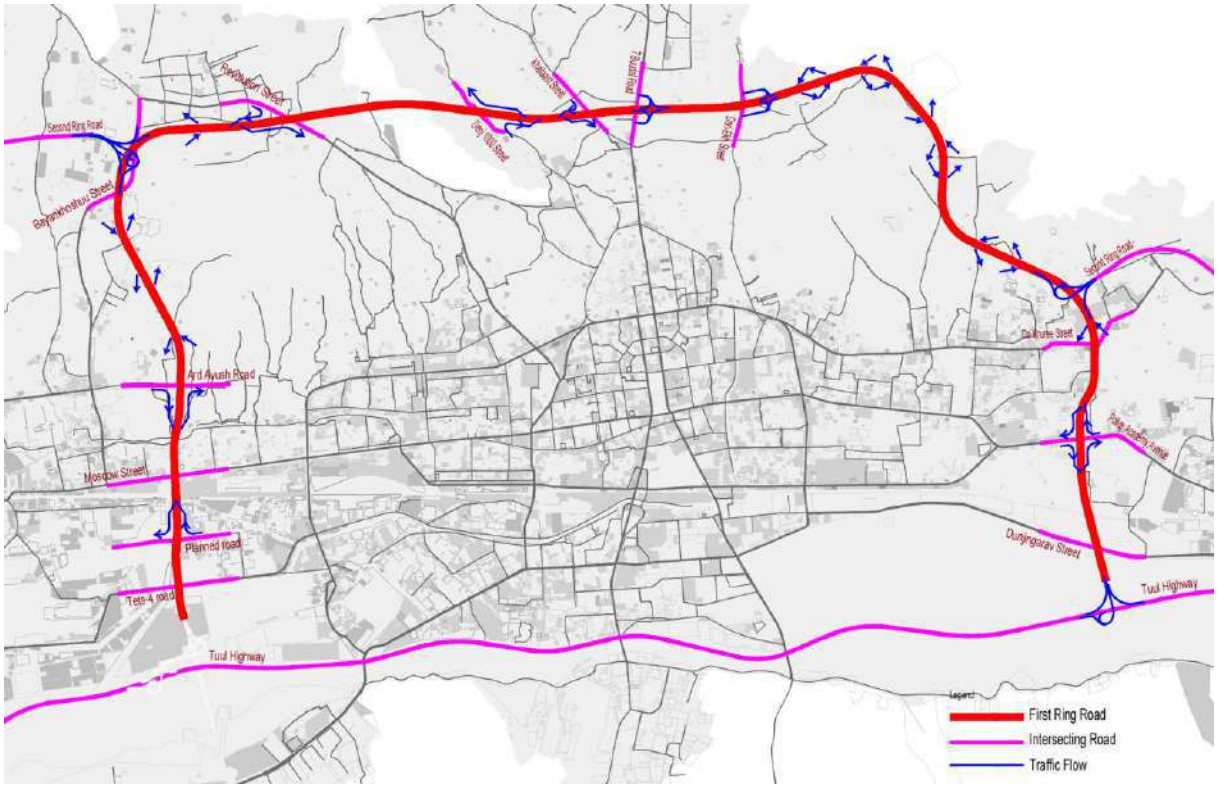


Figure 3. 12. Traffic transition between main road and side road systems

Table 3. 18. Access Points Summary Table

Access Point Types	ID	Entrance Location	ID	Exit Location	Remarks
Interchange Access Points	1	K1+410 Right Side	1	K1+410 Left Side	
	2	K2+780 Left Side	2	K2+780 Right Side	
	3	K6+080 Left Side	3	K5+950 Right Side	
	4	K6+240 Right Side	4	K6+580 Left Side	
	5	K13+375 Left Side	5	K13+310 Right Side	
	6	K13+530 Right Side	6	K13+600 Left Side	
	7	K14+980 Left Side	7	K14+900 Right Side	

Access Point Types	ID	Entrance Location	ID	Exit Location	Remarks
	8	K20+650 Left Side	8	K20+230 Right Side	
	9	K20+730 Right Side	9	K21+140 Left Side	
	10	K22+410 Left Side	10	K22+410 Right Side	
	11	K23+320 Right Side	11	K23+320 Left Side	
	12	K24+790 Left Side	12	K24+790 Right Side	
Frontage Road Access	1	K3+610 Right Side	1	K3+610 Left Side	
	2	K5+390 Left Side	2	K4+475 Right Side	
	3	K7+200 Right Side	3	K4+600 Left Side	
	4	K7+930 Left Side	4	K5+390 Right Side	
	5	K8+010 Right Side	5	K7+160 Left Side	
	6	K11+490 Right Side	6	K7+790 Right Side	
	7	K12+250 Left Side	7	K8+140 Left Side	
	8	K15+490 Left Side	8	K11+490 Left Side	
	9	K15+700 Right Side	9	K12+250 Right Side	
	10	K16+350 Left Side	10	K15+490 Right Side	
	11	K16+560 Right Side	11	K15+700 Left Side	
	12	K17+310 Right Side	12	K16+350 Right Side	
	13	K17+925 Left Side	13	K16+610 Left Side	
	14	K18+150 Right Side	14	K17+410 Left Side	
	15	K19+540 Left Side	15	K17+925 Right Side	
	16	K19+750 Right Side	16	K18+150 Left Side	
			17	K19+540 Right Side	
			18	K19+750 Left Side	

The biggest feature of this project is the use of two systems, i.e., the main road and the side road. During the design, the design speed for the outermost lane of the main road is 80 km/h, and the design speed for the side road is 40 km/h. Acceleration lanes and parallel lanes are set between the main road and the side road to ensure safe traffic transitions between them. After setting up side roads, the current roads and plots along the road can enter the main road through the side roads, thus improving the service function of the road to surrounding areas and reducing the fragmentation on both sides. Meanwhile, 21 pairs of bus stops will be set up on side roads, allowing buses to pass through the outer lanes of the main road and side roads, thus building a fast urban public transportation network for Ulaanbaatar.

3.2.2. Road longitudinal section design

3.2.2.1 Principle of longitudinal section design

(1) The requirements of current relevant technical standards and specifications in Mongolia are met.

(2) The natural terrain elevation is fully integrated to reduce the volume of filling and excavation and save engineering investment.

(3) The road elevation meets the needs of flood prevention and drainage along the route.

(4) The basic requirements for elevation and clearance of each control point are met.

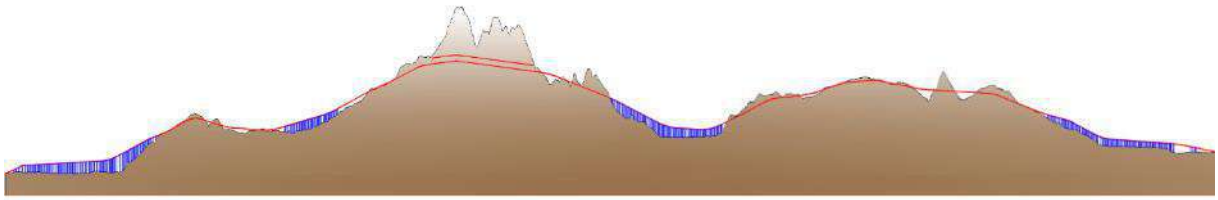
(5) The longitudinal section of roads in urban construction areas is designed according to the current elevation of the city and the requirements of relevant departments, and meet the needs of laying underground municipal pipelines.

(6) The elevation under the viaduct section meets the clear height requirements for crossing roads and railways, and the elevation under the viaduct with the ground side road laid under is to meet the clear height requirements for side roads.

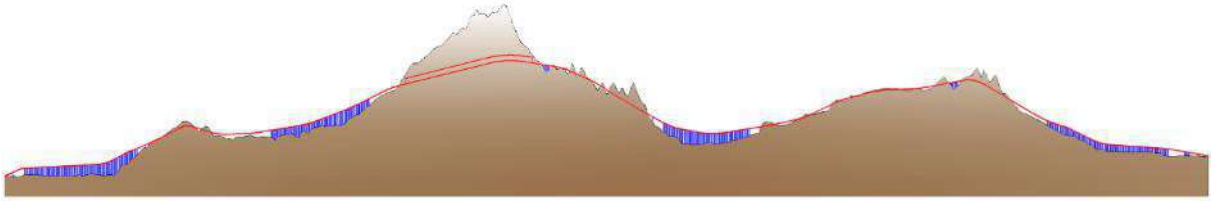
3.2.2.2 Longitudinal section design

When planning the radius of vertical curves, longitudinal section design is carried out based on relevant specifications and standards, taking into account factors such as sight distance and slope. In the design process, the requirements of the Urban Road Design Code BNbD 32-01-24 are required to ensure that the longitudinal section planning of the road fully meets traffic safety and other conditions.

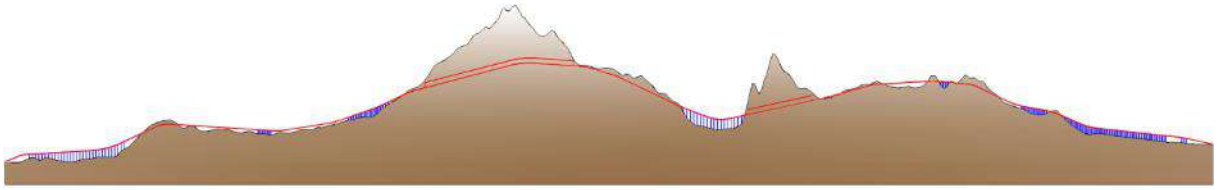
For the longitudinal section design of this project, factors such as road drainage, meeting the bridge control elevation, intersecting railways, and the urban road elevation are comprehensively considered, and the overall alignment of the road longitudinal section is determined. On the premise of meeting the technical and planning requirements of the specifications, the longitudinal slope is uniform and smooth, with gentle undulations, appropriate slope length and vertical curve length, and coordinated design of the combination of plan and longitudinal section, and the amount of work is minimized. The western section of the route is mainly limited by the elevation of intersecting roads and the current terrain. The northern section of the route is mainly limited by the elevation of Sambalkhundev Mountain, the flood control needs of Selbe River, and the current elevation of intersecting roads. The eastern section of the route is mainly limited by the elevation of current roads, railways, and planned roads.



Longitudinal Section of Scheme I



Longitudinal Section of Scheme II



Longitudinal Section of Scheme III

Figure 3. 13. Longitudinal Section Design Diagram

According to the Norms and Regulations for Urban and Village Planning and Construction БНбД 30-01-24 and the Code for Design of Urban Planned Roads in Mongolia, the maximum longitudinal slope for the design of urban main roads with a designed speed of 100 km/h is 6%. However, Ulaanbaatar is located in a snow covered and frozen area, and the current ground elevation is 1,272-1,517. Excessive longitudinal slopes do not only require climbing lanes but also easily cause traffic accidents. Referring to the international restrictions on road longitudinal slopes in snow covered and frozen areas, the maximum longitudinal slope for this road design is 4.0%. Considering the demand for road drainage, the minimum longitudinal slope for the road is 0.38%. The minimum vertical curve radius is 3,500 m, and the maximum vertical curve radius is 60,000 m. Specific design parameters are shown in the table below:

Table 3. 19. Road Longitudinal Slope and Vertical Curve Table for Scheme

No.	Chainage No.	Vertical curve			Longitudinal slope	Distance between slope change points	Length of a straight slope section
		Elevation (m)	Convex curve radius R (m)	Concave curve radius R (m)	%	(m)	(m)
0	-K0+100	1272.35					
1	-K0+27.339	1271.9722		3000	-0.520	72.661	10.248
2	K0+340	1285.3468	4000		3.641	367.339	225.107
3	K1+120	1282.6168		23000	-0.350	780	596.743
4	K2+200	1288.551		6000	0.549	1080	874.879
5	K3+020	1320.85	10000		3.939	820	632.713
6	K3+430	1329.98		12000	2.227	410	218.006
7	K4+000	1352.78	4000		4.000	570	335.934
8	K4+530	1340.146		20000	-2.384	530	215.947
9	K5+440	1335.414		15000	-0.520	910	518.983
10	K6+660	1362.358		15000	2.209	1220	881.000
11	K7+520	1396.758	14000		4.000	860	654.595
12	K7+760	1403.9222		15000	2.985	240	106.359
13	K8+500	1432.188	8000		3.820	740	562.615
14	K9+220	1439.028	15000		0.950	720	459.712
15	K11+130	1420.119	18000		-0.990	1910	1593.788

No.	Chainage No.	Vertical curve			Longitudinal slope	Distance between slope change points	Length of a straight slope section
		Elevation (m)	Convex curve radius R (m)	Concave curve radius R (m)	%	(m)	(m)
16	K12+520	1379.9925	35000		-2.887	1390	1059.478
17	K13+570	1340.0925		12500	-3.800	1050	676.440
18	K14+450	1336.7485		10000	-0.380	880	469.985
19	K15+130	1360.8565		32000	3.545	680	410.982
20	K15+680	1382.8565	10000		4.000	550	318.171
21	K16+510	1389.6498		20000	0.818	830	494.676
22	K17+200	1407.4583	12000		2.581	690	388.244
23	K17+840	1410.5887	12000		0.489	640	396.907
24	K18+820	1396.1767		24000	-1.471	980	733.788
25	K20+240	1390.5149	9000		-0.399	1420	1177.016
26	K21+230	1361.4091		20000	-2.940	990	780.387
27	K21+800	1350.0808	10000		-1.987	570	374.115
28	K22+460	1323.6808		11000	-4.000	660	369.064
29	K23+930	1315.7448	20000		-0.540	1470	1211.637
30	K24+340	1310.7411	50000		-1.220	410	247.435
31	K24+793.006	1303.5			-1.598	453.006	358.496

Table 3. 20. Road Longitudinal Slope and Vertical Curve Table for Scheme II

No.	Chainage No.	Vertical curve			Longitudinal slope	Distance between slope change points	Length of a straight slope section
		Elevation (m)	Convex curve radius R (m)	Concave curve radius R (m)	%	(m)	(m)
0	AK0+000	1272.14					
1	AK0+100	1274.38		6000	2.240	100	50.742
2	AK0+350	1284.0848	5000		3.882	250	113.401
3	AK2+150	1291.0736		10000	0.388	1800	1532.072
4	AK2+630	1310.2736	20000		4.000	480	217.860
5	AK3+250	1330.0173		15000	3.184	620	477.282
6	AK3+880	1355.2173	5000		4.000	630	410.880
7	AK4+590	1338.75808		12000	-2.318	710	388.744
8	AK5+420	1342.107		25000	0.403	830	553.384
9	AK6+510	1356.386		20000	1.310	1090	817.072
10	AK7+420	1382.8318		28000	2.906	910	634.810
11	AK8+290	1415.297442	15000		3.732	870	616.979
12	AK10+750	1462.0154	25000		1.899	2460	1927.826
13	AK11+990	1446.407	10000		-1.259	1240	738.706

No.	Chainage No.	Vertical curve			Longitudinal slope	Distance between slope change points	Length of a straight slope section
		Elevation (m)	Convex curve radius R (m)	Concave curve radius R (m)	%	(m)	(m)
14	AK12+550	1427.423	20000		-3.390	560	347.440
15	AK13+790	1372.2433		20000	-4.450	1240	1089.005
16	AK14+330	1350.6433		12000	-4.000	540	342.002
17	AK15+140	1338.8983		18000	-1.450	810	419.647
18	AK16+490	1354.9263		25000	1.187	1350	1038.554
19	AK17+160	1366.8523		15000	1.780	670	454.907
20	AK17+930	1395.0343	12000		3.660	770	524.600
21	K18+750	1410.7783	15000		1.920	820	596.946
22	K19+580	1413.5833		24000	0.338	830	587.984
23	K20+790	1430.111545	8000		1.366	1210	851.127
24	K22+300	1361.8325		25000	-4.522	1510	1008.016
25	K22+790	1350.1215	12000		-2.390	490	142.846
26	K23+490	1323.9788		12000	-3.735	700	429.370
27	K24+936.960	1315.7478	18000		-0.569	1446.96	1195.990
28	K25+799.966	1304.9874			-1.247	863.006	801.986

Table 3. 21. Road Longitudinal Slope and Vertical Curve Table for Scheme III

No.	Chainage No.	Vertical curve			Longitudinal slope (%)	Distance between slope change points	Length of a straight slope section
		Elevation (m)	Convex curve radius R (m)	Concave curve radius R (m)	%	(m)	(m)
0	BK0+000	1272.14					
1	BK0+100	1274.38	2000		2.24	100	73.98
2	BK0+390	1273.3302		3000	-0.362	290	249.1652941
3	BK0+730	1275.4574	20000		0.625	340	222.6205882
4	BK1+340	1273.0174		8000	-0.4	610	468.6643137
5	BK1+850	1275.9207	15000		0.569	510	361.0334314
6	BK2+260	1272.2307		5000	-0.9	410	146.3044118
7	BK2+480	1283.7587		0	5.24	220	66.5
8	BK2+940	1314.0267	2000		6.58	460	420
9	BK3+080	1317.6387		2000	2.58	140	64.8
10	BK3+480	1342.0387	2000		6.1	400	298.4
11	BK6+050	1328.1607		12000	-0.54	2570	2394.865763
12	BK7+230	1343.1731		15000	1.272	1180	953.7830491
13	BK8+210	1370.9921		20000	2.838	980	746.3846333
14	BK8+970	1401.3921	20000		4	760	461.6818631

No.	Chainage No.	Vertical curve			Longitudinal slope (%)	Distance between slope change points	Length of a straight slope section
		Elevation (m)	Convex curve radius R (m)	Concave curve radius R (m)	%	(m)	(m)
15	BK11+450	1455.4101	20000		2.178	2480	2021
16	BK12+860	1447.0911	18000		-0.59	1410	964.8854839
17	BK13+510	1431.1011	20000		-2.46	650	327.7
18	BK14+920	1374.7011		25000	-4	1410	1155.238506
19	BK15+790	1346.9141		10000	-3.19	870	518.5431034
20	BK18+190	1390.5941		15000	1.82	2400	2111.804598
21	BK19+220	1414.4901	10000		2.32	1030	900
22	BK20+610	1421.0231	40000		0.47	1390	1032.92439
23	BK21+430	1414.0295	7000		-0.852	820	445.975122
24	BK22+360	1377.0155		10000	-3.98	930	699.4725464
25	BK23+200	1363.924635	25000		-1.558	840	464.9425674
26	BK23+990	1335.5615		10000	-3.590	790	402.5072392
27	BK26+000	1317.0695	20000		-0.92	2010	1793.074085
28	BK26+754.120	1303.8413			-1.754	754.12	670.7075988

3.2.2.3 Comparison of local vertical design

In addition, this scheme design compared the longitudinal section design of two local sections, KM1+500-KM4+000 and KM7+700-KM12+400 with different longitudinal slope limits. Different longitudinal sections mainly affect the length of bridges and tunnels, and excavation of earthwork and stonework.

(1) KM1+400-KM4+000

Scheme I: A maximum longitudinal slope of 4% is adopted, which is consistent with the maximum limit required by the bridge specifications. A form of a viaduct and a ground auxiliary lane is adopted. The overpassing main road is used at the intersection with the Ard Ayush Road, and the ground side road level intersects with the Ard Ayush Road. The bridge length is 1,700 m.

Scheme II: A maximum longitudinal slope limit of 6% is adopted and a level crossing with the Ard Ayush road is used. The length of the bridge is 900 m.

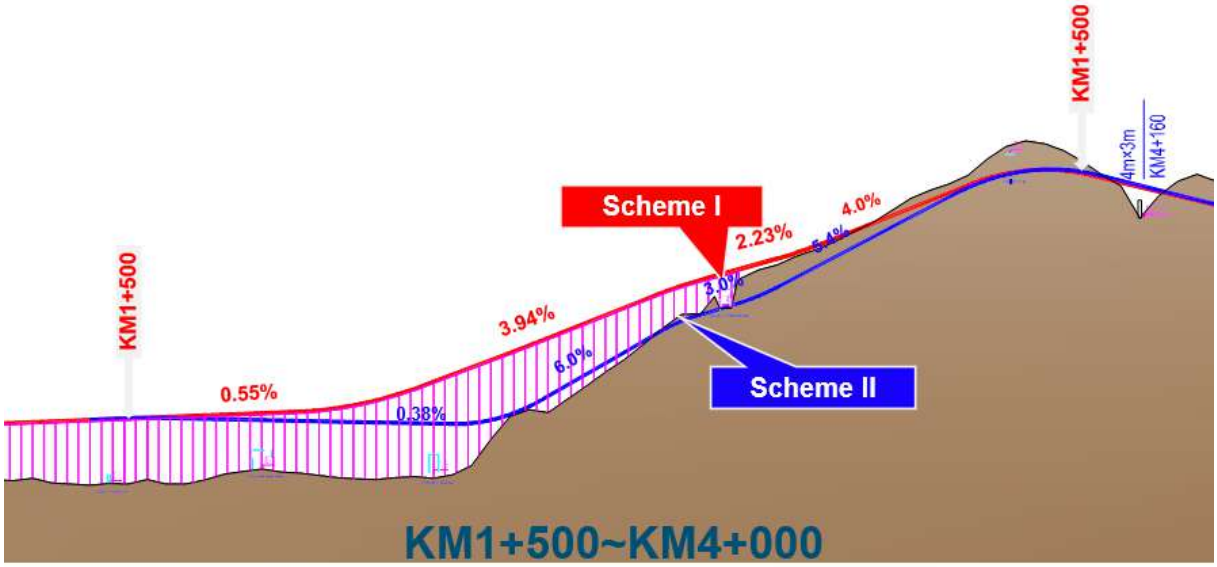


Figure 3. 14. Vertical Design Comparison between KM1+400-KM4+000

(2) KM7+700-KM12+400

Scheme I: A maximum longitudinal slope of 4% is adopted and a tunnel is used to directly pass through the mountain. The tunnel length is 2,080 m and there is no bridge in this section.

Scheme II: A maximum longitudinal slope limit of 6% is adopted, the mountain section still passes through two short tunnels with lengths of 590 m and 980 m respectively. A bridge with a length of 760 m is set up after exiting the tunnel.

Scheme III: A maximum longitudinal slope limit of 6% is adopted, the mountain is directly excavated with a slope. Bridges are set up at both ends to reduce the excavation height. A bridge is used to cross over the current road between the two mountains, with a total length of 1,180 m and an excavation height of 35 m or more. The excavation width at the top of the mountain is about 200 m.

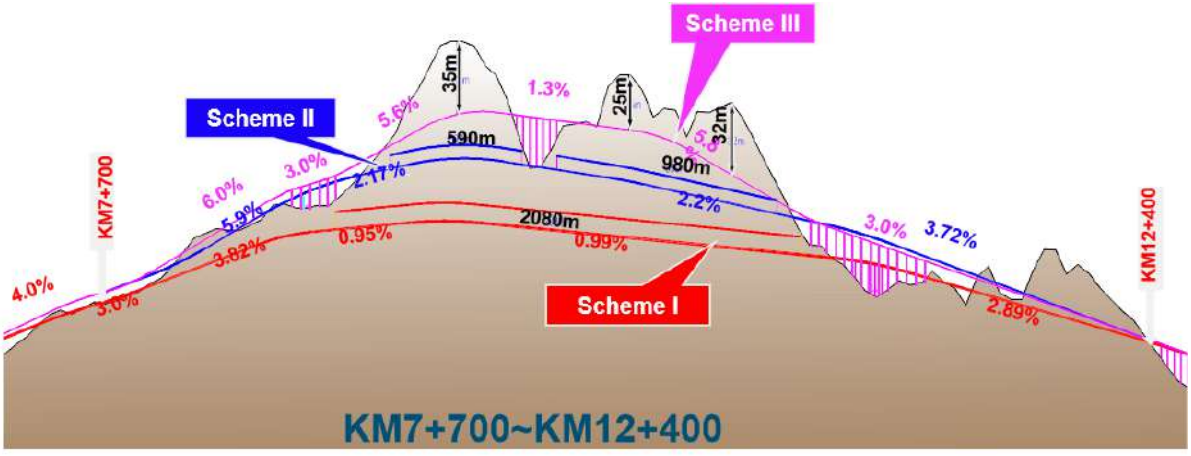


Figure 3. 15. Vertical Design Comparison between KM7+700-KM12+400

The longitudinal cross section figures of the entire route using three schemes with different longitudinal slope limits are as follows:

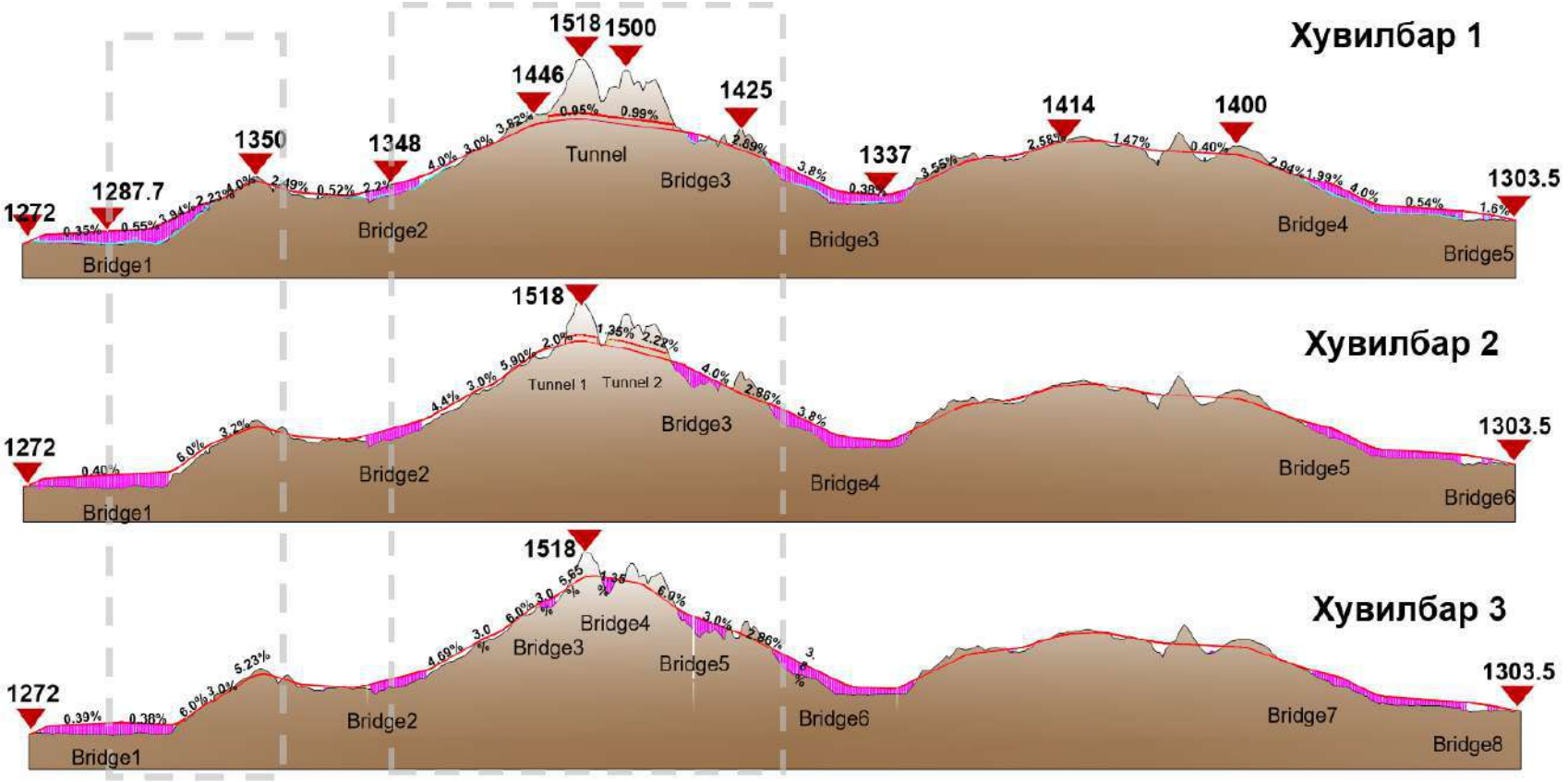


Figure 3. 16. Comparison Diagram of Longitudinal Sections of the Entire Route Using Three Schemes with Different Longitudinal Slope Limits

Table 3. 22. Comparison Table of Main Economic Indicators for Different Maximum Longitudinal Slope Schemes

Specifications	Version 1	Version 2	Version 3
Technical specifications			
Maximum slope of the main road	4%	**6%**	6%
Length of the bridge (m)	9034	9020	9310
Length of the tunnel (m)	2080	1570	0
Length of the embankment (m)	13679	14203	15483
Filling volume (10,000 m³)	337.14	359.62	241.35
Excavation volume (10,000 m³)	420.43	430.48	724.89
Construction period (months)	23	23	24
Economic and financial situation			
Total investment cost (USD) (Billion)	0.919	0.895	0.879
Operation and maintenance costs (Million)	5.40	5.35	5.25
Environmental and social impact			
Environmental impact	Minimum	Normal	Maximum
Traffic safety assessment	Good	Bad	Bad

Table 3. 23. Investment Comparison Table of Different Maximum Longitudinal Slope Schemes

Version	Version 1, 4%	Version2, 6%	Version 3, 6%
Route length (m)	24793.006	24793.006	24793.006
Road investment	456,498,067,433	479,468,925,743.92	696,906,041,193
Bridge investment	1,634,656,344,823	1,641,005,446,733.38	1,693,765,045,353
Tunnel investment	463,712,084,132	343,298,590,561	/
Network investment	176,376,940,000	181,668,248,200	197,542,172,800
Green space investment	25,497,826,822	25,497,826,822	25,497,826,822
Network relocation	16,227,343,503	16,227,343,503	19,167,343,503
Land acquisition	510,000,000,000	510,000,000,000	510,000,000,000
Total investment, MNT	3,282,968,606,712	3,197,166,381,563	3,142,878,429,671
Total investment, USD	918,569,840	894,562,502	879,372,812

Table 3. 24. Comparison Table of Advantages and Disadvantages of Different Vertical Schemes

Total evaluation		
Good	**Average**	**Bad**
Planning a slope of no more than 4% is safer. Tunnel: reduces land use, minimizes earthworks, and has less negative environmental impact. The investment cost is relatively high.	A slope of less than 4% reduces the length of the tunnel but increases the risk of road traffic accidents. The investment amount is lower compared to Option 1.	If the slope is less than 4%, a tunnel is not required. Continuous planning of roads and pedestrian paths is possible. Due to extensive earthworks during construction, the negative environmental impact is higher. Steeper slopes increase the risk of road traffic accidents.

		The investment amount is the lowest.

Table 3. 25. Case Analysis Table of the Maximum Slope for the Longitudinal Section at the Same Latitude of the World

Example	Maximum (%)	Turning slope (m)	Uphill lane	Safety lane (dimensions/km)
French ring road	3.5	≥ 3,000	None (entirely tunnel)	None (right side of the road is closed)
Munich inner ring	4.0	≥ 2,500	Special lane for heavy vehicles (slope ≤ 3.5%)	2.0 (additional layer of sand and gravel)
Vancouver road	4.5 (Local area 6.0)	≥ 1,500	Safe road provided every 3 km along continuous uphill sections	2.0 (additional layer of sand and gravel)
Seattle SR 520 floating bridge	3.0 (Water level)	≥5,000	None (planned with regular slope)	None (floating bridge)
Harbin 3rd ring expressway	3.5	≥ 2,000	Slope adjacent to the heavy vehicle lane (≤ 3.0%)	1.5 (heating and melting ice on slippery sections)

In summary, although Scheme I has the longest tunnel length and higher cost, the smaller longitudinal slope reduces vehicle accidents in rainy and snowy weather, while improving the safety and comfort of non-motorized vehicle riding; scheme II adopts a larger longitudinal slope value, and although the tunnel length is slightly reduced, the overall investment reduction is not significant, and the traffic safety is significantly reduced; scheme III involves setting up bridges on both sides and excavating extensively instead of tunnels. However, due to the excessive excavation height, the current Sambalkhundev mountain will be cut off, which will affect the passage of residents on both sides of the mountain and block animal migration passages. It is necessary to relocate the two 220 KV high-voltage lines. According to the reply letter from the power department (02/603): 220 KV relocation is difficult, and large-scale slope protection needs to be set up on both sides of the road, which poses a risk of crushed stone falling and landslides caused by spring snow melting. Taking into account factors such as engineering investment, environmental impact, impact on residents along the route, and later operation, as well as relevant cases from international regions at the same latitude and research on the traffic accident rate increase due to increasing the longitudinal slope, it is recommended to adopt Scheme I for the longitudinal section, which is a maximum longitudinal slope limit of 4%.

3.2.3. Cross section design of the road

This project determines the standard cross section of the designed road on the basis of the road traffic function, planned boundary line width, surrounding land use nature, road greening standards, and the current situation of land acquisition and demolition on both sides of the road.

3.2.3.1 Standard cross section of the main road

(1) Standard section of a 60 m roadbed section road

The road in this design passes through the suburbs with good land conditions. The width of the designed boundary line is 60 m, and the cross section form of ground main road and ground side road is adopted. The ground main road is a two-way six lane road, and the specific section form is as below: 3.0 m (sidewalk)+1.5 m (tree pit)+7 m (side road)+5 m (side strip)+12.25 m (main lane)+2.5 m (median strip)+12.25 m (main lane)+5 m (side strip)+7 m (side road)+1.5 m (tree pit)+3.0 m (sidewalk)=60 m, 7 m (side road)=2.5 m (non-motorway)+4.5 m (auxiliary lane), 12.25 m (main lane)=0.5 m (marginal strip)+3.75 m (motorway)+3.75 m (motorway)+3.75 m (motorway)+0.5 m (marginal strip).

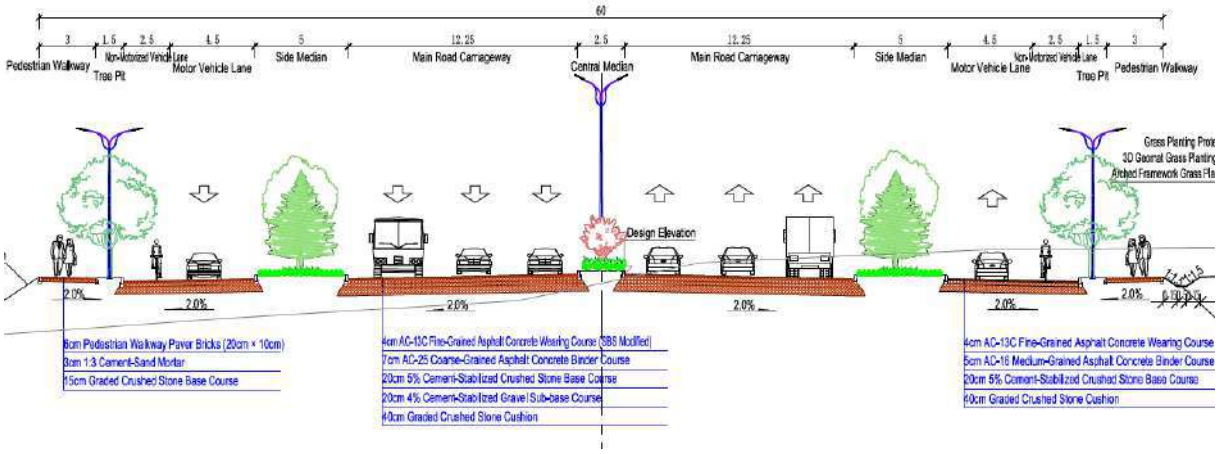


Figure 3. 17. Standard Section of 60 m-wide Roadbed Section Road

(2) Standard cross section of the 45 m elevated road section

The designed road passes through the central urban area with limited land use conditions. The width of the designed boundary line is 45 m, and the elevated main road + ground side road section form is adopted. The section width of the elevated section is 26.5 m, and it is a two-way six lane road. The specific section form is as below: 0.5 m (anti-collision guardrail)+12.25 m (main lane)+1 m (anti-collision guardrail)+12.25 m (main lane)+0.5 m (anti-collision guardrail)=26.5 m, of which 12.25 m (main lane)=0.5 m (marginal strip)+3.75 m (motorway)+3.75 m (motorway)+0.5 m (marginal strip); the section width of the ground side road is 45 m, and it is two-way four lane road. The specific section form is as below: 3.5 m (sidewalk)+2.5 m (non-motorway)+5 m (side strip)+8 m (ground auxiliary lane)+8 m (median strip)+8 m (ground auxiliary lane)+5 m (side strip)+2.5 m (non-motorway)+3.5 m (sidewalk)=45 m, of which 8 m (ground auxiliary lane)=0.5 m (marginal strip)+3.5 m (motorway)+3.5 m (motorway)+0.5 m (marginal strip).

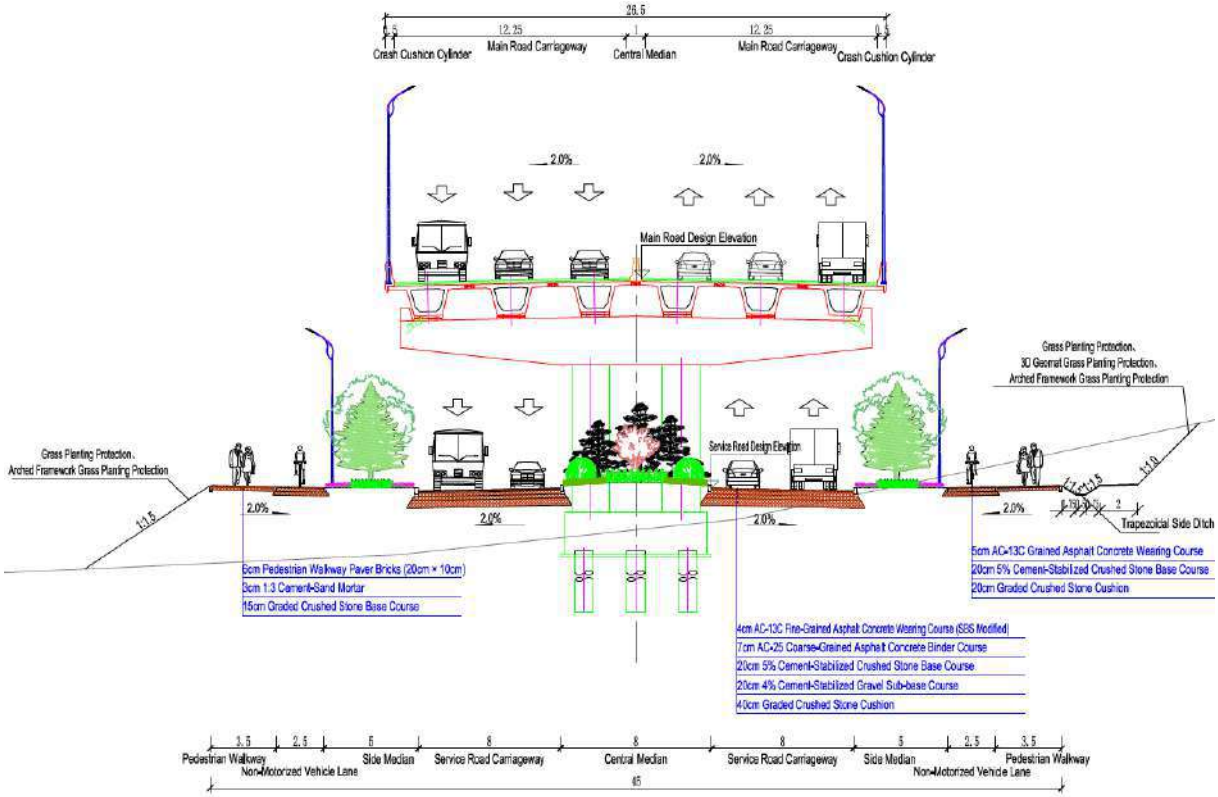


Figure 3. 18. Standard Cross Section of the 45 m Elevated Road Section

(3) Standard cross section of the 32 m elevated road section

The section from the start point of the designed road to K3+240 is limited by the 220 KV high-voltage power line, and the road land conditions are restricted. The width of the designed boundary line is 32 m, and the elevated main road + ground side road section form is adopted. The section width of the elevated section is 26.5 m, and it is a two-way six lane road. The specific section form is as below: 0.5 m (anti-collision guardrail)+12.25 m (main lane)+1 m (anti-collision guardrail)+12.25 m (main lane)+0.5 m (anti-collision guardrail)=26.5 m, of which 12.25 m (main lane)=0.5 m (marginal strip)+3.75 m (motorway)+3.75 m (motorway)+3.75 m (motorway)+0.5 m (marginal strip); the section width of the ground side road is 32 m, and it is a two-way four lane road. The specific section form is as below: 3 m (sidewalk)+2.5 m (non-motorway)+3 m (side strip)+15 m (ground auxiliary lane)+3 m (side strip)+2.5 m (non-motorway)+3 m (sidewalk)=32 m, of which 15 m (ground auxiliary lane)=0.25 m (marginal strip)+3.5 m (motorway)+3.5 m (motorway)+0.5 m (opposite lane dividing line)+3.5 m (motorway)+3.5 m (motorway)+0.25 m (marginal strip).

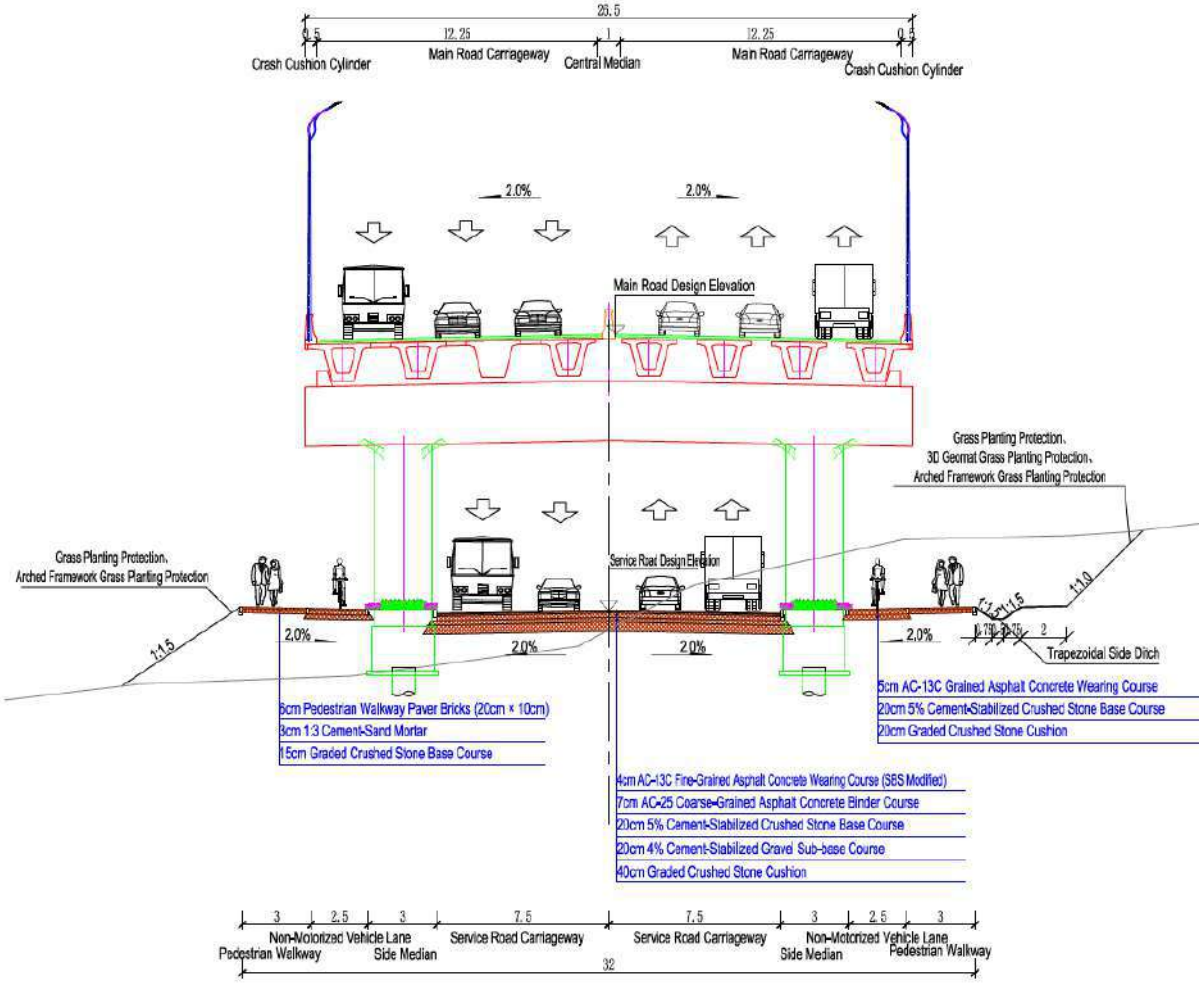


Figure 3. 19. Standard Cross Section of the 32m Elevated Road Section

(4) Standard cross section of 28.5 m road

The width for the designed boundary line of the section from the K23+975.437 to the end point of the designed road is 28.5 m, and it is a two-way six lane road. The specific cross section form is: 0.75 m (earth shoulder)+12.25 m (main lane)+2.5 m (median strip)+12.25 m (main lane)+0.75 m (earth shoulder)=28.5 m, 12.25 m (main lane)=0.5 m (marginal strip)+3.75 m (motorway)+3.75 m (motorway)+3.75 m (motorway)+0.5 m (marginal strip).

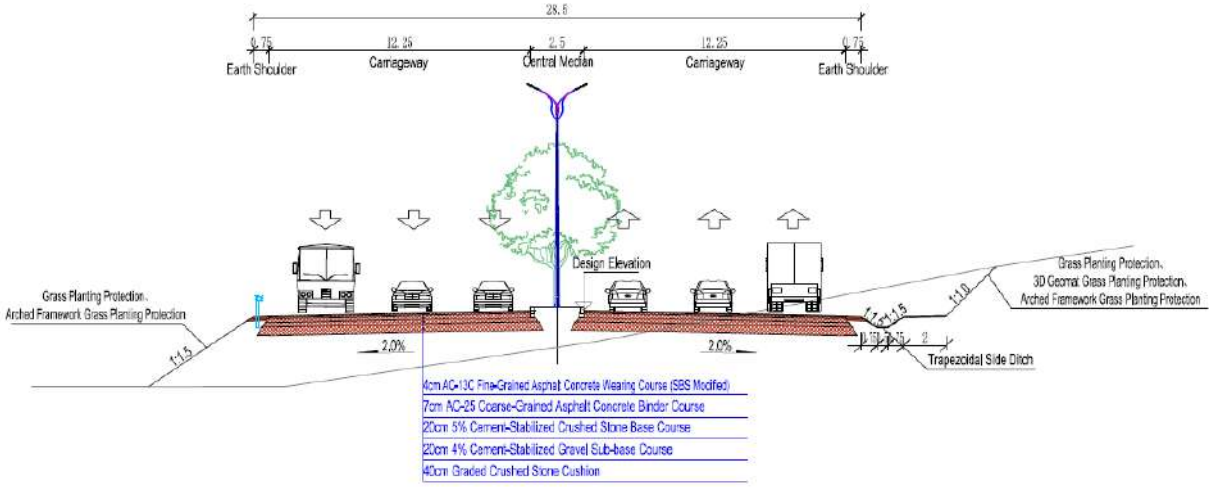


Figure 3. 20. Standard Cross Section of the 28.5 m Road

3.2.3.2 Standard Cross Section of the Interchange Ramp Road

(1) On-ramp or off-ramp at K1+090 on New Ring Road

The width of the on-ramp or off-ramp at K1+300 is 9 m, and it is single-way two lane road. The specific section form is as below: 0.5 m (anti-collision guardrail)+0.5 m (lateral clear width)+3.5 m (motorway)+3.5 m (motorway)+0.5 m (lateral clear width)+0.5 m (anti-collision guardrail)=9 m.

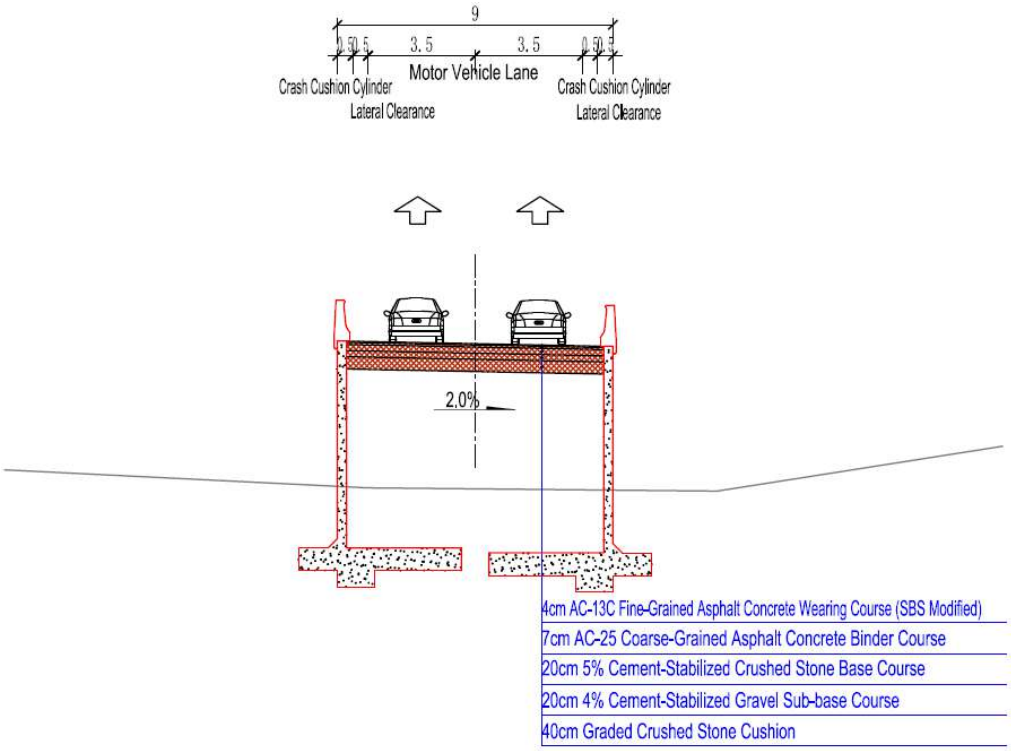


Figure 3. 21. Standard Cross Section of the On-ramp or Off-ramp at K1+090

(2) Interchange between the New Ring Road and the Ard Ayush Road

The width of the interchange ramp between the New Ring Road and the Ard Ayush Road is

9 m, and it is single-way two lane road. The specific section form is as below: 0.5 m (anti-collision guardrail)+0.5 m (lateral clear width)+3.5 m (motorway)+3.5 m (motorway)+0.5 m (lateral clear width)+0.5 m (anti-collision guardrail)=9 m.

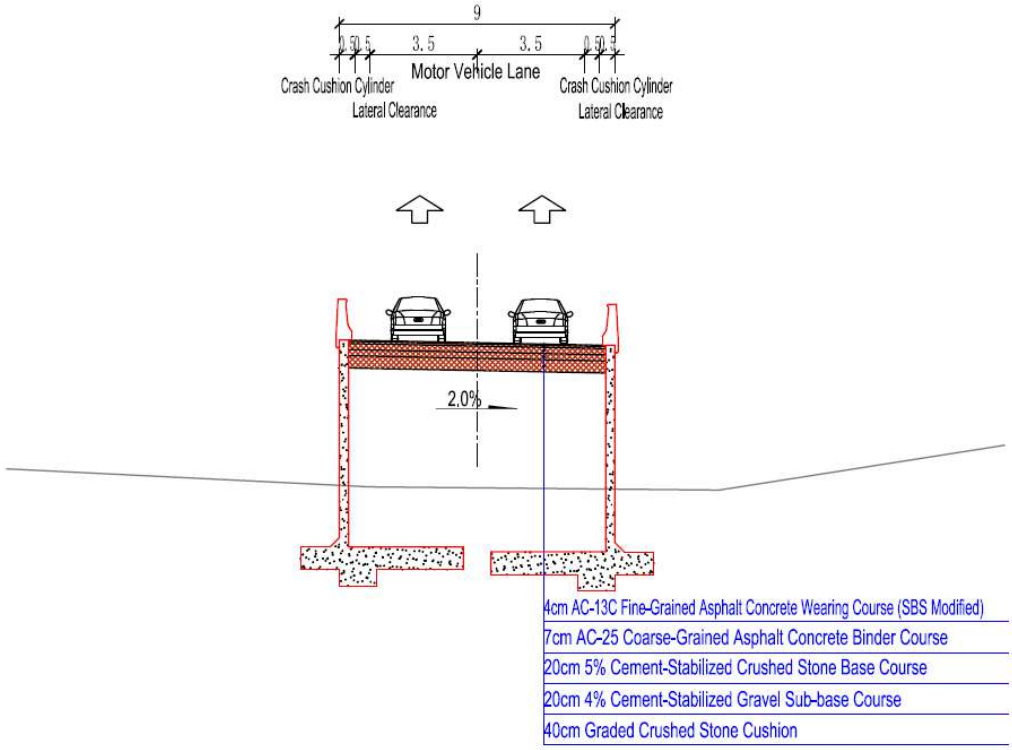


Figure 3. 22. Standard Cross Section of the Interchange Ramp between the New Ring Road and the Ard Ayush Road

(3) Interchange between the New Ring Road and the west side of the Second Ring Road

1) The width of the ramp C of the interchange between the New Ring Road and the west side of the Second Ring Road is 10 m, and it is single-way two lane road. The specific section form is as below: 0.5 m (earth shoulder)+0.75 m (lateral clear width)+3.75 m (motorway)+3.75 m (motorway)+0.75 m (lateral clear width)+0.5 m (earth shoulder)=10 m.

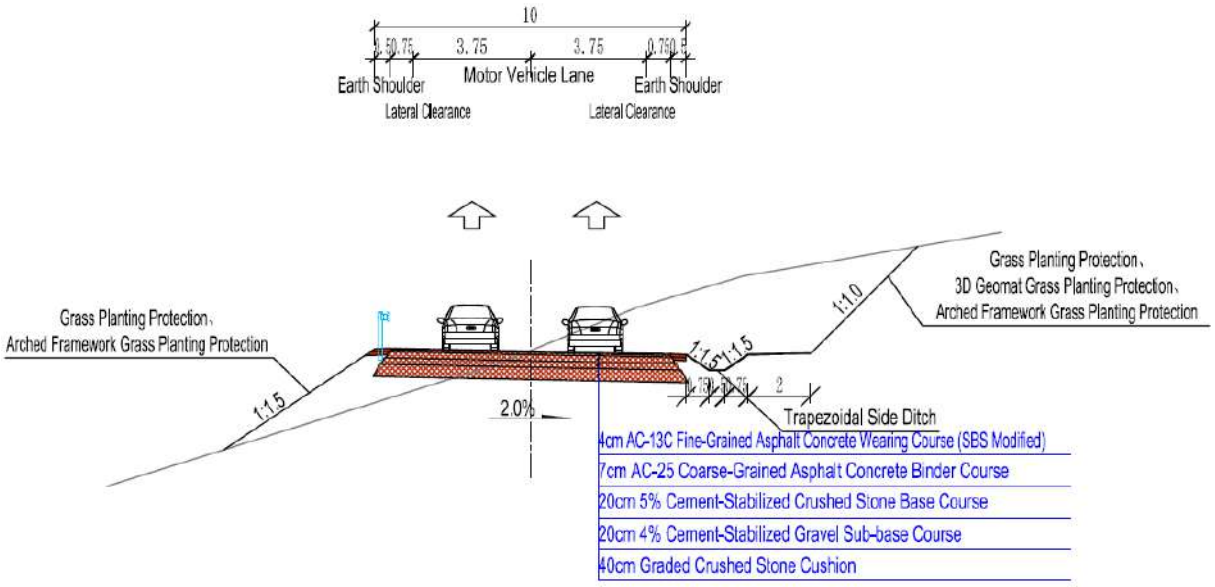


Figure 3. 23. Standard Cross Section of Ramp C of the Interchange between the New Ring Road and the West Side of the Second Ring Road

2) The width of ramps A, B, and D of the interchange between the New Ring Road and the west side of the Second Ring Road is 8.5 m, and it is a sing-way one lane road. The specific section form is as below: 0.5 m (earth shoulder)+0.75 m (lateral clear width)+3.75 m (motorway)+3 m (emergency parking strip)+0.5 m (earth shoulder)=8.5 m.

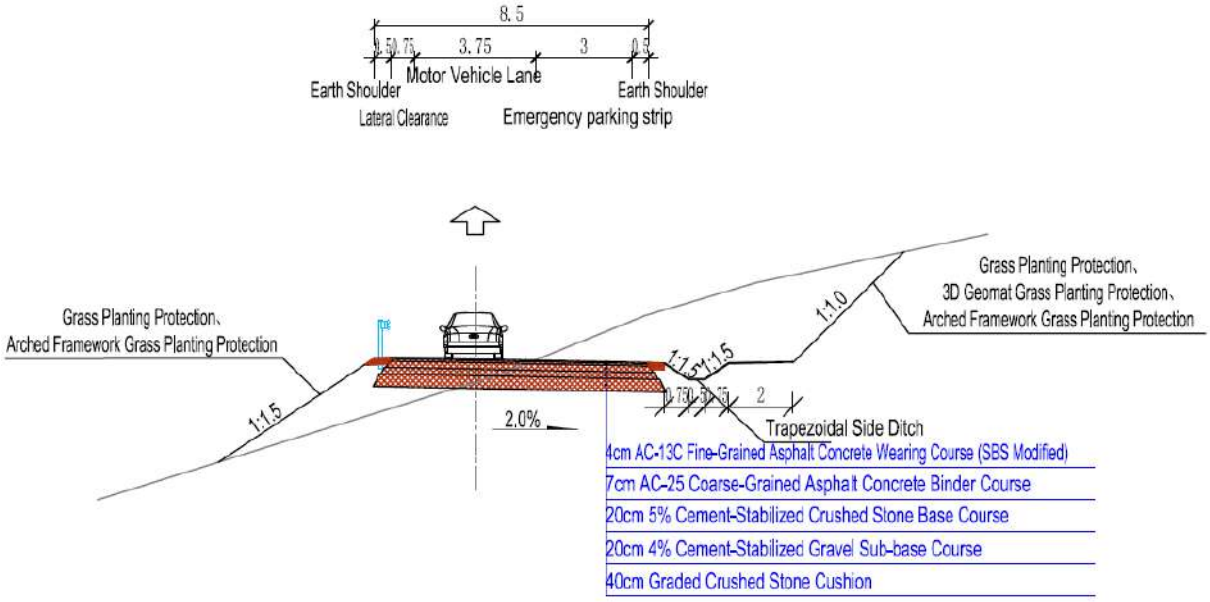


Figure 3. 24. Standard Cross Section of Ramps A, B, and D of the Interchange between the New Ring Road and the West Side of the Second Ring Road.

(4) Interchange between the New Ring Road and the Doloon Buudal road

1) The width of ramps B, C, E, and F of the Interchange between the New Ring Road and the Doloon Buudal road is 9 m, and it is single-way two lane road. The specific section form is

as below: 0.5 m (earth shoulder)+0.5 m (lateral clear width)+3.5 m (motorway)+3.5 m (motorway)+0.5 m (lateral clear width)+0.5 m (earth shoulder)=9 m.

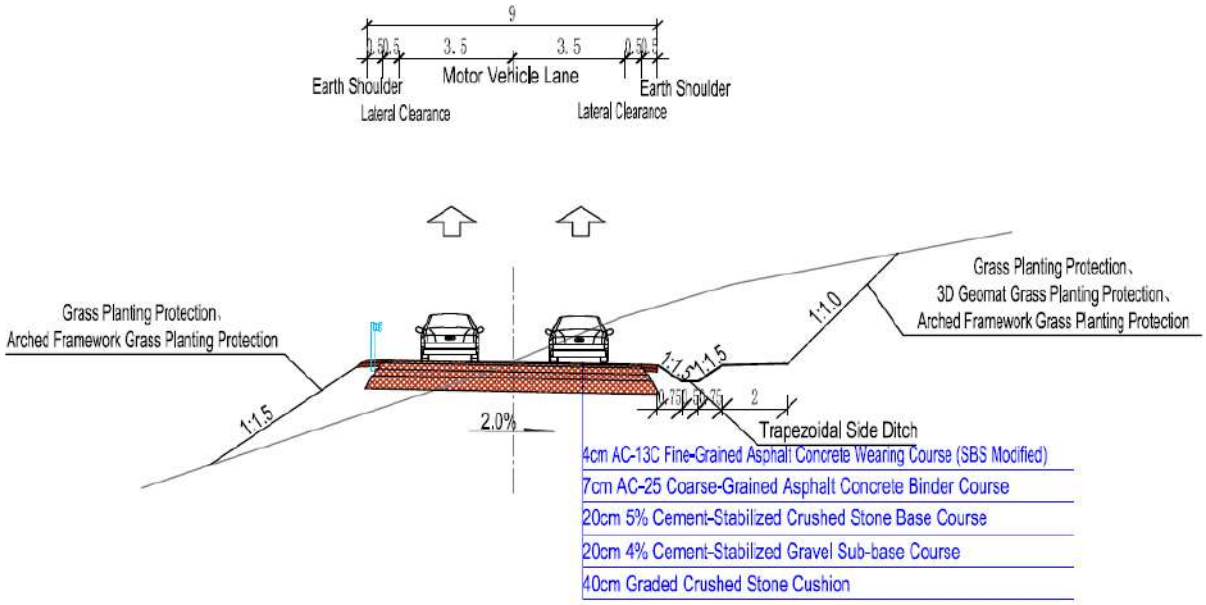


Figure 3. 25. Standard Cross Section of Ramps B, C, E, and F of the Interchange between the New Ring Road and the Doloon Buudal road

2) The width of ramps A and D of the Interchange between the New Ring Road and the Doloon Buudal road is 18.5 m, and it is a two-way four lane road. The specific section form is as below: 0.5 m (earth shoulder)+0.5 m (lateral clear width)+3.5 m (motorway)+3.5 m (motorway)+0.5 m (marginal strip)+1.5 m (strip)+0.5 m (marginal strip)+3.5 m (motorway)+3.5 m (motorway)+0.5 m (lateral clear width)+0.5 m (earth shoulder)=18.5 m.

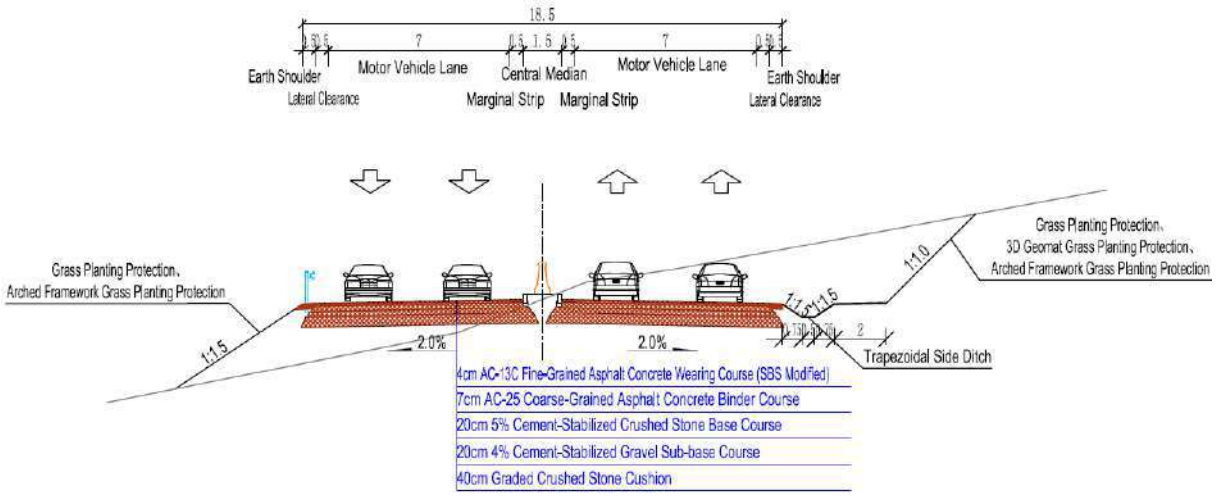


Figure 3. 26. Standard Cross Section of Ramps A and D of the Interchange between the New Ring Road and the Doloon Buudal road

(5) Interchange between the New Ring Road and the Dari-Ekh street

1) The width of ramps A and C of the interchange between the New Ring Road and the

Dari-Ekh street is 8.5 m, and it is a sing-way one lane road. The specific section form is as below: 0.5 m (earth shoulder)+1 m (lateral clear width)+3.5 m (motorway)+3 m (emergency parking strip)+0.5 m (earth shoulder)=8.5 m.

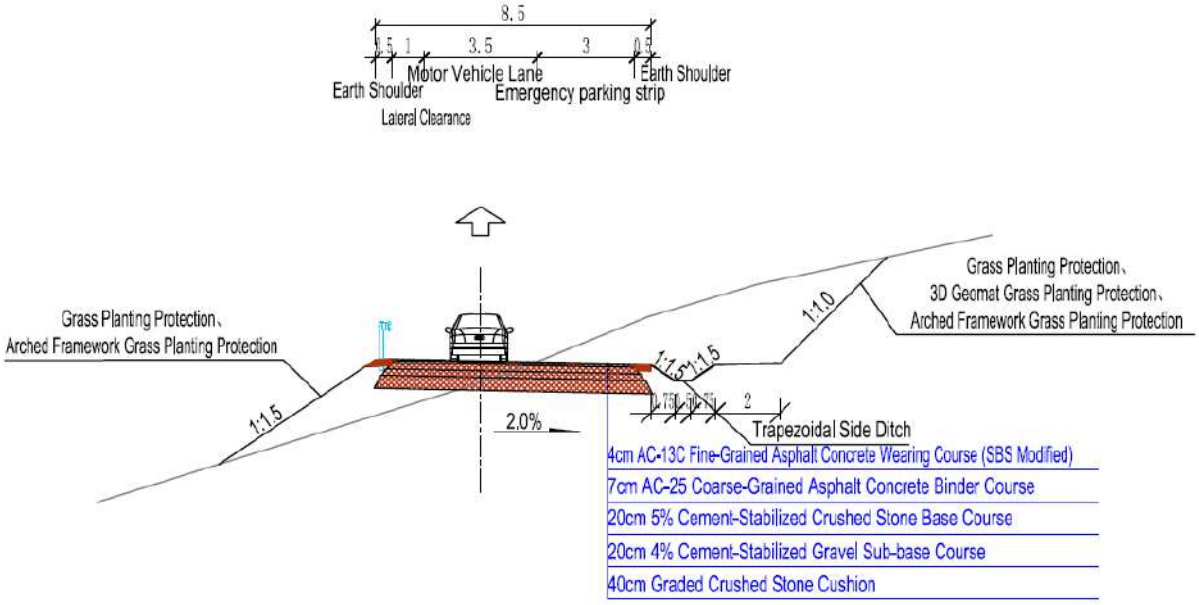


Figure 3. 27. Standard Cross Section of Ramps A and C of the Interchange between the New Ring Road and the Dari-Ekh street

2) The width of ramps B and D of the interchange between the New Ring Road and the Dari-Ekh street is 13.5 m, and it is single-way two lane road. The specific section form is as below: 0.5 m (earth shoulder)+1 m (lateral clear width)+3.5 m (motorway)+3.5 m (motorway)+2.5 m (non-motorway)+2.5 m (sidewalk)=13.5 m.

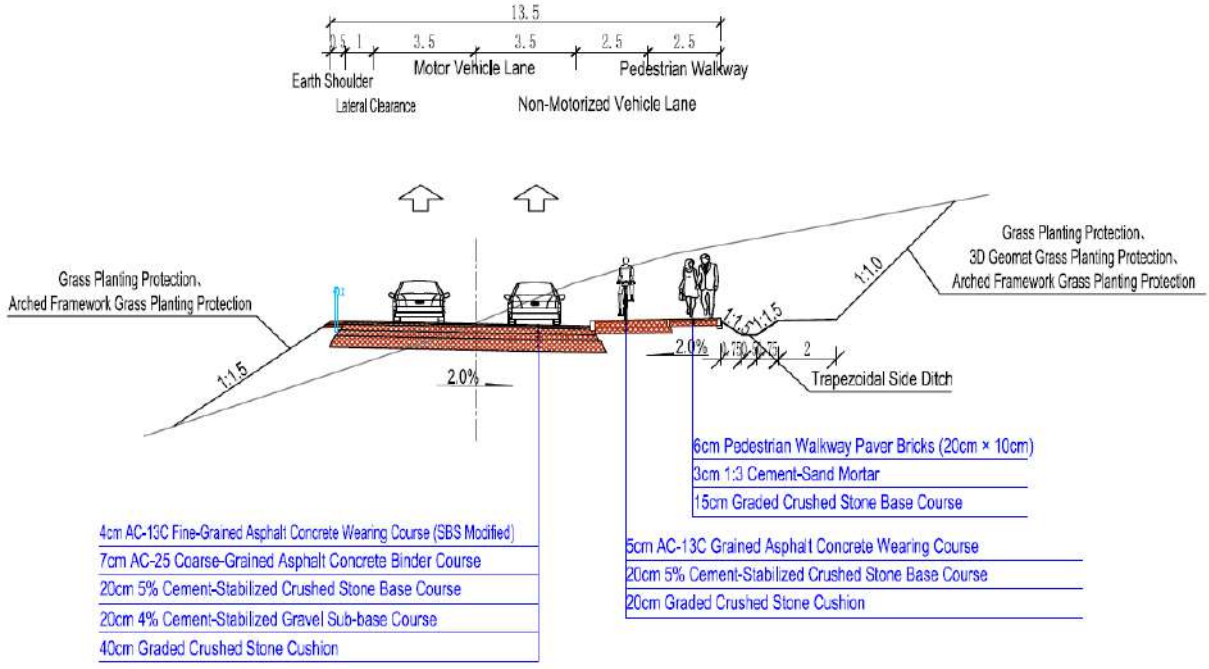


Figure 3. 28. Standard Cross Section of Ramps B and D of the Interchange between the New Ring Road and the Dari-Ekh street

(6) Interchange between the New Ring Road and the east side of the Second Ring Road

1) The width of ramp A of the Interchange between the New Ring Road and the Second Ring Road is 20.5 m, and it is a two-way four lane road. The specific section form is as below: 0.5 m (earth shoulder)+0.75 m (lateral clear width)+3.75 m (motorway)+3.75 m (motorway)+0.75 m (marginal strip)+1.5 m (strip)+0.75 m (marginal strip)+3.75 m (motorway)+3.75 m (motorway)+0.75 m (lateral clear width)+0.5 m (earth shoulder)=20.5 m.

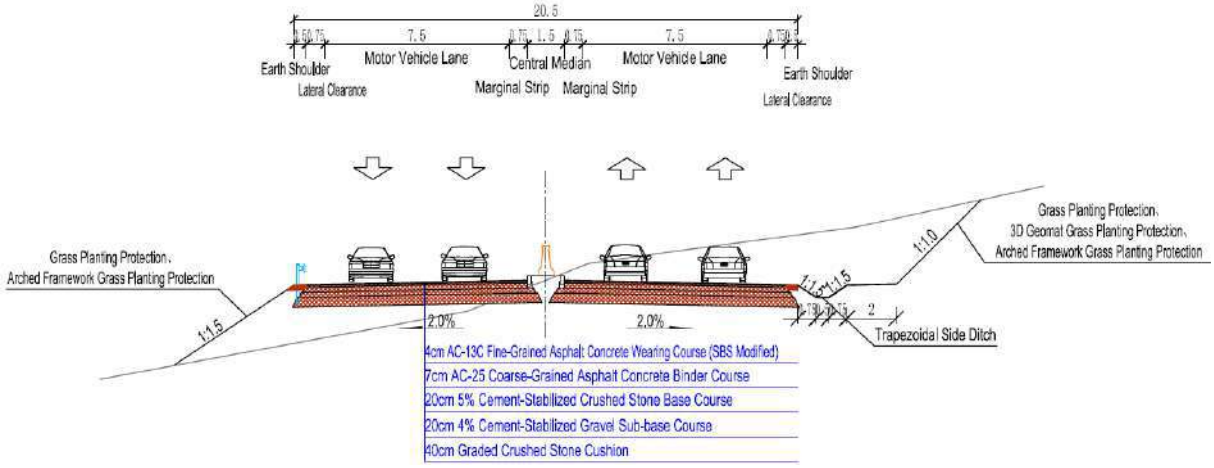


Figure 3. 29. Standard Cross Section of Ramp A of the Interchange between the New Ring Road and the East Side of the Second Ring Road

2) The width of the ramps B, C, D, and E of the Interchange between the New Ring Road and the east side of the Second Ring Road is 10 m, and it is single-way two lane road. The

specific section form is as below: 0.5 m (earth shoulder)+0.75 m (lateral clear width)+3.75 m (motorway)+3.75 m (motorway)+0.75 m (lateral clear width)+0.5 m (earth shoulder)=10 m.

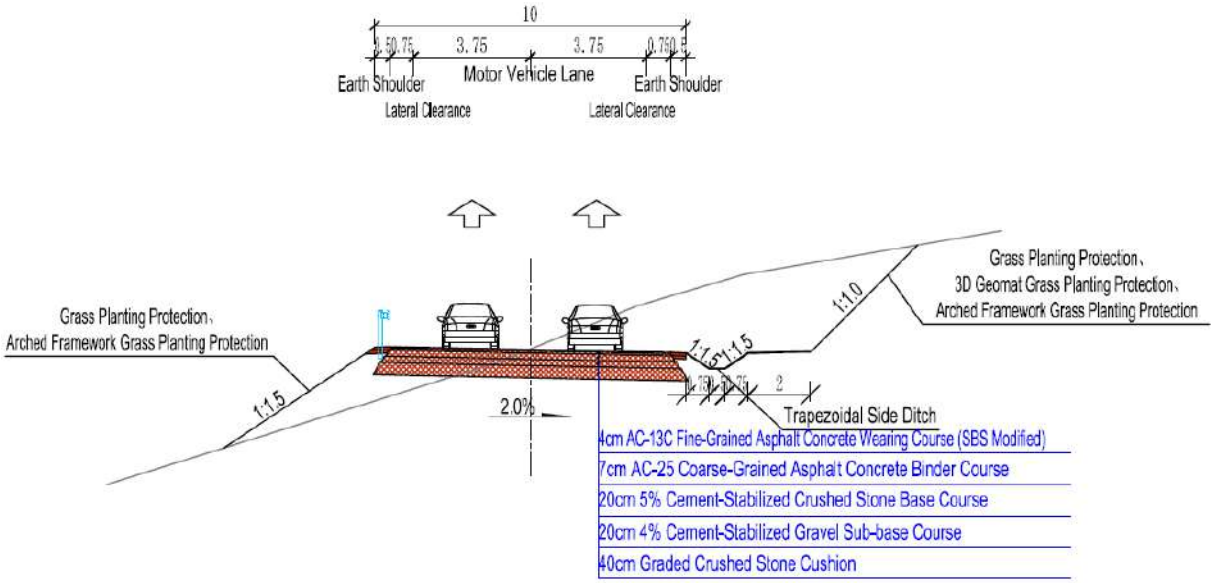


Figure 3. 30. Standard Cross Section of Ramps B, C, D, and E of the Interchange between the New Ring Road and the East Side of the Second Ring Road

(7) Interchange between the New Ring Road and the Police Academy Avenue

The width of the interchange ramp between the New Ring Road and the Police Academy Avenue is 9 m, and it is single-way two lane road. The specific section form is as below: 0.5 m (anti-collision guardrail)+0.5 m (lateral clear width)+3.5 m (motorway)+3.5 m (motorway)+0.5 m (lateral clear width)+0.5 m (anti-collision guardrail)=9 m.

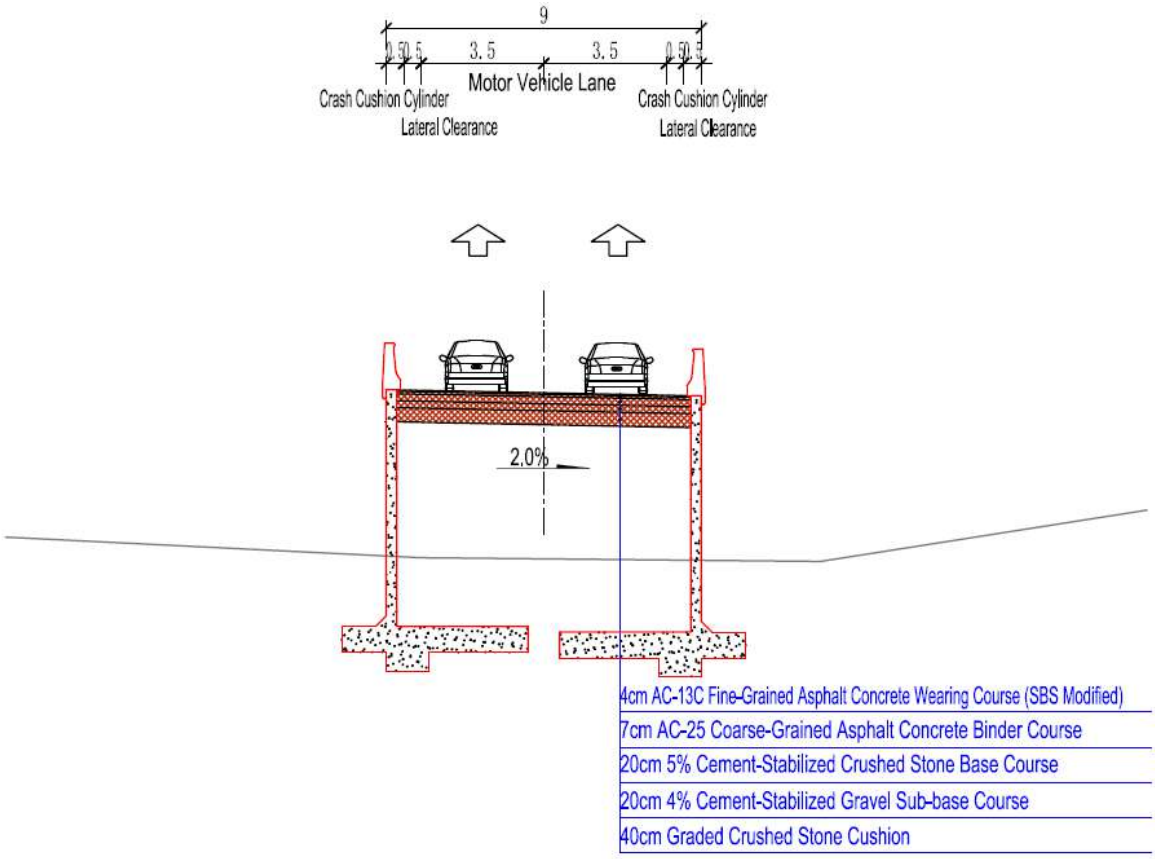


Figure 3. 31. Standard Cross Section of Ramps of the Interchange between the New Ring Road and the East Side of the Second Ring Road

(8) East side interchange between the New Ring Road and the Tuul Expressway

1) The width of ramp A of the Interchange between the New Ring Road and the east side of the Tuul Expressway is 20 m, and it is a two-way four lane road. The specific section form is as below: 0.5 m (earth shoulder)+0.75 m (lateral clear width)+3.75 m (motorway)+3.75 m (motorway)+0.75 m (marginal strip)+1 m (strip)+0.75 m (marginal strip)+3.75 m (motorway)+3.75 m (motorway)+0.75 m (lateral clear width)+0.5 m (earth shoulder)=20 m.

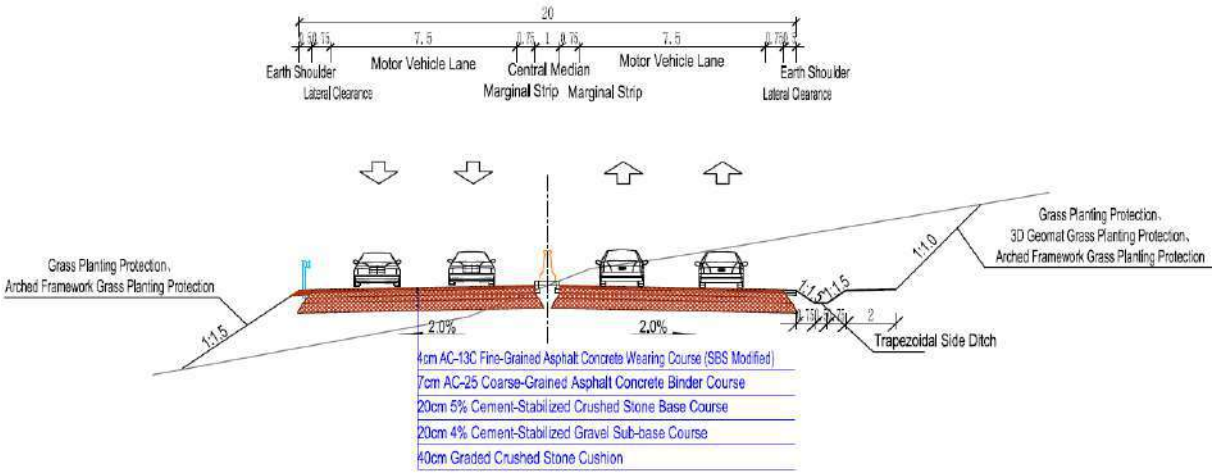


Figure 3. 32. Standard Cross Section of Ramp A of the Interchange between the New Ring Road and the East Side of the Tuul Expressway

2) The width of the ramps B, C, D, and E of the Interchange between the New Ring Road and the east side of the Tuul Expressway is 10 m, and it is single-way two lane road. The specific section form is as below: 0.5 m (earth shoulder)+0.75 m (lateral clear width)+3.75 m (motorway)+3.75 m (motorway)+0.75 m (lateral clear width)+0.5 m (earth shoulder)=10 m.

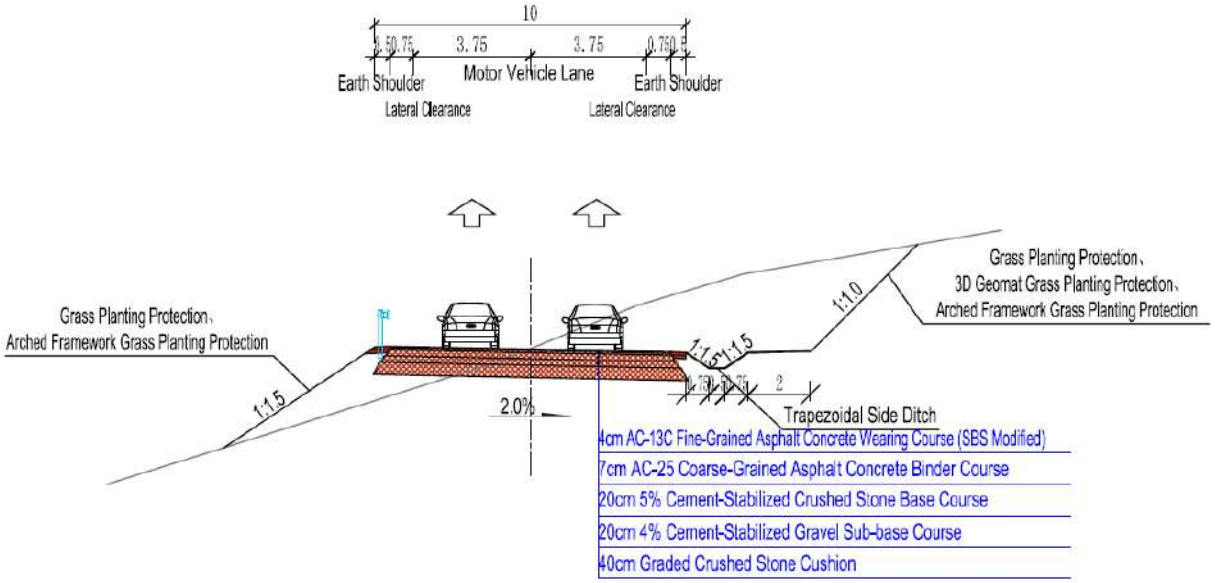


Figure 3. 33. Standard Cross Section of Ramps B, C, D, and E of the Interchange between the New Ring Road and the East Side of the Tuul Expressway

3.2.4. Road intersection design

3.2.4.1 Design principle

Intersections are important components of roads and play a crucial role as hubs in the road network. At the time of design, general principles of road design are to be followed. Considering that intersection engineering is a comprehensive and complex engineering involving road routes,

roadbeds, pavements, bridges, and various transportation facilities, the following principles are also to be followed.

(1) Principle of functionality

Intersection is an important facility for vehicle traffic transition on the road, and thus its design is to first meet the requirements of its traffic function:

① Driving safety is ensured and traffic accidents are reduced at intersections;

② Vehicles travel quickly and smoothly with short and convenient routes, minimizing delays at intersections as much as possible;

③ The direction of the driving route is clear;

④ Clear priorities are set, and the smooth flow of major transportation is first ensured;

⑤ The traffic capacity is large and can meet the requirements of long-term design traffic.

(2) Principle of economy

On the premise of ensuring traffic functions and meeting driving requirements, intersection engineering is to save costs as much as possible to meet the requirements of being economical and saving:

① Small investment and low engineering costs;

② Little demolition and land occupation;

③ Operation costs, fuel consumption, wheel wear, and vehicle damage during vehicle operation are minimized;

④ The lowest maintenance and management expenses.

(3) Principle of adaptability

As intersections are of a strong regional nature, their design is to be adapted to the local conditions, and their main requirements are as below:

① The intersection scheme and layout are flexible and adaptable to local conditions, and are to be compatible with the surrounding environmental, natural, social, and economic conditions and the like;

② Intersections are to be adapted to their position and role in the road network, and play their due functions in the road network;

③ Intersections are to be adapted to the surrounding land use, development, and economic development;

④ Intersection planning is to be adapted to regional planning and regional transportation planning.

(4) Principle of aesthetics

The completed intersection is one of the artificial environments that make up the region. Therefore, intersection design is to meet the following requirements:

① The shape and structure is to ensure the perfection of its own architectural art and have its unique artistic style;

② Attention is to be paid to coordinating with regional construction and natural scenery, so as to achieve a natural beauty that is in harmony with the outside world;

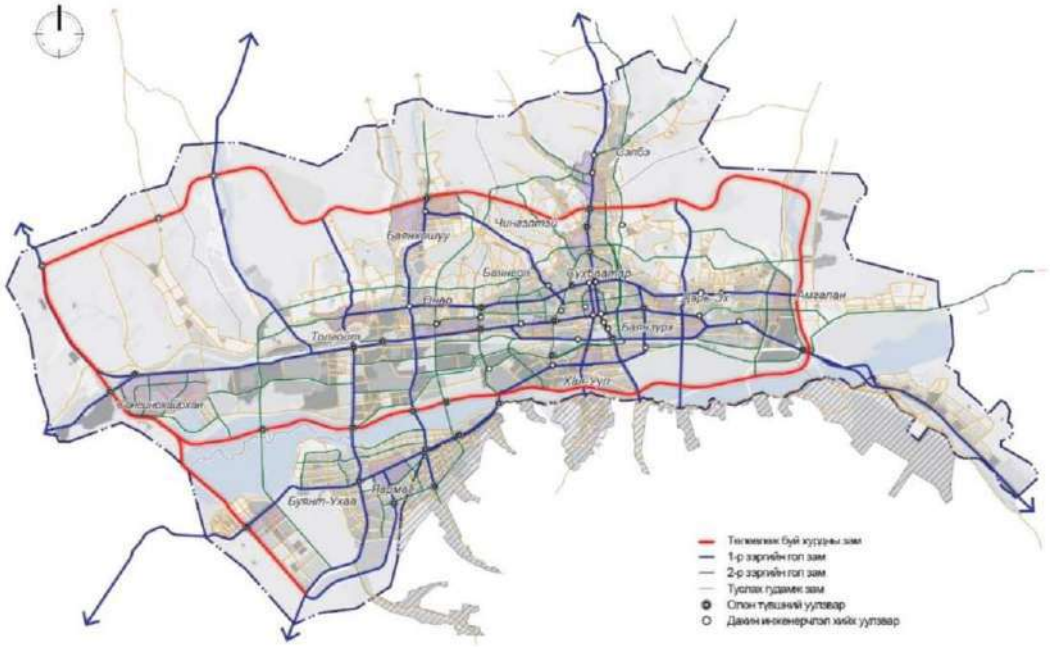
③ The construction of intersections is not allowed to weaken or damage the natural landscape of the region.

3.2.4.2 Interchange Design

(1) Selection of the interchange location

1) Planning basis

According to the Overall Urban Development Plan of Ulaanbaatar until 2040, the street network of Ulaanbaatar City is composed of main trunk roads and side roads in horizontal, vertical, and circular directions, connecting residential areas, architectural complexes, industrial areas, mixed use areas, urban public centers, and green facilities, and it will form a main urban trunk road network of 8 transverse and 12 longitudinal roads.



This project is an important component of the entire urban road network in Ulaanbaatar, which can improve the road network structure, expand urban space, and drive the development of peripheral satellite cities.

This project is connected to the Tuul Expressway on the south side and the planned Second Ring Road on the east and west sides, serving as an important transition hub for urban transportation and peripheral transit traffic; residents in the northern Mongolian yurt area and urban new city can use the proposed road to realize rapid travel, with significant transportation functions. Meanwhile, the New Ring Road also passes through the east and west urban built-

up areas, and the ground side roads on both sides of the viaduct serve the daily life and travel of residents along the route.

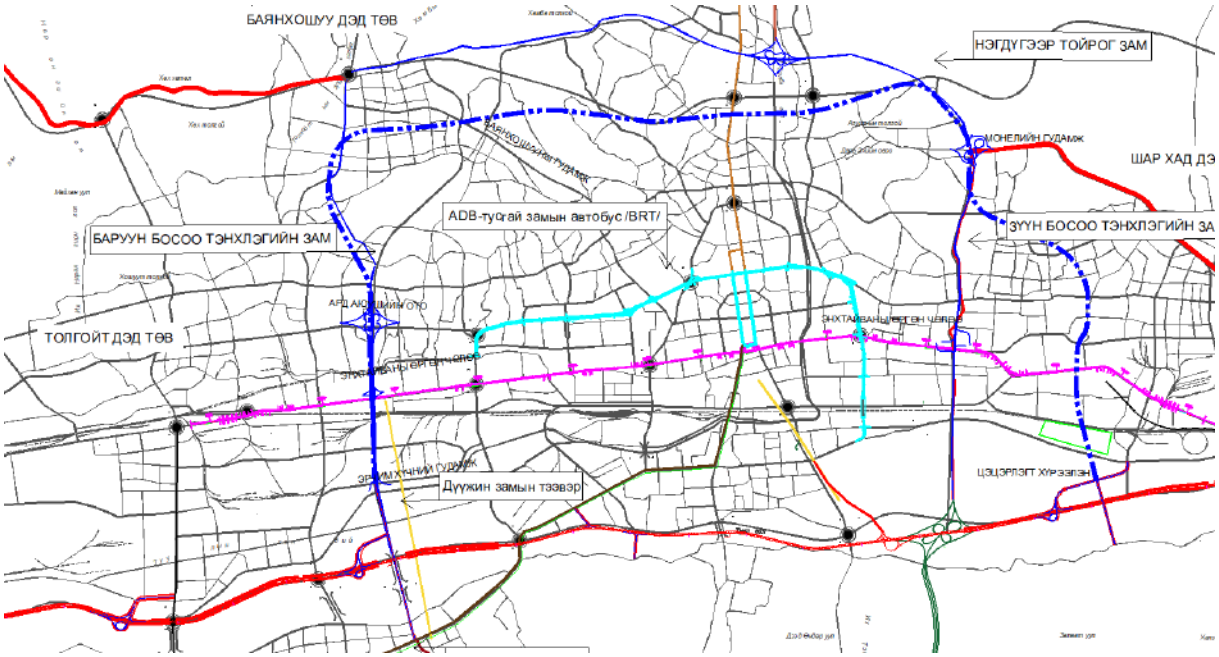


Figure 3. 34. New Planned Line Position for the New Ring Road Project

In the Overall Urban Development Plan of Ulaanbaatar until 2040, urban road traffic intensity is balanced and traffic capacity is improved through construction of overhead intersections at traffic congestion points. Figure 3.34 shows the latest planned line position of the New Ring Road project. It can be seen from the figure that there are a total of 8 planned interchanges along the project route, including the intersection with the existing Moscow Street, the intersection with Ard Ayush Road under construction, the intersection with the west side of the planned Second Ring Road, the intersection with the existing Doloon Buudal road, the intersection with the existing Dari-Ekh street, the intersection with the east side of the planned Second Ring Road, the intersection with the existing Police Academy Avenue, and the intersection with the planned Tuul Expressway.

2) Grade of the intersecting road

According to figure 3.2.4-1, there are a total of 7 main trunk roads intersecting with the New Ring Road, with 8 intersecting locations. The situations of the intersecting main trunk roads are shown in the table below.

Table 3. 26. Main Trunk Roads Intersected along the Route

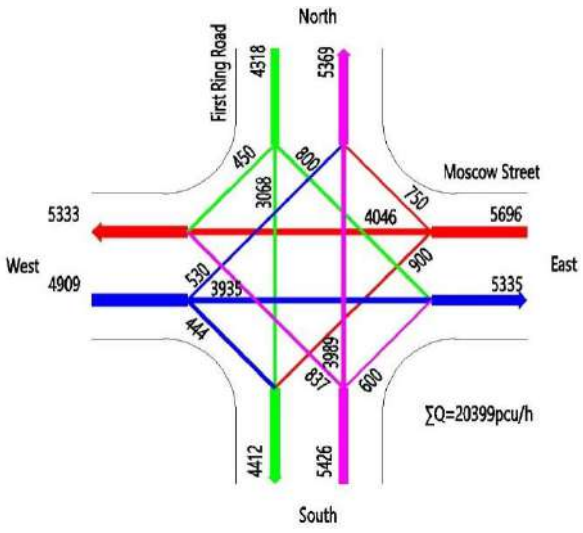
No.	Name	Grade	Number of lanes (two-way)	Current situations
1	Moscow Street	Grade-1 main trunk road	6	Existing
2	Ard Ayush Road	Grade-1 main trunk road	6	Under construction

No.	Name	Grade	Number of lanes (two-way)	Current situations
3	Second Ring Road	Expressway	6	Planned
4	Doloon Buudal road	Grade-1 main trunk road	4	Existing
5	Dari-Ekh street	Grade-2 main trunk road	2	Existing
6	Police Academy Avenue	Grade-1 main trunk road	6	Existing
7	Tuul Expressway	Expressway	6	Planned

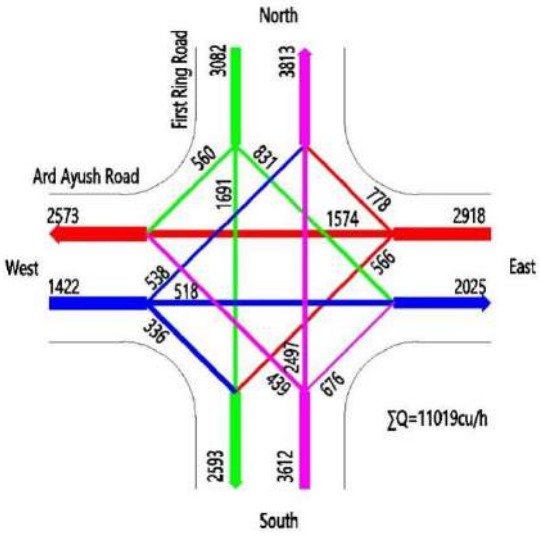
The New Ring Road and the above roads are important components of the framework road network in Ulaanbaatar City, serving as important carriers for urban and peripheral transit traffic. Considering the critical position of nodes in the urban road network and the importance of node traffic functions, it is necessary to set up interchanges at these intersections.

3) Prediction of the traffic volume at major intersections

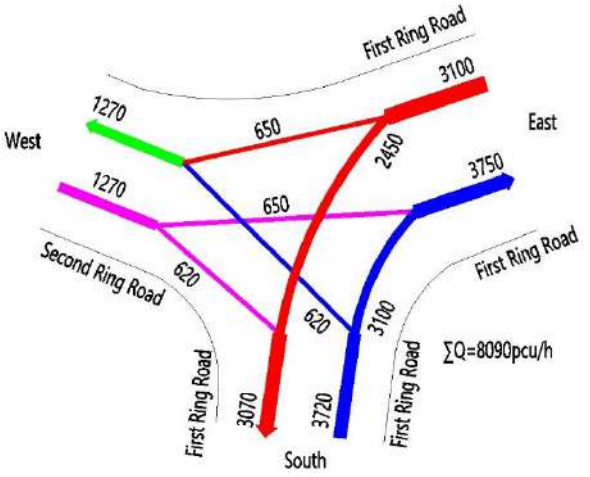
The traffic forecast results for major intersections along the New Ring Road are as follows:



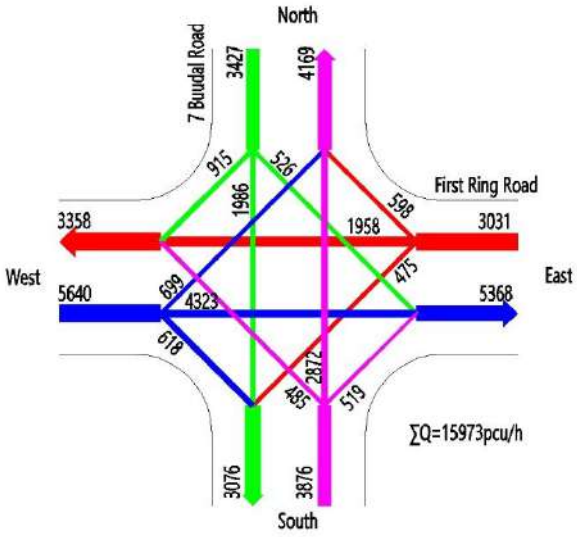
Intersection between the New Ring Road and the Moscow Street



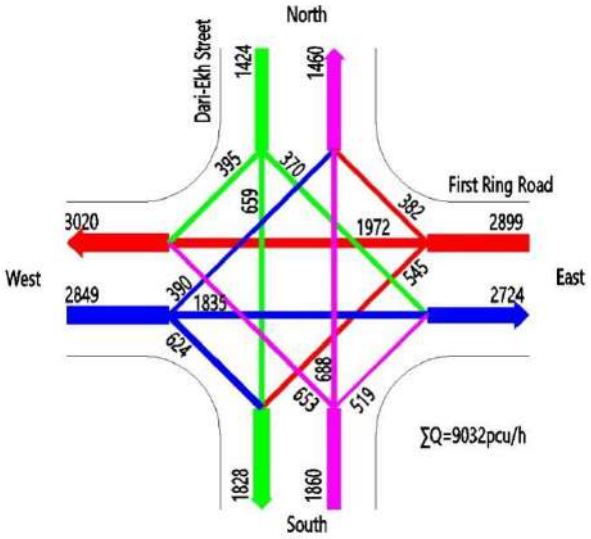
Intersection between the New Ring Road and the Ard Ayush Road



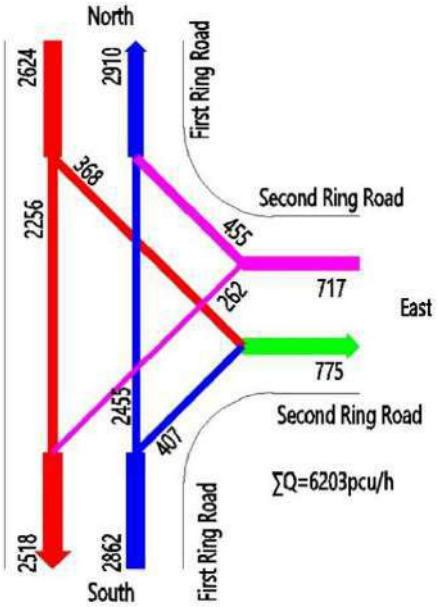
Intersection between the New Ring Road and the West Side of the Second Ring Road



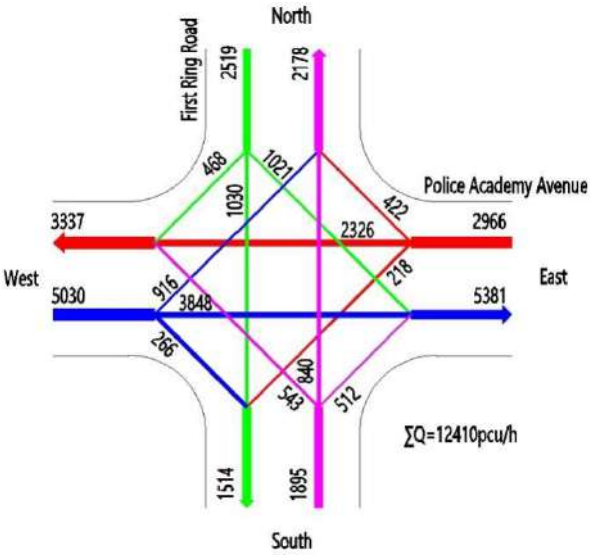
Intersection between the New Ring Road and the Doloon Buudal road



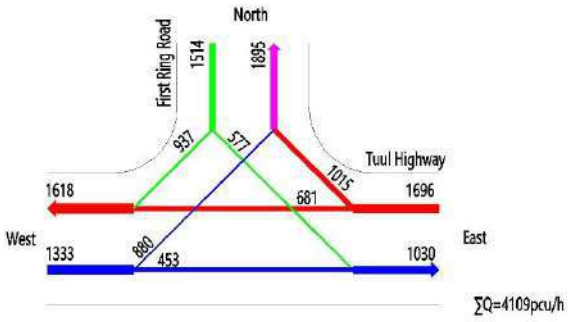
Intersection between the New Ring Road and the Dari-Ekh street



Intersection between the New Ring Road and the East Side of the Second Ring Road



Intersection between the New Ring Road and the Police Academy Avenue



Intersection between the New Ring Road and the Tuul Expressway

Figure 3. 35. Predicted Traffic Volume at Major Intersections along the Route

comparison of the service level grades of the level crossing scheme and the overhead crossing scheme in the long-term planning year, it can be concluded that by 2044, the service level requirements cannot be satisfied if the level crossing scheme is used at the above intersections. Therefore, the form of interchange is to be adopted at above intersections.

4) Comprehensive selection of interchange locations

According to the location of planned interchanges, the grade of intersecting roads along the route, and the predicted traffic volume at major intersections described in the Overall Urban Development Plan of Ulaanbaatar until 2040, it is recommended to set up interchanges at the following intersections:

① Intersection between the New Ring Road and the Moscow Street;

② Intersection between the New Ring Road and the Ard Ayush Road;

③ Intersection between the New Ring Road and the west side of the Second Ring Road;

④ Intersection between the New Ring Road and the Doloon Buudal road;

⑤Intersection between the New Ring Road and the Dari-Ekh street;

⑥ Intersection between the New Ring Road and the east side of the Second Ring Road;

⑦ Intersection between the New Ring Road and the Police Academy Avenue;

⑧ Intersection between the New Ring Road and the Tuul Expressway.

(1) Interchange scheme design

1) Interchange between the New Ring Road and the Moscow Street

① Construction conditions

The main road of the New Ring Road crosses over the existing two-way internal combustion

railway at K1+566.775 and crosses over the existing Moscow Street at K1+817.494. The intersection between the New Ring Road and Moscow Street, with the current river on the west side, has high-rise buildings in the first, second, and fourth quadrants. There are also 220 KV high-voltage iron towers arranged along both sides of the river on the west side of the road, making demolition extremely difficult. The underground of Moscow Street is the subway line that is about to be constructed.

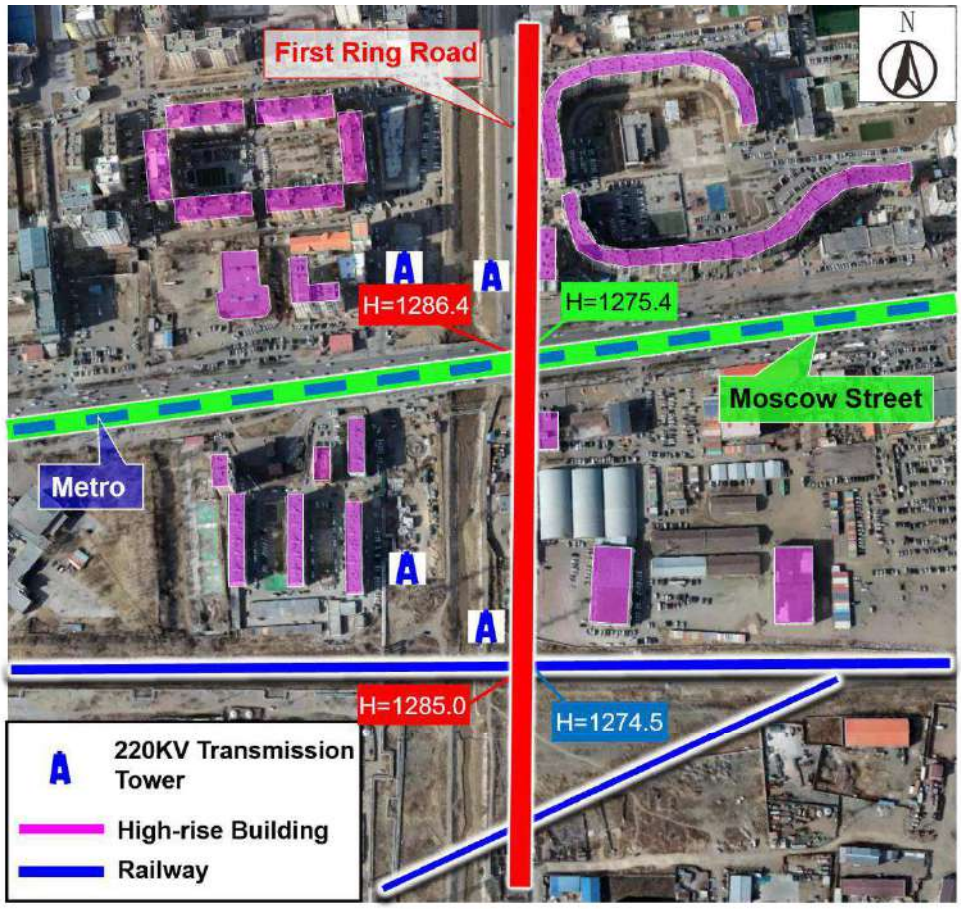


Figure 3. 36. Construction Conditions of the Interchange between the New Ring Road and the Moscow Street

② Prediction of the traffic direction and volume

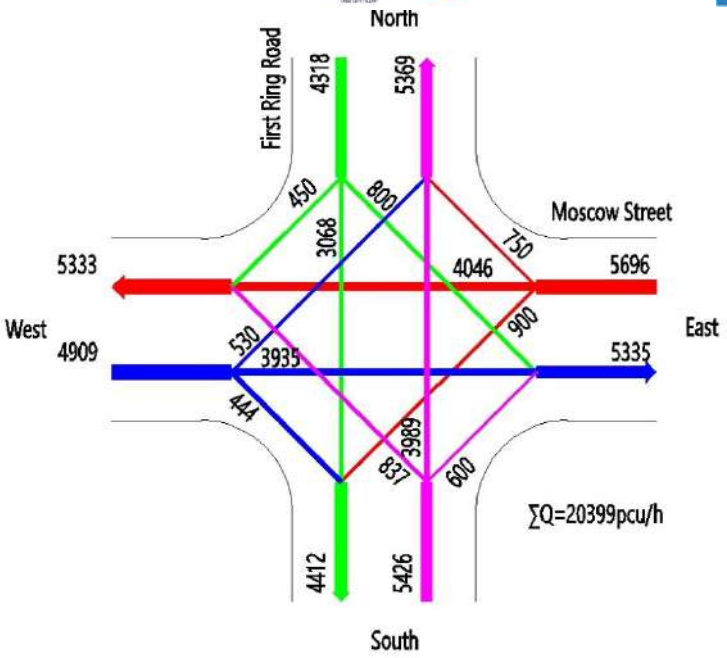


Figure 3. 37. Traffic Direction and Volume Figure at the Interchange between the New Ring Road and Moscow Street

③ Scheme design

A. Scheme I (separated interchange)

According to the reply letter (No. 02/603) from the National Power Transmission Grid State Owned Joint Stock Company in Mongolia, the 220 KV high-voltage iron tower on the west side of the road cannot be relocated, and the height of the high-voltage wire from the ground is only 13.27 m. If a ramp is arranged on the west side of the road, the horizontal safety distance and clearance from the high-voltage wire do not meet the requirements of Article 1.5.20 of the Mongolian Specification 33БНбД 22-004-2016 Road design.

There are lots of high-rise residential buildings on the north side of the intersection, with difficulty in demolition, and there is also no space for the layout of ramps.

Therefore, Scheme I adopts a separated interchange with the main road of the New Ring Road crossing over the Moscow Street. The ground level side road of the New Ring Road level intersects with Moscow Street, and the ground level intersection is used for traffic transition.

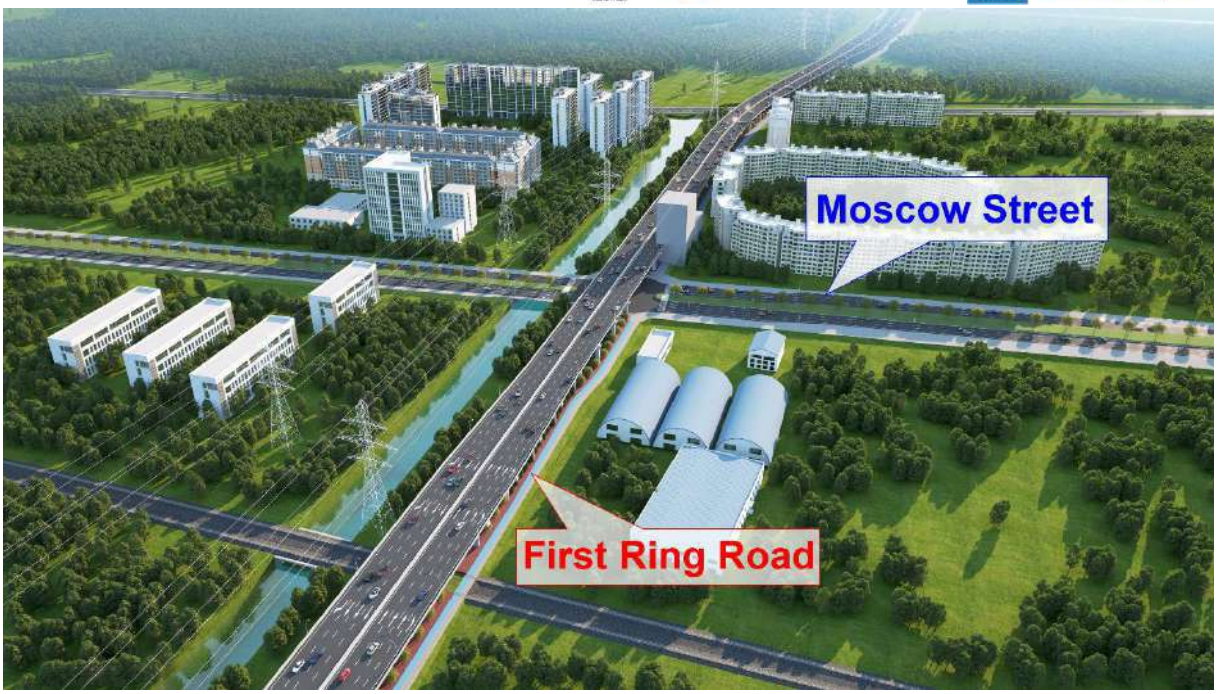


Figure 3. 38. Separation Interchange between the New Ring Road and the Moscow Street (Scheme I)

B. Scheme II (simple diamond interchange)

In the future, after the 220 KV high-voltage iron tower on the west side of the New Ring Road can be relocated, space will be created on the south side of the New Ring Road to arrange ramps.

Based on the results of predicted traffic volume and the presence of many high-rise buildings in the surrounding area, Scheme II adopts a simple diamond interchange with the New Ring Road crossing over the Moscow Street.

According to "The railway clearance is required to be 7.01 m" in Article 3.11 of the Mongolian Specification 33БНбД 22-004-2016 Road design, the design elevation value for the main road of the New Ring Road crossing over the railway on is 1,285.0 m. The current elevation of Moscow Street is 1,275.4 m, only 220 m away from the southern railway. If the two ramps on the south side are parallel to the main road, their average longitudinal slope is 4.36%, which exceeds the requirements stated in Article 1.6 "The longitudinal slope of the bridge should not exceed 4%" of the Mongolian Specification БНбД 32-02-12 Road bridge and culvert design. Therefore, the two ramps on the south side are connected to Moscow Street by turning to reduce the longitudinal slope value of the ramps.

Due to the sudden elevation of the terrain on the north side of the intersection, after crossing the intersection, the main road of the New Ring Road adopts a longitudinal slope value of 3.8% to climb 250 m north. If the two ramps on the north side are parallel to the main road, due to the slope and height difference, it will result in a longer ramp length and higher project cost; If the turning method is used, it will result in the demolition of high-rise buildings and 220 KV high-

voltage iron towers on both sides. Therefore, the two ramps on the north side will be designed together with the ramp at K3+024.8 interchange.

The detailed design of this scheme is shown in the drawing below.

Figure 3. 39. Interchange between the New Ring Road and the Moscow Street (Scheme II)

The traffic organization method of this scheme is shown in the figure below.

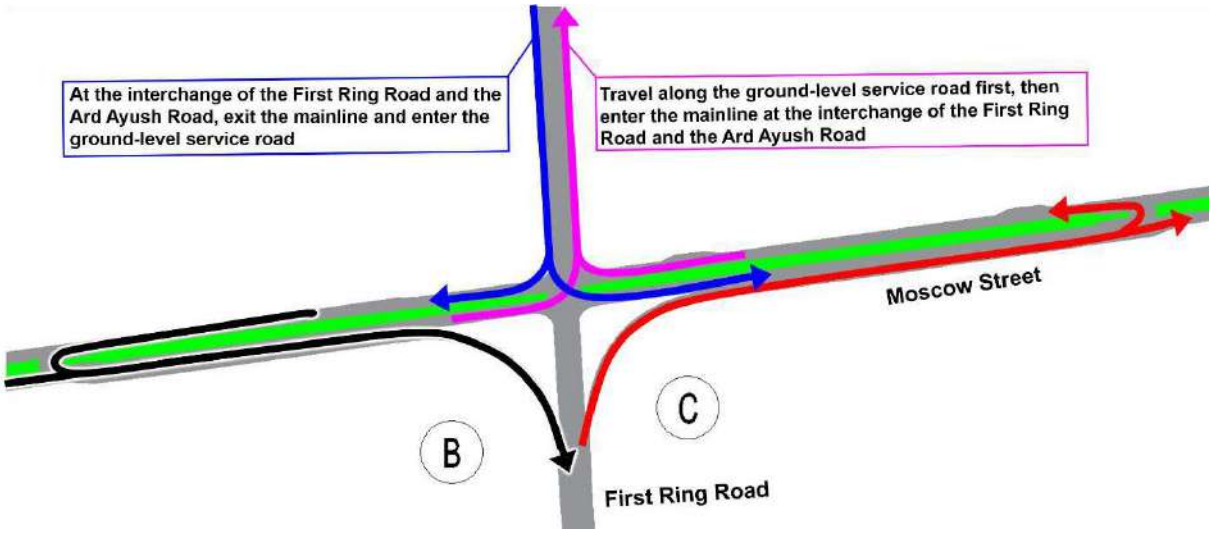


Figure 3. 40. Traffic Organization Chart for the Interchange between the New Ring Road and the Moscow Street (Scheme II)

C. Scheme III (variant cloverleaf interchange)

In the future, the 220 KV high-voltage iron tower on the west side of the New Ring Road will be relocated, and the high-rise buildings on the north side of the New Ring Road can be

demolished. There will be no restrictions around the intersection, and ramps can be arranged in all four directions.

Scheme III adopts a variant cloverleaf interchange with the New Ring Road crossing over the Moscow Street. The ramp A solves the problem of left turn traffic from north to east and adopts a directional ramp form. After crossing over the Moscow Street, it goes under the ramp F, the New Ring Road, and the entrance section of ramp B, then crosses over the exit section of ramp B, and finally connects to Moscow Street. The ramp B solves the problem of left turn traffic from west to north and adopts a circular ramp form. After separating from Moscow Street, it crosses over ramps G and A, and finally connects to the main road of the New Ring Road. The ramp C solves the problem of left turn traffic from south to wes and adopts a circular ramp form.

After separating from the main road of the New Ring Road, it crosses over the entrance sections of ramps D and H, then goes under the exit section of the ramp H, and finally connects to Moscow Street. The ramp D solves the problem of left turn traffic from east to south and adopts a directional ramp form. It separates from Moscow Street together with the ramp H, crosses over the entrance section of the ramp C, goes under the exit section of the ramp C, the main road of the New Ring Road, and Moscow Street, merges with the ramp F, crosses over the ramp A, and merges with the main road of the New Ring Road. Ramps E, F, G, and H solve the problem of right turn traffic in four directions.

Figure 3. 41. vInterchange between the New Ring Road and the Moscow Street (Scheme III)

D. Comparison of advantages and disadvantages of schemes

Table 3. 27. Comparison of Advantages and Disadvantages of Schemes

Item	Scheme I	Scheme II	Scheme III
Engineering cost	0 (no ramp is set up, and no separate engineering quantity is generated)	22,348,776 USD	89,850,907 USD
Land area	0 (no ramp is set up, and no separate land area is generated)	2258 m^2	31086 m^2
Demolition area	0 (no ramp is set up, and no separate demolition quantity is generated)	3194 m^2	32832 m^2
Advantages	Lowest engineering cost, smallest footprint, and least impact on the demolition of 220 KV high-voltage iron towers and high-rise buildings	Simple form, less land occupation, and lower project cost	Fast transition of traffic in all directions can be solved
Disadvantages	Traffic transition through level intersections, poor traffic capacity	Average traffic capacity	Large land area, large number of demolitions, and high engineering cost
Conclusions	As the 220 KV high-voltage iron tower cannot be relocated and surrounding high-rise buildings are difficult to be demolished, it is recommended to adopt Scheme I.		

2) Interchange between the New Ring Road and the Ard Ayush Road

① Construction conditions

The New Ring Road crosses over the Ard Ayush Road under construction at K3+024.8, with a design height difference of 6.8 m. The north and south sides of the intersection are both Mongolian yurt areas, with the north side having a higher terrain and the south side having a lower terrain. On both sides of the intersection, in order to ensure the smooth operation of the current village road, two frame bridges with a length of 35 m have been installed on the Ard Ayush Road under construction.

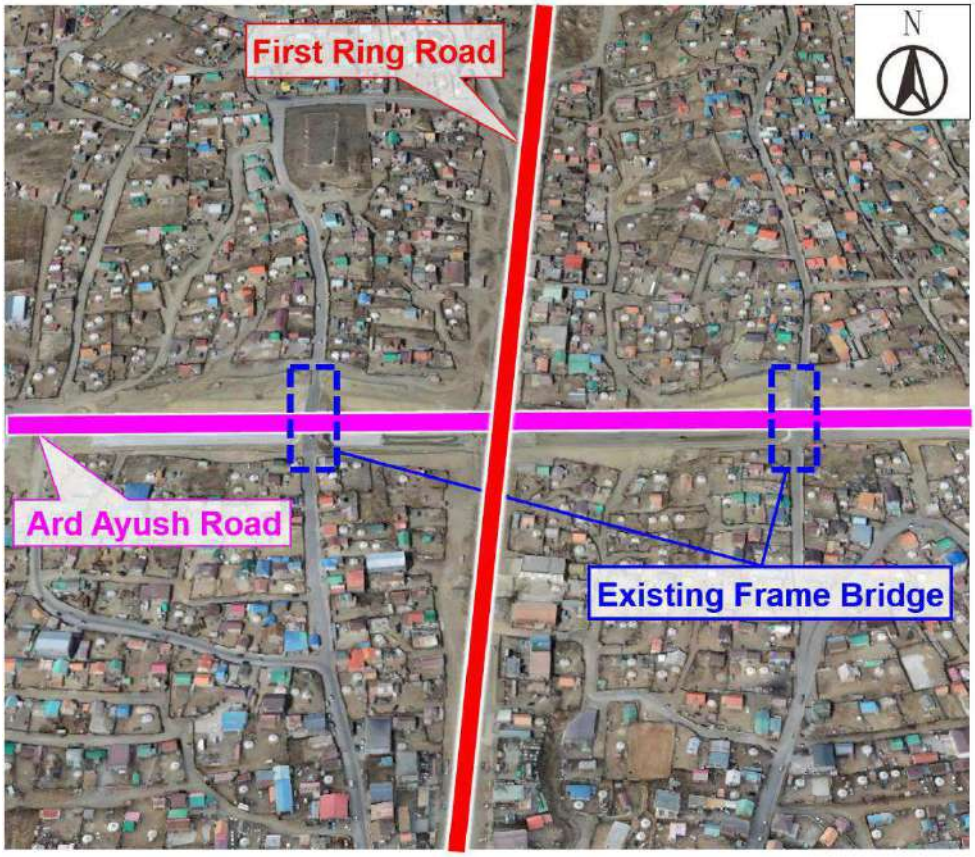


Figure 3. 42. Construction Conditions for the Interchange between the New Ring Road and the Ard Ayush Road

② Prediction of the traffic flow direction and volume

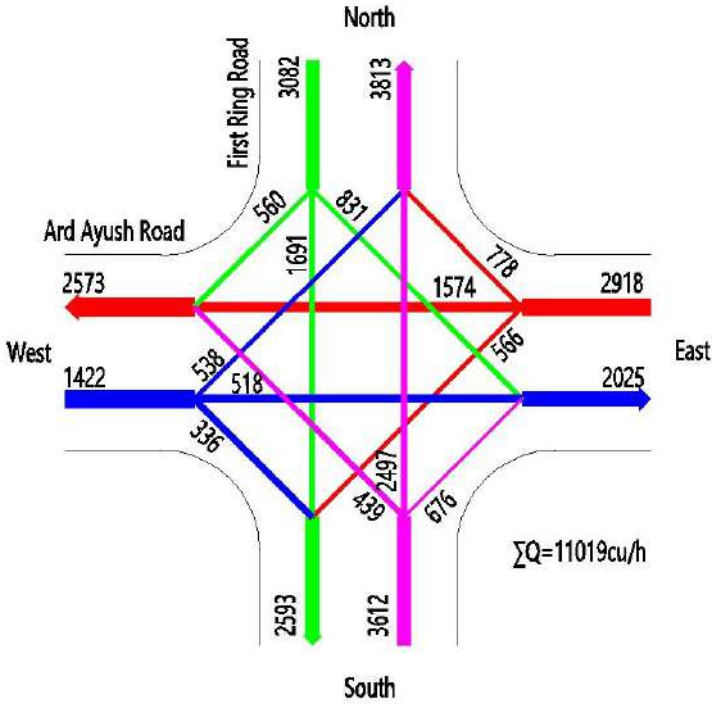


Figure 3. 43. Traffic Direction and Volume Figure at the Interchange between the New Ring Road and

③ Scheme design

A. Scheme I (diamond interchange)

Based on the results of predicted traffic volume and the presence of new frame bridges in the surrounding area, Scheme I adopts a simple diamond interchange with the New Ring Road crossing over the Ard Ayush Road.

Two ramp bridges parallel to the main road of the New Ring Road are set up on the south side, connecting to the ground intersection of Ard Ayush Road. Due to the high terrain on the north side of the intersection, the main road of the New Ring Road adopts a 2.8% longitudinal slope for climbing. If the two ramps on the north side are connected to the main road in the form of bridges, according to Article1.6 "The longitudinal slope of the bridge shall not exceed 4%" in Mongolian regulations БНбД 32-02-12 Road bridge and culvert design, it will result in the bridge length being too long and the project cost being too high. Therefore, the two ramps on the north side will be connected to the main road after climbing the slope using the subgrade method.

Figure 3. 44. Interchange between the New Ring Road and the Ard Ayush Road (Scheme I)

B. Scheme II (cloverleaf interchange)

Scheme II adopts a cloverleaf interchange with the New Ring Road crossing over the Ard Ayush Road. The left turn ramps are all circular ramps, and the right turn ramps are all directional ramps. Based on traffic prediction results and ramp capacity, the number of lanes on the ramps is calculated and determined separately. The auxiliary route of the New Ring Road has been

adjusted and optimized, and the existing framework bridge is utilized to cross over the Ard Ayush Road and guarantee smooth passage of the village road.

Figure 3. 45. Interchange between the New Ring Road and the Ard Ayush Road (Scheme II)

C. Comparison of advantages and disadvantages of schemes

Table 3. 28. Comparison of Advantages and Disadvantages of Schemes

Item	Scheme I	Scheme II
Engineering cost	3,903,831 USD	14,262,934 USD
Land area	0 (the ramp is parallel to the main road and within the scope of land acquisition on the main road, and there will be no separate land acquisition)	66051 m^2
Demolition area	0 (the ramp is parallel to the main road and within the scope of demolition on the main road, and there will be no separate demolition)	11,349 m^2
Advantages	Compact structure, minimal footprint, and low construction cost	The traffic flow in all directions can quickly change with high traffic capacity
Disadvantages	Moderate traffic efficiency	Large land area, large demolition area, and high engineering cost
Conclusions	Scheme I is recommended	

3) Interchange between the New Ring Road and the west side of the Second Ring Road

① Construction conditions

At the intersection between the New Ring Road and the west side of the Second Ring Road, the terrain is relatively flat, with Bayankhoshuu New City to the north. The original planned location of the Second Ring Road was on the north side of the intersection. The main road of the New Ring Road crosses over the existing Bayankhoshuu Street twice.

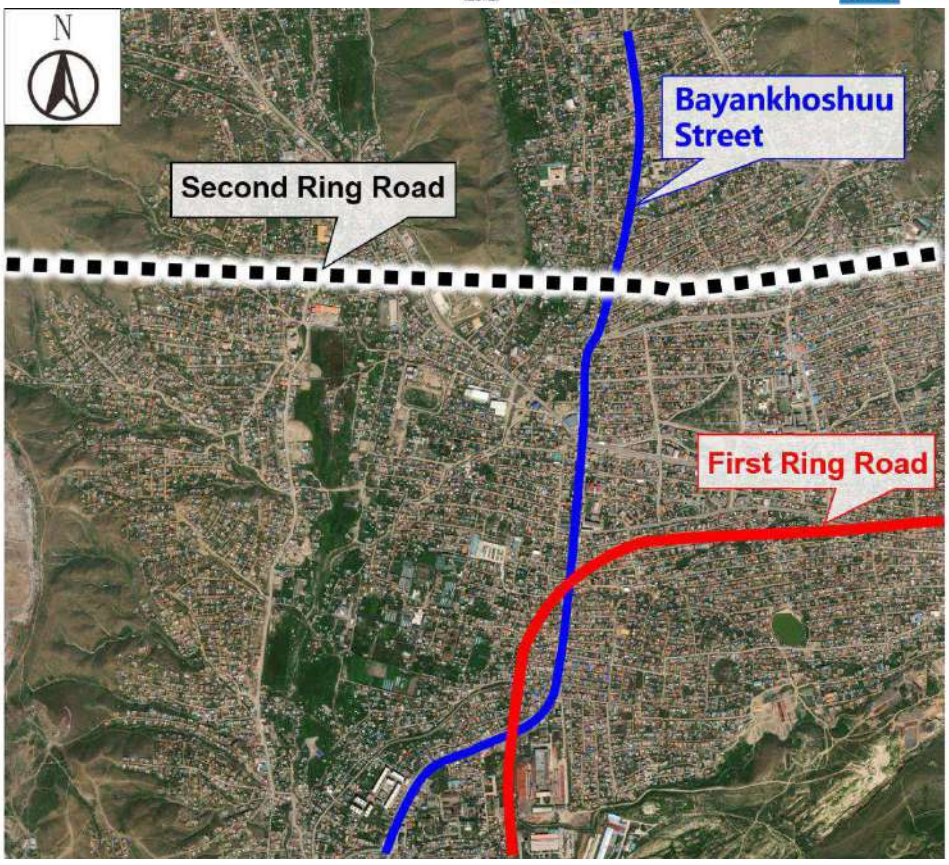


Figure 3. 46. Construction Conditions for the Interchange between the New Ring Road and the West Side of the Second Ring Road

② Prediction of the traffic flow direction and volume

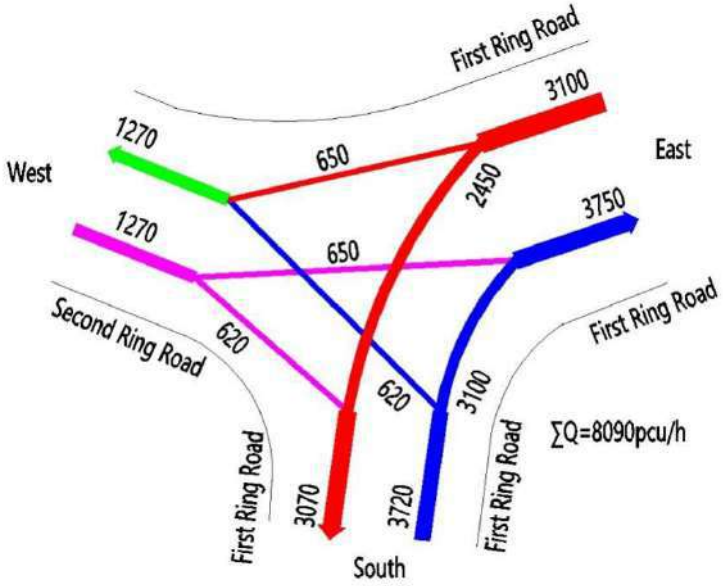


Figure 3. 47. Traffic Direction and Volume Figure at the Interchange between the New Ring Road and the West Side of the Second Ring Road

③ Scheme design

Considering the effective connection with the Second Ring Road, based on the regional

planning layout, road network structure, and terrain conditions, access points have been reserved and the following two schemes have been designed.

A. Scheme I (single horn interchange)

Based on the prediction results of traffic volume and the surrounding construction conditions, Scheme I adopts a single horn interchange with the New Ring Road crossing over the Second Ring Road. At the north and south ends of the intersection, the New Ring Road level intersects with the existing Bayankhoshuu Street through side roads.

The ramp A adopts a directional ramp to solve left turn traffic from south to west. After separating from the main road of the New Ring Road, the ramp A crosses Bayankhoshuu street and then underpasses the main road of the New Ring Road to enter the Second Ring Road. The ramp B adopts a circular ramp to solve the traffic problem of turning left on the Second Ring Road into New Ring Road. The ramp B runs under the main road of the New Ring Road, crosses Bayankhoshuu street, and then merges into the main road. The ramp D serves the traffic entering the Second Ring Road from east to west on New Ring Road. The ramp E serves the traffic entering New Ring Road from west to south on the Second Ring Road. Meanwhile, the traffic between Bayankhoshuu street and the Second Ring Road can be converted through ramps F and G.

Figure 3. 48. Interchange between the New Ring Road and the West Side of the Second Ring Road (Scheme I)

B. Scheme II (Y-shaped interchange)

Scheme II adopts a Y-shaped interchange with the New Ring Road crossing over the Second Ring Road.

Vehicles on New Ring Road can turn left and enter the Second Ring Road through ramp A. Vehicles on Second Ring Road can turn left and enter New Ring Road through ramp B. The ramps C and D serve the right turn traffic between the New Ring Road and the Second Ring Road. By setting up ramps E and F, traffic can be converted between Bayankhoshuu street and the Second Ring Road.

At the north and south ends of the intersection, the New Ring Road level intersects with the existing Bayankhoshuu Street through side roads.

Figure 3. 49. Interchange between the New Ring Road and the West Side of the Second Ring Road (Scheme II)

C. Comparison of advantages and disadvantages of schemes

Table 3. 29. Comparison of Advantages and Disadvantages of Schemes

Item	Scheme I	Scheme II
Engineering cost	23,688,763 USD	38,017,371 USD
Land area	54869 m^2	58798 m^2
Demolition area	21900 m^2	29405 m^2
Advantages	Simple form, short bridge length, and lower project cost	Good ramp alignment indicators and high traffic efficiency
Disadvantages	Average efficiency of circular ramp traffic	Multi-story structure, long bridge length, complex construction, and high engineering cost
Conclusions	Scheme I is recommended	

4) Interchange between the New Ring Road and the Doloon Buudal road

① Construction conditions

Near the intersection, there is a significant change in terrain, with the overall area being

higher in the west and lower in the east. To the west, there is a mountain 2.1 km away, and to the east, there is the Selene River 0.7 km away. The north and east sides are the Selebe New City, the south side is the main urban area of Ulaanbaatar City, and the west side is the Mongolian yurt area. The existing No. 7 Road is the only north-south transportation artery in Ulaanbaatar City currently, connecting the main urban area of Ulaanbaatar with the Selbe New City.

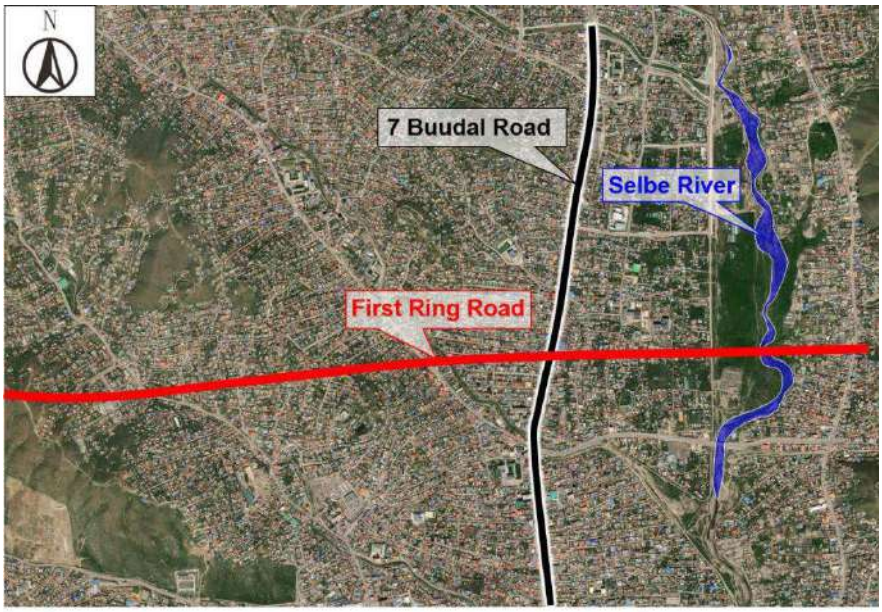


Figure 3. 50. Construction Conditions for the Interchange between the New Ring Road and the Doloon Buudal road

② Prediction of the traffic flow direction and volume

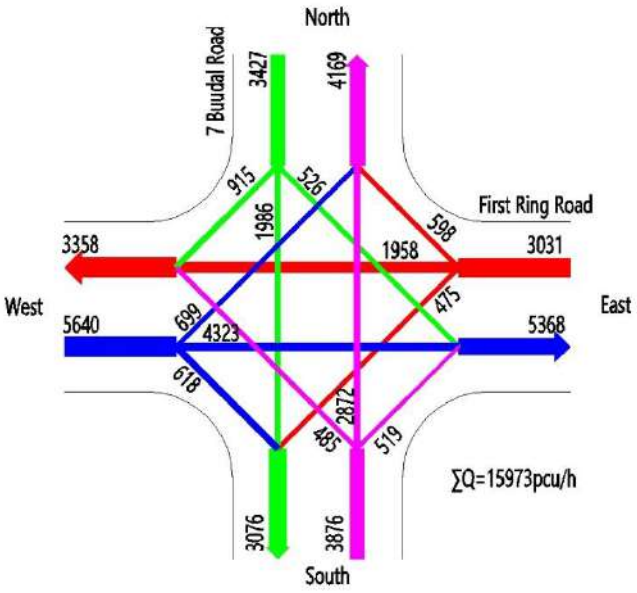


Figure 3. 51. Traffic Direction and Volume Figure at the Interchange between the New Ring Road and the Doloon Buudal road

③ Scheme design

A. Scheme I (partial cloverleaf interchange)

Due to the high terrain on the west side of the intersection, the main road adopts a 3.8% longitudinal slope. If a ramp is set up on the west side, it will cause the bridge length to be too long and the engineering cost to be too high. Therefore, Scheme I adopts a simple cloverleaf interchange with the New Ring Road crossing over Doloon Buudal road.

The ramps A and D level intersect with the Doloon Buudal road level, allowing vehicles to turn left and right, and then pass through the ramps B, C, E, and F to enter and exit New Ring Road.

Figure 3. 52. Interchange between the New Ring Road and the Doloon Buudal road (Scheme I)

B. Scheme II (single horn interchange)

Similarly, due to the terrain and longitudinal slope of the main road, no ramp is set up on the west side. Scheme II adopts a single horn interchange with the New Ring Road crossing over the Doloon Buudal road.

Vehicles can turn left and right at the level intersection between ramp A and Doloon Buudal road, and then use ramps B, C, D, and E to enter and exit New Ring Road.

Governor's Office of the Capital City

INTEGRATED PROJECT MANAGEMENT OFFICE

CSCEC AECOM Consultants Co., Ltd

FEASIBILITY STUDY & CONCEPT DESIGN

"FIRST RING ROAD" project

Engineering report Volume I-II

Ulaanbaatar
2025

Figure 3. 53. Interchange between the New Ring Road and the Doloon Buudal road (Scheme II)

C. Comparison of advantages and disadvantages of schemes

Table 3. 30. Comparison of Advantages and Disadvantages of Schemes

Item	Scheme I	Scheme II
Engineering cost	23,349,046 USD	60,523,785 USD
Land area	13378 m^2	17640 m^2
Demolition area	3099 m^2	4419 m^2
Advantages	Simple form, small project scale, and low cost	Relatively simple traffic organization
Disadvantages	Two level intersections are set with complex traffic organization	Large land area, long bridge length, and high engineering cost
Conclusions	Scheme I is recommended	

5) Interchange between the New Ring Road and the Dari-Ekh street

① Construction conditions

To the west of the intersection is the Selbe River, and to the northeast is the mountain. Dari-Ekh street extends north-south along the Selbe River.

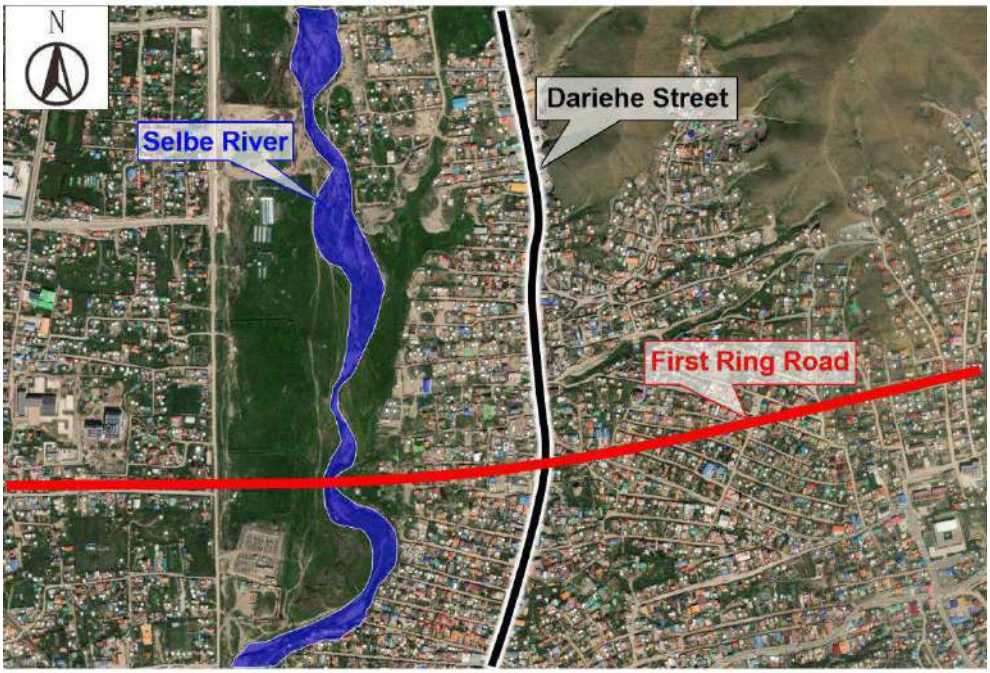


Figure 3. 54. Construction Conditions for the Interchange between the New Ring Road and the Dari-Ekh street

② Prediction of the traffic flow direction and volume

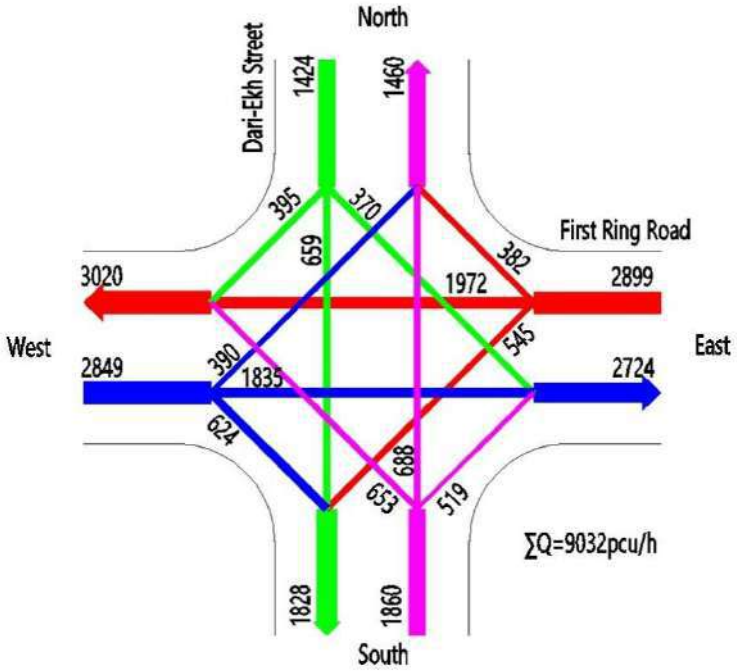


Figure 3. 55. Traffic Direction and Volume Figure at the Interchange between the New Ring Road and the Dari-Ekh street

③ Scheme design

A. Scheme I (partial cloverleaf interchange)

Based on the prediction results of traffic volume and the surrounding terrain conditions,

Scheme I adopts a partially cloverleaf interchange with the New Ring Road crossing over Dari-Ekh street. The ramps A and D level intersect with the Dari-Ekh street level, allowing vehicles to turn left and right, and then pass through the ramps B, C, E, and F to enter and exit New Ring Road.

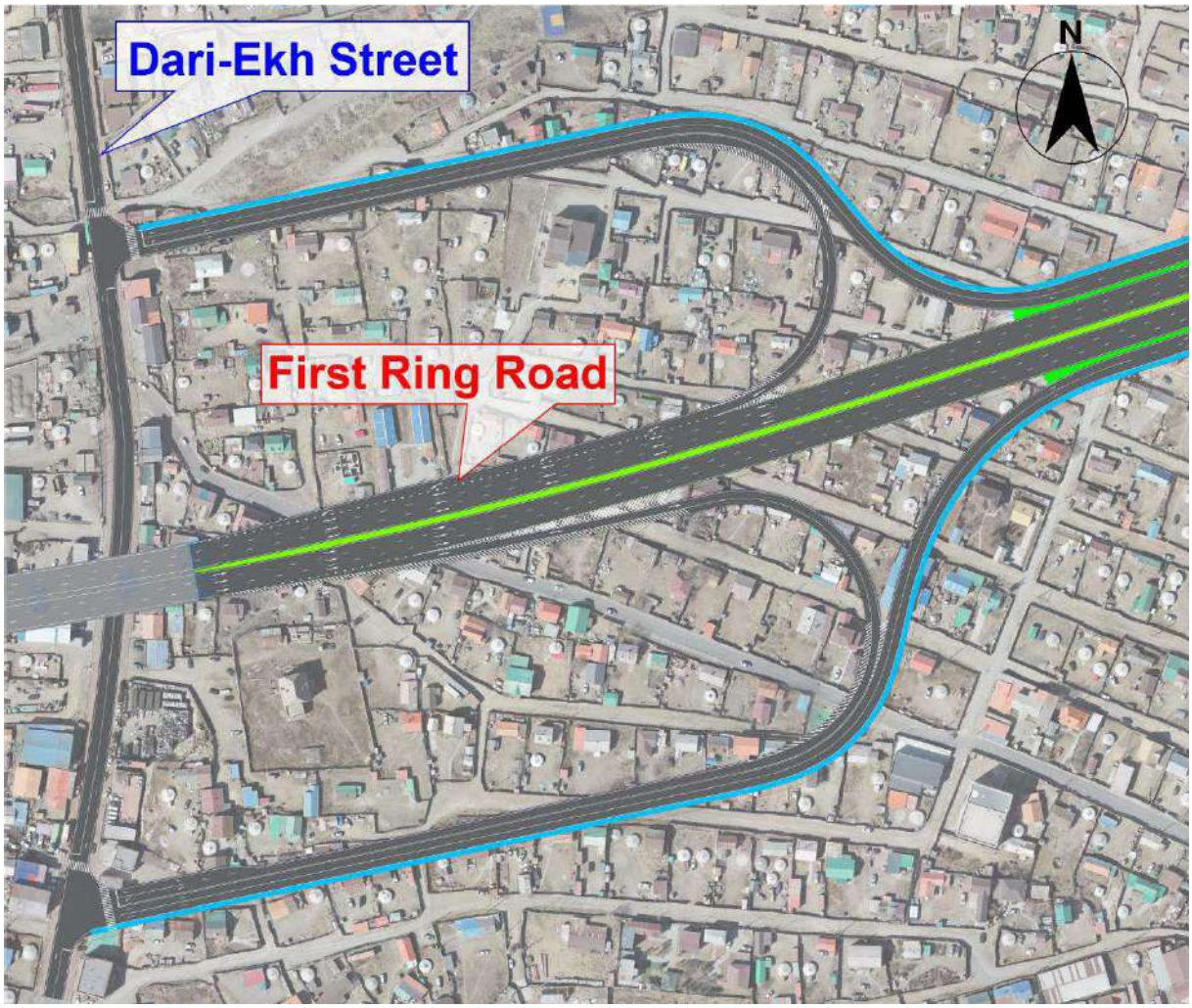


Figure 3. 56. Interchange between the New Ring Road and the Dari-Ekh street (Scheme I)

B. Scheme II (partial diamond interchange)

Scheme II adopts a partial diamond interchange with the New Ring Road crossing over the Dari-Ekh street. Due to terrain reasons, two ramps are set approximately 120 m on both sides of the main road of the New Ring Road to reduce the longitudinal slope of the ramps and minimize excavation work.

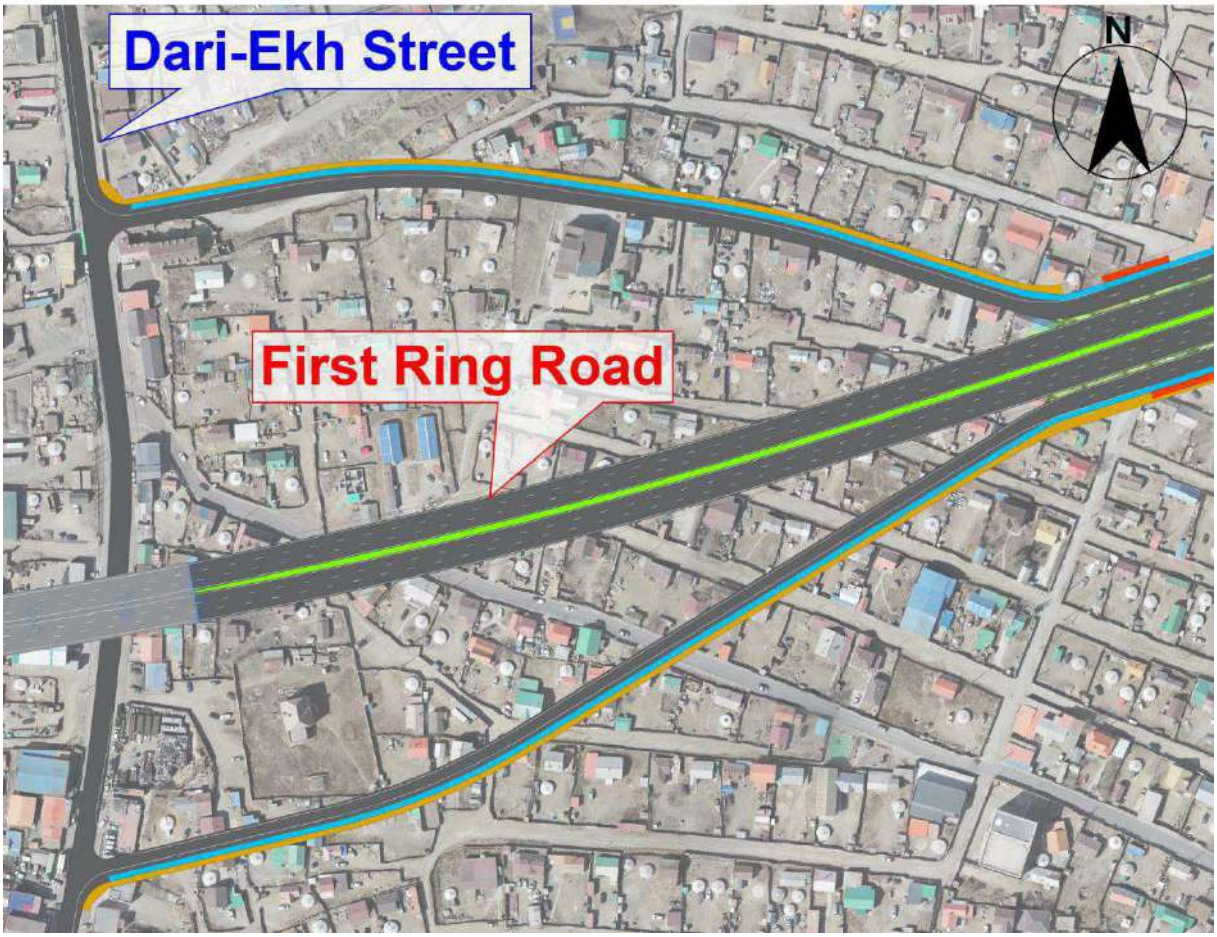


Figure 3. 57. Interchange between the New Ring Road and the Dari-Ekh street (Scheme II)

C. Comparison of advantages and disadvantages of schemes

Table 3. 31. Comparison of Advantages and Disadvantages of Schemes

Item	Scheme I	Scheme II
Engineering cost	798,541 USD	344,330 USD
Land area	33036 m^2	15440 m^2
Demolition area	14870 m^2	7105m^2
Advantages	Traffic transitions in all directions can be solved with high traffic efficiency	Small land area, few demolitions, and low engineering cost
Disadvantages	Large land area, large number of demolitions, and high engineering cost	Only traffic transitions in some directions can be solved
Conclusions	Scheme I is recommended	

6) Interchange between the New Ring Road and the east side of the Second Ring Road

① Construction conditions

The northeast side of the intersection is mountainous, while the north side has a military management area and a large cemetery.

Figure 3. 58. Construction Conditions for the Interchange between the New Ring Road and the East Side of the Second Ring Road

② Prediction of the traffic flow direction and volume

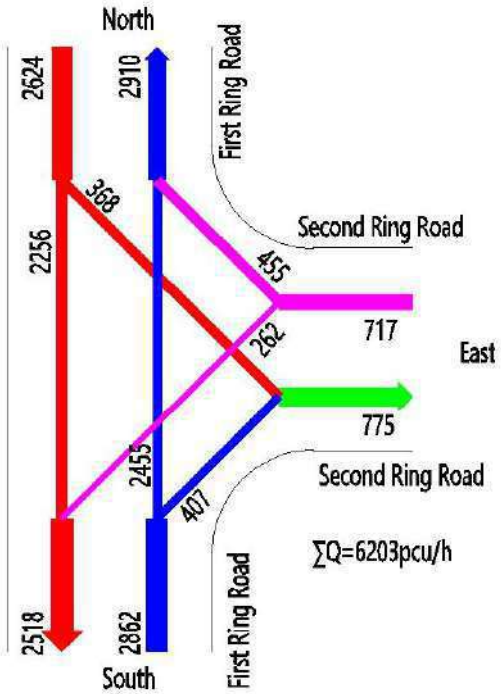


Figure 3. 59. Traffic Direction and Volume Figure at the Interchange between the New Ring Road and the Second Ring Road

③ Scheme design

The original planned route of the Second Ring Road crosses mountains, the excavation

work at the intersection with the New Ring Road is large, and it'll have a demolition impact on the military management area and cemetery. Considering these factors, to effectively connect New Ring Road with the Second Ring Road, access points have been reserved in this design, and the scheme design has avoided mountains and reduced the scale of the project.

A. Scheme I (single horn interchange)

Based on the prediction results of traffic volume and the surrounding terrain conditions, Scheme I adopts a single horn interchange with the New Ring Road passing under the Second Ring Road. The ramp B adopts a circular ramp type, serving the traffic flow of the Second Ring Road turning left into New Ring Road. The ramp C adopts a directional ramp type, serving the traffic flow from the left turn of the New Ring Road to the Second Ring Road. Vehicles turning right between the New Ring Road and the Second Ring Road can use the ramps D and E. The side road is set up by detouring outside the interchange.

Figure 3. 60. Interchange between the New Ring Road and the East Side of the Second Ring Road (Scheme I)

B. Scheme II (Y-shaped interchange)

Based on the prediction results of traffic volume and the surrounding terrain conditions, Scheme I adopts a Y-shaped interchange with the New Ring Road passing under the Second Ring Road. The ramps A and B both adopt a directional ramp type, serving the left turn flow between the Second Ring Road and New Ring Road. Vehicles turning right between the New Ring Road and the Second Ring Road can use the ramps C and D. The side road is set up by detouring outside the interchange.

Figure 3. 61. Interchange between the New Ring Road and the East Side of the Second Ring Road (Scheme II)

C. Comparison of advantages and disadvantages of schemes

Table 3. 32. Comparison of Advantages and Disadvantages of Schemes

Item	Scheme I	Scheme II
Engineering cost	10,653,700 USD	36,070,125 USD
Land area	74736 m^2	120559 m^2
Demolition area	23165 m^2	36669 m^2
Advantages	Simple form, short bridge length, and lower project cost	High traffic efficiency
Disadvantages	Average efficiency of circular ramp traffic	Multi-story structure, complex construction, large bridge scale, and high engineering cost
Conclusions	Scheme I is recommended	

7) Interchange between the New Ring Road and the Police Academy Avenue

① Construction conditions

There are many buildings near the intersection, making demolition difficult. To the northwest, two high-rise buildings are located close to New Ring Road; to the southwest, a residential area is located 160m away. To the southeast is a Mongolia-Japan Hospital of MNUMS. To the northeast, it is only 130 meters away from the University of Internal Affairs.

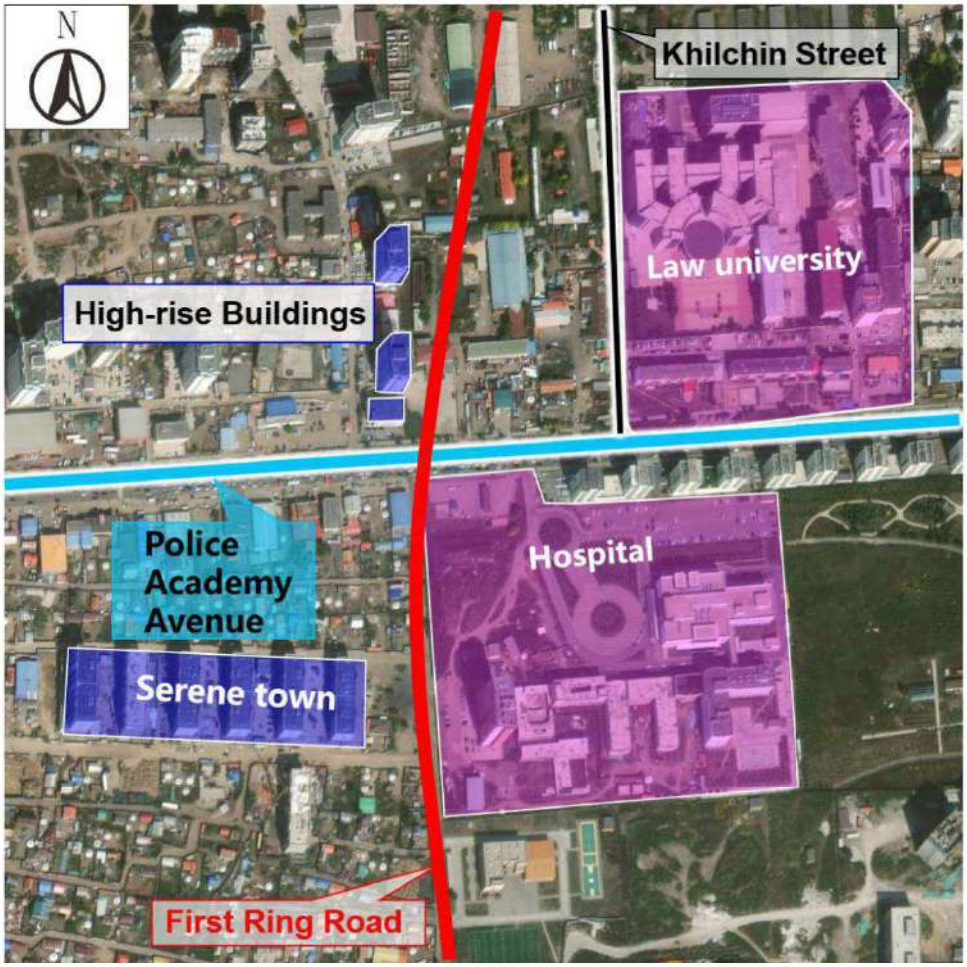


Figure 3. 62. Construction Conditions for the Interchange between the New Ring Road and the Police Academy Avenue

② Prediction of the traffic flow direction and volume

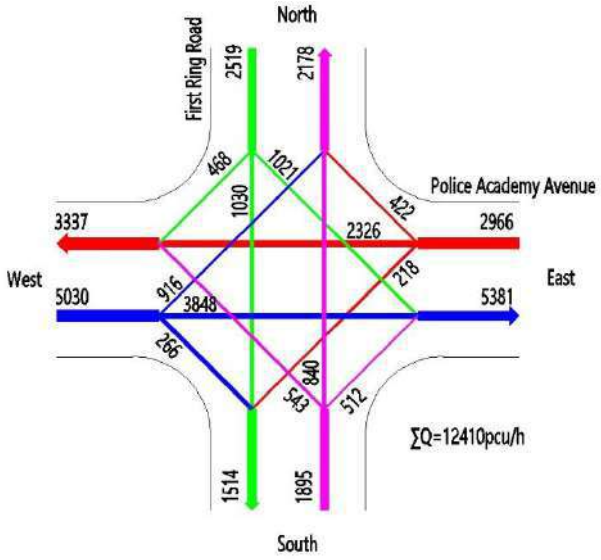


Figure 3. 63. Traffic Direction and Volume Figure at the Interchange between the New Ring Road and the Police Academy Avenue

③ Scheme design

A. Scheme I (diamond interchange)

Based on the predicted traffic volume and the distributions of surrounding buildings, Scheme I adopts a diamond interchange with the New Ring Road crossing over the Police Academy Avenue. Four ramps A, B, C, and D can be used to enter and exit the main road of the New Ring Road, and left and right turns can be achieved at ground level intersections.

Figure 3.63. Interchange between the New Ring Road and the Police Academy Avenue (Scheme I)

C. Scheme II (simple cloverleaf interchange)

Scheme II adopts a simple cloverleaf interchange with the New Ring Road crossing over the Police Academy Avenue. At the level intersection between ramp A and the Police Academy Avenue, vehicles can turn left and right, and then use ramps B and C to enter and exit the main road of the New Ring Road. The vehicle first passes through the intersection between Police Academy Avenue and Border Guard Street, and then uses the intersection between ramp D and Border Guard Street to enter and exit New Ring Road through ramps E and F.

Figure 3. 64. Interchange between the New Ring Road and the Police Academy Avenue (Scheme II)

D. Comparison of advantages and disadvantages of schemes

Table 3. 33. Comparison of Advantages and Disadvantages of Schemes

Item	Scheme I	Scheme II
Engineering cost	14,523,514 USD	26,389,392 USD
Land area	0 (the ramp is parallel to the main road and within the scope of land acquisition on the main road, and there will be no separate land acquisition)	8465 m^2
Demolition area	0 (the ramp is parallel to the main road and within the scope of demolition on the main road, and there will be no separate demolition)	2489 m^2
Advantages	Small land area, small project scale, and low engineering cost	High traffic efficiency of left turn
Disadvantages	Average traffic efficiency of the level intersection	Complex traffic organization, low traffic efficiency, large land area, and large number of demolitions
Conclusions	Scheme I is recommended	

8) Interchange between the New Ring Road and the Tuul Expressway

① Construction conditions

The terrain near the intersection is flat, with the Tuul River on the south side and a water source protection area on the west side.

Figure 3. 65. Construction Conditions for the Interchange between the New Ring Road and the Tuul Expressway

② Prediction of the traffic flow direction and volume

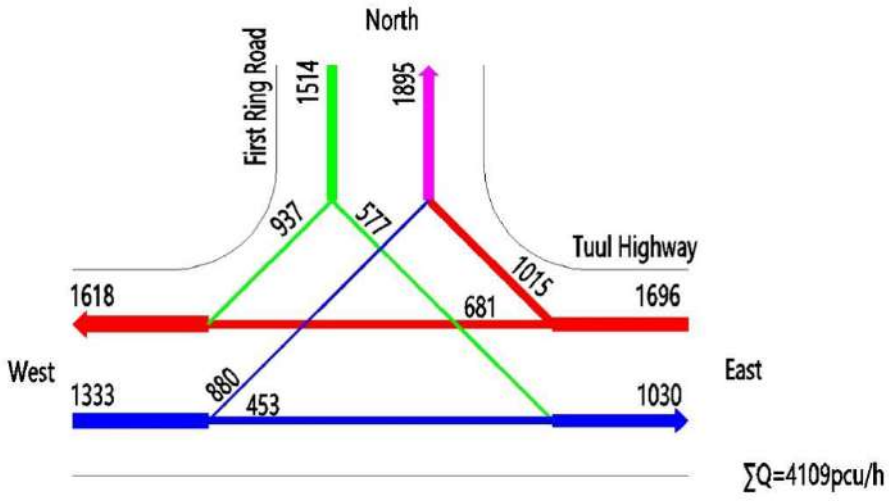


Figure 3. 66. Traffic Direction and Volume Figure at the Interchange between the New Ring Road and the Tuul Expressway

③ Scheme design

A. Scheme I (single horn interchange)

Based on the prediction results of traffic volume, Scheme I adopts a single horn interchange with the New Ring Road crossing over the Tuul Expressway. The ramp B adopts a circular ramp type, serving the traffic flow from the left turn of the New Ring Road to the Tuul Expressway. The ramp C adopts a directional ramp type, serving the traffic flow of turning left into New Ring Rampoad on the Tuul Expressway. Vehicles turning right between the New Ring Road and the Tuul Expressway can use the ramps D and E.

Figure 3. 67. Interchange between the New Ring Road and the Tuul Expressway (Scheme I)

B. Scheme II (Y-shaped interchange)

Based on the prediction results of traffic volume, Scheme II adopts a Y-shaped interchange with the New Ring Road crossing over the Tuul Expressway. Ramps A and B both adopt directional ramp type, serving the left turn traffic flow between Tuul Expressway and New Ring Road. Vehicles turning right between the New Ring Road and the Tuul Expressway can use the ramps C and D.

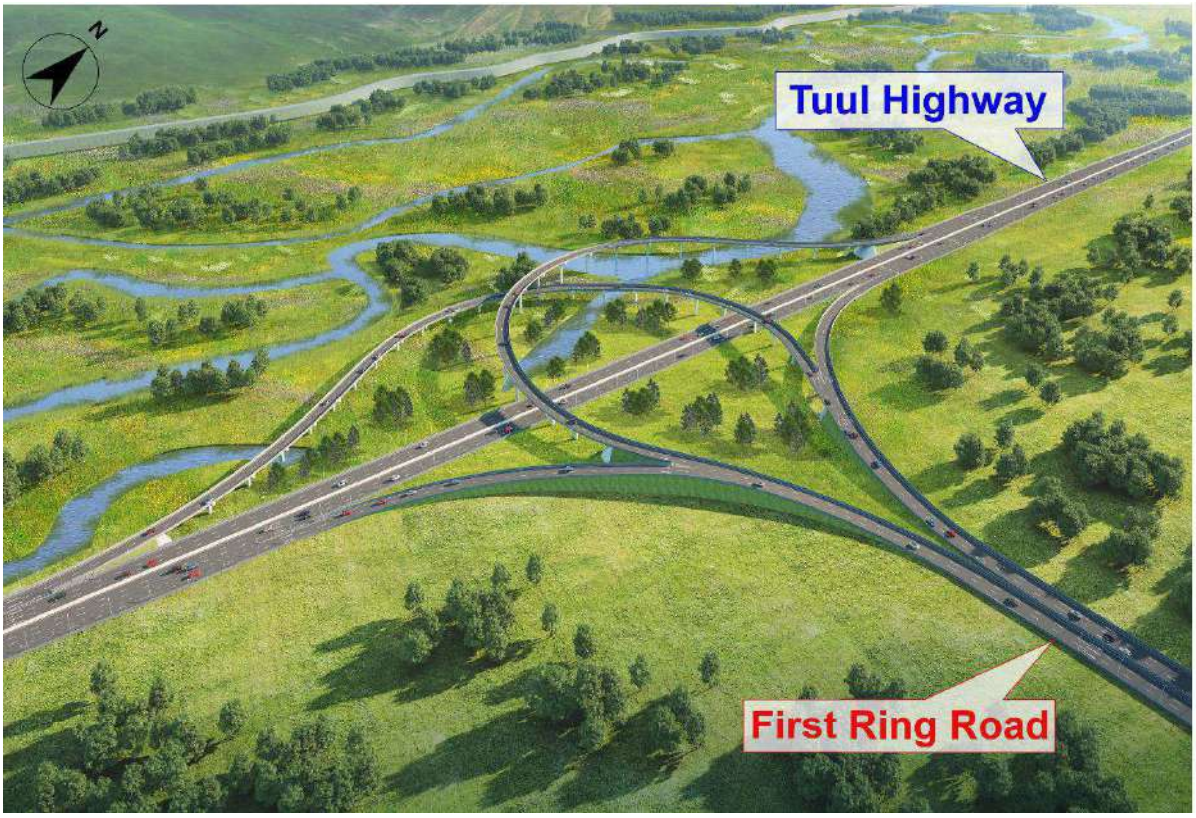


Figure 3. 68. Interchange between the New Ring Road and the Tuul Expressway (Scheme II)

3) Comparison of advantages and disadvantages of schemes

Table 3. 34. Comparison of Advantages and Disadvantages of Schemes

Item	Scheme I	Scheme II
Engineering cost	18,821,567 USD	29,477,595 USD
Land area	39357 m^2	41684 m^2
Demolition area	0 m^2	0 m^2
Advantages	Simple form, short bridge length, and lower project cost	High traffic efficiency
Disadvantages	Average efficiency of circular ramp traffic	Multi-story structure, complex construction, large bridge scale, and high engineering cost
Conclusions	Scheme I is recommended	

(3) Summary Table of Recommended Interchange Schemes

At the intersection of the New Ring Road and Moscow Street, a grade separation is recommended due to significant challenges in relocating 220KV transmission towers and the impracticality of demolishing surrounding high-rise buildings. Consequently, seven interchanges will be constructed between the New Ring Road and adjacent roads.

Table 3. 35. List of Interchange Design

No.	Pile Number	Name of Intersecting Road	Intersection Type	Recommended Scheme
1	K3+024.8	Ard Ayush Road	Main line Overpass	Diamond Interchange

No.	Pile Number	Name of Intersecting Road	Intersection Type	Recommended Scheme
2	K6+366	Second Ring Road	Main line Overpass	Single Trumpet Interchange
3	K13+232	Doloon Buudal road	Main line Overpass	Partial Cloverleaf Interchange
4	K14+658	Dari-Ekh street	Main line Overpass	Partial Cloverleaf Interchange
5	K20+835	Second Ring Road	Main line Underpass	Single Trumpet Interchange
6	K22+856	Police Academy Avenue	Main line Overpass	Diamond Interchange
7	K24+793	Tuul Expressway	Main line Overpass	Single Trumpet Interchange

3.2.4.3 Grade Separation Design

Grade Separation DesignBased on the Ulaanbaatar City Comprehensive Development Plan 2040 and the justification of optimized intersection schemes, twelve grade-separated crossings are planned between the New Ring Road and adjacent roads. Among these: 10 locations utilize at-grade intersections for frontage roads and crossing roads, 2 locations feature fully grade-separated structures between frontage roads and crossing roads.

Table 3. 36. List of Grade Separation Design

No.	Chainage No.	Name of the intersecting road	Grade of the intersecting road	Status of the intersection road	Number of lanes on the intersecting road	Mode of Crossing
1	K0+200	Road Rehabilitation Project in Selebore	Grade-2 main trunk road	Planned	6 lanes in two directions	Crossing under for the main road; Fully grade-separated
2	K0+355	No. IV Power Station Road	Grade-2 main trunk road	Existing	2 lanes in two directions	Crossing over for the main road; level crossing for the ground side road
3	K0+962	Planned road	Grade-2 main trunk road	Planned	4 lanes in two directions	Crossing over for the main road; level crossing for the ground side road
4	K1+817.494	Moscow Street	Grade-1 main trunk road	Existing	6 lanes in two directions	Crossing over for the main road; level crossing for the ground side road
5	K2+276.092	Planned road	Grade-2 main trunk road	Planned	4 lanes in two directions	Crossing over for the main road; level crossing for the ground side road
6	K5+794	Bayankhoshuu Street	Grade-2 main trunk road	Existing	4 lanes in two directions	Crossing over for the main road; level crossing for the ground side road
7	K6+480	Bayankhoshuu Street	Grade-2 main trunk road	Existing	4 lanes in two directions	Crossing over for the main road; level crossing for the ground side road
8	K8+587	Revolution Street	Grade-1 main trunk road	Existing	4 lanes in two directions	Crossing under for the main road; level crossing for the side road

9	K12+620	Khailaast street	Side road	Existing	2 lanes in two directions	Crossing over for the main road; level crossing for the ground side road
10	K13+979	Selbeseregelete Project Road	Grade-2 main trunk road	Existing	2 lanes in two directions	Crossing over for the main road; level crossing for the ground side road
11	K23+817	General's No. IX Street	Grade-2 main trunk road	Reconstructed	4 lanes in two directions	Crossing over for the main road; level crossing for the ground side road
12	K24+337	Dunjingarav Street	Grade-2 main trunk road	Existing	4 lanes in two directions	Crossing over for the main road Fully grade-separated

At the at-grade intersections between frontage roads and adjacent roads, where traffic capacity is lower than normal road sections, channelization designs and signalized controls are implemented based on traffic analysis and engineering requirements. These measures reduce vehicle conflict areas while ensuring efficient traffic flow through exclusive left-turn and right-turn lanes, as well as safe pedestrian crossings.

3.2.4.4 Railway Crossings

The New Ring Road intersects with railway lines at three locations. Among these: 2 locations feature at-grade crossings between frontage roads and railways, 1 location utilizes a fully grade-separated structure

Table 3. 37. List of Railway Crossings Design

No.	Chainage No.	Name of the intersecting Railway Line	Grade of the intersecting Railway Line	Status of the intersection Railway Line	Number of lanes on the intersecting Railway Line	Mode of Crossing
1	K1+457.982	Ulaanbaatar Railway	Internal combustion railway	Existing	Single line	Crossing over for the main road; level crossing for the ground side road
2	K1+566.775	Ulaanbaatar Railway	Internal combustion railway	Existing	Double lines	Crossing over for the main road; level crossing for the ground side road
3	K23+874	Ulaanbaatar Railway	Internal combustion railway	Existing	Single line	Crossing over for the main road; Fully grade-separated

At K1+457.982 and K1+566.775, at-grade crossings will be implemented in the short term, with space reserved for future railway underpasses. For the current at-grade crossings with railways:

1) Management principles

① Safety priority: The safe passage is ensured for pedestrians, vehicles, and trains, and conflicts are avoided.

② Efficiency coordination: Signal control and traffic organization are optimized to reduce waiting time for vehicles on road.

③ Clear rights and responsibilities: The collaborative management responsibilities are

defined between the railway department and the road department.

2) Traffic organization measures

① Priority regulations: Railway trains have absolute priority in passage, while road vehicles need to stop and give way.

② Speed limit requirement: On the roadside, the speed limit within 60 m before and after the intersection is 20 km/h (adjusted according to actual conditions).

Railway side: The speed of trains passing through intersections should be in accordance with the regulations of the railway department.

③ Prohibited behaviors: Vehicles are strictly prohibited from parking, overtaking, or turning around in the intersection area.

3) Protective design

Standard railway crossing signs, approach warning signs, and road markings should be set up at level intersections.

The crossing scheme for the new ring road and the Ulaanbaatar Railway should be further refined during the detailed design stage, with prior consent obtained from the railway authority, and the engineering costs for dismantling and relocating railway infrastructure should be itemized in the new ring road construction budget at this stage.

3.2.5. Roadbed engineering

3.2.5.1 General roadbed design

(1) The characteristics of materials used for embankments should be specified in detail in the technical requirements on the basis of geological survey results.

(2) Embankment parameters based on the bearing capacity of the foundation soil. The foundation soil is classified as hard soil, soft soil, settable soil, and non-settling soil. When there is a soft soil layer with a thickness of ≥ 0.5 m in the active layer of the foundation soil, it is judged as a weak foundation. The thickness of the active layer is calculated to be approximately equal to the width of the embankment bottom. When the natural foundation is composed of cohesive soil with a relative settlement of > 0.01, it is classified as a settable foundation.

(3) It is allowed to use soil with normal moisture content that does not decrease in strength over time under the influence of climate factors to fill embankments.

(4) The roadbed design is tailored to local conditions, fully considering natural conditions such as terrain, geology, meteorology, hydrology, etc., ensuring coordination with the terrain and surrounding environment, and fully considering the impact of adverse geology and uneven settlement of special road sections on the roadbed.

(6) The roadbed should be integrated with the pavement, and as the foundation engineering of the pavement, the characteristics of the roadbed filling and excavation materials should be

strictly controlled, and an economically reasonable filling and excavation scheme should be proposed to ensure the strength and compactness of the roadbed. When the roadbed crosses a sloping section, anti-slip measures should be taken, such as excavating anti-slip platforms. Road sections with zero filling and excavation should be strengthened to ensure the strength of the roadbed, proper drainage facilities should be equipped.

(7) Soil and water conservation and environmental protection should be guaranteed at the time of roadbed design.

(8) Excavation of side slope: Generally, slope excavation is the main method for side slope, supplemented by treatment and consideration for greening restoration.

3.2.5.2 Design of fill embankment

(1)Control factor of embankment design

1) The elevation of the embankments on both sides of large and medium-sized bridges should be at least 0.5 m higher than the calculated water level taking wave height into considerations.

2) The compactness requirement is expressed as the relative ratio of the standard maximum compactness (compactness coefficient), and the lower limit of compaction for each layer of the embankment should be specified in detail in the technical requirements.

3) When designing the connection section between the embankment and the bridge, it is advisable to use non-settling permeable soil filling. The filling range should extend to 2 m or more behind the bridge abutment, and the thickness of the lower filling should not be less than 2 m.

4) According to the Mongolian Highway Design Code (22-004-2016), to ensure the strength stability of the embankment top and pavement, the pavement elevation should be higher than the calculated water level of groundwater and surface water or the ground elevation without drainage facilities. The specific minimum uplift values are shown in the table below (Climate Zoning Indicators of the Highway).

Table 3. 38. Minimum Lifting Requirements for Pavement Elevation Relative to Groundwater/Surface Water Level (m)

Soil type of working layer	Minimum standard for road lifting (meter) divided by road climate zones				
	IA zone	IB zone	IIA zone	IIB zone	IIIA; IIIB zone
Fine sand, coarse sandy soil, light sandy soil	1.4	1.1	0.9	0.75	0.5
Silt, silty soil	1.8	1.5	1.2	1.1	0.8
Heavy silty soil, light silty loam, heavy silty loam	2.5	2.2	1.8	1.5	1.1
	0.5	0.4	0.3	0.3	0.2
Light and heavy sandy soil, clay	2.7	2.4	2.1	1.8	1.2

Soil type of working layer	Minimum standard for road lifting (meter) divided by road climate zones				
	IA zone	IB zone	IIA zone	IIB zone	IIIA; IIIB zone
	0.6	0.5	0.4	0.4	0.3

Note: 1. The values in the upper part of the table represent the minimum elevation height of the pavement relative to groundwater or after long-term stable (≥ 30 days) surface water level; the values at the bottom of the table represent the thickness requirements for the replacement layer. 2. The calculation of groundwater level adopts the highest water level that may be reached before the start of autumn freezing and thawing. 3. Setting up a waterproof isolation layer can reduce the above-mentioned lifting height requirements. 4. The compaction degree of the working layer should reach 98% or more, and its thickness needs to be determined through structural calculations to meet the requirements of road stability and strength.

(2) Requirements for filling materials

1) Priority: Gravel mixture (gravel content 65%-70%), crushed stone soil (particle size ≤ 150 mm, continuous grading) or lime stabilized soil (suitable for frost heave sensitive areas).

2) Prohibited materials: Organic soils, humus soils, frozen soil blocks (diameter 2,100 mm), saline soils (CI content>0.5%).

Table 3. 39. Requirements for Roadbed Filling Materials

Indicator	Requirement	Test method
Maximum particle size	≤ 2/3 compacted layer thickness	MNS 5325 Appendix A Screening Test
Liquid limit (LL)	≤35%	ASTM D4318
Plasticity index (PI)	≤12	ASTM D4318

(3) Layered filling and compaction control

Table 3. 40. Requirements for Compaction Degree and Roadbed Filling Materials

Project classification	Depth below the bottom surface of pavement (cm)	Heavy compaction degree (%)	Minimum strength of filling material (CBR) (%)
Fill roadbed	0-30	≥95	≥8
	30-80	≥95	≥5
	80-150	≥95	≥4
	>150	≥95	≥3
Zero filling and fill roadbed	0-30	≥95	≥8
	30-80	≥95	≥5

Moisture content control: The optimal moisture content is ± 2%. Construction in frozen soil areas should avoid exceeding the plastic limit in winter.

Table 3. 41. Layer Thickness

Type of compaction machinery	Maximum loose laying thickness
Vibratory roller (20t)	≤300 mm

Impact roller	≤500 mm

(4) Side slope design of the embankment

According to the height and segmentation of the roadbed fill, when the height of the fill roadbed slope H is ≤ 12 m, the slope ratio is 1:1.5 and a straight line slope is used; when the height of the fill roadbed slope is 12<H≤20 m, a stepped slope should be used, with a slope gradient of 1:1.5 for slopes above 8m and 1:1.75 for slopes below 8 m. A 2 m-wide slope platform should be set at the changing slope, with a 2% outward sloping transverse slope; When the height of the fill roadbed slope H is greater than 20 m, a stepped slope is used, with a slope gradient of 1:1.5 for slopes above 8.0 m, 1:1.75 for slopes between 8.0 m and 16 m, and 1:2.0 for slopes below 16 m. A 2 m-wide slope platform is set every 8 m, with a 2% outward sloping transverse slope.

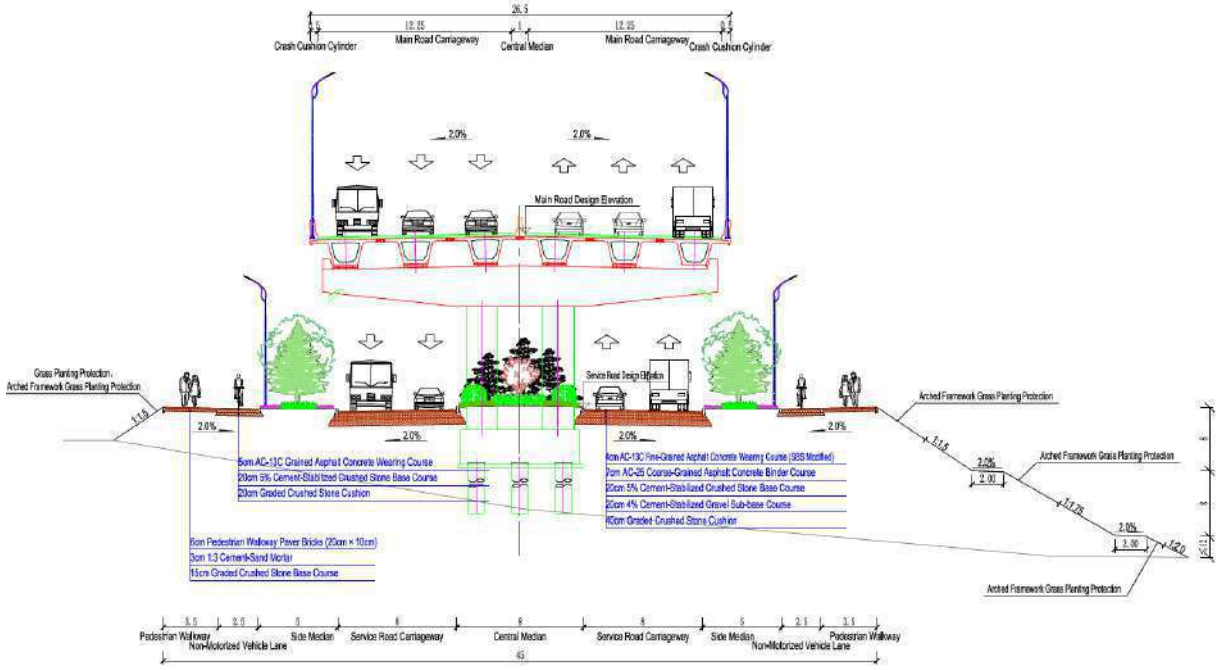


Figure 3. 69. General Roadbed Design Drawing of Fill

3.2.5.3 Excavation roadbed design

The gradient of the excavated slope should be adopted according to the following table for the soil with an impermeable layer that is not penetrated and stable (whose strength does not decrease due to climate impact).

Table 3. 42. Maximum Gradient of the Excavated Slope

Soil type	Excavation depth (m)	Maximum gradient of side slope
Unweathered bedrock	<16	1:0.2
Slightly weathered but not softened bedrock	<16	1:0.5-1:1.5

Softened bedrock	<16	1:1
Large crushed stone soil	<12	1:1-1:1.5
Sand and silt (homogeneous, hard plastic-semi hard plastic, plastic-soft plastic)	<12	1:1.5
Flowing sand dune	<2	1:10
	2-12	1:2
Cohesive soil	<12	1:0.1-1:0.5*
		1:0.5-1:1.5**

Note: 1. The upward values in the table are applicable to arid climate zones; **The downward values in the table are applicable to non-arid climate zones. 2. Vertical walls can be used for unweathered bedrock. 3. In vegetation sand fixation areas, steep slopes with gradient less than 1:2 are allowed when the height of the side slope does not exceed 2 m. 4. The height of the excavated side slope should be determined according to the elevation difference between its upper and lower edges. 5. For soils such as fine-grained sand, excessively wet silt (with a consistency coefficient greater than 0.3), weathered or fissured bedrock, excavation deeper than 2 m should have a protective walkway set on the outside of the side ditch. The width of the protective walkway for fine-grained sand is taken as 1 meter, and for other above-mentioned soils, it is taken as 2 m when the height of side slope is ≤ 12 m (bedrock ≤ 16 m).

Determine the excavation slope gradient based on the above specifications and geological survey report. It is recommended to adopt the "dynamic design method", adjust parameters based on the geological conditions revealed during construction, and synchronously implement vegetation restoration to ensure the safety of the entire life cycle.

The strata of the excavation section in this design are cohesive soil and crushed stone soil layers. The excavation slope in this design adopts graded excavation, with each slope height of 10m. The design slope ratio of the first slope is 1:1.0, the second slope is 1:1.25, the third slope is 1:1.5, and the fourth slope is 1:1.75.

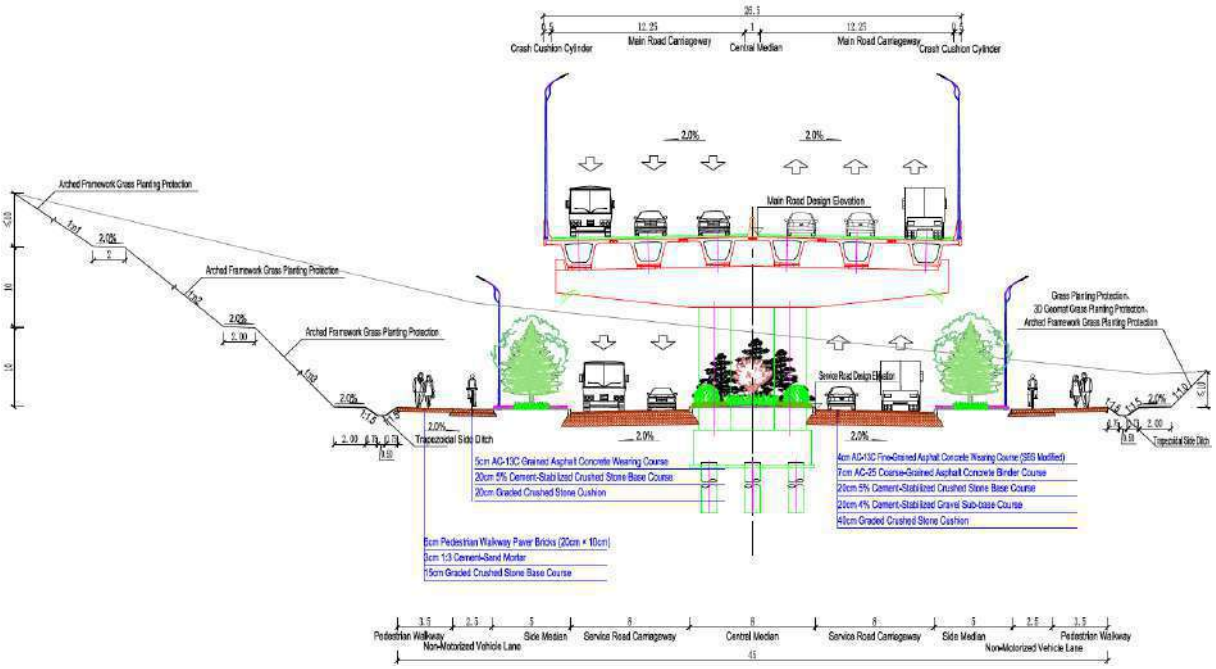


Figure 3. 70. General Roadbed Design Drawing for Excavation

3.2.5.4 Special roadbed design

(1) Roadbed design in frozen earth regions

1) Ulaanbaatar region parameters

Freezing depth: The maximum seasonal freezing depth is 1.8-2.2 m.

Extreme temperature: -40°C in winter, brief (30°C) in summer, with an annual freeze-thaw cycle of ≥ 50 times.

Typical soil type: Silty clay (high frost heave sensitivity, liquid limit>35%).

Ulaanbaatar has a freezing index F ≥ 2,000 (°C·d). According to the Technical Specification for Design and Construction of Highways in Seasonal Frozen Soil Regions (JTG/T D31-06-2017), Ulaanbaatar is classified as a severely frozen area.

2) Specific scheme for seasonal frozen soil

According to the Technical Specification for Design and Construction of Highways in Seasonally Frozen Soil Regions (JTG/T D31-06-2017), if the soil roadbed in the heavily frozen area does not meet the critical height requirements for roadbed freezing, the following anti-freezing measures should be taken:

① The roadbed design elevation is raised.

② The anti-freezing bedding and isolation layer are set up, and the infiltration ditch and drainage ditch are set up if necessary.

③ Replace with non-frost heave or weakly frost heave materials within the range of freezing depth.

When the height of the roadbed fill does not meet the critical height requirement for roadbed

freezing, the seasonal frozen soil scheme for this design is to set up a permeable isolation layer of crushed stone with a pass rate of 0.075 mm less than 5% and a pass rate of 4.75 mm between 10% and 30%. Geotextile filter layers should be installed above and below the isolation layer, and the upper and lower cross slopes should not be smaller than the pavement cross slope. The bottom of the isolation layer should be higher than the groundwater level or surface water level by 0.3 m or more, and its effective thickness should not be less than 0.3 m.

3.2.5.5 Roadbed protection

(1)Design principles

1) For road roadbed protection and support, comprehensive considerations should be given to the climate, terrain, geology, and local materials along the route in close combination with drainage engineering. The overall design principle should be based on slope stability, beautiful slope shape, and environmental protection. Practical, reasonable, economical, beautiful, and environmentally friendly protection forms should be selected according to local conditions to prevent rainwater and atmospheric factors from scouring and weathering the slope surface, ensure the stability of the road roadbed, and maintain the ecological environment while beautifying the road.

2) Combining the protective measures adopted according to local customs in Mongolia, local materials should be used as much as possible to facilitate construction and reduce project costs.

3) For road sections with insufficient roadbed stability and adverse geological factors, comprehensive considerations should be given to factors such as engineering geology, hydrogeology, slope height, environmental conditions, and construction conditions, and a comprehensive design method of roadbed slope protection and support reinforcement should be adopted. The design of retaining structures should consider meeting various design load combinations while adhering to the principles of economic rationality and ease of construction and maintenance.

(2) Comparison and selection of protection and support

Table 3. 43. Comparison Table of Roadbed Protection Schemes

Excavation mode	**Filled and excavated roadbed**			
Scheme	Grass planting protection	Three-dimensional geonet grass planting protection	Retaining wall protection	Grass planting protection of arched skeleton

Technical Features	Grass planting protection can beautify the pavement, coordinate the environment, regulate the moisture and temperature of the slope soil, and play a role in consolidating and stabilizing the slope.	Grass planting protection of slope three-dimensional network forms a ground network system with three-dimensional net through growth of grass roots, effectively preventing surface runoff erosion. While the root system penetrates deep into the original slope surface, forming a slope protection system with the soil layer, three-dimensional network, and lawn, which plays a stabilizing role on the slope surface.	The retaining wall protection is achieved by bearing lateral soil pressure through the retaining wall, preventing the sliding of the roadbed slope or foundation, ensuring the stability of the roadbed, and reducing the amount of fill and occupying less land area by shrinking the foot of the fill slope.	Skeleton grass planting protection is achieved by building a concrete skeleton on the slope, and then planting green plants in the soil inside the skeleton to stabilize the slope.
Environmental impact	Good coordination with the environment, but large land occupation.	Good coordination with the environment, but large land occupation.	Land occupation is small, but a large amount of masonry has a certain impact on the landscape.	Relatively good coordination with the environment, but large land occupation.
Cost	RMB 30/m^2	RMB 60/m^2	RMB 800/m^3	RMB 120/m^2
Explanations for Scheme Comparison	From the perspective of structural safety and environmental coordination, and taking into account the later development and construction of surrounding land parcels, this Project mainly adopts greening and ecological protection. To ensure the stability of the slope and provide the ability of the slope to resist erosion, the section with a slope height H>6 m adopts skeleton grass planting protection; the section with a slope height of 3m<H ≤ 6 m adopts three-dimensional mesh grass planting protection or grass planting slope protection.			
Excavation conclusions	Used for sections with slope height H ≤ 3 m	Used for sections with slope height 3 m< H ≤ 6 m	Used for a section with restricted land use	Used for sections with slope height H>6 m
Fill conclusions	Used for sections with slope height H ≤ 6 m	/	Used for a section with restricted land use	Used for sections with slope height H>6 m

(3) Roadbed Protection Design

1) After the fill embankment is sloped according to the designed slope gradient, the slope surface is protected. For slopes with a height of H ≤ 6 m, grass planting is used for slope protection. For slopes with a height H>6 m, arched skeleton grass planting is used for slope protection.

2) After the excavation, the slope is excavated according to the designed slope gradient, and the slope surface is protected. For soil slopes with a height of H ≤ 3 m, grass planting shall be used for slope protection. For slopes with a height of 3 m < H ≤ 6 m, three-dimensional geonet grass planting is used for slope protection. For slopes with a height of 6 m < H, arch skeleton grass planting is used for slope protection.

3) The main road and side road are separated without sloping conditions, and cantilevered and buttressed retaining walls are installed for support.

3.2.5.6 Roadbed drainage

In this design, trapezoidal side ditches are set up on the outside of the roadbed in sections with excavation height greater than 3 m. Trapezoidal intercepting ditches are set up at the excavation slope crest where water flows, and the collected water is discharged outside the

roadbed; Considering the low rainfall in Ulaanbaatar and the lack of side ditches in general fill sections, trapezoidal side ditches should be set up at the foot of the roadbed slope to prevent water flow from eroding the slope in sections with water flow collection. The trapezoidal side ditch is cast-in-place with C20 concrete, with a bottom width of 0.5 m and a gradient of 1:1.5.

3.2.6. Pavement engineering

3.2.6.1 Pavement Design Principle

Under the premise of meeting traffic volume and use requirements, in accordance with the local supply of road construction materials in Mongolia, and following the principles of adapting to local conditions, selecting materials reasonably, facilitating construction, facilitating maintenance, and saving investment, a pavement structure scheme that is technologically advanced, economically reasonable, safe and reliable, and conducive to construction should be selected. This will ensure that the pavement design meets the requirements of traffic carrying capacity, durability, comfort, and safety during its service life, guarantee project quality, and reduce project costs. The pavement design will be carried out according to the following principles:

(1) Fully consider the use function of this road. The pavement design should focus on meeting the bearing capacity, high-temperature anti rutting, and low-temperature anti-cracking requirements.

(2) This design is based on the local pavement design specifications in Mongolia, supplemented by the Chinese Specifications for Code for Design of Urban Road Pavements (CJJ 169-2011), and refers to the design theories and calculation methods regarding asphalt pavement in China.

(3) The pavement structure design fully considers the geological, hydrological, and climatic conditions of the region where Ulaanbaatar is located.

(4) Strictly implement the current relevant norms, regulations, and provisions in Mongolia.

3.2.6.2 Comparison, selection and demonstration of pavement structure schemes and types

(1) Pavement Structural Alternatives Comparison

According to the local construction habits in Mongolia, this design proposes comparison between asphalt pavement and cement concrete pavement.

Table 3. 44. Comparison Table for Advantages and Disadvantages of Asphalt Pavement and Cement Concrete Pavement

Pavement structure form	**4 cm upper layer of AC-13C fine-grained asphalt concrete (SBS modified) 7 cm lower layer of AC-25 coarse-grained asphalt concrete**	**25 cm C40 cement concrete panel 20 cm 5% cement-stabilized crushed stone base course 40 cm graded crushed stone bedding**

	20 cm 5% cement-stabilized crushed stone base course 20 cm 4% cement-stabilized gravel sub-base course 40 cm graded crushed stone bedding	
Service life	Under the same design level and construction technology level, the service life of cement concrete pavement is 30 years, while the service life of asphalt concrete pavement is 15 years	
Driving comfort	Seamless, low driving noise and vibration	Seamless, high driving noise and vibration
Damage	Good drainage should be ensured, as water damage is prone to occur when water accumulates	As the adaptability to vertical settlement deformation caused by uneven settlement of soft soil foundation after construction is low, it is easy to form early broken plates or damages under the action of vehicle load.
Maintenance and repair	Convenient local excavation and repair, faster traffic and easier thin layer paving than cement pavement, without considering joint crack prevention; relatively high maintenance cost	Insufficient initial maintenance and repair, complex repair of pavement cracks and damages, and long maintenance period; Low maintenance cost
Noise	Low	High
Fuel consumption	Low	High
Secondary laying of municipal pipelines	Convenient	Inconvenient
Construction period	Short, high degree of mechanization	Long, low degree of mechanization
Open traffic time	Open to traffic after paving	Cured to certain age
Cost/square meter	MNT 170,000	MNT 150,000
Recommend ation	√	×

(2) Comparison of Chemically Stabilised vs. Bituminous Base CoursesGlobally, both bituminous base courses (primarily asphalt-based) and chemically stabilised base courses (primarily cementitious) are extensively used in road construction. However, their selection and application approaches are significantly influenced by geographical conditions, climate, traffic loading, material availability, economic costs, technical traditions, and regulatory frameworks. Below is a comparative analysis of their primary applications:

Table 3. 45. Comparison of Chemically Stabilised vs. Bituminous Base Courses

Project Name	Organic Binder Base Course (Asphalt Stabilised Base)	Inorganic Binder Base Course (Cement-Stabilised Base Category)
Principal Representative	Asphalt Treated Base (ATB): Most commonly used. Hot Mix Asphalt Base (HMA Base): Sometimes, it directly uses the designed gradation HMA as the base layer. Recycled Asphalt Base:Cold or hot recycled asphalt mixtures used for base layers (e.g., Foamed Asphalt/Emulsion Treated Base in the USA and Europe). High Modulus Asphalt Concrete (HMAC):Used as a base layer/structural layer for heavily trafficked roads in Europe (especially France).	Cement Treated Base (CTB) / Cement Stabilized Material (CSM):Most commonly used. Cement Stabilized Soil:Often used for low-grade roads or in-situ utilization of local soil. Lime-Fly Ash Stabilized Base (LFASB): Utilizes industrial waste materials and is applied in areas with suitable resource availability. Lean Concrete Base (LCB):Offers higher strength and functions similarly to a rigid base layer.
Key Competitive Advantages	Superior Flexibility and Fatigue Cracking Resistance:Better accommodates subgrade	High Strength, High Modulus, and High Load-Bearing Capacity:Provides robust structural

Project Name	Organic Binder Base Course (Asphalt Stabilised Base)	Inorganic Binder Base Course (Cement-Stabilised Base Category)
	deformation and temperature fluctuations, reducing reflective cracking. Rapid Construction and Early Traffic Opening:Can be opened to traffic once cooled, minimizing construction disruptions. Ease of Maintenance and Recyclability: Can be milled and directly reused in hot recycling processes, offering environmental benefits and resource conservation. Structural Integrity:Forms a continuous, dense layer with excellent waterproofing properties. Enhanced Ride Comfort:Provides a smooth riding surface even when used as a base course.	support for pavements, particularly suitable for heavy-duty traffic. Slab-Like Behavior (Effective Load Distribution): Efficiently diffuses applied loads across the pavement structure. Superior Water Stability (After Curing): Exhibits strong resistance to moisture damagepost-hydration. Wide Material Availability: Utilizes readily accessible materials (cement, aggregates, and even local soils). Generally Lower Initial Costs: Raw materials (cement, aggregates) are more accessible and cost-effective** compared to asphalt stabilization.
International Application Features	North America (USA, Canada): Extensively used, especially in high-grade roads (Interstate highways, national routes) and urban roads. ATB is the mainstream choice. Strong emphasis on recycling technologies (cold recycling, hot recycling) for base courses cost-effective and eco-friendly. Europe:Widely applied with advanced technical standards. Western/Northern Europe: Frequent use of high-performance HMAC as base/structural layers for heavy-duty roads (following the "strong base-thin surface" design philosophy). Eco-focus:Adoption of warm-mix and cold-mix technologies to reduce energy/emissions; high recycling utilization rates. Australia/New Zealand: High application ratio in high-grade, high-traffic roads. Active implementation of recycling technologies. Japan: Widely adopted in expressways and critical national highways. Features stringent technical standards prioritizing durability and rutting resistance. Other Regions (e.g., parts of Asia, Africa, South America): Gradually increasing in well-funded projects demanding high performance (especially crack resistance and ride comfort). Lower overall adoption than developed nations due to cost constraints and dependence on petroleum resources. Typically reserved for: High-grade highways Special sections (e.g., airport runways, bridge deck paving base courses).	China: The most extensive and mature application globally, serving as the absolute mainstream base type for high-grade roads (expressways, Class I highways) – a representative semi-rigid base course. Features well-established specifications, design methodologies, and construction expertise. Challenges: Persistent issues with reflective cracking. India: Widely adopted in major national highway networks as one of the primary base options. Australia: Extensively used, particularly for interstate highways and heavy-duty roads. Stringent requirements for material design and construction control (moisture content, compaction, curing). Often combined with asphalt bases in composite base systems. United States: Applied but less prevalent than asphalt-stabilised bases. Primary uses: Specific regions (e.g., arid zones with suitable materials). Base/sub-base for **heavy-duty pavements or airport runways. Strengthening existing roads(overlay over fractured concrete slabs). Europe: Less common than asphalt bases but used in specific scenarios: As a sub-base layer. Projects requiring ultra-high load-bearing capacity or utilising local materials (e.g., lime-fly ash). There is relatively higher adoption in some Eastern European countries. Developing Regions (Africa, South America, Southeast Asia): Widespread use**, especially in budget-constrained projects due to: Lower costs (vs. asphalt bases). Reduced technical barriers (vs. high-performance asphalt mixes). Ability to utilise local materials (soil, aggregates). Functions as the primary structural layer for trunk roads or secondary highways, offering adequate heavy-load adaptability.。
Major Technical Hurdles	Higher Costs: Dependence on petroleum resources typically results in higher costs compared to inorganic binder bases, notably during international oil price fluctuations. Stringent High-Temperature Stability Requirements: In hot climates, exceptional attention to rutting resistance design is critical. Demanding Subgrade Strength and	Drying and Thermal Shrinkage Cracking: This primary concern can easily lead to reflective cracks that penetrate the asphalt surface, compromising pavement performance and service life. Extremely Stringent Construction Control Requirements (Moisture Content, Compaction, Curing): Failure to adhere may cause **strength inconsistencies and cracking issues.

Project Name	Organic Binder Base Course (Asphalt Stabilised Base)	Inorganic Binder Base Course (Cement-Stabilised Base Category)
	Evenness: Flexible bases exhibit greater reliance on robust subgrade support**.。	High Brittleness and Limited Deformation Tolerance: Prone to fracturing once cracked or under localised subgrade settlement. Difficult Maintenance: Repairs are less straightforward compared to asphalt-stabilised bases. Extended Curing Period: Impacts construction scheduling (though modern techniques like curing membranes have reduced this duration).

Conclusion: In international practice, asphalt-stabilized base courses predominate in high-grade roads of developed countries due to their comprehensive performance (particularly crack resistance and construction convenience) better aligning with their needs. Conversely, inorganic binder-stabilized base courses (especially cement-stabilized types) are extensively utilized in China, India, Australia, and numerous developing countries, serving as the backbone of their high-grade highways, primarily relying on their high strength and cost-effectiveness.

This project is located in Ulaanbaatar, Mongolia, a developing nation. Cement-stabilized crushed stone inorganic binder base courses offer low cost and mature construction techniques. Ulaanbaatar possesses abundant local supplies of raw materials required for inorganic binders, such as cement, sand, and aggregates, whereas organic binder materials like asphalt need to be imported. Furthermore, current issues with reflective cracking in inorganic binder courses can be mitigated through technologies such as optimizing mix designs, incorporating fibers, improving curing practices to enhance construction quality, and adding admixtures. Therefore, the current pavement structure design adopts a cement-stabilized crushed stone inorganic binder base course.

3.2.6.3 Design standards

Performance climate zoning used for asphalt pavement: Average highest temperature in the hottest month (°C): 22°C; Extreme minimum temperature (°C): -38°C; Annual rainfall (mm): 300; the climate zoning for asphalt pavement design is 2-1-3 (hot in summer and cold in winter, semi-dry).

Standard axle load: Double wheelset with single axle load of 100 kN is used as the standard axle load, represented by BZZ-100kN.

Design lifespan: 20 years for the asphalt pavement.

3.2.6.4 Pavement structure calculation

(1) Calculation basis

1) АВТО ЗАМ ТОСОЛЛҚХ (БН6Д 32-01-16)

2) Design Specification for Urban Road Pavement (CJJ 169-2012)

3) Calculation software HPD2012 version

(2) Pavement structure for the main road and elevated section ground side road and ramp landing section

1) Design deflection value and calculation of allowable tensile stress

Table 3. 46. Predicted Average Daily Traffic Volume in One Direction for the First Year

No.	Vehicle model	Weight of front axle	Weight of rear axle	Number of rear axles	Number of rear axle wheelsets	Rear axle distance (m)	Traffic volume
1	Small bus	13	25.6	1	Dual-wheelset	/	22154
2	Medium and large-sized bus	40	80	1	Dual-wheelset	/	216
3	Small goods vehicle	23.5	44	1	Dual-wheelset	/	2551
4	Medium goods vehicle	83	78.5	2	Dual-wheelset	<3	1235
5	Heavy goods vehicle	26.9	77.2	2	Dual-wheelset	>3	755

Design life of 20 years, lane coefficient of 0.4;

Table 3. 47. Annual Growth Rate of Traffic Volume within the Design Life

No.	Segmented time (year)	Annual growth rate of traffic volume (%)
1	2027-2030	4.1
2	2030-2035	2.6
3	2035-2042	2.6
4	2042-2047	2.1

① If the daily average traffic volume of large buses and various medium-sized and above goods vehicles on a lane:

Nh is 1,903, and it belongs to heavy traffic level;

② If using the design deflection value and the tensile stress at the bottom of the asphalt layer as indicators:

the average daily equivalent axle count in one direction in the first year of road operation is 5,256, and

the accumulated equivalent axle count on one lane within the design period is 2.025948E+07,

It belongs to a heavy traffic level.

③ If using the bottom tensile stress of semi-rigid material structure layers as the design index:

The average daily equivalent axle count in two directions in the first year of road operation is 5,914, and

The accumulated equivalent axle count on one lane within the design period is 2.279577E+07,

It belongs to a heavy traffic level.

④ The design traffic level of the pavement is classified as a heavy traffic level.

Urban road type: main road (big city)

Road classification coefficient 1, coefficient of surface layer type 1, coefficient of pavement

structure type 1;

Design deflection value of pavement: 20.7 (0.01 mm).

Layer level	Material name of the structural layer	Splitting strength (MPa)	Allowable tensile stress (MPa)
1	Fine-grained asphalt concrete	1.4	0.38
2	Coarse-grained asphalt concrete	0.8	0.22
3	Cement stabilised crushed stone	0.7	0.31
4	Cement stabilised gravel	0.5	0.22
5	Graded crushed stone	/	/

(2) Calculation of thickness for newly constructed pavement structure

Number of layers for newly constructed pavement: 5

Standard axle load: BZZ-100

Design deflection value of pavement: 20.7 (0.01 mm)

Layer level of pavement design layer: 4

Layer	Material name of the structural layer	Thickness (mm)	Average compressive modulus at 20°C (MPa)	Standard deviation (MPa)	Average compressive modulus at 15°C (MPa)	Standard deviation (MPa)	Allowable stress (MPa)
1	Fine-grained asphalt concrete	40	1400	0	2000	0	0.42
2	Coarse-grained asphalt concrete	70	1000	0	1200	0	0.24
3	Cement stabilised crushed stone	200	1600	0	3600	0	0.32
4	Cement stabilised gravel	?	1500	0	3200	0	0.23
5	Graded crushed stone	400	250	0	250	0	/
6	New roadbed	/	35				

① Calculate the thickness of the design layer based on the design deflection value:

LD=20.7 (0.01 mm), H(4)=200 mm, LS=19.3 (0.01 mm);

LS<=LD. Therefore, the deflection calculation has met the requirements.

H (4)=200 mm (only deflection considered)

② Calculate the thickness of the design layer based on the allowable tensile stress:

H (4)=200 mm (the calculation of tensile stress on the bottom surface of the first layer meets the requirements)

H (4)=200 mm (the calculation of tensile stress on the bottom surface of the second layer meets the requirements)

H (4)=200 mm (the calculation of tensile stress on the bottom surface of the third layer meets the requirements)

H (4)=200 mm (the calculation of tensile stress on the bottom surface of the fourth layer meets the requirements)

Thickness of pavement design layer:

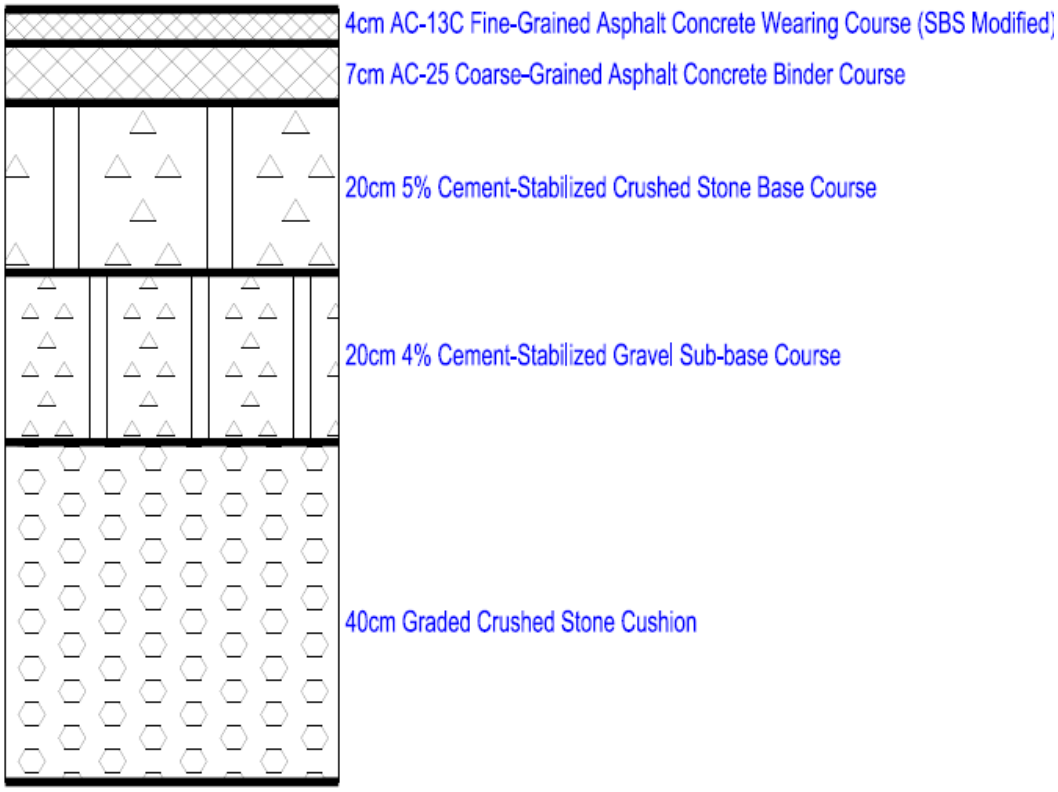
H (4)=200 mm (only deflection considered)

H (4)=200 mm (deflection and tensile stress simultaneously considered)

3.2.6.5 Pavement structure design

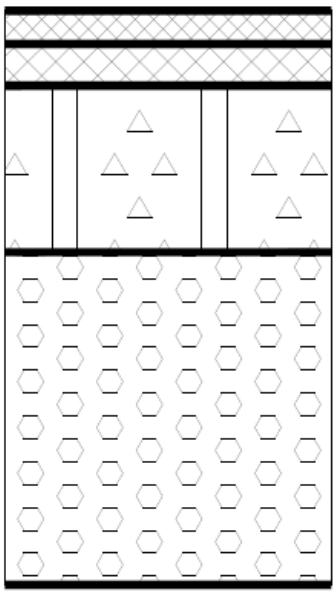
This design is based on the commonly used pavement materials in Ulaanbaatar. Combined with the local existing road pavement structure and considering the local climate conditions, the pavement structure is determined through traffic volume calculation as follows:

(1) Pavement structure for the main road and elevated section, ground side road, and ramp landing section

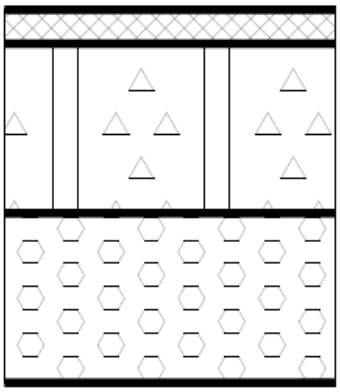


SBS modified asphalt is a high-performance asphalt material obtained by adding styrene butadiene styrene block copolymer to the matrix asphalt for physical and chemical modification. The dosage of SBS modifier in the asphalt accounts for about 3% to 6% of the original matrix asphalt, and on-site construction tests mainly determine the specific dosage. The technical indicators of SBS modified asphalt must meet the requirements of the Code for Construction and Quality Acceptance of Urban Road Engineering (CJJ1-2008).

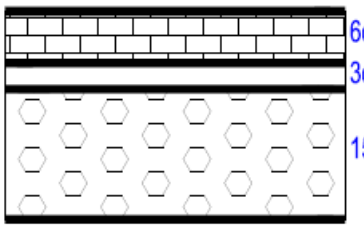
(2) Pavement structure for the ground section side road of the main road



(3) Pavement structure of the non-motorway



(4) Pavement structure for the sidewalk and staged crosswalk paving



3.2.7. Road ancillary engineering

(1) Curbstone

This Project sets up curbstones at the separation points of the strip, carriageway, non-motorway, and sidewalk, and sets up tree pool frames at the roadside trees.

(2) Barrier-free design

The barrier-free design of this Project requires meeting the needs of visually and physically disabled individuals, as well as frail elderly and children, who use road transportation facilities for travel on sidewalks, unit entrances along the route, road intersections, pedestrian crossing

facilities, bridges, bus stops and other facilities.

Figure 3. 71. Rendering of Barrier-free Facilities

In the road design this time, tactile paving is used on the road section to guide the visually disabled to walk with the touch of their feet. The tactile paving is laid continuously on the road section. When there is no obstacle, the laying position should be no less than 0.5m away from the tree hole on the road, and the width of the tactile paving should be 0.3m. A prompt tactile paving is set at the turning point of the tactile paving. For obstacles or objects that may pose a danger to the visually impaired, the tactile paving enclosure serves as a reminder to bypass them. At the same time, there are no sudden height differences or horizontal ridges on the sidewalk of the road section to facilitate the use of wheelchairs by physically disabled individuals. If there is a height difference or cross slope, transition with a slope, and the slope gradient should not exceed 8%.

At the intersection of the road, a curb ramp shall be set at the edge of the corresponding sidewalk, and the gradient of the curb ramp should not exceed 8%. The entrance of the ramp should have no height difference from the ground of the carriageway. Prompt tactile paving should be installed at the intersection to facilitate a clear connection between the tactile paving and the walking tactile paving of the sidewalk. If necessary, audio facilities can be installed to allow visually impaired individuals to confirm that they can pass through the intersection. The longitudinal slope of the bridge sidewalk should not exceed 4% to facilitate wheelchair access. The tactile paving on the bridge sidewalk is continuous with the tactile paving on the road sidewalk, and a gradient of no more than 8% is set at the height difference between the bridge and the road sidewalk.

(3) Public transportation station

There are bus stops along the entire line, and harbour-style or linear bus stops are used at these stops. The straight length of the bus stop is 30m, and the platform width is 2m. This project has nine pairs of 18 harbour-style bus stops and 12 pairs of 24 linear bus stops. The distribution of bus stops is shown in the table below. The current bus routes and the distribution of bus stops

designed on the New Ring Road are shown in the drawing below.

Table 3. 48. List of Bus Stop Distribution

No.	Location	Stop type
1	K0+480	Harbor type
2	K0+930	Harbor type
3	K1+970	Harbor type
4	K2+740	Harbor type
5	K3+540	Harbor type
6	K4+450	Harbor type
7	K7+470	Direct type
8	K11+300	Direct type
9	K12+330	Direct type
10	K13+120	Harbor type
11	K13+720	Harbor type
12	K15+120	Direct type
13	K16+500	Direct type
14	K17+300	Direct type
15	K18+000	Direct type
16	K18+630	Direct type
17	K19+680	Direct type
18	K21+600	Harbor type
19	K22+350	Harbor type
20	K23+350	Harbor type
21	K23+720	Harbor type

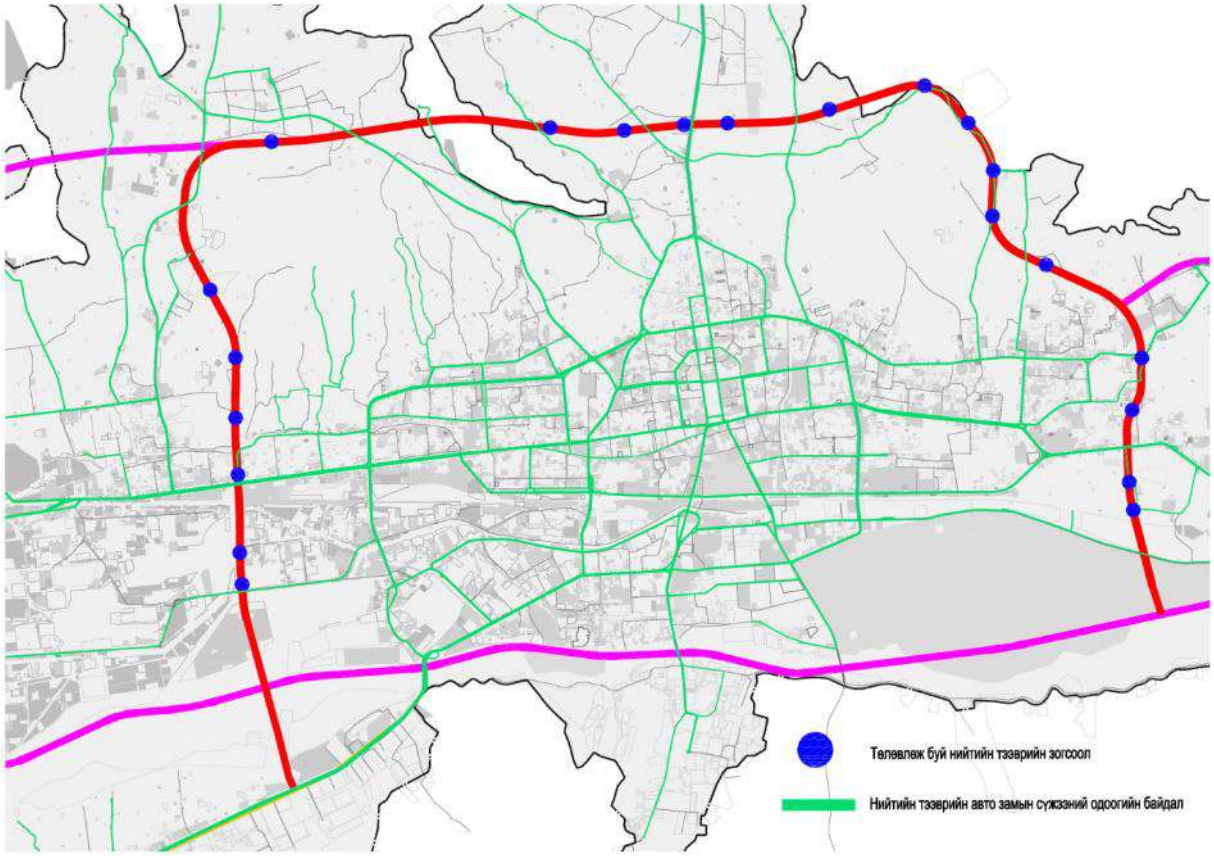


Figure 3. 72. Current Bus Routes and Distribution of Bus Stops Designed on the New Ring Road

(4) Pedestrian crossing

Pedestrians can cross the street through pedestrian crossings designed at ground-level intersections on elevated road sections, and cross the street through pedestrian footbridges and pedestrian passages on ground-level road sections. This time, three pedestrian footbridges and seven channel culverts will be set up on the ground-level main road section, and four pedestrian footbridges will be reserved in the non-densely populated northern area. Construction will be carried out after the future development of surrounding land reaches the scale of pedestrian flow.

3.2.8. Traffic safety and management facilities

3.2.8.1 Basis for traffic design

(1) Road grade: Grade-I main trunk road;

(2) Design speed: main road 100 km/h (local 80 km/h), side road 40 km/h;

(3) Importance coefficient of sign structure: cantilevered structure γ0=1.0; other types of signs γ0 =0.95.

3.2.8.2 Design contents

The design content encompasses marking and layout design, traffic safety facilities (including safety barrels and delineators), monitoring facilities (such as traffic information collection and surveillance), and signal control facilities (including signals and lane indicators).

(1) Marking and layout design, traffic safety facilities such as safety barrels and delineators

The color, line width, line type, and position of the marking are determined according to the road grade and design speed stated in the Rules for the Use of Road Signs, Markings, Traffic Lights, Barriers, and Rules for Application of Road Signs, Markings, Traffic Lights, Barriers and Guidance Devices (MNS 4596:2014), Road Markings. General Technical Requirements (MNS 4759:2014), Road Signs. General Technical Requirements (MNS 4597:2014), Road Traffic Signals. General Technical Requirements (MNS 4980:2014 / Version dated 2019.11.18 C/50/) and other relevant regulations, to guarantee complete signs and intact functions.

(2) Traffic signal control system, electronic police system, and traffic video monitoring system

According to traffic management demands and professional traffic conditions, traffic signal control systems should be installed at intersections as needed. Tunnels should be equipped with a traffic signal control system, a traffic video monitoring system, and a traffic flow detection system. This design is responsible for the power supply and cable design of the external monitoring equipment of the tunnel traffic monitoring system. The control platform of the traffic police centre is not within the scope of this design.

3.2.8.3 Traffic signs

(1) Principles of traffic sign design

The layout of traffic signs in this project strictly adheres to the regulations outlined in the

Rules for the use of road signs, markings, traffic lights, barriers, and guide devices (MNS 4596 2014), specifically Road Signs. General Technical Requirements (MNS 4597:2014) and other relevant regulations, to guarantee complete signs and intact functions. The principles for the layout of traffic signs aim to ensure smooth traffic flow and driving safety, provide comprehensive, accurate, and timely traffic information to road users, facilitate fast and smooth driving, and target drivers who are entirely unfamiliar with the road and its surrounding road network system. Through the guidance of traffic signs, they can reach their destination smoothly and quickly without driving in the wrong direction.

The layout of traffic signs is based on the road alignment, traffic conditions, and facilities along the route to set up different types of traffic signs. Details are as follows:

Set up prohibition signs at locations where vehicle traffic behaviours need to be restricted.

Set up indicator signs at places where vehicles need to be directed to move.

Set up directional signs at places where road direction, location, distance, and other information need to be conveyed.

Set up auxiliary signs below the main signs that require auxiliary explanations for the signs.

The layout of traffic signs should fully consider the connection with the layout of traffic signs on intersecting roads, and consider the setting of signs from a holistic perspective.

Prohibition sign: A sign that prohibits or restricts the traffic behaviours of vehicles and pedestrians. Directional sign: A sign that conveys information about the direction, location, and distance of a road. The above types of signs can be set separately or combined, and commonly used methods for combining include vertical poles, F-shaped poles, and R-shaped poles.

According to the principles of project logo design, the layout of traffic signs should be designed so that drivers can timely and accurately recognise the content of the signs when driving at the designed speed, and make the layout of traffic signs beautiful and eye-catching. The layout of various types of signs within the design scope is unified and coordinated, both before and after, and takes into account the setting of signs and markings on the surrounding current roads to form a cohesive system.

Types of traffic signs designed this time: Prohibition signs, indicator signs, and directional signs.

When two or more types of traffic signs need to be installed at the exact location, they can be installed on one signpost, but the maximum number should not exceed three. When the signboard is placed on a post, it should be arranged in the order of warning, instruction, prohibition, and information, from top to bottom and from left to right.

When traffic signs are placed on the roadside, they should be as perpendicular or angled as possible to the centerline of the road; Prohibition and directional signs are at an angle of 0-45°, while directional and warning signs are at an angle of 0-10°.

(2) Principles of sign layout design

Road Signs. General Technical Requirements (MNS 4597:2014);

Warning sign: Single-column support method, triangle side length A=120 cm;

Prohibition sign: Single-column support method, outer diameter of circular sign D=90 cm; Triangle symbol, side length A=120 cm;

Indicator sign: Single-column support method, outer diameter of circular sign D=90 cm, square side length A=90 cm;

Directional signs: Rectangular and square, with signboard dimensions in line with Mongolian height and text layout requirements.

Emergency telephone indicator sign (active luminous type): preferably 25cm × 40 cm;

Fire equipment indicator signs: preferably 25cm × 40 cm;

indicator sign of pedestrian cross passage (active luminous type): preferably 50 cm × 80 cm;

Evacuation indicator mark (active luminous type): preferably 75cm × 25cm;

Emergency parking strip sign (active luminous type): preferably 50 cm × 80 cm;

The design of a traffic signboard encompasses its geometric design, shape, pattern, layout, and colour.

Warning signs and prohibition signs have a white base, a red circle, a red bar, a black pattern, and a patterned bumper. Directional signs use a blue base with white text and a white pattern.

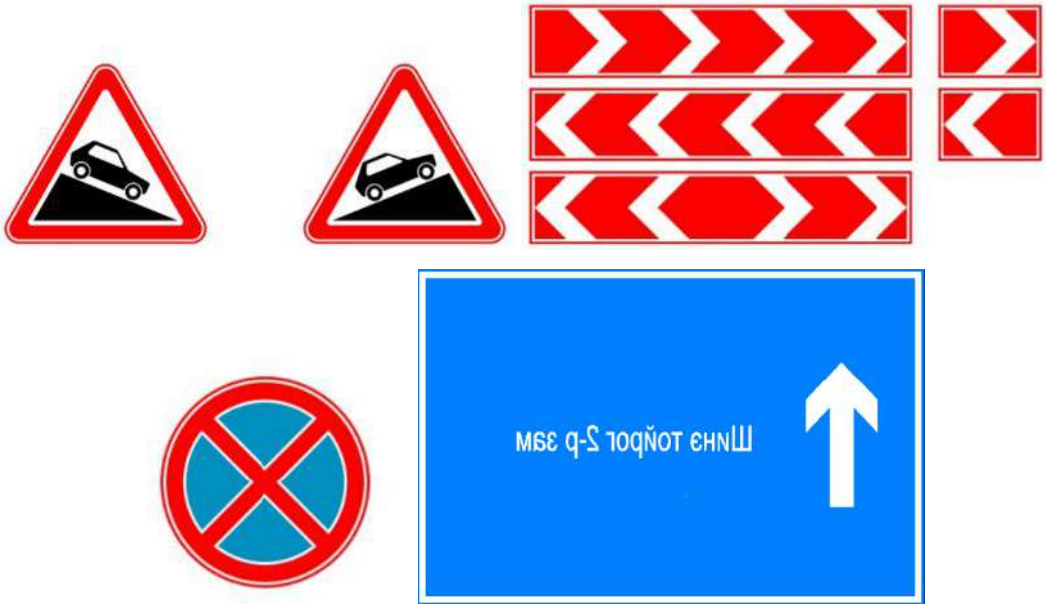


Figure 3. 73. Schematic Diagram of Traffic Signs

Oversized signs are installed on-site for convenient transportation.

Determination of support methods: The structural support methods for traffic signs can be

classified as column type, cantilever type, and attached type. The design can be selected based on the composition of the vehicle model, the dimensions of the signboard, and the location of the sign layout.

3.2.8.4 Traffic markings

(1) Types of markings

Determine the colour, line width, line type, and position of the marking according to the Rules for the use of road signs, markings, traffic lights, barriers, and guide devices (MNS 4596 2014), Road Markings. General Technical Requirements (MNS 4759 2014), Road Traffic Signs and Markings (GB 51038-2015), Road Traffic Signs and Markings-Part 3: Road Traffic Marking (GB 5768.3-2009), and Pavement Marking Paint (JT/T280-2004). Traffic markings are used to regulate and guide traffic. They should ensure that traffic flows in different directions, guide the traffic direction, guide vehicles into the correct lane before merging and diverging, regulate driving disciplines and orders, and reduce accidents. Ensure the visual guidance function operates effectively during both day and night, clearly delineating lane boundaries, lines, and contours, and integrating organically with traffic signs to guide traffic flow reasonably.

The types of traffic markings designed for this project are classified as transverse markings and longitudinal markings.

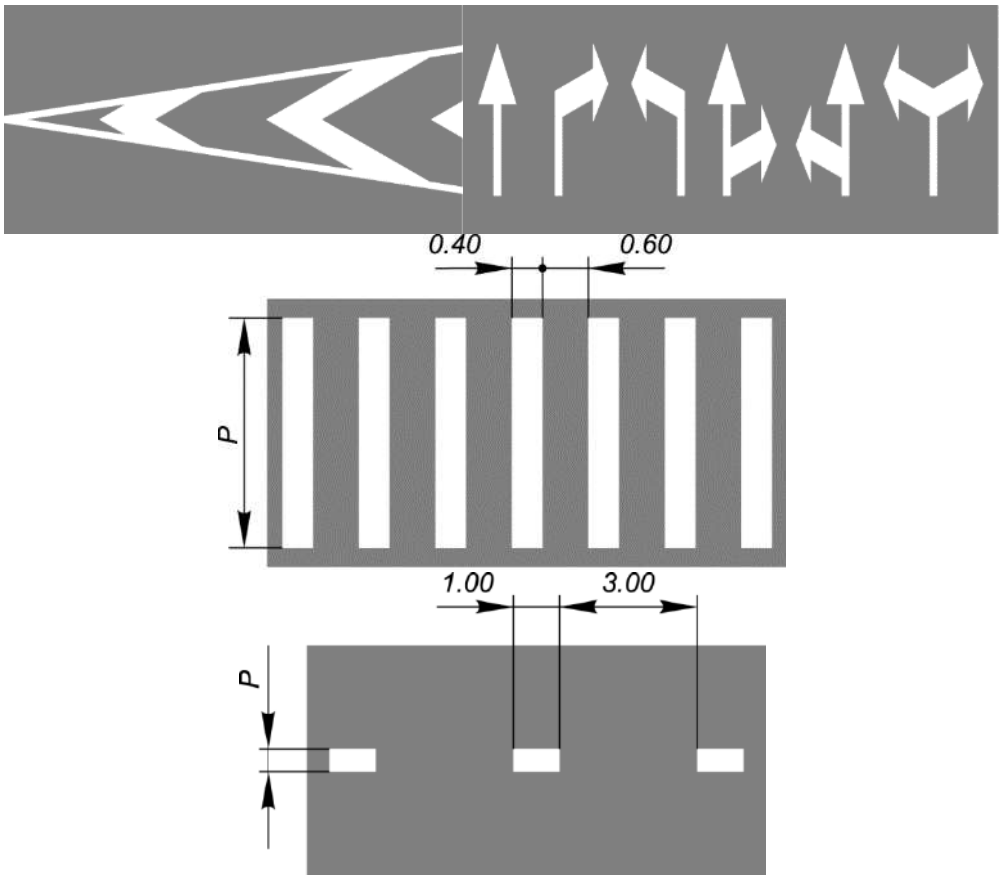


Figure 3. 74. Schematic Diagram of Traffic Markings

Edge line of carriageway: Use a white solid line with a width of 15 cm.

Boundary through which the same direction of carriageway can be crossed: White dashed lines with line segments and intervals of 3 m and 9 m respectively, and a line width of 15cm.

Pedestrian crossing line: Use white markings with a width of 40 cm, spacing of 60 cm, and a width of 4 m.

Stop line: Use a white solid line, 3m away from the pedestrian crossing, with a line width of 40 cm. The length should be drawn according to the specific on-site conditions.

Guiding lane line: Use a white solid line with a line width of 15 cm and a drawn length of 30m.

Boundary through which the object carriageway is restricted to be crossed: Use a white solid line with a line width of 15 cm.

Directional arrows: To better indicate the driving direction of the vehicle, when the design speed is ≥ 60 km/h, the ground directional arrows are 6.0 m long and white. The number of setting times for directional arrows at level crossings is 3. The first group of directional arrows is positioned 3 m away from the stop line. In contrast, the second group is set at the starting position of the directional lane, with the arrow's starting end aligned with the directional lane line's starting end. The third group is set 30-50 m in front of the second group of arrows.

Markings of acceleration and deceleration lanes: These markings serve as a boundary to separate the main driving lane. Use white dashed lines with line segments and spacing lengths of 1m and 3m, respectively, and a line width of 40 cm.

Marking for the same direction of traffic merging island: With a line width of 10 cm, a filling line width of 40 cm, and an interval of 1.2 m.

Vertical marking: It is used at the edge of tunnel entrances and maintenance lanes, with yellow and black diagonal stripes (45° inclination), with a line width of 20 cm.

(2) Marking materials

The longitudinal markings on the pavement are oscillatory, and a qualified test report should accompany the product. The coating is pre-mixed with glass beads and then spread with glass beads on the surface during hot melt construction. The coating density should be ≥ 1.8-2.3 (g/cm2), the softening point should be 90°C-120°C, and the appearance of the coating should be free of wrinkles, blooming, foaming, cracking or sticking. The colour and appearance of the coating should not differ significantly from the standard board. Drying time for reaching a zero tire sticking force ≤ 3 (min), compressive strength ≥ 12 MPa, glass bead content 15% to 23%; pre-mixed glass beads and surface scattered glass beads should comply with the requirements of Glass Beads for Road Markings JT/T446-2001.

Except for longitudinal markings, other marking coatings should be hot-melt coatings, and the product should be accompanied by a qualified test report; The coating density is 1.8-2.3

(g/cm), and the amount of glass beads sprinkled on the surface is (0.3-0.4) kg/m2; The softening point should be 90°C-125°C, and the appearance of the coating should be free of wrinkles, blooming, bubbling, cracking, and sticking. The colour and appearance of the coating should not differ significantly from the standard board. Drying time for reaching a zero tire sticking force ≤ 3 (min), compressive strength ≥ 12 MPa, glass bead content 18%-25%. The application of glass beads on the surface should comply with the requirements of Glass Beads for Road Markings JT/T446-2001. Continuous solid line markings should have drainage joints set every 15m. When other markings may obstruct water, drainage joints should be set along the drainage direction, with a width generally ranging from 3cm to 5cm.

3.2.8.5 Traffic Signal Facilities

Determine the traffic signal facilities according to the Rules for the use of road signs, markings, traffic lights, barriers, and Guide Devices (MNS 4596 2014), Road Traffic Signals. General Technical Requirements (MNS 4980:2014 / Amendment C/50 dated 2019.11.18).

Traffic signal facilities are set up in this project based on the traffic flow at the level crossing, including traffic signals, pedestrian signals, and lane indicators.

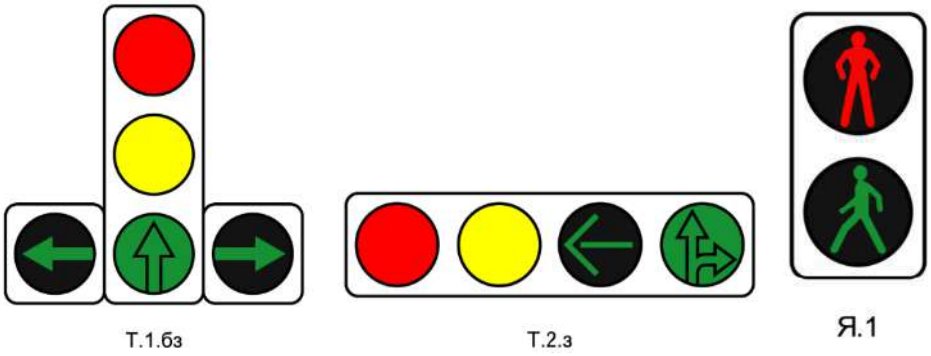


Figure 3. 75. Schematic Diagram of Traffic Signals

(1) Motor vehicle signals

When setting up traffic signals, it should be ensured that any lane within their operating range is visible at a distance of no less than 100 meters.

Technical requirements:

Diameter of supporting lampshade: 300 mm

(2) Pedestrian signals

1) Corresponding standards for signal specifications and road types:

For roads with four or more lanes in one direction:

Я. 1-type circular signal (diameter 300 mm) should be used

For roads with four or fewer lanes in one direction:

Я. 1-type circular signal (diameter 200 mm) should be used

(3) Lane indicator

Signal display: Lane indicators usually display a red "X" and a green "↓", where the red "X" indicates no entry information and the green "↓" indicates passage information.

Brightness and viewing angle: The lane indicator utilises an energy-saving LED light source, ensuring sufficient brightness and viewing angle for the driver to see the signal.

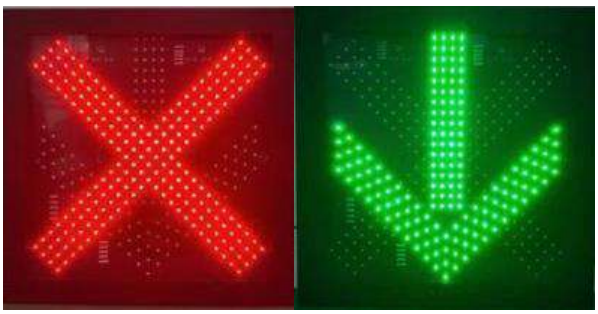


Figure 3. 76. Schematic Diagram of the Lane Indicator

3.2.8.6 Tunnel monitoring facilities

Monitoring facilities shall be determined by: Rules for Application of Road Signs, Markings, Traffic Lights, Barriers and Guidance Devices (MNS 4596:2014), Road Traffic Signals. General Technical Requirements (MNS 4980:2014 / Amendment C/50 dated 2019.11.18).

(1) Vehicle detector

1) Detect basic traffic parameters such as traffic volume and speed for each lane;

2) Detect the direction of travel;

3) Detect all types of motor vehicles, including motorcycles with two wheels and above, and detect trailers as one vehicle.

(2) Camera

1) The camera should be installed inside and outside the tunnel and at the management building attached to the tunnel.

2) The camera is set up in the emergency parking zone, vehicle cross passage, and pedestrian cross passage inside the tunnel.

3.2.8.7 Other facilities

(1) In this design, crash cushion cylinder is installed on the top of the primary and auxiliary separation retaining walls to prevent secondary accidents caused by vehicle falls; Set up W-beam guardrails at the soil shoulder of the fill section to avoid secondary accidents caused by cars driving out of the road; Install safety barrels at the diversion point at the nose end of the interchange to reduce injuries caused by vehicle collisions.

(2) Delineators: Bidirectional delineators should be installed inside the tunnel, and should be placed on both the tunnel sidewall and the edge of the maintenance track.

3.3. TRAFFIC SURVEY AND DEMAND ANALYSIS

3.3.1. OD survey along the New Ring Road

Determine the sample range and collect survey data: To minimise the standard error of the study, survey questionnaires were distributed to traffic communities along the New Ring Road and within a 1km radius. A total of 52 communities were surveyed, and 50 valid questionnaires were collected from each community. A total of 2,600 survey questionnaires were obtained. The specific situation of the traffic zones within the sample range is shown in the table and drawing below.

Table 3. 49. Traffic Communities Surrounding the New Ring Road

Position	Traffic communities
West side	96, 114, 117, 120, 121, 199
North side	22, 32, 39, 43, 49, 60, 108
East side	27, 63, 125, 128, 129
Surrounding	37, 38, 40, 41, 57, 64, 68, 85, 86, 87, 89, 118, 122, 130, 131, 191, 192, 205
Internal	6, 23, 69, 90, 91, 92, 110, 126, 127, 144, 145, 180, 181, 190

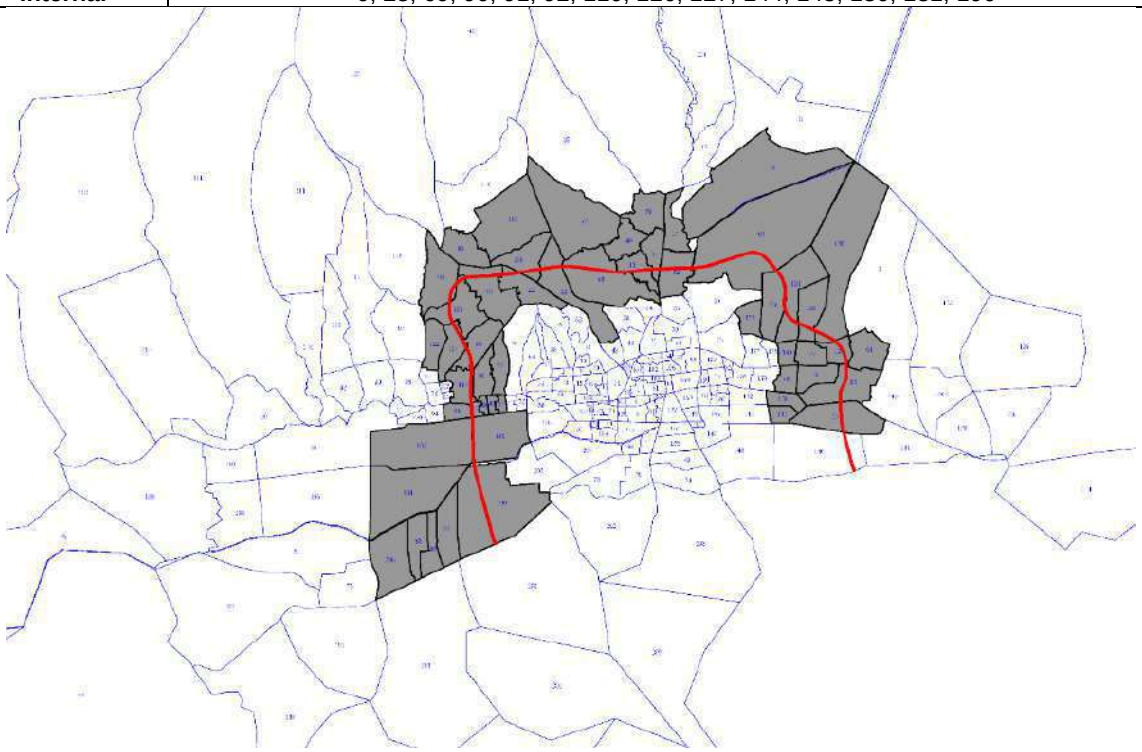


Figure 3. 77. Distribution Diagram of Traffic Communities around the New Ring Road

3.3.2. Analysis of current traffic situations

The changes in the congestion ratio of overall roads, east-west road axes, and north-south road axes over time during weekdays in the urban area of Ulaanbaatar are shown in the drawing below. The changes in the traffic intensity ratio of overall roads, east-west road axes, and north-south road axes over time during weekdays are shown in the drawing below.

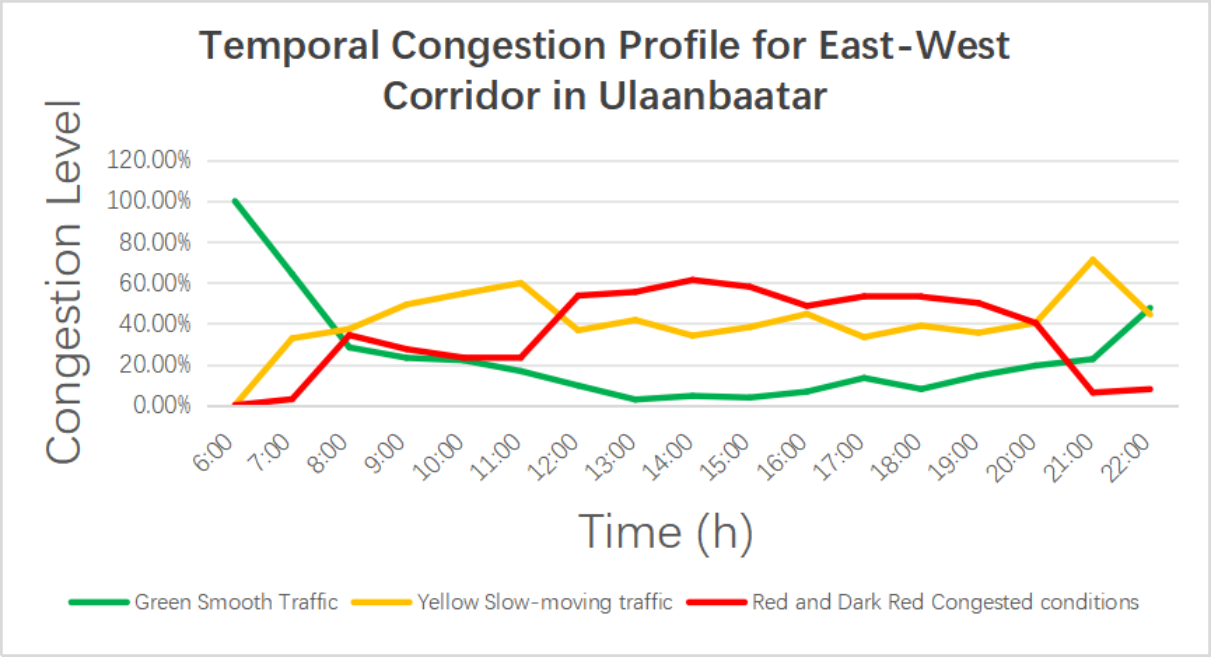


Figure 3. 78. Time-varying Graph for Overall Traffic Congestion Ratio in Ulaanbaatar

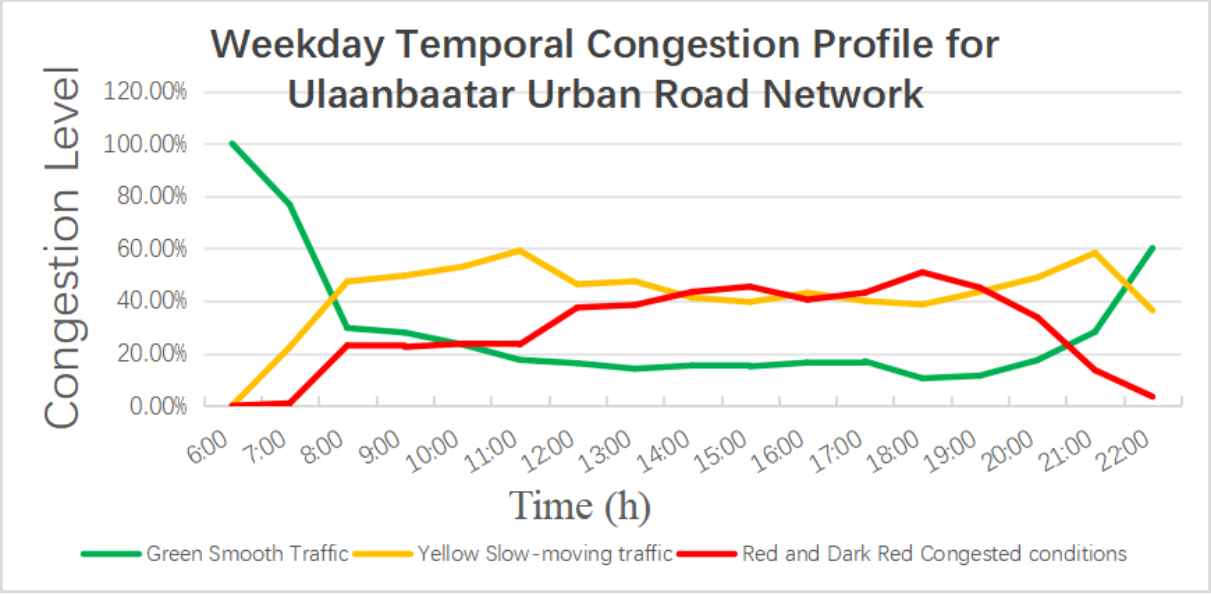


Figure 3. 79. Time-varying Graph for Traffic Congestion Ratio Along the East-West Axis of Ulaanbaatar

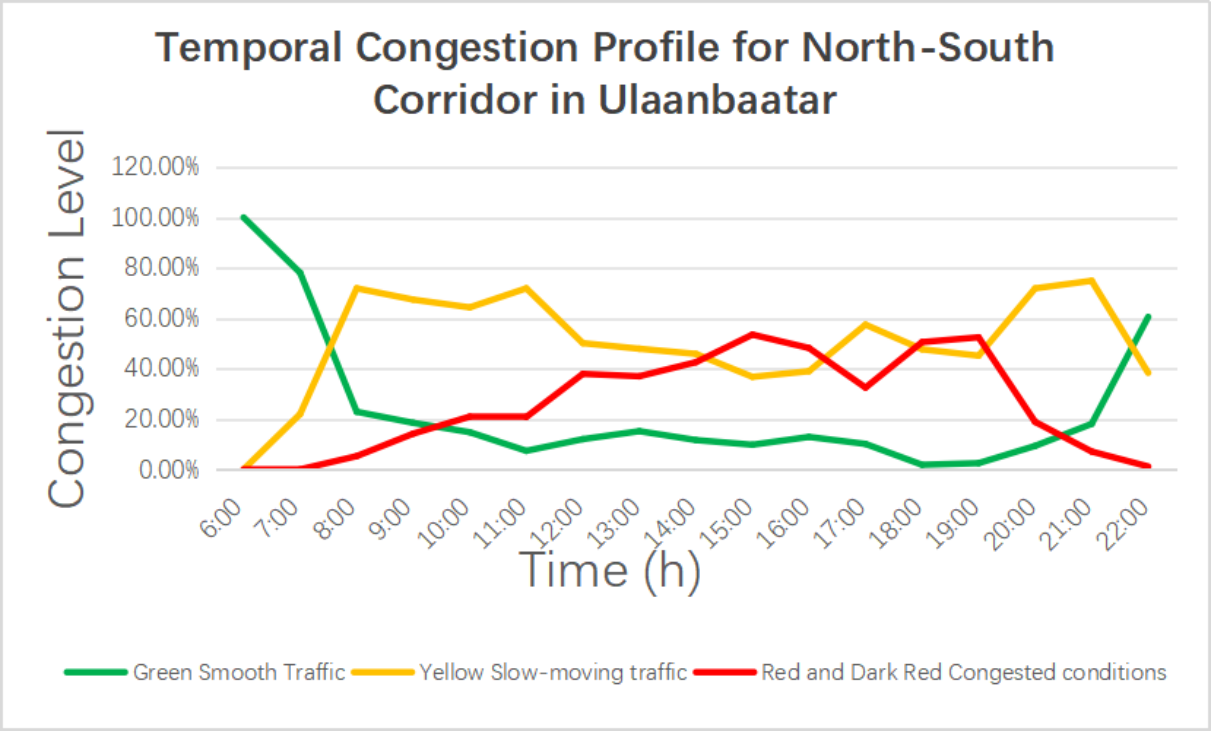


Figure 3. 80. Time-varying Graph for Traffic Congestion Ratio Along the North-South Axis of Ulaanbaatar

3.3.3. Modelling and analysis of transportation demands

Build models before and after the implementation of the New Ring Road through TransCAD software. Conduct traffic allocation before and after the implementation of the New Ring Road, and obtain the allocation results for the current year and forecast year. Analyse the main urban road sections and intersections before and after the implementation of the New Ring Road, compare the changes in saturation and flow in each year, and compare the saturations before and after the implementation of the New Ring Road. Calculate the congestion coefficient based on the saturation of road sections before and after the implementation of the New Ring Road, and obtain the average speed of the road network. Analyse the impact of the New Ring Road on traffic by calculating the overall changes in saturation of road sections and intersections. Analyse and predict the road sections and intersections on the newly built ring road, and obtain the results.

(1) Traffic modelling analysis results before the implementation of the New Ring Road

1) Traffic modelling analysis in 2028

Allocate traffic for the morning and evening peak of the road network before the implementation of the New Ring Road, and obtain the allocation map. The modelling results of the morning and evening peaks are shown in the drawing below.

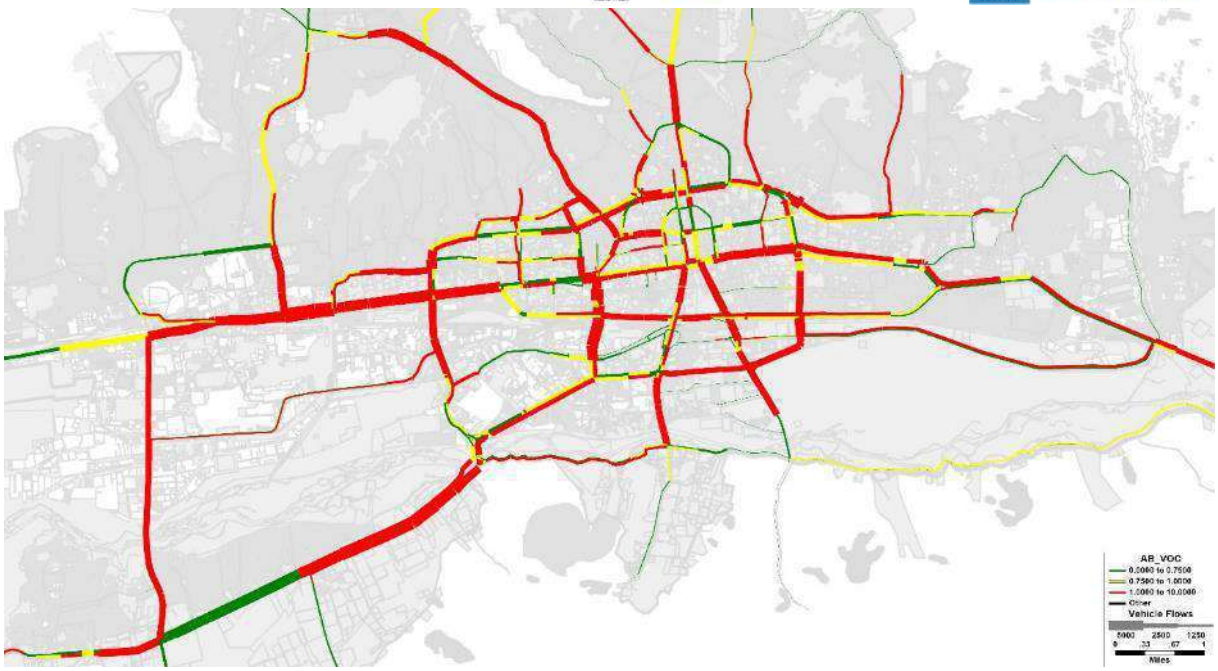


Figure 3. 81. Morning Peak Allocation Map for Road Network before Implementation of the New Ring Road in 2028

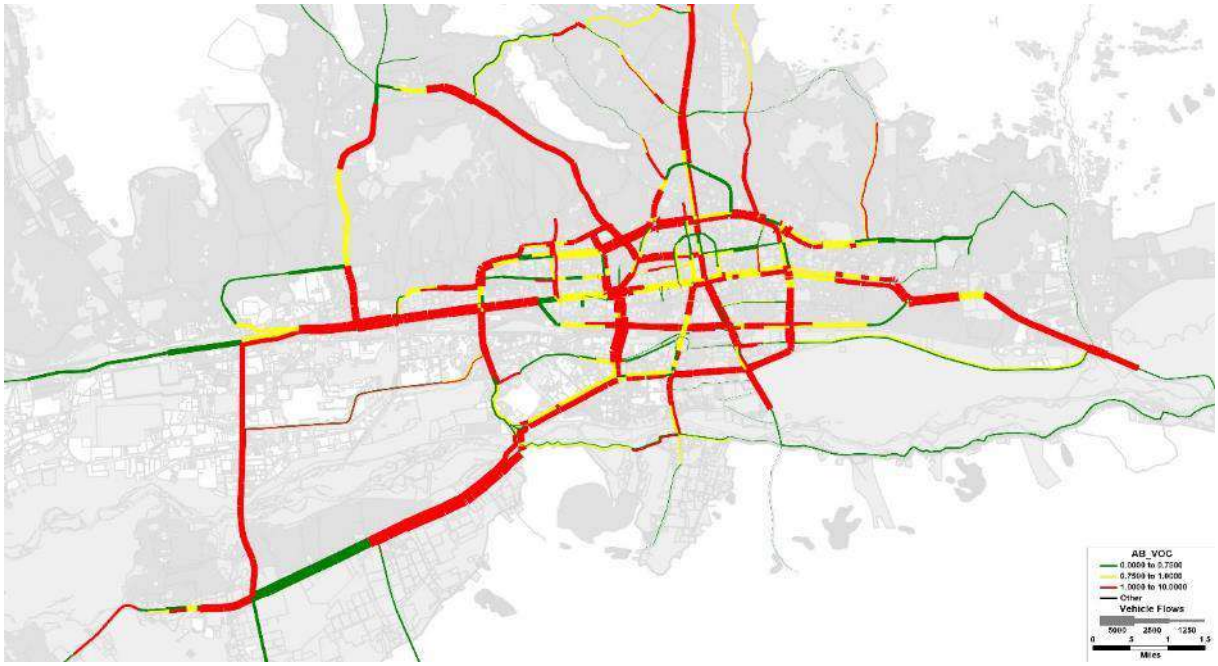


Figure 3. 82. Evening Peak Allocation Map for Road Network before Implementation of the New Ring

Road in 2028

2) Traffic modelling analysis in 2030

Allocate traffic for the morning and evening peak of the road network before the implementation of the New Ring Road, and obtain the allocation map. The modelling results of the morning and evening peaks are shown in the drawing below.

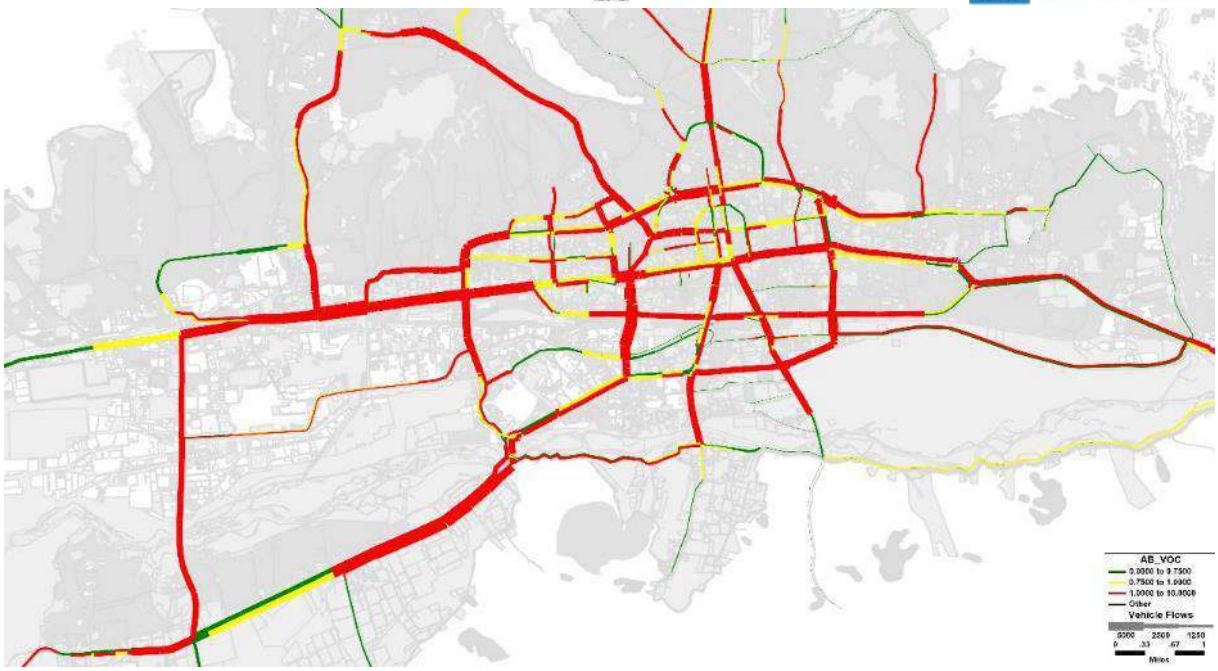


Figure 3. 83. Morning Peak Allocation Map for Road Network before Implementation of the New Ring Road in 2030

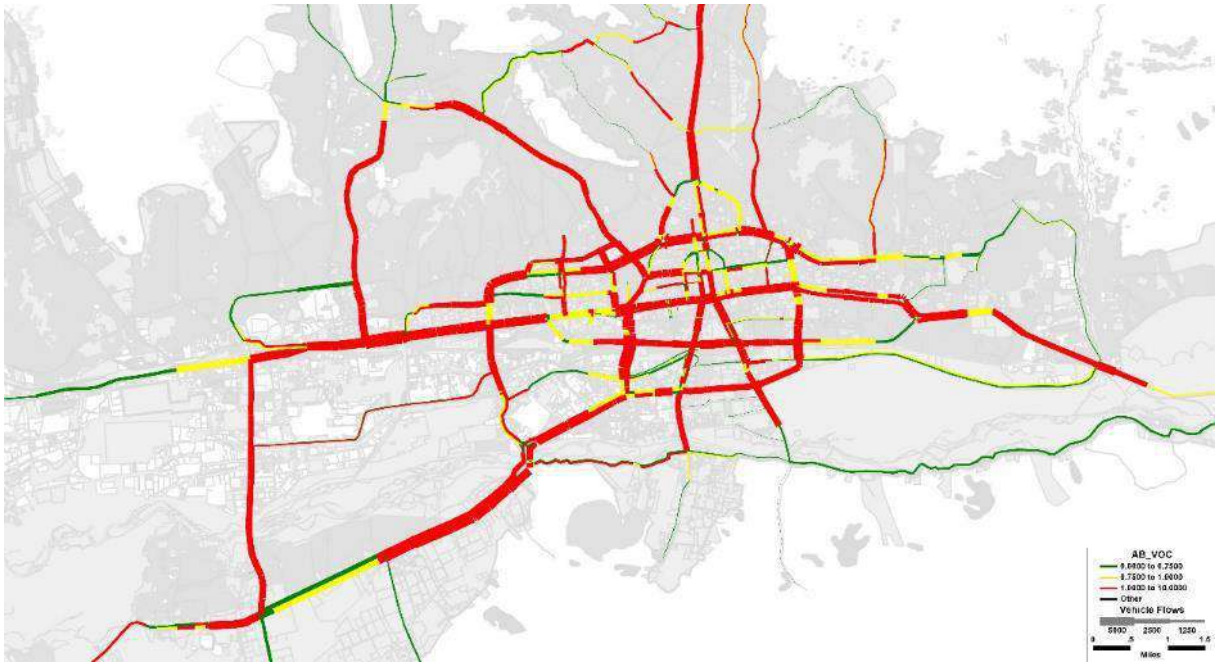


Figure 3. 84. Evening Peak Allocation Map for Road Network before Implementation of the New Ring Road in 2030

3) Traffic modelling analysis in 2040

Allocate traffic for the morning and evening peak of the road network before the implementation of the New Ring Road, and obtain the allocation map. The modelling results of the morning and evening peaks are shown in the drawing below.

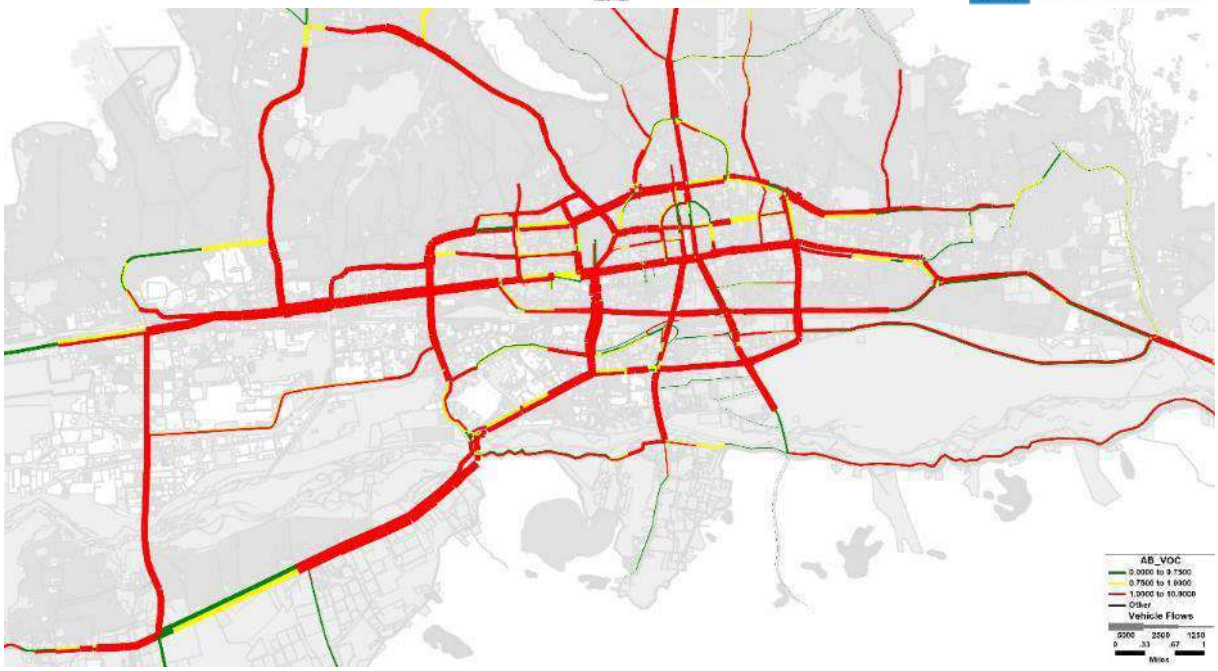


Figure 3. 85. Morning Peak Allocation Map for Road Network before Implementation of the New Ring Road in 2040

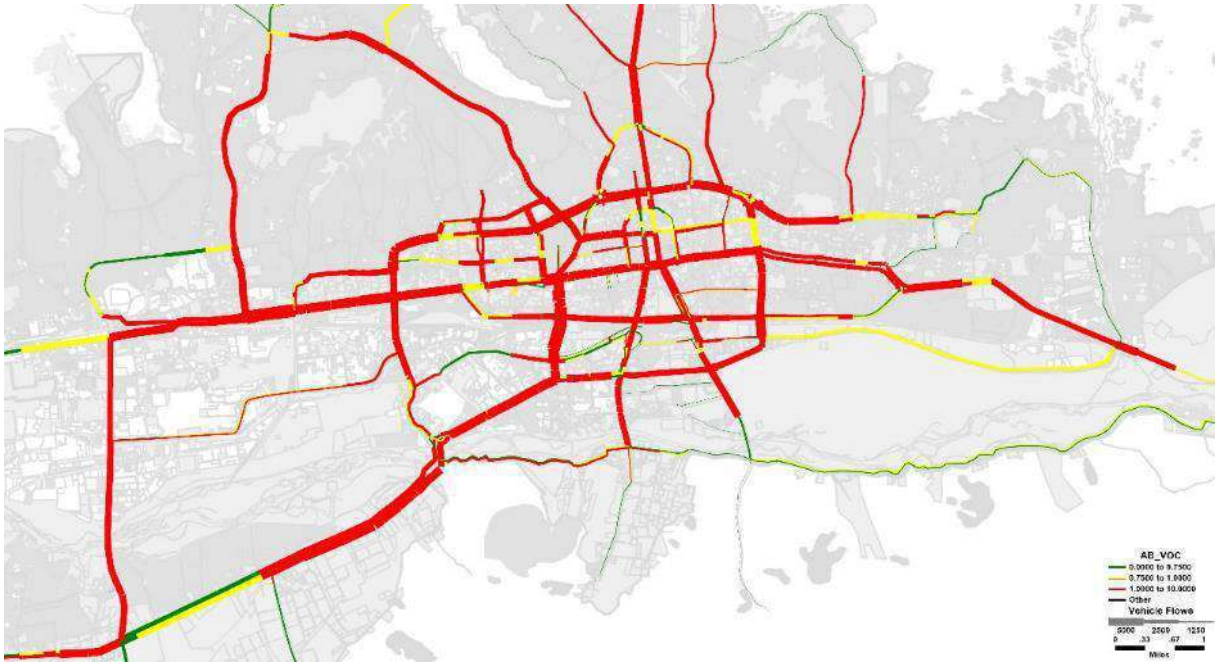


Figure 3. 86. Evening Peak Allocation Map for Road Network before Implementation of the New Ring Road in 2040

(2) Traffic modelling analysis results after the implementation of the New Ring Road

1) Traffic modelling analysis in 2028

Allocate traffic for the morning and evening peak of the road network after the implementation of the New Ring Road, and obtain the allocation map. The modelling results of

the morning and evening peaks are shown in the drawing below.

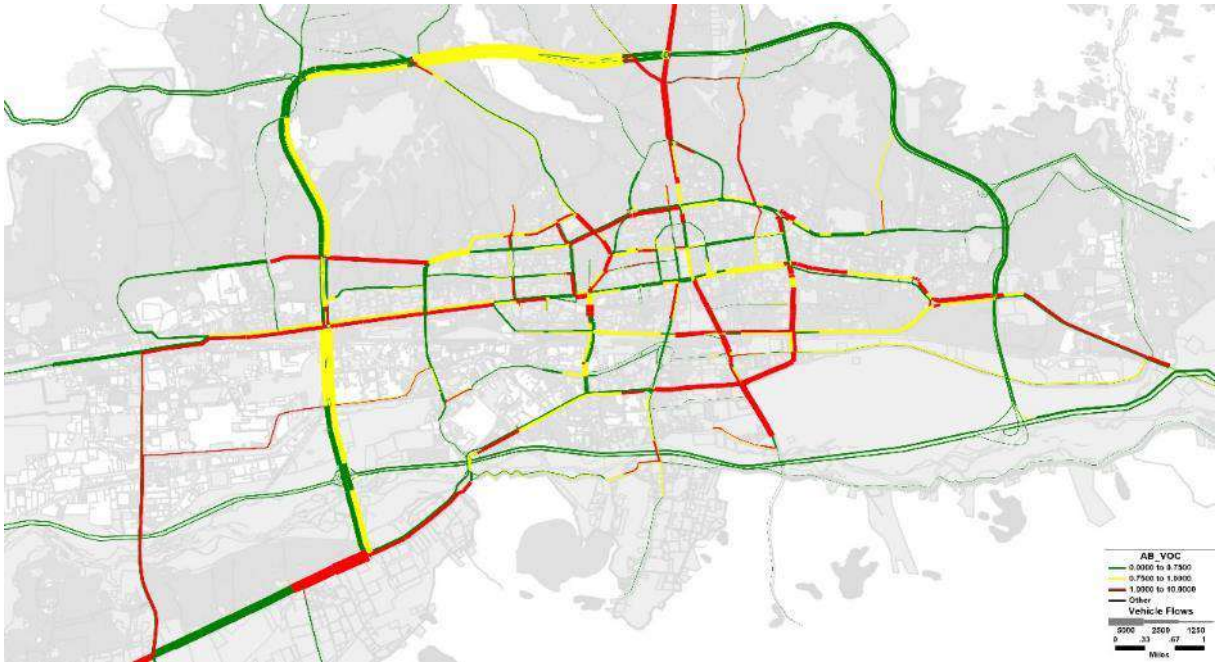


Figure 3. 87. Morning Peak Allocation Map for Road Network after Implementation of the New Ring Road in 2028

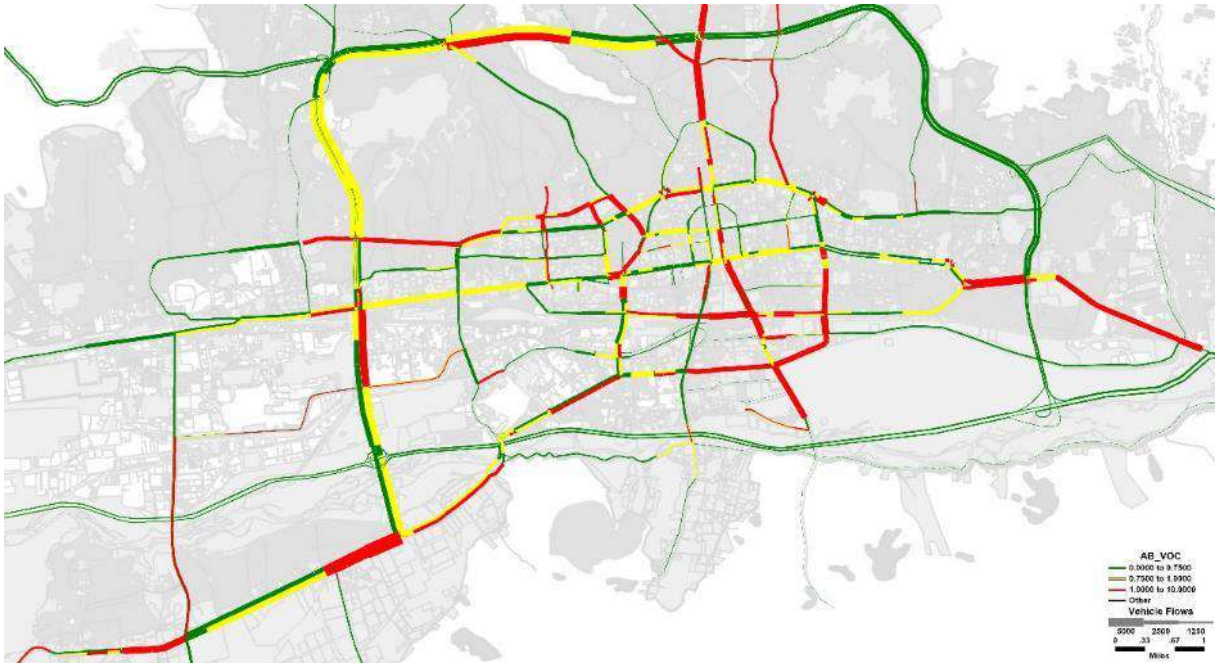


Figure 3. 88. Evening Peak Allocation Map for Road Network after Implementation of the New Ring Road in 2028

2) Traffic modelling analysis in 2030

Allocate traffic for the morning and evening peak of the road network after the implementation of the New Ring Road, and obtain the allocation map. The modelling results of the morning and evening peaks are shown in the drawing below.

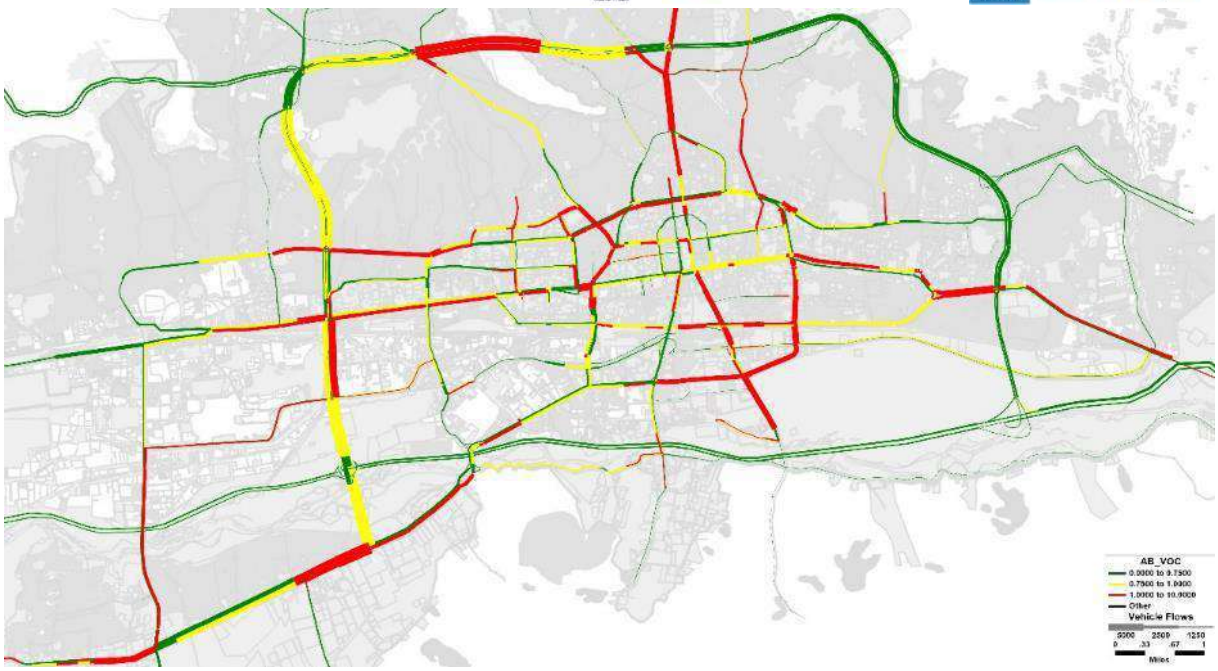


Figure 3. 89. Morning Peak Allocation Map for Road Network after Implementation of the New Ring Road in 2030

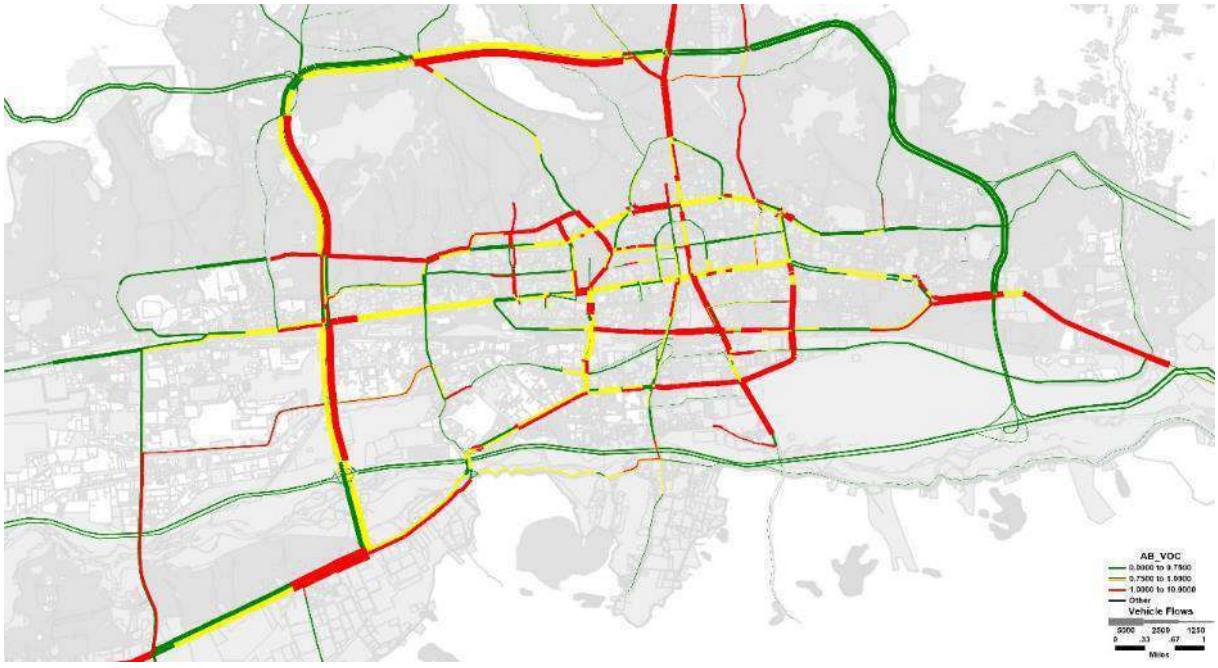


Figure 3. 90. Evening Peak Allocation Map for Road Network after Implementation of the New Ring Road in 2030

3) Traffic modelling analysis in 2040

Allocate traffic for the morning and evening peak of the road network after the implementation of the New Ring Road, and obtain the allocation map. The modelling results of the morning and evening peaks are shown in the drawing below.

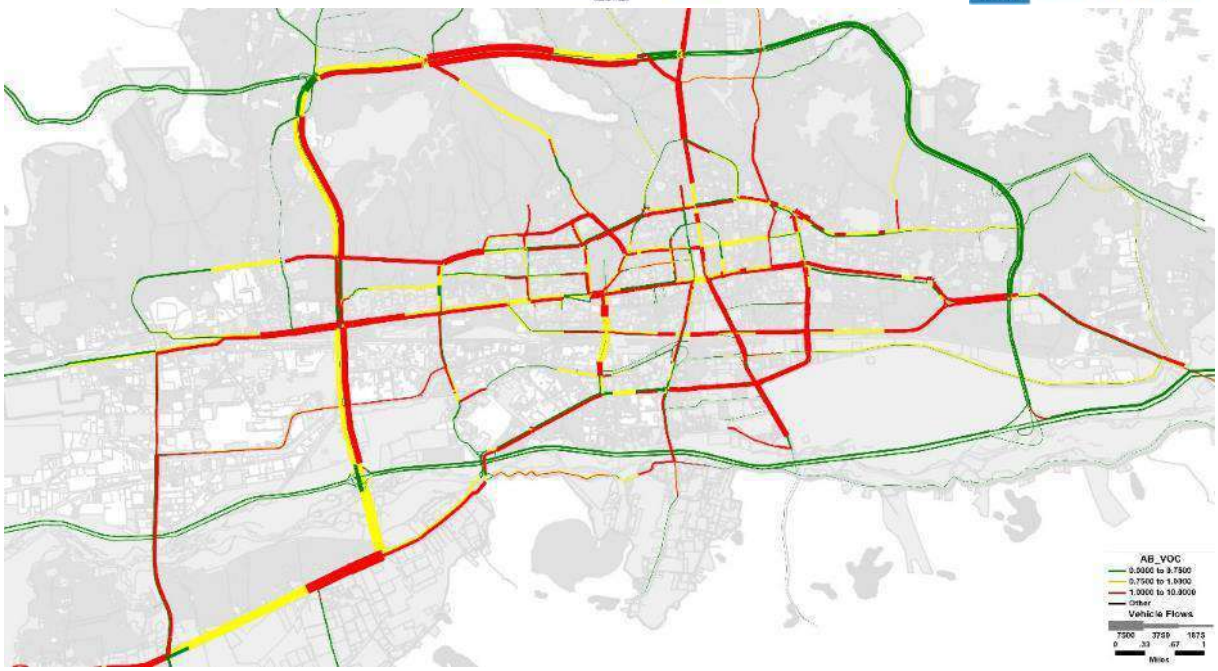


Figure 3. 91. Morning Peak Allocation Map for Road Network after Implementation of the New Ring Road in 2040

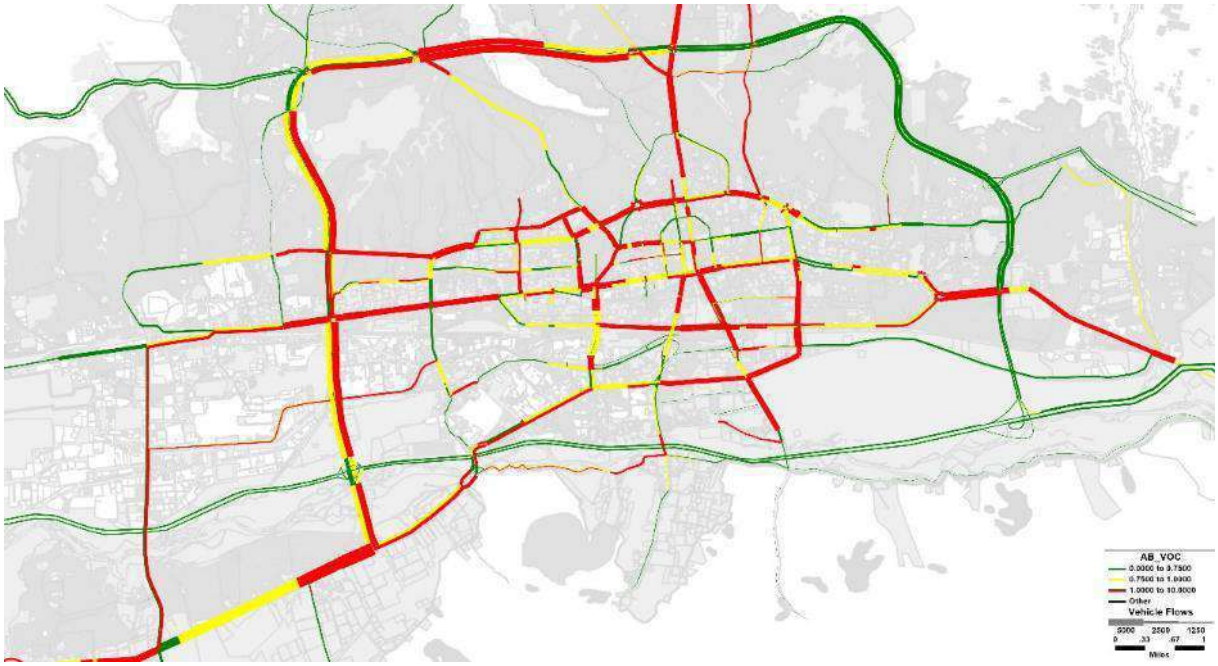


Figure 3. 92. Evening Peak Allocation Map for Road Network after Implementation of the New Ring Road in 2040

3.3.4. Comparative analysis of road network segments before and after the implementation of the New Ring Road

Conduct traffic flow and VCR analysis on important road sections in the main urban area before and after the implementation of the New Ring Road, with a focus on 19 road sections. The road section division is shown in the drawing below.

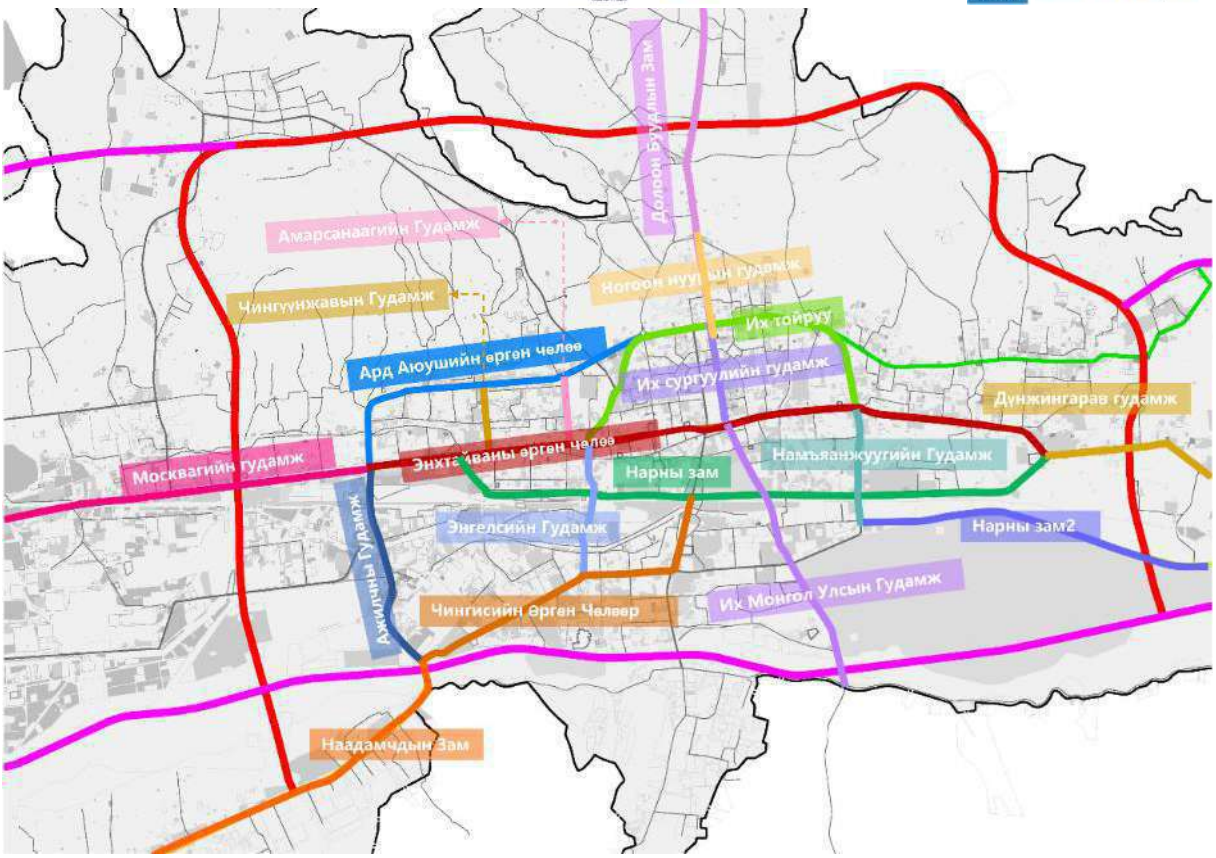


Figure 3. 93. Distribution of Important Road Sections

Calculate the overall saturation change of the road section based on the saturation before and after the implementation of the New Ring Road. Multiply the saturation change calculated for each road section by the weight coefficient of the number of lanes in each road section. The weight coefficient of the lane in each road section is equal to the number of lanes in each road section divided by the number of lanes in all road sections. The average saturation change for all road sections is obtained by summing up the values of each road section, as shown in the table below.

Table 3. 50. Proportion of Changes in Overall Saturation (VCR) of Road Sections.

Road section	Overall change rate in 2028	Overall change rate in 2030	Overall change rate in 2040
19 important road sections	-20.27%	-21.94%	-25.21%

By analysing the saturation levels before and after the implementation of the New Ring Road and comparing the saturation levels of road sections before and after the implementation of the New Ring Road, the overall trend of road saturation changes in 2028, 2030, and 2040 is obtained. The saturation of the planned road network has decreased by 20.27%, 21.94%, and 25.21% compared to the current road network, indicating that the planned route has had a

positive impact on traffic in Ulaanbaatar city, significantly improving residents' travel speed and alleviating traffic pressure.

3.3.5. Analysis of changes in the average speed of overall road sections

Calculate the overall average speed change of the road section based on the average speed before and after the implementation of the New Ring Road. Multiply the average speed change calculated for each road section by the weight coefficient of the number of lanes in each road section. The weight coefficient of the lane in each road section is equal to the number of lanes in each road section divided by the number of lanes in all road sections. The average speed change for all road sections is obtained by summing up the values of each road section, as shown in the table below.

Table 3. 51 Overall Average Speed Changes of Road Sections

Road section	Overall change in 2028	Overall change in 2030	Overall change in 2040
19 important road sections	4.6km/h	4.8km/h	5.1km/h

By analysing the average speed before and after the implementation of the New Ring Road, and comparing the average speed of the road sections before and after the implementation, the overall trend of average speed changes in 2028, 2030, and 2040 is obtained. After the implementation of the New Ring Road, the average speed of the section has increased by 4.6 km/h, 4.8 km/h, and 5.1 km/h compared to the period before the New Ring Road's implementation. The planned construction of the ring road reveals its positive impact on the transportation of Ulaanbaatar city, significantly improving the travel efficiency of residents and reducing the pressure of traffic congestion.

3.3.6. Comparative study on intersections before and after the implementation of the New Ring Road

Conduct traffic flow and VCR analysis on essential intersections in the main urban area before and after the implementation of the New Ring Road, with a focus on 11 intersections. The intersection division is shown in the drawing below.

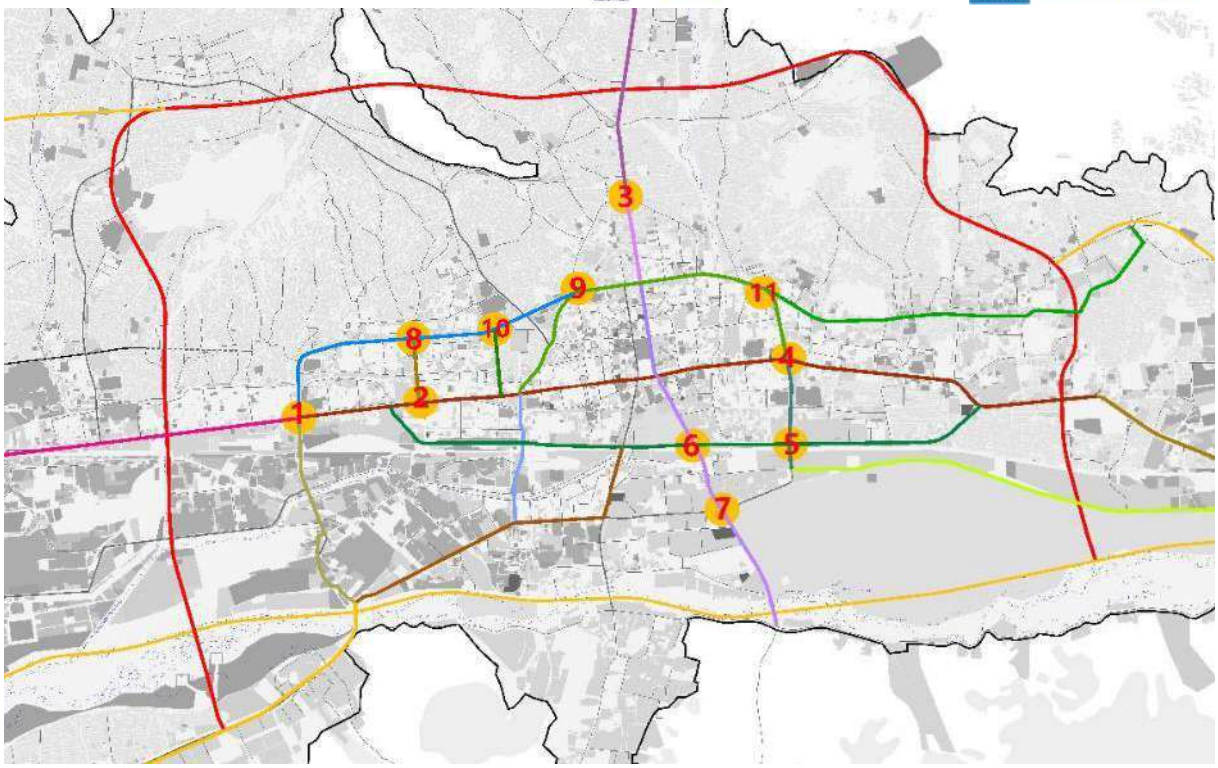


Figure 3. 94. Critical Intersections in the Main Urban Area

By recalculating the overall saturation change of the intersection, the saturation change of each intersection is multiplied by the weight coefficient of the corresponding lane number. The weight coefficient of intersection lanes = the number of lanes at individual intersections / the number of lanes at all intersections. The average saturation change of all intersections is obtained by summing up the lanes at each intersection, as shown in the table below.

Table 3. 52. Overall CVR Changes at Intersections

Intersection	Overall change rate in 2028	Overall change rate in 2030	Overall change rate in 2040
11 important intersections	-20.24%	-23.12%	-25.57%

By analysing the above table and comparing the saturation levels of intersections before and after the implementation of the New Ring Road, the overall trend of intersection saturation changes in 2028, 2030, and 2040 is obtained. After the implementation of the New Ring Road, the saturation levels decreased by 20.24%, 23.12%, and 25.57% compared to those before, indicating that the New Ring Road has reduced traffic pressure and alleviated traffic congestion.

3.3.7. Traffic volume forecast analysis for the proposed New Ring Road

(1) Vehicle model distribution and vehicle conversion factor

According to the Urban Data Statistical Analysis provided by the Owner, the proportion of various vehicle types in 2023 vehicle ownership is based on the 2023 statistical data.

Table 3.3.7-1 Proportion of Vehicle Models in Total Number of Vehicles in 2023

Car	Truck	Bus	Special vehicles include tractors, water trucks, and construction vehicles.
0.81	0.16	0.02	0.01

(2) Prediction period of traffic volume

According to the design standards of Mongolia and based on the road grade of the New Ring Road, the expected lifespan is 20 years. The number and scale of lanes are determined based on the predicted traffic volume at the end of the traffic forecast year.

(3) Traffic volume forecast results for the New Ring Road section

Divide the main and auxiliary roads of the New Ring Road into 10 sections based on important nodes along the line, and predict the traffic volume of different sections. The segmentation of the New Ring Road is shown in the drawing below.

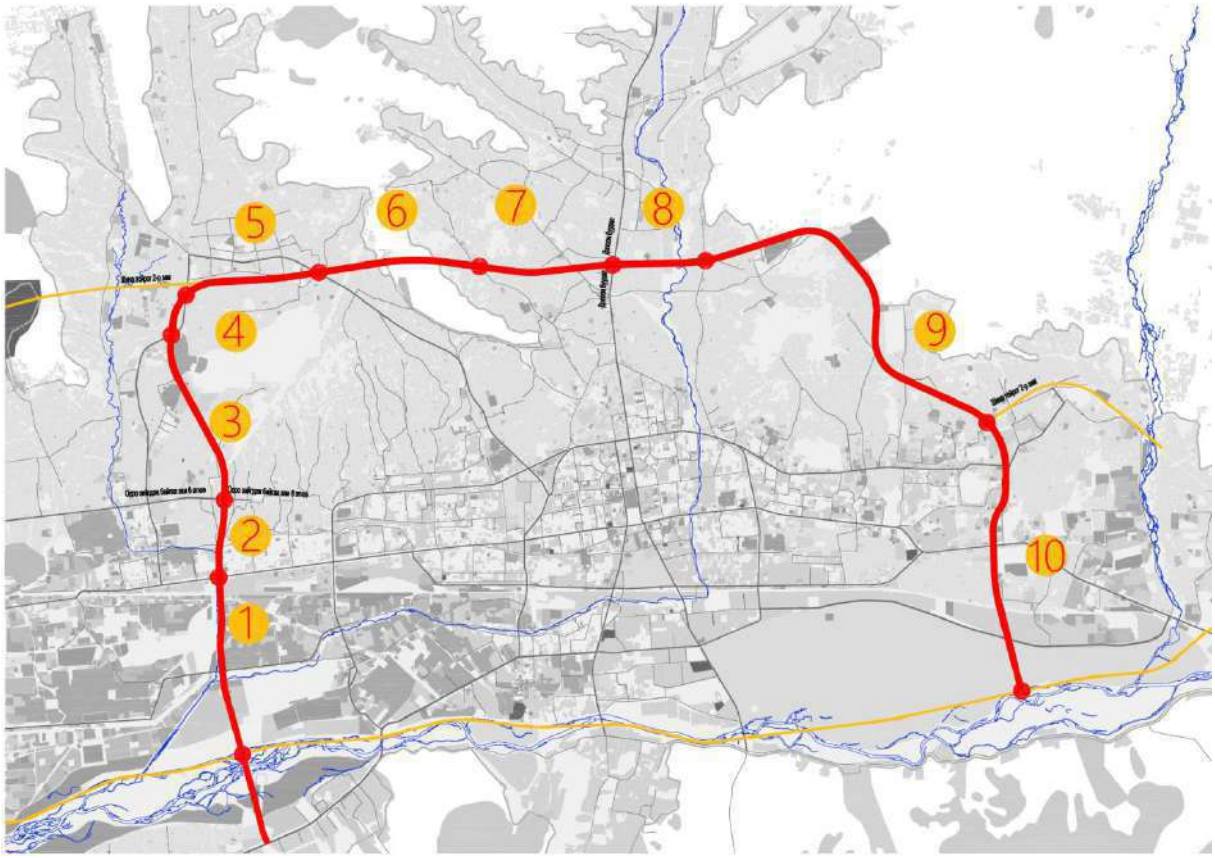


Figure 3. 95. Schematic Diagram of Division of the New Ring Road Section

The predicted traffic volume for each section at the end of the year is shown in the table below.

Table 3. 53. Predicted Peak Hour Volume for the New Ring Road Section at the End of the Year (pcu/h)

Section		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Main road	East to west					2631	3268	2114	2361		
	West to east					3951	4232	3436	3168		

Section		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
	South to north	2282	3612	4279	3774					2910	1920
	North to south	1988	2538	3373	3065					2624	1598
Auxiliary road	East to west					2074		1853			
	West to east					1694		1457			
	South to north	2011	1755	1434	1388					188	463
	North to south	1755	1799	1304	989					766	362

(4) Demonstration of the number and scale of lanes on the main line

1) Traffic capacity

According to the requirements of the standards and work task book, the road grade for this project is classified as Grade-I main trunk road; Considering that the current terrain is between hills and mountains, the route passes through densely populated urban areas, and has better connection with the current road network, the designed traffic capacity of the primary and auxiliary roads can be based on the values in the table below.

Table 3. 54. Actual Capacity Values for Main and Auxiliary Roads with Different Numbers of Lanes

No.	Road section type	Number of lanes (one-way)	Designed traffic capacity (pcu/h)
1	Main line	2	3240
		3	4550
2	Auxiliary road	1	1300
		2	2405

2) Lane scale demonstration

The determination of the basic number of lanes on the main road section is mainly based on the design capacity of the section (corresponding to the corresponding service level) to meet the demands of traffic flow and ensure smooth traffic flow. Now calculate the ratio of peak hour traffic volume to design capacity for the one-way two lane and one-way three lane sections on the main line, respectively, to determine whether the road can meet the traffic flow requirements. The specific calculation results are shown in the table below.

Table 3. 55. Analysis of Number of Lanes on the Main Line Section

End of forecast period (four or six lanes in two directions)					
Section	Maximum flow during peak hours in one direction (pcu/h)	Designed traffic capacity for two lanes in one direction (pcu/h)	Ratio of max. flow to the designed traffic capacity	Designed traffic capacity for three lanes in one direction (pcu/h)	Ratio of max. Flow to the designed traffic capacity.
1	2282	3240	0.70	4550	0.50
2	3612	3240	1.11	4550	0.79
3	4279	3240	1.32	4550	0.94
4	3774	3240	1.16	4550	0.83
5	3951	3240	1.22	4550	0.87

End of forecast period (four or six lanes in two directions)					
Section	**Maximum flow during peak hours in one direction (pcu/h)**	**Designed traffic capacity for two lanes in one direction (pcu/h)**	**Ratio of max. flow to the designed traffic capacity**	**Designed traffic capacity for three lanes in one direction (pcu/h)**	**Ratio of max. Flow to the designed traffic capacity.**
6	4232	3240	1.31	4550	0.93
7	3436	3240	1.06	4550	0.76
8	3168	3240	0.98	4550	0.70
9	2910	3240	0.90	4550	0.64
10	1920	3240	0.59	4550	0.42

Based on the analysis of traffic flow prediction results, the conclusions are as follows:

1) At the end of the forecast period, when a two-way four lane road is set up, the saturation level of the entire line is high, and the service level VCR is 0.70-1.32, with most sections exceeding one and in a saturated state.

2) At the end of the forecast period, when a two-way six lane road is set up, the saturation level of the entire line is high, and the service level VCR is 0.42-0.94, and the section meets the requirements for service level.

3) Conclusions on the number of lanes

According to the above analysis, the main line of the New Ring Road has four lanes in both directions from the starting point to Moscow Street, and six lanes in both directions for the remaining sections.

(5) Demonstration of the number and scale of lanes on the auxiliary road

The determination of the basic number of lanes on the auxiliary road section is mainly based on the design capacity of the section (corresponding to the corresponding service level) to meet the demands of traffic flow and ensure smooth traffic flow. Now calculate the ratio of peak hour traffic volume to design capacity for the one-way one lane and one-way two lane sections on the auxiliary road, respectively, to determine whether the road can meet the traffic flow requirements. The specific calculation results are shown in the table below.

Table 3. 56. Analysis of Number of Lanes on Auxiliary Road Section

End of forecast period (2 or 4 lanes in both directions)					
Section	**Maximum flow during peak hours in one direction (pcu/h)**	**Designed traffic capacity for one lane in one direction (pcu/h)**	**Ratio of max. flow to actual traffic capacity**	**Designed traffic capacity for two lanes in one direction (pcu/h)**	**Ratio of max. Flow to the designed traffic capacity.**
1	2011	1300	1.55	2405	0.84
2	1799	1300	1.38	2405	0.75
3	1434	1300	1.10	2405	0.60
4	1388	1300	1.07	2405	0.58

End of forecast period (2 or 4 lanes in both directions)					
Section	**Maximum flow during peak hours in one direction (pcu/h)**	**Designed traffic capacity for one lane in one direction (pcu/h)**	**Ratio of max. flow to actual traffic capacity**	**Designed traffic capacity for two lanes in one direction (pcu/h)**	**Ratio of max. Flow to the designed traffic capacity.**
5	2074	1300	1.60	2405	0.86
6	No auxiliary road	1300	-	2405	-
7	1853	1300	1.43	2405	0.77
8	No auxiliary road	1300	-	2405	-
9	766	1300	0.59	2405	0.32
10	463	1300	0.36	2405	0.19

Based on the analysis of traffic flow prediction results, the conclusions are as follows:

1) At the end of the forecast period, when a two-way two-lane road is set up, there are six sections of the entire line with saturation greater than 1, and the service level VCR is 0.36-1.6.

2) At the end of the forecast period, when a two-way four lane road is set up, the saturation level of the entire line is high, and the service level VCR is 0.19-0.86, and the section meets the requirements for service level.

3) Conclusions on the number of lanes

According to the above analysis, the number of lanes on the auxiliary road of the New Ring Road is four lanes in both directions.

CHAPTER 4. ENGINEERING SOLUTION AND PLANNING- BRIDGE

According to the terms of reference, it was intended to plan a plan and solution that would create conditions for the passage of livestock within the scope of the research and calculations, but since the location of the project road route is included in the first appendix of the Resolution No. 09 of the Capital City Citizens' Representatives Khural dated February 8, 2024, "BOUNDARIES OF THE CAPITAL LIVESTOCK PROHIBITION ZONE", it was deemed unnecessary to include a solution that would provide conditions for the passage of livestock in the plan.

4.1. DESIGN BASIS AND TECHNICAL STANDARDS

4.1.1. Design basis

(1) Applicable Codes and standards

1）Design of Highway Bridges and Pipelines БНбД 32-02-12；

2）Highway Design 33БНбД 22-004-2016；

3）Technical Requirements for Bridge and Pipeline Construction in 2020;

4）Code for Design of Building Foundation БНбД 50-01-16；

5）Code for Design of Building Foundation and Appendix: Explanation of the Provisions) БД 50-103-21;

6）Code for Seismic Design of Buildings БНбД 22-01-21;

7) Other relevant codes and standard documents.

(2) Referenced Codes and standards

1) Code for Design of the Municipal Bridges (2019 Edition) CJJ 11-2011;

2) Code for Seismic Design of Urban Bridges CJJ 166-2011;

3) Technical Specifications for Waterproofing of City Bridge Decks CJJ 139-2010;

4) Hydrological Specifications for Survey and Design of Highway Engineering JTG C30-2015;

5) General Specifications for Design of Highway Bridges and Culverts JTG D60-2015;

6) Specifications for Design of Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts JTG 3362-2018;

7) Code for Design of Ground Base and Foundation of Highway Bridges and Culverts JTG 3363-2019;

8) Specifications for Seismic Design of Highway Bridges JTGT 2231-01—2020;

9) Wind-resistant Design Specification for Highway Bridges JTG/T 3360-01-2018;

10) Technical Specifications for Construction of Highway Bridges and Culverts JTG/T 3650-2020;

11) Standard for Design of Steel Structures GB 50017-2017;

12) Code for Design of Concrete Structures (2015 Edition) GB 50010-2010;

13) Specifications for Design of Highway Safety Facilities JTGD81-2017;

14) Code for Durability Design of Concrete Structures GB/T 50476-2019;

15) Specifications for Design of Highway Culverts JTG/T 3365-02—2020;

16) Code for Design on Railway Bridges and Culverts TB10002--2017;

17) Code for Design of Concrete Structures of Railway Bridges and Culverts TB10092--2017;

18) Code for Design on Subsoil and Foundation of Railway Bridges and Culverts TB10093—2017;

19) Other relevant codes and standard documents.

4.1.2. Technical standards

(1) Automobile load: Automobile load: According to the comparative conclusion of the special report of Sino-Mongolian Design Code Comparison Report——New Ring Road (Ulaanbaatar) Feasibility Study Report and Conceptual Design Consulting Service Project: lane load is adopted by the overall calculation of a bridge structure, and an unfavorable value of Chinese Code and Mongolian Code is taken as the characteristic value of loads of Chinese Code:$q_k = 10.5\,kN/m$,$P_k = 270{\sim}360kN$; and vehicle load is adopted by the local calculation of the bridge structure, an unfavorable value of Chinese Code and Mongolian Code is taken as the characteristic value of vehicle gravity of Chinese Code, and the vehicle standard NK-80 of Mongolia Code is used for checking calculation.

(2) Road clearance:

Meet the requirements of Mongolia's railroad clearance ≥7010mm, and consider long-term upgrading to electrified railways, referring to the requirements of China's electrified railway "bridge clearance-2B"; and take into account the safety distance of an overhead line system, the construction height of a cantilever casting movable suspended scaffolding, and the reserved clearance for the height of setting up a protective shed;

Urban roads:≥4900mm;

Channels and culverts:≥2500mm.

(3) Seismic requirements: A bridge shall be located in an area with a seismic basic intensity of 8 degrees and a ground motion peak acceleration of 0.20 g.

(4) Design flood frequency of bridges: Bridges: 1/100; flood discharge culverts: 1/100.

(5) Design safety level: Due to the lack of precise requirements for design safety level in Mongolian Code, the design safety level of this project is adopted as the first level according to the Code for Design of the Municipal Bridges (2019 Edition) (CJJ 11-2011) of the Chinese Code.

(6) Environment category: Due to the lack of precise durability requirements in Mongolian

Code, the environment category of this project refers to the Specifications for Design of Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts (JTG 3362-2018) of China code, the superstructure is designed for Class I environment (general environment), and the substructure is designed for Class II environment (freeze-thaw environment).

(7) Design service life: Due to the lack of precise requirements for design service life in Mongolian Code, the design safety level of this project refers to the Code for Design of the Municipal Bridges (2019 Edition) (CJJ 11-2011); and the design service life is: 100 years for main line viaducts and interchanges, 50 years for overpasses, 30 years for culverts and channels, and 15 years for railings, telescopic devices, supports, etc.

4.2. DESIGN PRINCIPLES

Bridge design shall comply with the requirements of regulatory detailed planning and water affairs planning, follow the construction policy of “applicability, safety, durability, economic efficiency and aesthetics”, and adhere to the following technical principles:

(1) based on drawing on the bridge construction practices and successful experiences of similar bridge projects at home and abroad, combined with the characteristics of this project, through careful analysis and in-depth research, we will fully implement the overall technical objectives of “functional applicability, structural safety, cost-effectiveness, structural durability, aesthetic appearance, environmental coordination, and advanced technology” and project implementability, fully absorb new concepts, new materials, new processes and advanced experience in bridge design and construction at home and abroad, and follow the principles of people-oriented, green and low-carbon, energy-saving and environmentally friendly, and sustainable development.

(2) The type selection and layout form of a bridge shall fully consider the factors such as the feasibility, implementability, and social and economic benefits of a project. They shall be adapted to local conditions, combined with the terrains and land features, rivers and intersecting roads within the scope of this project, and reasonably arranged according to the requirements of the overall planning. To ensure traffic function, the impact on the surrounding environment and overall planning shall be minimised, and optimisation shall be carried out through a comparison of multiple schemes. The main comprehensive functions and aesthetic design requirements of the bridge type, as well as the requirements for natural site conditions, construction conditions, and economic efficiency, are determined according to a recommended scheme obtained after the technical and economic comparison of multiple schemes.

(3) Urban bridge design should adopt a once-in-a-century flood frequency. Suppose the design is based on the once-in-a-century flood frequency in an area with low flood control standards in a city, resulting in a high bridge deck elevation that causes difficulties. In that case,

the design can be based on the planned flood frequency of intersecting rivers or flood drainage ditches, but the safety of the bridge structure under the once-in-a-century flood frequency should be ensured.

(4) The bridge aperture arrangement should comply with the approved river regulation plan in the urban and rural planning, combined with the current situation. When there is no plan, the arrangement should be based on the current situation according to the design flood flow to meet the requirements of flood discharge or navigation. It is not advisable to change the natural state of the water flow too much. The design flood flow can be analysed and calculated according to the current national standards.

(5) Bridge construction should meet the requirements of urban and rural planning, with a focus on overall layout and main structure. The structural stress should be reasonable, and the overall design should be spacious, aesthetically pleasing, and coordinated with the surrounding environment and landscape.

(6) The landscape design of a bridge must be closely combined with the current environment of the surrounding plots, improve the overall appearance of the plots, and serve the construction of regional landscape and landforms. It shall meet the needs of higher-level planning and link the common development of the plots near the bridge. The landscape design of the bridge aims for an aesthetic appearance and overall coordination with the surrounding environment. Meanwhile, we will pay full attention to protecting the urban environment during both bridge construction and service, embodying the idea of “people-oriented” to minimise the adverse impact on residents’ lives.

(7) Fully consider the impact of natural disasters (such as earthquakes, floods, and strong winds) and human-caused damage (such as collisions) on bridge structures.

(8) The structural types and materials adopted for bridges should fully take into account the anti-corrosion properties of the materials and improve the durability of the structure.

(9) Bridges should be equipped with lighting, traffic signal signs, aviation obstacle signs, lightning protection grounding devices, as well as ancillary facilities such as bridge deck waterproofing, drainage, maintenance, and safety facilities according to the project scales and different bridge structures. In addition, the structural construction of bridge expansion joints, abutment slabs, sidewalks, guardrails, and the like should be handled well to meet the requirements of smoothness, comfort, speed, and safety for both vehicles and pedestrians during the operation phase.

4.3. OVERVIEW OF BRIDGES

There are five mainline bridges in this project, with a length of 9034m and a width of 19.5-45.5m, constructed by precast prestressed concrete small box girders or prestressed concrete

cast-in-place box girders. There are seven interchange ramp bridges with a length of 4989.3m, constructed by precast prestressed concrete small box girders or prestressed concrete cast-in-place box girders. There are two ground-level auxiliary road bridges with a length of 168m, constructed by precast prestressed concrete small box girders. There will be a grade-separated bridge for planning, with a length of 100m and a width of 14.5m, constructed by precast prestressed concrete small box girders. According to the actual situation, one culvert and seven channels are set up. Additionally, three pedestrian overpasses have been recently implemented, and four more are planned for the future.

4.4. BRIDGE LOCATION SELECTION AND BRIDGE TYPE SELECTION

4.4.1. Bridge location selection

(1) Bridge location selection shall be determined after all-around analysis and comprehensive comparison based on the urban and rural planning and the needs of short-term and long-term traffic flow direction and volume, combined with hydrological, topographical and geological conditions, environment, and the impact on adjacent buildings and public facilities.

(2) The bridge location should avoid river shoals, sandbars, ancient river courses, sharp turns, confluence points, river sections prone to formation of flowing ice and driftwood blockage, as well as river sections with active faults, strong karst, landslides, collapses, liquefaction during earthquakes, mudslides and other adverse geological conditions.

(3) In addition to urban and rural planning, the location of piers and abutments shall be considered according to the local actual conditions during bridge location selection.

4.4.2. Bridge type selection principles

(1) According to the construction conditions of Ulaanbaatar, the appropriate bridge structural type shall be selected according to local conditions. In addition to considering factors such as safety, reliability, applicability, durability, advanced technology, and economic rationality during the comparison and selection of bridge type schemes, particular emphasis shall be placed on bridge aesthetics and coordination with the surrounding environment.

(2) The bridge structure should adopt standardised construction, which is conducive to prefabrication in factories and mechanised construction.

(3) Urban bridges should adopt structural types that are comfortable for driving, durable, and easy to maintain, with priority given to continuous structural systems.

(4) The commonly used structural forms for the superstructure include prefabricated prestressed concrete small box girders, prestressed concrete box girders, steel box girders, steel-concrete composite girders, etc.

4.4.3. Analysis of structural forms corresponding to bridge spans

The bridges that meet the functional requirements of this project and are suitable for this project environment are basically within a range of 20-70 m, belonging to medium and large spans. Cable-stayed bridges and suspension bridges are generally suitable for long-span bridges, which are not ideal for this bridge scheme, so they will not be considered. This time, the comparison and selection of design schemes are only for bridge types with spans of 20-70 m.

4.4.4. Comparison of superstructure forms of standard sections of mainline bridges

The Ulaanbaatar New Ring Road project is located in Ulaanbaatar and belongs to the category of urban roads. The bridge structures span the main terrains and land features of the central urban districts in the form of viaducts, so that the form of the bridge structure of the standard section of the viaduct not only determines the total project cost of the entire alignment, but also affects the traffic organization, construction mode, construction period and urban landscape of the entire alignment, which is the focus of the bridge engineering design. Therefore, the comparison and selection of multiple schemes for the structural forms of the standard sections of the mainline viaducts shall comply with the overall design requirements of the project, in combination with the design principles of safety, economic efficiency, applicability, and aesthetics based on meeting the traffic functions and construction progress of the entire alignment, and draw on the existing bridge structures in Ulaanbaatar and the international bridge construction experience.

Girder bridges commonly used in urban bridge structures can be divided into steel structures, steel-concrete composite structures and concrete structures according to their different structures and materials.

Urban steel structure bridges generally adopt integral steel box girder structures. Steel box girders have the advantages of high adaptability and fast construction. Considering the large scale of the bridge engineering in this project, if steel structures are used throughout the entire alignment, the amount of steel required for the bridges will be significant, and the maintenance cost after completion will be high. Therefore, it is not advisable to widely adopt steel structures in this project.

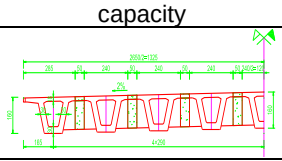
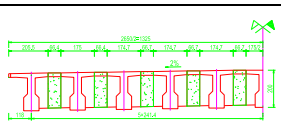
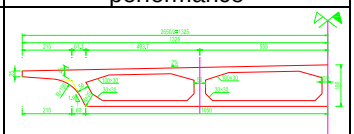
Steel-concrete composite girders typically consist of composite steel plate girders and composite steel box girders combined with concrete (prestressed concrete) bridge deck slabs. Composite girder bridges have the advantages of both steel structures and reinforced concrete structures. Due to their simple construction and convenient manufacturing, they have high adaptability. However, urban viaducts all adopt continuous systems for better driving comfort, while composite girders are more suitable for supported systems. For continuous systems, the concrete in the negative moment zone is unfavourable in stress and prone to cracking. Adopting

specific technical measures (such as construction by the Pilger method, pier top pre-jacking, and longitudinal prestressing) can alleviate or avoid this problem. Still, their economic efficiency and construction efficiency are slightly inferior. Therefore, steel-concrete composite girders are only used when large-span crossing conditions, such as crossing intersections and rivers, are required.

Concrete structure bridges are the most widely used types, including ordinary reinforced concrete girders and prestressed reinforced concrete girders. The construction methods mainly include prefabrication and cast-in-place. Concrete girders have the characteristics of being made from local materials, and having high durability, high adaptability (moldability) and good integrity. If the bridges need to span the existing nodes, such as roads and rivers, prestressed concrete girders may be selected for use. The prestressed concrete girders may be made from high-strength materials (such as high-strength steel strands and high-grade concrete). Compared with ordinary reinforced concrete girders, the adoption of prestressed concrete girders reduces the cross sections of components, saves materials, and reduces the self-weight of a structure, making the bridge have a stronger span ability. Moreover, the concrete girders are low in cost, mature in construction technology, and have low maintenance costs. Mainly, precast concrete girders are widely used in the construction of urban bridges due to their characteristics of being prefabricated in factories, rapid in construction speed and economical in cost.

The concrete structures suitable for this project may adopt prefabricated prestressed small box girders, T-beams, and cast-in-place concrete box girders. The options for comparison are as follows:

Table 4. 1. Comparison of structural forms of standard sections

Structural options	Prefabricated prestressed concrete small box girder	Prefabricated T-beam	Cast-in-place concrete box girder
Cross-section characteristic	Closed cross-section, high torsional stiffness, high integrity, and high bearing capacity	Open cross-section, weak torsional stiffness, and moderate bearing capacity	High overall stiffness, without transverse joints, high bearing capacity, and good seismic performance
Sectional form			
Applicable range of span	Applicable span: 20-40 m (economic span: about 30 m)	Applicable span: 20-40 m (economic span: 25-35 m)	Suitable for large-span (over 40 m) or irregular structures
Lateral integrity	Excellent (requiring cast-in-place wet joints or transverse prestress)	Medium (transverse connection depends on cast-in-place part)	Excellent
Seismic performance	Relatively good	Relatively good	Good

Structural options	Prefabricated prestressed concrete small box girder	Prefabricated T-beam	Cast-in-place concrete box girder
Construction method and difficulty level	Prefabrication in a factory, on-site hoisting construction, and low construction complexity.	Prefabrication in a factory, on-site hoisting construction, and low construction complexity.	Cast-in-place construction with the falsework method or cantilever (over 60 m long span) involves high construction complexity.
Impact on traffic during the construction period	The transportation of beam segments significantly impacts traffic. Additionally, the protection under the bridge during girder erection affects part of the traffic, and the construction period is short.	The transportation of beam segments significantly impacts traffic. Additionally, the protection under the bridge during girder erection affects part of the traffic, and the construction period is slightly extended.	Falsework construction has a significant impact on traffic, and the construction period is extended.
Landscape effect	The structure is smooth and straightforward, and the landscape effect under the bridge is relatively good.	The structure is smooth and straightforward, but the landscape effect under the bridge is relatively poor.	The appearance is simple, the lines are smooth, and the landscape effect is good.
Project cost	Lower	Higher	Highest
Rendering			

Table 4. 2. Comparison Table of Main Engineering Quantities for Different Structural Forms in Standard Sections (One Bridge Length: 120 m)

Item	Structure scheme	Prefabricated prestressed concrete small box girder	Prefabricated T-beam	Cast-in-pace concrete box girder
Upper structure	**C50 concrete of main beam (m3)**	1569.3	1630.1	2375.7
	Steel strands of main beam (kg)	70694.4	50545.8	98298.2
	Ordinary rebar (kg)	309207.8	350108.8	498897.0
Lower structure	**C50 concrete of bent cap (m3)**	435.2	503.4	None
	C40 concrete of pier (m3)	181.4	187.2	303.7
	Steel strands of bent cap (kg)	27833.1	36938.4	None
	C35 concrete of pile cap (m3)	409.3	409.3	625.0
	C30 concrete of pile foundation (m3)	1085.7	1085.7	1696.5
	Ordinary rebar (kg)	268313.3	290435.1	273859.4
Ancillary works	**D80-type expansion joint (m)**	38.5	38.5	38.5
	Acoustic pipe (kg)	6146.3	6146.3	8097.5
	Support model	LNR rubber support with a dispersed horizontal force	LNR rubber support with a dispersed horizontal force	GPZ basin-type support
	Number of supports (pcs)	88	88	10

From the above comparative analysis, it can be seen that prefabricated prestressed concrete small box girders are suitable for medium spans (20-40 m), with high bearing capacity

and torsional property, and are high in section efficiency, good in landscape effect and high in integrity, thus being capable of better adapting to urban elevated standard sections.

Based on the above comparison, the prefabricated prestressed concrete small box girder structure is good on the whole, with the advantages such as convenient and fast construction, minimal interference with traffic during construction, good landscape effect, and lowest project cost. Therefore, it is recommended to use the prefabricated prestressed concrete small box girder structures for standard sections of viaducts, and structures such as cast-in-place concrete box girders and steel-concrete composite girders are employed for the bridges at special nodes (such as cross intersections, small radius curved beams, widened sections, and long-span node bridges).

4.4.5. Comparison of superstructure forms of non-standard sections (such as crossing rivers, railways, intersections, and interchange irregular sections) of mainline bridges

When crossing rivers, railways, intersections, and interchange irregular sections in this project, variable cross-section cast-in-place continuous girders, constant cross-section cast-in-place continuous girders, or steel-concrete composite girders can be used for crossing. The options for comparison are as follows:

Table 4. 3. Comparison of structural forms of non-standard sections

Structural options	Variable cross-section cast-in-place concrete box girder	Constant cross-section cast-in-place concrete box girder	Steel-concrete composite girder
Construction method	Cast-in-place construction using the falsework method	Cast-in-place construction using the falsework method	Prefabrication in a factory, on-site lifting and welding, with multiple processes involved
Structural mechanical properties	Good overall performance, high torsional stiffness, suitable for large spans	Good overall performance, high torsional stiffness, suitable for small and medium spans	Relatively good stress performance and a broad application scope
Construction difficulty level	Requiring a large number of construction supports, with more working procedures involved	Mature technology, requiring a large number of construction supports, with more working procedures involved	Relatively complex technology, with a large amount of on-site welding work and high requirements for construction technology
Impact on traffic during the construction period	The erection of falseworks requires a long construction period, resulting in a significant impact on traffic.	The erection of falseworks requires a long construction period, resulting in a significant impact on traffic.	A temporary traffic closure is required during the erection and welding of beam segments.
Landscape effect	The overall shape and lines are smooth and straightforward, and the landscape effect is the best.	The overall shape and lines are simple, and the landscape effect is relatively good.	The structure is smooth and straightforward, but there is a colour difference between the two materials.
Project cost	Lower	Higher	Highest
Construction period	Longer	Shortest	Shorter

Structural options	Variable cross-section cast-in-place concrete box girder	Constant cross-section cast-in-place concrete box girder	Steel-concrete composite girder
Landscape rendering			

From the above comparative analysis, it can be seen that the variable cross-section cast-in-place concrete box girders are suitable for an extensive span range, have good overall structural performance, superior seismic performance, convenient construction, optimal landscape effect, and the lowest project cost. The cast-in-place concrete box girder structures are employed for the bridges at special nodes (such as cross intersections, small radius curved beams, widened sections, and long-span node bridges).

4.4.6. Comparison and selection of standard spans

Because the viaducts of this project are long and the bridge structures account for a large proportion of the whole project cost, it is necessary to compare and select the economic span of the bridge structures. If the standard span is too small, the number of substructures will be significant, so the landscape effect and economic efficiency will be poor. Suppose the standard span is too large, although the substructures can be reduced appropriately. In that case, the amount of work for the superstructures will increase accordingly, and the higher girders will also negatively impact the landscape effect and economic efficiency.

The standard span arrangements for prefabricated structures used in urban bridges are shown in the table below:

Table 4. 4. Common prefabricated and assembled bridges for urban bridges

No.	Name	Structural type	Recommended span (m)
1	Prestressed concrete small box girder	Prefabricated box girder+wet joint	20-40
2	Prestressed concrete box girder	Segment prefabrication+epoxy adhesive joint or cast-in-place concrete joint	30-100
3	Steel box girder	Prefabricated assembly of large segments	30-150
4	Composite steel plate girder	Steel plate girder+concrete bridge deck slab	20-50
5	Composite steel box girder	Trough-type closed-section steel girder+concrete bridge deck slab	30-100

According to the preliminary survey report of this project, the site overburden layer is relatively thin, and the burial depth of the bearing stratum is relatively shallow. Moreover, considering the construction experience of similar projects in the vicinity, along with factors such as safety, economic efficiency, applicability, aesthetics, and other relevant criteria, the optional economic span range is 25-35 m, and the basic span is determined through economic

comparison on this basis. Therefore, a financial comparison is conducted on prefabricated prestressed concrete small box girders with spans of 25 m, 30 m, and 35 m for road sections with bridge deck widths of 26.5 m. The construction methods are all precast hoisting, and double-column piers with a cap beam and a bored cast-in-place pile foundation are adopted as the substructure. By comparison, the prefabricated prestressed concrete small box girder structure has good economic efficiency when its span is 30 m. Therefore, it is recommended to use a 30m span as the basic span for the main line viaducts.

When a larger span is required to meet the crossing conditions, cast-in-place concrete or suspended concrete box girders, or steel-concrete composite girders can be used for crossing.

4.4.7. Continuous unit selection

Suppose the length of each unit of a continuous girder is too short. In that case, the number of expansion joints in a bridge will increase, which is not conducive to the comfort of driving on the bridge, and more connecting piers need to be installed, resulting in poor landscape effect of the bridge; and if the length of continuous unit is too long, there will be fewer work faces for bridge construction, and the construction period of the bridge will be relatively prolonged. Considering that these elevated bridges are primarily located in busy traffic areas, the construction period should be shortened as much as possible to alleviate the traffic pressure during the construction period. This design should choose a moderate length of continuous unit, generally 3-5 holes per unit, with a length of constant unit of 90-150 m, which can not only carry out work on more work faces and shorten the construction period, but also does not affect the driving comfort.

4.4.8. Pier shape selection

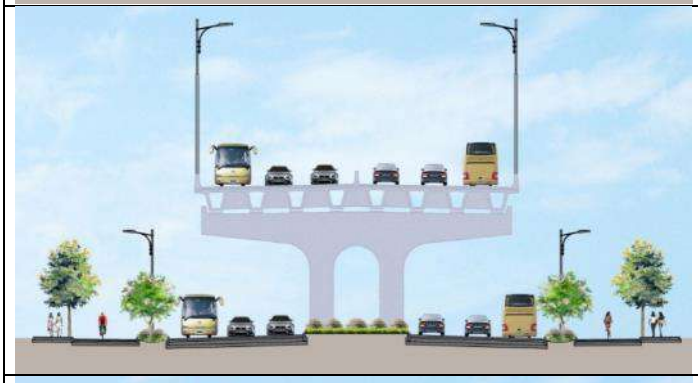
A bridge pier is an essential component of a bridge, which not only meets the stress requirements but also serves as the most direct visual object for pedestrians and vehicles under the bridge. The form and shape of a bridge have a significant impact on the urban landscape, posing considerable challenges in design. Therefore, it is essential to make a well-informed decision regarding the pier's shape.

(1) Selection of pier shape for prefabricated prestressed concrete small box girder

Three pier shape schemes for precast girders are proposed for comparison, and the results are as follows:

Table 4. 5. Comparison of mainline precast girder piers

Mainline bridge pier	Feature

	Option I: A variable-height cap beam is directly added above a double-column pier, which makes the structure simple with a sense of strength, and ensures good underbridge transparency; the construction formwork is simple, and the construction is convenient.
	Option II: A variable-height cap beam is connected to a double-column pier, and the connection positions between the pier columns and the cap beam are in curved shapes. Hence, the bridge pier has a smooth line form, and the underbridge sight is clear, with a balance of rigidity and flexibility, resulting in a good landscape effect. The cross-sectional lines of the pier columns are complex, which places high requirements on formwork production and processing, so the construction is also complicated.
	Option III: A pier column is made into a vase-shaped slab pier, with a variable-height cap beam connected above, which creates a visually robust and structurally stable configuration. The bridge pier lines are slightly complex, which places high requirements on formwork production and processing. The underbridge transparency is poor, which negatively impacts driver sightlines.

Based on a comprehensive comparison of the above options, Option I is concise and straightforward in structure, clear in stress distribution, and simple in construction formwork, which saves investment, reduces waste, shortens the construction period, and meets the demands of the urban landscape. Therefore, it is recommended to adopt Option I for bridge piers.

(2) Pier shape selection of cast-in-place box girder

For cast-in-place box girders, three pier shapes are compared, and the results are as follows:

Table 4. 6. Comparison of mainline cast-in-place box girder piers

Mainline bridge pier	Feature
Pier type option I	Advantages: Double columns are like strong arms for supporting an upper box girder, giving a sense of strength. The structure is simple, with high underbridge transparency and a wide field of view, thus being suitable for

	road sections with wider bridges. The construction is simple, and the construction period is short. Disadvantages: The shapes of the pier columns are single, and their appearances and line forms are relatively stiff.
Pier type option II 	Advantages: The slab pier is thick and strong, and structurally stable, which is suitable for road sections with narrower bridges. Disadvantages: The underbridge transparency with this pier type is poor, which has a significant influence on the line of sight at a U-turn lane.
Pier type option III (recommended option) 	Advantages: The pier type is characterised by precise stress distribution, small pier column size, relatively high underbridge transparency, and a wide field of view. The pier type is smooth in line form, with a balance of rigidity and flexibility, and achieves a good landscape effect, thus being suitable for road sections with wider bridges.

Based on a comprehensive comparison of the above options, Option III adopts a frame pier, which is clear in stress distribution and good in visual transparency under a bridge. The construction formwork can be made from the finished products of related projects, which saves investment, reduces waste, shortens the construction period, and effectively meets the demands of landscape and other aspects. Therefore, it is recommended to adopt option III for the pier type of a cast-in-place box girder.

4.4.9. Selection of cast-in-place construction and prefabricated assembly construction for pier columns and cap beams

With the development of fully prefabricated bridge construction technology, prefabricated assembly technology for bridge substructures is gradually applied to bridge construction. Based on the actual situation of standard pier columns and cap beams in this project, the comparison between a cast-in-place construction scheme and a prefabricated assembly construction scheme is as follows:

Table 4. 7. Comparison of substructure construction schemes

Item	Scheme I: Cast-in-place construction	Scheme II: Prefabricated assembly construction
Construction method	Erecting formwork for cast-in-place construction	Prefabricating in sections in a factory, and performing assembly construction through transportation and erection equipment

Item	Scheme I: Cast-in-place construction	Scheme II: Prefabricated assembly construction
Structural mechanical properties	The structure has good static and seismic performance, high integrity, and good durability.	(1) There is still a lack of unified understanding or regulations on the seismic performance test research, theoretical analysis and seismic structural requirements for precast assembled piers. The post-earthquake damage situation and self-resetting ability still need to be tested in practice, followed by tracking and studying. (2) The durability, structure, and construction technology of segmented precast assembled piers and cap beams are still worth exploring and researching. (3) There is still a lack of systematic research on the influence of temperature and environment on the mechanical properties of the precast assembled piers and cap beams.
Construction difficulty level	The amount of construction work is relatively large, the workforce input is high, and the construction procedures are complex. Still, the construction experience is mature, and the construction quality can be guaranteed.	(1) The amount of construction work is relatively small, and thus there is less personnel input. (2) For the construction process of the joints using bonded prestressed tendons, the experience is mature, but the process is more complex. (3) The joint construction with grouting sleeves and grouting metal corrugated pipes is simple in process, but the experience is not yet mature. (4) The joint connection process with wet joints involves many working procedures, which have limited advantage compared with cast-in-place construction.
The status of the industry	Chinese Codes and Standards are well-established, and the industry and government have a unified understanding.	There is a lack of basic research, the current design and construction specifications are outdated, and the related industries of precast assembly supply chains are insufficient.
Social and environmental impacts	Less environmental pollution and medium energy consumption.	Less environmental pollution and lower energy consumption.
Project cost	Medium	Higher
Construction period	Long	Short

Based on a comprehensive comparison of the above two schemes, Scheme I (cast-in-place construction) is lower in cost, and the construction conditions of this project are good, which meet the requirements of cast-in-place construction. However, the precast assembly construction has disadvantages such as immature joint connection structures and incomplete industry-related codes and standards. Therefore, it is recommended to adopt the cast-in-place construction scheme with mature technology and lower cost for this design.

4.4.10. Selection of foundation forms

According to the geological survey results, the soil stratum can be roughly classified as topsoil, clay, gravel, and weathered sandstone geologically from top to bottom, and the moderately weathered bedrock is deeply buried within the project scope. The topsoil is mainly composed of clay and gravel geologically, with poor bearing capacity. Therefore, expanding the foundation is not suitable for this project. It is recommended to use a bored cast-in-place pile foundation, designed as end bearing piles where the moderately weathered bedrock is shallowly buried, and designed as friction piles in areas with deeper bedrock.

4.4.11. Selection of crash barriers

For the selection of crash barriers, three different materials are compared, and the results are as follows:

Table 4. 8. Comparison of mainline crash barriers

Mainline crash barrier	Feature
Barrier option I	Advantages: It has high aesthetic appeal, good visual transparency, and adaptability to different landscape needs. It is high in strength and good in impact resistance, being suitable for high-grade urban bridges. Disadvantages: It is more expensive than concrete barriers. The installation requirements are high, and embedded parts or high-strength bolts are needed for fixation.
Barrier option II	Advantages: Its aesthetic is just so-so. It has high strength and good impact resistance, making it suitable for high-grade urban bridges. Disadvantages: It requires regular maintenance, and compared to concrete barriers, it is more expensive and more complicated in the installation process.
Barrier option III (recommended option)	Advantages: It has a contoured surface and thus has a particular landscape effect. It has ultra-high strength, is capable of withstanding the impact of large vehicles, and is suitable for high-grade urban bridges. It is durable and has a long service life, and requires almost no maintenance. The cost is moderate, the materials are easy to obtain, and the construction technology is mature.

Based on a comprehensive comparison of the above schemes, Option III adopts a concrete crash barrier with mature construction technology, which is low in production and maintenance

costs, good in economic efficiency, and high in crash resistance. The formwork can be reused, which saves investment and reduces waste, being conducive to large-scale construction. The barrier has a contoured surface, which can well meet the requirements of landscape and other aspects. Therefore, option III is recommended for the crash barrier of the bridge.

4.5. HYDROLOGICAL CALCULATION

This project crosses the middle reaches of the Selbe River at K14+250, crosses the lower reaches of the Selbe River at K0+212, and crosses the floodplain of the Tuul River together with the A, B, and C ramps of the Tuul Interchange at the terminal point.

4.5.1. Selbe River

(1) Basic river hydrological characteristics

Selbe River originates from Bagamuhar Pass at an altitude of 2000.0m and the southern foot of its branch, and flows to the Tuul River Valley at an altitude of 1289.9m, with a height difference of 710.0m between the headwater and the estuary. The upper reaches of this river are called Bayan River, the middle reaches are called Selbe River, and the lower reaches are called Dunde River. The Selbe River Valley is about 32km long and finally flows into the right bank of the Tuul River in the southeast direction of Ulaanbaatar. Selbe River basin covers a total area of 498.0km², and includes small tributaries such as Shargamolt River and the Damba River, which originate from the branch of Little Kent Mountains. Due to the confluence of these tributaries, the river flow has increased significantly from the upper reaches to the lower reaches, and the river channel has gradually widened and levelled. The average gradient of the river is 3‰. The average width is 1.2km, with a narrowest part of 0.8km and a widest part of 2km. More than ten tributaries flow into the left and right banks of the Selbe River, jointly forming the main flood channel. The larger tributaries include rivers such as Ikhbayan, Bagabayan, Erengunan, Hangait, Bayanbulag, Shargamolt, Goydoi, Berkh, and Ganjuur Hudag, which are located on the left bank, and Khalzan, Sharhaocai, Övörkhangai, Jiggid, Yalgait, Shadivlin, Chingeltei and Khyargas, which are located on the right bank.

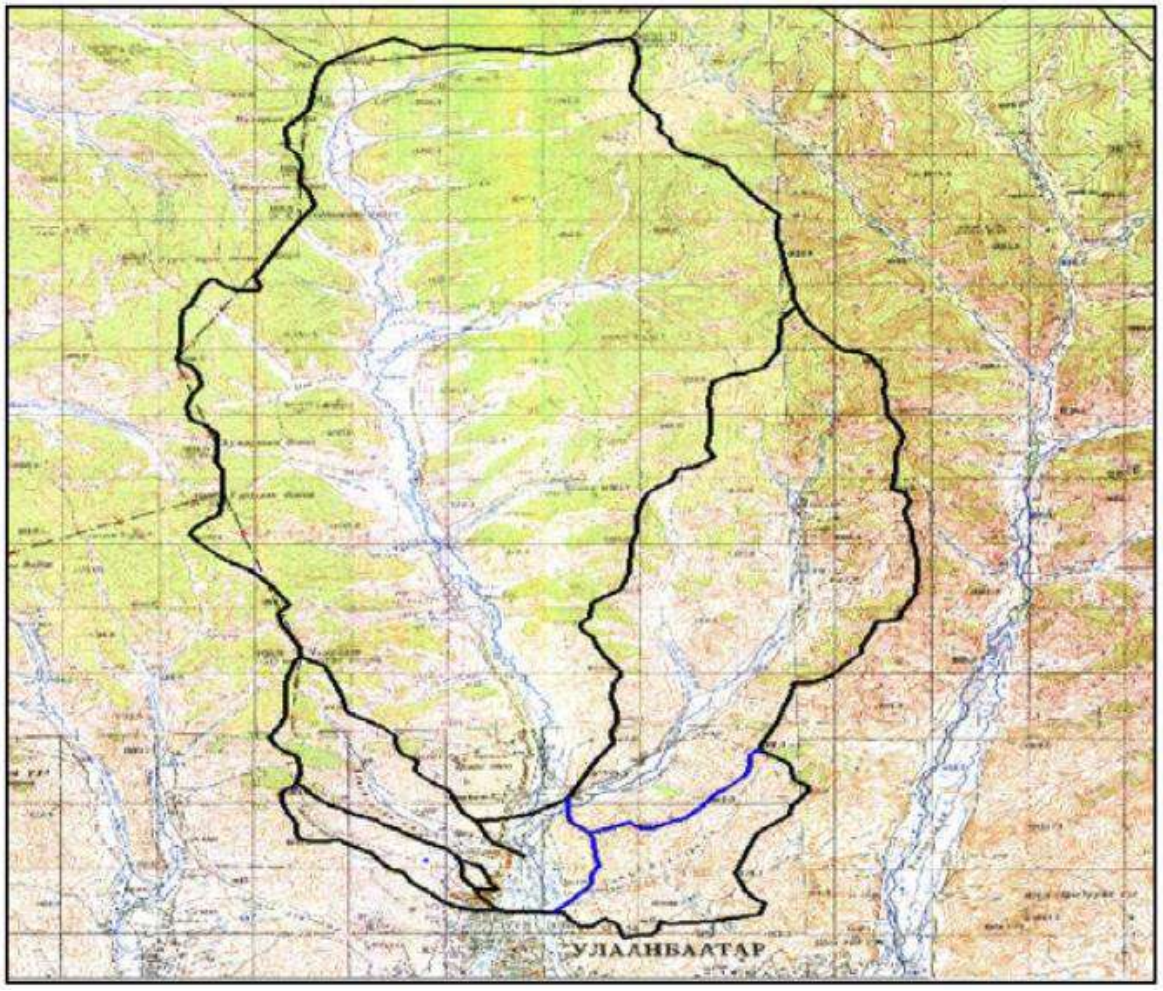


Figure 4. 1. Selbe River catchment area (at K14+250)

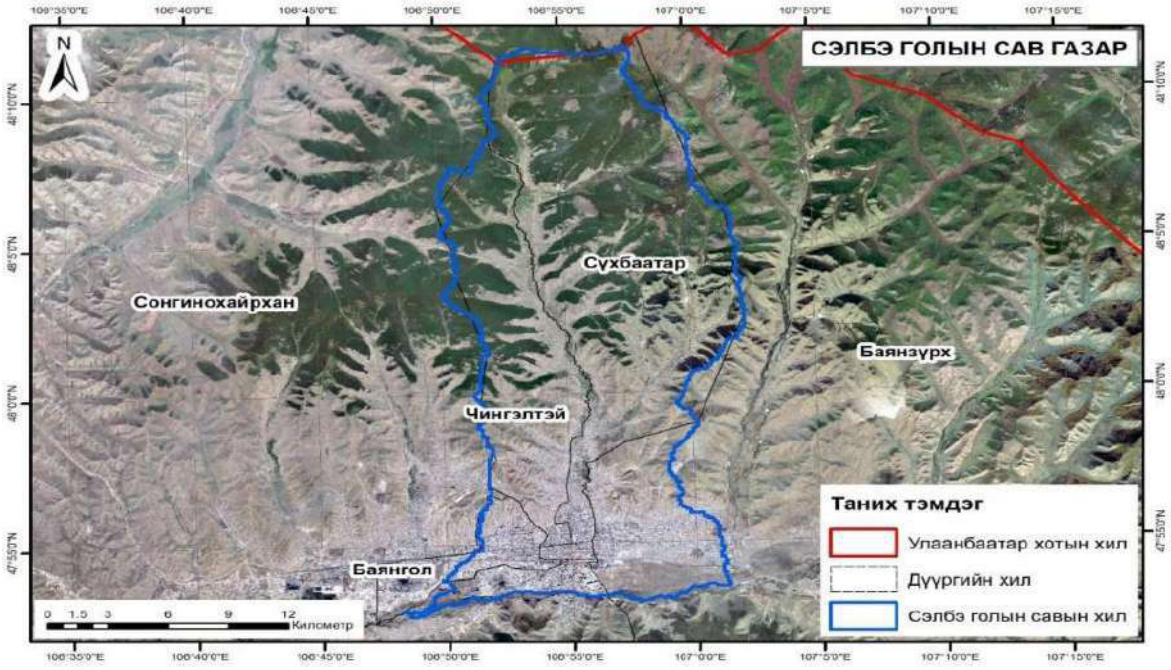


Figure 4. 2. Selbe River catchment area (at K0+212)

The snowmelt runoff of the Selbe River in spring is not significant, but it lasts for a long time. After the spring flood, the flow tends to be stable, and the water volume increases significantly from July to September due to rainfall replenishment. The flood process caused by a rainstorm is short, and the water recedes quickly. The daily increase in river water can reach 0.5-1.0m in some years. After September 20, the water level drops sharply, entering the dry season in winter. It begins to freeze at the end of October, with a freezing period of about 150 days throughout the year. In winter, the river channel is completely frozen to the bed.

Historical maximum flow record: In August 1959, the flow reached 45.0m³/s; in August 1982, the water level rose to 250cm, and the flow reached 131.0m³/s, nearly twice the average annual flow of the Tuul River.

The annual runoff distribution characteristics of rivers are: from November to March of the following year (the dry season in winter), accounting for 9.5% of the annual runoff; the spring snowmelt period, accounting for 25%; and the summer and autumn rainfall period, accounting for 65%.

The average annual flow is 1.90m^3/s, and the runoff modulus is 0.91L/s·km^2; the maximum average flow is 12.1m^3/s, and the corresponding runoff modulus is 43.8L/s·km^2.

According to the Hydrological calculation report, this project crosses the middle reaches of the Selbe River at K14+250 and crosses the lower reaches of the Selbe River at K0+250. See the following table for basin area and design peak discharge:

Table 4. 9. Main hydrological parameters of the Selbe River

River	Intersection road mileage	Basin area (km^2)	Design peak discharge (m³/s)			i (‰)
			1%	2%	5%	
Selbe River	K0+212	373	402	349.7	253.3	3
	K14+250	304.2	278.5	192.2	157.3	3

(2) Determination of flood surface elevation

By analysing the correlation between flood surface elevation and flow, the water level at a bridge section is calculated by a hydraulic method, and a relationship curve between flood surface elevation and flow is established by using the Chézy formula based on the data of the hydrological cross section, river slope gradient and bed roughness at the bridge location. The formula is as follows:

$$Q = A_c v_C + A_t v_t$$

$$v_c = \frac{1}{n_c} R_c^{\frac{2}{3}} I^{\frac{1}{2}}$$

$$v_t = \frac{1}{n_t} R_t^{\frac{2}{3}} I^{\frac{1}{2}}$$

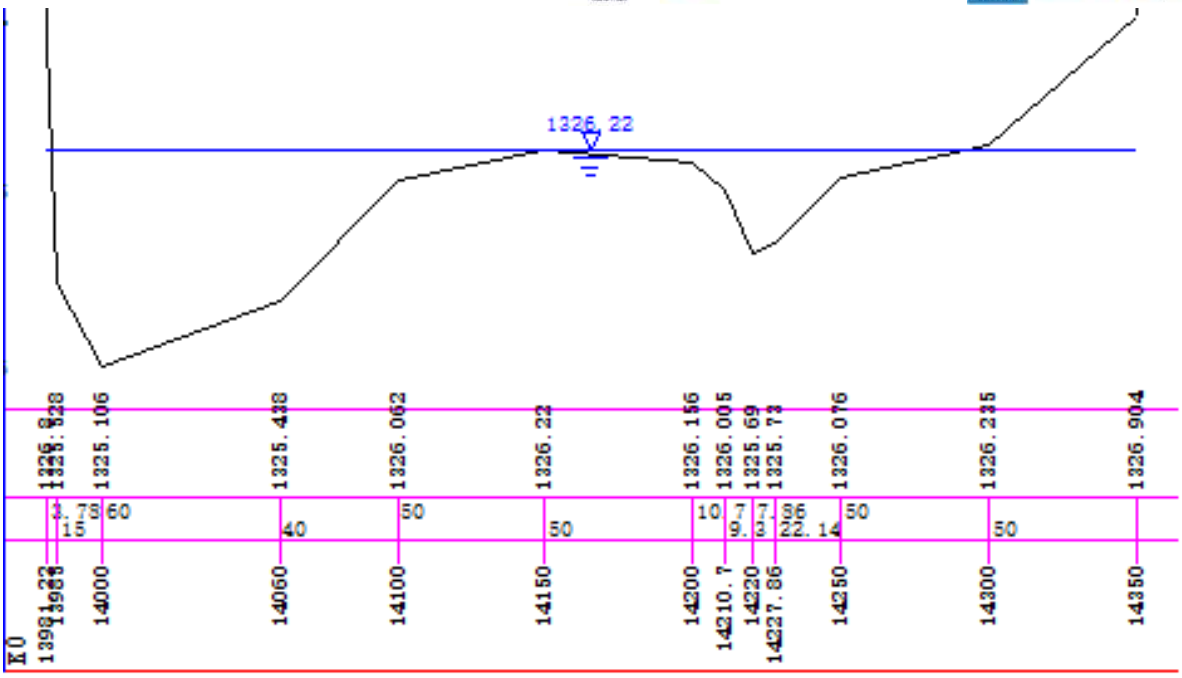


Figure 4. 3. River section diagram

After calculation, the once-in-a-century flood surface elevation under the bridge is 1326.22m. According to Article 1.21 of the Designing road bridges and culverts (БНбД 32-02-12), the elevation of the girder soffit shall be not less than 0.5 m above the design flood surface elevation, that is, not less than 1326.22+0.5=1326.75m. The minimum elevation of the girder soffit in the design scheme is 1335.385, which meets the requirements.

(3) Determination of bridge opening length

Bridge span size: yp:=319m. If a design scheme with a 30m bridge span and 11 spans is adopted, the total length is 330m. The bridge scheme is 11×30m=330 m>319m, which meets the requirements.

(4) Calculation of general scour depth of bridges

General scour calculation

For a non-cohesive soil riverbed, general scour calculation is carried out according to the following formula.

$$h_p = 1.04(A_d \frac{Q_2}{Q_c})^{0.9}(\frac{B_c}{(1-\lambda)\mu B_{cg}})^{0.66} h_{cm}$$

In the formula, A_d represents a single-width flow concentration factor;

Q_2 represents design discharge through the channel under the bridge, m^3/s;

Q_c represents the design discharge of the channel in a natural state, m^3/s;

B_c represents the width of the cross-section channel (m);

B_{cg} represents the width of the channel within the bridge length range (m);

λ represents the ratio of pier obstruction area to total flow area

h_{cm} represents the maximum water depth of the channel, m;

μ represents the lateral flow contraction coefficient at bridge piers;

After calculation, the general scour depth is 2.31m. After general scour occurs in the main channel, the elevation of the main channel bottom is determined to be 1326.22-2.31=1323.92m.

(5) Calculation of local scour depth near bridge piers

For non-cohesive soil, the following formula is used to calculate local scour.

When $V \le V_0$, $$h_b = K_\xi K_{\eta 2} B_1^{0.6} h_p^{0.15} \left(\frac{V - V_0'}{V_0} \right)$$

When $V > V_0$, $$h_b = K_\xi K_{\eta 2} B_1^{0.6} h_p^{0.15} \left(\frac{V - V_0'}{V_0} \right)^{n2}$$

In the formula: h_b Represents local scour depth at bridge piers, m;

k_ξ represents pier shape coefficient;

$k_{\eta 2}$ represents the influence coefficient of riverbed particles;

B_1 represents the calculated width of the pier, m;

V represents approach velocity at bridge piers after general scour, m/s;

V_0 represents the critical incipient velocity of bed sediment, m/s;

V_0 represents the critical incipient motion velocity of sediment at bridge piers, m/s;

After calculation, the local scour depth near the bridge pier is 2.41 m, and the local scour elevation is 1323.92-2.41=1321.51 m.

(6) Conclusion

According to project calculations, the Selbe River at the bridge site has a design flood surface elevation (BVT=1326.22) of 319m. When the once-in-a-century flood surface elevation is 1326.22m, the flow rate is 279m^3/s. The minimum elevation of the girder soffit in the design scheme is 1335.385, which meets the requirements.

The lowest elevation of the channel is 1325.106m, and the maximum water depth is 1.114m at the once-in-a-century flood surface elevation. The width at a low water level is 319m, and the bridge adopts the design scheme, with a 30m bridge span structure length and 11 spans, and the total length is 330 m. The local scour elevation near the bridge pier is 1321.51m, and the planned buried elevation of the bridge foundation is 2.5m below the local scour line, which is 1319.01m.

(7) Other

This project crosses the lower reaches of the Selbe River at K0+212, using a (40+65+40)m

continuous beam for crossing, with a main span of 65m across the river channel. There are no piers and abutments in the river. Moreover, the viaducts are higher than the existing bridges, so hydrological calculation is no longer done.

4.5.2. Tuul River

(1) Basic river hydrological characteristics

The Tuul River originates from the Nuomin River at an altitude of over 2200m in the Khangai-Khentii Mountains, as well as two source streams of its branch from the southern slope of the Shuorute Daban at an altitude of 2154 m. The tributaries such as the Galaite River, Saridaghid River, Hague River, Hongor River, East Barron River, Thelergi River, Helin River, Uliastay River, and Selbe River, which originate from the branches of the Khentii Mountains, all converge into the Tuul River.

The Tuul River has a catchment area of 49600km², a river length of 874km, an average elevation of 1474m, and an average gradient of 1.3‰. It accounts for 38% of the total area of the Orkhon River basin and is the largest tributary on the right bank of the Orkhon River. Finally, it flows into the right bank of the Orkhon River at 57°00′ north latitude and 104°47′40″ east longitude.

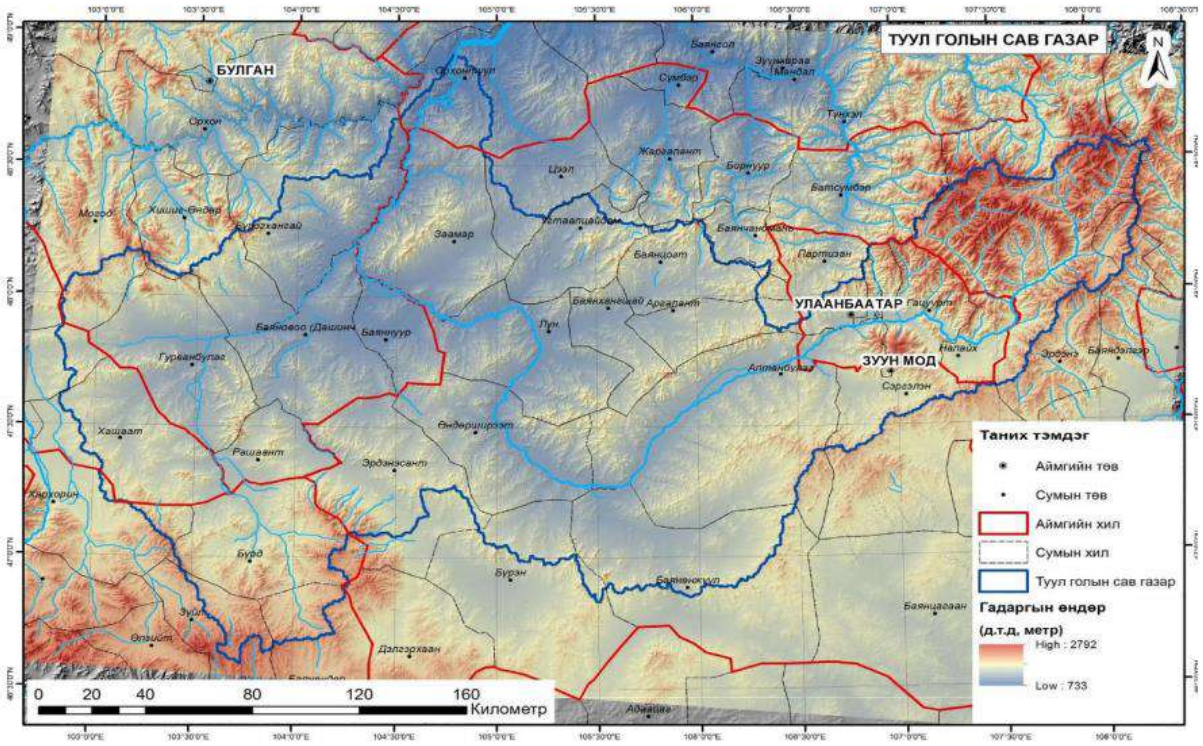


Figure 4. 4. Tuul River basin

The riverbed of the Tuul River has a standard width of 35-75m and a depth of 0.8-3.5m, with a flow rate of 0.50-1.50m/s and a riverbank height of 0.5-2.5m. The average drainage

density in the Tuul River basin is 0.39km/km2. Long-term water regimen observation and research have been carried out by the Tuul River-Ulaanbaatar observation station since 1945, the Selbe River-Dambadarjaa observation station since 1985, the Selbe-Sangzai observation station since 1994, and the Uliastai River-Uliastai observation station since 1992, respectively.

According to the 2023 ULAANBAATAR CITY MASTER PLAN FOR MUNICIPAL ENGINEERING PREPARATION MEASURES, the once-in-a-century flow of the Tuul River is 2994.3m^3/s.

(2) Determination of flood surface elevation

By analysing the correlation between flood surface elevation and flow, the water level at a bridge section is calculated by a hydraulic method, and a relationship curve between flood surface elevation and flow is established by using the Chézy formula based on the data of the hydrological cross section, river slope gradient and bed roughness at the bridge location. The formula is as follows:

$$Q = A_c v_C + A_t v_t$$

$$v_c = \frac{1}{n_c} R_c^{\frac{2}{3}} I^{\frac{1}{2}}$$

$$v_t = \frac{1}{n_t} R_t^{\frac{2}{3}} I^{\frac{1}{2}}$$

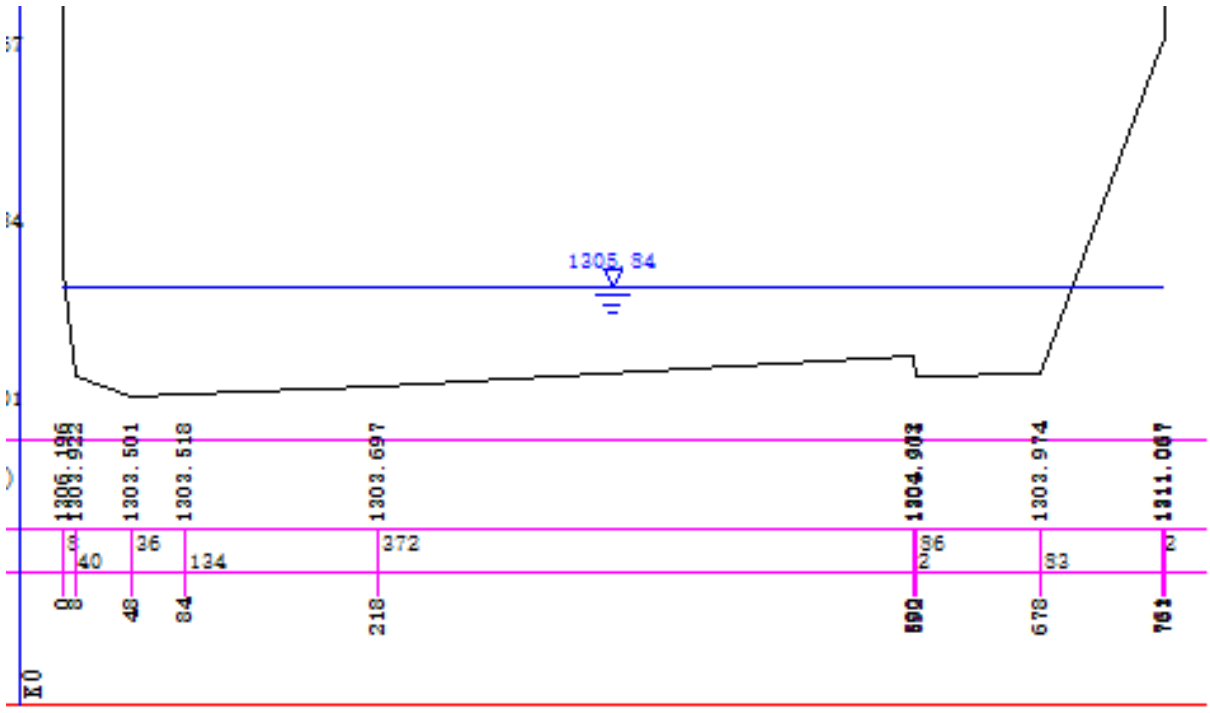


Figure 4. 5. River section diagram

After calculation, the once-in-a-century flood surface elevation under the bridge is 1325.84 m. According to Article 1.21 of the Designing road bridges and culverts (БНбД 32-02-12), the elevation of the girder soffit shall be not less than 0.5m above the design flood surface elevation, that is, not less than 1325.84+0.5=1326.34m.

(3) Conclusion

According to the project calculation, the once-in-a-century flood surface elevation of the Tuul River at the bridge site is 1325.84m, and the once-in-a-century flow is 2994.3m^3/s. This project crosses the floodplain of the Tuul River together with the A, B, and C ramps of the Tuul Interchange at the terminal point, and the A, B, and C ramps connected to the Tuul Expressway will be adjusted according to the design elevation of the Tuul Expressway in a later stage.

4.6. BRIDGE DESIGN

4.6.1. Design parameters

The calculation parameters for the bridge engineering in this project refer to the relevant provisions of the Chinese Code on the design of urban bridges, and are designed using two types of limit state methods: ultimate limit state and serviceability limit state.

Table 4. 10. List of design parameters

Item	Parameter description
Design live load	Lane load reference city-Class A
Temperature load	-40°C≤T≤40°C
Seismic design	Time history analysis or response spectrum method
Superstructure	Mainline: Cast-in-place concrete box girder+precast prestressed concrete small box girder Interchange section: Cast-in-place concrete box girder+precast prestressed concrete small box girder
Bearing type	Shock-absorbing pot bearing/horizontal force dispersing rubber bearing
Substructure	Abutment/pier: Prestressed cap beam/frame pier/straight abutment Foundation: φ1000 mm/φ1200 mm/φ1500 mm/bored pile
Rebar	HRB400 grade
Concrete	C50/ C40/ C35/ C30
Railway crossing section	Building clearance: H=7.0m Clearance from permanent structure to track centerline: L=3.5m
Road intersection section	Building clearance: H=5.2m
Crash barrier	Concrete crash barrier

4.6.2. Technical indicators of materials

The materials used in the design of this project shall comply with the following standards:

Table 4. 11. Technical indicators of basic design materials for bridges

Material	Application part	Technical standards
C50 concrete	Concrete cast-in-place box girders	Elastic modulus 34500MPa

Material	Application part	Technical standards
	Precast prestressed concrete small box girders Prestressed cap beam	Design axial compressive strength 22.4MPa Design axial tensile strength 1.83MPa
C40 concrete	Frame pier Rectangular pier	Elastic modulus 32500MPa Design axial compressive strength 18.4MPa Design axial tensile strength 1.65MPa
C35 concrete	Bearing platform Abutment body	Elastic modulus 31500MPa Design axial compressive strength 16.1MPa Design axial tensile strength 1.52MPa
C30 concrete	Pile foundation	Elastic modulus 30000MPa Design axial compressive strength 13.8MPa Design axial tensile strength 1.39MPa
Hot-rolled ribbed steel bar HRB400 grade steel bar	All	Elastic modulus 210000MPa Design compressive strength 330MPa Design tensile strength 330MPa
Nominal diameter φs15.2mm Prestressed steel strand	Cast-in-place box girder precast prestressed concrete small box girders Prestressed cap beam	Standard compressive strength 1860MPa

Note: The strength grade of concrete shall be determined according to the standard compressive strength of a cube specimen with a side length of 150mm.

Temperature load: According to the meteorological data of Ulaanbaatar over the years, the extreme minimum/maximum temperature is ±40°C. The Mongolian Design Code (BNbD32.02.03) also adopts the same parameters, so the structural temperature load of this project is set as -40°C≤T≤40°C.

Wind load: The maximum instantaneous wind speed of 30m/s in Ulaanbaatar over the years is used as the calculation basis.

4.6.3. Overall bridge design

There are 5 mainline bridges in this project, with a length of 9034m and a width of 19.5-45.5m, constructed by precast prestressed concrete small box girders or prestressed concrete cast-in-place box girders. There are 7 interchange ramp bridges with a length of 4989.3m, constructed by precast prestressed concrete small box girders or prestressed concrete cast-in-place box girders. There are 2 ground-level auxiliary road bridges with a length of 168m, constructed by precast prestressed concrete small box girders. There will be an grade-separated bridge for forward planning, with a length of 100m and a width of 14.5m, constructed by precast prestressed concrete small box girders. According to the actual situation, 1 culverts and 7 channels are set up, and there will be 3 pedestrian overpasses for recent implementation, and 4 pedestrian overpasses for forward planning.

(1) Mainline viaducts

1) Mainline viaduct No. 1

The mainline viaduct No.1 is in the north-south direction, spanning major obstacles

including the existing bridges, rivers, railways and roads. Balanced cantilever continuous beams are employed when crossing the railways and existing bridges, cast-in-place continuous beams with partial scaffolding are employed when crossing the roads. For spanning rivers and the standard section of the viaduct, precast prestressed concrete small box girder structures are employed.

The start point is connected with the Tuul Expressway Interchange, extending northward along the planned alignment, and crosses an existing 3×18m reinforced concrete T-beam bridge crossing the Zhong River (lower reaches of the Selebe River), at K0+212, followed by Current state of the road. This design adopts (40+65+40)m cast-in-place continuous beams crossing the existing bridges and the Current state of the road, and the (40+65+40)m cast-in-place continuous beams are employed to cross Planned road.

This project spans the Ulaanbaatar Railway at K1+458 and K1+563, which is a single-track diesel-powered railway at K1+458 with a railway subgrade width of 4.5m and a crossing angle of 65 degrees with this project, and is a double-track diesel-powered railway at K1+563 with a railway subgrade width of 22m and a crossing angle of 88 degrees with this project. This bridge separately adopts (30+45+30)m and (30+50+30)m cast-in-place continuous beams for spanning, with main spans of 45m and 50m respectively spanning the railways.

Bridge No. 1 continues to extend northward, crossing Moscow Street at K1+817. Moscow Street is a first-class main road (a subway is planned to be built under the pavement in the later period, and the central median of the road does not meet the conditions for setting up piers), with 6 lanes in both directions. (45+70+45)m cast-in-place continuous beams are employed to span Moscow Street, and then (45+65+45) m cast-in-place continuous beams are employed to span the planned road and 12m wide flood drainage ditches at K2+275. The planned road is a second-class main road, with 4 lanes in both directions, and (45+70+45)m cast-in-place continuous beams are employed to span the road. (40+60+40)m cast-in-place continuous beams are employed to span the Ard Ayush Road at K3+021, Ard Ayush Road is a first-class main road under construction, with 6 lanes in both directions, which will be connected to the planned subgrade. When the bridge No. 1 spans the existing roads, bridges and railway lines, it adopts variable cross-section prestressed concrete cast-in-place box girders, while the remaining bridge spans are constructed by 25m and 30m precast prestressed concrete small box girders. The bridge is 2951m long and 19.5-45.5m wide.

2) Mainline viaduct No. 2

The mainline viaduct No. 2 is located in the northwest of the project route, spanning major obstacles including the under-construction roads or existing roads. When crossing roads, cast-in-place continuous beams with partial scaffolding are employed. In the small-radius curve

sections and widened sections of the viaduct, cast-in-place continuous beams with partial scaffolding are employed. For spanning rivers and the standard section of the viaduct, precast prestressed concrete small box girder structures are employed.

When crossing the west side of the Ring Expressway, vehicles can pass smoothly through interchanging with the west side of the Ring Expressway. The bridge No. 2 spans the existing road Bayankhoshuu street at K5+794 and K6+480. Bayankhoshuu street is a second-class main road, with 4 lanes in both directions, and (30+45+30)m cast-in-place continuous beams and (27+40+27)m cast-in-place continuous beams are separately used for crossing this street. The remaining bridge spans are constructed by 25-30m precast prestressed concrete small box girders. The bridge is 1078m long and 26.5-37.9m wide.

3) Mainline viaduct No. 3

The mainline viaduct No. 3 runs east-west and is located on the northern line of the route, spanning major obstacles including rivers and roads. When crossing roads, cast-in-place continuous beams with partial scaffolding are employed. In the widened sections of the viaduct, cast-in-place continuous beams with partial scaffolding are employed. For spanning rivers and standard section of the viaduct, precast prestressed concrete small box girder structures are employed.

(35+50+35)m cast-in-place continuous beams are used for crossing the existing road Denj 1000 Terminal Road at K12+620, which is a second-class main road, with 2 lanes in both directions, and then crossing the tributary of Selbe River at K12+720. The tributary of Selbe River is 14m wide, which obliquely intersects at a 60-degree angle with the planned route.

Bridge No. 3 extends eastward, and adopts (30+40+30)m cast-in-place continuous beams to span the Doloon Buudal road at K13+232, and the Doloon Buudal road is a first-class main road, with 4 lanes in both directions. (2×33.65+32.7)m cast-in-place continuous beams are employed to cross the Seredget Project Road at K13+979, and the Sereglet Project Road is a second-class main road, with 4 lanes in both directions. (20+30+20)m cast-in-place continuous beams are employed to cross the Dari-Ekh street at K14+658, and the Dari-Ekh street is a second-class main road, with 2 lanes in both directions.

Bridge No. 3 spans the Selbe River from K13+981 to K14+300. The riverbed of the Selbe River is wide and flat, with a width of about 319m, and is crossed by 30m precast prestressed concrete small box girders.

When the bridge No. 3 spans the existing roads, it adopts variable cross-section prestressed concrete cast-in-place box girders, while the remaining bridge spans are constructed by 25-30m precast prestressed concrete small box girders. The bridge is 2315m long and 26.5-42.9m wide.

4) Mainline viaduct No. 4

The mainline viaduct No. 4 runs north-south and is located on the east side of the planned route, spanning major obstacles including railways and roads. Balanced cantilever continuous beams are employed when crossing the railways, and cast-in-place continuous beams with partial scaffolding are employed when crossing the roads. In the small-radius curve sections and widened sections of the viaduct, cast-in-place continuous beams with partial scaffolding are employed. For spanning rivers and the standard section of the viaduct, precast prestressed concrete small box girder structures are employed.

(35+50+35)m cast-in-place continuous beams are employed to cross the existing road at K21+560, and (35+50+35)m cast-in-place continuous beams are employed to cross the existing road at K22+400, extending southward. (35+50+35)m cast-in-place continuous beams are employed to cross the Police Academy Avenue at K22+856, and the Police Academy Avenue is a first-class main road, with 6 lanes in both directions, followed by crossing several existing roads in residential areas. (30+40+30)m cast-in-place continuous beams are employed to cross the existing road General's No. IX Street at K23+817, and the General's No. IX Street is a second-class main road, with 4 lanes in both directions.

This project spans the Ulaanbaatar Railway at K23+874, which is a single-track diesel-powered railway with a 5.5m railway subgrade width and an intersection angle of 67 degrees with the route, and is connected to the filling subgrade direction after crossing the planned 6.3m wide road again. When the bridge No. 4 spans the existing roads and railways, it adopts variable cross-section prestressed concrete cast-in-place box girders, while the remaining bridge spans are constructed by 25m and 30m precast prestressed concrete small box girders. The bridge is 2570m long and 26.5-41m wide.

5) Mainline viaduct No. 5

The mainline viaduct No. 5 spans the planned road at K24+339, the width of the planned road is 23.75m, and an intersection angle between the planned route and the road is 60 degrees. The bridge No. 5 is constructed using (35+50+35)m cast-in-place continuous beams for crossing, and constructed with the reduced-scaffolding method. The bridge is 120 m long and 26.5 m wide.

Table 4. 12. List of layout of mainline viaducts

Bridge name	Structure form	Span arrangement (m)	Bridge length (m)	Bridge width (m)	Superstructure construction method
Mainline viaduct No. 1	Prestressed concrete cast-in-place girders +	2×(40+65+40)+5×(3×30)+(40+65+40)+2×(3×30)+4×30+3×27+(30+45+30)+(30+50+30)+(3×30+31)+(45+70+45)+4×30+(2×30+25)+4×25+(45+70+45)+2×(4×30)	2951	19.5 - 45.5	Casting with Cast-in-place cantilever method +

Bridge name	Structure form	Span arrangement (m)	Bridge length (m)	Bridge width (m)	Superstructure construction method
	precast prestressed concrete small box girders	+(3×30+28)+(2×28+2×30)+4×27.5+(40+60+40)			Casting with reduced-scaffolding method + Erecting with girder erecting machine
Mainline viaduct No. 2	Prestressed concrete cast-in-place girders + precast prestressed concrete small box girders	30+(30+45+30)+(3×25+30)+4×27+(27+3×26)+(2×26+25)+(2×25+2×30)+(30+2×27)+(27+40+27)+(2×25+30)+2×(3×30)	1078	26.5 - 37.9	Casting with reduced-scaffolding method + Erecting with girder erecting machine
Mainline viaduct No. 3	Prestressed concrete cast-in-place girders + precast prestressed concrete small box girders	2×(3×30)+(35+50+35)+(2×30+25+30)+4×30+3×(3×30)+(30+40+30+30)+2×30+3×26+2×26+3×30+2×(4×30)+3×30+(2×33.65+32.7)+ 5×(4×30)+ (20+30+20)	2315	26.5 - 42.9	Casting with reduced-scaffolding method + Erecting with girder erecting machine
Mainline viaduct No. 4	Prestressed concrete cast-in-place girders + precast prestressed concrete small box girders	(5×30)+(35+50+35)+6×(4×30)+(35+50+35)+(4×30)+(3×30)+(4×30)+(35+50+35)+(3×25)+(4×30)+(5×30)+(3×30)+2×(4×30)+(5×30)+(1×25)+(30+40+30)+(2×30)	2570	26.5 - 41	Casting with reduced-scaffolding method + Erecting with girder erecting machine
Mainline viaduct No. 5	Prestressed concrete cast-in-place girders	35+50+35	120	26.5	Casting with reduced-scaffolding method

(2) Interchange ramp bridge

The overpass is constructed using cast-in-place continuous beams with partial scaffolding when crossing roads. In the small-radius curve sections and widened sections of the overpass, cast-in-place continuous beams with partial scaffolding are employed. For large-radius curved sections, straight lines, and equal-width cross sections, precast prestressed concrete small box

girder structures are employed.

1) On-ramp and off-ramp at K1+090

This bridge is mainly designed to cross the Ulaanbaatar railway, and ground-level auxiliary road vehicles access to the mainline viaducts through ramps, crossing over the railway line. The bridge spans are constructed by 27m and 30m precast prestressed concrete small box girders. The ramp bridge is 171m long and 9m wide.

2) Interchange between New Ring Road and Ard Ayush Road

The under-construction Ard Ayush Road interchange, located at K3+054, is mainly designed to connect the mainline viaducts to the under-construction Ard Ayush Road. Vehicles from the Ard Ayush Road enter the mainline viaducts through ramps, and vehicles from the mainline viaducts enter the under-construction road through ramps. The bridge spans are constructed by 27m and 30m precast prestressed concrete small box girders. The ramp bridges on both sides are 87.5m long and 9.0m wide.

3) Interchange between New Ring Road and west side of Second Ring Road

The interchange on the west side of the Ring Expressway is mainly designed to connect the Second Ring Road (at K6+366 of the mainline) and the Bayankhoshuu street (at K5+794 and K6+480 of the mainline) to the mainline viaducts. Vehicles from the mainline viaducts enter the ramp C through the ramp A and then enter the Second Ring Road; vehicles from the Second Ring Road enter the ramp B through the ramp C to enter the mainline viaducts; the ramp C is designed to merge the ramps A and B; and vehicles from the Second Ring Road can turn right and directly enter the mainline viaducts through the ramp D, while vehicles from the mainline viaducts can directly turn right and enter the ramp E to enter the Second Ring Road. The ramp A is constructed using prestressed concrete cast-in-place box girders and concrete cast-in-place box girders, with a bridge length of 370m and a bridge width of 6.25-10m. The ramp B is constructed using prestressed concrete cast-in-place box girders and concrete cast-in-place box girders, with a bridge length of 257m and a bridge width of 7.05-10m. The ramp C is constructed using prestressed concrete cast-in-place box girders, concrete cast-in-place box girders and precast prestressed concrete small box girders, with a bridge length of 303m and a bridge width of 20.5m. The ramp D is constructed using precast prestressed concrete small box girders, with a bridge length of 130m and a bridge width of 6.25-10.5m. The ramp E is constructed using precast prestressed concrete small box girders, with a bridge length of 225m and a bridge width of 10m.

4) Interchange between New Ring Road and east side of Second Ring Road

This interchange is mainly designed to connect the mainline viaducts to the Second Ring Road (at K20+835 of the mainline). Vehicles from the Second Ring Road enter the mainline viaducts by turning left or right through the ramp A, and vehicles from the mainline viaducts enter

the Second Ring Road by turning right through the ramp E. The ramp A is constructed using prestressed concrete cast-in-place box girders and precast prestressed concrete small box girders, with a bridge length of 240m and a bridge width of 20.5m. Each of the ramps D and E has a 12m wide single-span frame bridge.

5) Interchange between New Ring Road and Doloon Buudal road

This bridge is mainly designed to connect mainline viaducts to the Doloon Buudal road (at K13+232 of the mainline). On the left side of the mainline viaducts, ramps B and C are merged into the ramp A, so as to be connected to the Doloon Buudal road; and on the left side of the mainline viaducts, ramps E and F are merged into the ramp D, so as to be connected to the Doloon Buudal road. The ramp A is constructed using concrete cast-in-place box girders, with a bridge length of 100m and a bridge width of 17.5m. The ramp B is constructed using concrete cast-in-place box girders, with a bridge length of 155m and a bridge width of 9m. The ramp C is constructed using concrete cast-in-place box girders, with a bridge length of 243m and a bridge width of 8.05-8.35m. The ramp D is constructed using concrete cast-in-place box girders, with a bridge length of 120m and a bridge width of 17.5m. The ramp E is constructed using concrete cast-in-place box girders, with a bridge length of 180m and a bridge width of 9m. The ramp F is constructed using prestressed concrete cast-in-place box girders, with a bridge length of 188m and a bridge width of 8.01-8.3m.

6) Interchange between New Ring Road and Police Academy Avenue

It is mainly designed to connect the mainline viaducts to the Police Academy Avenue (at K22+856 of the mainline). Vehicles from the Police Academy Avenue enter the ground-level auxiliary road through ramps B and D, and then enter the mainline viaducts; and vehicles from the mainline viaducts enter the ground-level auxiliary road through ramps A and C, and then enter the Police Academy Avenue. The bridge spans are constructed using precast prestressed concrete small box girders, which are hoisted by cranes. The ramp A has a bridge length of 240m and a bridge width of 9m; the ramp B has a bridge length of 270m and a bridge width of 9m; the ramp C has a bridge length of 270m and a bridge width of 9m; and the ramp D has a bridge length of 240m and a bridge width of 9m.

7) Interchange between New Ring Road and Tuul Expressway

It is mainly designed to connect the planned route to the Tula Expressway. The Tula Expressway is connected to the planned route via the ramp A merged by the ramps B and C. The ramp A is constructed using prestressed concrete cast-in-place box girders and concrete cast-in-place box girders, with a bridge length of 358m and a bridge width of 20m. The ramp B is constructed using concrete cast-in-place box girders, with a bridge length of 194m and a bridge width of 10m. The ramp C is constructed using concrete cast-in-place box girders, with a bridge length of 241m and a bridge width of 10m.

Table 4. 13. List of layout of interchange ramp bridges

Bridge name	Location	Structural type	Span arrangement (m)	Bridge length (m)	Bridge width (m)	Superstructure construction method
on-ramp and off-ramp at K1+090	Ramp B	Precast prestressed concrete small box girders	3×30+3×27	171	9	Hoisting by cranes
	Ramp C	Precast prestressed concrete small box girders	3×30+3×27	171	9	Hoisting by cranes
Interchange between the New Ring Road and the Ard Ayush Road	Ramp B	Precast prestressed concrete small box girders	2×30+27.5	87.5	9.0	Hoisting by cranes
	Ramp C	Precast prestressed concrete small box girders	2×30+27.5	87.5	9.0	Hoisting by cranes
Interchange between New Ring Road and west side of Second Ring Road	Ramp A	Prestressed concrete cast-in-place box girders +concrete cast-in-place box girders	6×20+5×18+(20+30+20)+(4×18+18.5)	370	6.25 - 10	Casting with reduced-scaffolding method
	Ramp B	Prestressed concrete cast-in-place box girders +concrete cast-in-place box girders	3×20+(2×20+18)+(20+30+20)+(18+3×17)	257	7.05 - 10	Casting with reduced-scaffolding method
	Ramp C	Prestressed concrete cast-in-place box girders +concrete cast-in-place box girders+precast prestressed concrete small box girders	(2×19+20)+(20+30+20)+4×25+3×25	303	20.5	Casting with reduced-scaffolding method Hoisting by cranes
	Ramp D	precast prestressed concrete small box girders	2×25+30+2×25	130	6.25 - 10.5	Hoisting by cranes
	Ramp E	precast prestressed concrete small box girders	3×(3×25)	225	10	Hoisting by cranes
Interchange between New Ring Road and east side of Second Ring Road	Ramp A	Prestressed concrete cast-in-place box girders +precast prestressed concrete small box girders	(1×30)+(30+45+45+30)+(2×30)	240	20.5	Casting with reduced-scaffolding method
	Ramp D	Frame bridge	1×12		12	Casting with scaffolding method
	Ramp E	Frame bridge	1×12		12	Casting with scaffolding method
Interchange between New Ring Road	Ramp A	Concrete cast-in-place box girders	5×20	100	17.5	Casting with reduced-scaffolding method

Bridge name	Location	Structural type	Span arrangement (m)	Bridge length (m)	Bridge width (m)	Superstructure construction method
and Doloon Buudal road	Ramp B	Concrete cast-in-place box girders	(18.2+21)+(2×18+20)+3×20	155	9	Casting with reduced-scaffolding method
	Ramp C	Concrete cast-in-place box girders	(20+22.8)+2×(5×20)	243	8.05 - 8.35	Casting with reduced-scaffolding method
	Ramp D	Concrete cast-in-place box girders	2×(3×20)	120	17.5	Casting with reduced-scaffolding method
	Ramp E	Concrete cast-in-place box girders	(19.7+20.5)+4×20+3×20	180	9	Casting with reduced-scaffolding method
	Ramp F	Concrete cast-in-place box girders	(21.6+22)+4×21+3×20	188	8.01 - 8.3	Casting with reduced-scaffolding method
Interchange between New Ring Road and Police Academy Avenue	Ramp A	precast prestressed concrete small box girders	2×(4×30)	240	9	Hoisting by cranes
	Ramp B	precast prestressed concrete small box girders	3×(3×30)	270	9	Hoisting by cranes
	Ramp C	precast prestressed concrete small box girders	3×(3×30)	270	9	Hoisting by cranes
	Ramp D	precast prestressed concrete small box girders	2×(4×30)	240	9	Hoisting by cranes
Interchange between New Ring Road and Tuul Expressway	Ramp A	Concrete cast-in-place box girders+prestressed concrete cast-in-place box girders	3×20+(30+45+30)+2×(3×20)+ (3×18+19.3)	358	20	Casting with reduced-scaffolding method
	Ramp B	Concrete cast-in-place box girders	(3×18)+3×20+4×20	194	10	Casting with reduced-scaffolding method
	Ramp C	Concrete cast-in-place box girders	(2×20+20.7)+3×(3×20)	241	10	Casting with reduced-scaffolding method

(3) Auxiliary road bridges

The ground-level auxiliary road of the bridge No.1 at K0+212 partially utilizes the existing bridge, and some of them need to be widened. The existing bridge is 3×18m reinforced concrete T-beam bridge crossing the Zhong River established by 3×18m reinforced concreteT-beam bridge crossing the Zhong River (the lower reaches of the Selbe River), and the widening is designed as a 3×18m precast prestressed concrete small box girder bridge, with 4m widening on both sides.

In order to ensure that the ground-level auxiliary road crosses the tributaries of the Selbe River with a tributary channel width of 14m at K12+720, a ground-level auxiliary road bridges are set up, with left and right separated spans.

Table 4. 14. List of layout of ground-level auxiliary road bridges

Bridge name	Location	Structural type	Span arrangement (m)	Bridge length (m)	Superstructure construction method
Ground-level auxiliary road bridge at K0+212	Left auxiliary road	Precast prestressed concrete small box girders	3×18	54	Hoisting by cranes
	Right auxiliary road	Precast prestressed concrete small box girders	3×18	54	Hoisting by cranes
Ground-level auxiliary road bridge at K12+720	Left auxiliary road	Precast prestressed concrete small box girders	1×30	30	Hoisting by cranes
	Right auxiliary road	Precast prestressed concrete small box girders	1×30	30	Hoisting by cranes

(4) Grade-separated bridge

A grade-separated bridge is set up at K8+586.927, with an existing road width of 13.2m and an intersection angle of 37 degrees with this line.

A grade-separated bridge is planned and reserved at K19+370, with an existing road width of 7.5m and an intersection angle of 30 degrees with this line. As the northern part of the road is located at the foot of a mountain, there is not much traffic demand. In the near future, a temporary at-grade intersection with the auxiliary road of this project will be implemented. In the long term, whether it is constructed or not will be considered based on the planned road construction situation, so as to avoid duplication with other projects and reduce waste.

Table 4. 15. List of layout of grade-separated bridge

Bridge name	Location	Structural type	Span arrangement (m)	Bridge length (m)	Superstructure construction method
Grade-separated bridge	Crossing existing road at K8+586.927 of the mainline	Precast prestressed concrete small box girders	4×25m	100	Hoisting by cranes

(5) Pedestrian overpasses and channel culverts

To ensure that residents on both sides of the road can pass through after the implementation of the route, pedestrian overpasses and channel culverts are set up.

Table 4. 16. List of layout of pedestrian overpasses

Overpass	Location	Structural form and function	Bridge length (m)	Bridge width (m)	Superstructure construction method
Pedestrian overpass	At K3+575	2-32m prestressed concrete overpass	64	3.5	Casting with reduced-scaffolding method
Pedestrian overpass	At K7+975	2-32m prestressed concrete overpass	64	3.5	Casting with reduced-scaffolding method
Pedestrian overpass	At K17+200	2-32m prestressed concrete overpass	64	3.5	Casting with reduced-scaffolding method
Pedestrian overpass	At K5+110	2-32m prestressed concrete overpass	64	3.5	Forward planning
Pedestrian overpass	At K7+100	2-32m prestressed concrete overpass	64	3.5	Forward planning

Overpass	Location	Structural form and function	Bridge length (m)	Bridge width (m)	Superstructure construction method
Pedestrian overpass	At K11+800	2-32m prestressed concrete overpass	64	3.5	Forward planning
Pedestrian overpass	At K15+650	2-32m prestressed concrete overpass	64	3.5	Forward planning

Table 4. 17. List of layout of culverts and channels

Culvert and channel	Location	Structural form and function	Main construction method
Flood discharge culvert	At K2+303.3	2-5.0×5.0m reinforced concrete box culvert	Casting with scaffolding method
Interchange ramp	At K4+500	1-4.0×3.0 m reinforced concrete box culvert	Casting with scaffolding method
Interchange ramp	At K11+124	2-5.0×5.0m reinforced concrete box culvert	Casting with scaffolding method
Interchange ramp	At K16+450	2-5.0×5.0m reinforced concrete box culvert	Casting with scaffolding method
Interchange ramp	At K18+075	1-4.0×3.0m reinforced concrete box culvert	Casting with scaffolding method
Interchange ramp	At K18+750	2-5.0×5.0 m reinforced concrete box culvert	Casting with scaffolding method
Interchange ramp	At K19+586	1-4.0×3.0 m reinforced concrete box culvert	Casting with scaffolding method
Interchange ramp	At K19+900	1-4.0×3.0 m reinforced concrete box culvert	Casting with scaffolding method

There are a total of 1 culverts and 7 channels, all utilizing reinforced concrete box culvert structures as main structures with monolithic casting. The culvert invert elevation generally follows the natural ground level to minimize excavation. The entrance and exit forms of culverts shall be flared wing wall openings or straight wall openings that are suitable for the characteristics of all the culverts.

There will be 3 pedestrian overpasses for recent implementation, and 4 pedestrian overpasses for forward planning. The superstructure is constructed using a prestressed concrete box girder structure, with span arrangement of 2×32.0m, a bridge length of 64m and a bridge width of 3.5m. A reinforced concrete stairway with a width of 2.5m is adopted. Considering the distance between two wheelchair users, the slope gradient should be less than 8%. When the slope gradient is 4-5%, step grading shall be implemented according to 15.0m. When the slopegradient is 5-6%, landings are spaced at 12.0m intervals. When the slope gradient is 6-8%, landings are spaced at 9.0m intervals. The landing length is 2.44m, and the ramp is made of a non-slip material. Handrails are installed on both sides of the stairway. The heights of the double handrails are 0.85m and 0.65m, respectively. In order to guide people with visual impairment, braille marks are set at the beginning of the handrails.

4.6.4 Superstructure design outcome

In the design for the durability of the bridge superstructure, the bearing capacity of components should be calculated according to the requirements of the ultimate limit state, and

the crack resistance of components should be checked according to the requirements of the serviceability limit state.

In this project, the calculation of cantilever casting box girders is designed as fully prestressed components, which means that the entire cross-section of the box girder must remain in compression with no tensile stresses permitted in the serviceability limit state. Cast-in-place concrete box girders with scaffolding and precast prestressed concrete small box girders are designed as Class A components, which means that the cross-sections of the box girders are allowed to have tensile stress in the serviceability limit state, but the tensile stress should not exceed the design tensile stress value, and no cracks are allowed.

For variable cross-section box girders, typical control cross-sections are selected for calculation and review, which are the lower edge at the mid-span of the side span denoted by 1, the upper edge at the intermediate support denoted by 2, and the lower edge at the mid-span of the main span denoted by 3, respectively.

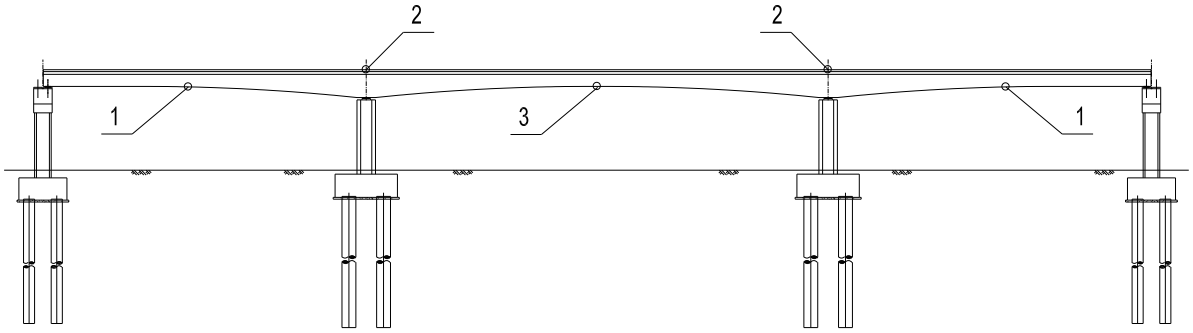


Figure 4. 6. Schematic diagram of control points for variable cross-section box girder

(1) Calculation results of cast-in-place cantilever variable cross-section box girder

Prestressed steel strands with a nominal diameter of 15.2 mm are arranged on variable cross-section box girder with a cantilever pouring method. HRB400 rebars with a diameter of 16 mm and a spacing of 100 mm are uniformly arranged at the top of the box girder. HRB400 rebars with a diameter of 16 mm and a spacing of 100 mm are uniformly arranged at the bottom of the box girder. The diameter of the stirrup is 12 mm and the spacing is 100 mm.

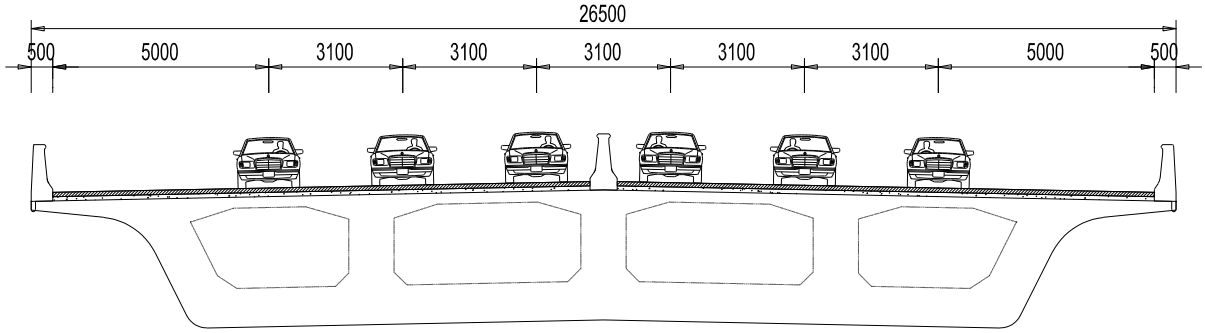


Figure 4. 7. Schematic Diagram for Centered Layout of Live Load

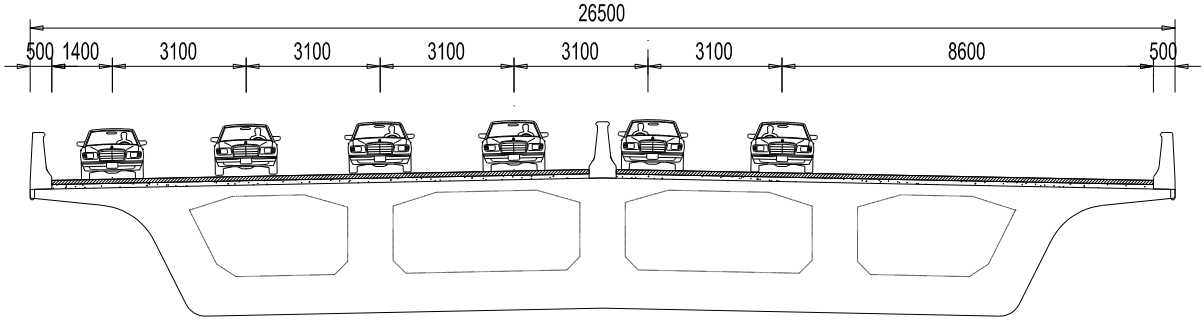


Figure 4. 8. Schematic Diagram for Left Leaning Layout of Live Load

Table 4. 18. Calculation Results of Box Girder at Ultimate Limit State

Bridge span arrangement	Location	Calculated internal force value (kN*m)	Design bearing capacity value (kN*m)	Note
45+70+45	1--lower edge at mid-span of side span	48583.2	97899.5	Ultimate limit state
	2--upper edge at intermediate support	220173.8	324171.3	
	3--lower edge at mid-span of main span	57414.9	64562.7	

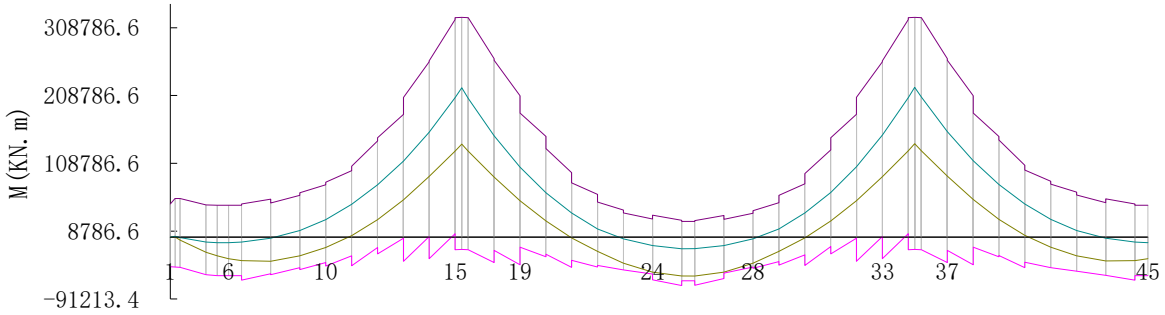


Figure 4. 9. Envelope Diagram of Normal Section Bending Resistance Checking Calculation at Ultimate Limit State

Table 4. 19. Calculation Results of Box Girder at Serviceability Limit State

Bridge span arrangement	Location	Calculated stress value (MPa)	Design stress value (MPa)	Note
45+70+45	1--lower edge at mid-span of side span	11.85	19.44	Serviceability limit state
	2--upper edge at intermediate support	9.60	19.44	
	3--lower edge at mid-span of main span	12.04	19.44	

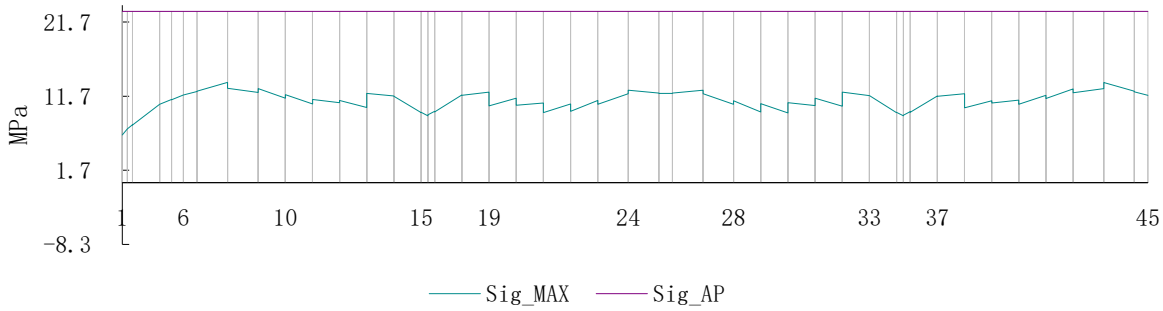


Figure 4. 10. Envelope Diagram of Principal Compressive Stress in Oblique Section at Serviceability Limit State

(2) Calculation results of scaffolding casting variable cross-section box girder

Prestressed steel strands with a nominal diameter of 15.2 mm are arranged on variable cross-section box girder with a support pouring method. HRB400 rebars with a diameter of 16 mm and a spacing of 100 mm are uniformly arranged at the top of the box girder. HRB400 rebars with a diameter of 16 mm and a spacing of 100 mm are uniformly arranged at the bottom of the box girder. The diameter of the stirrup is 12 mm and the spacing is 100 mm.

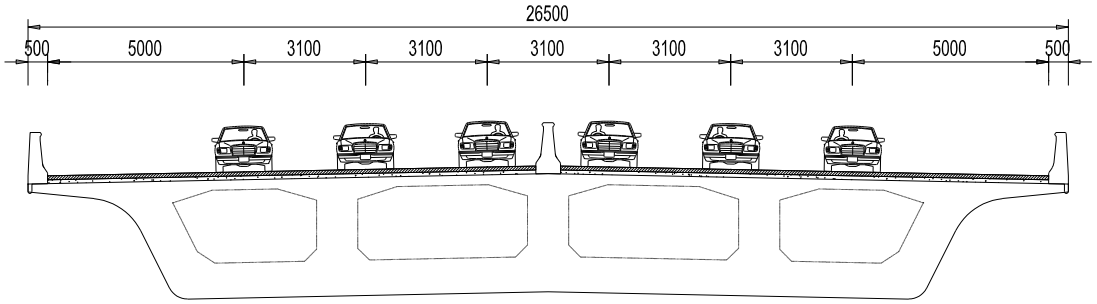


Figure 4. 11. Schematic Diagram for Centered Layout of Live Load

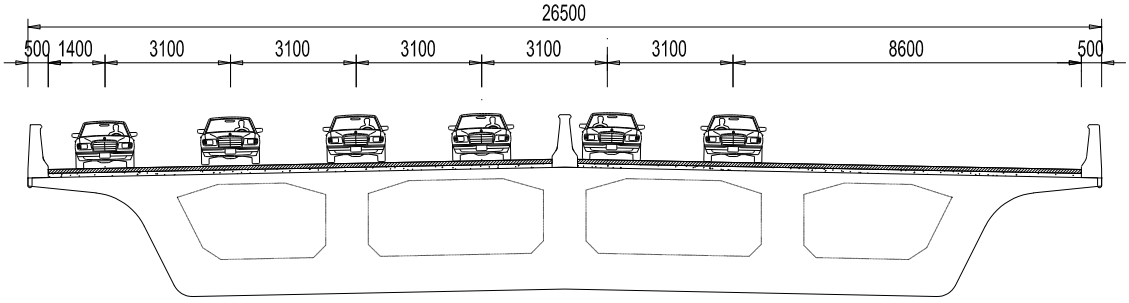


Figure 4. 12. Schematic Diagram for Left Leaning Layout of Live Load

Table 4. 20. Calculation results of box girder at ultimate limit state

Bridge span arrangement	Location	Calculated internal force value (kN*m)	Design bearing capacity value (kN*m)	Note
35+50+35	1--lower edge at mid-span of side span	96896.1	128024.0	ultimate limit state
	2--upper edge at intermediate support	185776.2	309141.6	

	3--lower edge at mid-span of main span	165298.6	182970.0	

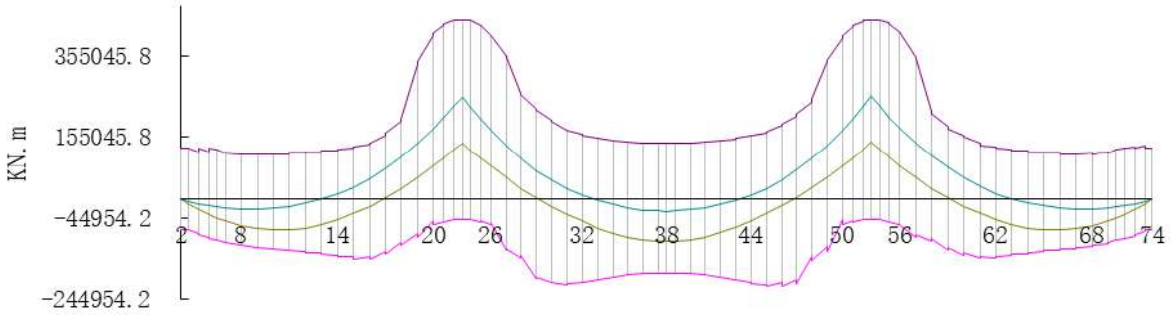


Figure 4. 13. Envelope diagram of normal section Flexural Capacity checking calculation at ultimate limit state

Table 4. 21. Calculation results of box girder at serviceability limit state

Bridge span arrangement	Location	Calculated stress value (MPa)	Design stress value (MPa)	Note
35+50+35	1--lower edge at mid-span of side span	8.98	19.44	serviceability limit state
	2--upper edge at intermediate support	19.28	19.44	
	3--lower edge at mid-span of main span	13.31	19.44	

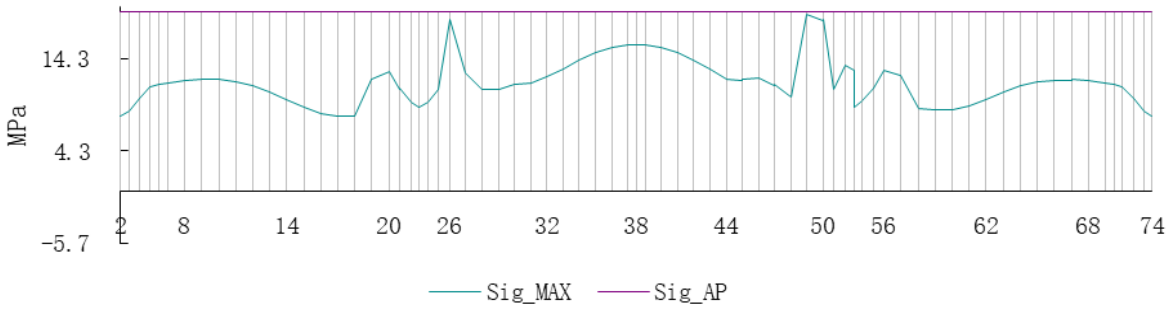


Figure 4. 14. Envelope diagram of principal compressive stress in oblique section at serviceability limit state

The calculation results show that the scaffolding casting variable cross-section box girder meets the code requirements in both the ultimate limit state and the serviceability limit state.

(3) Calculation results of precast prestressed concrete small box girder

Prestressed steel strands with a nominal diameter of 15.2 mm are arranged on the prefabricated prestressed concrete small box girder. HRB400 rebars with a diameter of 10 mm and a spacing of 100 mm are uniformly arranged at the top of the box girder. HRB400 rebars with a diameter of 20 mm and a spacing of 100 mm are uniformly arranged at the bottom of the box girder. The diameter of the stirrup is 12 mm and the spacing is 100 mm.

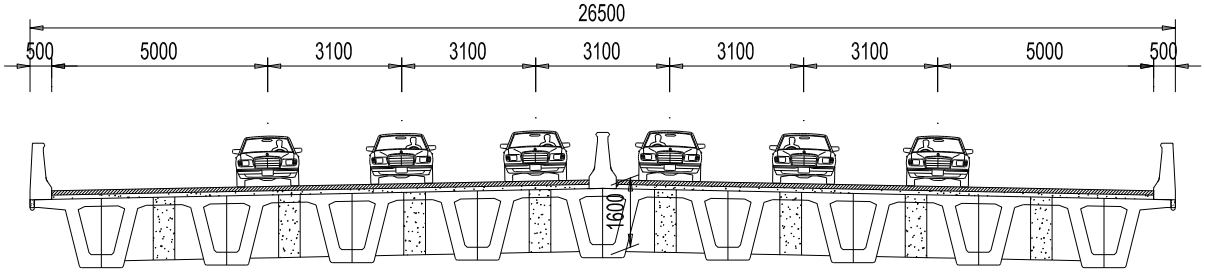


Figure 4. 15. Schematic Diagram for Centered Layout of Live Load

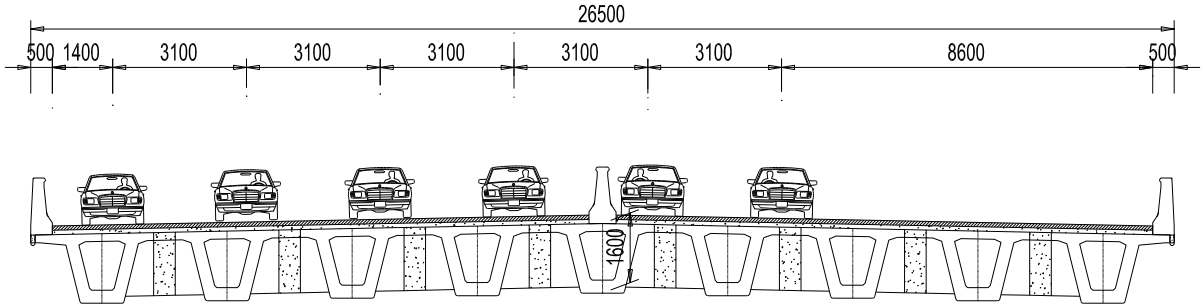


Figure 4. 16. Schematic Diagram for Left Leaning Layout of Live Load

Table 4. 22. Calculation results of box girder at ultimate limit state

Bridge span arrangement	Location	Calculated internal force value (kN*m)	Design bearing capacity value (kN*m)	Note
30m small box girder	Midspan of exterior girder	12598.6	12801.7	ultimate limit state
	Midspan of interior girder	11454.6	13204.0	

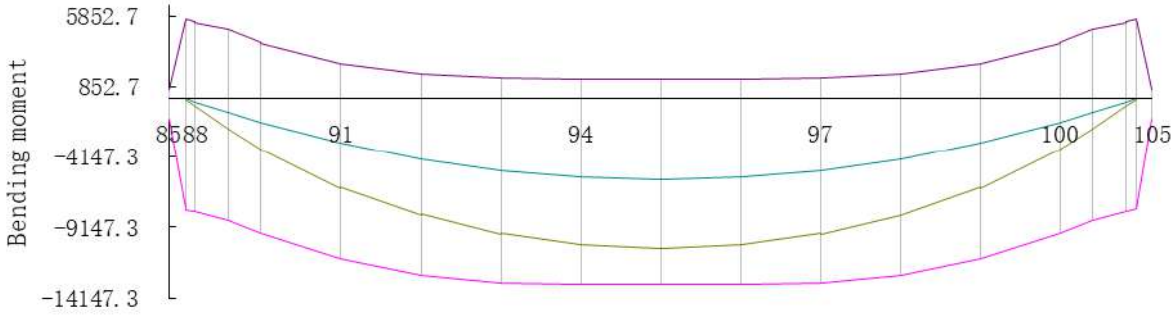


Figure 4. 17. Envelope diagram of normal section bending resistance checking calculation at ultimate limit state

Table 4. 23. Calculation results of box girder at serviceability limit state

Bridge span arrangement	Location	Calculated stress value (MPa)	Design stress value (MPa)	Note
30m small box girder	Midspan of exterior girder	12.65	19.44	serviceability limit state
	Midspan of interior girder	12.45	19.44	

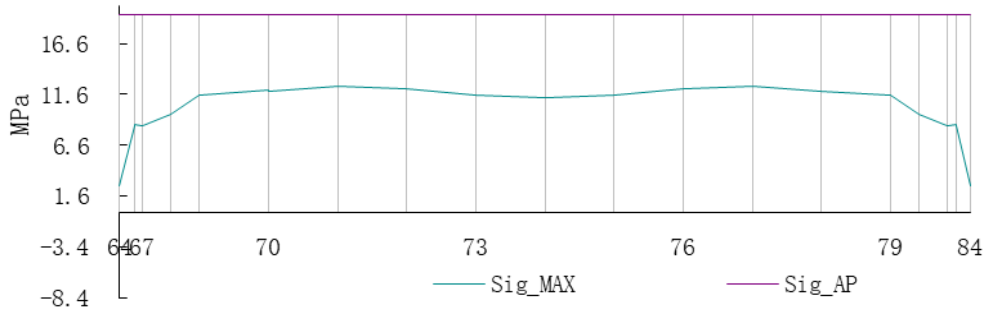


Figure 4. 18. Envelope diagram of principal compressive stress in oblique section at serviceability limit state

The calculation results show that the precast prestressed concrete small box girder meets the code requirements in both the ultimate limit state and the serviceability limit state.

4.6.5. Substructure design outcome

In the design for the durability of the bridge substructure, the bearing capacity of components should be calculated according to the requirements of the ultimate limit state, and the crack resistance of components should be checked according to the requirements of the serviceability limit state.

In this project, prestressed cap beams are designed as Class A components, which means that the cross sections of the cap beams are allowed to have tensile stress in the serviceability limit state, but the tensile stress should not exceed the design tensile stress value, and no cracks are allowed. Bridge piers are designed as reinforced concrete components, which means that the cross sections of the piers are allowed to have cracks in the serviceability limit state, but the crack widths should not exceed the specified value.

For a prestressed cap beam and a pier, typical control cross sections are selected for calculation and review, which are the upper edge of the cap beam at the support location denoted by 1, the pier footing position of the rectangular pier denoted by 2, and the pier footing position of the frame pier denoted by 3, respectively.

(1) Calculation results of prestressed cap beam

Prestressed steel strands with nominal diameters of 15.2mm are arranged for a prestressed cap beam, and HRB400 rebars with diameters of 28mm are uniformly arranged on the top of the cap beam, with spacing of bars being 120mm; HRB400 rebars with diameters of 25mm are uniformly arranged at the bottom of the cap beam, at 120mm spacing of bars; and the stirrup diameter is 20mm, and the stirrup spacing is 100mm.

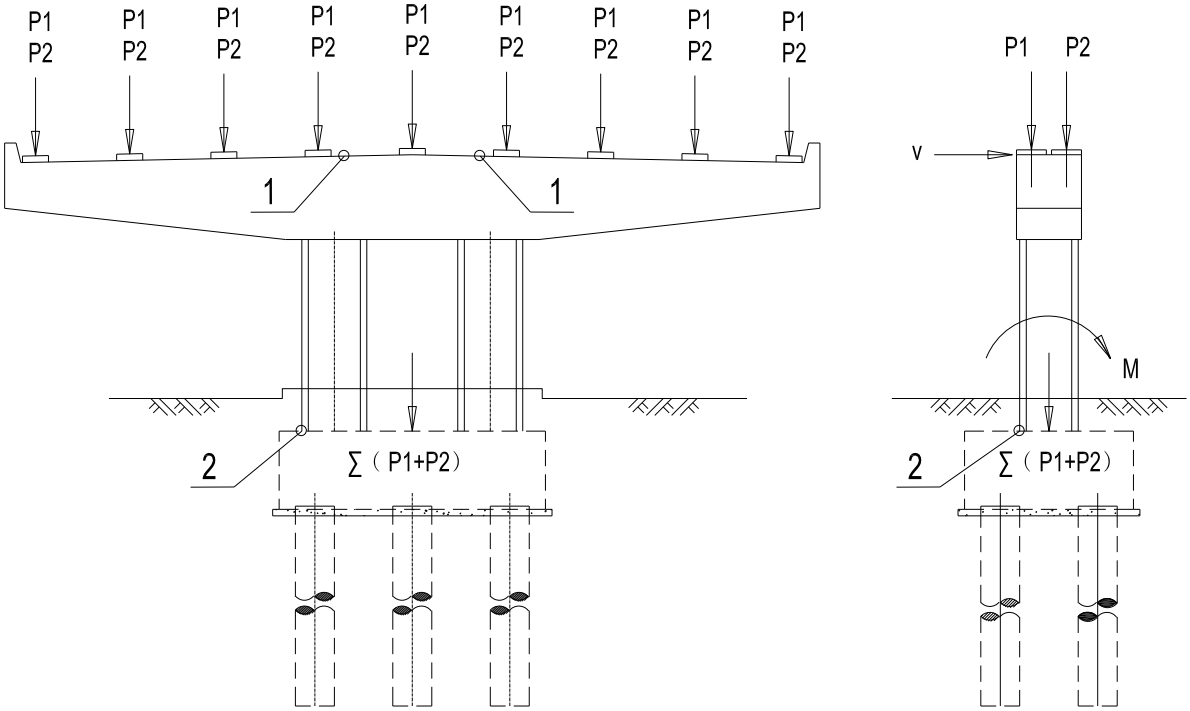


Figure 4. 19. Stress diagram of prestressed cap beam

Table 4. 24. Calculation results of box girder at ultimate limit state

Component	Location	Calculated internal force value (kN*m)	Design bearing capacity value (kN*m)	Note
Prestressed cap beam	1-upper edge of cap beam at support location	5987.5	28395.9	ultimate limit state

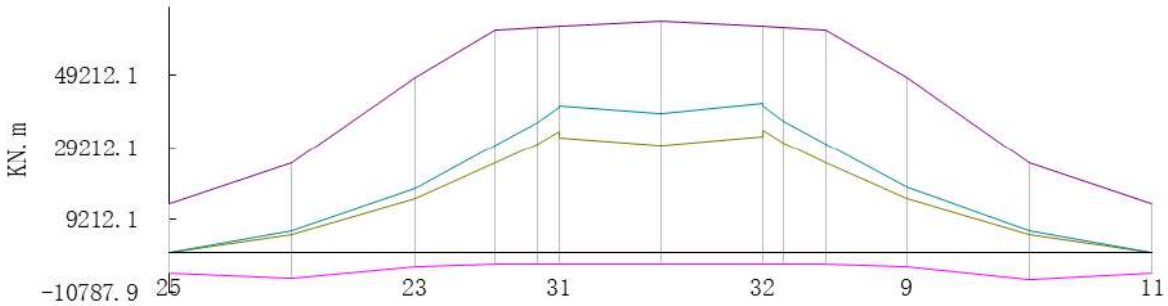


Figure 4. 20. Envelope diagram of normal section bending resistance checking calculation at ultimate limit state

Table 4. 25. Calculation results of box girder at serviceability limit state

Component	Location	Calculated stress value (MPa)	Design stress value (MPa)	Note
Prestressed cap beam	1-upper edge of cap beam at support location	16.42	19.44	serviceability limit state

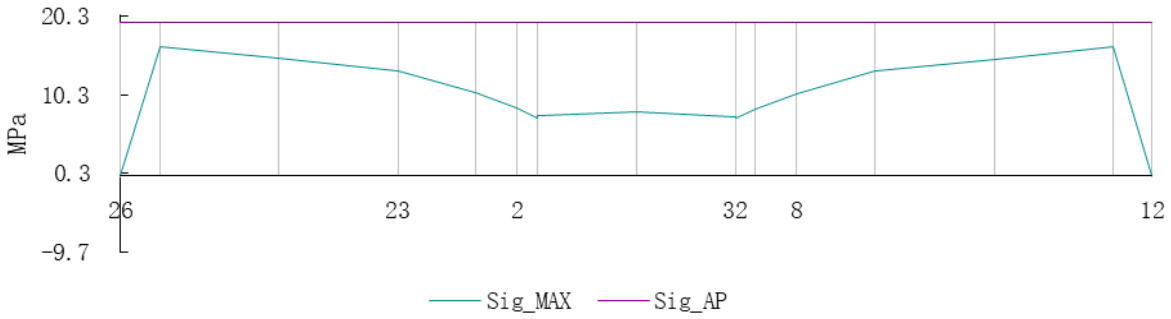


Figure 4. 21. Envelope diagram of principal compressive stress in oblique section at serviceability limit state

The calculation results show that the prestressed cap beam meets the code requirements in both the ultimate limit state and the serviceability limit state.

(2) Calculation results of bridge pier

HRB400 rebars with diameters of 25mm are evenly arranged around pier shafts of rectangular piers and frame piers at 100m spacing of bars; and the stirrup diameter is 14mm, and the stirrup spacing is 100mm.

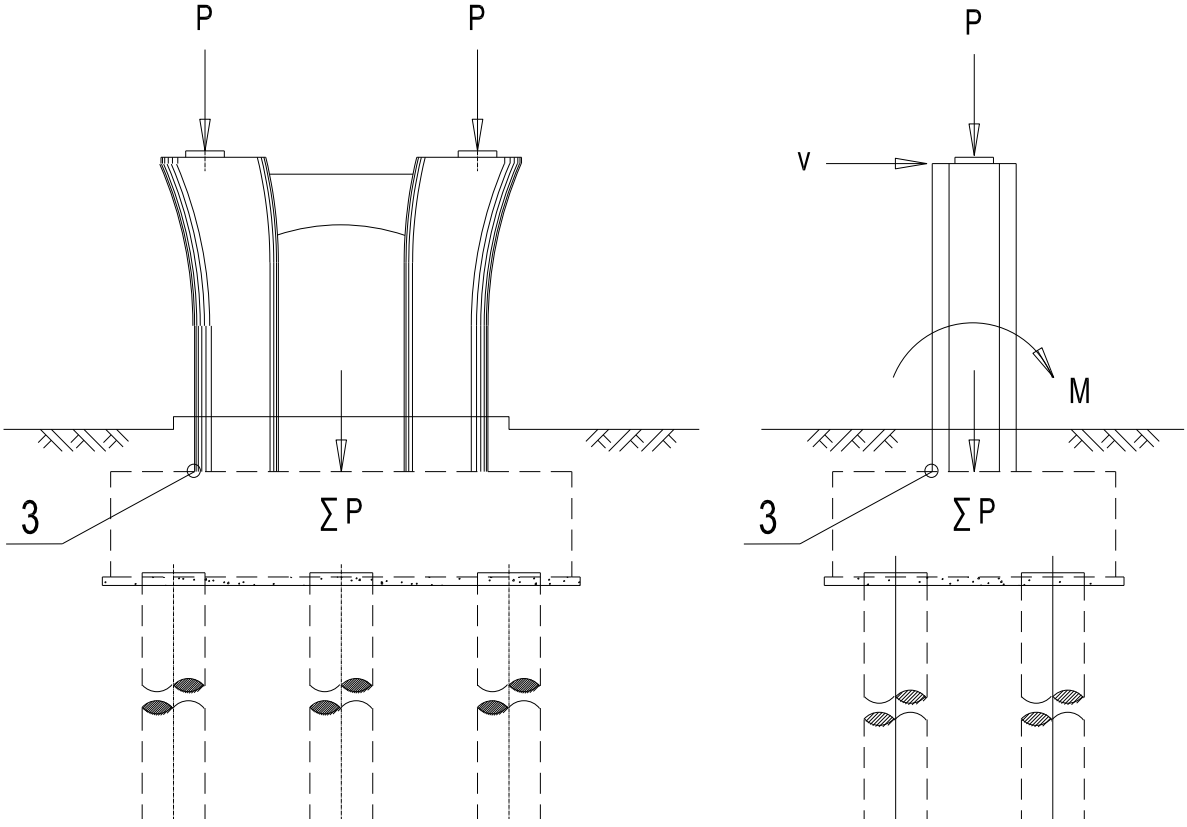


Figure 4. 22. Stress diagram of frame pier

Table 4. 26. Calculation results of box girder at ultimate limit state

Component	Location	Calculated internal force value (kN*m)	Design bearing capacity value (kN*m)	Note

Rectangular pier	2--pier footing	10998.1	58839.5	ultimate limit state
Frame pier	3--pier footing	28333.5	49923.7	

Table 4. 27. Calculation results of bridge pier at serviceability limit state

Component	Location	Calculated crack width value (mm)	Allowable value of crack width (mm)	Note
Rectangular pier	2--pier footing	0.042	0.200	serviceability limit state
Frame pier	3--pier footing	0.098	0.200	

The calculation results show that the bridge pier meets the code requirements in both the ultimate limit state and the serviceability limit state.

(3) Calculation results of abutment

HRB400 structural rebars with diameters of 12mm are evenly arranged around an abutment shaft, at 150m spacing of bars; and the stirrup diameter is 10mm, and the stirrup spacing is 150mm.

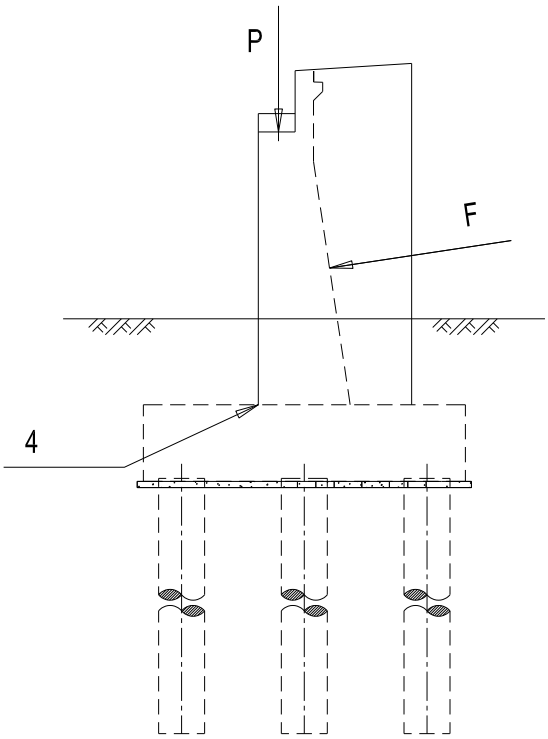


Figure 4. 23. Stress diagram of abutment

Table 4. 28. Calculation results of box girder at ultimate limit state

Component	Location	Calculated internal force value (kN*m)	Design bearing capacity value (kN*m)	Note
Abutment	1-abutment base	38553.2	1336216.1	ultimate limit state

Table 4. 29. Calculation results of box girder at serviceability limit state

Component	Location	Calculated crack width value (mm)	Allowable value of crack width (mm)	Note
Abutment	1-abutment base	0.000	0.200	serviceability limit state

The calculation results show that the abutment meets the code requirements in both the ultimate limit state and the serviceability limit state.

(4) Pile foundation calculation

1) Determination of soil physical and mechanical properties

According to geological survey data, the strata are as follows:

Soil of layer I: Embankment fill, yellow-brown,thickness: 2.0m, depth to layer base: 2.0m;

Soil of layer II: Water-saturated sandy gravel layer, yellow-brown, thickness: 11.0m, depth to layer base: 13.0m;

Soil of layer III: Flow-plastic gravel layer, yellow-brown, thickness: 2.0m, depth to layer base: 15.0m;

Soil of layer IV: Water-saturated sandy gravel layer, yellow-brown, thickness: 3.5m, depth to layer base: 18.5m;

Soil of layer V: Soft plastic gravel layer containing loam, light yellow, thickness: 8.7m, depth to layer base: 27.2m;

Soil of layer VI: Hard gravel layer containing loam, light yellow, thickness: 3.3m, depth to layer base: 30.5m;

Soil of layer VII: Hard gravel layer containing clay, yellow-brown, thickness: 5.5m, depth to layer base: 36.0m;

Soil of layer VIII: Sandstone, gray-green, thickness: 6.0m, depth to layer base: 42.0m.

2) Calculation results

The diameter of a pier pile foundation in the standard section of a precast beam is 1200mm, and the pile length is 40m. Twenty-eight HRB400 rebars with diameters of 25mm are uniformly arranged around a pile shaft, at 115mm spacing of bars; and the stirrup diameter is 12mm, the stirrups are arranged as spiral bars, and the stirrup spacing is100mm.

The diameter of a cast-in-place bridge pier pile foundation is 1500mm, and the pile length is 45m. Thirty-two HRB400 rebars with diameters of 25mm are uniformly arranged around a pile shaft, at 130m spacing of bars; and the stirrup diameter is 12 mm, the stirrups are arranged as spiral bars, and the stirrup spacing is spacing 100mm.

Table 4. 30. Calculation results of vertical compressive bearing capacity of single pile

Component	Location	Design axial force value (kN)	Allowable bearing capacity value (kN)	Note
Standard section of precast beam	65# pier of 1# bridge	5986.4	6928.9	Vertical compressive bearing capacity of single pile
Cast-in-place beam section	4# pier of 1# bridge	9950.1	11492.1	

Table 4. 31. Calculation results of pile foundation at ultimate limit state

Component	Location	Internal force value ($\gamma_0 N_d/\gamma_0 N d \eta e_0$) (kN /kN*m)	Bearing capacity value (N_{ud}/M_{ud}) (kN*m)	Note
Standard section of precast beam	65# pier of 1# bridge	5237.6/1237.1	12624.6/7681.2	ultimate limit state
Cast-in-place beam section	4# pier of 1# bridge	9325.7/1504.9	19725.9/7924.2	

Table 4. 32. Calculation results of pile foundation at serviceability limit state

Component	Location	Calculated crack width value (mm)	Allowable value of crack width (mm)	Note
Standard section of precast beam	65# pier of 1# bridge	0.038	0.200	serviceability limit state
Cast-in-place beam section	4# pier of 1# bridge	0.065	0.200	

The calculation results show that the vertical compressive bearing capacity of a single pile of the pile foundation and the bearing capacity thereof in both the ultimate limit state and the serviceability limit state meet the code requirements.

4.6.6. Frost resistance design

According to the Preliminary Geotechnical Investigation Report for Ulaanbaatar New Ring Road Survey Project (referred to as the Preliminary Investigation Report), this project is located in a seasonally frozen soil area with a freezing depth of 2.5-3.5 m. The superstructure is designed for Class I environment (general environment), and the substructure is designed for Class II environment (freeze-thaw environment).

(1) Design principles

1) Controlling frost heaving and thaw settlement: This constitutes the primary objective for avoiding or minimizing the uplift effect of the frost heaving force on the structure and the sinking or uneven settlement caused by thaw settlement.

2) Ensuring foundation stability: The foundation must be able to resist changes in bearing capacity caused by the frost heaving force and thaw settlement, and resist ice loads when approaching water bodies.

3) Guaranteeing structural integrity: The structural design shall accommodate or resist potential limited deformations, so as to prevent cracking or functional failure.

4) Improving the durability of materials and structures: Resisting harsh environments such as freeze-thaw cycles.

(2) Key points in design

1) Foundation selection and design

A form of pile foundation+pile cap is adopted. The pile toe is embedded into the stable stratum, with a depth greater than the maximum freezing depth, thus ensuring that the pile tip is located in the bearing stratum (such as bedrock and dense sand gravel layer) that does not suffer from frost heaving or suffers from weak frost heaving, and avoiding the pile side friction

being affected by the frost heaving force; and the self weight of a pile cap can also withstand the frost heave normal force (uplift force). Considering that during the freezing process, the frost heaved soil around the pile will exert an additional downward pulling force (negative skin friction) on the pile, so the negative skin friction should be appropriately considered in the design.

2) Superstructure design

In order to adapt to uneven settlement and reduce the number of expansion joints, this project gives priority to a simply supported first and then continuous, simply supported first and then bridge deck continuous, or continuous structure, selects a bearing suitable for large displacement for use, employs an expansion joint device with large displacement, low temperature resistance and excellent waterproof performance, and strengthen the drainage at expansion joints to prevent frost heaving damage of accumulated water.

3) Material selection

When selecting materials for this project, concrete resistant to freeze-thaw cycles is adopted, the water-binder ratio is strictly controlled, and a high-quality air entraining agent is added. The thickness of concrete cover shall be increased in accordance with the requirements of the design code.

The frost resistance durability factor DF of the concrete for the lower substructure and foundation of the bridge in this project is required to be no less than 70%. The frost resistance durability factor (DF) is the ratio of the dynamic elastic modulus E1 of the concrete specimen after 300 rapid freeze-thaw cycles to its initial value E0, i.e., DF=E1/E0.

4) Design of drainage system

A complete and unobstructed bridge deck drainage system (longitudinal slope, cross slope and drain pipe) shall be designed, with a combination of longitudinal and transverse drainage schemes. Drain holes shall be set every 5m along the longitudinal direction near a crash barrier to collect rainwater to the pier along the longitudinal direction and guide it to a surface drainage system. The drainage pipe shall be a Φ200 PVC pipe. Rainwater from the bridge deck of a ground-level auxiliary road bridge flows into discharge outlets arranged at intervals in the median curb through the cross slope of the bridge deck, and is then discharged into the river channel under the bridge through the steel drain pipe.

5) Filling treatment behind abutment

Backfill materials shall be strictly controlled. Non-frost heaving materials (such as sand gravel) with good water permeability shall be used for back filling behind abutment, and the frost-susceptible soil (such as silt and clay) is strictly prohibited. Layered compaction shall be performed, with the degree of compaction meeting the code requirements.

6) Construction control

①Avoid construction during the cold winter and spring thawing period as much as possible.

If it is difficult to avoid, strictly follow the winter construction specifications (preheating materials, thermal insulation and maintenance, controlling temperature of casting concrete, etc.) to ensure that the concrete is not damaged by freezing before reaching the critical strength.

2Foundation soil protection: If the foundation cannot be poured in a timely manner after excavation, effective measures (such as covering with insulation materials) must be taken to prevent the foundation base from being frozen or softened due to immersion.

3Backfilling control: When backfilling non-frost heaving materials, it is necessary to ensure that the materials themselves are not frozen and the compaction process meets the requirements.

4.6.7. Seismic design

(1) Selection of seismic design standards

According to the Mongolian seismic design standard BNbD22.01.01/2021, the applicable MSK seismic intensity is classified as 7, 8 and 9 degrees, the intensity levels for which seismic measures shall be taken in architectural design have been defined, and the probability of exceedance of the seismic intensity within the 50-year reference period is specified:

10% probability (corresponding to a recurrence interval of 475 years) - basic fortification intensity;

2% probability (corresponding to a recurrence interval of 2475 years) - rare earthquake intensity.

See the following table for the corresponding relationship between probability of exceedance and recurrence interval in different codes:

Table 4. 33. Provisions on probability of exceedance and recurrence interval in different codes

Seismic code	Basic fortification intensity		Rare earthquake intensity	
	Probability of exceedance	Recurrence interval	Probability of exceedance	Recurrence interval
Mongolian seismic design standard	10% for every 50 years	475 years	2% for every 50 years	2475 years
Chinese seismic design standard	10% for every 50 years	475 years	2% for every 50 years	2450 years

Based on the fact that the above provisions are basically consistent with the seismic code for urban bridges in China, and considering that the Chinese code has more detailed provisions on ductility design, seismic isolation and energy dissipation design and anti-unseating design for substructure components such as piers, the seismic design of this bridge project is carried out with reference to the Chinese code.

(2) Ground motion peak acceleration

For the seismic design of conventional bridges, the standard practice is to follow the seismic design code, that is, the seismic action can be determined by using the ground motion peak

acceleration under the probability of exceedance within the 50-year design reference period, or the seismic fortification standard of the structure and the ground motion parameters (mainly referring to the ground motion peak acceleration) of the site where the bridge is located can be calculated through the design reference period.

Ground motion peak accelerations within different design reference periods are calculated according to the following formula:

$$\log A = 3.612 - (4.079 - 0.301 I_0)\left[-\ln(1 - p_T)\frac{50}{T}\right]^{1/k} - 0.1072$$

$$p_T = 1 - e^{-T/R}$$

In the formula, A represents ground motion peak acceleration, I_0 represents basic intensity, T represents design reference period, and R represents recurrence interval.

When a time-history method is used for analysis, the value of ground motion peak acceleration can be taken from the values calculated according to the table below.

Table 4. 34. Relationship between ground motion peak acceleration and basic intensity under different probabilities of exceedance (within 50-year design reference period)

Basic intensity / degree I_0	Ground motion peak accelerations under different probabilities of exceedance				
	63.2%	10%	3%	2.5%	2%
6	0.017g	0.050g	0.082g	0.088g	0.095g
7	0.034g	0.100g	0.161g	0.172g	0.186g
7.5	0048g	0.143g	0.231g	0.246g	0.265g
8	0.068g	0.200g	0.316g	0.336g	0.361g
8.5	0.096g	0.288g	0.451g	0.478g	0.513g
9	0.136g	0.400g	0.612g	0.647g	0.691g

When a response spectrum method is used for analysis, if the basic fortification intensity (10% probability of exceedance for every 50 years) is taken as a unit value, the ground motion peak accelerations under other probabilities of exceedance within the 50-year reference period can be described by a ratio relationship. The adjustment coefficients of ground motion peak accelerations under different basic intensities can be determined based on the calculated ratios in the following table.

Table 4. 35. Ratio of ground motion peak accelerations under different probabilities of exceedance (within 50-year design reference period

Basic intensity/degree I_0	Ground motion peak accelerations under different probabilities of exceedance				
	63.2%	10%	3%	2.5%	2%
6	0.342	1.000	1.641	1.757	1.907
7	0.342	1.000	1.615	1.752	1.865

7.5	0.336	1.000	1.607	1.714	1.850
8	0.342	1.000	1.581	1.681	1.808
8.5	0.335	1.000	1.567	1.663	1.784
9	0.342	1.000	1.532	1.620	1.729
Average	0340	1.000	1.591	1.693	1.824

(3) Structural regularity analysis

In order to ensure the regularity of seismic conceptual design for bridges, the following three measures are mainly taken:

1) The bridge shall be symmetrically arranged along the bridge alignment.

2) The restraint systems in all directions of the bridge shall be symmetrically arranged, with a clear and balanced load-transfer system.

3) The cross-section structure of the bridge pier shall be rectangular or circular, to achieve well-defined seismic force distribution.

(4) Strengthening measures for seismic design

In order to ensure that the bridge structure achieves a certain seismic capacity, the following measures are mainly taken to strengthen the seismic design:

1) The volumetric reinforcement ratio of stirrups outside the potential plastic hinge area of the pier shall not be less than 50% of that of dense stirrups in the plastic hinge area.

2) Horizontal stop blocks are installed on the cap beam to avoid excessive lateral displacement of the main girders.

3) The lap width between the cap beam and the abutment shaft meets the minimum distance a from the beam end to its side edge, i.e., $a \geq 70 + 0.5L$.

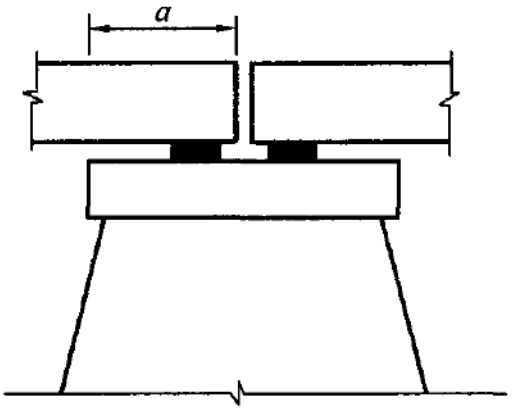
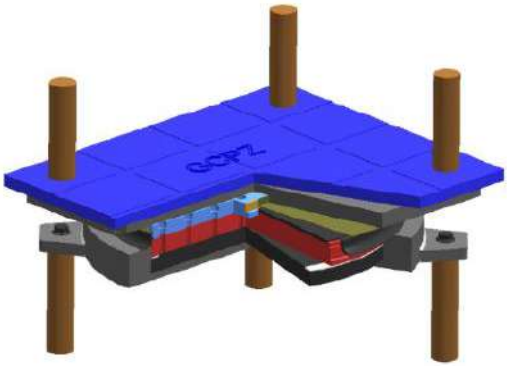


Figure 4. 24. Schematic diagram of minimum distance of lap width

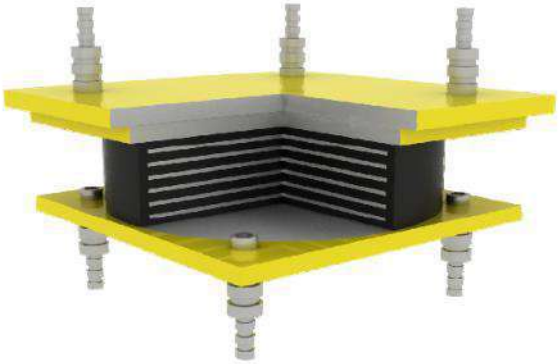
4) Rubber pads or other elastic pads shall be additionally arranged between the main girders and between the main girder and the abutment breast wall to mitigate the impact and limit the displacement of the girders.

5) The design concept of “resilient bridge” is introduced into the seismic design of the main

viaducts in this project. In order to reduce the seismic response of the main viaducts under seismic action, this design adopts the method of installing damping pot bearings at the cast-in-place box girders and horizontal force-distributing rubber bearings at the precast prestressed concrete small box girders, which can effectively reduce the stress on the bridge piers, control the relative displacement between the main girders and the pier tops, and improve the overall viability of the bridge.



Horizontal force-distributing rubber bearing



Damping pot bearing

Figure 4. 25. Seismic bearings

6) For bridges with seismic fortification intensities of 7 degrees or above, restrainers shall be arranged along the bridge alignment to control the relative displacement of piers and girders. The commonly used restrainers are shown in the following pictures.

Steel plate restrainer

Buffer chain restrainer

Figure 4.26 Restrainer

4.7. CONSTRUCTION METHOD

To accelerate project construction, shorten construction period, and improve efficiency, it is advisable to start construction of bridge structures on multiple working surfaces simultaneously. The main procedures for bridge construction are: relocation of underground pipelines and

simultaneous completion of land acquisition and demolition within the red line range of road planning→construction of roads→encirclement construction of bridge structures (including foundation, substructure, superstructure, bridge deck systems, etc.)→construction of ground roads, landscaping, traffic signs, and markings.

4.7.1. Construction of precast prestressed concrete small box girder

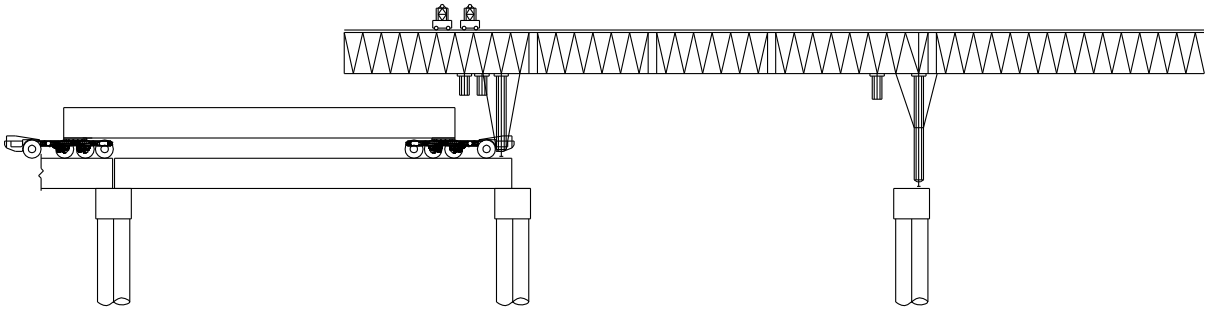
precast prestressed concrete small box girders can be constructed by a precast hoisting method and a bridge erection machine construction method.

The construction process of the precast hoisting method is as follows: prefabricating precast prestressed concrete small box girders in a precast yard, transporting to an assembly site, integrally hoisting individual girders with a crane, construction of longitudinal wet joints between longitudinal beams by hoisting formwork.

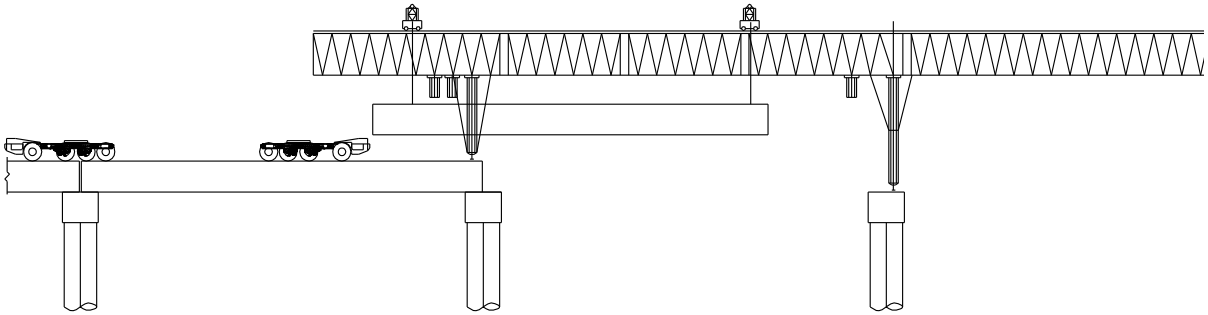
This construction method basically realizes factory construction, with mature construction technology, fast construction speed, and minimal impact on ground traffic.

Figure 4. 26. On-site hoisting of precast prestressed concrete small box girder

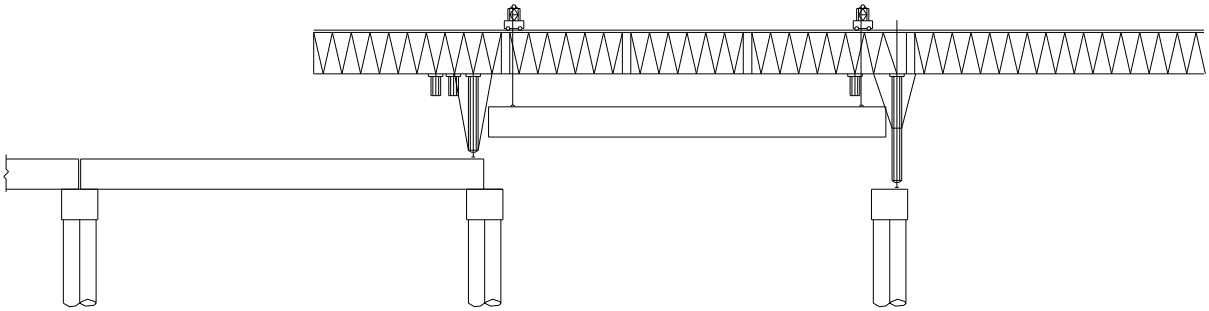
Erecting construction with bridge erection machine: The bridge erection machine eliminates the need for temporary scaffolding or track installation in deep valleys or over water additional scaffolding and lay tracks in deep valleys or water, but can be directly supported on the pier and the erected bridge deck to vertically lift girder bodies, move them along the bridge direction, move them across the bridge and hoist them with a crane longitudinally. The construction is efficient and safe. The schematic diagram of the construction steps of the bridge erection machine is as follows.



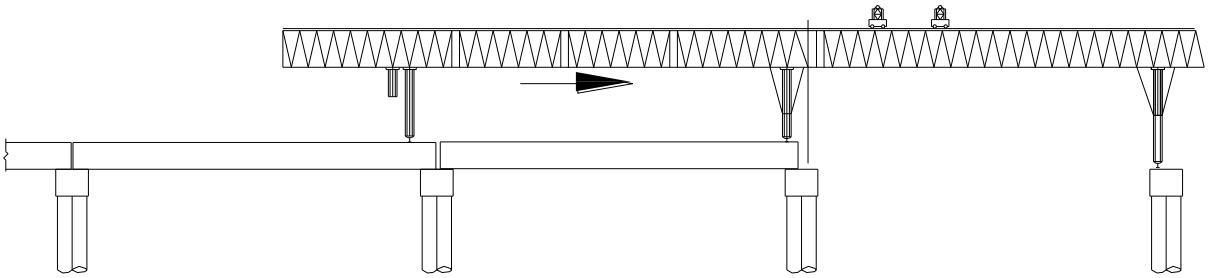
Step 1: Transporting a small box girder to the bridge location



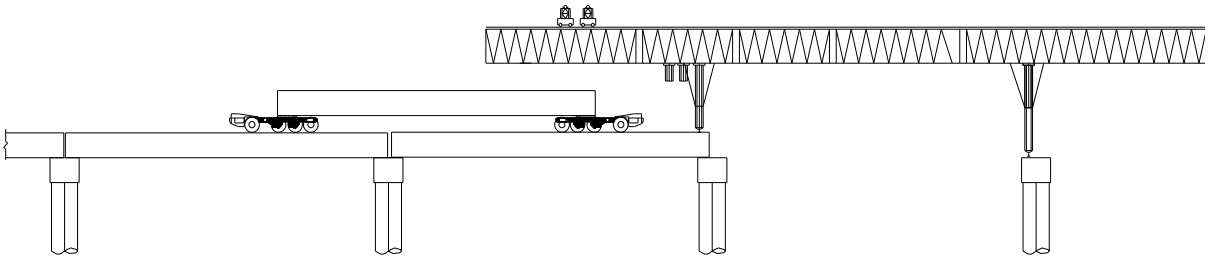
Step 2: Hoisting the small box girder using a bridge erection machine to enable its longitudinal movement



Step 3: Hoisting the small box girder using the bridge erection machine to enable its horizontal movement



Step 4: Hoisting the small box girder using the bridge erection machine to move it vertically to a pier top bearing



Step 5: Moving the bridge erection machine forward

Figure 4. 28. Construction steps of bridge erection machine

Figure 4. 27. Photo of hoisting site of bridge erection machine

Figure 4. 29. Photo of hoisting site of crane

4.7.2. Construction of cast-in-place concrete girders

Cast-in-place concrete girders are mainly constructed by a full scaffolding method, a partial scaffolding method, and a cantilever method.

The full scaffolding method is a commonly used construction method, with mature construction technology, safety and reliability, and low construction costs. But it occupies a large amount of existing road surface which has a significant impact on ground traffic. For example, if the ground road is wide, the construction site is large, and the traffic on the construction section is diverted during the construction period, this method can be used on general road sections when there is no clearance requirement for passage under the bridge.

Figure 4. 30. Full scaffolding construction

The partial scaffolding method is suitable for situations where the foundation bearing capacity is small and there is a requirement for clearance under the bridge, and can avoid large-scale foundation treatment and reduce the impact on ground traffic. It is mature in construction technology, with high reliability, and can adapt to changes in the cross sections of box girders. However, its construction cost is relatively high compared to the full scaffolding method. As the scaffolding is implemented with a longitudinal and transverse beam structure, an appropriate vehicle passage space can be reserved under the scaffolding through design, and protective plates can be arranged at the lower edge of the scaffolding to prevent falling objects and ensure driving safety.

Figure 4. 31. Construction with partial scaffolding method

The cantilever method construction is characterized by no need to establish ground scaffolding and large lifting and transportation equipment, and the main equipment is a pair of

movable suspended scaffoldings. It is suitable for the construction requiring traffic under the bridge without interruption or not suitable for the use of partial scaffolding method, and can avoid large-area foundation treatment and reduce the impact on ground traffic. It is mature in construction technology, with high reliability, and can adapt to changes in the cross sections of box girders. However, its construction cost is relatively high compared to the scaffolding methods. An appropriate vehicle passage space can be reserved under the bridge through design, and protective plates can be arranged around the cast girder bodies to prevent falling objects and ensure driving safety.

Figure 4. 32. Construction with cantilever method

Based on the bridge structures of all parts of this project, suitable construction schemes will be adopted according to the current terrain and road conditions, as shown in the table below:

Table 4. 36. Construction scheme of superstructure

Road section	Construction scheme
Precast prestressed concrete small box girders	Combination of crane lifting method and erecting method with bridge erection machine
Cross intersections of mainline cast-in-place continuous girder bridges, ground-level auxiliary road sections, and road sections with traffic demand under the bridge during construction	Cast-in-place construction with cantilever method and limited scaffolding casting

Ordinary sections of mainline cast-in-place continuous girder bridges and road sections without traffic demand under the bridge during construction	Cast-in-place construction with full scaffolding method or partial scaffolding

4.7.3. Construction of substructure

The viaducts of this project are predominantly located on land, and the substructures are all constructed using conventional onshore construction methods. According to the geological investigation report, the appropriate hole-forming construction technology is adopted for the pile foundation based on the geological conditions of different soil layers. The pile cap shall be constructed by sloped excavation or supported excavation. The pier column shall be constructed using conventional scaffolding cast-in-place method.

4.8. DESIGN OF ANCILLARY FACILITIES

The ancillary structures of bridges mainly include crash barriers, noise barriers, bridge deck pavement, bridge deck drainage, bearings, expansion joints, etc.

4.8.1. Crash barrier

The road grade of the bridges within the project scope is urban main roads, and concrete crash barriers are used for the mainline viaducts and ramp bridges.

4.8.2. Noise barrier

According to the functions of noise barriers, they can be classified as: sound-absorbing type, sound insulation type, and sound-absorbing and sound insulation hybrid type. According to their

Figure 4. 33. Schematic diagram of noise barrier

forms, they can be classified as two basic forms: an arc form and a straight flat form.

Due to the fact that this project belongs to an urban main road with a high traffic volume, there are high requirements for the design of noise barriers, which require both good noise reduction effects and appropriate consideration of landscape requirements. Sound-absorbing

type noise barriers will cause significant damage to the landscape, which are currently less used on urban viaducts. Although sound insulation type noise barriers can be designed to be lightweight and transparent, noise reflection will seriously affect sections with a large number of high-rise buildings and cannot achieve effective noise reduction. Therefore, they are not suitable for use in the sections with more high-rise buildings. A sound-absorbing and sound insulation hybrid type noise barrier is based on the above two basic types and combines their respective advantages. Currently, it is widely used on urban viaducts. Therefore, it is recommended to adopt the sound-absorbing and sound insulation hybrid noise barrier scheme for this project.

According to the environmental impact assessment report of this project, noise insulation barrier measures are adopted for noise-sensitive points along the line. The noise barriers are arranged on crash barriers outside the viaducts. Sound barriers with lengths of 1,800 m and 2,056m respectively are set up at noise sensitive points on the No. 1 and No. 4 bridges on the main line of this project.

4.8.3. Bridge deck pavement

The bridge deck pavement of precast prestressed concrete small box girders on the mainline and ramps has a total thickness of 20cm, which includes: 4cm AC-13 fine-grained asphalt concrete (SBS modified), PC-2 emulsified asphalt tack coat (0.3-0.6 L/m), 6cm AC-25 coarse-grained asphalt concrete, Spread 3-5 mm stone chip protective layer, and a waterproof layer from top to bottom. A 10cm C40 cast-in-place impermeable concrete layer is set under the asphalt pavement of precast prestressed concrete small box girders. C40 cast-in-place impermeable concrete layer with 10@100 rebar welded mesh.

The bridge deck pavement of cast-in-place box girders on the mainline has a total thickness of 18cm, which includes: 4cm AC-13 fine-grained asphalt concrete (SBS modified), PC-2 emulsified asphalt tack coat (0.3-0.6 L/m), 6cm AC-25 coarse-grained asphalt concrete, Spread 3-5 mm stone chip protective layer, and a waterproof layer from top to bottom, A 8 cm C40 cast-in-place impermeable concrete layer is set under the asphalt pavement of cast-in-place girders, C40 cast-in-place impermeable concrete layer with 10@100 rebar welded mesh.

The bridge deck pavement of an auxiliary road bridge has a total thickness of 20cm, which includes: 4cm AC-13 fine-grained asphalt concrete (SBS modified) , PC-2 emulsified asphalt tack coat (0.3-0.6 L/m), 6cm AC-25 coarse-grained asphalt concrete, Spread 3-5 mm stone chip protective layer, and a waterproof layer from top to bottom. A 10cm C40 cast-in-place impermeable concrete layer is set under the asphalt pavement of precast prestressed concrete small box girders, C40 cast-in-place impermeable concrete layer with 10@100 rebar welded mesh.

The bridge deck pavement of overpass bridges has a total thickness of 20cm, which

includes: 4cm AC-13 fine-grained asphalt concrete (SBS modified), PC-2 emulsified asphalt tack coat (0.3-0.6 L/m), 6cm AC-25 coarse-grained asphalt concrete, Spread 3-5 mm stone chip protective layer, and a waterproof layer from top to bottom. A 10cm C40 cast-in-place impermeable concrete layer is set under the asphalt pavement of precast prestressed concrete small box girders, C40 cast-in-place impermeable concrete layer with 10@100 rebar welded mesh.

4.8.4. Bridge deck drainage

Drainage adopts a scheme of combining longitudinal and transverse drainage. Drain holes are set every 5m along the longitudinal direction near a crash barrier to collect rainwater to the pier along the longitudinal direction and lead it to a surface drainage system. The drainage pipe is a Φ200 PVC pipe.

Rainwater from the bridge deck of a ground-level auxiliary road bridge flows into discharge outlets arranged at intervals in the median curb through the cross slope of the bridge deck, and is then discharged into the river channel under the bridge through the steel drain pipe.

4.8.5. Bearing

Horizontal force dispersion rubber bearings are installed at the precast prestressed concrete small box girders, and damping pot bearings are installed at the cast-in-place continuous girders.

4.8.6. Expansion joint

Comb-Type Expansion Joints for bridges is one of the most commonly used and technologically mature types of expansion joints in modern large bridges. The core advantages of comb-type expansion joints lie in their extra-large displacement capacity, exceptional load-bearing capacity, superior ride comfort, and effective water/dust resistance properties. Comb-Type Expansion Joints are used for the bridge expansion joints of this project, and two models, i.e., D80 and D120, are used according to the specific expansion volume. The parameters of the D80 and D120 expansion joints are as follows.

Table 4. 37. Parameter Table of D80 and D120 Comb-Type Expansion Joints

Comparison items	80-type expansion joint	120-type expansion joint
Expansion range	± 80 mm (total displacement 160 mm)	± 120 mm (total displacement 240 mm)
Structural composition	Fixed/Movable Comb Plates, Anchorage System, Neoprene Sealing Strips, Support System, Connectors	
Type of rubber strip	Neoprene (CR) or Ethylene Propylene Diene Monomer (EPDM)	
Steel material	Q355NH/Q355N weathering steel or Q355 steel with heavy-duty anti-corrosion coating (e.g. hot-dip galvanized, zinc/aluminum sprayed)	

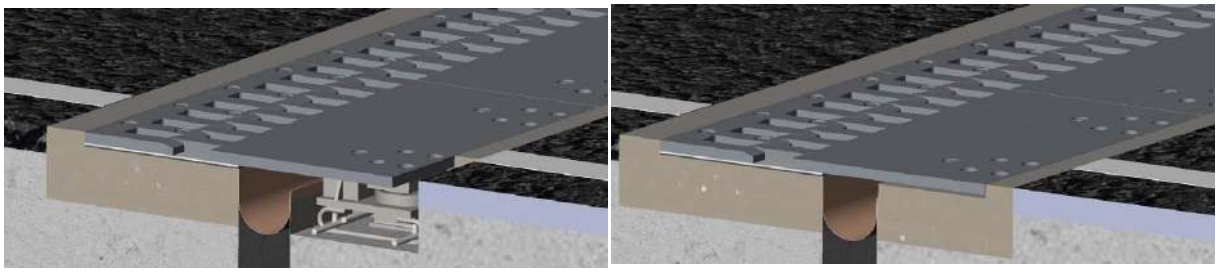
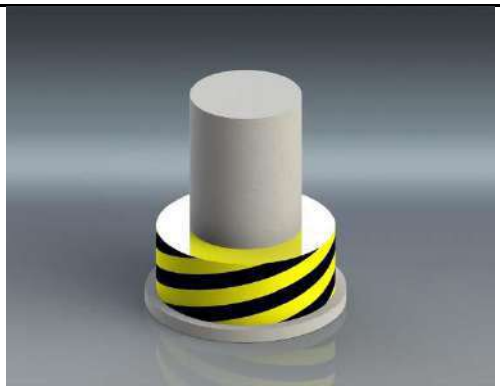


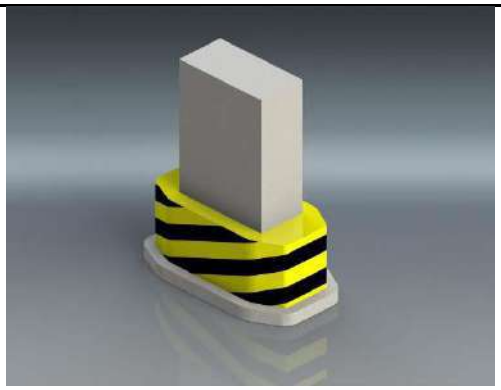
Figure 4. 34. Effect diagram of expansion joints

Anchoring system	Embedded Steel Bars/Sleeves + High-Strength Bolted Connection + Concrete Post-Pouring Belts
Scope of applicable temperature	-40°C-+60°C
Waterproof performance	Q355NH/Q355N Weathering Steel or Q355 Steel + Heavy-Duty Anti-Corrosion Coating (e.g., Hot-Dip Galvanizing, Thermal Spraying of Zinc/Aluminum)
Fatigue life	≥ 2,000,000 cycles

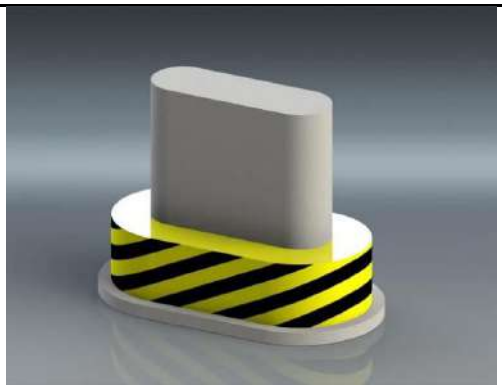
4.8.7. Anti-collision isolation measures

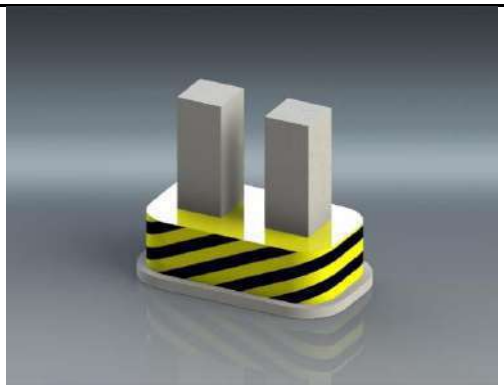
Anti-collision isolation measures shall be formulated for pier columns located on the median strips, and different types of measures can be adopted depending on the specific situations.





Round pier	**Rectangular pier**





Elliptical pier	Double-rectangular-column pier

Figure 4. 35. Multi-stage composite material energy-dissipation anti-collision devices

4.9. DURABILITY DESIGN OF BRIDGE STRUCTURES

According to the Preliminary Geotechnical Investigation Report for Ulaanbaatar New Ring Road Survey Project (referred to as the Preliminary Investigation Report), this project is located in a seasonally frozen soil area with a freezing depth of 2.5-3.5m. The superstructure is designed for Class I environment (general environment), and the substructure is designed for Class II environment (freeze-thaw environment). The design reference period for the structure is 100 years. The main structures (including main girders, bridge piers, and abutments) are designed to have the service lives of 100 years, while crash barriers, sidewalks, drainage structures, expansion joints, and bearings are replaceable components with design service lives of 15 years.

4.9.1. Durability design of concrete structures

In the design of corrosion resistance and durability of concrete structures, reasonable structural form, configuration and high-quality concrete with good corrosion resistance and impermeability shall be selected, and reasonable construction scheme and measures shall be selected according to the structural function and surrounding environment. In the design, specific requirements are put forward for the selection of concrete raw materials and the main proportioning parameters, such as water cement ratio, of concrete, so that the concrete has good resistance to penetration, volume stability and crack resistance.

The frost resistance durability factor DF of the concrete for the lower substructure and foundation of the bridge in this project is required to be no less than 70%. The frost resistance durability factor (DF) is the ratio of the dynamic elastic modulus E1 of the concrete specimen after 300 rapid freeze-thaw cycles to its initial value E0, i.e., DF=E1/E0.

The waterproof grade of the channel is designed as Grade-II, and the impermeability grade is required to be no less than P6.

Cement: Portland cement or ordinary Portland cement shall be used, and the mixing material is preferably slag or fly ash. It is not advisable to use early strength cement.

Aggregate: Fine aggregates should be selected from clean natural medium coarse river sands with reasonable grading, uniform and strong texture, low water absorption rate, and small porosity. Artificial sands produced by specialized units can also be used. Coarse aggregates should be selected from clean crushed stones with reasonable grading, good particle shape, uniform and strong texture, and low linear expansion coefficient. Sandstone crushed stones should not be used.

Water reducer: A suitable water reducer can significantly improve the working performance

of concrete, reduce the hydration heat, lower the internal temperature of concrete, and delay the appearance of temperature peak.

Additives: Adding appropriate concrete additives can prevent early shrinkage cracks and creep of concrete, and avoid excessive porosity.

The construction measures are as follows:

(1) During design, try to keep the shape simple and avoid exposed edges and corners. The shape, arrangement and construction of the structure shall be conducive to avoiding the accumulation of water, water vapor and harmful substances on the concrete surface. The structural shape shall be conducive to the tamping and curing of concrete during construction, and shall also reduce the stress concentration and restraint stress generated under the action of loads.

(2) Reliable drainage design.

(3) Arrange A reliable waterproof layer between a concrete bridge deck slab and a pavement structure layer.

(4) Increase the minimum protective layer thickness for steel bars and prestressing tendons to limit construction errors.

(5) Improve the concrete grade appropriately.

(6) Control the calculated widths of surface cracks in concrete structures, with the crack width in this bridge controlled at 0.2mm.

(7) Set up a concrete structure coating, which has both protective and finishing functions. The concrete surface of this bridge is coated with anti-corrosion paint in combination of landscape design, and the coating system is determined according to the landscape design.

4.9.2. Concrete construction control

(1) Before concrete construction, the concrete mix ratio selection test shall be carried out in advance according to the design and construction process requirements, and the quality control measures and quality assurance measures shall be formulated for the whole construction process and all construction links according to the characteristics of the concrete structures, the construction environment and the usage environment conditions. Important concrete structures shall undergo concrete trial pouring to verify and improve the construction process of concrete.

(2) When casting concrete in hot weather, reduce the temperature of formwork, rebars, and nearby air as much as possible before entry into the formwork. The temperature of casting concrete shall not be higher than the air temperature and shall not exceed 30°C.

(3) During the concrete curing period, the highest temperature inside the concrete shall not be higher than 65°C, and the temperature difference between the curing water temperature on the concrete surface and the temperature of the concrete surface shall not be greater than 15°C.

The difference between the highest internal temperature and the surface temperature of a concrete structure or component in any curing time shall not be greater than 20°C. When the difference between the ambient atmospheric temperature and the surface temperature of the concrete under curing exceeds 20°C, the concrete surface must be covered with a thermal insulation layer.

(4) When dismantling the concrete formwork, the temperature difference between the core concrete and the surface concrete as well as the temperature difference between the surface concrete and the environment shall not exceed 20°C. In hot and windy dry seasons, effective measures shall be taken to prevent concrete from cracking during formwork removal.

(5) Pay attention to temperature monitoring and crack control when casting mass concrete such as pile caps.

4.9.3. Durability design of steel structures

Steel is currently one of the main building materials used in engineering facilities. Steel without anti-corrosion treatment has extremely fragile durability, and necessary anti-corrosion measures must be taken to ensure that steel structures can be used normally within their design lives. At present, one of the commonly used anti-corrosion measures for steel structures is mechanical isolation, which involves covering the surface of a material to be protected with a certain material to isolate it from corrosive substances such as water and oxygen, thus achieving the purpose of corrosion prevention, and the other one is based on the principle of corrosion micro-batteries, where the potential of a material to be protected is artificially increased to the higher pole, thus achieving the purpose of protection.

(1) Coating anti-corrosion

A coating anti-corrosion system is established by coating the steel structure surface with a material having good adhesion, corrosion resistance, and permeability resistance, such as chlorinated rubber, acrylic acid, polyurethane, epoxy asphalt, or epoxy powder,, which isolates the steel structure surface from the external environment, thus eliminating the influence of external environmental factors and achieving an anti-corrosion effect.

(2) Metal spraying

A metal spraying protection system generally includes a sprayed metal layer and a barrier coat. The metal layer is usually made from zinc, aluminum or zinc-aluminum alloy. This measure is to spray the molten metal zinc, aluminum or zinc-aluminum alloy onto the surface of a treated steel structure by flame spraying or arc spraying, and form a dense and uniform thin layer on its surface. On the one hand, this metal coating plays a role in mechanical sealing of the structure, and on the other hand, it also plays a role in protecting the local sacrificial anode. Generally,

metal coatings only serve as the primer in coating protection systems, and their surfaces also require barrier coats, intermediate coats, and topcoats. Therefore, the cost is relatively high.

The above two coating systems for steel girders are widely used in current domestic steel bridges. For this project, corrosion protection by coatings has the characteristics of simple process, convenient construction, flexibility, and low cost, and the anti-corrosive coatings are easy to repair if being damaged and have high adaptability to the shapes of components. In recent years, with the development of anti-corrosion technology, coating protection systems with service lives of 20 years or more have been applied in engineering projects.

In order to reduce the workload during the operation period, considering comprehensive economy, it is recommended to use a long-term anti-corrosion coating protection system for the steel structures of this project. Specifically, 2 coats of 2×40um epoxy zinc-rich primer, 2 coats of 2×40um epoxy micaceous iron oxide intermediate, and 2 coats of 2×35um fluorocarbon topcoat are recommended for use.

4.10 Special Safety Provisions for Major Hazardous Bridge and Culvert Works

Table 4. 38. List of special safety provisions

No.	Work sections and items	Hazardous nature	Precautions	Notes
1	Reexamination of survey data	Due to limitations in surveying technical means, data on geotechnical properties, groundwater, underground pipelines, etc. may not match the actual situations on site, leading to issues with engineering quality and safety.	During the construction process, it is necessary to compare the actual situations on site in a timely manner. In case of any discrepancy with the survey data, the construction, geological exploration and design departments shall be notified in time, and the corresponding handling suggestions shall be put forward.	
2	Pile foundation works	For bored piles constructed under the particularly complex engineering geological, hydrogeological, or technical conditions, if the actual soil layer parameters differ greatly from the investigation report, it potentially compromises in unsafe pile foundation design.	Before construction, a process test pile must be conducted to obtain relevant process parameters before formal construction can begin.	
		During the construction process of bored piles in karst areas, mined-out areas, karst caves, or other special areas, safety accidents such as hole collapse are prone to occur, endangering the safety of platforms, drilling, and construction personnel. Failure to timely handle karst caves can result in significant safety hazards for bridges during operation.	The geological conditions at the pile locations shall be explored in detail, a feasible emergency plan shall be formulated, and sufficient emergency rescue equipment and materials shall be provided; and effective measures shall be taken to ensure the safety of the platform, drilling rig and construction personnel. For karst cave geological conditions, the construction unit shall prepare a special construction plan, and carry out karst cave treatment and pile foundation construction after expert evaluation and demonstration.	

No.	Work sections and items	Hazardous nature	Precautions	Notes
		A steel fixed construction platform for pile foundation is not installed firmly, is unstable or has insufficient bearing capacity, resulting in platform collapse, personnel and equipment falling, etc.	The steel fixed construction platform shall be firm, stable and able to bear all static and dynamic loads during the construction of bored piles.	
3	Pile cap works	During the excavation of a pile cap, the excavation depth is 3m<H<5m, which is prone to the risk of slope instability and collapse.	The construction unit shall prepare special construction plans and safety measures plans.	
		During the excavation of a pile cap, the excavation depth is H≥8m, which is extremely prone to the risk of slope instability and collapse.	The construction unit shall prepare special construction plans and safety measures plans, and conduct expert demonstration.	Ultra-large-scale major hazardous works
		In the construction of a cofferdam of the pile cap, it is easy for the cofferdam structure to collapse when its strength, rigidity, or stability is insufficient. During the construction process, the cofferdam may collapse due to abnormal conditions such as quicksand, sand gushing or support deformation.	The cofferdam structure shall have sufficient strength, rigidity and stability, and the construction unit shall prepare special construction plans and safety measures plans.	
		During the process of binding steel bars of a large-scale pile cap, it is easy for them to become unstable and collapse.	Strictly follow the design requirements to set up a sufficient quantity of erection bars with sufficient strength.	
		When mass concrete is poured, the concrete shrinkage and hydration heat effect are obvious, which easily leads to concrete cracks.	Effective monitoring measures shall be taken to reduce hydration heat and temperature difference between inside and outside. Control water cement ratio, reduce the temperature of aggregates, strengthen curing, and control formwork removal time.	
4	Bridge pier works	When tall piers are constructed under the influence of strong wind and severe weather, there is a high risk of accidents such as equipment, formwork and personnel falling.	A special safety construction plan shall be prepared for high-altitude operations.	
		The age differences between pier bodies and the pile cap and between pier body segments are significant, which can easily lead to cracks.	Strict technology process and construction organization design shall be formulated according to the construction period requirements, and curing and moisturizing work shall be strengthened.	
		High-pier reinforcement cages are prone to instability and collapse during the construction of binding erection.	Necessary stiffening steel skeleton shall be set up for the pier body.	
5	Scaffolding and Formwork works	When the erection height is 3 m<h<8 m, it is prone to scaffolding collapse incident and formwork bulging risk.	The construction unit shall prepare special construction plans.	
		When the erection height is H≥8m, it is extremely prone to scaffolding collapse incident and formwork bulging risk.	The construction unit shall prepare special construction plans and conduct expert demonstration.	Ultra-large-scale major hazardous works

No.	Work sections and items	Hazardous nature	Precautions	Notes
6	Cast-in-place concrete beam works	When prestressed tensioning, if the concrete strength is insufficient or the age is not sufficient, it is easy to cause cracking of main girders, which will affect the safety and durability of the structures.	The concrete strength, elastic modulus, and curing age must meet the design requirements before tensioning prestress. The tensioning of longitudinal, transverse, and vertical prestressing tendons must be carried out according to the sequence stipulated by the design requirements. Take relevant measures during the construction process to prevent corrugated pipes from getting clogged.	
7	Precast beam works	Insufficient bearing capacity of the beam storage platform foundation will easily lead to uneven settlement of the foundation and result in the overturning of the main girders.	The foundation shall be treated and pre-pressed before beam storage to meet the requirements of bearing capacity and settlement.	
		During the storage and transportation of main girders, the upper edges of the main girders are prone to cracking.	During the storage and transportation of main girders, the fulcrum positions must meet the design requirements.	
		There are a large number of precast beams and lifting eyes, and their quality control is poor, so it is easy to cause beam-falling accidents due to the failure of lifting rings during hoisting.	A load test shall be conducted on the lifting eyes.	
		During the hoisting process of main girders, it is easy to cause accidents such as instability and overturning of the main girders, damage to equipment and casualties.	Precast beam hoisting technology process and safety precautions shall be prepared.	
		Because of the depth-width ratio of a T-beam and an I-beam, if the construction measures are not appropriate, the beam body is prone to lateral bending.	The prestressing force shall be applied symmetrically and uniformly, and practical measures shall be taken during construction and transportation to prevent lateral bending of the beam body.	
8	Balanced cantilever bridge works	A movable suspended scaffolding requires many connecting and anchoring components, and bears a large self-weight and the weight of cantilever segments during the construction process. Due to insufficient counterweight, insecure anchoring, or unstable connection of components during the construction process, movable suspended scaffolding falling accidents are straightforward to occur.	The construction unit shall conduct a comprehensive inspection of the installation quality of the movable suspended scaffolding, carry out a load test, prepare a special construction plan for the movable suspended scaffolding construction, and conduct an expert demonstration.	Ultra-large-scale major hazardous works
		Movable suspended scaffolding construction belongs to high-altitude operation and thus is prone to safety accidents such as equipment and personnel falling.	The construction unit shall prepare security prevention measures plans.	Ultra-large-scale major hazardous works

No.	Work sections and items	Hazardous nature	Precautions	Notes
		Mass concrete is employed at Plot No. 0, and the shrinkage and hydration heat effect of concrete are obvious during concreting, which is easy to cause concrete cracks. Furthermore, the rebars and prestressed ducts at Plot No. 0 are relatively dense, and the quality of concreting is difficult to control, which affects the safety and durability of the structure.	Formulate strict technology process and strengthen concrete curing and moisturizing work.	
		Due to the segmented construction of main girders and multiple connections of prestressed ducts, quality accidents such as void shrinkage and duct blockage are prone to occur. During prestressed tensioning, if the concrete strength is insufficient or the age is not enough, and the tensioning sequence is not properly controlled, cracking of main girders easily occur, affecting the safety and durability of the structure.	Prepare strict prestressed construction technology process.	
		The concrete for closure segment may experience additional tensile and compressive stresses before forming strength, resulting in cracks. Improper selection of closure temperature will easily lead to contraction fissure.	Formulate strict technology process and strengthen concrete curing and moisturizing work.	
9	Demolition of old bridges	When demolishing existing bridges, accidents such as bridge instability and collapse as well as equipment tipping and falling are prone to occur.	The construction unit shall prepare special demolition construction plans, and the construction can only be carried out after expert evaluation; and construction emergency plans shall also be prepared.	Combined with the specific situation, determine whether it is listed as ultra-large-scale major hazardous works
10	Railroad overpass bridge works	The construction of railway-related bridges is prone to the risk of affecting the safe operation of railways.	Before the formal construction, the construction unit shall prepare a detailed construction organization design plan and submit it to the relevant railway management department for approval before implementation.	Ultra-large-scale major hazardous works
		During the construction process, it is easy to cause damage to existing railway cables and pipelines, which affects the safe operation of railways.	Before construction, it is necessary to investigate the underground directions and burial depths of various cables and pipelines within the scope of this project, obvious signs shall be set up, and the existing cables and pipelines must be well protected.	Ultra-large-scale major hazardous works
		The excavation of foundation pits is prone to the risk of slope instability and collapse, which will disturb the railway subgrade and affect the safe operation of railways.	The construction unit shall prepare special construction plans and conduct expert demonstration.	Ultra-large-scale major hazardous works
		Formwork and scaffolding construction is prone to the risks of scaffolding collapse and formwork bulging.	The construction unit shall prepare special construction plans and conduct expert demonstration.	Ultra-large-scale major hazardous works

No.	Work sections and items	Hazardous nature	Precautions	Notes
		The operation or overturning range of construction machinery intrudes into the railway boundary, affecting the safety of railway bridges and railway transportation.	The construction unit shall prepare special construction plans and submit them to the competent railway department for approval.	Ultra-large-scale major hazardous works
		Frame jacking during railway operation will seriously affect the safe operation of railways.	It is strictly prohibited to implement frame jacking when the trains pass through. It is necessary to strengthen communication with the railway operation department, timely grasp the train operation situations, and prevent jacking construction from affecting the safety of train operation.	Ultra-large-scale major hazardous works
		Girder bodies fall off during erection, and collapse during incremental launching.	The bridge erection machine or support system shall be specially designed, and the construction can only be carried out after expert evaluation; and at the same time, construction emergency plans shall be prepared.	Ultra-large-scale major hazardous works
		During bridge girder swing construction, it is easy to encounter tipping and collapse accidents.	The construction unit shall prepare a special construction plan for the swing construction, and the construction can only be carried out after expert evaluation; and at the same time, construction emergency plans shall be prepared.	Ultra-large-scale major hazardous works
		The influence of bridge construction on railway subgrade or piers is a dynamic process, and major safety accidents are prone to occur because delayed or inadequate monitoring during construction.	A construction dynamic monitoring scheme and construction emergency plans shall be prepared and demonstrated by experts.	Ultra-large-scale major hazardous works
11	Bridge construction adjacent to high-voltage transmission tower	If the minimum safe distance between a charged body and personnel as well as construction machinery is insufficient, and on-site machinery, equipment, and steel components are not reliably grounded, construction carried out in adverse weather conditions such as thunder, rain, fog, and strong winds may easily lead to safety accidents such as electric shock.	The construction unit shall prepare safety protection measures against electric shock accidents and stop all construction in bad weather.	Ultra-large-scale major hazardous works
		Pile foundation and foundation pit construction are prone to hole collapse and slope instability, resulting in displacement or overturning accidents of high-voltage transmission towers.	The construction unit shall prepare reasonable construction techniques and special construction organization plans, formulate safety protection measures, and conduct expert demonstration if necessary.	Ultra-large-scale major hazardous works
		The influence of bridge construction on the settlement and horizontal displacement of high-voltage transmission tower footing is a dynamic process, and major safety accidents are prone to occur because delayed or inadequate monitoring during construction.	A construction dynamic monitoring scheme and construction emergency plans shall be prepared and demonstrated by experts.	Ultra-large-scale major hazardous works

No.	Work sections and items	Hazardous nature	Precautions	Notes
12	Bridge construction adjacent to high-pressure gas pipeline	Due to inadequate investigation of basic data for high-pressure gas pipelines, insufficient construction safety distance, inadequate pipeline protection, and hole collapse and slope instability occurred during the construction of pile foundations and foundation pits, pipeline rupture and explosion are easily caused by collision or disturbance on pipelines, resulting in serious safety accidents.	Complete investigation and collection of on-site underground pipeline data shall be conducted, and communication with the asset owner shall be made to propose pipeline relocation or protection plans. Before construction, a reasonable construction process and a special plan for bridge construction adjacent to high-pressure gas pipelines shall be prepared, and a special evaluation shall be conducted. Construction can only be carried out after approval by the competent gas regulatory department.	Ultra-large-scale major hazardous works
		The influence of bridge construction on the settlement and horizontal displacement of supporting structures and soil around pipelines is a dynamic process, and significant safety accidents are prone to occur because of delayed or inadequate monitoring during construction.	A construction dynamic monitoring scheme and construction emergency plans shall be prepared and demonstrated by experts.	Ultra-large-scale major hazardous works
13	Other bridges involving underground pipelines	For other underground pipelines such as national defence optical cables, high-voltage power trenches, oil pipelines, and water supply pipelines, the estimated space is insufficient, resulting in signal and power interruptions, water outages, etc.	It is necessary to thoroughly investigate and collect data on underground pipelines on site, communicate with the asset owner, study the pipeline relocation or protection scheme, conduct a special evaluation of the construction plans, and submit them to the pipeline asset owner for approval and assistance with construction if necessary.	Combined with the specific situation, determine whether it is listed as ultra-large-scale major hazardous works

CHAPTER 5. ENGINEERING SOLUTION AND PLANNING- TUNNEL

5.1. DESIGN BASIS AND TECHNICAL STANDARDS

5.1.1. Design Basis

(1) Applicable Codes and Standards

1) Railway and Highway Tunnels БНбД 32-05-07;

2) Railway and Highway Tunnel Facilities БНбД 32-07-10;

3) GOST Standards for Highway Tunnel - Clearance Dimensions for Structures and Equipment ГОСТ 24451;

4) General Code for Concrete and Reinforced Concrete Structures БНбД 52-01-10;

5) Code for Concrete and Reinforced Concrete Structures with Non-Prestressed Reinforcement БД 52-105-10;

6) Cast-in-Place Reinforced Concrete Structures БД 52-106-12;

7) Loads and Actions БНбД 20-04-17;

8) Code for Seismic Design of Buildings БНбД 22-01-21;

9) General Requirements for the Reliability of Building Structures and Foundations БНбД 20-01-11;

10) Loads, Actions and Clause Interpretations БД 20-102-21;

11) Corrosion Protection for Building Structure БНбД 20-02-11;

12) Corrosion Protection for Building Structure and Facility БНбД 20-03-11;

13) Foundation Design БНбД 50-01-16;

14) Foundation Design and Clause Interpretations БД 50-103-21;

15) Foundations on Permafrost СНИП 2.02.04-88;

16) Codes and Regulations for Urban and Rural Planning and Development БНбД 30-01-04;

17) Fire Safety for Buildings and Structures БНбД 21-01-02;

18) Fire Safety Standards for the Design of Buildings and Structures БНбД 21-02-02;

19) Thermal Protection Planning for Buildings БД 23-101-10;

20) Thermal Insulation of Buildings БНбД 25-01-02;

21) Planning Buildings and Facilities for Accessibility and Inclusion of Persons with Disabilities БНбД 35-01-22;

22) Electrical Equipment and Facilities Code of Mongolia БД-43-101-03;

23) Code for Construction of Power Systems ЗХД-1.13-01-2006;

24) Technical Requirements for Road and Street Lighting in Cities, Counties, and Other Settlements MNS 6846 2020;

25) Planning of Street and Road Lighting in Cities, Counties, and Settlements БД30-102-11

26) Code for Outdoor Lighting Design in Urban, Town, and Rural Residential Areas CH 541-82

27) Technical Specifications for Lighting and Light Decoration UCS 1902A:2022

28) Other relevant codes and standard documents.

(2) Referenced Codes and Standards

1) Code for design of urban road engineering, CJJ 37-2012 (2016 Edition);

2) Technical Standard of Highway Engineering, JTG B01-2014;

3) Specifications for Design of Highway Tunnels Section 1 Civil Engineering, JTG 3370.1-2018;

4) Specifications for Design of Highway Tunnels Section 2 Traffic Engineering and Ancillary Facilities, JTG D70/2 -2014;

5) Guidelines for Design of Highway Tunnels, JTG/T D70-2010;

6) Technical Specifications for Construction of Highway Tunnels, JTG/T 3660-2020;

7) Technical Guidelines for Construction of Highway Tunnel, JTG/T F60-2009;

8) Guidelines for Design of Lighting of Highway Tunnels, JTG/T D70/2-01-2014;

9) Guidelines for Design of Ventilation of Highway Tunnels, JTG/T D70/2-02-2014;

10) Specification of Seismic Design for Highway Engineering, JTG B02-2013;

11) Code for design of urban underground road engineering, CJJ221-2015

12) Code for Design of Concrete Structures, GB 50010-2010 (2015 Edition);

13) Code for acceptance of constructional quality of concrete structures, GB 50204-2015;

14) Standard for design of concrete structure durability, GB/T 50476-2019;

15) Specification for deterioration prevention of highway concrete structures, JTG/T B07-01-2006;

16) Specifications for Design of Highway Cement Concrete Pavement, JTG D40-2011;

17) Specifications for Design of Highway Asphalt Pavement, JTG D50-2017;

18) Technical code for waterproofing of underground works, GB 50108-2008;

19) Technical code for engineering of ground anchorages and shotcrete support, GB 50086-2015;

20) Technical Code for Building Slope Engineering, GB 50330-2013;

21) Code for design of building foundation, GB 50007-2011;

22) Safety regulation for blasting, GB 6722-2014/XG1-2016;

23) Nine Safety Provisions for Tunnel Construction, issued by the Second Department of State Administration of Work Safety, Document No. [2014] 104;

24) Unified Standard for Reliability Design of Building Structures, GB50068-2018;

25) Standard for classification of seismic protection of building constructions, GB50223-2008;

26) General code for engineering structures, GB55001-2021;

27) Load code for the design of building structures, GB50009-2012;

28) General specification for waterproofing of buildings and municipal works, (GB55030-2022);

29) Standard for anticorrosion design of industrial constructions, (GB50046-2008);

30) General code for foundation engineering of building and municipal projects, GB 50003-2021;

31) General specification for concrete structures, GB55008-2021;

32) General code for seismic precaution of buildings and municipal engineering, GB55002-2021;

33) Code for seismic design of buildings, GB/T50011-2010;

34) Code for fire protection design of buildings, GB50016-2014 (2018 Edition);

35) Technical specification for retaining and protection of building foundation excavations, JGJ120-2012;

36) Technical standard for building engineering against uplift, JGJ476-2019;

37) Code for design of foam extinguishing systems, GB50151-2010;

38) Technical code for fire protection water supply and hydrant systems, GB50974-2014;

39) Code for design of extinguisher distribution in buildings, GB50140-2005;

40) Code for urban engineering pipelines comprehensive planning, GB50289-2016;

41) Code for urban wastewater and stormwater engineering planning, GB50318-2017;

42) Standard for design of outdoor wastewater engineering, GB50014-2021;

43) Standard for design of outdoor water supply engineering, GB50013-2018;

44) Structural design code for pipelines of water supply and wastewater engineering, GB50332-2002;

45) Code for construction and acceptance of water and sewerage pipeline works, GB50268-2008;

46) Environmental quality standards for surface water, GB3838-2002;

47) Code for Highway Engineering Geotechnical Investigation, JTGC20-2011;

48) Safety Management standard divisional work and sub-divisional work with higher risks, Order No. 37 [2018] of the Ministry of Housing and Urban-Rural Development;

49) Other relevant codes and standard documents.

5.1.2. Technical Standards

(1) Road Grade: Ⅰ Class I arterial road;

(2) Design Speed: 80 km/h for the tunnel;

(3) Construction clearance of a tunnel: Clear width 0.75 m + 0.5 m + 3 × 3.75 m + 0.75 m + 0.75 m = 14.00 m, Clear height 5.0 m;

(4) Design Service Life: As there are no clearly defined requirements for design service life in Mongolian standards, the design safety level of this project refers to the Chinese standard Specifications for Design of Highway Tunnels Section 1 Civil Engineering (JTG 3370.1-2018), in which the design service life of the main structure is 100 years;

(5) Tunnel Structural Loads: By Mongolian standards, Railway and Road Tunnels (БНбД 32-05-07), Load and Action (ВНбД 20-04-17), and Concrete and Reinforced Concrete Structures. General Rules (ВНбД 52-01-10), and concerning the Chinese standards Specifications for Design of Highway Tunnels Section 1 Civil Engineering (JTG 3370.1-2018) and Code for Design of Concrete Structures (GB 50010-2010, 2015 Edition), the tunnel lining structure shall be subject to structural strength verification under the ultimate limit state I (Case 1), and crack width verification under the ultimate limit state II (Case 2). The load combinations for different cross-sections are shown in the following table.

Table 5. 1. Load Combination Table

Calculated Section	Combination Name	Combination Type	Verification Item	Partial Coefficient for Structural Dead Load	Partial Coefficient for Earth Pressure
Open-cut tunnel lining	Case 1	Ultimate Limit State I	Strength verification	1.2	1.15
	Case 2	Ultimate Limit State II	Crack width verification	1.0	1.0
Class V surrounding rock section lining	Case 1	Ultimate Limit State I	Strength verification	1.2	1.6
	Case 2	Ultimate Limit State II	Crack width verification	1.0	1.0
Class IV surrounding rock section lining	Case 1	Ultimate Limit State I	Strength verification	1.2	1.6
	Case 2	Ultimate Limit State II	Crack width verification	1.0	1.0

(6) Structural Fire Resistance Rating: Class I;

(7) Seismic Requirements: The tunnel is located in a seismic zone with a basic intensity of 7 degrees, with a peak ground acceleration (PGA) of 0.11–0.14g.

(8) Tunnel Control Parameters Table

Table 5. 2. Tunnel Control Parameters Table

Item	Length Classification	Span Classification	Tunnel Classification	Design Reference Period	Safety Level of Support Structure	Waterproof Grade	Environmental Action Grade	Seismic Fortification Intensity	Seismic Fortification Category
New Ring Road Tunnel	Long tunnel	Large-span shallow-buried tunnel	Class I	100 years	Grade I	Grade II	B	7 degrees	Category B

(9) Power Supply Load Classification

The load classification of the New Ring Road Tunnel is Class I, among which the loads of

emergency lighting facilities, electro-optic signs, traffic monitoring facilities and central control facilities are classified as specifically critical loads within Class I. The loads of the fire pump and tunnel smoke extraction fans are classified as Class I loads. The loads of basic tunnel lighting and reinforced lighting are classified as Class II loads. In contrast, the loads of tunnel maintenance power supply, approach lighting, and other electrical demands are classified as Class III loads.

(10) Lighting Technical Standards

Segmented lighting is adopted for tunnel illumination. The adaptation luminance L20(s)is 3000cd/m². The luminance reduction factor(k) of the threshold zone of the tunnel for this project is 0.026.

(11) Monitoring Technical Standards

The tunnel monitoring facilities classification: Grade A+.

(12) Tunnel Ventilation Hygiene Standards

Under normal conditions, Carbon monoxide (CO) concentration shall not exceed 150 ppm, and the smoke concentration K shall be$\leq 7.5\times10^{-3}m^{-1}$;

In case of traffic congestion, CO concentration shall not exceed 150 ppm, and the smoke concentration K shall be$\leq 1.2\times10^{-2}m^{-1}$.

(13) Fire Protection Standards

The New Ring Road tunnel of this project is classified as a Category I tunnel. The fire protection systems in the tunnel include a fire hydrant system, a foam fire hydrant system, and a fire extinguisher system.

(14) Fire Resistance Rating Requirements

According to the Code for fire protection design of buildings, this tunnel is classified as a Category I tunnel in terms of safety level.

The fire resistance rating of load-bearing structures: ≥ 2.0 h, tested under RABT standard time-temperature curve.

5.2. Design Principles

The tunnel design should comply with current applicable codes and standards, while comprehensively considering the tunnel's geographical location, geological and seismic conditions, hydrology, and construction environment. The design should also take into account construction, operation, and maintenance features, and adhere to the principles of "safety, durability, economy, energy efficiency, and environmental protection." The tunnel layout should be determined based on the overall route direction and burial depth, while also considering construction conditions, project duration, fire protection, emergency rescue, and operational management.

Key design considerations for the tunnel include:

(1) The selection of tunnel location takes geological conditions and overall route direction as the primary control factors. The tunnel should avoid crossing as severely unfavourable geological zones as possible and be located in strata with better ground conditions. Portal sections must be situated on stable slopes to facilitate connection at both ends and external works.

(2) Structural design of the tunnel must be safe, technically feasible, watertight, and economically efficient.

(3) Attention should be paid to soil and water conservation, environmental protection, and portal landscaping to minimise ecological disturbance and integrate the portal into the natural landscape.

(4) In line with the principle of "safety, reliability, economic efficiency, and human-centred", the tunnel shall be equipped with operation and management monitoring facilities proportional to the traffic volume and importance. All systems are designed to be scalable and upgradeable, forming an integrated transportation system that unifies people, vehicles, roads, environment, and management, thereby providing a safe, efficient, comfortable, and economical driving environment.

(5) New technologies, new processes, and new equipment are to be adopted actively yet prudently.

Figure 5. 1. Interior Rendering of Tunnel

Figure 5. 2. Schematic Diagram of Tunnel Traffic and Mechanical and Electrical Facilities

5.3. TUNNEL GENERAL DESIGN

5.3.1. Tunnel Civil Engineering

The tunnel location is determined based on the comprehensive analysis of the topography, geological conditions, environment, construction costs, and functional requirements of the tunnel site area. Under the premise of comprehensively considering linear indicators and project costs, on-site investigations were conducted to fully assess the topographical and geological conditions of the tunnel area. The tunnel plan is formulated mainly considering factors such as the topographic conditions of the tunnel entrance and exit, the engineering geological conditions of the tunnel site, and the site of operation and management facilities.

The New Ring Road Tunnel is a long tunnel designed following the principles of the New Austrian Tunnelling Method (NATM), using a composite lining structure. The tunnel entrance is at chainage K8+730, with an elevation of approximately 1434.37 m; the exit is at chainage K10+810, with a design elevation of approximately 1423.29 m. The longitudinal slope inside the tunnel is set as a herringbone slope of 0.95% and -0.99%, with a total length of 2080m, and the maximum burial depth is about 80m. The tunnel structure adopts a separated (locally neighbouring) tunnel. The standard section road inside the tunnel is three-lane, with a designed full width of 12.5m, and the width of the maintenance walkway on both sides is 0.75m on each side. The tunnel inner profile adopts a "three-centred arch" cross-section.

There are two vehicle cross passages every 750m inside the tunnel, with a clear width of 4.5m and a clear height of 5m; there are five pedestrian cross passages every 250m, with a clear width of 2m and a clear height of 2.5m. The vehicle cross passage can also serve as a

pedestrian cross passage. Pedestrian and vehicular cross passages are alternately arranged in a pattern of 1 vehicular to 2 pedestrian passages. The tunnel is equipped with an emergency lay-by on the right side of the driving direction, with a spacing of 750m, an adequate length of 40m, and a total length of 50m. There are four emergency lay-bys in total.

The entrance and exit of the tunnel adopt a bamboo cutting-type tunnel portal, and a certain length of cut-and-cover tunnel is set up.

The specific layout of the tunnel is shown in the following table:

Table 5. 3. Tunnel Table

No.	Tunnel Name	Start and End Chainages	Length (m)	Tunnel Classification	Construction Clearance (m)	In-tunnel Alignment Gradient (%)	Lighting Method	Ventilation Mode
1	New Ring Road Tunnel	K8+730～K10+810	2080	Class I	14×5	0.95%, -0.99%	LED Lamp	Mechanical Ventilation

In addition, the tunnel is also equipped with ventilation, fire protection, lighting, power supply and distribution, monitoring and other tunnel operation facilities, and a certain amount of space is reserved for some municipal pipelines to pass through the tunnel.

5.3.2. Tunnel Ventilation Engineering

(1) Ventilation Mode: Combined with the length, terrain, characteristics and air flow of this tunnel, and by the requirements of the current relevant specifications, according to the characteristics of this project, it is recommended to adopt the whole jet fan longitudinal ventilation method.

(2) The selection of the fan is based on the calculation of the air flow, and the actual performance of a single jet fan should meet the indicators in the following table.

Table 5. 4. Performance Indexes of Jet Fans

Item	Technical Specifications	Item	Technical Specifications
Impeller Diameter	1250mm	Motor Insulation Class	Class H
Outlet Airflow	43.5m^3/s	High Temperature Performance	The fan can work continuously for one hour at a high temperature of 250℃
Outlet Air Velocity	35.5m/s	Service Life of Main Parts	≥20 years
Axial Thrust	1668N	Reversibility	Yes, full-speed reversal within 90 seconds, reverse efficiency ≥60% of forward operation.
Protection Class	Not lower than IP55	Noise	≤75dB(A) at 45º below the air outlet, 10 meters away (in an open field)
Motor Power	55kW (AC380V±10%, 50HZ)	Load-bearing capacity of fan installation accessories and connections	Required to withstand at least 15 times or more of the combined weight of the fan and its accessories

(3) Fan layout plan:

The fan shall be laid out at about 160m from the tunnel entrance; the fans are arranged in

groups of 2, with an interval of about 250m between the two adjacent groups.

When substations are installed at both ends of the tunnel, the fans should be laid out as evenly as possible at both ends of the tunnel. When only one substation exists, the fans should be laid out on the side close to the tunnel substation.

According to the ventilation calculation results, the required airflow for the New Ring Road tunnel under normal traffic conditions is governed by the CO dilution requirement. Under congestion conditions, it is also governed by the CO dilution requirement. In case of fire, the system switches to the tunnel fire smoke extraction system.

For this project, a total of 8 groups of fans are needed for each of the left and right tunnels. Each group consists of 2 fans, for a total of 16 fans.

5.3.3. Tunnel water supply, drainage, and fire protection engineering

The location of the tunnel fire water tank and fire pump room is determined based on the following factors:

(1) Terrain

According to the longitudinal section of the tunnel designed this time, the selected location is at the high point of the tunnel, near both the entrance and exit, which is conducive to reducing pipeline head loss, lowering fire pump energy consumption, and maintaining stable water supply pressure.

(2) System safety

The fire pump room is designed to ensure the regular operation of the tunnel fire protection system. If it is installed inside the tunnel, when a fire occurs in the tunnel, the fire may spread and affect the fire pump room, thereby affecting the stability and safety of the entire fire protection system.

(3) Ease of management and operation

The fire pump room is located near the tunnel entrance and exit, which is convenient for future operation and maintenance management. When you arrive at the tunnel entrance and exit, you can enter the fire pump room to monitor and control the tunnel fire protection system. If a fire occurs in the tunnel, the fire extinguishing system can be activated at the tunnel entrance and exit to extinguish the fire, thereby improving the fire extinguishing capacity and efficiency. It is convenient for firefighters to arrive quickly, thereby reducing rescue delays caused by long-distance tunnel crossings during fires.

(4) Specification requirements

According to the Code for Fire Protection Design of Buildings GB50016-2014 (2018 edition), the fire pump room must ensure that the equipment inside the pump room can still work normally in the event of a fire, and the fire will not threaten the equipment and personnel who need to

enter the room for operation. It should be convenient for operators to enter the pump room in the event of a fire, and ensure that the pump room will not be affected by external fire.

Based on the above analysis, the design location of the fire water tank and fire pump room of this project is determined to be 30 meters away from the tunnel entrance at the small mileage end of the tunnel.

5.3.4. Tunnel power supply and distribution project

A substation and a box substation will be installed on both sides of the tunnel, with a power supply radius of 1000 meters. Two 1600kVA dry-type transformers will be installed in the substation and the box substation, respectively, and two 10kV power lines will be introduced from the municipal power grid to the two 10kV busbars of the substation and the box substation, respectively. Each 10kV power supply runs simultaneously and is required to ensure 100% load regular operation.

5.3.5. Tunnel lighting project

Table 5. 5. The tunnel lighting adopts zoned lighting:

Category	Length (m)	Luminaire Model	Layout Method	Single-Side Luminaire Spacing	Road Surface Luminance Target Value cd/m^2	Road Surface Luminance Design Value cd/m^2	Quantity (unit)
Threshold Zone luminance L_{th1}	40	400W LED Lamp	Bilateral Symmetry	3	78	90.8	27
Threshold Zone luminance Lth_2	40	250W LED Lamp	Bilateral Symmetry	4	39	43.1	20
Transition Zone luminance L_{tr1}	71	100W LED Lamp	Bilateral Symmetry	5	11.7	18.7	26
Transition Zone luminance L_{tr2}	89	100W LED Lamp	Bilateral Symmetry	16	3.9	10.8	12
Interior Zone luminance L_{in}	1858	100W LED Lamp	Bilateral Symmetry	16	2.5	3.6	232
Exit Zone luminance L_{ex1}	32	100W LED Lamp	Bilateral Symmetry	8	7.5	14.4	8
Exit Zone luminance L_{ex2}	30	100W LED Lamp	Bilateral Symmetry	5	12.5	18.7	14
Emergency Lighting		27w LED Tunnel Lamp	Bilateral Symmetry	12	0.2	1.3	346

The lighting control adopts a stepless dimming system.

5.3.6. Tunnel Monitoring Project

Tunnel monitoring includes: a central control management system, a video monitoring system, a lighting monitoring system, a traffic monitoring system, an automatic fire alarm and fire protection linkage system, a ventilation monitoring system, an emergency telephone and wired broadcasting system, a wireless communication system, etc.

5.4. TUNNEL ENGINEERING GEOLOGICAL DESCRIPTION

(1) Geological Conditions

The project will encircle the city of Ulaanbaatar, passing through the northern part of the city from west to east, forming a ring, and will traverse diverse geomorphological features, such as depressions and uplifted surfaces.

In the northern part of the zone, around the Chingeltei, Sharkhad, and Dar-Ekh mountains, conditions are favourable for linear erosion through small gullies and depressions between the hills. In contrast, the area as it gradually enters the Tuul River basin has a flat surface at its southwest and southeast ends. There are conditions for small-scale erosion and surface flooding through depressions.

Around the study zone, the surface soil and sediments are relatively thin. The area features modern Quaternary, alluvial-origin (pQ1) sediments that are stiff but flexible, composed of brown and grey clay, as well as gravel sediments that are either sandstone- or clay-dominated. In addition, modern Quaternary, alluvial-origin (pQ1), low-humidity, water-saturated brown, yellow-brown and grey gravel sediments are distributed in layers. According to the geomorphology, weathered sandstones of carbonate rocks are distributed in the highland part of the belt area.

1) Surface soil: Brown surface soil with plant roots is distributed throughout the area with a thickness of up to 0.2m.

2) Basal clay: a type of modern Quaternary, alluvial-origin (pQ1), stiff but flexible brown and grey clay sediments.

3) Clay-dominated gravel sediments: a type of modern Quaternary, alluvial-slope-derived (dpQ1), brown and grey clay-dominated gravel sediments with flexibility from stiff to soft.

4) Gravel sediments dominated by sand: a type of modern Quaternary, slope-wash-derived (pQ1), gravel sediments dominated by brown-yellow and grey sand with low to saturated moisture.

5) Weathered sandstone: a type of greenish-grey weathered sandstone originating from Carboniferous/soda/sedimentary deposits.

Figure 5. 3. Geological conditions of exposed surfaces around the tunnel

(2) Hydrological conditions

The groundwater level was found at 2.5-3.5 meters in the boreholes in the Tuul River valley along the study area. As of March 11, 2025, the groundwater is hydraulically connected to the Tuul River, and the seasonal groundwater level can rise by 1.0-1.5 meters. The chemical composition of groundwater revealed substantial amounts of freshwater with neutral pH and soft water characteristics, along with contaminant indicator compounds, classified as Type Ⅱ magnesium-calcium bicarbonate species. The water at this water supply point meets the requirements of the standard Technical Conditions for Water Used in Concrete and Building Mortar UST 3821:85.

(3) Climate conditions

The study area belongs to the intermountain steppe subzone of Mongolia's Climate Zone ⅡB, exhibiting an extreme continental climate like other regions. This region is characterised by an exceptionally arid-cold climate with severe conditions, abundant precipitation, and deep freezing of soils and bedrock. The entire section of this tunnel is in the permafrost zone and requires cold-proof and thermal insulation design.

5.5. TUNNEL IMPLEMENTATION PLAN SELECTION

(1) Common tunnel construction methods

Common tunnel construction methods can be divided into two categories: cut-and-cover method and under-cutting method. The cut-and-cover method involves first opening up the ground, building the lining in the open air, and then covering and backfilling. The under-cutting

method involves digging and building the lining underground, rather than opening up the stratum above the tunnel. The under-cutting method can be divided into the mining method and the tunnel boring machine method.

1) Cut-and-cover method

The cut-and-cover method involves excavating the foundation pit from the ground surface down to the designed elevation. Then, the main structure of the tunnel and its waterproofing measures are constructed from bottom to top at the predetermined position in the foundation pit. Finally, the area is backfilled and restored to its original state. The cut-and-cover method has the advantages of simple construction process, mature technology, reliable quality, good waterproofing effect and low risk. It is the preferred method for municipal tunnel construction. The cut-and-cover method is usually used in places where ground traffic and the environment permit.

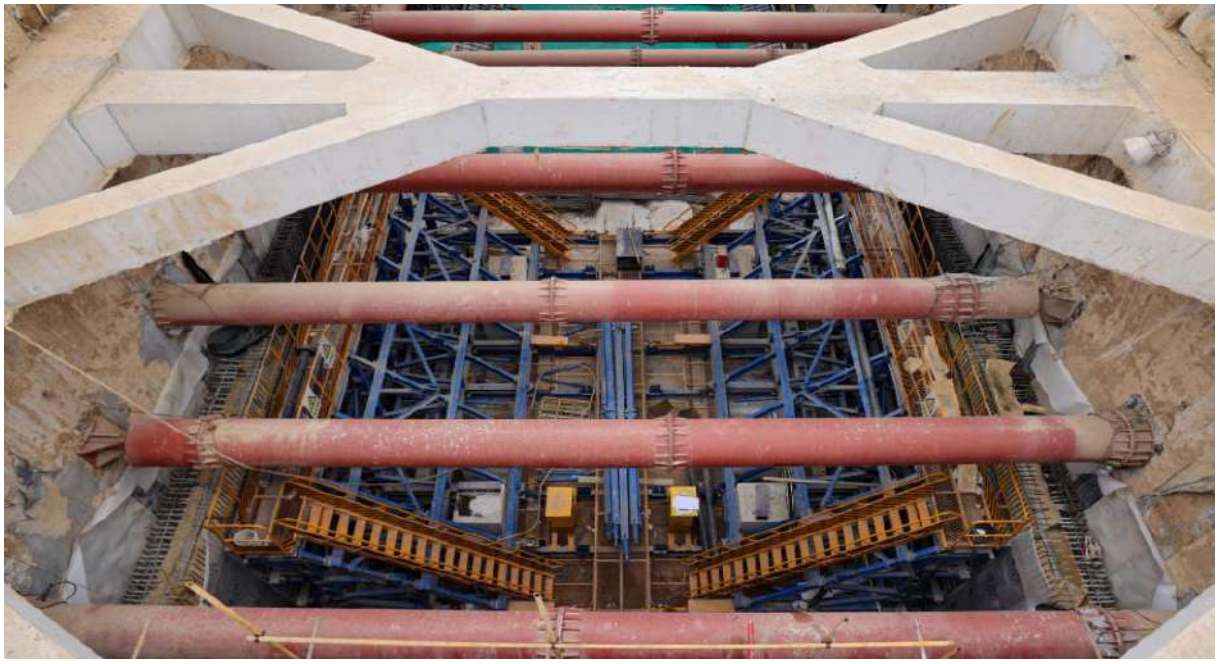


Figure 5. 4. Cut-and-cover method

2) Mining method

The mining method, also known as the mining tunnelling approach, is one of the methods for building tunnels in rock formations. During construction, blast holes are first drilled into the tunnel rock surface, followed by charging and blasting to create a rough tunnel. The full face is then excavated in a specified sequence to the designed dimensions, after which the lining is constructed sequentially. In hard formations, the surrounding rock has good integrity. After the tunnel is excavated, the surrounding rock has a certain self-stabilizing ability, allowing for minimal segmentation or even full-face tunneling in a single pass. When excavating a tunnel in formations where the rock is not hard and complete enough, it is generally necessary to first

excavate a pilot tunnel (also known as a heading) and install temporary supports to prevent soil and rock collapse.

Figure 5. 5. Mining method

3) Tunnel boring machine method

The tunnel boring machine method is a construction technique that uses a continuously advancing integrated system to excavate the entire cross-section of the tunnel. The tunnel boring machine consists of a rotating cutterhead (with a disc cutter and a sulfur bucket on the disc), a rock ballast loading device, a propulsion device for the machine to move forward and a support device, a laser collimator to control the direction, equipment for installing temporary supports and other mechanical devices. During construction, the rotating cutterhead applies substantial thrust pressure against the tunnel excavation surface to cut the rock. The excavated muck is collected by buckets around the cutterhead, lifted into the muck discharge chute, and then transferred onto a conveyor system, from which the muck is transported out of the tunnel by other hauling equipment. Several pairs of retractable support devices extend outward from the middle of the machine body and are tightly supported on the rock wall to fix the machine body and transmit strong torque and thrust. After completing one stroke, the support device retracts to allow the machine body to advance to a new position, and the process is then repeated. The tunnel boring machine has the advantages of fast excavation speed, safe operation, and little surrounding rock disturbance, making it suitable for tunneling projects in medium-hard or softer rock formations.

Figure 5. 6. Tunnel boring machine method

(2) Tunnel implementation plan selection

Based on the route plan discussion and research, the tunnel of this project is a long tunnel with a maximum burial depth of about 80m. There are no critical structures within tunnel main body, and there are few environmental risk sensitive points. The tunnel mainly passes through weathered rock strata. Combined with the characteristics of commonly used construction methods and their adaptability to the strata, the cut-and-cover method is first excluded. In order to save project costs, shorten construction period, and ensure project safety, a comprehensive comparative study of the mining method and the tunnel boring machine method shall be conducted to make a proper choice.

Table 5. 6. Comparison of tunnel construction methods

Item	Tunnel Boring Machine Method	Mining Method
Construction Method Description	The tunnel boring machine method is a method for excavating tunnels, lanes and other underground spaces. Tunnel boring machine method (TBM for short) uses specially made large-scale cutting equipment to shear, squeeze and crush rocks, and then transports the crushed stones out through matching haulage device.	The mining method is a traditional construction method. Its basic principle is that after tunnel excavation, the rock mass will be fractured and become loose by blasting, which may collapse at any time. Based on this loose load theory, its construction method adopts sequential divided excavation using block-by-block advancement. To ensure safety, excavation and support are carried out simultaneously. With the emergence of shotcrete and rockbolt support, the number of divisions has been reduced, and the method has then been developed into the New Austrian Tunnelling Method.
Project Cost	High	High
Tunnel Cross-Section	Single tunnel cross-section	Flexible selection of various cross-sectional shapes

Item	Tunnel Boring Machine Method	Mining Method
Excavation Cross-Section Utilization Rate	Relatively low	High
Applicable Conditions	Applicable to hard rock tunnels. From the perspective of tunnel construction investment, generally, when the tunnel length is greater than 6km or the ratio of tunnel length to diameter is greater than 600, a tunnel boring machine should be prioritised.	It has a wide range of applications and is not limited by the size and shape of the tunnel cross-section. It can be applied to various surrounding rocks. When the geological conditions change, the construction process can be flexible and adjust accordingly.
Construction Safety	The tunnel boring machine method is safer than the mining method.	
Construction Economy	The tunnel boring machine method is much more expensive than the mining method.	

Based on the above analysis and research, considering the project overview and the hydrogeological conditions of the tunnel site, a technical-economic evaluation concludes that the mining method shall be adopted for the proposed tunnel construction.

5.6. Tunnel cross-section design

The cross-section layout of the tunnel must first meet the requirements of the vehicle clearance, and at the same time meet the needs of the layout of various tunnel operating equipment and consider construction errors. Based on the above principles, the vehicle clearance and the layout of operational equipment are determined, and the tunnel cross-section is defined. The operating equipment layout must not encroach upon the vehicle clearance, meet the process layout requirements of each equipment, and be easy to repair and maintain.

(1) Structure Gauge

The tunnel is designed according to the Class I arterial road (Mongolian standard) standard, with a design speed of 80km/h.

Clear width of clearance: 0.75m (maintenance roadway) + 0.5m (lateral width) + 3×3.75m (driving lane) + 0.75m (lateral width) + 0.75m (maintenance roadway) = 14.00m;

Clearance height: 5.0m for driving lane and 2.5m for maintenance roadway.

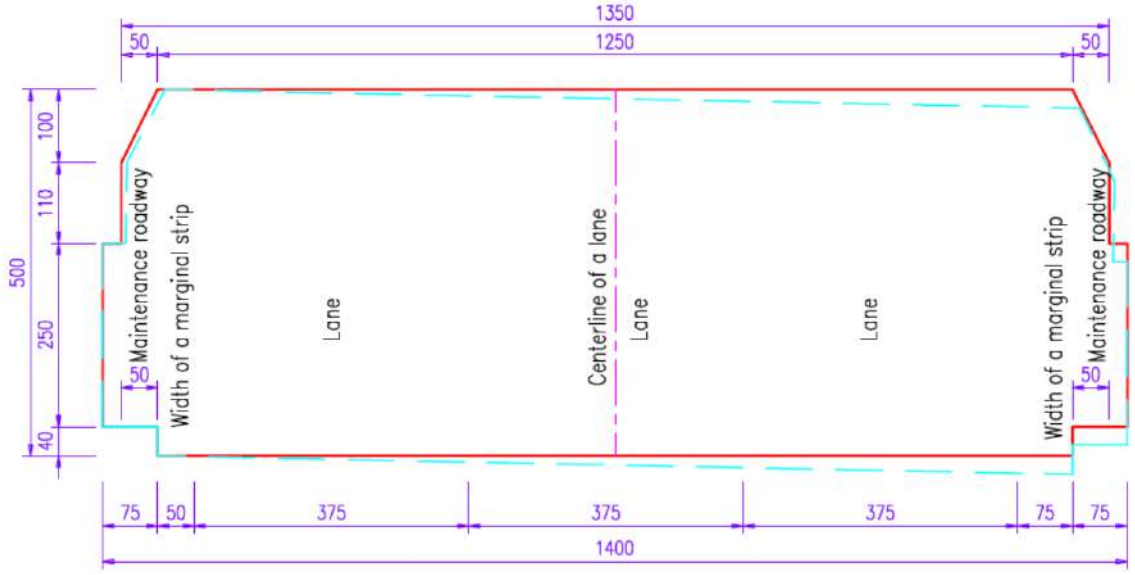


Figure 5. 7. Structure Gauge of the Ulaanbaatar New Ring Road Tunnel (unit: cm)

(2) Tunnel internal profile:

In addition to complying with the regulations on tunnel structure gauge, the design of the tunnel internal profile should also meet the needs of the pavement, drainage facilities, and decoration in the tunnel, and provide installation space for ventilation, lighting, fire protection, monitoring, operation management and other facilities, while considering factors such as surrounding rock deformation and construction methods.

According to the overall design principles and the conditions of the tunnel section in this project, the tunnel cross-section is a curved wall with an invert. The tunnel follows a "three-centered arch" cross-section. The internal profile standards are as follows: the arch and the side wall are connected by two smoothly circular arcs; the side wall and the invert are connected by a large-radius circular arcs; and the junction between the invert and the side wall uses a small-radius circular arc. The internal profile of the tunnel structure is shown below:

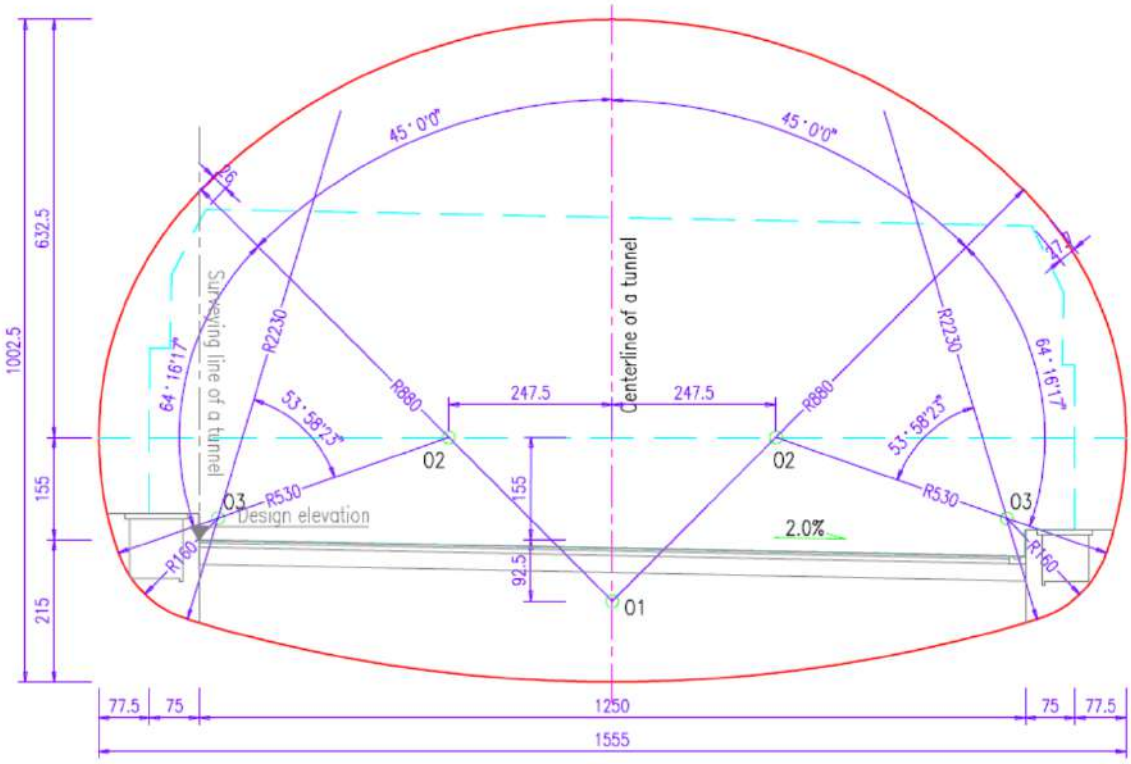


Figure 5. 8. Internal profile of the Ulaanbaatar New Ring Road Tunnel (unit: cm)

(3) Cross-passage design

Taking into account the requirements of the Specifications for Design of Highway Tunnels Section 1 Civil Engineering (JTG 3370.1-2018), the Code for fire protection design of buildings (GB50016-2014) 2018 Edition, the Highway, Railway and Highway Tunnels Code (БНбД 32-05-07) and the Highway and Railway Tunnels Code (БНбД 32-07-10), the length of the Ulaanbaatar New Ring Road Tunnel is 2080m, with 2 vehicle cross passages and 5 pedestrian cross passages.

Structure gauge for vehicle cross passage: The clearance has a clear width of 4.5 m and a clear height of 5.0 m, and adopts a straight-walled cross-section.

Structure gauge for pedestrian cross passage: The clearance has a clear width of 2.0 m and a clear height of 2.5 m, and adopts a straight-walled cross-section.

5.7. TUNNEL CIVIL ENGINEERING DESIGN

5.7.1. Tunnel type selection

(1) Structural type classification

Based on the clear distance between two tunnels, the tunnel is divided into three types: separated tunnels, neighboring tunnels, and multi-arch tunnels.

(2) Specification requirements

Referring to Section 4.3.3 of the Specifications for Design of Highway Tunnels Section 1

Civil Engineering (JTG 3370.1-2018), the clear distance between separated tunnels shall be determined based on the principle that the two tunnel structures do not adversely affect each other, taking into comprehensive consideration factors such as portal connection, geological conditions of surrounding rock, cross-section shape and dimensions, structural design, construction methods, and project schedule requirements. The clear distance between the two tunnels should be 0.8 to 2.0 times the excavation width, with the lower value applied where overall surrounding rock conditions are favorable, and the higher value adopted where overall surrounding rock conditions are relatively poor.

According to Article 4.4.2 of Guidelines for Design of Highway Tunnels (JTG/T D70-2010), the selection of the minimum spacing of standard-spacing separated tunnels is most closely related to geological conditions and tunnel span, but factors such as tunnel burial depth and ventilation during operation should also be considered comprehensively. When the burial depth is large, the spacing between the two tunnels should also consider the influence of in-situ stress, following the principle that no adverse interaction occurs between the two tunnels. In actual design, the selection of the minimum spacing of separated tunnels can refer to the following table.

Table 5. 7. Recommended Spacing Between Twin Tunnels (m)

Tunnel Cross-Section	Tunnel Length (m)	Surrounding Rock Conditions in 80% of the Alignment		
		Ⅲ	Ⅳ	Ⅴ
Dual-lane Tunnel	≤200	5-10	8-12	10-20
	200-500	5-10	10-15	15-25
	500-1000	10-15	15-20	20-30
	≥1000	15-20	20-30	30-40
Three-lane Tunnel	≤200	5-10	10-15	15-20
	200-500	10-15	15-20	20-30
	500-1000	15-20	20-30	30-40
	≥1000	20-30	30-40	40-50

When the tunnel clearance distance cannot meet the above requirements, a neighboring tunnel or a multi-arch tunnel can be adopted.

According to Article 4.4.3 of the Guidelines for Design of Highway Tunnels (JTG/TD70-2010), neighboring tunnels may be considered when the terrain conditions are too constrained to allow conventional clear distance layout for separated tunnels, or when adopting separated tunnels would result in substantially increased construction quantities for approach embankments (or bridges) at both portals and significantly higher construction difficulties. The clear distance of a neighboring tunnel should not be too small, otherwise the construction between the two tunnel chambers will have a great impact on each other, which will not only

increase the difficulty of construction, but also increase the cost. The reasonable maximum length and clear distance of a neighboring tunnel can refer to the provisions of the following table.

Table 5. 8. Reference Value Table for Reasonable Maximum Length and Clear Distance of Neighboring Tunnels

Tunnel Cross-Section	Reasonable Maximum Tunnel Length (m)	Clear Distance Between Tunnels (m)
Dual-lane Tunnel	750-1000	5-15
Three-lane Tunnel	500-750	8-20

Note: Lower values apply under favorable geological conditions; and higher values apply under poor geological conditions.

According to Article 4.4.4 of Guidelines for Design of Highway Tunnels (JTG/TD70-2010), both ends of the multi-arch tunnel can adopt an combined embankment, which has the advantages of saving land, smooth alignment connection, and small volumes of connection works, but the construction of the multi-arch tunnel is complex and the cost is high. The key factors of the multi-arch tunnel are its horizontal alignment and tunnel length. The length of a multi-arch tunnel can be determined by combining geological conditions with the scale of the project outside the tunnel. The reasonable maximum length of a multi-arch tunnel can refer to the provisions of the following table.

Table 5. 9. Reference Values for Reasonable Maximum Lengths of Multi-Arch Tunnels

Tunnel Cross-Section	Reasonable Maximum Tunnel Length (m)	Tunnel Cross-Section	Reasonable Maximum Tunnel Length (m)
Six-lane tunnel	400-750	Six-lane tunnel	300-500

Note: This table is formulated based on economic considerations and reasonable construction period. If there are special requirements, the maximum value recommended in the table can be exceeded.

(3) Determination of structural type

Summarizing the experience of mountain tunnel construction in recent decades at home and abroad, in general, for long and extra-long tunnels, separated tunnels should be the preferred option; and for medium and short tunnels, neighboring tunnels and multi-arch tunnels are more advantageous.

For the three types of tunnels, assuming that each type of tunnel is used under appropriate conditions, the comparative table is as follows:

Table 5. 10. Comparative Table of Three Tunnel Structural Types

Structural Type	Ordinary Separated Tunnel	Neighboring tunnel	Multi-Arch Tunnel
Rendering			
Minimum Clear Distance Between Twin Tunnels	(1.5-5.0)B	3m-1.5B	
Land Occupation Width	(2.5-7.0)B	2B+(3m-1.5B)	2B+3m
Alignment Connection Difficulty	High	Low	Low
Construction Difficulty	Low	Medium	High
Construction Period Requirements	t	1-1.5t	2-3t
Project Cost	M	1.1M	1.3-1.5M
Quality Control Complexity	Easy	Medium	Difficult
Blasting Vibration	Not required	<10-20cm/s	<10cm/s
Environmental Protection	High slopes may occur in narrow mountainous areas	Slopes heights may be reduced in narrow mountainous areas	Slopes heights may be reduced in narrow mountainous areas
Applicable Conditions	All tunnel types	Short tunnels or medium tunnels with good surrounding rock conditions	Short tunnels
Note: B represents the width of a single tunnel bore. T is the construction period of a separated independent tunnel of the same length, and M is the portal construction cost of a separated tunnel.			

The length of the New Ring Road Tunnel of this project is about 2080m. Based on the current geotechnical investigation data and field reconnaissance of the mountain terrain, and taking into full consideration factors such as tunnel length, surrounding rock grade, tunnel portal environment, construction difficulty, construction period, and cost, it is recommended that the New Ring Road Tunnel adopt a separated (local neighboring) tunnel.

5.7.2. Tunnel Portal Design

The design of tunnel portals should comprehensively consider multiple factors such as the terrain and landform at the entrance and exit, geological conditions, stability of excavated slopes, waterproofing and drainage needs, lighting at the portal, and environmental protection landscape. In accordance with the design principle of "early entry, late exit", excavation of portal slopes and heading slopes should be minimized as far as possible to ensure the stability of the mountain. Under this premise, the portal structure should be simple, attractive, and generous, and coordinated with the terrain of the portal. The portal forms mainly adopt bamboo-cut portals, straight-cut portal, end-wall portals. The foundation of the tunnel portal needs to be verified for bearing capacity. If it cannot meet the requirements of the portal, surface grouting or hollow grouting anchor bolt shall be used to reinforce the stratum to improve the bearing capacity of

the foundation. The geological conditions shall be further investigated during the construction phase, and appropriate treatments shall be performed on the tunnel portal according to the specific geological conditions of the tunnel. The portal should be designed in combination with the terrain, landform and location, and in accordance with the principle of economic efficiency and practicality. The layout of the cable entries and management facilities at the portal should be combined to beautify the portal.

Figure 5. 9. Current Condition of Tunnel Entrance

Figure 5. 10. Current Condition of Tunnel Exit

(1) Principles of portal design

Determine the location of the portal according to the terrain and geological conditions, and in combination with environmental protection and construction conditions.

Follow the principle of "early entry, late exit". Minimize or avoid excavation at the portal wherever possible. Reduce the height of excavation for portal slopes and heading slopes to the greatest extent to ensure the stability of the mountain, minimize damage to the natural landscape at the portal, and facilitate vegetation restoration. Enhance the coordination between the structure and the environment, carry out necessary protection and greening design, which not only ensures the stability of the slope, but also reduces the excavation of the slope, achieving the purpose of "safety, environmental protection, nature, and coordination".

The portal drainage system is integrated with the road drainage system.

(2) Selection of tunnel portal type

1) Classification of tunnel portal types

Common portal types of tunnels include: end-wall portals, wing-wall portals, stepped portals, column-supported portals, bamboo-cut portals, and flared portals, etc.

2) Comparison of tunnel portal types

Table 5. 11. Comparison and Selection of Portal Types

End-Wall Portal	Wing-Wall Portal	Bamboo-Cut Portal
Applicable to all surrounding rock classes with open terrain and basically stable rock mass. Supports the heading slope at the portal, collects and discharges the heading slope water flow, and effectively resists the longitudinal thrust of the mountain.	Applicable to surrounding rocks of Class IV and above with large longitudinal thrust of the mountain and poor geology at the portal. Increases the anti-sliding and anti-overturning capabilities of the tunnel portal.	Applicable to tunnel portal sections with long cut-and-cover tunnel linings. Since the backfill soil is mainly used within a certain range behind the tunnel portal, the thrust or sliding force of the mountain is not large. The terrain is relatively symmetrical and not too steep. It has the advantages of less excavation of the heading slope at the tunnel portal, reducing the damage to vegetation and being beneficial to environmental protection, and being applicable to all classes of surrounding rocks.
Stepped Portal	**Column Portal**	**Flared Portal**

Suitable for hillside terrain. When one side at the tunnel portal has a higher slope, it can reduce the height of the heading slope and the length of the exposed slope, thus reducing excavation.	Suitable for steep terrain and poor geological conditions where the heading slope may slip, and wing walls cannot be installed due to topographical or geological constraints.	Suitable for narrow portal areas, connections between bridges and tunnels, or locations where rockfall or debris may occur along heading slopes.

According to Mongolia's building seismic design standard In seismic zones (БНбД 22-01-21) and historical earthquake data, the seismic fortification intensity at the location of the Ulaanbaatar New Ring Road Tunnel is 7 degrees, with a basic seismic acceleration of 0.11g-0.14g. Considering the gentle gradients of the tunnel entrance and exit, overall safety, portal landscape and economic rationality, combined with the seismic requirements, **it is recommended to adopt the bamboo-cut portal, and set a cut-and-cover tunnel of a certain length.**

Figure 5. 11. Rendering of the Adopted Tunnel Portal Form for This Project

(3) Special design requirements for portals

1) According to the analysis of the damage form and cause of the tunnel in the earthquake, corresponding seismic measures should be taken for the portal section. The specific measures are as follows: designing the wall of the bamboo-cut portal with a certain slope angle or constructing a retaining wall structure in front of the portal; using high-grade cast-in-place reinforced concrete for the portal material; connecting the portal wall and the cut-and-cover tunnel with circumferential connecting reinforcement to form an integrated structure, thereby enhancing the seismic stability.

2) The portal structure of the tunnel portal project in permafrost areas should have sufficient resistance effect to resist structural deformation and force effects caused by frost heave and thaw settlement. When the portal foundation is a frost heave or thaw settlement stratum, the portal foundation should be placed 0.25m below the freezing line. If the foundation is too deep, the replacement and filling of the foundation should be carried out.

5.7.3 Lining design

(1) Design principles of lining structure

1) The lining structure is designed as a composite support lining structure according to the principle of the New Austrian Tunneling Method based on factors such as surrounding rock classification, terrain, burial depth, tunnel construction conditions.

2) The type and size of the lining structure should be determined through comprehensive analysis of engineering analogy and structural calculation based on the use requirements, surrounding rock classification, crown cover thickness, structural stress characteristics, and combined with engineering construction conditions and environmental conditions.

3) The design and excavation of the tunnel should follow the principle of "less disturbance, fast reinforcement, frequent monitoring, and early closure".

4) The lining structure in the area with poor surrounding rock should extend 5 to 10 meters to the area with good surrounding rock.

(2) Lining structure support parameters

In addition to the cut-and-cover tunnel set up in the portal section of this project in accordance with the terrain and geological conditions, the lining design for tunnel main body is guided by the principles of the New Austrian Tunneling Method and adopts a composite lining. That is, the initial support consists of system anchor bolts, reinforcing mesh, shotcrete, lattice girders and I-beam. Depending on different surrounding rock classifications, advance support measures such as large pipe sheds, advanced small guide pipes may be used. The secondary lining adopts cast-in-place waterproof concrete or reinforced concrete, and waterproof boards and non-woven geotechnical fabrics are laid between the initial support and the secondary lining as a waterproof layer. The design of tunnel lining type, lining cross-section type and lining structure size mainly adopts the engineering analogy method, supplemented by necessary theoretical calculations and verification of the tunnel structure. Combined with the structural requirements and economic and technical comparisons, the corresponding support parameters are formulated according to the surrounding rock classification and the depth of the tunnel.

Table 5. 12. Support Parameters of Tunnel Cross-Section Linings for the New Ring Road Tunnel

Lining Type	Advance Support	Initial Support				Secondary Lining	
		Anchor Bolt (Circumferential x Longitudinal)	Reinforcing Mesh	Shotcrete	Steel Arch Frame	Arch Ring Side Wall	Invert
Ⅴ	Large pipe shed A108×6mm Single-layer small pipe φ42×4mm	A25 hollow grouting anchor bolt (1.0×0.5m, length 4.0m)	A8 spacing 20×20cm Double layer	28cm	I 22b I-beam spacing 0.5m	60cm reinforced concrete	60cm reinforced concrete
Ⅳ	C22 mortar anchor bolt	C22 mortar anchor bolt (1.0×0.8m, length 3.5m)	A8 spacing 20×20cm	24cm	I 18 I-beam spacing 0.8m	55cm reinforced concrete	55cm reinforced concrete

(3) Cut-and-cover tunnel design

The cut-and-cover tunnel is arranged according to the actual situation at each portal. The cut-and-cover tunnel structure adopts cast-in-place reinforced concrete structure, and its foundation bearing capacity shall not be less than 300kpa. The temporary slope protection of the cut-and-cover tunnel adopts shotcrete and anchor bolt protection, and the backfilled slope should be smoothly connected to the original terrain as much as possible. The top of the cut-and-cover tunnel is generally protected by grid grass planting, and the higher slope position can be protected by anchor bolt frame grass planting for permanent protection.

(4) Initial support

The initial support is mainly supported by shotcrete, anchor bolts, reinforcing mesh, and I-beam steel frame.

The steel frame should be welded with the anchor bolt and reinforcing mesh as a whole, and closely attached to the surrounding rock to form a bearing structure.

The shotcrete shall be C25 concrete and applied using the wet-spraying method. The anchor bolts adopt A25 hollow grouting anchor bolts and C22 mortar anchor bolts. Steel base plates shall be installed to the exposed anchor bolts. The anchor heads shall be threaded and the plates shall be tightly pressed against the surrounding rock using nuts. The anchor heads and plates shall be covered with shotcrete. It should be noted that when the peripheral displacement of the surrounding rock is large, deformation joints should be set along the circumferential direction in the initial support.

(5) Secondary lining

The secondary lining adopts C30 reinforced concrete structure. During construction, it is required to use full cross-section formwork jumbos for single-pour integral casting. The concrete shall be transported by mechanical pumping to improve the overall compactness of the secondary lining, reduce transverse construction joints, and avoid longitudinal construction joints. The reasonable time for the construction of the secondary lining shall be determined by monitoring data obtained during construction, aiming to fully utilize the load-bearing capacity of the initial support while ensuring it is not exceeded.

5.7.4. Auxiliary construction measures

Auxiliary construction is a temporary support or temporary reinforcement measure adopted to ensure construction safety, without considering the impact of its support capacity on the permanent safety of the structure. When the tunnel passes through shallow-buried sections, unsymmetric loading zones, crushed zones and weak areas with poor self-stability, auxiliary engineering measures should be adopted. Auxiliary construction measures should be closely coordinated with the design of the main support structure of the tunnel and the selection of excavation methods. During the construction process, monitoring, measurement and information feedback should be strengthened to timely adjust the auxiliary construction methods or design parameters, ensuring the design aligns more closely with actual site conditions. The auxiliary engineering measures adopted in the tunnel mainly include: pipe shed, advanced small guide tube, advanced anchor bolt, surface grouting reinforcement, etc.

The advance support measures adopted in this tunnel design mainly include advanced long pipe shed, advanced small guide tube and advanced anchor bolt. Advanced long pipe shed: installed at both ends of the tunnel to prevent tunnel excavation collapse and heading slope deformation; advanced small guide tube: suitable for Class V surrounding rock sections; advanced anchor bolt: suitable for Class IV surrounding rock sections, mainly to prevent tunnel excavation collapse.

(1) Advanced long pipe shed

It is installed at the entrance of the main tunnel. The insertion depth of the pipe shed is determined with the terrain and geological conditions. The steel pipe of the pipe shed adopts A108×6mm hot-rolled seamless steel pipe, with a circumferential spacing of 40cm. Threaded joints are directly connected end-to-end. The construction error of the steel pipe deviating from the design position shall not exceed 15cm, the number of joints in the same cross section along the longitudinal direction of the tunnel shall not exceed 50%, and the number of adjacent steel pipe joints shall be staggered by at least 1m. In order to ensure the direction of drilling, a 70cm thick C25 reinforced concrete casing arch with steel framework is constructed outside the lining, with a longitudinal length of 2.0m. Considering the sagging during drilling, the drilling direction should deviate upward by 1–3 degrees from the designed direction of the steel pipe. The drilling position and direction must be measured by measuring instruments. During the drilling process, the deviation of the steel pipe must also be measured with the inclinometer. If the deviation approaches the allowable limit, it should be corrected in time to avoid affecting the excavation and support.

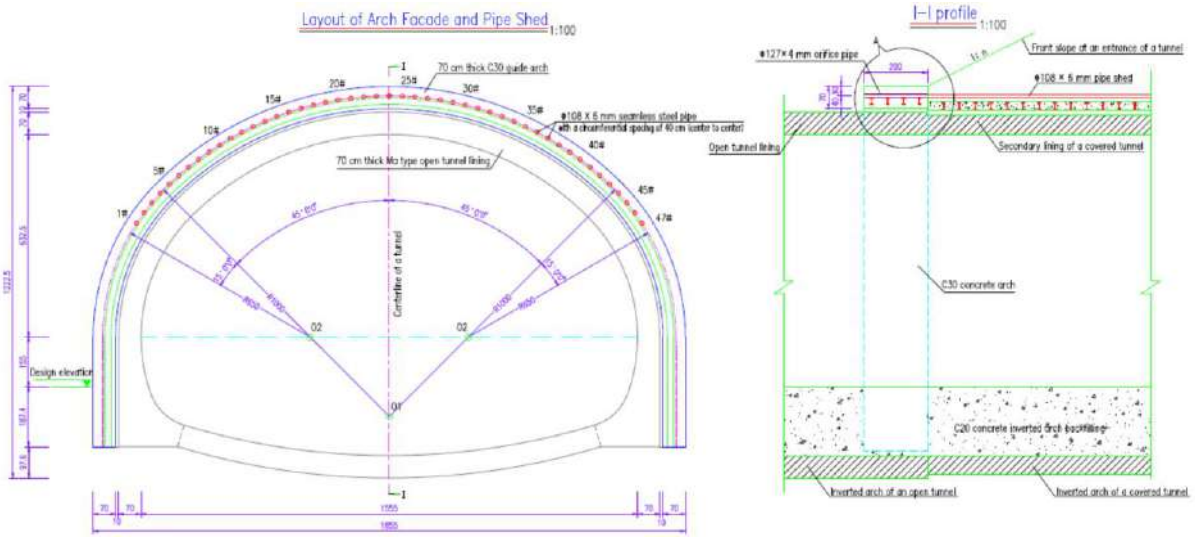


Figure 5. 12. Schematic diagram of advanced long pipe shed

(2) Advanced small guide pipe

The small-diameter steel pipe adopts hot-rolled seamless steel pipe with an outer diameter of 42mm. The circumferential spacing of the steel pipe is about 40cm, and the external insertion angle is controlled at about 10 to 15 degrees. The tail end is supported on the steel frame. Each row of small guide pipes must overlap at least 1.0m in the longitudinal direction.

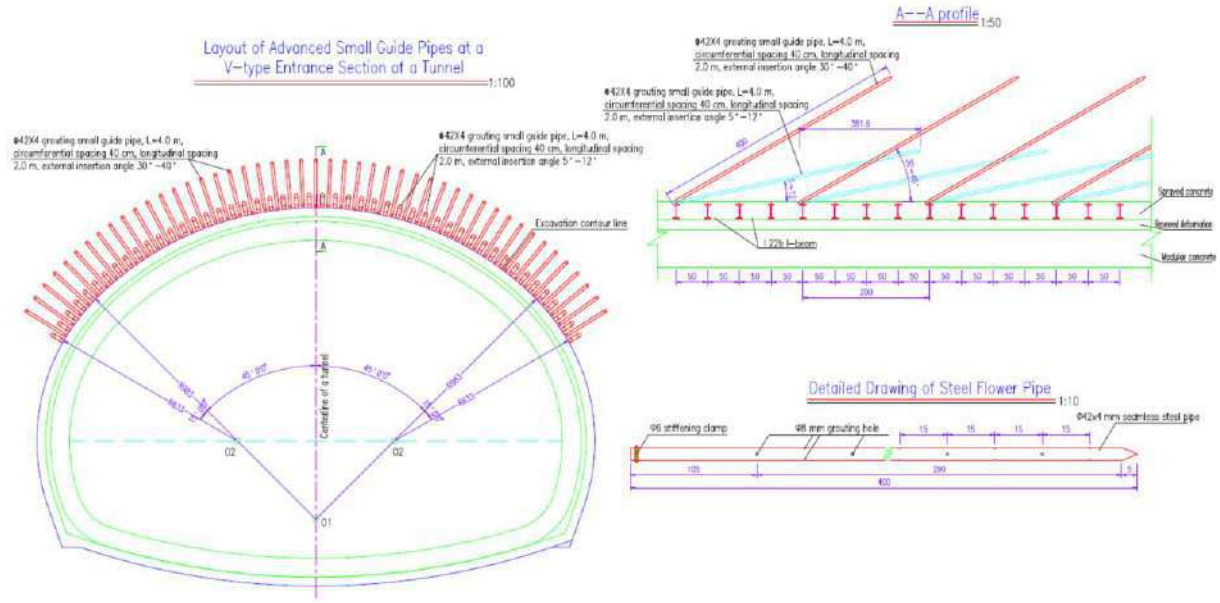


Figure 5. 13. Schematic diagram of advanced small guide pipe

(3) Advanced anchor bolt

C22 early strengthening mortar anchor bolt is used. The circumferential spacing of the anchor bolts is about 40cm, the external insertion angle is controlled at about 10°-20°, the tail end is supported on the outside of the steel frame, and each row of anchor bolts must overlap at least 1.0m in the longitudinal direction.

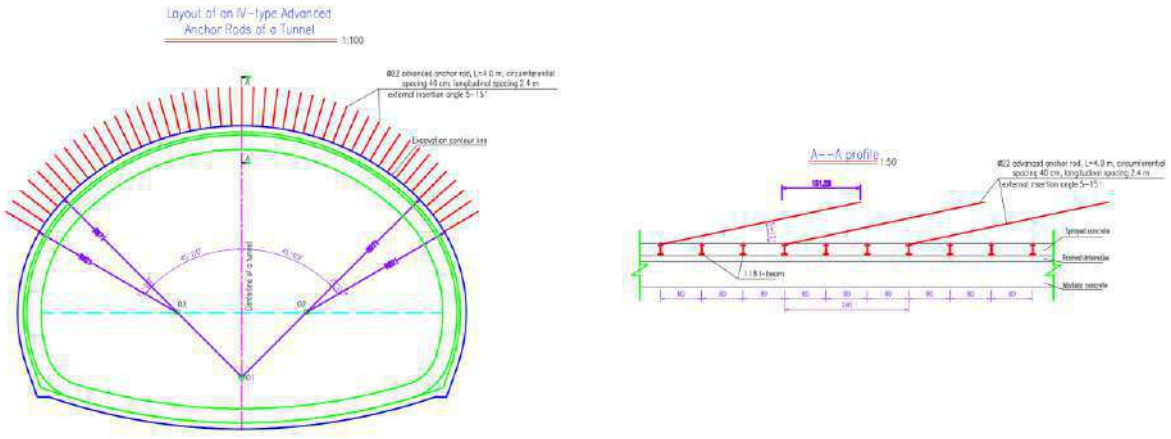


Figure 5. 14. Schematic diagram of advanced anchor bolt

(4) Auxiliary construction measures for neighboring tunnels

The construction procedure arrangement of neighboring tunnels should take into account the integrated planning of the construction processes for two adjacent and parallel tunnels. Based on the New Austrian Tunneling Method, with the requirements of implementation of micro-vibration blasting and the reinforcement of the intermediate rock pillars, through the establishment of a data and information mechanism, strengthening vibration testing, as well as careful monitoring and measurement, various surrounding rock excavation methods shall be scientifically selected, shotcrete and anchor bolt support shall be timely adopted, and the step distance of each process of the left and right tunnels shall be reasonably arranged, so as to minimize the disturbance of the construction to the surrounding rock (especially the intermediate rock pillars) and the tunnel structure, and ensure the safety and quality of construction.

A25 hollow grouting anchor bolt (Class Ⅴ surrounding rock at tunnel portal section) is used as the system support for reinforcing the surrounding rock. Reinforcement measures for intermediate rock pillars in lining are shown in the table below.

Table 5. 13. Reinforcement measures for intermediate rock pillars

Lining type	AA25 hollow grouting anchor bolt	
Class Ⅴ surrounding rock at tunnel portal section	Length (m)	Circumferential × longitudinal spacing (m)
	5.0	1.0×0.5

5.7.5. Seismic design

According to Mongolia's building Seismic design standard In seismic zones (БНбД 22-01-21) and historical earthquake data, the seismic fortification intensity at the location of the Ulaanbaatar New Ring Road Tunnel is 7 degrees, with a basic seismic acceleration of 0.11g-0.14g. Referring to Articles 3.1.1 and 3.2.2 of China's Code for Seismic Design of Building (GB

50011) and Code for Seismic Design of Highway Tunnels (JTG 2232-2019), the seismic fortification category is Class B. Referring to Articles 3.1.1 and 3.3.2 of Code for Seismic Design of Highway Tunnels (JTG 2232-2019), the seismic fortification level of the tunnel is Class 3. Considering the requirements of seismic measures, seismic analysis and seismic verification are not required.

The primary seismic measures for tunnels include the following aspects:

(1) The location of the tunnel should be selected in an area with stable mountains, good geological conditions and favorable seismic resistance, and the tunnel portal should avoid adverse geological conditions such as landslides and collapses.

(2) The lining structure of the cut-and-cover tunnel and the segments with Class V and Class IV surrounding rocks shall adopt reinforced concrete curved wall lining with an invert, and circumferential seismic joints shall be set at the transition between cut-and-cover and mined sections.

(3) Rebar shall be used to effectively connect the tunnel portal and the cut-and-cover tunnel to enhance the overall seismic performance.

(4) The sides of the cut-and-cover section are backfilled and compacted using mortared rubble masonry, with a backfill height of no less than 7 meters. The top of the cut-and-cover section is compacted with gravelly soil (with a compaction degree not less than 90%) to effectively enhance the seismic performance of the structure.

(5) The backfill heading slope should be strictly controlled, and the heading slope gradient should not be steeper than 1:1.5.

(6) Appropriate protection should be provided for the mountain above the tunnel portal and the roadbed slope outside the tunnel. All potential safety hazards, such as collapse and rolling stones, should be resolutely removed or handled during the construction stage.

(7) The secondary lining adopts a cast-in-place reinforced concrete structure, and a circumferential seismic joint is set every 9 to 12 meters along the longitudinal direction, which can be put together with the settlement joint and expansion joint.

(8) For fault fracture zones, transitions between soft and hard strata, and sections with changes in structural form, the seismic design protection range should extend into the more stable surrounding rock or regular structural sections. The protection length should include the extension lengths on both ends: not less than 10 meters for Class V surrounding rock sections and not less than 5 meters for Class IV sections.

(9) At the location of the vehicle and pedestrian cross passages, necessary structural measures should be taken to enhance the seismic performance of the structure at the junction

between the main tunnel and the auxiliary passage.

(10) Voids behind the lining are strictly prohibited. If such issues are detected, cement-sand grout shall be pressure-injected behind the lining. fault zones are characterized by poor geological conditions, with surrounding rock typically classified as Class Ⅴ or Ⅳ and often accompanied by abundant groundwater. A stronger support form should be adopted in combination with perfect auxiliary construction measures to ensure the safety of the construction stage and lining structure. Considering the loose and heavily loaded support structures in fault zones, all secondary linings should be designed as reinforced concrete structures to ensure structural safety. The tunnel advance support should adopt a grouting small guide pipe to pre-support the rock mass in front of the tunnel face, followed by ring cut method. In sections with abundant groundwater, pre-grouting should also be carried out in advance to seal the ground and prevent hazardous incidents such as sudden water or mud inrush.

5.7.6. Inside and Outside waterproofing and drainage plan for tunnel

(1) Waterproofing and drainage design principles

1) The tunnel waterproofing and drainage design should be carried out in combination with engineering characteristics, terrain conditions, engineering topographic conditions, hydrogeological conditions and survey data. The surface water and groundwater should be properly handled to form a complete, smooth and easy-to-maintenance waterproofing and drainage system inside and outside the tunnel.

2) The tunnel waterproofing and drainage system is designed based on the principles of "combining waterproofing, drainage, interception, and blockage, tailored to local conditions, and comprehensive management", with the objective of ensuring a dry tunnel interior upon completion, thereby guaranteeing the normal use of tunnel structures and operational facilities, as well as the driving safety.

3) For underground rivers and karst water in pipelines, the principle of “drainage is prioritized over blockage” shall be adopted, without altering the overall flow pattern of the groundwater.

4) When tunnel construction has a significant impact on the surface villages’ living and production activities, or even triggers geological disasters, a countermeasure of “blockage with limited discharge” shall be adopted for tunnel drainage and waterproofing.

(2) Waterproofing of tunnel main body

The secondary lining of the tunnel shall use waterproof concrete with an impermeability grade of no less than P8. A waterproof layer (1.5mm EVA waterproof membrane and 400g/m² geotextile)shall be installed between the initial support and the secondary lining. For

construction joints and settlement joints, embedded rubber waterstops shall be used, while steel-plate-and-putty waterstops shall be adopted for longitudinal construction joints. To ensure that the geotextile effectively performs its filtration and drainage functions, it shall be installed separately from the waterproof membrane. That is, the geotextile shall be laid first, followed by the hanging of the waterproof membrane.

When a large amount of water is encountered after tunnel excavation and surface water leakage poses a profound impact on the surface ecological environment, grouting measures shall be considered to block water inflow in the surrounding rock, to restrict or reduce water discharge.

Figure 5. 15. Schematic diagram of the tunnel leading body waterproofing

(3) Tunnel main body drainage

The lining drainage for the tunnel main body involves the installation of comprehensive longitudinal and circumferential drainage blind ditches between the waterproofing layer and the shotcrete, ensuring that seepage water from the surrounding rock behind the lining is effectively drained through the side drainage ditches. After tunnel excavation, based on the development of groundwater in the surrounding rock, Ω-shaped spring drainage pipes shall be vertically installed along the rock surface to guide and discharge seepage water from the surrounding rock, thereby ensuring smooth internal drainage within the initial support. A50 HDPE single-wall perforated corrugated pipe shall be laid between the initial support and the waterproofing layer as a circumferential drainage blind ditch. At the foot of both sidewalls along the entire length of the tunnel, A100 HDPE double-wall perforated corrugated pipes shall be installed longitudinally and connected to the drainage ditch via transverse drainage pipes to discharge groundwater

outside the tunnel. Roadside ditches shall be arranged on both sides of the tunnel pavement to discharge road surface runoff and cleaning wastewater during operation, ensuring separation between wastewater and surrounding rock water behind the lining. In areas with abundant bedrock fissure water, such as lithological contact zones and fault zones, circumferential drainage pipes and transverse drainage pipes shall be densely installed.

Curb-side ditches shall be installed along the tunnel pavement to discharge firefighting water and cleaning water, ensuring that water behind the lining from surrounding rock is separated from polluted water during drainage. Inspection ports shall be installed on the longitudinal drainage pipes at the foot of the sidewalls, making the tunnel drainage facilities repairable.

Due to the excavation of the tunnel, groundwater infiltration and runoff conditions have been changed, causing groundwater to accumulate within the tunnel and resulting in a humid tunnel environment. In order to improve the usability of the tunnel pavement, and considering the difficulty of pavement maintenance inside the tunnel, permeable blind pipes shall be designed beneath the tunnel pavement base to reduce the damage caused by water to the tunnel pavement.

(4) Waterproofing of construction joints and deformation joints

For tunnel deformation joints, a double-layer waterproofing system is adopted, consisting of externally bonded rubber waterstops and embedded rubber waterstops, both fixed in place using rebar clamps. The joint sealing materials are also required to be waterproof. The arrangement of circumferential construction joints may be adjusted based on actual construction conditions; the number of joints should be minimized. An embedded rubber waterstops shall be installed at the circumferential construction joints, with a typical spacing of 10m. Steel-plate-and-putty waterstops shall be installed on construction joints at both sides of the arch foot of cut-and-cover and under-cut sections, running continuously along the tunnel in the longitudinal direction.

During construction, attention shall be paid to the overlapping of waterproof membranes, pre-embedding of drainage pipes, installation of waterstops, and pre-embedding of grouting ports. If the installation positions are found to be inappropriate, proper adjustments shall be made accordingly.

(5) Portal drainage and waterproofing

The external waterproofing layer of the cut-and-cover tunnel lining shall adopt a "double geotextile + one membrane" system (400g/m² geotextile + 1.5mm EVA waterproof membrane + 400g/m² geotextile). A 50cm thick impermeable clay layer shall be provided at the top of the backfill, which shall extend no less than 20cm into the side slopes and heading slopes to ensure proper overlap.

For portal drainage, based on the terrain, an interceptor ditch shall be constructed at least 5m outside the excavation line on the side slope and heading slope of the portal crown. This ditch can divert surface water to natural gullies or roadside drainage ditches, preventing rainwater from directly scouring the slope or tunnel portal.

Figure 5. 16. Schematic diagram of the intercepting ditch of the tunnel portal

When the tunnel portal is located on an uphill section, a reverse drainage side ditch shall be provided along the portal subgrade section to prevent the water outside the tunnel from entering the tunnel and to divert water away from the tunnel portal. When the tunnel portal is located on a downhill section, the roadside drainage ditches inside the tunnel shall be connected to the subgrade drainage ditches at the tunnel portal.

(6) Water environment protection

During construction, measures such as grouting and water blockage should be taken to avoid the loss of surface water and avoid affecting the surrounding ecology and the lives of residents.

5.7.7. Tunnel pavement structure

The design of the tunnel pavement should comprehensively select the pavement type, pavement structural layers and thickness based on factors such as road classification, traffic volume, subgrade bearing capacity, local environmental conditions, material supply conditions, climatic conditions, and construction conditions. The tunnel subgrade should be stable, well-compacted, and homogeneous to provide uniform support for the pavement structure. The tunnel pavement should have sufficient strength and properties such as smoothness, durability, anti-slipping, and wear resistance.

Carriageway pavement inside the tunnel: 4cm thick AC-13C fine-grained asphalt concrete (SBS modified) + 7cm thick AC-25 coarse-grained asphalt concrete + 26cm thick C40 concrete base layer (the C40 concrete shall be controlled by flexural strength, with a required flexural strength of no less than 5.0MPa).

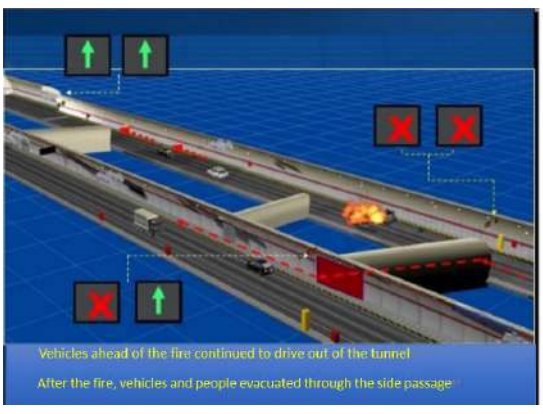
5.7.8. Design of cross passage and emergency parking strip

To evacuate the vehicles as soon as possible and facilitate maintenance in the event of a tunnel fire, two vehicular cross passages shall be provided between the left and right tunnels, with a spacing of 750m. The clearance of the cross passage shall comply with relevant standards, taking into account factors such as drainage ditches and its dual function as a pedestrian passage, with a clear width of 4.5m and a clear height of 5.0m.

To ensure the prompt evacuation of personnel during a tunnel fire, five pedestrian cross passages shall be provided between the left and right tunnels, with a spacing of 250m. The vehicle cross passage shall also be designed to serve as a pedestrian cross passage. Pedestrian and vehicular cross passages are alternately arranged in a pattern of 1 vehicular to 2 pedestrian passages. The clearance of the cross-section of the pedestrian cross passage shall meet the specification requirements, with a clear width of 2m and a clear height of 2.5m.

An emergency parking strip shall be arranged on the right side of the driving direction, with a spacing of 750m, an adequate length of 40m, and a total length of 50m. A total of four emergency parking strips shall be provided, with the width increased by at least 3m compared to standard lanes.

The centerline of a pedestrian cross passage shall be perpendicular to the tunnel axis, and the centerline of a vehicle cross passage shall be perpendicular to the tunnel axis. Fire doors shall be installed in both vehicular and pedestrian cross passages. The cross passages and emergency parking strips should be arranged in geologically favourable sections of surrounding rock as much as possible, and appropriate adjustments may be made based on actual geological conditions that change. When constructing the intersection section, reasonable construction methods should be chosen to minimise the disturbances to the surrounding rock.



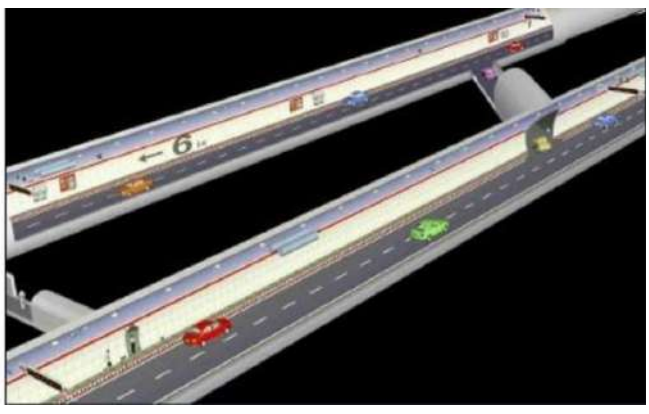


Figure 5. 17. Schematic diagram of tunnel cross passage

5.7.9. Durability Design

According to Code for Design of Concrete Structures (GB 50010-2010, 2015 Edition) and Standard for design of concrete structure durability (GB/T 50476-2019), the structural durability guarantee measures should be taken as follows:

(1) Corrosion-resistant concrete shall be used, and the corrosion resistance coefficient of the concrete shall not be less than 0.8.

(2) High-performance waterproof concrete shall be used for secondary lining and other tunnel structures to meet the waterproofing and crack resistance requirements of this project. The impermeability grade of the secondary lining concrete shall not be lower than P8.

(3) For mass concrete used in tunnel structures, high heat of hydration cement shall be avoided. The dual admixture technique is recommended (with a high-efficiency water-reducing agent and high-quality fly ash or finely ground slag), and the mix ratio shall be optimized through laboratory testing.

(4) The water-binder ratio shall be strictly controlled, with a maximum limit of 0.45.

(5) The maximum chloride ion content in concrete is 0.06%. In environments free of chloride salts, the chloride ion content of all raw materials used to prepare reinforced concrete (cement, mineral admixtures, aggregates, chemical admixtures, and mixing water) shall not exceed 0.2% and 0.1% of the weight of cementitious material, respectively. Chloride ion diffusion coefficient (28-day curing age) DRCM<10×10-12m^2/s.

(6) Non-alkali-reactive aggregates are recommended for concrete; and when alkali-reactive aggregates are used, the maximum alkali content in concrete shall be 3.0kg/m^3.

(7) Aggregates used to prepare concrete shall be uniformly textured, hard, with good particle shape, gradation and low void ratio. The crushing value of coarse aggregates shall not exceed 7%, and the water absorption rate shall be less than 2%.

(8) The chloride ion content in concrete chemical admixtures shall not exceed 0.02% of the total weight of cementitious materials in the concrete. The sodium sulfate content in high-efficiency water-reducing agent shall not exceed 15% of the dry weight of water-reducing agent.

(9) Requirements for construction

1) For the construction of durable concrete, quality control and quality assurance measures for the entire construction process and each construction stage shall be proposed, and corresponding construction technical regulations shall be formulated, combined the engineering and environmental characteristics.

2) Before formal construction, trial mixes of (commercial) concrete shall be conducted to evaluate its workability, strength, and durability performance indicators. Comparative tests shall also be carried out on crack resistance to determine the concrete mix proportions and selection

of raw materials.

3) Ensure the design thickness of the concrete cover. Cover spacers may be made of fine aggregate concrete, and their strength should be higher than that of the concrete of the main body of the structural component.

4) The construction of mass concrete shall be carried out strictly by relevant codes and regulations.

5) Concrete construction during rainy season: Drainage facilities of the sand and aggregate storage bins must remain unobstructed. Transportation equipment shall be equipped with rainproof and anti-slip measures. Rain protection measures shall be provided for placement surfaces, along with waterproof covering materials for standby. The frequency of aggregate moisture content measurements shall be increased to allow timely adjustments to mixing water content. During moderate or heavier rainfall, new concrete placement shall not be initiated. Concrete requiring impact resistance, wear resistance, or surface finishing shall not be placed during rainy weather. For construction during light rain, appropriate measures shall be taken: moderately reduce mixing water and concrete slump, and if necessary, reduce the water-binder ratio accordingly; enhance drainage and prevent surrounding rainwater from flowing into the placement block; and ensure proper protection of the interface between new and old concrete, especially at joints. In the event of heavy or torrential rain during placement, the feed should be stopped immediately. The concrete that has been entered into the placement block should be vibrated and compacted before covering it. After the rain, water accumulated in the placement block must be removed first, and the parts washed by rain should be treated immediately. If the concrete can be remodelled, it should be laid with joints and continued placement; otherwise, it should be treated as construction joints. Understand weather forecasts promptly, strengthen meteorological observation in the construction area, and arrange construction reasonably.

6) Quality inspection

The thickness of the concrete cover: The actual thickness of the on-site concrete cover shall be determined through non-destructive detection of rebar cover thickness gauge.

The compactness of the concrete cover: The density of the concrete cover is generally inferred indirectly by measuring the compressive strength of the surface concrete of the structural element using a rebound hammer test. It is recommended that the strength test be conducted at around 28-day curing age, and the average measured strength shall not be lower than the predetermined value.

According to the durability requirements, quality inspections shall be carried out on site and record reports shall be formed.

7) An additional external waterproof layer shall be applied to the tunnel structure to isolate the inner lining concrete from contact with corrosive media.

8) The clear cover thickness of the main reinforcement in reinforced concrete structures shall be strictly controlled.

5.7.10. Tunnel disaster prevention and Finishing

(1) Design Principles

1) The construction of tunnel projects shall enhance the modern urban multi-dimensional transportation system for traffic relief, with a focus on people-oriented design, protection of the urban environment, and preservation of cultural and historical landscapes.

2) While enhancing modern urban transportation systems, the construction of tunnel projects must also create a highly perceptible and efficient transportation space that matches the system for its users and operators. The design of above-ground structures should be coordinated with the surrounding urban landscape and architectural context.

3) As a traffic facility, tunnels shall fulfil basic requirements such as smooth traffic flow, orderliness and safety.

4) The tunnel cross-section design shall establish reasonable and economical construction clearance based on the road type and grade.

5) Tunnel design must consider disaster prevention and safe evacuation.

6) The tunnel finishing shall be bright and straightforward, with a smooth spatial feeling and a modern style. The interior finishing of the tunnel shall prioritise the side wall, and the finishing materials should have basic properties such as fire resistance, waterproofing, corrosion resistance, ease of cleaning, and a sufficiently high diffuse reflectance coefficient.

(2) Tunnel finishing

As an underground transportation facility, a tunnel shall be appropriately finished based on its functional requirements and the surrounding urban landscape considerations. The tunnel should embody the characteristics of simplicity, clarity, solemnity, aesthetic appeal, and smooth lines of transportation architecture in terms of color, form, and design, while also reflecting a contemporary sense of style.

According to the above requirements, the tunnel is planned to be finished by applying tunnel-specific fireproof coating and flame-retardant exterior paint across the entire cross-section. The sidewalls (extending 3.5m above the inspection walkway) will be coated with a base layer of fireproof coating and a top layer of light-colored fireproof paint, while the arch section above 3.5m will be coated with a base layer of fireproof coating and a top layer of dark-colored fireproof paint. Before applying the fireproof coating, the concrete surface shall be cleaned of dust and contaminants. The fireproof coating shall be applied in multiple times.

(4) Construction disaster prevention

Design principles of disaster prevention system:

1) As a municipal transportation facility, tunnel disaster prevention is primarily focused on fire hazards. A single tunnel shall be designed considering one concurrent fire incident within the same time period as the baseline scenario.

2) The fire protection and fortification target of tunnel structures shall be as follows: when suffering from fires below the fortification standards, the main structure is generally not damaged or is capable of continued use without repair; and when suffering from fires equivalent to the fortification standards, the main structure may be damaged to a certain extent and can continue to be used after repairs.

3) The main structure at the tunnel crown shall be provided with fire protection. Its fire resistance limit and the temperature rise curve used in fire resistance testing shall comply with the relevant code requirements.

4) The clear height of motor vehicle tunnels should meet the requirements for fire truck passage.

5) The tunnel shall be equipped with active fire prevention and passive fire prevention facilities as needed.

5.8. TUNNEL STRUCTURE CALCULATION

5.8.1. Tunnel Initial Support Calculation

(1) Main Support Parameters and Excavation Methods

The tunnel lining (support) design of this project is divided into three types according to the surrounding rock class and burial depth: Type Ⅴ Portal Section, Type Ⅴ Shallow-Buried Section and Type Ⅳ. The primary parameters of initial support for these three types of lining design are summarized in the following table. The initial support calculations are based on the cross-sections representative of the three lining types, with typical burial depths of the three calculated sections determined according to the tunnel longitudinal section at 17 m, 30 m, and 60 m, respectively.

Table 5. 14. Main parameters of the initial support of the tunnel

Calculation Section	Type Ⅴ Portal Section	Type Ⅴ Shallow-Buried Section	Type Ⅳ
Surrounding Rock Class	Class Ⅴ	Class Ⅴ	Class Ⅳ
Calculated Overburden Thickness	17m	30m	60m
Advance Support	120° arch crown range Double-layer A42 grouting small guide pipe Reinforcement thickness about 2m	120° arch crown range Single-layer A42 grouting small guide pipe Reinforcement thickness about 1m	120° arch crown range Single-layer A22 anchor rod Reinforcement thickness about 1m

Calculation Section	Type Ⅴ Portal Section	Type Ⅴ Shallow-Buried Section	Type Ⅳ
Steel Arch Frame	I22b I-beam Longitudinal spacing 0.5m	I22b I-beam Longitudinal spacing 0.6m	I18 I-beam Longitudinal spacing 0.8m
Shotcrete	C25 shotcrete Thickness 28cm	C25 shotcrete Thickness 28cm	C25 shotcrete Thickness 24cm
Reserved Deformation Allowance	15cm	15cm	12cm
Excavation Method	Double-sided drift method	Double-sided drift method	Step method with reserved core soil

(2) Calculation model

The initial tunnel support is analysed using a two-dimensional ground-structure interaction method based on a continuum model. The isotropic Drucker-Prager constitutive model represents the geotechnical material behaviour, while structural materials such as shotcrete and steel components (including anchor rods and steel arch frame) are modelled using linear elastic constitutive behaviour. The model dimensions extend to 3D (where D is the tunnel diameter) from both lateral sides and the bottom of the tunnel. The lateral boundary conditions restrict only horizontal displacement, while the bottom boundary condition restricts only vertical displacement. The calculation model is shown in the figure below.

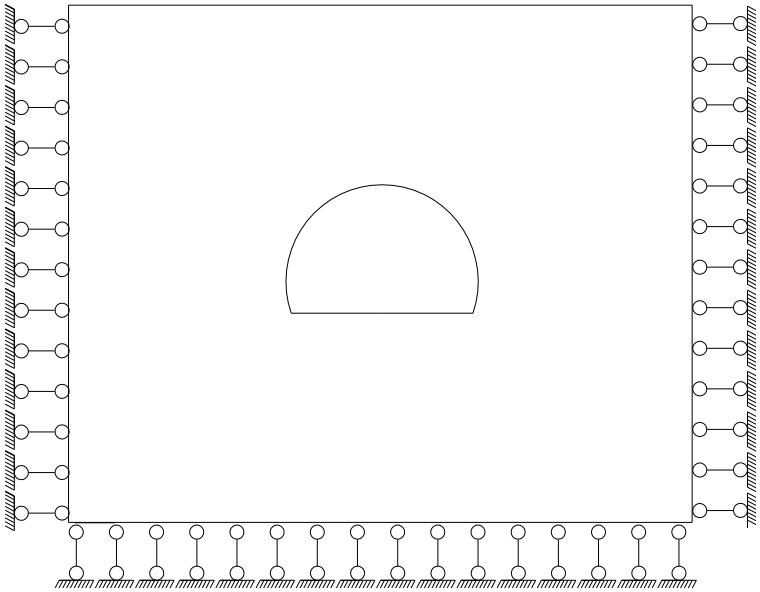


Figure 5. 18. Schematic diagram of the initial support calculation model of the tunnel

A two-dimensional finite element model is developed using MIDAS GTS NX software to conduct construction stage analysis. The calculation results at each stage represent the incremental responses of the current and preceding stages. The ground (advance reinforcement) is simulated using 2D plane strain elements in the software, the shotcrete and steel arch frames are modeled with 1D beam elements, and 1D truss elements represent the anchor rods.

(3) Material parameters

The initial support structure of the tunnel in this project mainly includes shotcrete, steel arch

frame and anchor rods. All shotcrete used is C25 concrete. The system anchor rods and steel arch frame are made of Q235 steel. The surrounding rock classes involved are Class Ⅴ and Class Ⅳ. The mechanical properties parameters of the above materials are summarized in the following table.

Table 5. 15. Calculation parameters of surrounding rock and structural materials

Material	Surrounding Rock		Q235 Steel (Anchor Rod, Steel Arch Frame)	C25 Shotcrete
	Class Ⅴ	Class Ⅳ		
Unit Weight (kN/m³)	20 (23)	23 (24)	77	25
Poisson's Ratio	0.4	0.33	0.3	0.2
Elastic Modulus (MPa)	1000	2000	2.1e5	2.5e4
Cohesion (kPa)	100 (200)	200 (255)	/	/
Internal Friction Angle (°)	25	30	/	/

Note: The values in () are the parameters after considering the advance reinforcement.

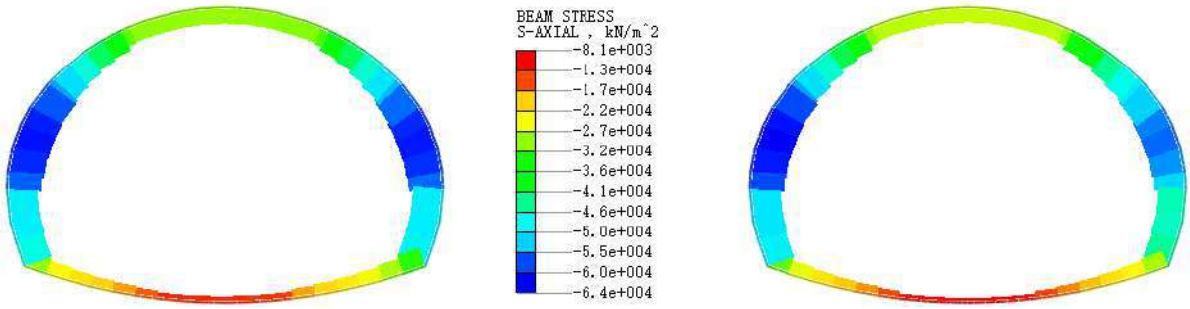
(4) Section verification method

The primary support section verification adopts the limit state method. As the secondary lining is cast immediately after the completion of initial support construction, and it subsequently bears the majority of the surrounding rock pressure, only Limit State Category Ⅰ (Ultimate Limit State, ULS) verification is considered for the initial support, while Limit State Category Ⅱ (Serviceability Limit State, SLS) verification is not required. In the verification of Limit State Category Ⅰ (Ultimate Limit State, ULS), design values of loads are adopted. The partial safety factors for surrounding rock pressure and structural self-weight are taken as 1.6 and 1.2, respectively. Design values of material strengths are taken from relevant codes. For C25 concrete, the design values of compressive and tensile strength are 11.9 MPa and 1.27 MPa, respectively. For Q235 steel, the design values of compressive strength, tensile strength, and flexural strength are all 215 MPa. The design stress shall not exceed the design strength of the material.

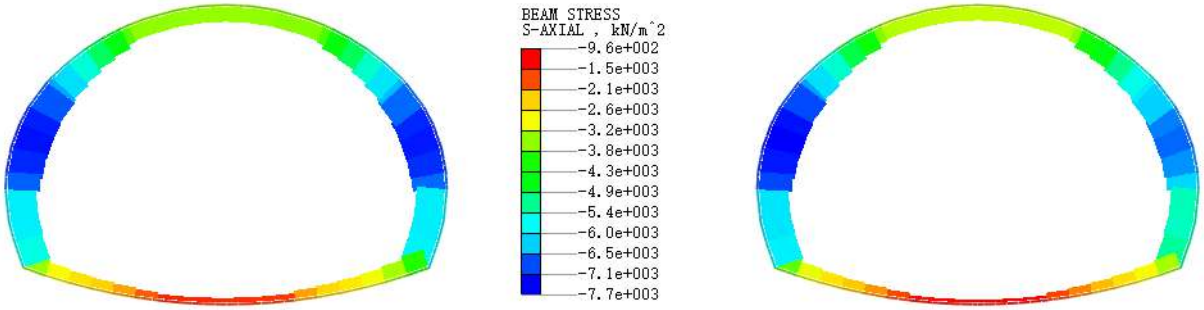
Since deformation of the initial support beyond the reserved deformation allowance would directly affect the tunnel clearance envelope, deformation verification of the initial support is also conducted under Limit State Category Ⅰ (Ultimate Limit State, ULS). The design value of tunnel deformation, accounting for load partial safety factors, shall not exceed the reserved deformation allowance of the tunnel.

(5) Calculation results

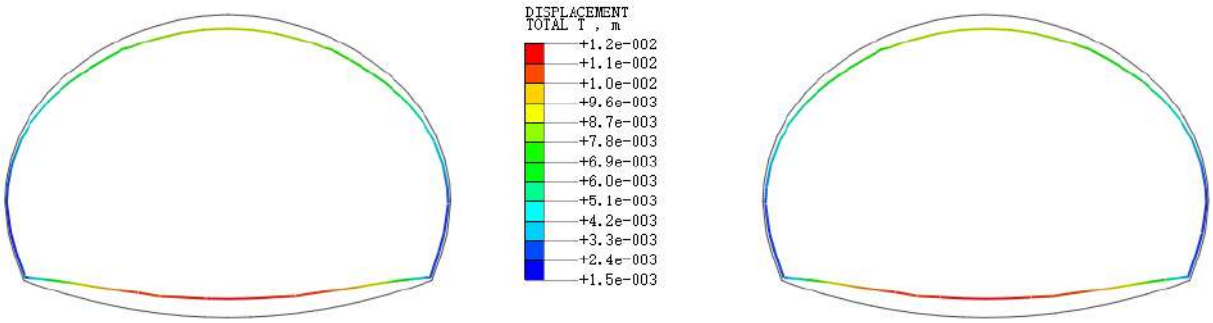
1) Type V portal section calculation results



Stress Contour Map of Steel Frame in Type V Portal Section



Stress Contour of Shotcrete in Type V Portal Section



Deformation Contour of Tunnel Convergence in Type V Portal Section

Figure 5. 19. Computation Results Diagram for Type V Portal Section

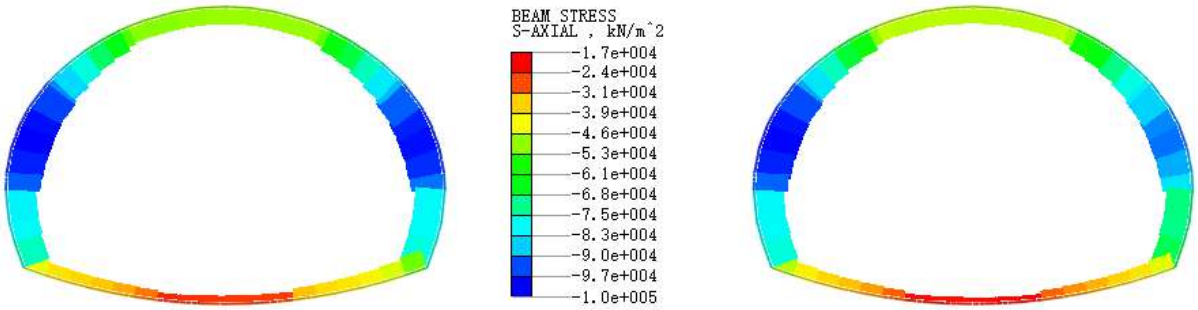
Table 5. 16. Statistical Table of Calculation Results of Initial Support for Type V Shallow-Buried Section

Verification Item		Effect Calculation	Resistance Design Value (Allowable	Verification Result
Steel Frame Stress (Mpa)	**Compressive Stress**	-64	-215	Satisfied
	Tensile Stress	/	+215	Satisfied
Shotcrete Stress (Mpa)	**Compressive Stress**	-7.7	-11.9	Satisfied
	Tensile Stress	/	+1.27	Satisfied
Convergence Deformation (mm)		+12	+150	Satisfied

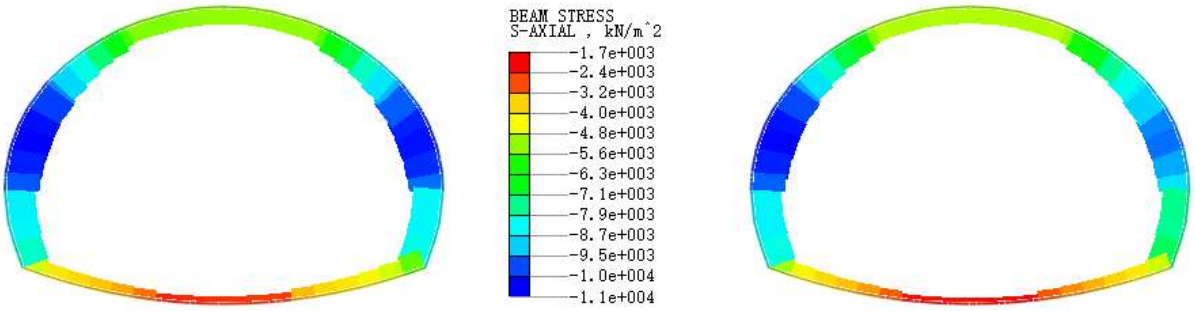
Note: In the figure, stress "+" indicates tension, stress "-" indicates compression, convergence deformation "+" indicates inward displacement of the tunnel, and

convergence deformation "-" indicates outward displacement of the tunnel.

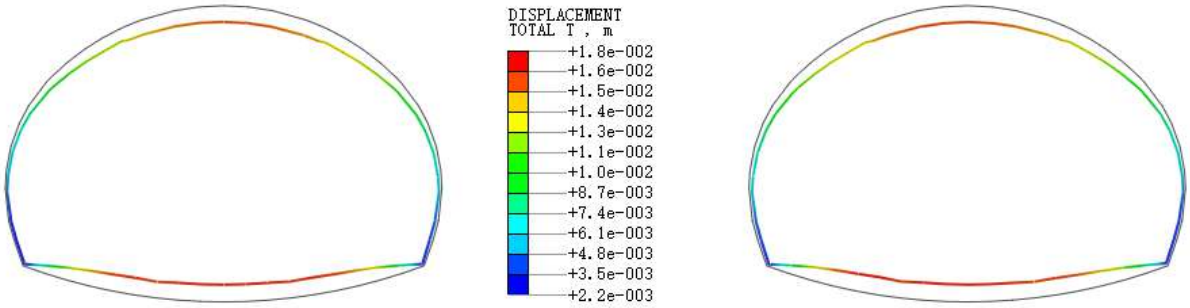
2) Calculation results of the Type V shallow-buried section



Stress Contour Map of Steel Frame in Type V Shallow-Buried Section



Stress Contour of Shotcrete in Type V Shallow-Buried Section



Deformation Contour of Tunnel Convergence in Type V Shallow-Buried Section

Figure 5.8.1-3 Calculation Results of Type V Shallow-Buried Section

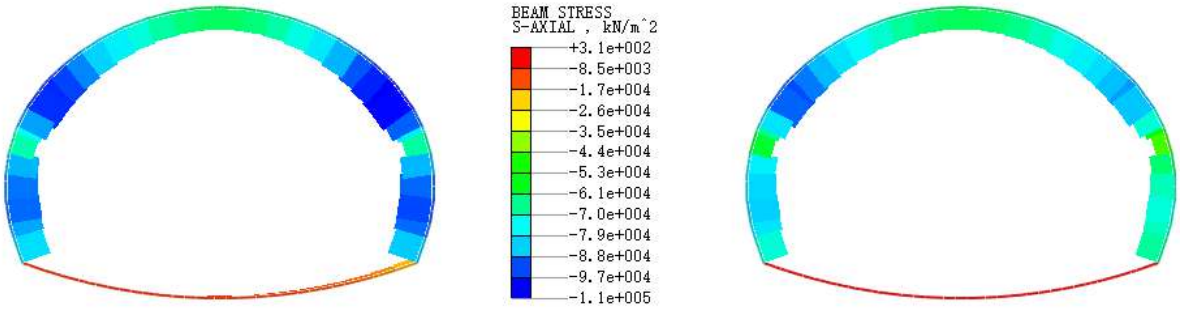
Table 5. 17. Statistical Table of Calculation Results of Initial Support for Type V Shallow-Buried Section

Verification Item		Effect Calculation	Resistance Design Value (Allowable	Verification Result
Steel Frame Stress (MPa)	Compressive Stress	-100	-215	Satisfied
	Tensile Stress	/	+215	Satisfied
Shotcrete Stress (MPa)	Compressive Stress	-11	-11.9	Satisfied
	Tensile Stress	/	+1.27	Satisfied
Convergence Deformation (mm)		+18	+150	Satisfied

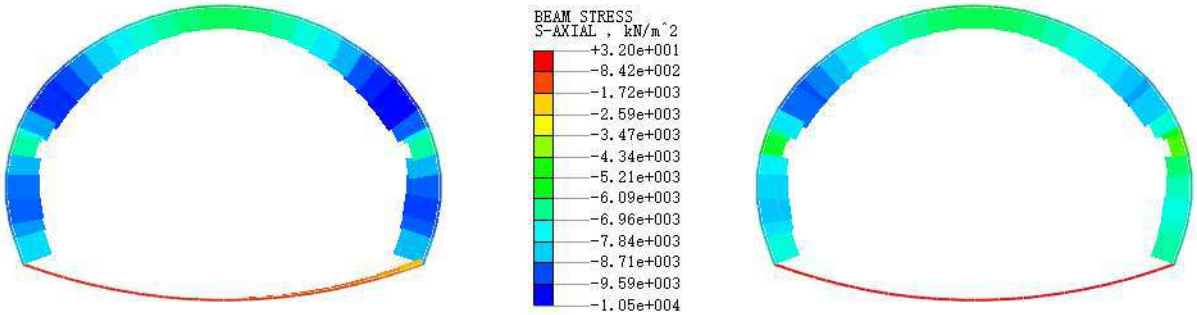
Note: In the figure, stress "+" indicates tension, stress "-" indicates compression, convergence deformation "+" indicates inward displacement of the tunnel, and convergence deformation "-" indicates

outward displacement of the tunnel.

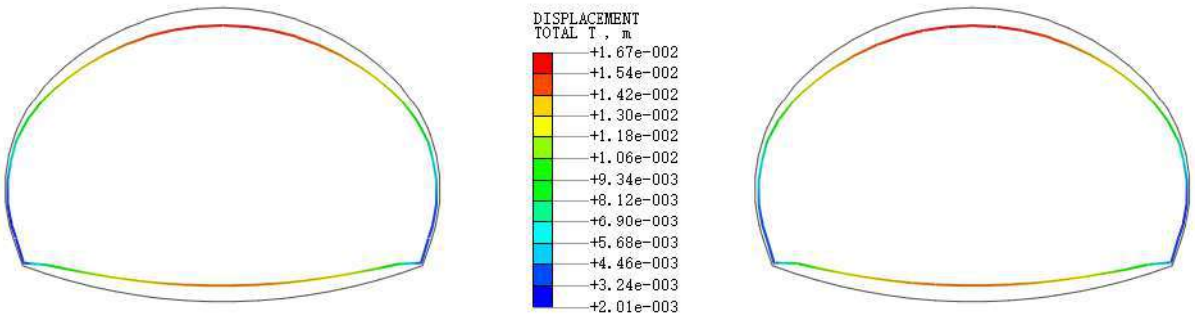
3) Calculation results of type IV tunnel



Stress Contour Map of Type IV Steel Frame



Stress Contour Map of Type IV Shotcrete



Convergence Deformation Contour Map of Type IV Tunnel

Figure 5. 20. Calculation Results of Type Ⅳ Tunnel

Table 5. 18. Statistical Table of Calculation Results of Initial Support of Type Ⅳ

Verification Item		Effect Calculation Value	Resistance Design Value (Allowable Deformation Value)	Verification Result
Steel Frame Stress (Mpa)	**Compressive Stress**	-110	-215	Satisfied
	Tensile Stress	+0.31	+215	Satisfied
Shotcrete Stress (Mpa)	**Compressive Stress**	-10.5	-11.9	Satisfied

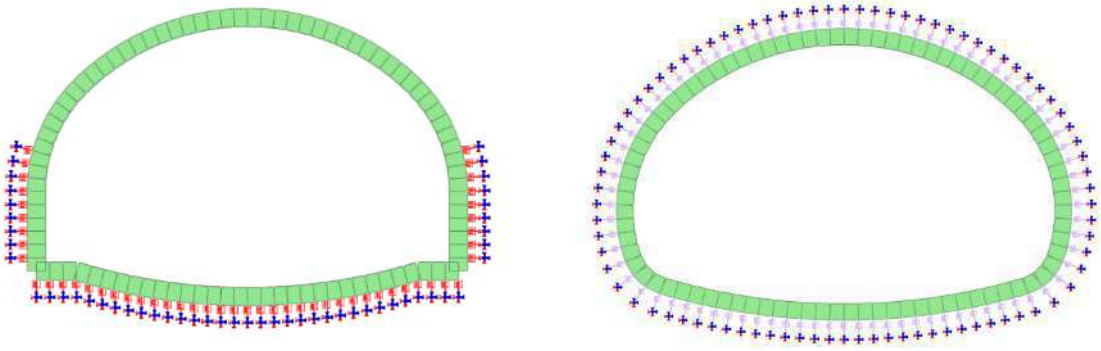
Verification Item		Effect Calculation Value	Resistance Design Value (Allowable Deformation Value)	Verification Result
	Tensile Stress	+0.03	+1.27	Satisfied
Convergence Deformation (mm)		+16.7	+120	Satisfied

Note: In the figure, stress "+" indicates tension, stress "-" indicates compression, convergence deformation "+" indicates inward displacement of the tunnel, and convergence deformation "-" indicates outward displacement of the tunnel.

5.8.2. Calculation of tunnel secondary lining structure

(1) Calculation principle

The tunnel secondary lining structure is calculated using the load-structure method. The lining structure is modeled using beam elements, while the elastic resistance of the surrounding rock is simulated using compression-only spring elements. In the calculation process, the earth pressure is first determined based on the formation at the tunnel location. Then, the internal forces of the lining are calculated using the calculation method for the structure on the elastic foundation, and the structural section design is carried out accordingly. The calculation model is shown in the figure below.



Calculation model of cut-and-cover tunnel **Calculation model of mined tunnel**

Figure 5. 21. Schematic diagram of calculation model of secondary lining of tunnel

(2) Load and combination

According to the Mongolian standards Railway and Road Tunnels (БНбД 32-05-07), Load and Action (БНбД 20-04-17), and Concrete and Reinforced Concrete Structures. General Rules (БНбД 52-01-10), and referring to the Chinese standards Specifications for Design of Highway Tunnels Section 1 Civil Engineering (JTG 3370.1-2018) and Code for Design of Concrete Structures (GB 50010-2010) (2015 edition)， combined with the general situation of this tunnel and the engineering geological conditions, the loads acting on the tunnel are as follows：

1) Self-weight of the structure: Refers to the vertical load caused by the weight of the lining itself. The unit weight of reinforced concrete is taken as 25 kN/m³.

2) Formation pressure: Includes both vertical formation pressure and horizontal formation pressure.

3) Elastic resistance: It represents the constraining force provided by the formation to the structure, and its value is the product of the resistance coefficient and the constraint displacement.

4) Hydrostatic pressure: According to the preliminary geological survey report, there is no groundwater present in the formation at the tunnel location, and the hydrostatic pressure effect is not considered.

The tunnel lining structure shall be subjected to structural strength verification under the Ultimate Limit State and crack width verification under the Serviceability Limit State. According to the Mongolian standard, Concrete and Reinforced Concrete Structures. General Rule (БНбД 52-01-10), and concerning the Chinese standard Code for Design of Concrete Structures (GB 50010-2010) (2015 edition), the crack width should be verified under the Serviceability Limit State (Case 2) load combination, and the maximum limit of the crack width is 0.2mm. In this calculation, internal force analysis is conducted for the typical sections of the cut-and-cover tunnel lining, the Class V surrounding rock lining, and the Class IV surrounding rock lining. Reinforcement and maximum crack width verification are performed for the most unfavorable sections. The load combinations under different sections are shown in the following table.

Table 5. 19. Load combination table

Calculation Section	Combination Name	Combination Type	Verification Item	Partial Factor for Structural Self-Weight	Partial Factor for Earth Pressure
Cut-and-Cover Tunnel Lining	Case 1	Ultimate Limit State	Strength Check	1.2	1.15
	Case 2	Serviceability Limit State	Crack Width Check	1.0	1.0
Class V Surrounding Rock Lining	Case 1	Ultimate Limit State	Strength Check	1.2	1.6
	Case 2	Serviceability	Crack Width	1.0	1.0
Class IV Surrounding Rock Lining	Case 1	Ultimate Limit State	Strength Check	1.2	1.6
	Case 2	Serviceability Limit State	Crack Width Check	1.0	1.0

(3) Formation pressure calculation

The vertical pressure on the cut-and-cover tunnel section is equal to the weight of the overlying backfill material. In contrast, the horizontal earth pressure is calculated as the vertical pressure multiplied by the lateral earth pressure coefficient. The backfill material for the cut-and-

cover section is gravel soil with a unit weight of γ = 20 kN/m³. The maximum backfill depth of the tunnel crown is 5 meters. The simplified calculation diagram is shown below.

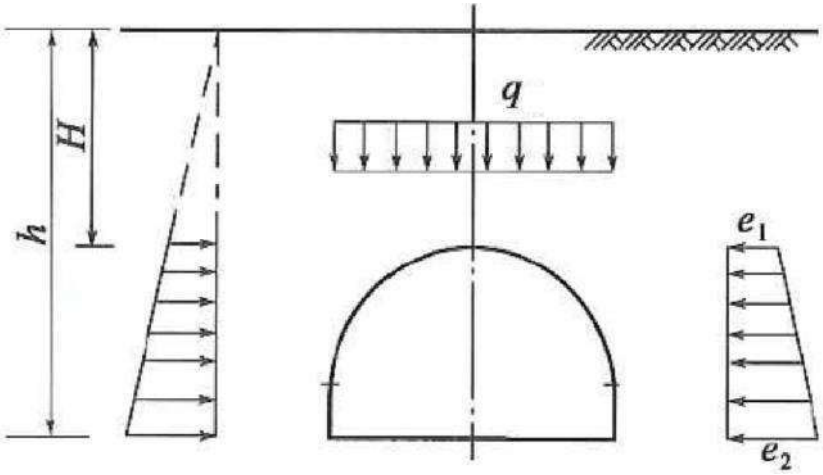


Figure 5. 22. Schematic diagram of cut-and-cover tunnel load calculation

The tunnel sections in Class V and Class IV surrounding rock zones are small-spaced tunnels. The surrounding rock pressure is calculated using the method applicable to small-spaced tunnels. The distribution of surrounding rock pressure for the Class V and IV sections is shown in the figure below. The initial support and secondary lining bear the tunnel surrounding rock pressure. In this calculation, the secondary lining is assumed to bear 60% of the total surrounding rock pressure.

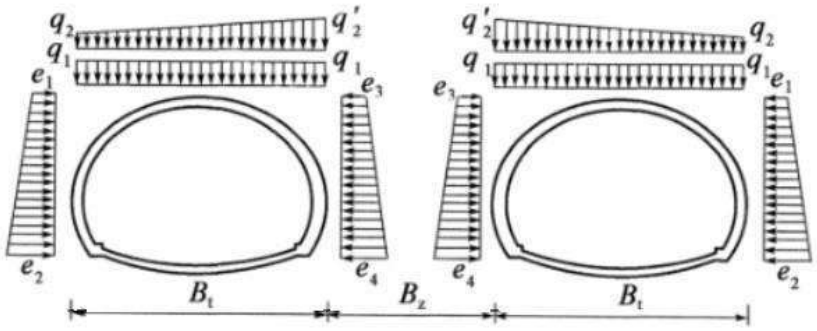
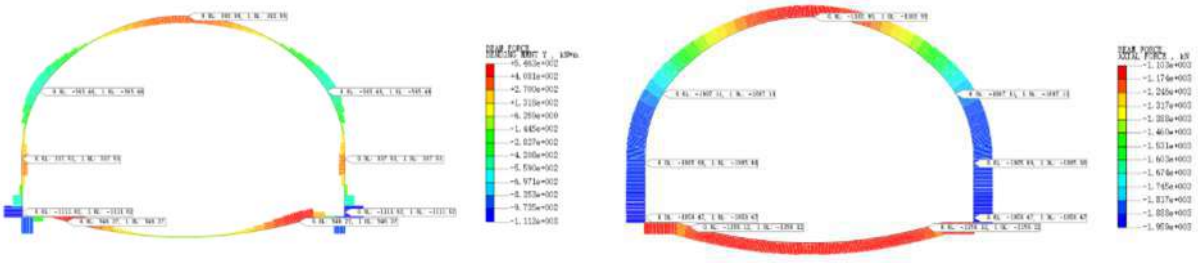


Figure 5. 23. Schematic diagram of lining pressure calculation for Class V and IV surrounding rock sections

(4) Calculation results

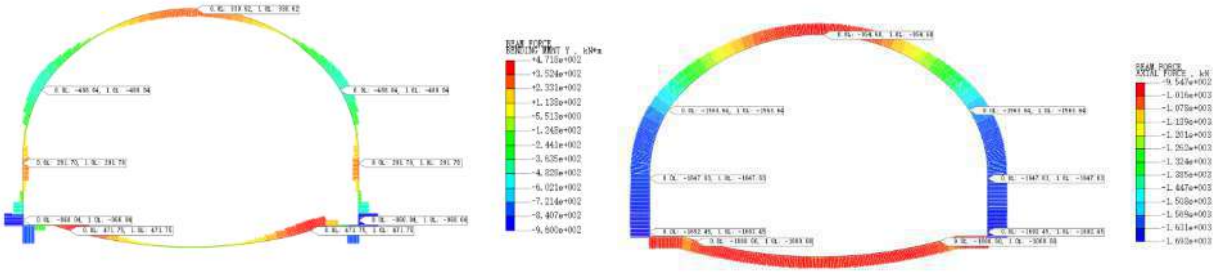
1) Calculation results of the cut-and-cover tunnel lining structure

The internal force distribution of the cut-and-cover tunnel lining structure is shown in the figure below.



Bending Moment Diagram (KN*m) **Axial Force Diagram (KN)**

Figure 5.8.2-4 Internal force diagram of cut-and-cover tunnel lining structure under Case 1 load combination (strength verification)



Bending Moment Diagram (KN*m) **Axial Force Diagram (KN)**

Figure 5. 24. Internal force diagram of cut-and-cover tunnel lining structure under Case 2 load combination (crack width verification)

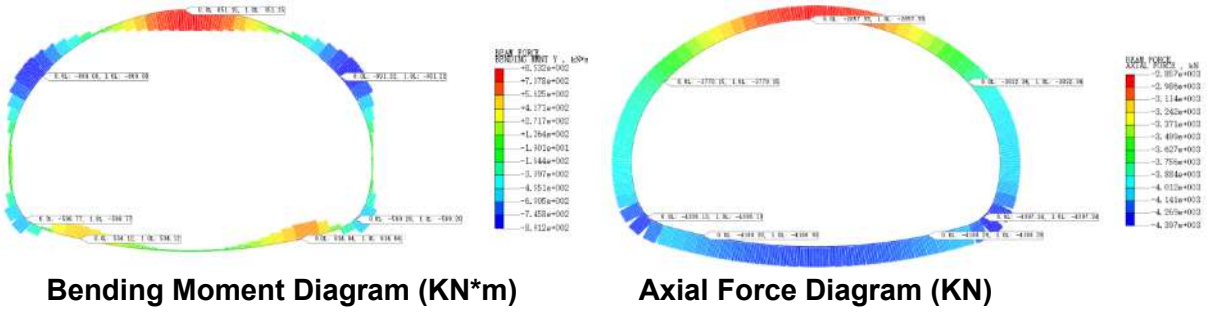
Table 5. 20. Summary table of calculation results of cut-and-cover tunnel lining

Location	Case 1		Required Reinforcement Area (mm²)	Case 2		Provided Reinforcement Area (mm²)	Crack Width Check
	Maximum Bending Moment (KN*m)	Corresponding Axial Force (KN)		Maximum Bending Moment (KN*m)	Corresponding Axial Force (KN)		
Crown	-565.46	-1807.11	1750	-488.84	-1563.64	2454	Satisfied the requirements
Sidewall	-1111.62	-1959.47	1750	-960.04	-1692.45	2454	Satisfied the requirements
Invert	546.27	-1158.12	1750	471.75	-1000.6	2454	Satisfied the requirements

The tunnel lining structure adopts symmetrical reinforcement. The minimum reinforcement ratio for the whole cross-section is 0.5%, and the minimum reinforcement area of the cross-section is 3500 mm². The minimum reinforcement area on each side is 1750 mm². The actual reinforcement provided for the cut-and-cover tunnel lining is As=As'=2454 mm²（C25@200）. Calculation shows that all parts of the cut-and-cover tunnel lining section meet the strength and crack width verification requirements.

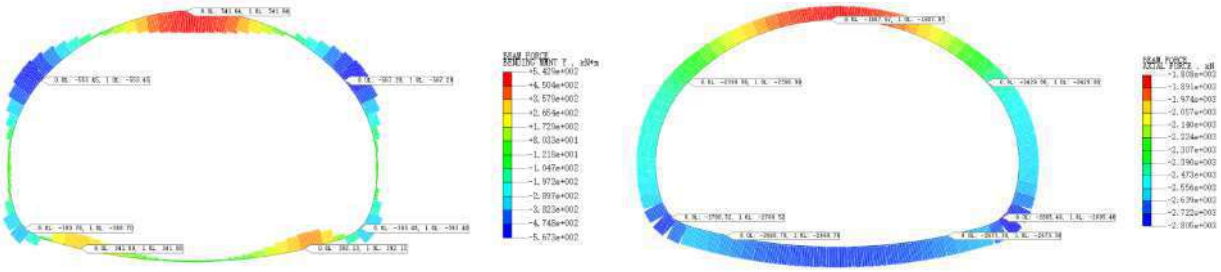
2) Calculation results of the lining structure of the Class V surrounding rock section

The internal force distribution of the lining structure of the Class V surrounding rock section is shown in the figure below.



Bending Moment Diagram (KN*m) **Axial Force Diagram (KN)**

Figure 5. 25. Internal force diagram of lining structure of Class V surrounding rock section under Case 1 load combination (strength verification)



Bending Moment Diagram (KN*m) **Axial Force Diagram (KN)**

Figure 5. 26. Internal force diagram of lining structure of Class IV surrounding rock section under Case 2 load combination (crack width verification)

Table 5. 21. Summary table of calculation results of lining structure of the Class V surrounding rock section

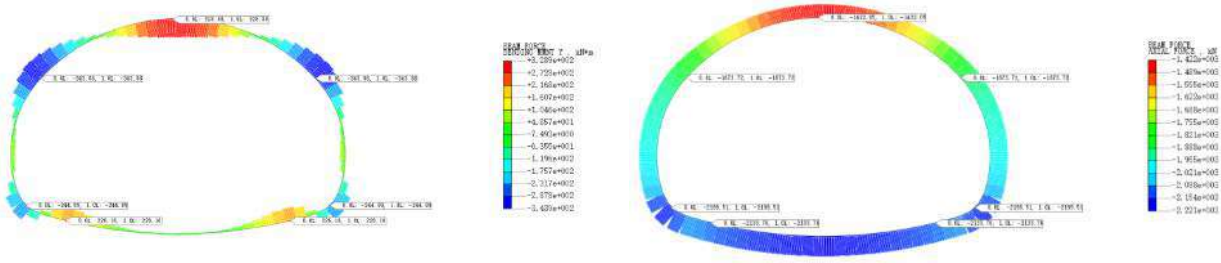
Location	Case 1		Required Reinforcement Area (mm²)	Case 2		Provided Reinforcement Area (mm²)	Crack Width Check
	Maximum Bending Moment (KN*m)	Corresponding Axial Force (KN)		Maximum Bending Moment (KN*m)	Corresponding Axial Force (KN)		
Crown	-891.22	-3832.34	2107.18	-567.29	-2429.86	2454	Satisfied the requirements
Sidewall	-596.77	-4338.13	1500	-380.7	-2768.52	2454	Satisfied the requirements
Invert	614.14	-4186.29	1500	392.13	-2673.38	2454	Satisfied the requirements

The lining structure adopts symmetrical reinforcement. The minimum reinforcement ratio for the full cross-section is 0.5%, and the minimum reinforcement area is 3000 mm². The minimum reinforcement area on one side is 1500 mm². The actual reinforcement provided for Class V surrounding rock section lining is As=As'=2454 mm² (C25@200). Calculation shows that all parts of the full cross-section of Class V surrounding rock section lining meet the strength

and crack width verification requirements.

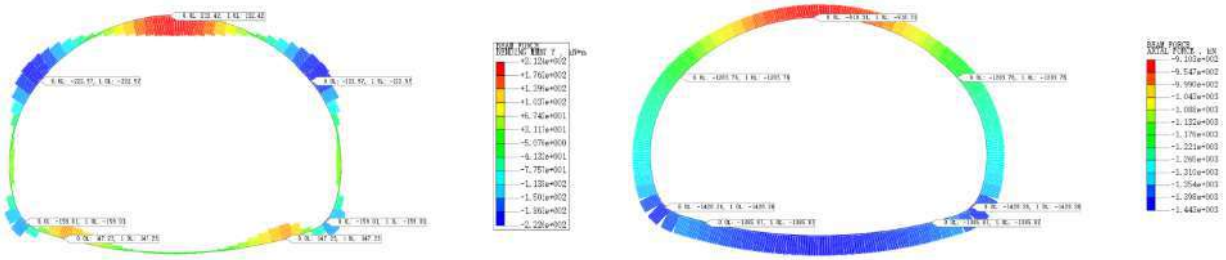
3) Calculation results of the lining structure of the Class IV surrounding rock section

The internal force distribution of the Class IV surrounding rock lining structure is shown in the figure below.



Bending Moment Diagram (KN*m) **Axial Force Diagram (KN)**

Figure 5. 28. Internal force diagram of lining structure of Class IV surrounding rock section under Case 1 load combination (strength verification)



Bending Moment Diagram (KN*m) **Axial Force Diagram (KN)**

Table 5. 22. Summary table of calculation results of lining structure of Class IV surrounding rock section

Location	Case 1		Required Reinforcement Area (mm²)	Case 2		Crack Width Check
	Maximum Bending Moment (KN*m)	Corresponding Axial Force (KN)		Maximum Bending Moment (KN*m)	Corresponding Axial Force (KN)	
Crown	-343.86	-1873.72	1350	-222.57	-1203.76	Satisfied the requirements
Sidewall	-244.89	-2199.51	1350	-159.01	-1428.20	Satisfied the requirements
Invert	226.18	-2133.76	1350	147.23	-1385.87	Satisfied the requirements

The lining structure adopts symmetrical reinforcement. The minimum reinforcement ratio for the full cross-section is 0.5%, and the minimum reinforcement area is 2700mm². The minimum reinforcement area on one side is 1350mm², and the actual reinforcement provided for Class IV surrounding rock section lining is As=As'=1520mm² (C22@250). It can be calculated that all parts of the full cross-section of Class IV surrounding rock section lining meet the strength and crack width verification requirements.

5.9. TUNNEL THERMAL INSULATION AND FROST PROTECTION DESIGN SCHEME AND MEASURES

The project area belongs to the intermountain steppe subzone of Mongolia's Climate Zone Ⅱ B, with an extreme continental climate. This region is characterized by an exceptionally arid-cold climate with severe conditions, abundant precipitation, and deep freezing of soils and bedrock. The design elevation of the proposed tunnel alignment is approximately 1,440 meters, with the annual minimum temperature reaching as low as -45°C. Therefore, it is necessary to consider the safety and the long-term service life of the structure of cold-region tunnels during operation. After referring to the use of railway and highway tunnels in cold regions of China, Europe, the United States, Japan and other countries, it is found that similar tunnels have very serious frost damage, and there are even precedents of severe frost damage leading to the scrapping of the main structure of the tunnel and major traffic safety accidents during operation. According to the latest statistics from the Japan Highway Public Corporation and the Japan Railway Technical Research Institute, 1,100 of the 3,800 railway tunnels in Japan endanger driving safety due to frost damage during winter operations. Among highway tunnels, 104 of the 302 large highway tunnels in Hokkaido alone suffered serious frost damage. In order to eliminate ice on the sidewalls and icicles on the crowns, electric heating devices were installed in many tunnels, and the cost of remediation invested was truly staggering. In China, there were also repeated examples of failed tunnel projects built in the same special environment in the early years. For example, the Tianshan No. 2 Tunnel in Xinjiang, China, was almost scrapped because the tunnel leakage was extremely serious and the water leakage froze in winter, making it impossible to ensure normal traffic conditions. Another example is the Qiaodalang Tunnel in Gansu Province, China. Due to the freezing of the drainage ditches in winter, the tunnel drainage was not smooth, causing frost heave behind the lining and triggering cracks in the lining concrete. The tunnel experienced leakage and icy pavement, affecting traffic safety. The main reason for this result is that most of these tunnels were built before the 1990s, the anti-freeze design of the tunnels was not given enough attention during construction, and the lessons learned are extremely profound. Therefore, it is very important to study the influence patterns of the freeze-thaw zone of the tunnel in different seasons and the reasonable cold-proof and heat-insulating technology. Building tunnels in high-altitude and cold areas is a comprehensive technical problem in the world. During construction, it is necessary to prevent both frost heave and freeze-thaw damage, ensure waterproofing and seepage control, and maintain smooth drainage channels. Issues such as ensuring project quality and guaranteeing normal construction under cold conditions must be tested and explored through construction practice. China has drawn lessons from the failures of similar tunnel projects constructed under comparable environmental

conditions, and has successfully overcome key technical challenges related to cold-region tunnels, including frost heave prevention for tunnel linings, insulation technology for tunnel linings, waterproofing and drainage systems, high in-situ stress management, and fault-induced water inflow control. The types of frost damage in the tunnel are illustrated in the following figure:

Icicle formation due to water seepage from the tunnel crown

Ice formation due to water seepage from tunnel sidewalls

Pavement icing

Severe frost damage

Figure 5. 29. Common forms of frost damage

(1) Main forms of tunnel frost damage

1) Instability of the tunnel lining structure caused by frost damage in the surrounding rock, resulting in partial extrusion of tunnel lining structure, or even overall collapse of the tunnel.

2) Large-scale spalling and cracking of the tunnel lining due to frost damage.

3) Freezing behind the lining, leading to thawing and leakage, or even water inrush.

4) Formation of icicles at the tunnel crown.

5) Wall ice formation due to freezing on the tunnel sidewalls.

7) Water accumulation and icing at the bottom of the tunnel.

For cold-region tunnels constructed in frost-susceptible surrounding rock, the additional frost heaving stress exerted on the tunnel lining due to freezing of the surrounding rock can be substantial. This stress primarily manifests in two aspects: On one hand, the crown and curved walls of the secondary lining are subjected to significant compressive stress. When the frost

heaving stress is superimposed on the compressive stress from other structural loads, the concrete lining becomes highly susceptible to damage. On the other hand, under the action of such frost heaving forces, the corner zones of the side walls may fail due to excessive tensile stress.

(2) Causes of frost damage in cold-region tunnels

1) The volume change of the concrete causes cracks, which leads to water seepage.

The volume change of concrete is mainly caused by three factors: (1) Chemical shrinkage, which refers to the volume reduction resulting from the transformation of free water into bound (crystalline) water during cement hydration; (2) Drying shrinkage, which refers to the volume reduction caused by moisture loss when the cement paste is exposed to a low-saturation humidity environment; (3) Carbonation shrinkage, which refers to the volume change due to the carbonation process. These three factors can all cause cracking in concrete, but such cracks are generally fine and shallow.

2) Temperature cracks cause water seepage

Temperature cracks are common in concrete structures and may be superficial, deep and penetrating. Surface cracks tend to follow irregular patterns, often intersecting, and typically occur during the construction period. Such surface temperature cracks are mostly caused by large temperature differences between the concrete surface and its interior. For example, during winter construction, premature removal of formwork or insulating layer may lead to cooling and shrinkage of the concrete surface, while being restrained by the inner concrete, resulting in cracking. The deep and penetrating temperature cracks are generally distributed circumferentially, and tend to appear intermittently along the entire length. The most common type is the circumferential construction joint of the lining, which often occurs 2 to 3 months or longer after concrete pouring, with wider crack openings in winter and narrower ones in summer. Although such circumferential cracks have little effect on the bearing capacity of the lining structure, they serve as effective channels for water leakage of lining. The deep and penetrating temperature cracks are developed mostly due to the cooling of the overall structure, and the temperature difference is large, and the outside is further constrained by the surrounding rock, which will produce a large tensile stress in the lining, causing cooling-induced shrinkage cracks caused by external constraints.

3) Water seepage caused by "three types of joints"

The three joints are settlement joints, deformation joints and construction joints. Through the investigation, analysis and statistics of tunnel diseases, it is found that all tunnels with diseases generally have water seepage from settlement joints, deformation joints and construction joints, especially cracking and leakage from construction joints.

4) Water seepage caused by improper waterproofing and drainage measures

If the waterproofing and drainage system behind and at the bottom of the tunnel lining in cold regions is improperly designed and constructed, the lining will produce wall ice or hanging ice due to water seepage, or the water will overflow to the pavement due to blockage and freezing of the ditch, causing frost damage such as pavement icing.

(3) Comprehensive anti-frost measures for long mountain tunnels in cold regions

1) Use of frost-resistant concrete and appropriate reinforcement at tunnel portal sections.

2) Reduction of localized water accumulation space through pre-grouting of surrounding rock and secondary grouting behind the lining,

which also helps to prevent water seepage.

3) In portal sections that are susceptible to frost damage, thermal insulation measures such as surface insulation layers or geothermal heat pump lining systems shall be considered to prevent frost heave of the surrounding rock and localized water accumulation behind it.

4) Adoption a suitable waterproofing and drainage system, especially in the portal zone. Deep-buried ditches or frost-protected ditches should be used to prevent the water discharged from the portal section from overflowing and causing pavement icing due to inability to discharge from the tunnel.

5) Improvement of construction quality to avoid cracking, water leakage, and other defects in the lining caused by improper construction.

(4) Anti-frost measures to be taken for the tunnel in this project

According to the geological investigation data, the route passes through the intermountain steppe subzone of Mongolia's Climate Zone Ⅱ B, with an extreme continental climate. This region is characterized by an exceptionally arid-cold climate with severe conditions, abundant precipitation, and deep freezing of soils and bedrock. After the tunnel is completed, the intrusion of warm and cold air may create a freeze–thaw zone along the tunnel periphery from the portal inward to a certain depth, where water freezes in winter and melts in summer.

1) In order to ensure that the temperature behind the lining in winter remains above 0℃, setting up a thermal insulation lining section within a certain range of the portal shall be considered. The insulation layer of the thermal insulation lining shall be set on the inner surface of the secondary lining and consist of a 5–6 cm thick foam polyurethane (PU) insulation material, or a geothermal heat pump shall be installed in the tunnel lining (specific research is still needed). In addition, the foundations of all structures in the portal section shall be buried below the depth line of the permafrost to ensure structural stability.

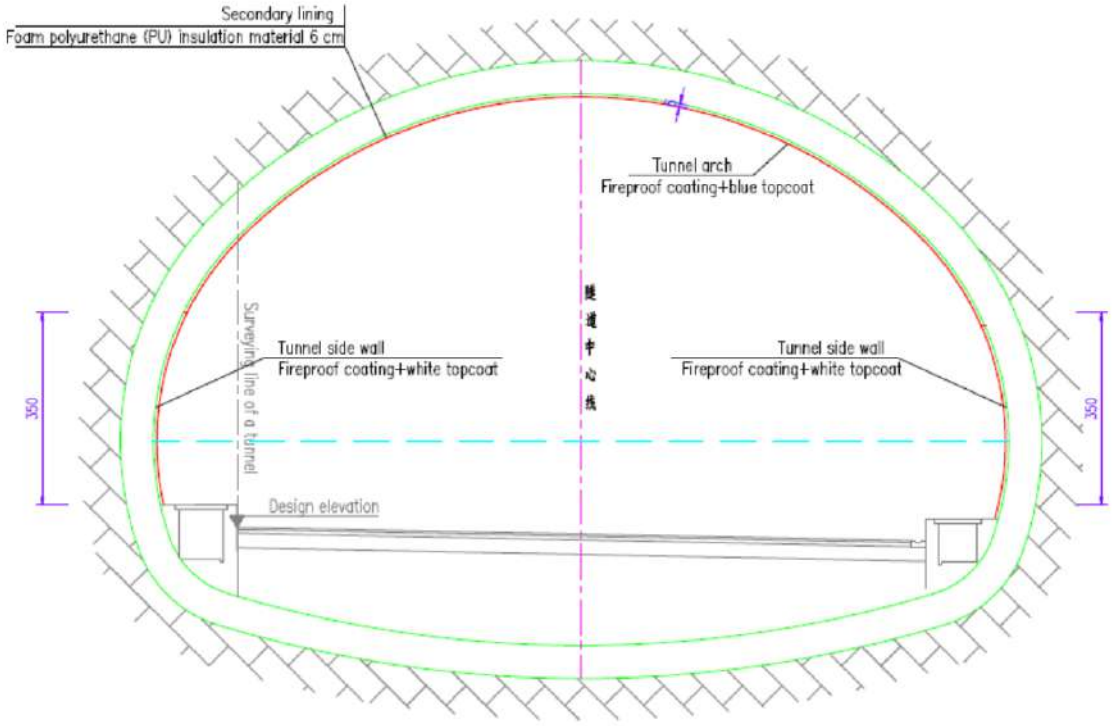


Figure 5. 30. Setting of the thermal insulation layer at the portal

2) Within a certain distance from the tunnel portal, a central drainage channel shall be installed beneath the invert. The central drainage ditch shall be buried at a certain depth under the pavement to ensure that the burial depth of the central drainage ditch are below the maximum permafrost depth. The central drainage ditches set up in other tunnel areas shall be buried at a depth of no less than 0.85 meters under the pavement, utilising geothermal heat to prevent freezing.

3) The joints of the circumferential drainage pipes, longitudinal drainage pipes and transverse drainage pipes at the foot of the wall shall be wrapped with geotextile to prevent silt and sand from blocking the pipes, and avoid frozen water blocking the circumferential drainage pipes, longitudinal drainage pipes, and transverse drainage pipes of the lining, thereby preventing the failure of the tunnel drainage system, which could endanger the surrounding rock and lining structure.

4) A central inspection well shall be set up at intervals of every 200 m along the tunnel central drainage channel. The wellhead shall be sealed with concrete, and an internal thermal insulation layer shall be installed to ensure the regular use of the central inspection well.

5) A buried insulated drainage outlet shall be installed at the outlet of the tunnel frost-proof drainage ditch to ensure the smooth operation of the tunnel drainage system.

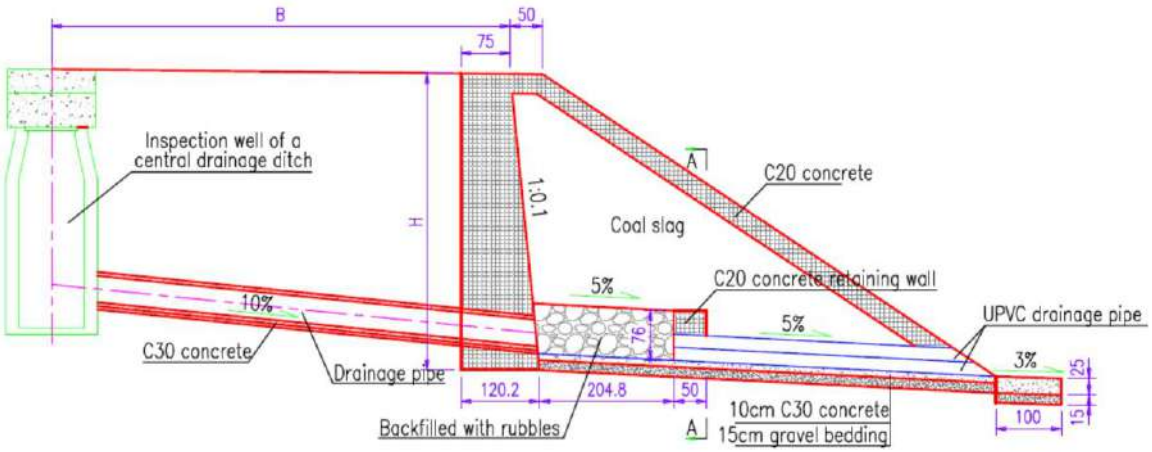


Figure 5. 31. Schematic diagram of drainage outlet insulation

6) The side ditches in the main tunnel shall be installed below the road surface to ensure adequate burial depth. A sedimentation pit shall be installed every 25 meters along the side ditch. The sedimentation pits shall adopt a double-cover structure, with asphalt glass wool used as the insulation layer between the two covers. Under the cable trench cover, a 5cm thick polyurethane foam plastic insulation layer shall be applied.

7) The initial support strength of the portal section shall be strengthened to reduce the pressure of secondary lining.

8) Grouting shall be carried out in the surrounding rock to seal fissure water and reduce the impact of freeze–thaw action on the surrounding rock.

9) Improve the quality and smoothness of the shotcrete of initial support, protect the waterproof membrane, enhance the adhesion between layers, and increase the frost protection depth of the structure. Use a specialized air-conditioning ventilation fan for permafrost tunnels to adjust the temperature at any time according to the needs of the working surface. This ensures that the excavation face maintains minus temperatures to prevent thaw-induced collapse and the expansion of the freeze–thaw zone, while also ensuring the normal development of concrete strength.

10) The secondary lining of the portal section shall adopt a reinforced concrete structure to improve the stress performance of the structure and avoid damage caused by frost damage.

11) Based on the relevant experience and research results of mountain tunnels in cold areas of China, relevant suggestions were put forward for the fortification length and insulation materials of the tunnel insulation section.

The temperature inside the tunnel decreases progressively from the portal toward the interior, influenced by the external air temperature. After reaching a certain depth, the internal tunnel temperature becomes largely unaffected by outside temperature. The extent of this

influence is closely related to factors such as the coldest monthly temperature at the portal, tunnel length, and prevailing wind direction. The relationship between tunnel temperature and distance from the portal is illustrated in the following figure.

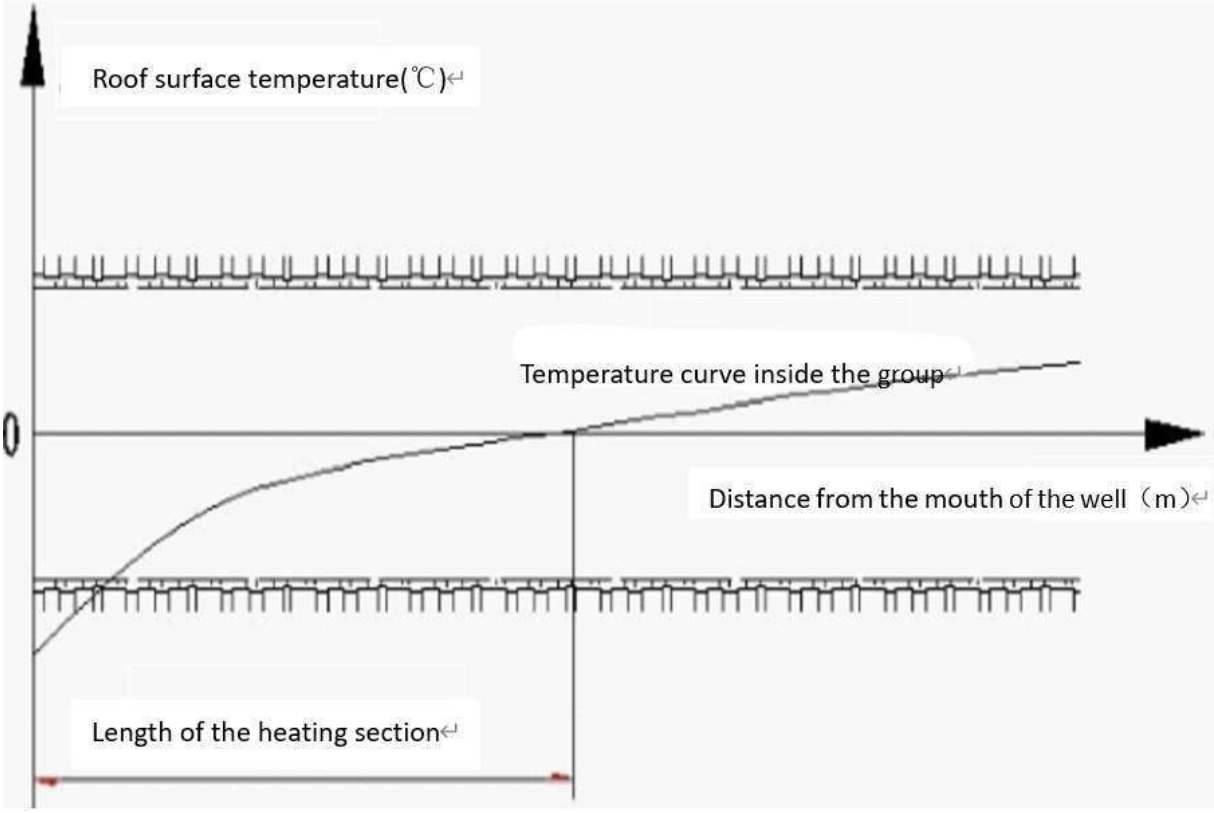


Figure 5. 32. Relationship diagram between lining surface temperature and distance from tunnel portal

For tunnels shorter than 2,000 m, it is recommended to apply thermal protection along the entire length. For tunnels longer than 2,000 m, the thermal protection lengths at both ends should be determined based on calculations. In cases where significant differences exist in terrain, climatic conditions, or elevation between the two ends of a tunnel—particularly for tunnels influenced by prevailing wind directions—the thermal protection lengths should be arranged asymmetrically. In the next stage, based on geological and hydrogeological conditions and the results of meteorological data analysis, fundamental parameters shall be obtained to further calculate and determine the required thermal insulation length of the tunnel.

The tunnel lining concrete shall be frost-resistant concrete. Where necessary, special concrete mixed with basalt fibers may be considered to enhance the frost resistance of the concrete. In addition, it is feasible to apply frost-proof insulation materials for thermal protection of the tunnel. It is recommended to use foam polyurethane (PU) insulation materials for tunnel lining.

5.10. Tunnel construction method

5.10.1. Tunnel excavation method

The cut-and-cover tunnel shall be excavated using the cut-and-cover method, while the mined tunnel shall be designed and constructed based on the principles of the New Austrian Tunneling Method (NATM). Given that this is a large-span tunnel, and to ensure construction safety, it is recommended that mechanical excavation method be primarily adopted in the portal section with Class Vsurrounding rock, considering the lithological conditions. For shallow-buried sections with Class Vsurrounding rock and sections with Class IV surrounding rock, "smooth blasting" or "pre-splitting blasting" techniques shall be used to maximize the preservation of the integrity of the surrounding rock mass and to control over- and under-excavation. A trackless muck removal system shall be employed.

Before commencing excavation at the portal section, a intercepting ditch shall be constructed at the tunnel crown to prevent surface water from seeping into the excavated surface,which could affect the stability of the cut-and-cover tunnel slope and the excavated surface. During excavation, slope protection works must be carried out simultaneously with slope excavation. A core soil section shall be reserved near the excavated surface. Tunnel excavation shall commence only after the completion of the construction of the long pipe shed at the tunnel portal. For cases where the slopes and backfill slopes after cut-and-cover tunnel excavation are relatively high (generally exceeding 15 m), or where the overburden at the portal is thick and geological conditions are poor, construction of the mined tunnel shall only commence after the backfilling and counter-pressure of cut-and-cover tunnel have been completed.

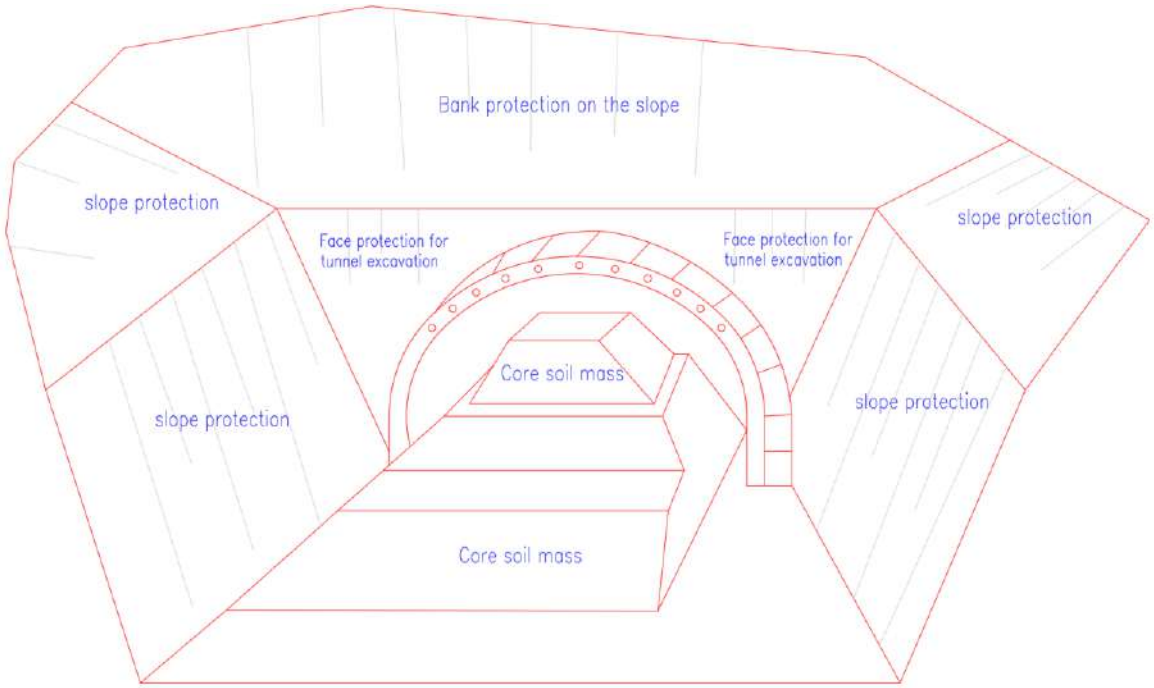


Figure 5. 33. Schematic diagram of tunnel portal excavation

The main tunnel section is constructed using the mined method. It is recommended to adopt the double side drift method for excavation in Class V surrounding rock sections, and the ring excavation method with reserved core soil for Class IV surrounding rock sections. The specific details can be adjusted according to the on-site geological conditions. Tunnel excavation shall be carried out in a staggered manner, with the leading tunnel always ahead of the following tunnel by no less than 50 meters. The staggered length of the secondary lining concreting shall not exceed the length of one lining cycle. During construction, the condition where both left and right tunnels are only supported by initial support shall be strictly avoided. During excavation, advanced support shall be reinforced and primary support shall be applied in a timely manner. To prevent subsidence of the initial support arch foot, each arch frame shall be equipped with foot-locking forepoling pipes or foot-locking anchor rods.

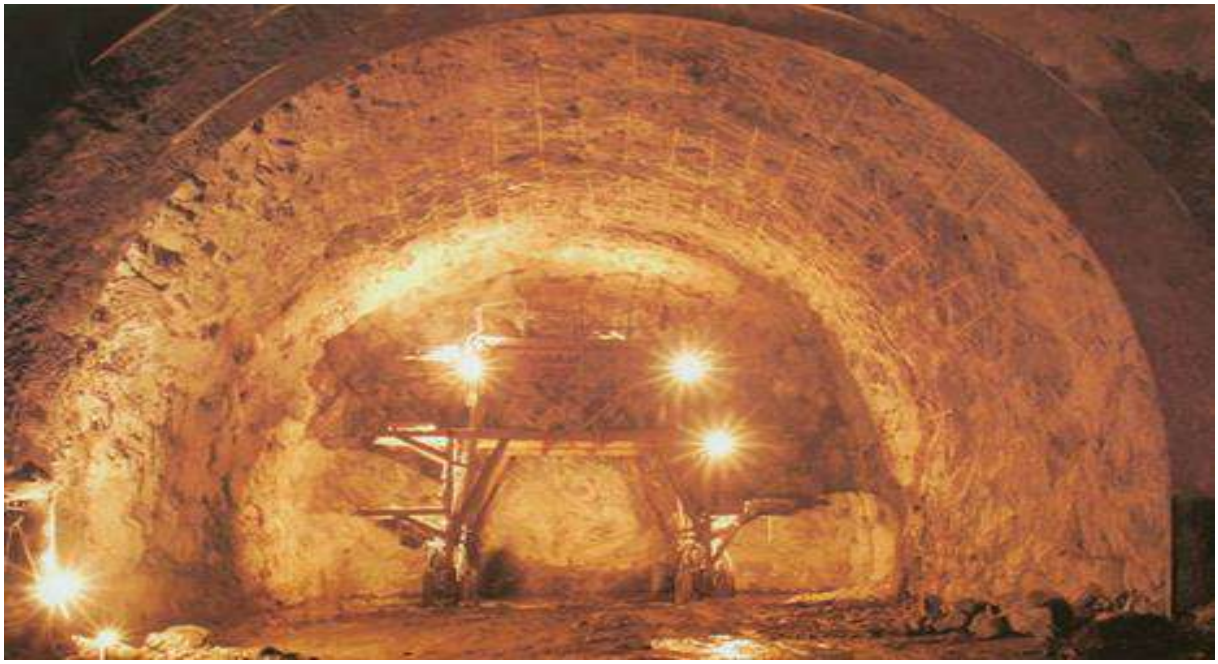


Figure 5. 34. Full cross-section excavation construction

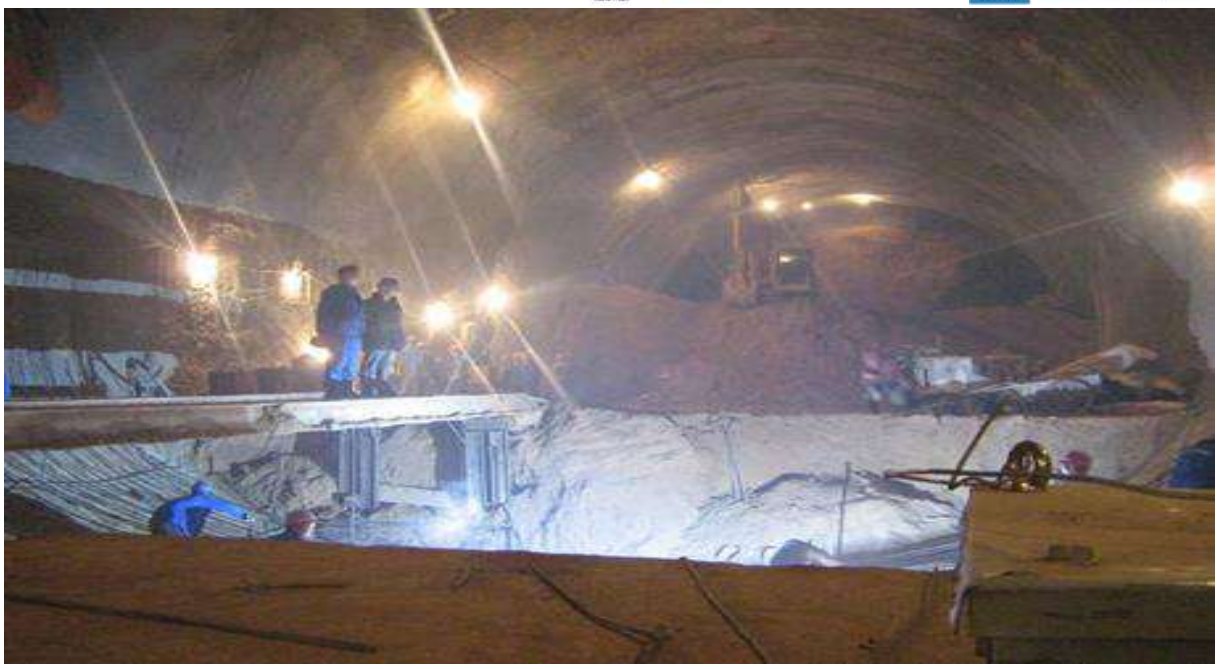


Figure 5. 35. Ring excavation method with reserved core soil

Figure 5. 36. Excavation construction with double side drift method

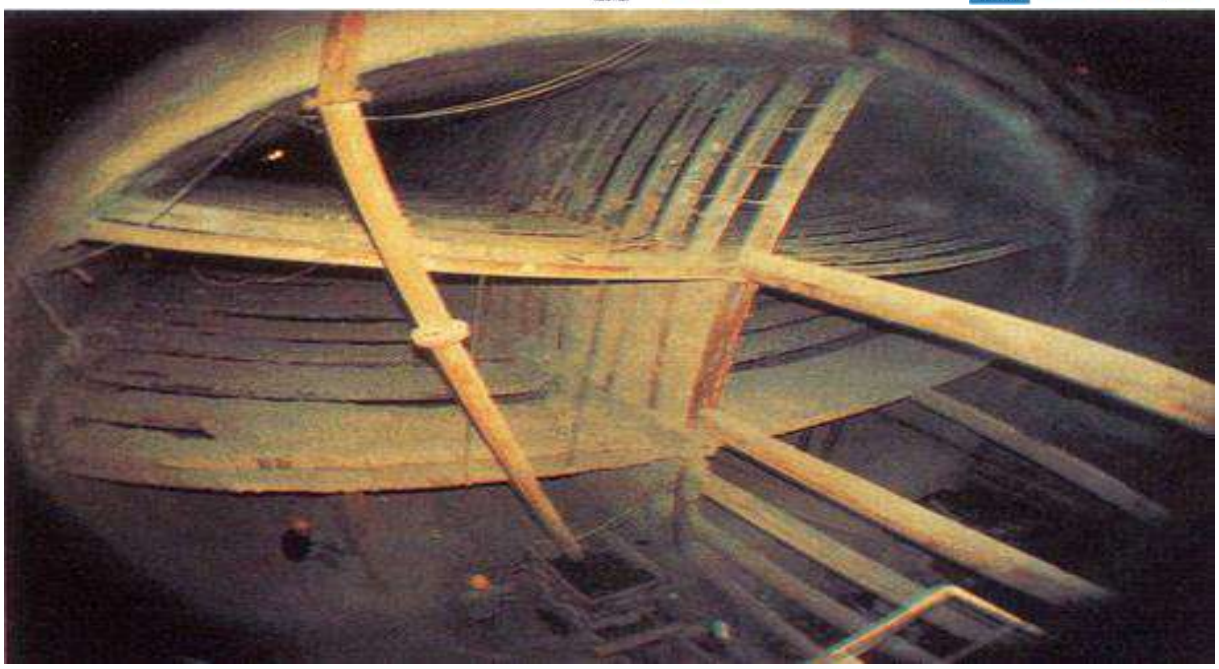


Figure 5. 37. Excavation construction with CRD method

During tunnel excavation, disturbance to the surrounding rock should be minimized, and over-excavation and under-excavation must be strictly controlled. The steel mesh and steel supports must be closely attached to the rock surface, with tight contact. Precast concrete blocks shall be padded and wedged to ensure that the primary support is installed in a timely and reliable manner. The secondary lining shall be constructed using a mechanized system consisting of concrete transit mixers, delivery pumps, and a lining formwork trolley, ensuring that the concrete achieves a dense interior and smooth surface finish.

Figure 5. 38. Schematic diagram of mechanized equipment for tunnel construction

5.10.2 Construction period

Based on the scale of tunnel construction, geological conditions, and the technical capabilities of construction machinery and equipment, the project adopts a bidirectional excavation approach, divided into two construction zones at the entrance and exit, with a total of four working faces. The preparation phase is estimated to take 3 months, and tunnel construction and electromechanical installation are expected to take 18 months, resulting in a total construction period of 21 months.

To ensure construction safety and avoid mutual interference between the excavation operations of the left and right tunnels, the following control requirements are proposed for the longitudinal spacing between the tunnel faces of the left and right tunnels, based on differences in surrounding rock conditions: in sections with weak surrounding rock, the longitudinal distance between adjacent working faces shall be no less than 50 meters; in sections with hard rock, the spacing may be appropriately reduced but shall not be less than 30 meters. During construction, the principle of "support first, then excavation" must be strictly followed. Excavation of the opposite tunnel shall only commence after the support structure of the leading tunnel has achieved the designed stability, in order to avoid the superposition of surrounding rock stresses. According to the construction organization design and taking into account all factors, the staggered time for the excavation operation of the left and right tunnels is temporarily controlled to be 1 month.

5.10.3. Tunnel construction organization design

(1) Construction organization plan

The tunnel construction shall adopt a series of mechanized construction equipment, tunnel muck removal shall use a trackless transportation method, and the secondary lining casting shall use a formwork trolley.

During the construction period of the tunnel, a large amount of excavated material will be produced. Some of them can be used for roadbed filling, roadbed protection, pavement base, and subbase filling. However, a portion of the excavated material will be treated as waste spoil. Therefore, a spoil disposal site needs to be established and properly protected to prevent soil erosion and environmental damage. At the same time, construction will also cause damage to the groundwater system, causing the redistribution of groundwater resources, which may cause inconvenience to the villages around the tunnel that rely on groundwater to live. Therefore, tunnel construction should minimize adverse effects on the ecological environment near the project.

(2) Construction site layout

The layout of tunnel construction sites should determine the scale, location and main layout

organization form based on factors such as the scale of the tunnel project, construction method, construction environment. The main facilities outside the tunnel include: explosive storage depot, building material storage yard, power supply and distribution station, muck transportation yard, cement and aggregate stacking yard, sewage treatment plant, laboratory and living and working facilities. Construction sites are generally arranged near the entrance and exit. Considering the transportation distance, transportation, safety and other reasons, the steel bar sites and sand and gravel yards shall be arranged near the entrance and exit to facilitate construction. Office places and dormitories are arranged more flexible, and are generally arranged near the tunnel portal. The compressor room is arranged near the tunnel portal based on the principle of minimizing ventilation energy loss by close proximity.

(3) Construction access road layout

The layout of the construction access road should make full use of existing roads wherever possible. Dedicated design should be carried out for major access roads, with priority given to selecting favourable horizontal and vertical alignments while minimising environmental impact. The layout of access roads for tunnel construction shall be planned in coordination with the overall alignment of bridges, culverts, and subgrade works along the route.

(4) Spoil disposal plan. The primary considerations for tunnel spoil disposal are to prevent environmental pollution and soil erosion. Therefore, tunnel excavated material should be reused as much as possible. For spoil that cannot be reused, proper slope toe protection works shall be implemented after disposal, and surface greening measures such as topsoil covering, tree planting, and grass seeding shall be carried out.

5.10.4. Construction monitoring and measurement

On-site monitoring and measurement are one of the core technologies of the design and construction of composite linings based on the NATM (New Austrian Tunnelling Method). Through construction site monitoring, the mechanical behaviour and stability of surrounding rocks and support structures can be mastered during the construction process, ensuring construction safety, and providing a basis for evaluating and modifying support parameters and determining the implementation time of secondary lining.

According to the specific conditions of this tunnel, it is recommended to conduct the following measurement items during construction.

(1) Tunnel surrounding rock deformation measurement

Through the deformation convergence measurement in the tunnel, the stability of the tunnel is monitored and the deformation characteristics of the tunnel are evaluated. This is one of the primary monitoring items and includes measurements of tunnel clearance convergence, crown settlement, and internal displacement of the surrounding rock.

(2) Stress-strain measurement

Strain gauges, stress cells, and load cells are used to monitor the stress and deformation of steel arch frames, lattice supports, anchor rods, and tunnel linings, to assess and evaluate the support effect.

(3) Analysis of surrounding rock stability and support effect

By organising and performing a regression analysis of the measurement data, the internal laws can be found to evaluate the stability and support effect of the surrounding rock. Then the displacement analysis method is used to inversely calculate the initial stress field and the comprehensive physical and mechanical parameters of surrounding rock, which are subsequently compared and validated against the actual results.

5.10.5. Geological advance forecast

In order to ensure the safety of tunnel construction and structure, advance geological forecasts should be made for tunnels during construction. Methods such as drilling and geophysical exploration shall be used to detect and predict the engineering geological and hydrogeological conditions of the surrounding rock ahead of the excavation face. Based on these investigations, and combined with geological changes observed during excavation, timely forecasts shall be made regarding potential collapses of the surrounding rock, sudden water inflows, inflow volume, groundwater conditions, mud and sand content, and their possible impacts on construction. Corresponding countermeasures shall be analyzed and proposed to ensure construction safety. Tunnel geological forecasting should be included in the construction organization management as a necessary process.

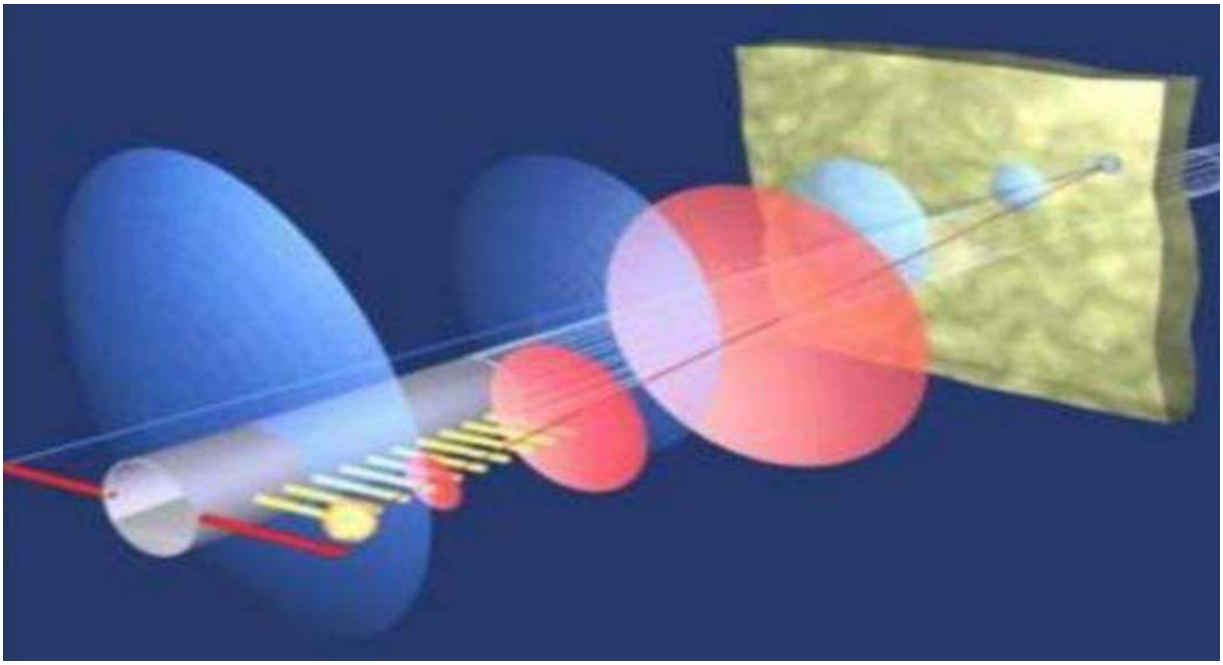


Figure 5. 39. Schematic diagram of tunnel advance geological forecast

5.11. RISK MANAGEMENT IN TUNNEL ENGINEERING CONSTRUCTION

5.11.1. Overview

As a primary mode of route laying, tunnels involve significant engineering risks during the construction process. In case of tight schedules and strict investment controls, the concept of risk management has gradually been applied to urban transportation system construction over years of practice and development in urban engineering. This project should fully leverage successful experiences in this field to facilitate risk management, mitigate risks, and ensure the successful completion of the project.

5.11.2. Phases Division and Phased Tasks of Engineering Risk Management

(1) Risk Management Phases

Based on the project features and environmental conditions, as well as the general rules of risk management and the characteristics of tunnel engineering, a rigorous risk management plan should be formulated. The risk management for this project is divided into three phases: scheme phase, design phase (including preliminary design, technical design, and construction design), and construction phase. The main tasks for each phase include: risk identification, risk assessment (further divided into estimation and evaluation), and risk control. Key tasks for each phase are detailed in the table below.

Table 5. 23. Phases Division and Key Work Statistics of Risk Management

Risk Management Phase	Risk Management Content		
	Risk Identification	**Risk Assessment**	**Risk Control**
Scheme Phase	Collect basic data and expert consultation opinions to form the foundation of the engineering risk management system. Identify risk sources in the engineering environment and the project itself to provide reference for planning and design.	Focus on risk estimation, primarily using analogy methods and expert consultation to determine the scale of risks and their acceptable levels in case of occurrence.	Propose main engineering measures for risk avoidance using analogy methods and expert consultation, ensuring the feasibility of future projects.
Design Phase	Re-identify risk sources, supplement risk items, and improve or revise basic risk source data.	Focus on risk assessment, combining numerical simulation analysis with engineering analogies and expert consultation; establish risk levels and define risk control indicators.	Design comprehensive risk disposition measures and strategies; and set risk alert, pre-warning, and alarming indicators.

Risk Management Phase	Risk Management Content		
	Risk Identification	Risk Assessment	Risk Control
Construction Phase	Investigate, verify, and correct risk sources.	Conduct supplementary assessments for newly identified risk points, as generally, newly added risk sources are not large in scale.	Monitor, track, and record risks; develop engineering contingency plans for post-risk scenarios; and implement risk avoidance engineering measures.

(2) Identification and Analysis of Engineering Risk Factors

Tunnel engineering are high-risk projects, primarily manifested in complex risk-incubation environments, numerous risk-inducing factors, fragile risk-bearing capacity of carriers, high interdependence among anticipated risks, significant potential for primary disasters to trigger secondary disasters, and severe consequences that are difficult to accept or mitigate. Therefore, it is necessary to investigate, identify, determine, categorize, and pinpoint risk sources that may trigger risks. Through extensive and meticulous efforts, the risk sources for this project mainly include the following categories: underground pipelines, village roads, high-voltage towers, and existing structures.

It should be noted that, in addition to the complex engineering environment mentioned above, the tunnel's own structural complexity is also managed as a risk source: The project site features significant variations in topography and poor geological strata, making geological risks another major concern.

Consequently, in addition to environmental risk sources, tunnel structural risks and engineering geological risks are typically incorporated into the scope of risk management.

(3) Risk Control Outline for the Construction Phase

1) Establish a risk management system based on the project management framework, developing dedicated organizational structures, personnel systems, and work flows for risk management.

2) Inherit all information and data from the survey and design phases, conduct comprehensive and in-depth foundational investigations, and identify all construction-related risk factors in the project's vicinity, including municipal pipelines, roads and bridges, and existing structures.

3) Conduct thorough risk management planning to form a closed and independent risk management system, which covers all stages of risk management: risk identification, risk assessment, and risk control.

4) For each risk source, develop a strict risk management plan, setting three-phase (identification, assessment, and control) risk management objectives. Progression to the next phase is permitted only upon completion of the current phase's objectives, thereby enhancing risk management execution and ensuring no blind spots are carried forward to the next phase.

5) Rigorous construction organization is a critical measure for controlling risk incidents. Conduct in-depth reviews of the completeness of geological survey data and construction design documents. Based on stable construction design documents, carry out overall project planning in advance to form a stable Implementation Construction Organization Design; all key nodes, difficult points, and critical construction schemes must be stable and reliable, with specialized detailed construction organization designs prepared for "relevant nodes or processes"; and equipment plans affecting civil engineering plans should undergo early design reviews and the preparation of implementation construction organization designs.

6) Based on the characteristics of each risk source, classify the risks into appropriate levels; for different risk sources, carry out specialized construction organization design work; and for major risk sources, potential danger signs and adverse conditions should be estimated in advance, and at least one alternative scheme should be prepared beforehand.

7) Integrate traditional quality management with the risk management proposed in this project to ensure the comprehensiveness and uniqueness of control items and inspection indicators, eliminating overlaps and omissions in management.

8) To meet the information needs of risk management, re-integrate and optimize the information platform, enabling traditional underground engineering information platforms to incorporate "alert", "early warning", and "alarming" functions.

9) Fully leverage expert experience within the industry for risk management. For integrated scheme issues, convene large-scale expert review meetings to discuss and finalize solutions; for key nodes, difficult points and other specialized issues, hold irregular expert seminars to incorporate expert insights; and organize quarterly expert consultation meetings to identify and address gaps using expert knowledge.

10) While adopting traditional techniques, explore and implement new processes and materials based on the characteristics of risk sources.

11) Given that risk sources fall under the jurisdiction of various management departments, pro-actively communicate project plans to relevant property units and sign agreements with them to maintain plan stability and rigor, avoiding major disruptions to the project plans due to external factors.

12) Develop "emergency response plans" for all risk sources and conduct specialized drills and comprehensive exercises to ensure timely, effective, and systematic risk incident disposition.

5.11.3. Tunnel Construction Risks and Countermeasures

(1) Main Construction Risks of Tunnels

1) Collapse and Rockfall

During tunnel excavation, various factors can lead to collapses, which can generally be

categorized as: natural factors, such as geological conditions, stress state, groundwater fluctuations, etc.; and human factors, such as inappropriate design or improper construction methods. Technical measures: The "pre-reinforcement" technique is adopted, which involves installing advanced pipe sheds and pre-grouting to reinforce the surrounding rock, thereby improving its performance indicators. Alternatively, jet grouted arches or pre-cutting troughs can be employed to reduce surrounding rock deformation. Before or during construction, feasible drainage measures should be implemented to divert surface water and prevent it from seeping into the tunnel. Appropriate excavation methods, such as the bench cut method, short bench cut method, cross diagram method, or double-side drift method, should be adopted for tunnel excavation. Initial support should be reinforced by increasing the thickness of shotcrete, adding more and longer anchor rods, installing reinforcing mesh or steel fiber-reinforced shotcrete, and using or densifying steel frames. Additionally, measurement of surrounding rock deformation should be intensified. If deformation or abnormal conditions are detected, emergency measures must be promptly implemented, which includes permanent concrete lining support as designed, the use of reinforced concrete lining, increasing the thickness of lining concrete, modifying the lining cross-section form, or enhancing the strength grade of lining concrete.

Figure 5. 40. Tunnel Collapse

2) Water Inrush

Water inrush is one of the most common geological disasters in tunnel construction, second only to collapses. The most common unfavorable geological conditions leading to water and mud inrushes include faults (fault fracture water), large karst caves and underground rivers (karst water), goaf areas in coal-bearing strata (accumulated water in old mines), and water

accumulation in abandoned metal and non-metal mines. Technical measures: Drainage and Diversion: investigate the water flow direction of karst caves or underground rivers, and their relationship with the tunnel's position, and use culverts, concealed pipes, french drain, drainage tunnels, open diversion channels, or paved drainage ditches for diversion. Water sealing: if the water flow from karst caves or underground rivers is not excessive and there are alternative outlets or branches, grouting applicable; Tunnels counter-slope drainage: utilize water pumps with pipelines for drainage, fixed pumping stations and sump wells are installed at intervals, while temporary mobile pumping stations are set up between fixed stations and the excavation face, and submersible pumps are used to lift water to the sump wells of the fixed pumping stations.

Figure 5. 41. Tunnel Water Inrush

(2) Construction Risk Countermeasures for Tunnel

1) Construction Risk Countermeasures for Tunnel Portal and Shallow Buried and Underground Excavation Section

① Before construction, carefully verify the tunnel's topography, geomorphology, geological conditions, and elevations at each mileage point. Potential hazards such as collapses and falling rocks must be systematically eliminated. If loose collapsed soil mass or other unfavorable geological bodies exist on the cut slope crest, they must be thoroughly removed. Loose falling rocks, boulders, or perilous rocks on the cut slope crest must be thoroughly removed; and for those difficult to remove, reinforcement measures should be implemented.

② Before excavation of the portal section begins, an interception ditch must be constructed at the tunnel crown to prevent surface water from infiltrating the excavation face, which would otherwise destabilize the open-cut tunnel slope and the tunnel formation surface. During excavation, slope protection must proceed simultaneously with slope excavation. When nearing the tunnel formation surface, the core soil must be reserved.

③Based on the currently collected geological data, the geological conditions at the entrance sections at both ends of the tunnel are relatively poor. To ensure construction safety, long pipe sheds and micropipe are used for advanced pre-reinforcement before entering the tunnel portal section.

2) Construction Risk Countermeasures for Gully Sections

① Surface Treatment

Prior to tunnel excavation, conduct on-site verification of water presence. If water is present in the gully, drainage measures must be implemented in advance. If no water is observed on-site, construct interception ditches first to prevent running water or rainwater from entering the gully, while simultaneously enhancing anti-seepage measures.

③ Reinforce the ground surface through grouting and anchor rod installation.

3) Inside-Tunnel Measures

Select appropriate construction methods based on the surrounding rock conditions. Strengthen advanced support inside the tunnel, strictly control construction procedures, regulate excavation cycle length, and enhance monitoring and measurement to guide design and construction promptly.

(3) Construction Risk Countermeasures for fault zones and Water-Rich Strata

1) Based on terrain analysis and collected data, localised fracture zones exist in the tunnel site, posing significant construction risks such as collapses. Auxiliary construction measures must be reinforced during the process.

2) Enhance advanced geological forecasting to identify the distribution of fault zones and groundwater development, enabling targeted technical measures.

3) For mine tunnelling through fault zones, employ medium-length pipe sheds and advanced small conduits to reinforce the strata. Select appropriate grouting methods based on groundwater conditions.

Figure 5. 42. Full-Section Grouting

4) For mine tunnelling through fault zones, excavation methods such as the three-bench seven-step method and the CD method should be adopted. During construction, the excavation sequence must be strictly followed, and the excavation progress should be properly controlled.

5) On-site monitoring and measurement should be strengthened, and regression analysis should be conducted on the monitoring data to guide design and construction.

(4) Construction Risk Countermeasures for Water Inrush Sections

Based on tunnel construction experience and the tunneling characteristics of this project, the following engineering measures are mainly adopted for water inrush strata.

1) Apply scientific management methods, emphasizing and enhancing the prediction and forecasting of water inrush in underground engineering.

2) Implement on-site grouting for water sealing

When using grouting to treat water inrush, the range should cover the surrounding rock loosening zone. The length of the grouting section should be determined based on geological conditions, water inflow, and water pressure, etc.. The center distance between grouting holes should be determined considering factors such as grout curtain thickness, grout diffusion radius, and overlapping diffusion ranges of holes.

3) Advanced Borehole Drainage Measures

When implementing advanced borehole drainage measures, it must be ensured that the water discharged from the boreholes is quickly drained out of the tunnel. The bottom of the advanced boreholes should extend 1–2 cycle lengths ahead of the excavation face.

(5) Countermeasures for Landslides and Unstable Surface Soil Mass

Based on experience, the following measures should be taken for landslides or unstable surface soil mass:

1) During route selection, tunnels should avoid landslides or unstable surface soil sections as much as possible;

2) If functional requirements prevent bypassing landslide sections, the tunnel should pass through the edge of the landslide zone or take the shortest possible route. Additionally, the tunnel foundation should be constructed on stable bedrock whenever possible.

(6) Safety Technical Measures for Tunnel Excavation and Drilling-Blasting Construction

1) Tunneling is the most critical phase of tunnel safety control. Due to the large excavation profile, construction must strictly follow the design drawings and construction organization plan, adopting a reasonable excavation method. The cycle length should be strictly controlled, and the optimal blasting parameters should be selected to ensure construction safety.

2) For shallow-buried sections and fault zones, tunnel excavation shall adopt mechanical methods or short-hole controlled blasting. After blasting, monitoring shall be intensified, and blasting parameters shall be promptly adjusted based on monitoring data and geological conditions to ensure safety. Construction shall adhere to the principles of "advanced pipe, short length, strong support, strict water control, early closure, and frequent measurement." All work procedures shall be tightly scheduled and coordinated.

3) When drilling with a jumbo or rock drill, wet drilling must be used, and drilling in dead holes is strictly prohibited.

4) Tunnel blasting operations shall comply with the Blasting Safety Regulations. During in-tunnel blasting, a unified command system must be implemented, and all personnel shall evacuate to a location beyond the hazardous range of toxic gases, vibrations, and flying debris, with a minimum safe distance of 200 meters.

5) After blasting, ventilation and smoke extraction must be conducted, and no less than 15 minutes shall elapse before safety inspectors are permitted to enter the working surface. Only after confirmation of safety through inspection and necessary handling may other workers enter the working surface.

6) The handling of misfires must establish a precautionary area, and misfires must be dealt with by the original blaster in accordance with regulations. The specific handling method shall be determined based on the situation: reconnect the lead or wire and then detonate again, but drilling into a dead hole is strictly prohibited; drill a parallel borehole at a distance of 0.6 meters from the misfire to induce detonation, but the rock joints must be carefully considered to ensure there are no fissures connecting to the misfire at the drilling location; and safely and properly remove the blockage and reload for detonation.

7) The processing of blasting materials shall be conducted in a workshop located no less

than 100m away from the tunnel entrance.

8) During tunneling, surrounding rock measurement is an important link of construction management. Corresponding safety technical measures shall be taken based on different geological conditions.

9) After tunnel excavation, construction support shall be carried out promptly. If measurement data of the surrounding rock changes, the sprayed concrete surface cracks, or ground fissures appear, these shall be regarded as danger warning signals. Workers must be immediately notified to evacuate the site, and construction may only resume after reinforcement measures are implemented.

5.12. SAFETY RISK NOTIFICATION FOR TUNNEL CONSTRUCTION

Table 5. 24. Hazard Sources and Preventive Measures

No.	Location or Name	Hazard Source	Potential Accident	Preventive Measures
1	Construction Plan	No specialized construction plan; no specific plans are developed for major risk sources (blasting operations, water and mud inrush, toxic gas strata, crossing buildings/structures, existing railways, subway lines or highways, etc.); plans lack operational feasibility; plan is not approved according to required procedures; specialized tunnel construction plan and blasting plan are not reviewed by experts or revised per expert opinions; failure to verify buildings/structures and underground pipelines in and adjacent to the construction site and formulate corresponding protection measures before excavation; incomplete or non-specific safety measures in the plan; no dedicated section in the plan for dewatering construction; no targeted emergency response plan; incomplete content in plans and emergency response plans	Collapse; Water Inrush; Fire; Blasting; Explosion; Pneumoconiosis; Gas Explosion; Roof Fall & Rib Spalling, etc.	Preparation of specialized construction plan; development of specialized plan for major risk sources (blasting operations, water and mud inrush, toxic gas strata, crossing buildings/structures, existing railways, subway lines and highways, etc.); ensure plan operational feasibility; plan shall be approved according to required procedures; specialized tunnel construction plan and blasting plan shall be reviewed by experts or revised per expert opinions; verify buildings/structures and underground pipelines in and adjacent to the construction site and formulate corresponding protection measures before excavation; ensure complete or specific safety measures in the plan; dedicated section in the plan for dewatering construction; development of targeted emergency response plan; all plans and emergency response plans must be complete in content and regularly practiced.
2	Portal Engineering	No specialized construction plan or safety measures for excavation at the junctions of cross aisles, shafts, or the main tunnel; failure to strictly adhere to the approved construction plan for excavation at the junctions of cross aisles, shafts, or the main tunnel; no establishment of registration management system for ascending and descending shafts; incomplete or missing registration records; insufficient reinforcement measures at the junctions of cross aisles, shafts, or the main tunnel; no specialized safety measures for portal engineering; failure to construct roadcuts, side	Collapse Earthfall Landslide Settlement Fall from Height Struck-by Objects	Preparation of specialized construction plan or safety measures for excavation at the junctions of cross aisles, shafts, or the main tunnel; strictly adhere to the approved construction plan for excavation at the junctions of cross aisles, shafts, or the main tunnel; establish registration management system for ascending and descending shafts; complete or existing registration records; sufficient reinforcement measures at the junctions of cross aisles, shafts, or the main tunnel; specialized safety measures for portal engineering; construct roadcuts, side slopes, or

No.	Location or Name	Hazard Source	Potential Accident	Preventive Measures
		slopes, or heading slopes from top to bottom; inadequate waterproofing and drainage systems; and failure to implement protective measures when portals are adjacent to buildings/structures.		heading slopes from top to bottom; adequate waterproofing and drainage systems; and implement protective measures when portals are adjacent to buildings/structures.
3	Tunnel Excavation	Excavation (blasting) is not carried out in strict accordance with the design requirements, dedicated plan, and operating procedures; dewatering construction before or during excavation is not implemented as per the plan; insecure support around the working face, or loose soil and rocks are not cleared in time; core soil is not retained, or non-compliant bench length and pilot tunnel spacing; and tunnel face is exposed for too long, or not promptly sealed during prolonged work stoppages.	Collapse Water Inrush Fire Explosion Pneumoconiosis	Excavation (blasting) shall be carried out in strict accordance with the design requirements, dedicated plan, and operating procedures; dewatering construction before or during excavation shall be implemented as per the plan; secure support around the working face, or loose soil and rocks shall be cleared in time; core soil shall be retained, or ensure compliant bench length and pilot tunnel spacing; tunnel face shall be exposed for a short time, or promptly sealed during prolonged work stoppages.
4	Stratum advanced support reinforcement	Failure to conduct advanced support, reinforcement, or protection of surrounding environments for underground pipelines and other engineering in accordance with design requirements and specifications; the material, specifications, length, or perforation of large pipe sheds (or small guide pipes) are not meet design or plan requirements; grouting parameters (for pipe sheds, advanced small guide pipes, or deep-hole at excavation faces) are not meet design requirements; excavation is performed before the grout strength meets the required standards after completion of grouting; no dedicated personnel is assigned to manage grout preparation or storage; and no geological description of the excavation face or advanced geological forecast.	Collapse Water Inrush	Conduct advanced support, reinforcement, or protection of surrounding environments for underground pipelines and other engineering in accordance with design requirements and specifications; the material, specifications, length, or perforation of large pipe sheds (or small guide pipes) shall meet design or plan requirements; grouting parameters (for pipe sheds, advanced small guide pipes, or deep-hole at excavation faces) shall meet design requirements; excavation shall proceed after the grout strength meets the required standards after completion of grouting; dedicated personnel shall be assigned to manage grout preparation or storage; and geological description of the excavation face or advanced geological forecast.
5	Initial support	The construction plan does not specify safety technical measures; support work is not carried out in accordance with design technical parameters and specifications; support materials such as section steels, steel gratings, concrete, and anchor bolts do not meet design requirements; the spacing of steel frames does not comply with design requirements; steel frames are not connected with bolts or the connection (plates) does not meet requirements; the base of steel frames is not properly padded, and the spacing of connecting bars, overlap length, and welds do not conform to design document requirements; the overlap length of	Collapse	The construction plan shall specify safety technical measures; support work shall be carried out in accordance with design technical parameters and specifications; support materials such as section steels, steel gratings, concrete, and anchor bolts shall meet design requirements; the spacing of steel frames shall comply with design requirements; steel frames shall be connected with bolts or the connection (plates) shall meet requirements; the base of steel frames shall be properly padded, and the spacing of connecting bars, overlap length, and welds shall conform to design document requirements; the overlap length of reinforcing welded wire meshes shall meet design and

No.	Location or Name	Hazard Source	Potential Accident	Preventive Measures
		reinforcing welded wire meshes does not meet design and specification requirements and are not securely welded to the steel frames; the material, specifications, length, and perforations of anchor bolts and locking anchor pipes do not comply with design and plan requirements; grouting is not performed as required by the design; deformed or damaged supports are not repaired in a timely manner; backfill grouting behind the arch is not conducted promptly; sprayed concrete exhibited cracks, spalling, exposed reinforcement or anchor bolts, or missed spraying; and the support surface is uneven and fails to meet design requirements.		specification requirements and shall be securely welded to the steel frames; the material, specifications, length, and perforations of anchor bolts and locking anchor pipes shall comply with design and plan requirements; grouting shall be performed as required by the design; deformed or damaged supports shall be repaired in a timely manner; backfill grouting behind the arch shall be conducted promptly; measures shall be taken to address sprayed concrete cracks, exposed reinforcement and anchor bolts, with timely rectification; and the support surface shall meet the design requirements.
6	Waterproof Engineering	The work site fails to comply with fire management regulations; there is no fire equipment provided on site as required; operators of thermal welding machines and similar equipment lacked proper training and certification; operators of air heaters and similar equipment lacked proper training; and the muzzle of nail gun is pointed at a person.	Fire Thermal injury	The work site must comply with fire management regulations; there must be fire equipment provided on site as required; operators of thermal welding machines, air heaters and similar equipment must be trained and certified; and the muzzle of a nail gun must not be pointed at a person.
7	Secondary lining	The construction plan does not specify safety technical measures; the formwork jumbo had not undergone stability verification; the formwork jumbo, work platform, handrails, guardrails, and access ladders do not meet safety technical requirements; equipment, wires, and pipelines are not removed or protected when the formwork jumbo is moved; there is no protective measure for the formwork jumbo bulkhead removal; and the formwork jumbo lacked safety warning signs; and no dedicated plan for high-formwork construction in non-standard sections.	Fall from Height Struck-by Objects Electric shock	The construction plan shall specify safety technical measures; the formwork jumbo shall undergone stability verification; the formwork jumbo, work platform, handrails, guardrails, and access ladders shall meet safety technical requirements; equipment, wires, and pipelines shall be removed in advance or properly protected when the formwork jumbo is moved; there shall be protective measures for the formwork jumbo bulkhead removal; the formwork jumbo shall have safety warning signs; and formulate dedicated plan for high-formwork construction in non-standard sections.
8	Work scaffold protection	The work scaffold lacks a working platform and guardrail protection, with scaffold planks improperly laid or unstable, and no climbing ladder is installed.	Fall from Height Struck-by Objects	The work scaffold shall have a working platform or guardrail protection; scaffold planks shall be properly laid or stable, and climbing ladders shall be installed.
9	Tunnel transportation	During the vertical transportation of materials in the shaft, underground workers fail to evacuate to a safe area; transport vehicles lacked product certification; in-tunnel transport vehicles had brake failures, mixed cargo and personnel, overloading, over-width, and over-height transport; no drainage ditches on both sides of the tunnel roads; accumulated water and mud on tunnel roads; incomplete lighting and signal	Vehicle injury	During the vertical transportation of materials in the shaft, underground workers must evacuate to a safe area; transport vehicles shall have a product certification; in-tunnel transport vehicles shall be equipped with functional brakes, mixed cargo and personnel, overloading, over-width, and over-height transport are prohibited; drainage ditches shall be established on both sides of the tunnel roads; accumulated water and mud on

No.	Location or Name	Hazard Source	Potential Accident	Preventive Measures
		systems of in-tunnel vehicles; no speed limit regulations or lack of personnel command in the tunnel; drivers working without proper certification; failure to inspect or sound the horn before starting the vehicle; and objects are encroached on the tunnel road boundaries.		in-tunnel roads must be cleared promptly; complete lighting and signal systems of in-tunnel vehicles; there shall be speed limit regulations or personnel command in the tunnel; drivers working with proper certification; inspect or sound the horn before starting the car; and objects must not be encroached on the tunnel road boundaries; separate pedestrian and vehicle lanes; install safety guardrails along sidewalks; maintain road surfaces and spray water for dust suppression; use personnel transport vehicles in longer tunnels.
10	Construction monitoring	Failure to prepare a tunnel construction monitoring plan by the design; the plan is not approved as required; failure to monitor key items such as crown settlement, tunnel convergence, and initial support stress as stipulated in the monitoring plan; failure to conduct settlement observations for buildings/structures, existing railway lines, subway lines, critical pipelines, and roads within the construction-affected scope as required; monitoring point setup or monitoring frequency is not complying with the monitoring plan; failure to promptly restore damaged measurement points; failure to process monitoring data and provide feedback in time to guide construction, as per the design and project conditions; failure to follow prescribed procedures for timely and effective action when monitoring data—such as tunnel crown settlement, tunnel convergence, initial support stress, or deformation of protected objects—reached warning or alarm thresholds.	Collapse Water Inrush Interrupting vehicle operations Damaging pipelines Gas explosion Roof Fall & Rib Spalling, etc.	Prepare a tunnel construction monitoring plan by the design; the plan shall be approved as required; monitor key items such as crown settlement, tunnel convergence, and initial support stress as stipulated in the monitoring plan; conduct settlement observations for buildings/structures, existing railway lines, subway lines, critical pipelines, and roads within the construction-affected scope as required; monitoring point setup or monitoring frequency shall be complying with the monitoring plan; promptly restore damaged measurement points; process monitoring data and provide feedback in time to guide construction, as per the design and project conditions; follow prescribed procedures for timely and effective action when monitoring data—such as tunnel crown settlement, tunnel convergence, initial support stress, or deformation of protected objects—reached warning or alarm thresholds.
11	Working environment	No dedicated ventilation and dust control plan; failure to install ventilation systems as required; no safety technical measures briefing conducted for occupational hazards; inability to perform oxygen, gas methane, and dust level inspections; improper routing of air, water, and power lines deviating from the construction design requirements; accumulation of water and mud in the work area; inadequate ventilation, insufficient airflow velocity at work face, failing to meet fresh air supply requirements; personnel enter the tunnel within less than 15 minutes after blasting without proper ventilation; failure to implement dust	Pneumoconiosis Poisoning Occupational disease Gas explosion	Formulate dedicated ventilation and dust control plan; install ventilation systems as required; perform safety technical measures briefing conducted for occupational hazards; perform oxygen, methane, and dust level inspections; properly lay out air, water, and power lines by the construction design requirements; accumulated water and mud in the work area shall be removed in time; ventilation, airflow velocity at work face and fresh air supply shall meet operational demands; personnel are allowed to enter the tunnel only after ventilation has been carried out for at least 15 minutes; implement dust prevention measures (e.g., spray fog and sprinkle

No.	Location or Name	Hazard Source	Potential Accident	Preventive Measures
		prevention measures (e.g., spray fog and sprinkle water) during dust-generating operations such as drilling, blasting, and shotcreting, or workers are not wearing dust masks; inadequate illumination at insufficient lighting areas; poor maintenance of air ducts (damaged, leaking, or improperly suspended); and workers fail to use dust masks or noise-proof protective gear as required.		water) during dust-generating operations such as drilling, blasting, and shotcreting, or workers shall wear dust masks; adequate lighting shall be provided, and the light intensity shall meet the requirements.); and workers shall use dust masks or noise-proof protective gear as required.
12	Smoking	Smoking carelessly during work and littering cigarette butts.	Fire	No casual smoking, no littering cigarette butts; smoke only at designated smoking areas.

5.13. ENVIRONMENTAL PROTECTION DESIGN FOR TUNNELS

(1) Design Principles

The tunnel scheme offers advantages such as conserving land resources, minimising surface vegetation destruction, and protecting the ecological environment. Throughout the tunnel design process, environmental protection is prioritised by adopting advanced new technologies and techniques. The principle of "prevention first, combined with prevention and treatment" is upheld, emphasising comprehensive planning and rational layout. The engineering, construction, and ecological environment protection must be implemented simultaneously, avoiding new mountain hazards due to human factors as much as possible.

(2) Environmental Protection Measures in the Design Phase

1) The selection of tunnel portal locations should maximise the preservation of the natural mountain and ensure harmony with the surrounding environment.

2) Greening design for the tunnel entrance area can reduce the need for shade canopy engineering while providing environmental benefits such as smoke and dust prevention, as well as air purification.

3) Optimise the tunnel cross-section design to achieve a balance between cut and fill, minimising the amount of waste residue generated. The excavated rock debris from tunnel construction should be utilised for longitudinal allocation as much as possible, serving as subgrade filler. Complex and high-quality stone materials should be centrally stockpiled at designated stone processing plants for use in masonry works or as coarse aggregates for concrete. Materials unsuitable for reuse shall be concentrated in dedicated spoil sites based on the actual conditions of each construction site.

4) In tunnel waterproofing and drainage design, the principle of "prevention first, supplemented by sealing and interception, with controlled drainage as a secondary measure" should be adopted. This ensures adequate tunnel drainage while protecting water resources.

5) Water inside the tunnel and at the tunnel crown should be discharged in coordination

with the surrounding environment.

(3) Environmental Protection Measures During Construction

1) The wet shotcreting should be. This not only reduces dust pollution caused by dry shotcreting but also ensures concrete quality.

2) The construction methods and machinery used should have low noise and minimal vibration.

3) On-site spoil should be reused whenever possible, such as utilising excavated gravel as subgrade construction material.

4) For unusable spoil, appropriate dumping sites (e.g., wasteland, depressions, or gullies) should be selected.

5) Post-construction site cleanup, greening, and farmland restoration should be carried out to protect the natural environment.

6) Wastewater and chemical slurries that may pose environmental hazards during construction must be treated before discharge.

(4) Soil and Water Conservation

1) Construction Soil and Water Conservation Measures

① Before construction, waterproofing and drainage facilities shall be installed in advance. Before tunnelling begins, protective measures for heading slopes and side slopes at the tunnel portal and entrance, as well as drainage works for roof gutters, shall be completed. Drainage from inside the tunnel shall be treated to meet standards before discharge to prevent pollution of streams.

② Temporary road construction shall avoid uncontrolled excavation to prevent soil erosion.

2) Soil and Water Conservation Measures for Spoil Disposal Site

① The location of spoil disposal sites shall comply with the design documents. Generally, gently sloped barren gullies shall be selected, avoiding large catchment areas or stagnant valleys. The masonry rubble spoil-retaining wall shall be provided with weep holes, and a drainage pipe shall be installed at the base of the spoil pile. After project completion, the site shall be levelled, covered with soil, and rehabilitated with grass and trees.

② Spoil materials shall not be dumped randomly and must be disposed of at designated spoil disposal sites.

5.14. TUNNEL VENTILATION WORKS

5.14.1. Design Principles

(1) The design of the tunnel ventilation system shall comply with current applicable standards and regulations, draw on successful experiences from similar international projects, and be based on principles of safety, cost-effectiveness, advancement, rationality, and

environmental protection, tailored to the actual conditions of the project.

(2) Under normal traffic conditions, natural ventilation, traffic-induced ventilation, and mechanical ventilation shall be fully utilised to dilute vehicle exhaust (e.g., CO, smoke) and odours in the air to meet hygiene and environmental protection standards. This ensures a suitable in-tunnel environment for drivers and maintenance personnel, while also providing fresh air and clear visibility for safe driving.

(3) In the event of a tunnel fire, ventilation equipment shall supply airflow at a certain velocity to control the spread of smoke and hot gases. At the same time, a sufficient amount of fresh air must be delivered to support the evacuation of passengers and the entry of firefighting personnel. This ensures safe evacuation during the initial phase and enables fire engines to approach the fire site safely from the upwind direction, creating conditions for effective firefighting and rescue.

(4) The tunnel ventilation system shall be designed based on the occurrence of a single fire incident at any given time.

(5) The capacity of the ventilation equipment shall be designed with consideration for long-term future demands. While meeting design standards, efforts shall be made to minimise construction investment and operating energy consumption, and to ensure ease of maintenance and management.

(6) The selection of ventilation equipment shall prioritise safety and reliability, and be based on advanced technology. Localisation of equipment is encouraged wherever possible.

Noise and vibration from all ventilation system components, both external and internal, must comply with relevant standards and the requirements specified in the environmental impact assessment report.

5.14.2. Meteorological Param

Average elevation: 1350m; Average atmospheric pressure: 850hPa; Average temperature: -0.4°C-1.3°C

5.14.3. Design Scope

This design covers the determination of ventilation standards, ventilation volume, ventilation method, and smoke control system for the underground section of the Ulaanbaatar New Ring Road from K8+730 to K10+810. It includes the selection, layout, and control strategy of the ventilation equipment.

5.14.4. Design Standards

Ventilation and Health Standards:

(1) Permissible CO Concentration (δ) in Tunnel:

1) During regular operation, the design CO concentration in the tunnel shall be: $\delta \leq 150$ppm;

2) During traffic congestion (all lanes in idle mode with average vehicle speed Vt ≤ 30 km/h and congestion duration ≤ 20 minutes), the design CO concentration in the tunnel is: δ = 150 ppm;

3) For tunnels with mixed traffic (pedestrian and vehicle), the CO concentration shall not exceed 70ppm.

(2) Permissible Particulate Concentration (K) in Tunnel: Since all tunnel lighting uses LED light sources, the permissible particulate concentration K shall follow the specifications provided in the "Guidelines for Design of Ventilation of Highway Tunnels" (JTG/T D70/2-02-2014) for tunnels equipped with LED lighting, as follows.

Table 5. 25. Permissible Particulate Concentration K in Tunnels (for Fluorescent, LED, and Similar Light Sources)

Service Conditions	Normal Operation			
Calculated Vehicle Speed (km/h)	90＜v≤60	60＜v≤50	50＜v＜30	v≤30
Design particulate concentration K (m^{-1})	0.0065	0.0070	0.0075	0.0120

(3) Dilution of Odors in Air: based on the traffic volume and tunnel scale of this project, the continuous ventilation rate for the tunnel space is set at 3 air changes per hour. At the same time, it must be ensured that the ventilation airspeed inside the tunnel is > Vr ≥ 1.5 m/s.

(4) Fire Scenario: during a fire, the smoke extraction airspeed is set at Vr = 2.5-3.0 m/s.

5.14.5. Main Technical Param of the Tunnel

Tunnel Scale: twin-tube separated tunnel, dual-bore, one-way traffic with three lanes per tunnel;

Tunnel Clearance Section Area: 126.07m²; Clearance perimeter of single bore: 41.77m;

Design Speed: 80km/h.

Table 5. 26.Horizontal and Vertical Alignment Data of the Tunnel

No.	Tunnel Name		Start-End Chainage Length	Length (m)
1	New Ring Road Tunnel	Left Tunnel	K8+730-K10+810	2080
		Right Tunnel	K8+730-K10+810	2080

5.14.6. Traffic Volume and Composition

Traffic volume and composition are among the fundamental data used for ventilation calculations. According to the feasibility study report by the transportation engineering discipline, the traffic composition of the road section where this tunnel is located is shown in the table below:

Table 5. 27. Forecast of Average Peak Hourly Traffic Volume in Characteristic Years for the Tunnel (Unit: pcu/h)

No	Section	Number of Vehicles per Type During Peak Hour (vehicles/hour)

		Passenger Car	Light Truck	Medium Truck	Large (Heavy) Truck	Light Bus	Medium Bus	Large Bus
1	New Ring Road Tunnel (West - East)	1865	217	75	64	21	2	15
2	New Ring Road Tunnel (East - West)	1790	208	72	62	21	2	15

5.14.7. Tunnel Ventilation Airflow Calculation

Based on traffic analysis, forecasting, and technical standard data, the required airflow for different design years under various operating conditions is calculated.

For each calculated traffic speed and operating condition, vehicle speeds are classified in increments of 10km/h, with consideration of traffic congestion states. The required airflow to dilute CO and smoke concentrations is calculated accordingly. Additionally, the tunnel ventilation must satisfy a ventilation frequency of 3 air changes per hour, with the ventilation airflow velocity inside the tunnel not falling below 1.5m/s. Furthermore, the ventilation system shall also meet the requirements for smoke exhaust and rescue ventilation during tunnel fire incidents. Considering all the above ventilation demands, the larger one is taken as the design ventilation airflow.

(1) Calculation of Required Airflow for Dust Dilution

The articulate emission inside the tunnel shall be calculated using the following formula:

$$Q_{VI} = \frac{1}{3.6 \times 10^6} \times q_{VI} \times f_{a(VI)} \times f_d \times f_{h(VI)} \times f_{iv(VI)} \times L \times \sum_{m=1}^{n_D} (N_m \times f_{m(VI)})$$

In the formula:

Q_{VI} represents Particulate emission inside the tunnel (m²/s);

q_{VI} represents Design target year baseline particulate emission\[m²/(veh·km)]; ;

$f_{a(VI)}$ represents Vehicle condition coefficient for particulate emission;

f_d represents Vehicle density coefficient;

$f_{h(VI)}$ represents Altitude coefficient for particulate emission;

$f_{iv(VI)}$ represents Longitudinal slope and vehicle speed coefficient for particulate emission;

L represents Tunnel length (m);

$f_{m(VI)}$ represents Diesel vehicle type coefficient for particulate emission;

n_D represents Number of diesel vehicle categories;

N_m represents Traffic volume of the corresponding vehicle type (veh/h), as per the "Converted Design Peak Hour Traffic Volume by Vehicle Type" table in this section.

The required airflow for dust dilution shall be calculated using the following formula:

$$Q_{req(VI)} = \frac{Q_{VI}}{K}$$

In the formula:

$Q_{req(VI)}$ represents Airflow required for particulate dilution inside the tunnel (m^3/s);

K represents Design particulate concentration K (m-1).

(2) Calculation of Required Airflow for CO Dilution

The particulate emission inside the tunnel shall be calculated using the following formula:

$$Q_{CO} = \frac{1}{3.6 \times 10^6} \times q_{CO} \times f_a \times f_d \times f_h \times f_{iv} \times L \times \sum_{m=1}^{n} (N_m \times f_m)$$

In the formula:

Q_{CO} represents CO emission inside the tunnel (m^3/s);

q_{CO} represents Design target year CO baseline emission [m^3/(veh•km)];

f_a represents Vehicle condition coefficient for CO emission;

f_d represents Vehicle density coefficient;

f_h represents Altitude coefficient for CO emission;

f_{iv} represents Longitudinal slope and vehicle speed coefficient for CO emission;

f_m represents Vehicle type coefficient for CO emission;

n represents Number of vehicle categories;

N_m represents Traffic volume of the corresponding vehicle type (veh/h), as per the

"Converted Design Peak Hour Traffic Volume by Vehicle Type" table in this section.

The required airflow for CO dilution shall be calculated using the following formula:

$$Q_{req(CO)} = \frac{Q_{CO}}{\delta} \times \frac{P_0}{P} \times \frac{T}{T_0} \times 10^6$$

In the formula:

$Q_{req(CO)}$ represents Required airflow for CO emission inside the tunnel (m3/s);

Q_{CO} represents CO emission inside the tunnel (m3/s);

δ represents CO concentration, taken as δ = 70 ppm;

P_0 represents Standard atmospheric pressure, taken as 101.325 kN/m²;

P represents Atmospheric pressure at tunnel site (kN/m²);

T_0 represents Standard temperature (K), taken as 273 K;

T represents Summer temperature at tunnel site (K).

(3) Required Airflow for Tunnel Air Exchange

According to the "Guidelines for Design of Ventilation of Highway Tunnels" (JTG/T D70/2-02-2014), the required airflow for tunnel air exchange shall be calculated by the following formula:

$$Q_{req(ac)} = \frac{A_r \times L \times n_s}{3600}$$

In the formula:

$Q_{req(ac)}$ represents Ventilation airflow required for tunnel air exchange (m³/s);

A_r represents Net cross-sectional area of the tunnel (m²), taken from the tunnel cross-section drawings;

n_s represents Number of air exchanges in the tunnel.

(4) Calculation of Required Smoke Exhaust Airflow for Fire Conditions

According to the "Guidelines for Design of Ventilation of Highway Tunnels" (JTG/T D70/2-02-2014), the required smoke exhaust airflow for tunnel fire conditions shall be calculated using the following formula:

$$Q_{req(f)} = A_r \times v_c$$

In the formula:

$Q_{req(f)}$ represents Ventilation Airflow required for tunnel smoke exhaust for fire conditions (m³/s);

v_c represents Critical wind speed for tunnel fire conditions (m/s), taken as 2.5 m/s according to the standard.

Based on detailed analysis of vehicle OD survey data, combined with the tunnel's clear cross-sectional area, longitudinal slope, altitude, vehicle composition, and traffic speed, the required airflow for each design year is calculated for the following conditions: dilution of CO and particulate during normal operation, air exchange, smoke exhaust airflow during fire, and required airflow during traffic congestion. Among these ventilation requirements, the largest one shall be adopted as the design ventilation airflow.

Table 5. 28. Required Airflow for CO Dilution Inside Tunnel (m³/s)

Ventilation Section	80km/h	70km/h	60km/h	50km/h	40km/h	30km/h	20km/h	Traffic Congestion (10km/h)
New Ring Road Tunnel (West - East)	106.49	120.68	141.98	170.38	212.97	227.17	340.76	681.51
New Ring Road Tunnel (East - West)	102.52	116.19	136.70	164.04	205.04	218.71	328.07	656.14

Table 5. 29. Required Airflow for Particulate Dilution Inside the Tunnel (m³/s)

Ventilation Section	80km/h	70km/h	60km/h	50km/h	40km/h	30km/h	20km/h	Traffic Congestion (10km/h)
New Ring Road Tunnel (West - East)	260.31	249.63	266.98	297.49	295.01	208.24	260.31	520.61
New Ring Road Tunnel (East - West)	250.71	240.42	257.13	286.52	284.13	200.56	250.71	501.41

Table 5. 30. Required Airflow by Other Sections of the Tunnel (m³/s)

Ventilation Section	Required Airflow for Air Exchange	Fire Scenario
New Ring Road Tunnel (West - East)	218.52	315.18
New Ring Road Tunnel (East - West)	218.52	315.18

From the above table, it can be seen that CO dilution conditions control the required airflow for the New Ring Road tunnel under normal driving conditions and congestion conditions; in case of fire, the system switches to the tunnel fire smoke prevention and exhaust system.

5.14.8. Comparison and Selection of Tunnel Ventilation Methods

The determination of a specific mechanical ventilation scheme should be made based on a comprehensive comparison and consideration of factors such as traffic, terrain, geomorphology,

geological conditions, fire prevention and rescue, environmental protection, project cost, maintenance, operation management level, and expenses.

According to the airflow direction inside the tunnel, mechanical ventilation methods for highway tunnels can be classified into longitudinal, semi-transverse, full transverse, and combined ventilation methods based on these three basic types. In longitudinal ventilation, airflow moves along the tunnel axis (longitudinal direction); in transverse ventilation, airflow moves perpendicular to the tunnel axis (transverse direction); in semi-transverse ventilation, airflow moves both transversely and longitudinally within the traffic space.

Longitudinal ventilation is the simplest form of ventilation. Fans are installed at appropriate locations within the tunnel, and the ventilation pressure generated by the fans forces air to flow along the tunnel axis to achieve ventilation. This system is simple and widely used in highway tunnels. Standard longitudinal ventilation methods include jet fan longitudinal ventilation, ventilation shaft centralised exhaust longitudinal ventilation, and combined supply and exhaust longitudinal ventilation.

(1) Jet Fan Longitudinal Ventilation

When a jet fan is activated, it blows a jet stream in one direction. The high-speed airflow pushes the air in front forward while creating a negative pressure zone behind, which draws in air from the rear. This generates a unidirectional airflow along the tunnel axis within a certain distance in front of and behind the fan. Fresh air enters from one end of the tunnel, while polluted air is discharged from the other end, forming a complete ventilation airflow pattern throughout the tunnel length.

Jet fans have high air velocity, small airflow volume, low power, and short ventilation distance. However, the Jet fans do not require ventilation shafts, making the facilities simple, with low construction and equipment costs.

(2) Centralised Exhaust Longitudinal Ventilation

This ventilation system consists of ventilation shafts, ducts, and fan units. Ventilation shafts are usually located in the middle section of the tunnel. Ducts are excavated for fan installation. Fresh air enters from both tunnel portals and converges toward the ventilation shaft in the middle. The polluted air is collected and discharged to the atmosphere via the shaft and exhaust fans.

The centralised exhaust longitudinal ventilation system is simple in design but requires the excavation of vertical ventilation shafts in the middle of the tunnel. As a result, its construction cost is higher than that of the jet fans. This method may be considered when construction shafts are already available or if digging ventilation shafts is convenient.

(3) Combined Supply and Exhaust Longitudinal Ventilation

On both sides of the ventilation shaft, the direction of vehicle travel is consistent with the direction of airflow inside the tunnel. This ventilation method significantly improves ventilation

efficiency and is generally adopted in highway tunnels longer than 5km. A combined supply and exhaust shaft is constructed, with its cross-section divided and tightly separated as needed.

In a transverse ventilation system, the tunnel cross-section is divided into three parts: the supply air duct, the exhaust air duct, and the traffic lane. Fresh air is delivered into the supply duct by fans, then enters the traffic lane through supply openings, where it mixes with polluted air. This mixture flows transversely across the tunnel and enters the exhaust duct through exhaust openings, and is finally discharged by fans. This method ensures a uniform air supply and high driving safety and comfort. However, it requires installing deck slabs, suspended ceilings, and ventilation shafts within the tunnel, leading to substantial civil works and high construction costs. Moreover, due to the limited tunnel cross-section, the supply and exhaust ducts located beneath the road deck and above the ceiling are often small, resulting in high airflow resistance, high energy consumption, and elevated operational and maintenance costs. Therefore, this method is used only in very long and critical tunnels.

Semi-transverse ventilation is a hybrid between longitudinal and transverse ventilation. It combines the advantages and disadvantages of both systems, offering ventilation performance and safety levels between the two.

In summary, the semi-transverse and fully transverse ventilation systems feature low tunnel airflow speeds, reduced ventilation noise, improved driving comfort, flexible and effective smoke control during fires, and better portal environmental conditions. However, they cannot fully utilise the piston effect generated by moving vehicles, require larger tunnel cross-sections, are high in construction costs, are unsuitable for phased construction, and pose challenges in management and maintenance. They are mainly used in single-bore, bidirectional tunnels. Longitudinal ventilation can be classified into several types, including complete jet fan systems, vertical (or inclined) shaft supply, vertical (or inclined) shaft exhaust, combined shaft (or inclined) supply and exhaust, and various combinations thereof, each with its advantages and disadvantages. Longitudinal ventilation makes full use of the vehicle piston effect and is relatively low in construction costs. It represents the mainstream development direction for highway tunnel ventilation systems worldwide.

Considering the tunnel's length, terrain, characteristics, air volume, and in compliance with current relevant standards, the recommended ventilation method for this project is the whole jet fan longitudinal ventilation system.

5.14.9. Tunnel Fan Selection and Layout

Based on the calculated airflow, the actual performance of each jet fan shall meet the following indicators:

Table 5. 31. Jet Fan Performance Specifications

Item	Technical Specifications	Item	Technical Specifications
Impeller Diameter	1250mm	Motor Insulation Class	Class H
Outlet Airflow	43.5m^3/s	High Temperature Performance	The fan can work continuously at a high temperature of 250°C for one hour
Outlet Air Velocity	35.5m/s	Service Life of Main Parts	≥ 20 years
Axial Thrust	1668N	Reversibility	Yes, full-speed reversal within 90 seconds, reverse efficiency ≥ 60% of forward operation.
Protection Class	Not lower than IP55	Noise	≤75dB(A) at 45° below the outlet, 10m away (in an open field)
Motor Power	55kW (AC380V ±10%, 50Hz)	Load-bearing capacity of fan installation accessories and connections	Required to withstand at least 15 times the combined weight of the fan and its accessories

Note: Tunnel fan supports, hangers, and seismic design shall be provided and installed by the fan manufacturer.

The fan layout plan is as follows:

Fans shall be laid out about 160m from the tunnel entrance; the fans are arranged in groups of 2, with an interval of about 250m between the adjacent groups.

When substations are installed at both ends of the tunnel, the fans should be laid out as evenly as possible at both ends of the tunnel. When only one substation exists, the fans should be laid out on the side close to the tunnel substation.

According to the ventilation calculation results, the required airflow for the New Ring Road tunnel under normal traffic conditions is governed by the CO dilution requirement; under congestion conditions, it is also governed by the CO dilution requirement; in case of fire, the system switches to the tunnel fire smoke extraction system.

For this project, a total of 8 groups of fans are needed for each of the left and right tunnels. Each group consists of 2 fans, for a total of 16 fans.

5.14.10. Tunnel Ventilation Control

(1) Number of Operating Tunnel Fans

When natural wind and the piston effect caused by vehicle flow are insufficient to keep CO and VI values within the specified limits, a certain number of fans must be activated to provide forced ventilation. Ventilation equipment is the primary consumer of electrical energy during tunnel operation. To achieve energy efficiency, the number of operating fans is controlled based on the required CO and VI values under various operating conditions. The tunnel airflow is regulated by adjusting the number of operating fans, allowing for stepwise modulation from 0% to 100% of the rated airflow.

According to the ventilation calculation results, under normal traffic conditions, the required airflow for a single tunnel is governed by the required airflow for CO dilution. This condition involves a total of 4 groups of fans, two fans per group, totalling eight fans. Under congested

traffic conditions, the needed airflow for a single tunnel is also governed by the required airflow for CO dilution. This condition involves a total of 8 groups of fans, two fans per group, totalling 16 fans. Under fire conditions, the system switches to the tunnel fire smoke extraction system. This condition requires a total of 4 groups of fans, two fans per group, totalling eight fans.

Table 5. 32. Number of Jet Fans Activated Under Various Operating Conditions

Operating Conditions	Recommended Number of Jet Fans per Tunnel
Normal Conditions	4 groups (2 fans/group)
Traffic Congestion	All eight groups are activated.
Fire Scenario	4 groups (2 fans/group)

The operating conditions and control targets listed in the table represent basic requirements. Additional scenarios may be added based on actual operational needs. Within a single tunnel, fans can operate either individually or in paired groups. The system must allow for flexible adjustment of the number of running fans during actual operation. The fans used in each condition should not be fixed, enabling alternation among all fans throughout the tunnel for balanced usage. In the event of a fire inside the tunnel, vehicles ahead of the fire should exit the tunnel quickly at normal speed. The jet fans are configured to maintain airflow inside the tunnel at 2-3 m/s, directing smoke downstream and ensuring vehicles behind the fire remain in a safe zone.

(2) Ventilation Control Mode

The ventilation control system shall be integrated with the lighting control system, fire alarm and firefighting system, traffic monitoring system, and central control system to achieve coordinated control.

There are two main types of tunnel ventilation control methods: automatic control and manual control.

Automatic control: The system receives sensor signals (e.g., CO/VI detectors, vehicle detectors, wind speed and direction sensors) installed inside the tunnel, and regulates airflow via the network accordingly.

Manual control: This involves manually operated instruments to regulate airflow, and includes linked control and independent control modes. Manual control devices shall be installed in safe and accessible locations, with clear markings and protective measures. The operating buttons should not be higher than 1.5m from the ground.

Automatic control methods include direct control, indirect control, and program control.

Direct control: Smoke visibility sensors and carbon monoxide (CO) concentration sensors distributed throughout the tunnel detect real-time smoke and CO levels. After data processing, control signals are issued to operate the fans.

Indirect control: Based on traffic data from the section before the tunnel and in-tunnel

vehicle detectors, the system determines real-time traffic volume, speed, and vehicle types. From this, it estimates the emission levels of smoke and CO and adjusts ventilation accordingly.

Program control: This method does not rely on real-time VI, CO levels, or traffic data. Instead, it uses pre-determined programs based on estimated traffic volumes and corresponding smoke and CO emissions by time segments to control fan operation.

When operating tunnel fans, the following requirements shall be met:

① The motor should not be started and stopped frequently to avoid surge phenomena, which can adversely affect the fan's service life.

② The fan control cycle should not be shorter than 10 minutes.

③ When starting a single fan or a group of fans, priority should be given to starting the fan(s) with the shortest accumulated runtime.

④ When starting a single fan or a group of fans, a time interval should be maintained between starts, and this interval should not be less than 30 seconds. In actual operation, different control schemes may be adopted depending on the situation.

5.14.11. Tunnel Fire Smoke Control and Ventilation

In the event of a fire, manual ventilation control shall be adopted. If the original ventilation control mode is set to automatic, the system shall automatically switch to manual mode. The system shall use visual and audible alarms to alert the operator and provide recommended actions. The recommended action should ensure that the wind speed inside the fire tunnel is 2-3m/s, and the wind direction favours personnel evacuation. Operators may also choose to ignore the recommended action and operate the system entirely manually.

In case of fire: Both tunnels shall be closed, prohibiting further vehicle entry. Tunnel management personnel shall enter the tunnel immediately to organise evacuation, rescue, and fire suppression. As a general rule, the following traffic organisation applies:

Vehicles near the fire source (within the distance of one vehicular cross passage upstream) should be abandoned for evacuation.

Vehicles farther from the fire source (beyond one cross-passage upstream) may be organised to evacuate via cross passages into the non-fire tunnel, only after confirming that the non-fire tunnel is completely cleared. Vehicles closest to the nearest cross-passage to the fire evacuate first, followed by those near the second closest, and so on, in sequence, until all vehicles in the fire tunnel are evacuated.

In general, all evacuation and traffic organisation must proceed in an orderly, commanded manner.

Once a fire occurs, the fire tunnel switches to fire-rescue ventilation mode. The other tunnel operates under normal ventilation. Jet fans shall be used to ensure that the pressure at the open

cross passages in the fire tunnel is lower than that in the non-fire tunnel, preventing smoke and hot gases from spreading into the safe tunnel. If jet fans can ensure smooth airflow, vehicles blocked downstream of the fire can remain in a smoke-free and safe environment.

To prevent backflow of smoke and heat towards trapped vehicles and personnel, a longitudinal wind speed must be maintained during a tunnel fire. According to the standard, considering smoke temperature downstream and personnel evacuation speed, the smoke exhaust velocity during a fire should be set between 2 and 3 m/s. Transitioning from normal operation ventilation to fire-mode ventilation is not instantaneous; the time required depends on the complexity of the tunnel ventilation system. After a fire occurs, the first step is to adjust the operation status of the fans, adopting rescue wind speeds to control the fire's development and the direction of smoke flow. Once all personnel inside the tunnel have safely evacuated, the smoke exhaust ventilation system is activated. The mechanical ventilation of the smoke exhaust system should select different ventilation methods based on the fire location, with the fundamental principle that smoke is to be directed to exit through the nearest tunnel portal.

Specific ventilation control principles after a fire are as follows:

Ventilation in fire mode is divided into at least two stages: the evacuation and rescue stage, and the firefighting stage. Ventilation during the evacuation and rescue stage mainly focuses on controlling the distribution of airflow, and ventilation during the firefighting stage primarily aims to control the temperature distribution.

Figure 5. 43. Tunnel Jet Fan Installation Rendering

5.14.12. Tunnel Main Distribution Room and Tunnel Fire Pump Room

(1) Ventilation System

1) The low-voltage distribution room is equipped with a mechanical ventilation system, featuring mechanical exhaust and natural air supply. Temperature sensors are installed inside the low-voltage distribution room to monitor internal temperature changes. The fans operate with variable frequency drives to expel excess heat, maintaining the room temperature below 40°C at all times. The normal ventilation volume for the low-voltage distribution room is determined based on the greater one between the heat generated by transformers, low-voltage distribution cabinets, and the calculated air exchange rate. The emergency exhaust air exchange rate is set at 12 air changes per hour, resulting in a calculated ventilation volume of 5,627.95m³/h. Single-speed units are used based on this emergency ventilation volume, meeting both standard and emergency ventilation requirements. Variable frequency drives are installed to enable frequency adjustment during regular operation according to indoor temperature changes. Accident control switches are installed on the walls of the low-voltage distribution room and exterior walls, allowing manual shutdown or automatic shutdown triggered by smoke detectors during fire emergencies.

2) The high-voltage distribution room is equipped with a mechanical ventilation system, featuring mechanical exhaust and natural air supply. The normal ventilation volume is determined based on the greater one between the heat generated by transformers, high-voltage distribution cabinets, and the calculated air exchange rate. The emergency exhaust air exchange rate is set at 12 air changes per hour, resulting in a calculated ventilation volume of 3,813.98m³/h. Single-speed units are used based on this emergency ventilation volume, meeting both standard and emergency ventilation requirements. Variable frequency drives are installed to enable frequency adjustment during normal operation according to indoor temperature changes. Accident control switches are installed on the walls of the low-voltage distribution room and exterior walls, allowing manual shutdown or automatic shutdown triggered by smoke detectors during fire emergencies.

3) The low-voltage power supply room is equipped with a mechanical ventilation system, including mechanical exhaust and natural air supply. The normal ventilation volume is determined based on the greater of the two, between the heat generated by the equipment and the calculated air exchange rate. The emergency exhaust air exchange rate is set at 12 air changes per hour, resulting in a calculated ventilation volume of 2,517.91m³/h. Single-speed units are used according to the emergency ventilation volume, meeting both normal and emergency ventilation requirements. Variable frequency drives are installed to adjust the fan

speed during normal operation based on indoor temperature changes. Accident control switches are installed on the walls of the low-voltage distribution room and exterior walls, allowing manual shutdown or automatic shutdown triggered by smoke detectors during fire emergencies.

4) The weak current equipment room is equipped with a mechanical ventilation system, including mechanical exhaust and natural air supply. The normal ventilation volume is determined by taking the greater of the two, between the heat generated by the equipment and the calculated air exchange rate. The emergency exhaust air exchange rate is set at 12 air changes per hour, resulting in a calculated ventilation volume of 2,910.67m³/h. Single-speed units based on the emergency ventilation volume, meeting both standard and emergency ventilation requirements. Variable frequency drives are installed to adjust fan speed during normal operation according to indoor temperature changes. Accident control switches are installed on the walls of the low-voltage distribution room and exterior walls, allowing manual shutdown or automatic shutdown triggered by smoke detectors during fire emergencies.

5) The control centre is equipped with a mechanical ventilation system, including mechanical exhaust and natural air supply. The normal ventilation volume is determined based on the greater one between the heat generated by the equipment and the calculated air exchange rate. The emergency exhaust air exchange rate is set at 12 air changes per hour, resulting in a calculated ventilation volume of 5405.79m³/h. Single-speed units are used according to the emergency ventilation volume, meeting both standard and emergency ventilation requirements. Variable frequency drives are installed to adjust the fan speed during regular operation based on indoor temperature changes. Accident control switches are installed on the walls of the low-voltage distribution room and exterior walls, allowing manual shutdown or automatic shutdown triggered by smoke detectors during fire emergencies.

6) Mechanical ventilation facilities are installed in the fire pump room, with an air exchange rate of 5 times per hour, resulting in a calculated ventilation volume of 1,221.8m³/h. The airflow organisation adopts a supply-from-top and return-to-top mode. Due to the humid working environment in the pump room, all fan motors are of a moisture-proof type.

(2) Air Conditioning System

The control room is equipped with a comfort air conditioning system, with a cooling load of 11.48 kW (cooling index 130 W/m^2 ㎡) and a heating load of 7.51 kW (heating index 85 W/m^2 ㎡). The spare parts room is also equipped with a comfort air conditioning system, with a cooling load of 4.05kW (cooling index 130W/㎡) and a heating load of 2.65 kW (heating index 85W/㎡). Split-type air conditioners are selected, with one indoor unit and one outdoor unit installed. The outdoor unit is placed on an outdoor concrete platform. The air conditioner condensate water is drained via a soft hose to the outside and collected in a container, which should be emptied

regularly. The refrigerant pipes are copper tubes insulated with rubber-plastic insulation material.

(3) Energy saving and environmental protection

1) Start the ventilation system promptly based on the air temperature inside the power distribution room to remove excess heat.

2) Select ventilation equipment with a high energy efficiency ratio.

3) Choose low-noise fans with stable operation.

4) Use vibration-damping hangers for all suspended equipment and vibration-damping bases for floor-mounted equipment.

5) The air conditioning system uses environmentally friendly R410A refrigerant; all indoor units are low-noise models; outdoor units are placed in well-ventilated outdoor locations and installed on vibration-damping bases.

5.14.13. Primary Tunnel Ventilation Equipment

Table 5. 33. List of Major Tunnel Ventilation Equipment

Tunnels					
No.	**Equipment Name**	**Param and Specifications**	**Unit**	**Quantity**	**Notes**
1	Tunnel Jet Fan	Impeller Diameter: 1250mm; Outlet Flow Rate: 43.5m³/s; Outlet Wind Speed: 35.5m/s; Weight: 1280kg; Thrust: 1668N; Sound Pressure Level: 77dB(A); Power: 55kW.	Set	16×2	15 years of service life, import required
2	CO/VI Detector	CO: 0-500ppm	Piece	5×2	15 years of service life, import required
3	Wind Speed and Direction Detector	0-30m/s	Piece	5×2	15 years of service life, import required
4	NO_2 Detector	0-10cm³/m³	Set	5×2	15 years of service life, import required
Tunnel Main Distribution Room					
No.	**Equipment Name**	**Param and Specifications**	**Unit**	**Quantity**	**Notes**
1	Wall-mounted Axial Fan	L=5881m³/h, H=115Pa, N=0.25KW, 220V, n=1450rpm	Set	2	10 years of service life, no import required
2	Wall-mounted Axial Fan	L=3977m³/h, H=95Pa, N=0.12KW, 220V, n=1450rpm	Set	1	10 years of service life, no import required
3	Wall-mounted Axial Fan	L=2737m³/h, H=71Pa, N=0.09KW, 220V, n=1450rpm	Set	1	10 years of service life, no import required
4	Wall-mounted Axial Fan	L=3265m³/h, H=76Pa, N=0.09KW, 220V, n=1450rpm	Set	1	10 years of service life, no import required
5	Air Conditioner	Rated Heating Capacity: 7600W; Rated Cooling Capacity: 7300W; Heating Power Consumption: 2100W; Cooling Power Consumption: 2350W.	Set	2	10 years of service life, no import required

Tunnels					
No.	**Equipment Name**	**Param and Specifications**	**Unit**	**Quantity**	**Notes**
6	Air Conditioner	Rated Heating Capacity: 4300W; Rated Cooling Capacity: 2600W; Heating Power Consumption: 1050W; Cooling Power Consumption: 1280W.	Set	1	10 years of service life, no import required
Tunnel Fire Pump Room					
No.	**Equipment Name**	**Param and Specifications**	**Unit**	**Quantity**	**Notes**
1	Axial Fan	L=1500m³/h; n=1450r/min dB(A)≤63; H=146Pa N=0.37KW	Set	1	10 years of service life, no import required
2	Axial Exhaust Fan	L=1645m³/h; n=2900r/min dB(A)≤79; H=155Pa N=0.12KW	Set	1	10 years of service life, no import required
3	70°C Motorised Fire Damper	400×200, normally open	Piece	2	10 years of service life, no import required
4	Aluminum Alloy Single-layer Louver Air Outlet	500×300, normally open	Set	2	10 years of service life, no import required
5	Galvanised Steel Plate	Thickness: 1mm	Kg (㎡)	105Kg (13.5 ㎡)	15 years of service life, no import required

5.15. TUNNEL WATER SUPPLY, DRAINAGE, AND FIREFIGHTING FACILITIES

5.15.1. Design Principles

(1) Tunnel drainage shall follow the principle of “a combination of prevention, drainage, interception, and blocking, tailored to local conditions and comprehensive management”, to ensure the regular use of tunnel structures and operational equipment, as well as driving safety.

(2) The classification of tunnel traffic engineering shall be carefully determined, the fundamental principles of “safety, economy, and practicality” shall be adhered to, and the firefighting scale shall be reasonably formulated.

(3) Tunnel water supply shall prioritise safety and reliability while meeting different requirements for water quantity, quality, and pressure at each water point.

(4) The design of the firefighting and water supply system shall be based on the pattern of traffic flow growth, balancing both short-term and long-term needs, with emphasis on the short term.

(5) A holistic approach shall be taken, considering the tunnel maintenance system, scale and grade, project characteristics, and water source surveys to determine the firefighting and water supply system design scheme reasonably.

(6) The tunnel firefighting pipeline network shall be designed as a looped system, with the

assumption that only one fire incident occurs at any given time. A wet fire-fighting water supply system is adopted for fire protection.

(7) Tunnel firefighting water sources should preferably use nearby municipal water supply systems. For tunnels without surrounding water supply networks, priority should be given to underground water sources such as wells. If not feasible, natural water sources such as rivers, lakes, seas, and reservoirs may be used, but they must meet the requirements of relevant standards.

(8) Tunnel firefighting water sources shall be separated from domestic and industrial water sources. A dual-source intake system should be implemented for fire protection.

(9) The selection of various equipment shall adhere to the requirements of advanced technology, energy conservation, environmental protection, excellent performance, high reliability, and as much standardisation as possible for ease of maintenance.

(10) Ulaanbaatar experiences severe winters (as low as -40°C) and short summers (as high as 30°C) with frequent freeze-thaw cycles. Therefore, water supply, drainage, and firefighting pipelines shall incorporate anti-freezing and anti-condensation measures.

5.15.2. Design Scope

This project's water supply, drainage, and firefighting design mainly includes: the tunnel fire hydrant system, aqueous film-forming foam (AFFF) extinguishing devices, fire extinguisher deployment, and fire alarm system design.

5.15.3. Selection of Main Design Param

(1) Fire Hydrant

1) Fire water demand inside the tunnel: 20L/s;

2) Fire water demand outside the tunnel: 30L/s;

3) Full-water spout at the least favourable point: ≥10m;

4) When the outlet pressure at the hydrant is greater than 0.5MPa, a dual-valve, dual-outlet pressure-reducing fire hydrant shall be used, equipped with two 25m hoses and two 19mm nozzles with a straight stream and a safeguarding water stream;

5) Fire duration for Class I tunnels: not less than three hours.

6) Jet flow rate: ≥5L/s.

(2) Aqueous Film-Forming Foam Fire Hydrant

1) Cold-resistant foam solution mixing ratio: 3%

2) Mixture solution flow rate: ≥30L/min

3) Foam solution storage capacity: 30L

4) Spray range: ≥6m

5) Spray duration: ≥30 min

6) Water supply pressure: ≥0.35MPa

(3) Distribution of Fire Extinguishers

Built-in portable dry powder fire extinguishers (MF/ABC6): not fewer than four units.

(4) Insulation method: electric tracing as the primary measure, with external insulation as a supplement. External insulation consists of 0.5mm thick aluminium foil + 5cm thick polyurethane foam + 8cm thick rubber-plastic insulation material in a wrapped configuration.

5.15.4. Fire Protection Scale

According to the “Code for Fire Protection Design of Buildings” (GB 50016-2014) (2018 version), “Technical Code for Fire Protection Water Supply and Hydrant Systems” (GB 50974-2014), “Design Specifications for Highway Tunnels, Part 1: Civil Engineering” (JTG 3370.1-2018), and “Design Specifications for Highway Tunnels, Part 2: Traffic Engineering and Auxiliary Facilities” (JTG D70/2-2014), when planning and designing urban traffic tunnels, a fire protection water supply system should be included. For Class IV tunnels and Class III tunnels used by pedestrians or non-motorised vehicles, fire protection water supply systems may be omitted. This tunnel is classified as a Class I tunnel, and the fire protection water supply system adopts a temporary high-pressure water supply system.

5.15.5. Fire Water Demand

The tunnel fire water demand is determined based on the number of fires that may co-occur and the amount of water required for a single fire extinguishing event (including both inside and outside the tunnel). The fire water demand for each tunnel in this project is shown in the table below.

Table 5. 34. Tunnel Fire Water Demand Calculation

Tunnel Name	Start Chainage	End Chainage	Tunnel Length (m)	Tunnel Classification	Outdoor Hydrant Water Demand (L/s)	Indoor Hydrant Water Demand (L/s)	Total Fire Water Demand (L/s)	Fire Fire Duration (h)	Fire Water Volume per Event (m³) for a Tunnel
1	K8+730	K10+810	2080	Class I	30	20	50	3	540

5.15.6. Fire System Design

(1) Fire Water Source

This tunnel is located within the city and uses the municipal water supply as its fire water source.

(2) Fire Hydrant Water Supply System

The tunnel in this project is classified as a Class I tunnel. A temporary high-pressure water

supply system is adopted for the tunnel's fire hydrant water supply system. The fire-fighting water demand inside the tunnel is designed as 20L/s per fire event, while outside the tunnel it is 30L/s, with a fire duration of 3h. The total fire water volume required per event is 540m³. A 600m³ fire water tank and fire pump room are installed at the tunnel entrance at the lower stake number to store both internal and external tunnel fire-fighting water.

The tunnel's internal fire water supply main adopts DN300 hot-dip galvanised welded steel pipes, with a wall thickness of 6.0mm and pressure resistance ≥1.0MPa, using flange connections. The fire pipeline is laid inside cable trenches on both the left and right sides of the tunnel. The fire water supply mains outside the tunnel are connected into a ring to ensure a reliable water supply. The fire hydrant branch pipes adopt DN65 hot-dip galvanised welded steel pipes, with a wall thickness of 4.0mm and pressure resistance ≥1.0MPa.

The internal fire water supply main uses DN300 hot-dip galvanised seamless steel pipes with both internal and external galvanising, connected using grooved mechanical couplings (clamps). A DN300 pipeline connects the fire water supply mains of both tubes outside the tunnel portals to form a closed-loop fire network, ensuring a reliable bidirectional water supply. Fire hydrants are spaced every 50m and embedded into the outer tunnel wall. Pipe expansion joints shall be installed on the fire pipelines inside the tunnel as required. A pressure gauge is installed at both the tunnel entrance and exit. When the dynamic pressure at the fire hydrant outlet exceeds 0.5MPa, or the static pressure exceeds 1.0MPa, a pressure-reducing fire hydrant is used to regulate pressure. In case of fire, the fire start button shall be pressed to activate the system.

Mechanical tees (threaded connection) are used between the fire main and the hydrant riser. Solenoid valves are installed to ensure the main remains dry under normal conditions.

The fire water supply main is divided into several independent sections by valves. When one section is damaged, no more than five hydrants are taken out of service. An air release valve is installed at the highest point of the fire main inside the tunnel, and a drain valve is installed at the lowest point of the network.

The fire pipeline inside the tunnel is welded to the grounding grid every 50m to ensure reliable grounding.

(3) Aqueous Film-Forming Foam Fire Hydrant

This tunnel, in addition to the standard fire extinguishing functions, shall be equipped with an aqueous film-forming foam fire extinguishing device capable of rapidly and efficiently extinguishing early-stage oil fires.

An aqueous film-forming foam fire extinguishing device is installed inside every tunnel fire hydrant cabinet. This device mainly consists of an aqueous film-forming solution tank, rubber hose, proportioning mixer, intermittent spray nozzle, hose guide rack, etc. The aqueous film-

forming foam concentrate used is an environmentally friendly aqueous film-forming foam fire extinguishing agent with a concentration of 3%.

(4) Fire Extinguisher Setting

The fire extinguisher configuration for this project is classified under the “Severe Hazard” category, and the fire type is Class B. The fire extinguisher shall be a 6kg ammonium phosphate dry powder extinguisher type, with each integrated cabinet containing: a fire hydrant, an aqueous film-forming solution system, and four extinguishers in a shared enclosure. This ensures that on-site personnel can promptly use them for early fire suppression.

(5) Fire Pump Connector and Y-Strainer

The tunnel’s fire protection system includes a fire pump connector located about 3m to the right of the tunnel entrance, along the direction of traffic. It is used by fire trucks to replenish the pipe network and is installed underground. A Y-Strainer with an expansion joint is also installed to prevent debris in the water from clogging the aqueous film-forming foam extinguishing device.

(6) External Fire Hydrants

An external fire hydrant is installed approximately 5m outside each tunnel portal. It is installed in an underground configuration.

(7) Fire Water Tank and Fire Pump Room, etc.

The fire water tank and fire pump room of this project are located in the median strip at the lower stake number of the tunnel.

The building structure adopts a frame structure above ground and a reinforced concrete structure underground. The fire resistance rating is Class II. The roof waterproofing level is Class Ⅱ, and the basement waterproofing level is Class I. The waterproof concrete has an impermeability grade of P6.

The fire resistance rating of this project is Class II. The fire pump room in this project is designed as a single fire compartment.

The fire water demand for the tunnel in this design is 540m³. To ensure the safety of the fire water supply, a 600m³ reinforced concrete fire water tank is provided. The tank is equipped with inlet and outlet pipes, a drain pipe, an overflow pipe, and a vent pipe. This design also includes a reservoir, inspection and maintenance hole, steel ladder, wall-penetrating pipes, wall-penetrating pipe reinforcement, pipe hangers, and ventilation openings, all detailed in the standard drawing “Rectangular Reinforced Concrete Reservoir” (05S804). Gratings are installed at the inlet and outlet of the tank to prevent debris from blocking the pipes. The water from the reservoir, pressurised by the fire pumps, ensures that the dynamic pressure at the outlet of the most unfavourable fire hydrant in the tunnel fire pipeline network is not less than 0.35MPa.

1) The control cabinet in the fire pump room shall control both the fire pumps and the

pressure-stabilising pumps, featuring remote control and local manual control functions. The local control cabinet shall be equipped with a digital display showing real-time water level data of the reservoir.

2) In the event of a tunnel fire, the activation of a fire hydrant shall be capable of automatically starting the fire pump to supply water to the fire central, ensuring continuous firefighting capability.

3) Under normal conditions, when the pressure in the fire pipeline network drops, the pressure-stabilising pump shall automatically start to maintain adequate pressure in the system, ensuring that the dynamic pressure at the fire hydrant outlet meets the requirements.

4) The pump control cabinet shall have a low-frequency automatic inspection function, periodically running the pump at low speed to prevent shaft seizure due to rust.

5) Remote pressure gauges shall be installed on each pump outlet pipe to monitor whether the supply pressure is normal during pump operation. All data shall be transmitted to the pump control cabinet.

6) A remote water level display device shall be installed in the fire water tank, along with a float valve for high and low water level alarms.

7) The submersible sewage pump shall be installed using an automatic coupling system and shall be controlled by the water level in the sump. The manufacturer shall provide the control device.

8) The fire water tank shall be backfilled with soil cover no less than the local frost depth.

9) The fire water tank shall adopt a rectangular configuration. Given the relatively independent nature of the tunnel firefighting system, if no fire occurs, the stored water remains stagnant for long periods, making it prone to water quality deterioration and algal growth. Proposed solutions include:

10) Installation of self-cleaning and disinfection devices in the fire water tank: periodic cleaning and addition of disinfectants such as bleaching powder; regular flushing of the tunnel via hydrants to renew the water and improve water quality in the tank.

(8) Fire Extinguisher Setting for the Fire Pump Room and Power Distribution Rooms

In this project, the tunnel fire pump room is equipped with two sets of portable ammonium phosphate dry powder fire extinguishers (model MF/ABC5). The tunnel box substation is classified as a Class A moderate risk area and is equipped with two sets of portable ammonium phosphate dry powder fire extinguishers (model MF/ABC3).

(9) Fire Pipeline Corrosion Protection

Firefighting water supply steel pipes inside and outside the tunnel are coated with two layers of anti-rust paint, followed by one layer of fire-resistant paint.

(10) Fire Pipeline Insulation and Frost Protection

Considering the severe cold climate at the project location, the tunnel's fire pipelines adopt multiple insulation measures, including electric heat tracing, external thermal insulation, and protective insulated cover plates. The primary method is electric heat tracing, supplemented by external insulation.

1) Electric Heat Tracing

Electric heat tracing is a thermal insulation technology that continuously heats pipelines, tanks, or equipment by converting electrical energy into heat. Compared to traditional steam tracing, electric heat tracing offers advantages such as energy efficiency, precise temperature control, stable operation, and ease of maintenance. It is also easy to install, space-saving, flexible, safe, and durable, making it widely applicable in industries like petrochemicals, firefighting systems, and municipal water supply and drainage. Electric heat tracing technology is based on the Joule heating effect, in which electric current generates heat as it passes through a resistive element. The heat is transferred to the traced object via heating cables, compensating for heat loss to the surrounding environment and maintaining the target temperature. The heating element for electric heat tracing is the electric heat tracing cable.

In this design, each fire main (D325×5) within the tunnel's utility trench is equipped with three electric heat tracing cables. These cables are rated at 10W/m and are applied using a flat adhesive layout, attached to both sides and the underside of the pipeline to ensure efficient upward heat transfer. The system operates in a constant voltage mode to maintain the required water supply temperature.

2) External Insulation

Aluminium foil, as a highly effective thermal insulation and reflective material, is widely used in construction, HVAC systems, industrial pipeline insulation, and cold chain logistics due to its excellent reflectivity, lightweight nature, corrosion resistance, and ease of installation. Its good flexibility allows it to be wrapped directly around pipes or equipment. With outstanding reflective properties and versatile composite applications, aluminium foil has become an indispensable material in modern insulation engineering. In electric heat tracing systems, it not only helps secure heating cables in place but also reduces heat loss.

Polyurethane foam is a high-performance closed-cell/open-cell plastic foam material that is extensively applied in construction, cold chain logistics, and industrial equipment. It features a low thermal conductivity, high mechanical strength, and excellent waterproof and moisture-resistant properties, making it one of the best-performing insulation materials available. It can be directly bonded to metal, concrete, and other substrates without additional fixings, offering strong adhesion.

Elastomeric insulation material is a flexible closed-cell thermal insulation product made primarily from nitrile butadiene rubber (NBR) or polyvinyl chloride (PVC) through a foaming

process. It offers low thermal conductivity, fire resistance, moisture protection, ease of installation, flexibility, shock absorption, and sound insulation. With balanced performance and high cost-effectiveness, it is widely used in construction, HVAC, and the petrochemical industry.

In this project, the external insulation for tunnel fire protection main pipelines is a passive insulation layer composed of a 0.5mm thick aluminium foil, 5cm thick polyurethane foam, and 8cm thick elastomeric insulation material. These are wrapped around the pipe and laid within the fire protection pipe trench.

3) Insulated Cover Plate

In this design, the cover plates above the fire protection pipe trench in the tunnel are insulated cover plates, which serve to enhance the overall thermal insulation performance.

(11) Automatic Fire Alarm System

An automatic fire alarm system is installed within the tunnel. It consists of a fire alarm control panel, a graphical monitoring workstation, fire detectors, manual fire alarm buttons (with fire telephone jacks), fire hydrant buttons, a dedicated fire telephone, a fire broadcasting system, monitoring and control modules, and other related devices.

A fire alarm control panel is located in the central control room of the tunnel, which is connected to the local fire department for real-time fire monitoring and coordination. A dedicated fire telephone host is also installed in the central control room to enable on-site fire communication and communication with the fire department. The fire alarm control panel is equipped with a printer that can print out system operation information. The system also monitors the operational status of equipment such as submersible pumps and fans, and will shut off non-fire-related circuits during fire incidents. The fire broadcasting system is used for evacuation and rescue commands.

Automatic fire alarm system module boxes are installed in areas such as the tunnel central control room, drainage pump stations, and entrances/exits to monitor associated equipment. A communication interface is provided on the fire alarm control panel to enable communication with the tunnel central control room.

In the event of a fire, the automatic fire alarm system transmits the alarm signals detected by the sensors via a data bus to the server in the central control room. The system will then activate the fire alarm signal, automatic fire suppression devices, fire pumps, submersible pumps, fans, and other linked control equipment, shut down non-fire-related circuits, and display the fire location to guide evacuation and rescue operations.

5.15.7. Tunnel Water Supply, Drainage, and Firefighting Equipment

Table 5. 35. List of Major Tunnel Ventilation Equipment

No.	Name	Specifications	Unit	Quantity	Notes
I. Inside the Tunnel					
1	Fire Hydrant Cabinet	2400×1100×350 (W×H×L)	Set	84	Each location is equipped with one SN65 single-outlet, dual-valve pressure-reducing and pressure-stabilising fire hydrant, two 25-meter rubber hoses, two nozzles, one aqueous film-forming foam fire extinguishing device, connecting accessories, a cabinet door, etc. Annual maintenance required; no import required
2	Fire Extinguisher Cabinet	1000×800×350 (W×H×L)	Set	84	Annual maintenance required, no import required
3	Foam Fire Extinguisher	PMZ30	Set	84	Environmentally friendly aqueous film-forming foam system, all fittings up to DN80 branch tees, operate at a working pressure not less than 0.4MPa, annual maintenance required, no import required.
4	Hydrant Cabinet	1000×800×350 (W×H×L)	Set	4	Including hydrants and associated accessories, no import required
5	Portable Dry Powder Fire Extinguisher	MF/ABC6,6kg	Unit	756	10 years of service life, no import required
6	Fire Pump Start Button	Complete assembly	Set	84	Annual maintenance required, no import required
7	Maintenance Valve Cabinet	1200×1000×800 (W×H×L)	Set	16	Annual maintenance required, no import required
8	Maintenance Butterfly Valve	DN300	Piece	16	5-8 years of service life, no import required
9	Internally and Externally Hot-Dip Galvanised Steel Pipe	D325x5 PN=1.0MPa	m	4200	Only includes in-tunnel fire main; pipe supports installed every 6m; 15 years of service life, no import required.
10	Internally and Externally Hot-Dip Galvanised Steel Pipe	D76x4.5 PN=1.0MPa	m	168	Fire branch pipe, connecting the fire main to the fire hydrants; 15 years of service life, no import required
11	Steel Tee	DN300×65	Piece	84	no import required
12	Steel Tee	DN300×50	Piece	4	Emergency parking strip hydrant, no import required
13	90° Steel Elbow	DN300	Piece	20	no import required
14	90° Steel Elbow	DN65	Piece	84	no import required
15	90° Steel Elbow	DN50	Piece	4	no import required
16	Grooved Clamp	DN300	Set	700	Annual maintenance required, no import required
17	Grooved Clamp	DN65	Set	84	Annual maintenance required, no import required
18	Grooved Clamp	DN50	Set	4	Annual maintenance required, applicable to branch gate valves, tees, and elbows; no import required

No.	Name	Specifications	Unit	Quantity	Notes
19	Pipeline Expansion Joint	DN200JS-16P	Set	16	Annual maintenance required, no import required
20	Steel Flange	DN300	Piece	32	no import required
21	Steel Flange	DN65	Piece	168	no import required
22	Steel Flange	DN50	Piece	8	no import required
23	Fire Equipment Identification Sign	W × H = 25 × 40 cm	Set	168	Fluorescent sign, no import required
24	Fire Branch Pipe Bracket	L50 angle steel bracket, dimensions to be determined on site	Set	84	no import required
25	Rubber-Plastic Insulation Material	Thickness: 8cm	Square m (m^2)	4300	Length: 4200m, no import required
26	Polyurethane Foam	Thickness: 5cm	Square m (m^2)	6500	Length: 4200m, no import required
27	Aluminum Foil	Thickness: 0.5mm	Square m (m^2)	6500	Length: 4200m, no import required
28	Solenoid Valve	DN65	Set	84	5-8 years of service life, suitable for fire branch pipes; includes power distribution and monitoring cables; power consumption: 30W; no import required
29	Gate Valve	DN50	Set	4	5-8 years of service life, suitable for hydrant branch pipes; no import required
30	Electric Heat Tracing Cable	10w/m	m	12600	Each fire main is equipped with three electric heat tracing cables, operating in constant voltage mode; no import required
II. Outside the Tunnel					
1	Air Release Valve	To be installed on DN25 main pipe, including short pipe, globe valve, tee, and other accessories.	Set	2	To be inspected annually; installed at the highest point of the pipeline network; no import required.
2	Drain Valve	To be installed on DN25 main pipe, including short pipe, globe valve, tee, and other accessories.	Set	2	To be inspected annually; installed lowest the lowest point of the pipeline network; no import required
3	Water Pump Connector		Set	4	Annual maintenance required; underground type with single-unit arrangement; reinforced concrete chamber; top surface vehicle-loadable; no import required
4	Underground Fire Hydrant		Set	4	Annual maintenance required, no import required
5	Fire Hydrant Pit	φ1500	Unit	4	04S531-4-6
6	Valve Chamber	φ1500	Unit	4	04S531-4-6
7	Gate Valve	DN300	Piece	8	Double-layer insulated manhole cover, including full set of accessories and insulation materials; no import required
8	Welded Steel Pipe	Φ450×6.0	m	100	Fire crossing pipe sleeve, measured by actual quantity; no import required
9	Internally and Externally	D325x5 PN=1.0MPa	m	**300**	Measured by actual quantity; no import required

No.	Name	Specifications	Unit	Quantity	Notes
	Hot-Dip Galvanized Steel Pipe				
III. Fire Pump Room and Fire Water Tank					
No.	**Name**	**Specifications**	**Unit**	**Quantity**	**Notes**
1	Rectangular Water Storage Tank	600m³	Unit	1	Refer to National Standard Atlas 05S804-109, including accessories
2	Fire Pump	Q=50L/s, H=58m, N=45kW	Set	2	15 years of service life, one in use, one standby; import required
3	Fire Booster Pump	Q=1L/s, H=40m, N=3kW)	Set	2	15 years of service life, one in use, one standby; import required
4	Pressure Tank	SQL800-1.0	Set	1	15 years of service life, import required
5	Submersible Sewage Pump	Q=25Lm³/h, H=10m, N=1.5kW	Set	2	15 years of service life, one in use, one standby; import required
6	Internally and Externally Hot-Dip Galvanized Steel Pipe	D273x5 PN=1.0MPa	m	50	15 years of service life, no import required
7	Internally and Externally Hot-Dip Galvanized Steel Pipe	D108x5 PN=1.0MPa	m	50	15 years of service life, no import required
8	Internally and Externally Hot-Dip Galvanized Steel Pipe	D76x4 PN=1.0MPa	m	30	15 years of service life, no import required
9	Flexible Waterproof Sleeve	DN300	Piece	2	Import required
10	Flexible Waterproof Sleeve	DN250	Piece	5	Import required
11	Flexible Waterproof Sleeve	DN100	Piece	6	Import required
12	Flexible Waterproof Sleeve	DN65	Piece	1	Import required
13	Check Valve	DN300	Piece	2	Annual maintenance required, no import required
14	Check Valve	DN100	Piece	2	Annual maintenance required, no import required
15	Gate Valve	DN300	Piece	2	Annual maintenance required, no import required
16	Gate Valve	DN250	Piece	2	Annual maintenance required, no import required
17	Gate Valve	DN100	Piece	4	Annual maintenance required, no import required
18	Flexible Rubber Joint	DN250	Piece	2	Annual maintenance required, no import required
19	Flexible Rubber Joint	DN100	Piece	2	Annual maintenance required, no import required
20	Y-Strainer	DN250	Piece	2	Annual maintenance required, no import required

No.	Name	Specifications	Unit	Quantity	Notes
21	Y-Strainer	DN100	Piece	2	Annual maintenance required, no import required
22	Steel Grating Cover Plate	2100x1100	Piece	1	Annual maintenance required, no import required
23	Pressure Meter	DN250	Piece	2	Annual maintenance required, no import required
24	Pressure Meter	DN100	Piece	2	Annual maintenance required, no import required
25	Pressure Testing Unit	Product	Set	2	Annual maintenance required, no import required
26	Flow Testing Unit	Product	Set	2	Annual maintenance required, no import required
27	Water Test Valve	DN65	Piece	4	Annual maintenance required, no import required
28	Portable Dry Powder Fire Extinguisher	MF/ABC5, 5kg	Unit	2	Inside the pump room; no import required
IV. Electrical Substation Room and Box Substation					
1	Portable Dry Powder Fire Extinguisher	MF/ABC3, 3kg	Unit	14	10 years of service life, no import required

5.16. TUNNEL POWER SUPPLY AND DISTRIBUTION ENGINEERING

5.16.1. Design Overview

The left tunnel line of this project starts at stake number LK8+730 and ends at LK10+810, with a total length of 2080m. The right tunnel line starts at stake number K8+730 and ends at K10+810, also with a length of 2080m. The design vehicle speed for the tunnel is 80km/h. It is a bidirectional six-lane tunnel. Along the entire tunnel, there are 5 pedestrian cross passages and 2 vehicle cross passages.

5.16.2. Technical Standards and design principles

The highest power load classification for the tunnel's power supply and distribution is Level 1. Among these, the emergency lighting facilities, electric-optic signs, and traffic monitoring systems are classified as special critical Level 1 loads; basic lighting and other loads fall under Level 1 loads; maintenance sockets, approach lighting, and other remaining electrical loads are classified as Level 3 loads.

(1) The design is primarily based on relevant codes and industry standards.

(2) Power supply must ensure safe, reliable, and normal operation, meeting the power supply requirements for different load levels as specified in the design codes.

(3) The grounding system for the 220/380V distribution system is of the TN-S type, where the neutral (N) and protective earth (PE) conductors are strictly separated from the low-voltage distribution center and equipotential bonding is implemented.

(4) Reactive power compensation for the 220/380V distribution system combines local compensation at large-capacity inductive loads and centralized compensation at the low-voltage

distribution cabinet of the substation.

(5) Equipment selection favors technically advanced, mature, and reliable products with proven stable performance under similar operating environments, and with reasonable pricing.

5.16.3. Design Scope

(1) Design contents: the tunnel's 10kV/0.4kV power supply and distribution system, tunnel lighting system, power system, lightning protection and grounding system, power supply, lighting, and lightning protection and grounding systems for the tunnel substation and fire pump room.

(2) Power supply design boundary: The design boundary is set at the upper end of the 10kV high-voltage incoming switchgear. The section below this boundary is within the scope of this design, while the section above (including external power lines) is managed by the local power supply authority. The embedded protective conduit for the 10kV incoming line shall be pre-installed in this project design.

5.16.4. Load Classification

According to Article 12.5.1 of the Code for Fire Protection Design of Buildings (GB50016-2014) and Article 11.2.1 of the "Highway Tunnel Design Specification Part II: Traffic Engineering and Ancillary Facilities (JTG D70/2-2014)", the load classification for this project is Level 1. Among these, emergency lighting facilities, electric-optic signs, and traffic monitoring systems are classified as special critical Level 1 loads; basic lighting and other similar loads are Level 1 loads; maintenance sockets, approach lighting, and other remaining electrical loads are Level 3 loads. The detailed load classification is shown in the table below.

Table 5. 36. Load Classification

No.	Load Name	Load Level
1	Emergency Lighting Electric-optic signs Traffic Monitoring Facilities Ventilation and Lighting Control Facilities Emergency Call Facilities Fire Detection, Alarm, and Control Facilities Central Control Facilities	Level 1a
2	Fire Pump Fire Water Pipe Electric Heat Tracing Solenoid Valve Basic Lighting Smoke Exhaust Fan	Level 1
3	Blower	Level 2
4	Other Tunnel Electrical Loads	Level 3

Note: a) This Level 1 load is classified as especially important load.

b) Ventilation fans other than those classified as Level 1 loads.

5.16.5. Load Calculation

Table 5. 37. Main Substation Electrical Load Calculation

No.	Electrical Equipment Name	Operation Mode	Voltage kV	Rated Capacity (kW)	Demand Factor Kx	Cosφ	tgφ	Calculated Load			Notes
								Active Power kW	Reactive Power kvar	Apparent Power kVA	
1	Emergency Lighting	Continuous	0.38	10	1	0.9	0.48	10.00	4.84	11.11	Special Critical load
2	Monitoring and Alarm Facilities	Continuous	0.38	40	1	0.9	0.48	40.00	19.37	44.44	
3	Jet Fan	Non-Continuous	0.38	880	0.8	0.8	0.75	704.00	528.00	880.00	Level 1 and Level 2 Load
4	Fire Pump Room	Non-Continuous	0.38	49.5	0.8	0.8	0.75	39.60	29.70	49.50	
5	Fire Water Pipe Electric Heat Tracing	Non-Continuous	0.38	63	0.8	0.8	0.75	50.40	37.80	63	
6	Solenoid Valve	Non-Continuous	0.38	1.25	0.8	0.8	0.75	1.00	0.75	1.25	
7	Basic Lighting	Continuous	0.38	70	1	0.9	0.48	70.00	33.90	77.78	
8	Strengthened Lighting	Continuous	0.38	28	0.9	0.9	0.48	25.20	12.20	28.00	
9	Electrical Substation Room	Non-Continuous	0.38	10	0.8	0.85	0.62	8.00	4.96	9.41	
10	Maintenance Socket	Non-Continuous	0.38	20	0.5	0.8	0.75	10.00	7.50	12.50	Level 3 Load
11	Approach Lighting	Non-Continuous	0.38	6	0.9	0.9	0.48	5.40	2.62	6.00	
12	Subtotal		0.38	1177.75		0.86	0.59	963.60	681.65	1180.33	Take the maximum value
13	Simultaneity Coefficient (kP =0.9 kq =0.95)		0.38			0.81	0.72	915.42	661.20	1129.24	
14	Reactive Power Compensation		0.38	-480					-480.00		
15	After Compensation		0.38			0.99	0.17	915.42	181.20	933.18	
16	Transformer Power Loss							9.33	46.66		
17	10kV Side Total		10					924.75	227.86	952.41	
18	Selected Transformer Capacity (kVA)		10/0.4	2×1600						1600	
19	Transformer Load Rate (%)									58.32	

Table 5.16.6-2 Box Substation Electrical Load Calculation

No.	Power Equipment Name	Operation Mode	Voltage kV	Rated Capacity (kW)	Demand Factor Kx	Cosφ	tgφ	Calculated Load			Notes
								Active Power kW	Reactive Power kvar	Apparent Power kVA	
1	Emergency Lighting	Continuous	0.38	10	1	0.9	0.48	10.00	4.84	11.11	Special Critical load
2	Monitoring and Alarm Facilities	Continuous	0.38	40	1	0.9	0.48	40.00	19.37	44.44	

No.	Power Equipment Name	Operation Mode	Voltage kV	Rated Capacity (kW)	Demand Factor Kx	Cosφ	tgφ	Calculated Load			Notes
								Active Power kW	Reactive Power kvar	Apparent Power kVA	
3	Jet Fan	Non-Continuous	0.38	880	0.8	0.8	0.75	704.00	528.00	880.00	Level 1 and Level 2 Load
4	Fire Water Pipe Electric Heat Tracing	Non-Continuous	0.38	63	0.8	0.8	0.75	50.40	37.80	63	
5	Solenoid Valve	Non-Continuous	0.38	1.25	0.8	0.8	0.75	1.00	0.75	1.25	
6	Basic Lighting	Continuous	0.38	70	1	0.9	0.48	70.00	33.90	77.78	
7	Strengthened Lighting	Continuous	0.38	28	0.9	0.9	0.48	25.20	12.20	28.00	
8	Substation Auxiliary Power System	Non-Continuous	0.38	5	0.8	0.85	0.62	4.00	2.48	4.71	
7	Maintenance Socket	Non-Continuous	0.38	20	0.5	0.8	0.75	10.00	7.50	12.50	Level 3 Load
8	Approach Lighting	Non-Continuous	0.38	6	0.9	0.9	0.48	5.40	2.62	6.00	
9	Subtotal		0.38	1059		0.86	0.59	920.00	611.67	1104.78	Take the maximum value
10	Simultaneity Coefficient (kP =0.9 kq =0.95)		0.38			0.83	0.68	874.00	593.32	1056.36	
11	Reactive Power Compensation		0.38	-480					-480.00		
12	After Compensation		0.38			0.99	0.13	874.00	113.32	881.32	
13	Transformer Power Loss							8.81	44.07		
14	10kV Side Total		10					882.81	157.38	896.73	
15	Selected Transformer Capacity (kVA)		10/0.4	2×1600						1600	
16	Transformer Load Rate (%)									55.08	

5.16.6. Tunnel Power Supply and Distribution Design

(1) Power Supply

A substation integrated with an equipment room is planned to be constructed outside the tunnel at the smaller stake number side. The substation adopts a dual-circuit power supply configuration, with two 10kV incoming lines introduced from the municipal power grid into two sections of 10kV busbars within the substation. Both 10kV feeders operate simultaneously and are each capable of supporting 100% of the load independently to ensure normal operation. A box substation is to be installed outside the tunnel on the larger stake number side, also adopting a dual-circuit power supply. The 10kV incoming lines are tapped from the two sections of 10kV busbars of the main substation.

According to the load calculations, the main substation will be equipped with two 1600kVA dry-type transformers, and the box substation will also be equipped with two 1600kVA dry-type transformers. Both transformers operate in parallel and serve as mutual backup. In the event of a transformer failure, the remaining transformer shall be able to carry the full load without interruption. The two 10kV incoming line circuit breakers and the bus-tie circuit breaker are interlocked electrically, with manual switching enabled.

For special critical Level 1 loads, in addition to the two external power sources mentioned

above, uninterruptible power supply (UPS) systems and emergency power supply (EPS) units are provided as backup power sources. These systems ensure that lighting interruption period does not exceed 0.3s, and the backup power supply duration is no less than 90min.

(2) 10kV/0.4kV Power Distribution System

1) Two 1600kVA transformers shall be installed in the main substation, and two 1600kVA transformers shall be installed in the box substation. All transformers shall be dry-type, equipped with temperature controllers and corresponding communication interfaces. Remote control interface terminals shall be reserved on each circuit of other switchgear cabinets to facilitate monitoring system connections.

2) Power Distribution Methods for Each System

① Lighting Power Distribution

Tunnel lighting distribution adopts a trunk-and-branch configuration. The lighting trunk line, fed from the low-voltage busbar of the substation, is routed through the power cable tray duct inside the tunnel. At the distribution panel, cables are led from embedded conduits to the cable tray. Insulated piercing connectors are used for wiring at each luminaire.

② Monitoring Power Distribution

The tunnel monitoring distribution trunk line is routed via communication cable trays to the monitoring distribution panel. After branching into sub-lines in the monitoring distribution panel, cables are routed through embedded metal conduits to the cable trays, which lead to the electrical equipment. A radial power supply system is employed from the monitoring distribution panel to the monitoring equipment.

③ Fan Power Distribution

The electrical load capacity of tunnel jet fans is relatively large, and a radial wiring system is adopted. The fans serve as smoke exhaust fans and are used for regular ventilation, thus being classified as fire protection loads. local start-up control panels are installed at each fan location to enable end-point switching. Each set of jet fans is powered by two (one main and one backup), power distribution sources separately fed from the two sections of the low-voltage busbar in the substation. Cables are routed through the tunnel power cable trays to the fan local start-up control panels. From the local start-up control panels, cables are laid through embedded metal conduits to the fans. Independent circuits are taken from the start control boxes to separately supply power to each of the two fans in the set.

④ Fire Protection Power Distribution

The tunnel fire protection equipment is powered by two (one main and one backup) power distribution sources supplied from the substation. A dual power transfer switch cabinet is installed in the fire pump room for end-point switching. From the substation's switchgear cabinet,

cables are routed through embedded conduits to the dual power transfer switch cabinet in the fire pump room. From there, the cables are laid through embedded metal conduits to the fire pumps.

⑤ The low-voltage distribution system adopts a two-level distribution approach, comprising primary distribution (substation) and terminal distribution (on-site equipment) with selective or partially selective coordination between the protective devices at both levels.

3) Reactive Power Compensation

The substation employs a low-voltage centralized automatic reactive power compensation device. A low-voltage automatic reactive power compensation cabinet is installed at the 0.4kV low-voltage incoming line. The power factor on the 10 kV side after compensation shall be above 0.90.

4) Signaling, Protection, and Measurement

The 10kV incoming lines of the main substation are equipped with definite time overcurrent protection, instantaneous trip, zero-sequence protection, and overload protection. The 10kV outgoing lines of the main substation and the 10kV incoming/outgoing lines of the box substation are equipped with inverse time overcurrent protection, instantaneous trip, zero-sequence protection, and overload protection. Power instrument signals communicate with the monitoring center power monitoring computer via a bus system. On the 0.4kV side of the substation, the main low-voltage incoming circuit breaker is equipped with two-stage protection: overload with long time delay and short circuit with short time delay. Low-voltage distribution circuits use circuit breakers or fuses for overload, short circuit, and ground fault protection. Switch status of the 0.4kV incoming line and main feeder circuits, as well as power instrument signals, are uploaded to the monitoring system.

5) Metering

In this project, a metering cabinet is installed in the substation for local metering. Internal management metering and sub-item metering data are collected via low-voltage intelligent meters and centrally managed by the power monitoring system.

(3) Tunnel Power Supply Quality Requirements

Under normal operating conditions, the allowable voltage deviation from the secondary side outlet of the self-supplied transformer at the 10kV line to the primary side inlet of the transformer at the line end shall be within ±5% of the rated line voltage. The voltage deviation at the terminals of electrical equipment inside the highway tunnel shall meet the following requirements: For motors, ±5%. In rare cases where the motor's working location is far from the substation and cannot meet this requirement, voltage may drop below 95% but must not be lower than 90%. For other electrical equipment, when no special requirements exist, ±5% is applicable. To ensure power quality, an active power filter is installed.

Power factor requirements: low voltage (at user intake) COSΦ ≥ 0.85; high voltage COSΦ ≥ 0.9.

(4) Tunnel Power Monitoring

A communication management unit shall be installed at the box substation. All tunnels form an industrial Ethernet ring network, and tunnel power monitoring signals are transmitted via the communication optical fiber system to the tunnel management building.

1) System Monitoring Scope

Monitoring of 10kV feeder circuits in high-voltage switchgear cabinets;

Monitoring of emergency lighting UPS;

Monitoring of emergency power supply EPS;

Monitoring of 0.4kV incoming circuits in low-voltage switchgear cabinets;

Monitoring of 0.4kV fire protection outgoing circuits in low-voltage switchgear cabinets;

Monitoring of capacitor compensation cabinets;

Monitoring of other electrical equipment.

2) System Functional Requirements

Data Acquisition Function: Collect and monitor parameters such as voltage, current, active power, reactive power, and frequency of the monitored circuits. Acquire transformer temperature data, as well as the status signals of circuit breakers and switches.

Control and Operation Function: Through the LCD screen, perform remote control operations for circuit breakers, switches, and contactors (on/off control). Through the LCD screen, modify the upper and lower limits for telemetry values.

Screen Display Function: The display interface shall be aesthetically pleasing, clear, and soft in color with a consistent visual style across all windows. Support multi-window display. Display real-time single-line diagrams, telemetry parameter tables (with limit values), and graphical curves (e.g., load and voltage curves). Provide visualization of historical data charts and graphs for analysis.

Report Printing Function: The system shall include a simple, user-friendly, and flexible report generation module, capable of printing various types of daily, monthly, and annual reports. Daily reports can be stored for one month, monthly reports for one year, and annual reports for ten years.

Event Recording and Playback Function: The system shall record and print all circuit breaker trips/closures, with visual alerts (color changes, flashing, on-screen notifications). . It shall generate alarms and print records when analog measurements exceed preset thresholds. The system shall support event playback and maintain an automatic log of all events to help operators understand the historical status of the power distribution system. The system shall include power flow analysis tables.

Human-Machine Interaction Function: The user interface shall be intuitive and menu-driven, with password protection for critical operations. The interface shall be fully localized in Chinese. The system shall support voice alarms.

The system shall be equipped with software-based self-diagnosis capabilities.

(5) Electrical Equipment Selection and Installation

All products shall meet the requirements of operating reliably in low-temperature climate conditions. The selection of equipment within box substations shall be determined based on the operating environment and installation conditions of the transformer and distribution equipment. For electrical equipment installed outside the tunnel, products must be technically advanced, safe and reliable, energy-efficient and environmentally friendly, and cost-effective. For equipment installed inside the tunnel, in addition to meeting the above requirements, due to the constraints of the operational environment and limited maintenance conditions, equipment must be compact in size, low in power loss and noise, air-cooled, non-explosive, moisture-proof, corrosion-resistant, vibration-resistant, and compliant with fire safety standards.

10kV high-voltage switchgear shall adopt SF6 fixed ring main unit (RMU) cabinets. Transformers shall be SCB13 series high-efficiency dry-type transformers with protective enclosures. Low-voltage switchgear shall be GGD type fixed low-voltage switchgear cabinets, constructed with high-quality steel cabinets and finished with electrostatic powder coating.

The protection rating of power distribution cabinets, control boxes, socket boxes, insulated piercing connectors, and junction boxes inside the tunnel shall be no less than IP55.

Enclosure Materials for Distribution Panels: Inside tunnels, distribution panel enclosures shall be made of stainless steel. In other locations, enclosures shall be made of high-quality electrolytic steel plates, finished with electrostatic powder coating for anti-corrosion protection. Auxiliary mounting base plates shall be made of galvanized steel with the following thickness requirements: For enclosures with a height ≤ 400mm: 1.2mm thick box body. For enclosures with a height > 400mm: 1.5 mm thick box body. All auxiliary mounting base plates shall be 2.0mm thick.

5.16.7. Tunnel Power Supply and Distribution Equipment Materials

Table 5. 38. Tunnel Power Supply and Distribution Equipment Materials

No	Equipment Name	Model and Specifications	Unit	Quantity	Notes
I. Main Substation Supply and Distribution					
1	10kV Overhead Line for Tunnel	10kV Steel-Core Aluminum Stranded Conductor	Km	5	20 years of service life
2	High Voltage System				
2.1	High Voltage Incoming Switchgear Cabinet	KYN28A-12 800×1500×2300	Unit	2	20 years of service life

No	Equipment Name	Model and Specifications	Unit	Quantity	Notes
2.2	High Voltage Metering Panel	KYN28A-12 800×1500×2300	Unit	2	20 years of service life
2.3	High Voltage PT Panel	KYN28A-12 800×1500×2300	Unit	2	20 years of service life
2.4	Bus Coupler Panel	KYN28A-12 800×1500×2300	Unit	1	20 years of service life
2.5	Bus Sectionalizing Switchgear Cabinet	KYN28A-12 800×1500×2300	Unit	1	20 years of service life
2.6	High Voltage Outgoing Switchgear Cabinet	KYN28A-12 800×1500×2300	Unit	4	20 years of service life
3	Dry-Type Transformer	SCB13-1600kVA 10±2x2.5/0.4kV D, yn11	Set	2	20 years of service life
4	Low Voltage System				
4.1	Low Voltage Incoming Switchgear Cabinet	MNS 800×800×2200	Unit	2	20 years of service life
4.2	Low Voltage Compensation Cabinet	MNS 800×800×2200	Unit	2	20 years of service life
4.3	Low Voltage Outgoing Switchgear Cabinet	MNS 800×800×2200	Unit	11	20 years of service life
II. Box Substation Supply and Distribution					
1	High Voltage System				
1.1	High Voltage Incoming Switchgear Cabinet	SF6 Fully Insulated Ring Main Unit 800×1500×2300	Unit	2	20 years of service life
1.2	High Voltage PT Panel	SF6 Fully Insulated Ring Main Unit 800×1500×2300	Unit	2	20 years of service life
1.3	High Voltage Outgoing Switchgear Cabinet	SF6 Fully Insulated Ring Main Unit 800×1500×2300	Unit	2	20 years of service life
2	Dry-Type Transformer	SCB13-1600kVA 10±2x2.5/0.4kV D, yn11	Set	2	20 years of service life
3	Low Voltage System				
3.1	Low Voltage Incoming Switchgear Cabinet	GGD 800×800×2200	Unit	2	20 years of service life
3.2	Low Voltage Compensation Cabinet	GGD 800×800×2200	Unit	2	20 years of service life
3.3	Low Voltage Outgoing Switchgear Cabinet	GGD 800×800×2200	Unit	11	20 years of service life
III. Low Voltage Distribution System					
1	Fan local Start-up Control Panel	IP65 LFJ1-LFJ7 RFJ1-RFJ7 80*95*40cm	Set	16	10 years of service life
2	Tunnel Lighting Distribution Panel	IP65 LZM1-LZM4 RZM1-RZM4 80*95*40cm	Set	8	10 years of service life
3	Emergency Lighting Distribution Panel	IP65 LYJ1-LYJ4 RYJ1-RYJ4 80*95*40cm	Set	8	10 years of service life
4	Maintenance Power Distribution Panel	IP65 LJX1-LFJ6 RJX1-RFJ6 80*95*40cm	Set	12	10 years of service life
5	Monitoring Distribution Panel	IP65 LJK1-LJK3 RJK1-RJK3 80*95*40cm	Set	6	10 years of service life
6	EPS Main Power Control Cabinet	10kW Three-Phase Lighting Type	Unit	2	10 years of service life
7	EPS Battery Cabinet	180min of continuous power supply	Unit	2	10 years of service life

No	Equipment Name	Model and Specifications	Unit	Quantity	Notes
8	UPS Main Control Cabinet	40kVA Online Type Three-Input Three-Output UPS	Unit	2	10 years of service life
9	UPS Battery Cabinet	Tfd=180min	Unit	2	10 years of service life
10	SCADA Control Cabinet	19-Inch Standard Cabinet	Unit	2	10 years of service life
11	Surge Protection Module	19-Inch Standard Cabinet	Unit	2	10 years of service life
12	DC Power Panel	800×600×2200	Unit	2	8 years of service life
IV. Cable					
1	10kV Power Cable	ZR-YJV22-8.7/15kV-3×240	m	2200	20 years of service life
2	10kV Power Cable	ZR-YJV22-8.7/15kV-3×120	m	4664	20 years of service life
3	Mineral-Insulated Fire-Resistant Cable	Mineral-Insulated Fire-Resistant Cable-3×95+2×50	m	3289	20 years of service life
4	Mineral-Insulated Fire-Resistant Cable	Mineral-Insulated Fire-Resistant Cable-3×70+2×35	m	5060	20 years of service life
5	Mineral-Insulated Fire-Resistant Cable	Mineral-Insulated Fire-Resistant Cable-3×50+2×25	m	3542	20 years of service life
6	Mineral-Insulated Fire-Resistant Cable	Mineral-Insulated Fire-Resistant Cable-3×35+2×16	m	2024	20 years of service life
7	Cross-Linked Polyethylene (XLPE)	WDZB-YJY-0.6/1kV-3×35+2×16	m	3795	20 years of service life
8	Cross-Linked Polyethylene (XLPE)	WDZB-YJY-0.6/1kV-5×16	m	1298	20 years of service life
9	Cross-Linked Polyethylene (XLPE)	WDZB-YJY-0.6/1kV-4×35+1×16	m	3773	20 years of service life
10	Mineral-Insulated Fire-Resistant Cable	Mineral-Insulated Fire-Resistant Cable-4×25+1×16	m	3773	20 years of service life
11	Cross-Linked Polyethylene (XLPE)	WDZBN-YJY-0.6/1kV-3×35+2×16	m	1582	20 years of service life
12	Cross-Linked Polyethylene (XLPE)	WDZBN-YJY-0.6/1kV-3×50+2×25	m	2246	20 years of service life
13	Cross-Linked Polyethylene (XLPE)	WDZBN-YJY-0.6/1kV-3×35+2×16	m	3553	20 years of service life
14	Mineral-Insulated Fire-Resistant Cable	Mineral-Insulated Fire-Resistant Cable-3×95+2×50	m	220	20 years of service life
15	Mineral-Insulated Fire-Resistant Cable	Mineral-Insulated Fire-Resistant Cable-5×16	m	110	20 years of service life
16	Mineral-Insulated Fire-Resistant Cable	Mineral-Insulated Fire-Resistant Cable-3×50+2×25	m	110	20 years of service life
17	Mineral-Insulated Fire-Resistant Cable	Mineral-Insulated Fire-Resistant Cable-5×16	m	110	20 years of service life
18	Communication Cable for Electrical Fire	WDZBN-RYJSP-2×2.5	m	8756	15 years of service life
19	Controlling Cable	WDZBN-KYJY 20×2.5	m	13915	20 years of service life
V. Others					
1	Communication Management Unit	LSA1200	Set	2	10 years of service life
2	Electrical Fire Monitoring Main Unit		Set	1	15 years of service life

No	Equipment Name	Model and Specifications	Unit	Quantity	Notes
3	Fiber Optic Media Converter		Set	3	10 years of service life
4	Serial Server		Set	2	5 years of service life
5	Power Monitoring Software		Set	1	5 years of service life

Note: Whether import of power supply and distribution equipment is required shall be investigated during the construction drawing design phase.

5.17. TUNNEL LIGHTING ENGINEERING

5.17.1. Design Principles

(1) The basic design principles of the tunnel lighting system shall ensure driving safety and comfort while enabling easy operation of the lighting circuits. Maintenance convenience during tunnel operation shall also be considered, with an emphasis on energy saving.

5.17.2. Design Standards

The tunnel lighting shall adopt zoned lighting. The adaptation luminance L20(s) = 3000cd/m². For this project, the Threshold Zone reduction coefficient k = 0.026.

5.17.3. Calculation Conditions

Tunnel length: L = 2080m;

Roadway width: W = 12.5m;

Tunnel height: H = 7.875m;

Luminaire installation height: H = 5.7m;

Design speed: 80km/h;

Design hourly traffic volume = 860veh/(h.ln);

Lighting stopping sight distance: 100m;

Pavement type: Tunnel asphalt concrete pavement

Tunnel interior reflectance: Tunnel walls (light-colored fireproof coating, 4.0m high) 70%; arch (dark-colored fireproof coating) 10%.

Luminance uniformity UO ≥ 0.4, longitudinal uniformity UL ≥ 0.7.

Road Surface Luminance conversion coefficient: asphalt concrete pavement 15lx/(cd·m²).

Luminaire maintenance factor M = 0.7.

Adaptation luminance L20(s) = 3000cd/m²;

Threshold Zone reduction coefficient k = 0.026;

Luminaire utilization factor 0.6; luminaire maintenance factor 0.7.

LED lamps are used, with rated luminous flux values of the light sources as shown in the table below:

Table 5. 39. Reference for Rated Luminous Flux of Luminaires

Lamp Power (W)	Rated Luminous Flux (lm)
100W	11000
250 W	27500
400 W	48000

5.17.4. Road Surface Luminance Calculation

(1) Calculation of Zoned Lengths and Road Surface Luminance Target Values

1) Interior Zone Luminance: Lin=2.5cd/m²

2) Threshold Zone Length and Luminance:

Lth1=k×L20(s)= 0.026×3000=78.0cd/m²

Lth2=0.5× k×L20(s)= 0.5×0.026×3000=39.0cd/m²

$$Dth1 = Dth2 = \frac{1}{2}(1.154Ds - \frac{h-1.5}{\tan 10^{\circ}}) = \frac{1}{2}(1.154 \times 100 - \frac{7.8-1.5}{\tan 10^{\circ}}) = 40m$$

In the formula: Lth1 represents Luminance of Threshold Zone TH1 (cd/m²);

Lth2 represents Luminance of Threshold Zone TH2 (cd/m²);

Dth1 represents Length of Threshold Zone TH1 (m);

Dth2 represents Length of Threshold Zone TH2 (m);

Ds represents Lighting Stopping Sight Distance;

h represents Net Clearance Height Inside the Tunnel;

3) Length and Luminance of Transition Zone

L1r1 = 0.15 ×Lth1 =0.15 × 78.0=11.7 cd/ m²

L1r2= 0.05 × Lth1 = 0.05 × 78.0 = 3.9cd/ m²

L1r3 = 0.02 ×Lth1 = 0.02 × 78.0 = 1.56cd/m² < 2.5 × 2 = 5.0cd/ m², Transition Zone may be omitted.

Transition Zone TR1: $D_{tr1} = \frac{D_{th1} + D_{th2}}{3} + \frac{v_t}{1.8} = \frac{40 + 40}{3} + \frac{80}{1.8} = 71m$

Transition Zone TR1: $D_{tr2} = \frac{2v_t}{1.8} = \frac{2 \times 80}{1.8} = 89m$

In the formula: Ltr1 represents Luminance of Transition Zone TR1 (cd/m²);

Ltr2 represents Luminance of Transition Zone TR2 (cd/m²);

Ltr3 represents Luminance of Transition Zone TR3 (cd/m²);

Dtr1 represents Length of Threshold Zone TH2 (m);

Dtr2 represents Length of Threshold Zone TH2 (m);

vt represents Design Speed;

$\frac{v_t}{1.8}$ represents Distance Traveled within 2s;

4) Exit Zone Luminance

Lex1=3×Lin=7.5cd/m²

Lex2=5×Lin=12.5cd/m²

5) Emergency Lighting Luminance:

Lyj=0.1×Lin=0.25cd/m²

(2) Calculation of Road Surface Luminance Design Values

1) Interior Zone Design Luminance:

Nighttime Interior Zone Illuminance:

$$E'_{av} = \frac{\eta \bullet \Phi \bullet M \bullet \omega}{W \bullet S} = \frac{0.7 \times 11000 \times 0.7 \times 2}{12.5 \times 16} = 53.9\ lx$$

Interior Zone Design Luminance: $\frac{E'_{av}}{15}$ = 3.6cd/m²

Daytime Interior Zone Illuminance:

$$E_{av} = \frac{\eta \bullet \Phi \bullet M \bullet \omega}{W \bullet S} = \frac{0.7 \times 11000 \times 0.7 \times 2}{12.5 \times 8} = 107.8lx$$

Interior Zone Design Luminance: $\frac{E_{av}}{15}$ = 7.2cd/m²

In the formula: E_{av} represents Average Road Surface Horizontal Illuminance (lx);

η represents Utilization Factor, 0.45 for High-pressure Sodium Lamps, 0.7 for LED Panel Lamps;

Φ represents Rated Luminous Flux of the Luminaire (lm);

M represents Maintenance Factor of the Luminaire, taken as 0.7;

ω represents Luminaire Arrangement Coefficient, taken as 2 for symmetrical arrangement, and 1 for staggered, middle, or central offset single-row arrangements;

W represents Pavement Width (m);

S represents Luminaire Spacing (m);

2) Threshold Zone Design Luminance:

Threshold Zone 1 Enhanced Lighting Illuminance:

$$E_1 = \frac{\eta \bullet \Phi \bullet M \bullet \omega}{W \bullet S} = \frac{0.7 \times 48000 \times 0.7 \times 2}{12.5 \times 3} = 1254.4lx$$

Threshold Zone 1 Design Luminance:

$\frac{E_{av} + E_1}{15}$ = 90.8cd/m²

Threshold Zone 2 Enhanced Lighting Illuminance:

$$E_2 = \frac{\eta \bullet \Phi \bullet M \bullet \omega}{W \bullet S} = \frac{0.7 \times 27500 \times 0.7 \times 2}{12.5 \times 4} = 539 \text{ lx}$$

Threshold Zone 2 Design Luminance:

$$\frac{E_{av} + E_1}{15} = 43.1 \text{cd/m}^2$$

3) Transition Zone Design Luminance:

Transition Zone 1 Illuminance:

$$E_3 = \frac{\eta \bullet \Phi \bullet M \bullet \omega}{W \bullet S} = \frac{0.7 \times 11000 \times 0.7 \times 2}{12.5 \times 5} = 172.5 \text{lx}$$

Transition Zone 1 Design Luminance:

$$\frac{E_{av} + E_3}{15} = 18.7 \text{cd/m}^2$$

Transition Zone Design Luminance:

Transition Zone 2 Illuminance:

$$E_4 = \frac{\eta \bullet \Phi \bullet M \bullet \omega}{W \bullet S} = \frac{0.7 \times 11000 \times 0.7 \times 2}{12.5 \times 16} = 53.9 \text{lx}$$

Transition Zone 2 Design Luminance:

$$\frac{E_{av} + E_4}{15} = 10.8 \text{cd/m}^2$$

4) Exit Zone Design Luminance:

Exit Zone 1 Enhanced Lighting Illuminance: $E_5 = \frac{\eta \bullet \Phi \bullet M \bullet \omega}{W \bullet S} = \frac{0.7 \times 11000 \times 0.7 \times 2}{12.5 \times 8}$ = 107.8lx

Exit Zone 1 Design Luminance: $\frac{E_{av} + E_5}{15}$ = 14.4 cd/m²

Exit Zone Design Luminance:

Exit Zone 2 Enhanced Lighting Illuminance: $E_6 = \frac{\eta \bullet \Phi \bullet M \bullet \omega}{W \bullet S} = \frac{0.7 \times 11000 \times 0.7 \times 2}{12.5 \times 5}$ = 172.48lx

Exit Zone 2 Design Luminance: $\frac{E_{av} + E_6}{15}$ = 18.7 cd/m²

5) Emergency Lighting Design Luminance

Emergency Lighting Illuminance: $E_7 = \frac{\eta \bullet \Phi \bullet M \bullet \omega}{W \bullet S} = \frac{0.7 \times 2970 \times 0.7 \times 2}{12.5 \times 12}$ = 19.4lx

Emergency Lighting Design Luminance: $\frac{E_7}{15}$ = 1.3cd/m²

6) Lighting System Setting as follows.

Table 5. 40. Tunnel Lighting System Setting

Category	Length (m)	Luminaire Model	Layout Method	Single-side Luminaire Spacing	Road Surface Luminance Target Value (cd/m²)	Road Surface Luminance Design Value (cd/m²)	Quantity (Units)
Threshold Zone Luminance	40	400W LED Lamp	Bilateral Symmetrical	3	78	90.8	27
Threshold Zone Luminance	40	250W LED Lamp	Bilateral Symmetrical	4	39	43.1	20
Transition Zone Luminance	71	100W LED Lamp	Bilateral Symmetrical	5	11.7	18.7	26
Transition Zone Luminance	89	100W LED Lamp	Bilateral Symmetrical	16	3.9	10.8	12
Interior Zone Luminance L_{in}	1858	100W LED Lamp	Bilateral Symmetrical	16	2.5	3.6	232
Exit Zone Luminance L_{ex1}	32	100W LED Lamp	Bilateral Symmetrical	8	7.5	14.4	8
Exit Zone Luminance L_{ex2}	30	100W LED Lamp	Bilateral Symmetrical	5	12.5	18.7	14
Emergency Lighting		27W LED Tunnel Lamp	Bilateral Symmetrical	12	0.2	1.3	346

5.17.5. Lighting Power Supply Design

(1) The tunnel lighting power supply is drawn from the tunnel box substation and adopts a combination of radial and trunk distribution methods. The tunnel lighting is powered by four circuits: enhanced lighting on the right side, emergency lighting on the right side, enhanced lighting on the left side, and basic lighting on the left side.

The emergency lighting circuit is normally powered by the mains. In the event of a power outage, the EPS is automatically engaged. Under normal conditions, emergency lighting functions as part of the basic lighting system. The emergency lighting distribution cable is routed directly from the EPS power source in the substation.

(2)The grounding flat steel shall be laid continuously along the cable trench and connected with reserved grounding electrodes in the trench and connected with embedded tunnel reinforcement terminals for repeated grounding and jointly grounded with tunnel portal grounding electrodes and the tunnel box substation grounding grid. The grounding flat steel is reliably welded to the cable support tray.

Luminaires and electrical equipment are grounded via piercing clamps connected to the grounding wire laid inside the cable tray.

(3) Luminaire phases are connected in a staggered phase sequence pattern: L1(A) - L2(B) - L3(C) - L3(A) - L2(B) - L1(C).

5.17.6. General Requirements for LED Luminaires

Tunnel entrances and exits must be equipped with a normally closed lighting system. For motor vehicle tunnels, lighting fixtures with a protection rating of IP65 and beam control capability shall be used. Directional lighting fixtures with a beam divergence angle of less than 10° shall be used inside the motor vehicle tunnels.

LED luminaires utilize semiconductor light-emitting materials. Compared with other types of light sources, LEDs have distinct advantages in terms of being environmentally friendly, energy efficient, reliable, and durable. Their key features include long service life, high luminous efficacy, solid-state encapsulation, strong vibration resistance, and low heat emission. Therefore, this project adopts an LED lighting scheme: LED luminaires are used in the threshold zone, transition zone, and base lighting section of the tunnel.

The luminaire includes the mounting adapter, housing, LED light-emitting module, and power supply (including cables from the luminaire to the junction box).

Luminaire structure: flat-profile design, made of one-piece stretched aluminum alloy, sturdy and durable, able to withstand mechanical, electrical, and thermal stress, and electrical components must be moisture-proof, explosion-proof, fire-resistant, and flame-retardant.

Grounding continuity: The non-current-carrying metallic parts of the luminaires must be integrated and connected to the grounding mainline via a grounding screw on the housing.

The main structural components, power supplies, and the like of the luminaires shall be interchangeable.

Startup time shall not exceed 1 second while power factor shall be greater than 0.95.

Protection rating: The dust and water resistance rating of the luminaire housing shall be no less than IP65. If an acrylic panel is installed on the front of the luminaire, it must not be sealed with adhesive, and disassembling the panel shall not compromise the protection rating.

5.17.7. Cable Selection, Installation, and Fire Protection

High-voltage cables shall adopt WDZ-YJY-8.7/10kV flame-retardant cross-linked polyethylene insulated, polyvinyl chloride sheathed copper core power cables.

Low-voltage cables shall adopt WDZ-YJY-0.6/1kV flame-retardant power cables. Double-circuit power supply cables serving Level I and Level II loads, as well as cables for emergency lighting and other lighting, shall not be laid on the same cable tray along the same route. If they must be laid on the same tray, fire-resistant partitions shall be installed between them, and fire-retardant coatings shall be applied to the inner surface of the tray. Cables outside of cable trays

shall be routed concealed within hot-dip galvanized steel conduits along wall panels.

For tunnel outgoing lines and similar locations, WDZ-BYJ-450/750V flame-retardant wires shall be used, routed in concealed hot-dip galvanized steel conduits.

Control cables shall be of the WDZ-KVVP flame-retardant type, and those related to fire protection systems shall be of the WDZN-KVVP fire-resistant type.

Ordinary power cables and fire power cables shall be laid on separate cable trays or laid within trays with fire-resistant separation. Power cables (strong current) and signal cables (weak current) shall be laid on separate trays.

The power supply for tunnel emergency lighting, evacuation lighting, and similar equipment shall adopt WDZN fire-resistant cables and wires. For other electrical loads not specified above, WDZ flame-retardant cables and wires shall be used.

The tunnel lighting distribution system shall adopt a combination of tree-type and radial distribution methods. Power cables inside the tunnel shall be laid on brackets in the cable trench, and routed to the tunnel cable tray through pre-embedded steel conduits in the sidewall. Lighting branch circuits shall be laid along the cable trays. At each luminaire location, insulation-piercing connectors shall be used to branch out tap wires, which are routed to the luminaire in flexible metal conduits.

Power distribution cables for basic lighting and enhanced lighting shall be flame-retardant type, while those for emergency lighting shall be of fire-resistant type. Luminaires and electrical equipment are grounded via piercing clamps connected to the grounding wire laid inside the cable tray.

The steel cable trunking shall adopt specifications of 200mm × 150mm × 1.5mm (width × height × thickness). Both the trunking and its accessories shall be qualified, standardized products that have undergone hot-dip galvanizing treatment. The inner and outer surfaces of the trunking shall be smooth and flat, free from burrs, sharp edges, distortion, warping, or any other deformation. Cable trays used within the tunnel shall be hot-dip galvanized steel trays, with a zinc coating weight of 600g/m².

5.17.8. Tunnel Lightning Protection and Grounding System Design

The tunnel adopts a common grounding system integrating lightning protection grounding, operational grounding, and protective grounding, with a required grounding resistance not exceeding 1 ohm. At both tunnel portals, repeated grounding shall be provided, with a grounding resistance not exceeding 4 ohms. Galvanized flat steel of -40×4mm shall be installed continuously within the tunnel's power and communication cable trenches to serve as the main grounding conductor. In the tunnel lighting cable trays, a grounding cable shall be installed to form the branch grounding line. All electrical equipment within the tunnel must have their PE

terminals reliably and electrically connected to either the branch grounding line or main grounding line.

Surge protection devices (SPDs) specifically for induced lightning shall be installed on all levels of tunnel power distribution systems.

On the high-voltage incoming line, lightning arresters shall be installed for overvoltage protection. At the low-voltage power distribution cabinet incoming side, parallel-type surge suppressor for primary protection shall be installed (Class III test category, surge current rating ≥ 60kA, voltage protection level 6kV). At each secondary low-voltage distribution box incoming line, parallel-type surge suppressor for secondary protection shall be installed (Class III test category, surge current rating ≥ 40kA, voltage protection level 4kV). At each tertiary low-voltage distribution box incoming line, parallel-type surge suppressor for tertiary protection shall be installed (Class II test category, surge current rating ≥ 7kA, voltage protection level 2.5kV). For fire alarm systems, surveillance and alarm systems, communication systems, and other electronic equipment, a dedicated serial surge protector shall be installed at the equipment's power supply input (Class I test category, surge current rating ≥ 3 kA, voltage protection level 1.5kV).

5.17.9. Energy Saving and Environmental Protection

Dry-type transformers are selected to reduce operational losses and improve the transformer's technical and economic efficiency.

The low-voltage side of the transformer adopts centralized automatic reactive power compensation to reduce distribution losses.

Cable cross-sections are reasonably selected to minimize line power losses.

Energy-efficient components are used in the selection of devices and parts.

5.17.10. Tunnel Lighting Equipment and Materials

Table 5. 41. Tunnel Lighting Equipment Material

No.	Equipment Name	Model and Specifications	Unit	Quantity	Notes
I. Tunnel Lighting					
1	Tunnel Threshold Zone TH1 Enhanced Lighting	Linear LED Tunnel Light 400W, IP65, Wide Beam, Symmetrical Lighting Pattern	Set	54	5 years of service life
2	Tunnel Threshold Zone TH2 Enhanced Lighting	Linear LED Tunnel Light 250W, IP65, Wide Beam, Symmetrical Lighting Pattern	Set	40	5 years of service life
3	Tunnel Transition Zone TR1 Enhanced Lighting	Linear LED Tunnel Light 100W, IP65, Wide Beam, Symmetrical Lighting Pattern	Set	52	5 years of service life

No.	Equipment Name	Model and Specifications	Unit	Quantity	Notes
4	Tunnel Transition Zone TR2 Enhanced Lighting	Linear LED Tunnel Light 100W, IP65, Wide Beam, Symmetrical Lighting Pattern	Set	24	5 years of service life
5	Tunnel Basic Lighting	Linear LED Tunnel Light 100W, IP65, Wide Beam, Symmetrical Lighting Pattern	Set	464	5 years of service life
6	Tunnel Exit Zone EX1 Enhanced Lighting	Linear LED Tunnel Light 100W, IP65, Wide Beam, Symmetrical Lighting Pattern	Set	16	5 years of service life
7	Tunnel Exit Zone EX2 Enhanced Lighting	Linear LED Tunnel Light 100W, IP65, Wide Beam, Symmetrical Lighting Pattern	Set	28	5 years of service life
8	Tunnel Emergency Lighting	Linear LED Tunnel Light 27W, IP65, Wide Beam, Symmetrical Lighting Pattern	Set	693	5 years of service life
9	Type A Centralized Emergency Lighting Power Control Cabinet	5kVA IP65	Set	8	10 years of service life
10	Evacuation Indicator	1W Type A Fixture, DC24V, IP65	Set	818	3 years of service life
11	Fire Protection Emergency Lighting	10W Type A Fixture, DC24V, IP65	Set	842	3 years of service life
12	Cross-Linked Polyethylene (XLPE) Polyolefin Sheath Halogen-Free Low-Smoke Flame-Retardant Cable	WDZB-YJY-0.6/1kV-5×10	m	12355	20 years of service life
13	Cross-Linked Polyethylene (XLPE) Polyolefin Sheath Halogen-Free Low-Smoke Flame-Retardant Fire-Resistant Cable	WDZBN-YJY-0.6/1kV-5×4	m	8195	20 years of service life
14	Cross Passage Basic Lighting	LED Tunnel Light, 30W, IP65	Set	70	5 years of service life
15	Cross Passage Emergency Lighting	30W IP65	Set	70	5 years of service life
16	Copper Core Cross-linked Polyethylene Insulation Halogen-Free Low-Smoke Flame-Retardant Fire-Resistant Cable	WDZBN-BYJ-3×2.5	m	594	20 years of service life
17	Copper Core Cross-linked Polyethylene Insulation Halogen-Free Low-Smoke Flame-Retardant Cable	WDZB-BYJ-3×2.5	m	2442	20 years of service life
18	Tunnel Lighting Intelligent Dimming Control Signal Cable	WDZB-RYJSP-2×2.5	m	34980	10 years of service life
19	Tunnel Fire Emergency Lighting and Evacuation Indication System Communication Cable	WDZBN-RYJSP-2×2.5	m	17600	10 years of service life

No.	Equipment Name	Model and Specifications	Unit	Quantity	Notes
II. Others					
1	Intelligent Dimming Control Cabinet	Including tunnel intelligent lighting system controllers, control system power supplies, digital display manual/automatic converters, terminal blocks, signal converters, and signal drivers.	Set	4	10 years of service life
2	Lighting Signal Controller		Set	20	10 years of service life
3	Cable Rack	(200+200)*200	m	7931	10 years of service life
4	Insulated Piercing Connector	JTL-011	Piece	4895	10 years of service life
5	Flexible Metal Tube	LV-5Z-30#	m	2442	10 years of service life
6	Metal Junction Box		Piece	1628	10 years of service life
7	Cable Trench Bracket	Three layers, layer spacing 200mm, each layer length 350mm	Piece	6940	10 years of service life
8	Grounding Flat Steel	—50×5	m	17600	10 years of service life

Note: Whether import of lighting equipment is required shall be investigated during the construction drawing design phase.

5.18. Tunnel Monitoring Engineering

5.18.1. Design Scope

(1) The tunnel monitoring system design mainly includes various monitoring subsystems determined according to the tunnel monitoring classification.

(2) The design scope of the tunnel monitoring system, besides the tunnel itself, shall also include relevant road lighting and other facilities on the approach roads outside the tunnel (generally within 300m from the tunnel portal). These should be integrated into the tunnel monitoring system design.

5.18.2. Technical Standards

The tunnel monitoring facilities classification: Grade A+.

5.18.3. Design Principles

(1) Under the conditions of ensuring safety, practicality, reliable quality, economic feasibility, energy-saving, environmental protection, and advanced technology, new theories, technologies, materials, and equipment should be actively yet prudently adopted, while ensuring coordination and unity with other facilities.

(2) Monitoring facilities shall be configured according to the tunnel monitoring grade. The design shall follow the principle of “Single planning and design, phased implementation”,

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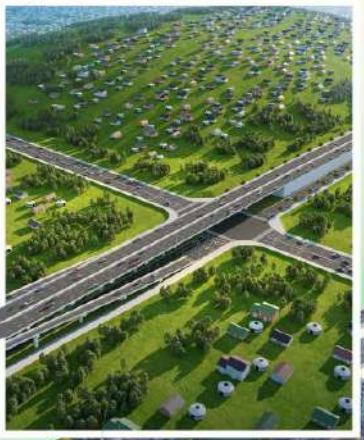

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considering traffic growth. Pre-installation and reservation of equipment and pipelines inside the tunnel shall be completed in one phase.

(3) Monitoring facilities inside the tunnel must not encroach on the tunnel's architectural boundaries.

(4) The system shall prioritize safe tunnel operation and accident prevention. Once a tunnel incident (including fire) occurs, the system shall ensure early detection, activate linkage functions, guide evacuation correctly, provide timely rescue, and prevent secondary accidents.

(5) The tunnel shall not be designed in isolation; it should coordinate with the road network and other structures to unify emergency rescue efforts.

5.18.4. Project Overview

The New Ring Road Tunnel is a long tunnel, with specific configuration as follows:

Table 5. 42. Tunnel Specific Conditions

Tunnel Name	Tunnel Classification	Start Mileage	End Mileage	Tunnel Length (m)	Structure Gauge		Tunnel Type
					Height Limit (m)	Width Limit (m)	
New Ring Road Tunnel	Class I	K8+730	K10+810	2080	5	14.00	Twin-tube, bidirectional Six lanes

5.18.5. Tunnel Monitoring System Configuration

(1) Tunnel Monitoring Level

The classification of tunnel monitoring system levels is based on the "Specifications for Design of Highway Tunnels Section 2: Traffic Engineering and Affiliated Facilities" (JTG D70/2-2014), Section 3.0.2, as shown in the diagram below.

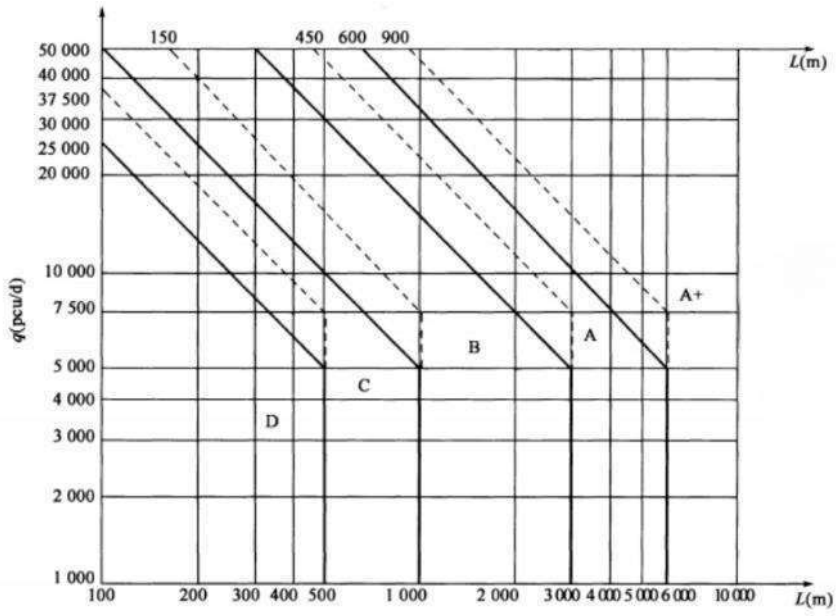


Figure 5. 44. Classification Diagram of Tunnel Traffic Engineering and Affiliated Facilities

In the figure: q is annual average daily traffic (converted into small passenger cars) per single tunnel bore; L is length of a single tunnel bore; the dashed line represents single bores with three or more lanes, and the solid line represents single bores with two lanes.

According to the tunnel length and the average annual daily traffic per single tunnel bore provided by the traffic engineering discipline, see the table below:

Table 5. 43. Annual Average Daily Traffic per Single Tunnel Bore

Forecast Year	2027	2030	2035	2040	2044
Annual Average Daily Traffic per Single Tunnel Bore (pcu/d)	35500	37390	39780	42450	44320

This tunnel's traffic engineering and affiliated facility configuration is classified as Grade A+.

The monitoring system shall be configured according to Table 3.0.3-2 in "Specifications for Design of Highway Tunnels Section 2: Traffic Engineering and Affiliated Facilities" (JTG D70/2-2014).

Table 5. 44. Traffic Engineering Facility Configuration

Facility Name		Subsystem for Facilities				
		A+	A	B	C	D
Traffic Safety Facilities		Installed in accordance with the provisions of Chapter 4				
Ventilation Facilities	Fans	Installed in accordance with the provisions of Chapter 5				
	Visibility Detector	★	★	▲	–	–
	CO Detector	★	★	▲	–	–
	NO2 Detector	■	■	▲	–	–
	Wind Speed and Direction Detector	★	★	▲	–	–
Lighting Facilities	Luminaire	Installed in accordance with the provisions of Chapter 6				
	Luminance Detector	★	★	▲	–	–
Traffic Monitoring Facilities	Vehicle Detector	★	■	▲	–	–
	Video Incident Detector	★	★	▲	–	–
	Camera	●	●	★	■	–
	Variable Message Sign	★	★	▲	–	–
	Variable Speed Limit Sign	★	★	▲	–	–
	Traffic Signal Light	★	★	■	▲	–
	Lane Indicator	●	★	■	▲	–
	Traffic Zone Control Unit	★	★	▲	▲	–
Emergency Call Facilities	Emergency Tel.	★	★	▲	–	–
	Tunnel Broadcast	★	★	▲	–	–
Fire Detector and Alarm Facilities	Fire Detector	★	★	■	–	–
	Manual Alarm Button	●	●	■	–	–

	Fire Audible and Visual Alarm	Installed in accordance with the provisions of Chapter 9				
Firefighting Facilities and Access	**Fire Extinguisher**	●	●	●	●	●
	Fire Hydrant	●	●	■	—	—
	Fixed Type Aqueous Film-forming Foam Fire Extinguisher	●	●	■	—	—
	Channel	Installed in accordance with the provisions of Chapter 10				
Central Control Management Facilities	**Computer Equipment**	★	★	▲	—	—
	Display Equipment	★	★	▲	—	—
	Control Console	★	★	▲	—	—
Power Supply and Distribution Facilities		Set according to the above power usage facilities configuration				
Grounding and Lightning Protection facilities		Set according to the above power usage facilities configuration				
Cables and Related Facilities		Set according to the above power usage facilities configuration				

Note: 1. "●": Mandatory; "★": Required; "■": Recommended; "▲": Optional; "—": No requirement.

According to the "Code for Fire Protection Design of Buildings" (GB 50016-2014), this tunnel is classified as a Class I motor vehicle tunnel over 1500m in length, allowing the passage of hazardous chemicals. Class I motor vehicle tunnels shall be equipped with an automatic fire alarm system.

Table 5. 45. Classification of Single-Bore and Twin-Bore Tunnels

Purpose	**Class I**	**Class II**	**Class III**	**Class IV**
	Tunnel Enclosed Section Length L (m)			
Permit the passage of vehicles transporting hazardous chemicals	L＞1500	500＜L≤1500	L≤500	—
Permit the passage of vehicles transporting non-hazardous chemicals only	L＞3000	1500＜L≤3000	500＜L≤1500	L≤500
Pedestrian Access Only or Non-motorized Vehicles Only	—	—	L＞1500	L≤1500

According to the "Code for Design of Urban Underground Road Engineering" (CJJ221-2015), to ensure driving safety inside the tunnel, improve emergency rescue efficiency, and achieve efficient daily management, a wireless communication system shall be installed within the tunnel.

The tunnel shall be equipped with an integrated monitoring system, including: central control management system, video monitoring system, lighting control system, traffic monitoring system, fire automatic alarm and firefighting linkage system, ventilation monitoring system, emergency telephone and wired broadcasting system, wireless communication system, and others.

(2) Central Control Management System

1) System Composition:

The tunnel control room facilities include workstations, PLCs, database servers, web

servers, video servers, video decoders, IP SAN disk arrays, monitoring storage hard drives, device monitoring UPS, power monitoring system, communication management units, core switches, and management software.

The layout of the tunnel control room is detailed in the drawing titled “Tunnel control room Equipment Layout”.

2) System Functions:

① The central control management system shall have the following capabilities: Accept various types of information sent from all facilities, including data, video, and voice information;

Perform comprehensive processing of all received information and coordinate control of various facilities;

Execute pre-set control schemes stored in the computer either automatically or manually; flexibly display traffic conditions inside and outside the tunnel and the operational status of equipment using data, graphics, images, and other formats;

Automatically perform data backup and document storage;

Facilitate easy querying, statistics, and report generation;

Periodically monitor the operational status of all equipment.

The tunnel control room computer network shall have interfaces to enable information exchange with other highway management systems.

② Workstation shall be equipped with the following functions:

Traffic control and monitoring:

Collect and process basic traffic information;

Collect status information of traffic monitoring facilities;

Provide control information to traffic control facilities, including traffic control schemes, traffic signal lights, and lane indicator control signals and information.

③ Lighting control functions:

Collect status information from lighting control facilities.

Display information to tunnel control room display devices;

Provide control information to lighting control units, including lighting control signals.

④ Management functions:

Perform computer network management functions;

Support routine system maintenance and management tasks.

⑤ Fire alarm and firefighting control computer shall be equipped with the following functions:

Collect and process data information provided by fire alarm facilities;

Collect status information of fire alarm and firefighting facilities and provide control signals;

Provide facility status and alarm address/time information to the central control room display devices, for facility status indication and automatic video image switching.

3) Control Mode:

This project involves a long tunnel using a centralized control method. Field terminal devices transmit data in real time directly to the tunnel control room. The central control room computer centrally analyzes and processes the collected data, and then sends commands directly to the control devices inside the tunnel.

(3) System Network Communication

1) Network Types

Two separate networks are set up for the tunnel project: the automation control network and the video monitoring network. The fire alarm and firefighting linkage system uses a centralized alarm system with a bus topology.

Traffic monitoring network: including the traffic monitoring system;

Video monitoring network: including the video monitoring system;

Both the traffic monitoring network and video monitoring network share one outdoor 8-core single-mode optical cable, with the traffic monitoring system occupying 2 cores, the video monitoring system occupying 2 cores, and the remaining cores reserved for backup.

The video monitoring system primarily comprises video monitoring equipment, featuring 2-megapixel cameras with a calculated 6M bandwidth, and a 100M fibre optic ring network that typically operates at around 70M bandwidth, supporting approximately 11 cameras.

2) Network Architecture

The traffic monitoring and video monitoring networks use 100M bandwidth.

The network architecture is a two-tier model: core layer and access layer.

The core and access layers form a 100M fiber optic ring network.

Switch setup in the two-layer network architecture:

Core switch: installed inside the tunnel control room.

Access layer switches: installed inside the tunnel, responsible for connecting tunnel network devices.

(4) Traffic Monitoring System

1) System Composition

The traffic monitoring system is responsible for real-time collection of traffic operation information along tunnel sections, performing analysis and processing, and applying various control measures to manage and guide traffic flow. This ensures driving safety, smooth traffic, reduces delays, and improves transportation efficiency.

The system consists of the tunnel management computer, PLC, transmission network, and

field devices outside the tunnel. All detection devices upload their results to the tunnel control room for statistics and processing to assess traffic and weather conditions. Based on specific road section situations, corresponding control plans are formulated. Control commands are then issued to control facilities and information dissemination devices along each road section.

2) Equipment Layout

Traffic engineering specialists determine the selection and arrangement of equipment. For this project's tunnel, the installed traffic monitoring devices include signal lights and lane indicators. One PLC is installed inside the tunnel control room.

3) System Functions

① Traffic Information Collection Function

Traffic parameters, especially traffic volume, are the fundamental data for evaluating the service level of a highway. The collection and accumulation of traffic data form the basic basis for making major traffic decisions. Additionally, changes in traffic flow, vehicle speed, and occupancy rate can be used to infer traffic flow conditions. Therefore, the monitoring system should accurately and dynamically detect traffic parameters for all highway sections along the route, perform data analysis, processing, and storage.

② Tunnel Traffic Control Function

Tunnel traffic control primarily manages the traffic flow within the tunnel area by regulating vehicle movement, imposing speed limits, and assisting in traffic guidance under abnormal conditions, while providing information to drivers to ensure driving safety and smooth traffic. The main traffic control measures inside the tunnel are implemented through traffic signals and lane indication signs.

③ Traffic Incident Detection Function

To minimise greater loss of life and property, it is essential to detect traffic abnormalities promptly and accurately, improving system response speed and gaining valuable time for incident handling and emergency rescue. Relying solely on patrol personnel, manual alarms, or video monitoring is insufficient; automatic traffic incident detection measures must be employed. The video-based automatic incident detection uses tunnel-installed cameras and upgrades their functionality through advanced image processing. By analysing camera images with algorithms, incident alarms are generated based on image processing results. This software algorithm has low requirements for image contrast and colour saturation and is applicable under various conditions, including daytime, nighttime, rain, snow, and fog. It can detect the following traffic incidents on highways: stopped vehicles, traffic congestion, excessive vehicle queue length, pedestrians entering the highway, wrong-way driving, slow-moving vehicles, vehicles following too closely, traffic accidents, and debris dropped by cars, accompanied by audible and visual

alarms. Video automatic incident detection provides an effective monitoring tool that enhances real-time responsiveness and visibility in traffic monitoring. It plays a crucial role in accelerating emergency responses, reducing secondary accidents, lowering accident losses, and improving operational management. Therefore, this project adopts this method as the automatic incident detection system.

(5) Video Monitoring System

1) System Composition

The video monitoring system consists of remote-controlled cameras outside the tunnel, fixed cameras inside the tunnel, remote-controlled cameras in pedestrian cross passages, video switches, video Ethernet switches, video storage servers, IP SAN disk arrays, and a fiber optic ring network.

Tunnel images are transmitted to the tunnel control room via video encoders. The uploaded video streams are decoded by video decoders for display in the tunnel control room and simultaneously stored in the disk array with a retention period of 60 days. Video footage triggered by alarm signals must not be automatically overwritten by the system.

A control workstation in the tunnel control room controls the decoder to switch output images to the main LCD monitor for display. At the same time, compressed video images are uploaded to the superior monitoring center.

2) Equipment Layout

The installation locations of cameras inside the tunnel and at tunnel portals are determined by the traffic engineering discipline. A fixed camera is installed in each of the tunnel control room and the fire pump room, while two fixed cameras are installed in the power distribution station.

3) Key Functions

① The tunnel management office can remotely control PTZ (pan-tilt-zoom) cameras, including power on/off, panning, tilting, zooming, and focusing.

② The tunnel management office can record video from all cameras.

③ The system supports programmable settings, allowing grouping and automatic switching of cameras and monitors for sequential display.

④ Upon various system alarms (such as fire, traffic accident, video processor alert, etc.), the system will automatically switch the relevant camera image to the main monitor for display. If a PTZ camera is installed near the alarm location, the system shall automatically adjust the camera's position (using preset angles), enabling the tunnel control room to immediately view the real-time scene of the incident.

(6) Lighting Monitoring System

For this project, the tunnel lighting monitoring system adopts a complete set of lighting

equipment and a dimming control system. The system primarily consists of: adaptation luminance detector, interior luminance detector, tunnel intelligent lighting system controller, on-site digital manual/automatic switch converter, dimming control cabinet, luminance-controllable LED tunnel lighting fixtures, communication system, and upper-level monitoring and management software.

The system's adaptation luminance detector converts the detected luminance level outside the tunnel into a standard 4-20mA signal and transmits it to the dimming control cabinet. Similarly, the interior luminance detectors convert the luminance levels at the tunnel threshold zone and interior zone into 4-20mA signals and transmit them to the dimming control cabinet. The system includes a traffic volume configuration, allowing dimming control based on preset traffic volume parameters. Located within the dimming control cabinet, the tunnel intelligent lighting system controller calculates the appropriate dimming power for enhanced and basic lighting at the threshold zones based on the exterior and interior luminance levels and the set traffic volume. It then outputs these control signals as DC 0-5V analog signals to regulate the output power of the corresponding enhanced and basic lighting fixtures. Changes in fixture power output subsequently alter the luminous flux, thereby adjusting the luminance of the illuminated areas.

A management computer in the tunnel control room communicates with the tunnel intelligent lighting system controller via an Ethernet switch. Using continuous dimming monitoring and management software, the management computer enables parameter configuration, command issuing, real-time signal acquisition, and data storage. In the event of a communication failure between the management computer and the dimming control cabinet, the cabinet shall independently adjust lighting based on adaptation luminance and preset traffic volume parameters.

(7) Tunnel Automatic Fire Alarm and Firefighting Linkage System

1) System Overview

The fire alarm system is designed to automatically or manually issue alarm signals in the event of a fire within the tunnel, enabling rapid notification to the upper-level monitoring center and initiating firefighting and rescue operations.

The fire alarm system shall promptly and accurately identify the fire location within the tunnel. Alarm signals are transmitted via the fire alarm control panel to the tunnel management center, where the fire alarm computer displays the corresponding alarm location. Based on this, the tunnel management computer system formulates appropriate traffic control plans and commands tunnel traffic signs, ventilation, firefighting, and lighting systems to respond, ensuring quick and orderly evacuation of vehicles and personnel, and securing safe tunnel operations.

For this project, the fire alarm system includes fiber Bragg grating (FBG) linear heat detectors, manual call points, and audible and visual alarm devices.

2) System Components

Centralized fire alarm control panel, graphical display unit, direct control panel, bus-type fire telephone master station, fire telephones, heat and smoke detectors, fiber-optic linear temperature detection system, manual fire alarm call points, audible and visual alarm devices, I/O input-output modules, fire hydrant buttons;

Fire alarm equipment protection rating: IP65.

3) Equipment Layout

① Centralized Fire Alarm Control Panel

The fire alarm control panel is installed in the tunnel control room.

It adopts cabinet-type installation.

The panel's capacity and the total addressable device capacity, including fire detectors, manual call points, control modules, or signal modules, connected to each bus loop shall include a 20% spare capacity.

The fire alarm control panel shall provide an alarm signal output interface to facilitate coordination of related response measures.

② Graphical Display Unit, Direct Control Panel, and Bus-type Fire Telephone Master Station

Installed in the tunnel control room.

Cabinet-type installation is adopted.

③ Manual Call Point (with Telephone Jack)

Installed approximately every 50m, co-located with fire hydrants and positioned prominently.

Installed on the right-hand side in the direction of tunnel traffic flow, at a height of 1.5m.

Also installed in the tunnel control room, transformer substation, and fire pump room.

Ceiling-mounted.

④ Audible and Visual Alarm Device

Installed approximately every 50m, co-located with fire hydrants and positioned prominently.

Installed on the right-hand side in the direction of tunnel traffic flow, at a height of 2.5m.

Also installed in the tunnel control room, transformer substation, and fire pump room.

Ceiling-mounted.

⑤ Fiber Optic Linear Heat Detector

The monitoring range shall cover the entire tunnel.

Installed along the tunnel crown, two cables per tunnel.

⑥ Heat and Smoke Detector

Also installed in the tunnel control room, transformer substation, and fire pump room.

Ceiling-mounted.

4) Key Functions

① The system shall realize seamless, uninterrupted monitoring of fire incidents occurring within the tunnel space. It shall feature high reliability, safety, rapid and accurate response, and a long service life. The primary equipment and materials shall have a service life of no less than 10 years. The system shall have self-diagnostic capabilities, and capable of continuously monitoring the operational status of devices and reporting accurate fault locations to the upper-level monitoring center.

② In the event of a fire, the system shall trigger audible and visual alarms, automatically record, store, display, and print the affected tunnel section and location information. The audible and visual alarms shall be manually resettable.

③ Upon fire detection, the local tunnel controller shall automatically execute the following functions:

Close the tunnel;

Activate the corresponding fans;

Open the solenoid valves;

Turn on all tunnel lighting.

④ Workstation:

Audible alarm for fire detection;

Automatic pop-up of the fire alarm interface on the fire alarm and firefighting linkage control computer (indicating the fire section, lighting level, fan rotation direction, and traffic signal mode);

Automatic switching of the video monitoring system monitor to the fire section and initiation of recording;

Display of operational feedback from all related equipment (fire alarm section, tunnel lighting level, fan operation status, traffic mode).

Fire alarm system equipment shall have anti-corrosion, moisture-proof, waterproof, dust-proof, and lightning protection features to suit the tunnel environment.

Detectors shall not be affected by high-speed airflow from jet fans or heat emissions from vehicle exhaust, to avoid false or missed alarms.

⑤ Linkage with smoke exhaust fans:

The linkage control mode of the smoke exhaust system shall comply with the following provisions:

The alarm signals from two independent fire detectors located within the same smoke control zone shall serve as the linkage trigger for the activation of the smoke exhaust fan, and the activation shall be executed by the firefighting linkage controller.

Manual control of the smoke exhaust system shall be performed on the firefighting linkage

controller located in the tunnel control room, enabling manual start/stop of smoke exhaust fans and other equipment. The start/stop buttons for the smoke exhaust fans shall be connected via dedicated wiring directly to the direct control panel of the firefighting linkage controller in the tunnel control room, allowing direct manual control.

The operation signals of the smoke exhaust fan start and stop actions shall be fed back to the firefighting linkage controller.

⑥ Linkage with fire pumps:

In automatic linkage control mode, the signal from a low-pressure pressure switch installed on the fire hydrant system's outlet main pipe shall serve as the trigger signal to start the fire pump. This linkage is not affected by whether the firefighting linkage controller is in automatic or manual mode. The action signal from a fire hydrant button shall serve both as an alarm signal and as the linkage trigger signal to start the fire hydrant pump, which is controlled by the firefighting linkage controller. In manual mode, the start/stop buttons on the fire pump control cabinet shall be connected via dedicated wiring directly to the direct control panel of the firefighting linkage controller in the tunnel control room, allowing direct manual control of the fire pump's start and stop operations. The operation signals of the fire pump shall be fed back to the firefighting linkage controller.

⑦ Linkage with pressure stabilizing pump:

The pressure stabilizing pump is controlled by an automatic start-stop pressure switch installed on the fire water supply pipeline.

5) Fire Control Room

Fire control room layout: The fire control room is integrated with the tunnel control room. The fire alarm and firefighting linkage control cabinet is installed with a spacing of 800mm from other monitoring cabinets, and the fire alarm and firefighting linkage control computer is clearly separated from the monitoring workstation.

The fire control room shall have the following control and display functions:

The control panel shall be equipped with manually operated direct-start pump buttons connected via dedicated circuits;

The control panel shall display the operating status of the fire pump and pressure stabilizing pump;

The control panel shall display high-level, low-level alarm signals and normal water level indications for fire water tanks, elevated fire water tanks, and other water sources.

(8) Emergency Telephone and Wired Broadcasting System

This project adopts an integrated system that combines the emergency telephone system with the tunnel's wired broadcasting system, sharing the same main controller, network

management, and system software. The emergency telephone and tunnel wired broadcasting system share the same optical fiber for transmission. Main-unit type emergency telephones are installed in both the left and right tunnel bores, as well as at the tunnel entrances. The emergency telephone system shares an optical cable with the transmission systems for field monitoring equipment and video transmission.

(9) Ventilation Monitoring System

Due to the accumulation of vehicle exhaust emissions, smoke, and dust stirred up by moving traffic within the tunnel, which are difficult to disperse, the air inside the tunnel can become extremely hazardous to human health and also compromise driving safety. Therefore, maintaining good air quality within the tunnel is essential for ensuring safe driving conditions. The ventilation monitoring system can control the number of operating fans, airflow direction, and operating time based on the detected environmental data and traffic volume information. It is also capable of energy-efficient operation and controlling fan operation in a manner that optimizes service life. In the event of a fire, the system can initiate appropriate smoke extraction procedures according to the specific location of the fire, thereby ensuring both tunnel safety and a comfortable operational environment.

(10) Wireless Communication System

The tunnel wireless communication system adopts a wireless AP coverage approach. Wireless access point (AP) units are installed at 100m intervals inside the tunnel, and a wireless communication system control cabinet is installed in the tunnel management center.

(11) Equipment Selection Principles

The equipment and materials used in the tunnel monitoring system shall be suitable for low-temperature environments, comply with relevant current standards, and be accompanied by valid product quality certification documents.

All fire alarm system equipment used in the tunnel monitoring project must be 3C-certified and have a protection level of IP65.

5.18.6. System Power Supply

(1) Power Supply for Monitoring Facilities

The power supply for the central control management system, traffic monitoring system, video monitoring system, lighting control system, and power monitoring system in this project shall use UPS power supply, with the UPS located in the monitoring center. The following requirements must be met:

All systems shall share a common uninterruptible power supply (UPS) device, with dedicated circuits supplying power from the shared UPS to each individual system.

The UPS shall be equipped with both automatic and manual bypass devices.

The capacity of the UPS device shall be no less than 1.3 times the total calculated load of all connected equipment, and the backup battery shall provide continuous power for more than 60 minutes.

(2) Power Supply for Fire Alarm and Firefighting Linkage Control System

The firefighting system load classification is Level 2. The fire alarm and firefighting linkage control system shall use a fire-rated AC power supply with integrated battery backup as its emergency power source. The fiber optic temperature fire detectors and similar equipment shall be powered by UPS, with battery or UPS backup time of no less than 3h. Audible and visual alarms, input/output modules, and other equipment inside the tunnel and buildings shall be powered by UPS with an integrated battery and a 24 VDC power module, providing a backup time of no less than 30 minutes.

5.18.7. Cable Selection and Installation

(1) Cable Selection

1) Non-firefighting Equipment Cable Selection

Instrument control cables and communication cables for non-firefighting equipment in monitoring and alarm systems shall use flame-retardant cables.

2) Cable Selection for Fire Alarm and Firefighting Linkage Control Systems

Transmission lines and control lines powered below 50V for the fire alarm system shall use flame-retardant copper-core insulated conductors or copper-core cables with a voltage rating of no less than AC 300V/500V. Conductors shall use power and control cables rated at 220V/380V, and cables shall use flame-retardant insulated conductors or copper-core cables with a voltage rating no less than AC 450V/750V. Wires and cables related to the firefighting system shall be installed within dedicated metal cable trays or metal protective conduits and shall not share conduits or cable trays with non-firefighting system cables. Furthermore, metal cable trays or protective conduits shall be coated with fireproof paint providing protection for no less than 30 minutes.

Cables of different voltage levels shall not be laid inside the same protective conduit. When sharing the same cable tray, a grounded metal partition shall be used to separate cables of different voltage levels.

Power distribution circuits for firefighting electrical equipment shall meet the requirements for continuous power supply during a fire: For exposed installation, cables shall be enclosed within metal conduits or closed metal cable trays and equipped with fire protection measures. For concealed installation, cables shall be laid inside non-combustible structures with protective layer thickness not less than 30mm and within conduits.

(2) Cable Laying

1) Communication cables inside the tunnel shall be laid in the low-voltage cable trench located on the outer side of the tunnel, while power distribution cables shall be laid in the high-voltage cable trench on the inner side of the tunnel.

2) Power and signal cables for monitoring equipment inside the tunnel shall be routed through pre-embedded conduits to connect to the respective high- and low-voltage cable trenches.

3) Power cables for monitoring equipment outside the tunnel shall be preferably laid directly underground using armored cables, and pass through pre-embedded steel conduits at structural crossings.

4) During cable installation both inside and outside the tunnel, the principle of separating low-voltage and high-voltage cables shall be followed. Cable crossings shall be reasonably arranged, and the required separation distance between low-voltage and high-voltage cables shall be maintained.

5) Optical fibers outside the tunnel shall be laid inside communication ducts.

5.18.8. Lightning Protection and Grounding

(1) Lightning Protection and Overvoltage Protection Measures

Considering that all types of cables are installed indoors or within tunnel cable trenches, lightning protection is primarily aimed at preventing lightning-induced surges. Direct lightning protection is applied only to electrical equipment installed on outdoor elevated structures.

SPD power surge protectors shall be installed in parallel at the terminals of all power supply lines.

SPD signal surge protectors shall be installed in series at both ends of all signal and communication cables.

(2) Grounding

1) All metallic lines entering or exiting the protected zone (e.g., electrical lines, control lines) shall be equipped with SPD surge protectors when connected to protected equipment, and all protectors shall be reliably grounded.

2) All non-current-carrying metal parts of electrical instruments such as enclosures, brackets, control cabinets, and protective conduit that could become energized due to insulation failure shall be provided with protective grounding.

3) Signal circuit grounding points shall be located on the side of the control box or control room.

4) Protective grounding, signal circuit grounding, and shielding grounding within the control cabinets shall each be connected to their respective grounding busbars, which in turn are connected to the main equipotential bonding bar via insulated copper conductors.

5) The lightning protection grounding system for the low-voltage equipment shall share a common grounding electrode system with the protective grounding of the low-voltage power distribution system. The grounding resistance shall not exceed 1Ω.

5.18.9. Tunnel Monitoring Equipment Materials

Table 5. 46. Tunnel Monitoring Equipment Materials

No.	Item Name	Key Parameters and Specifications	Unit	Quantity	Notes
I Monitoring System Software					
1	Tunnel Monitoring Software		Set	1	5 years of service life
2	OS Software		Set	8	Including servers, database, client software and multi-user license; 5 years of service life
3	Network Management Software		Set	1	Including multi-user license; 5 years of service life
4	Anti-virus Software		Set	1	Including multi-user license; 5 years of service life
5	Application Software		Set	1	5 years of service life
II Tunnel Management Computer System					
1	Dedicated Server		Set	2	5 years of service life
2	Monitoring and Management Computer		Set	8	5 years of service life
3	Laser Printer	A3 format, printing speed: 8ppm/16ppm	Set	1	5 years of service life
4	Three-Layer Ethernet Switch	48 Ports	Set	1	5 years of service life
5	Industrial Ethernet Switch	48 Ports	Set	1	5 years of service life
6	Video Ethernet Switch	48 Ports	Set	1	5 years of service life
7	Color Inkjet Printer	①Print format: A4; ②print speed: 4 pages per minute; ③resolution: 1200dpi;	Set	1	5 years of service life
8	19” Standard Cabinet	Customized, cabinet dimensions 800×800×1800	Set	10	10 years of service life
9	Monitoring Console	Dimensions: L 5.0m × W 1.2m × H 0.74m	Set	1	5 years of service life
10	Adjustable Chair		Unit	8	5 years of service life
11	Voltage Stabilized Power Supply	20kVA	Set	1	5 years of service life
12	Overvoltage Protection Device		Set	1	5 years of service life
13	Emergency Telephone and Tunnel Broadcast Controller	Including the Control Console	Set	1	5 years of service life
14	DVD Burner	External	Set	1	5 years of service life
15	Power Distribution Panel	Customized	Set	6	5 years of service life

No.	Item Name	Key Parameters and Specifications	Unit	Quantity	Notes
16	Data Optical Transceiver		Unit	9	5 years of service life
17	Metal Cable Tray	Under the control room floor	m	400	10 years of service life
18	Network Cable	Cat 5e UTP	m	500	10 years of service life
19	Ethernet Signal Surge Protector		Unit	25	5 years of service life
20	Power Cable	YJV22-3*10	m	800	20 years of service life
21	Power Cable	YJV22-3*16	m	600	20 years of service life
III Screen Display System					
1	46” LCD Display		Set	9	5 years of service life
2	Multi-screen Splicing Display Controller (including Control Management Software)		Set	1	5 years of service life
IV	Video Monitoring System				
1	Remote Access Device	4-channel video, IP65	Pair	29	5 years of service life
2	Video Coaxial Cable		m	3960	5 years of service life
3	GYTA-16 Core Single-mode Optical Fiber		m	10560	5 years of service life
4	Video Signal Surge Protector		Unit	70	5 years of service life
5	Coaxial Cable Signal Surge Protector		Unit	35	5 years of service life
6	Video Wall Bracket		Set	1	5 years of service life
7	Control Keyboard		Set	1	5 years of service life
8	29” LCD Main Monitor		Set	1	5 years of service life
9	Online Video Management Platform		Set	1	5 years of service life
10	Video Storage/Streaming Media Server		Set	1	5 years of service life
11	IP SAN Disk Array		Set	1	5 years of service life
12	Enterprise-level Surveillance Storage Hard Drive	6T	Unit	12	5 years of service life
V	Variable Message Sign				
1	Cantilever Variable Information Board	Including display screen, microprocessor, driver, enclosure, control cabinet, cables and junction boxes, power supply, software, etc. IP65-rated	Set	2	5 years of service life
2	Support Pole and Lightning Protection Device		Set	2	Including foundation

No.	Item Name	Key Parameters and Specifications	Unit	Quantity	Notes
3	Tunnel Interior Variable Information Board	Including display screen, microprocessor, driver, enclosure, control cabinet, cables and junction boxes, power supply, software, etc. IP65-rated	Set	2	5 years of service life
VI Fire Alarm System					
1	Expressway Tunnel Fire Management Software		Set	1	5 years of service life
2	Cross Passageway Button Box	Customized IP65	Unit	14	5 years of service life
3	Control Cabinet	Customized IP65	Unit	14	10 years of service life
4	Infrared Detector	IP65	Set	14	5 years of service life
5	Door Contactor	IP65	Set	14	5 years of service life
6	Fiber Optic Grating Fire Detector		Set	14	5 years of service life
7	Fiber Optic Splice Closure		Unit	10	5 years of service life
8	Flame-retardant Optical Cable	GYTZA—4B1	m	4510	20 years of service life
9	Galvanized Steel Stranded Wire		m	3850	15 years of service life
10	Installation Holder		Set	120	15 years of service life
12	8-channel Signal Processor		Set	2	5 years of service life
13	Instrument Cabinet	IP65	Set	2	10 years of service life
14	24V UPS	IP65	Set	2	5 years of service life
15	Terminal Box		Unit	2	5 years of service life
16	Fiber Optic Grating Protocol Converter		Unit	2	5 years of service life
17	Fire Alarm Controller		Set	1	5 years of service life
18	Data Optical Transceiver	IP65	Unit	2	5 years of service life
19	Fire Manual Alarm Button	IP65	Unit	85	5 years of service life
20	Audible and Visual Alarm Device	IP65	Unit	85	5 years of service life
21	STP Cable		m	9600	5 years of service life
24	Industrial Ethernet Switch		Set	2	5 years of service life
VII	Light Intensity Detector				
1	Light Intensity Detector		Set	4	5 years of service life
2	Light Intensity Detector Column for Funnel		Set	4	5 years of service life

No.	Item Name	Key Parameters and Specifications	Unit	Quantity	Notes
VIII	Emergency Telephone and Broadcasting System				
1	Internal Tunnel Broadcast	15w horn-type, IP65	Set	85	5 years of service life
2	External Tunnel Broadcast	30w	Set	4	5 years of service life
3	Tunnel Management Duty Telephone		Set	2	5 years of service life
4	Tunnel Emergency Telephone	IP65	Set	26	5 years of service life
5	Emergency Telephone Outside Tunnel (with Lightning Protection)		Set	4	5 years of service life
6	Remote Broadcast Amplifier and Control Module		Unit	26	5 years of service life
7	Power Cable for Emergency Telephone and Wired Broadcast	NH-VV-3X4	m	9600	Power Supply Cable for Emergency Telephone and Broadcast System; 10 years of service life
8	Signal Cable for Emergency Telephone and Wired Broadcast System	RVVP2X1.5	m	9600	Connection Cable between Microphone and Loudspeaker; 10 years of service life
9	Signal Cable for Emergency Telephone and Wired Broadcast System	HYAT5X2X0.9	m	700	Cable between Emergency Telephone and Amplifier Box; 10 years of service life
10	Optical Fiber Distribution Frame		Unit	2	5 years of service life
IX	Tunnel Wireless Communication System				
1	Wireless Communication System Control Cabinet	Including Router, Firewall, and VPN Gateway, etc.	Set	1	10 years of service life
2	Wireless AP		Set	44	5 years of service life
X	Tunnel Field Control System				
1	PLC	Including DI/DO, AI modules, Dual CPUs, Dual Power Supplies, etc.	Set	8	10 years of service life
2	Industrial Switch	Two Single-mode Optical Ports, Six Electrical Ports, Supporting Redundant Fiber Ring Network	Set	8	5 years of service life
3	Field Controller Control Cabinet	Customized, including Relay Terminal Blocks, etc., IP65	Set	8	10 years of service life
4	8 Core Single-mode Optical Fiber		m	5170	5 years of service life
5	Fiber Optic Splice Closure	8 Core	Unit	20	5 years of service life
6	Local Controller Software		Set	1	5 years of service life
XI	Monitoring System Power Supply				
1	Power Cable	NH－YJV－1KV－3X25+1X16	m	1320	20 years of service life
2	Power Cable	NH－YJV－1KV－5X16	m	15400	20 years of service life

No.	Item Name	Key Parameters and Specifications	Unit	Quantity	Notes
3	Power Cable	NH－BV－1KV－3X2.5	m	4180	20 years of service life
4	Controlling Signal Cable	ZR-KVVP 12X2.5	m	3850	20 years of service life
5	Controlling Signal Cable	ZR-KVVP 8X2.5	m	1210	20 years of service life
6	Controlling Signal Cable	ZR-KVVP 3X2.5	m	1100	20 years of service life
7	Overvoltage Protection Device	Three-phase High-capacity Parallel-type Surge Protector, Surge Current Rating Per Phase: 60-100kA	Set	2	5 years of service life
8	Signal Surge Protector		Unit	90	5 years of service life
9	Power Supply Surge Protector		Unit	112	5 years of service life
10	Angle Steel	50x5 L=2.5m	Piece	66	20 years of service life
11	Flat Steel	4x50	m	330	20 years of service life
XII	Galvanized Steel Pipe				
1	Galvanized Steel Pipe	SC100	m	520	20 years of service life
2	Galvanized Steel Pipe	SC50	m	260	20 years of service life
3	Galvanized Steel Pipe	SC32	m	1140	20 years of service life
4	Galvanized Steel Pipe	SC25	m	1320	20 years of service life
5	Galvanized Steel Pipe	SC20	m	1650	20 years of service life
Please refer to the lighting material list for the cable tray material list.					

Note: Whether import of tunnel monitoring equipment is required shall be investigated during the construction drawing design phase.

5.19. TUNNEL AFFILIATED ENGINEERING

5.19.1. Architectural Engineering

(1) Project Overview

The total building area of this project is 495.54m², comprising two individual buildings: the fire pump room and the power distribution room. The fire pump room covers an area of 102.95m², while the power distribution room covers 392.59m². The fire pump room is a one-story underground structure, with a one-story aboveground evacuation stairwell. The underground section has a total length of 11.8m, a total width of 7.4m, and a height of 4.85m, with a roof soil cover thickness of 3.35m. The evacuation stairwell is a one-story frame structure, with dimensions of 7.1m by 3.05m and an eave height of 3.6m. The power distribution room is a single-story aboveground structure, with an overall width of 12.9m, a length of 37.6m, and an

eave height of 5.1m.

(2) Site Plan Design

1) Project Overview

The New Ring Road Tunnel is long. The entrance stake number is K8+730, with an elevation of approximately 1434.37m; the exit stake number is K10+810, with a design elevation of approximately 1423.29m. The internal tunnel longitudinal slope follows a herringbone gradient design of 0.95% and -0.99%, with a total length of 2080m. The maximum burial depth is approximately 80m.

To meet operational needs, two auxiliary buildings, a fire water tank a fire pump room, and a power distribution room are located near the tunnel entrance.

2) General Layout Plan

The site selection is based on the on-site topographic survey. It follows the principles of rational land use, land resource conservation, and compliance with current land use policies, while fully considering operational functionality.

The proposed site features a relatively regular strip-shaped terrain. While meeting functional requirements, individual structures will be rationally arranged according to the site's topographical conditions to comply with fire safety regulations.

The main buildings and structures include: the power distribution room, the fire water tank, the fire pump room, etc. The fire water tank and fire pump room are located 30m from the tunnel entrance at the lower mileage end, and the power distribution room is positioned 12m from the fire water tank and fire pump room. Both architectural units are arranged parallel to the direction of the roadway. The layout complies with the required fire separation distance.

3) Vertical Design

The natural elevation within the site varies, with a length of approximately 130m and a width of approximately 18m. The designed gradient within the site is 1%, indicating gentle terrain suitable for construction.

(3) Design of Individual Buildings and Structures

1) Design Parameters:

① Building service life: 50 years (for rational use).

Fire resistance rating: Class II.

Seismic fortification: seismic fortification intensity of Grade 7.

Roof waterproofing: Class II waterproofing.

⑤ Fire hazard classification: Class D.

⑥ Masonry quality control grade: Grade B.

2) Main Building and Structure Finishing Standards

Exterior walls: cement mortar surface with 40mm thick inorganic insulation mortar (Type I insulation material).

Interior walls: finished with mixed mortar surface and enamel-like coating.

Ceilings: finished with cement mortar and enamel-like coating (applied to the soffit of the outdoor cantilever slab); finished with mixed mortar and enamel-like coating (applied to all other ceiling areas except the soffit of the outdoor cantilever slab).

Flooring: finished with cement mortar; waterproof coating applied to the inner walls and bottom surface of cable trenches.

Roofing: 20mm thick cement mortar protective layer, one layer of 4mm thick polymer-modified bitumen waterproof membrane, one coat of substrate primer, 25mm thick cement mortar levelling layer, 20mm thick gravel block with slope, 50mm thick dry-laid waterproof rock wool board, 15mm thick cement mortar levelling layer.

Doors and windows: fully steel-panel Class B fire-rated doors; series-70 thermal-break aluminium alloy energy-saving casement (single frame, double glazing with 6mm thick insulated glass: 6+12A+6mm hollow glass; air tightness rating: Class 6).

Stairs: cement mortar stairs.

Drip strip: 900mm wide concrete apron.

Ramp: cement serrated ramp; concrete apron.

3) Architectural Energy-saving Design

① The building layout is rational, providing good daylighting and ventilation conditions.

② The exterior walls of the fire water tank area are constructed with 400 mm-thick aerated concrete blocks. All other interior and exterior walls of the buildings use 200mm thick aerated concrete blocks, with an external finish of 40mm thick inorganic insulation mortar (Type I insulation material). The exterior windows are series-70 thermal break aluminium alloy energy-saving casement/fixed with single-frame and double glazing. Both glass panels are 6mm thick insulated glass (6+12A+6mm), and the windows meet airtightness Class 6.

4) Architectural unit Design

The architectural design of this project adheres to the principles of practicality, economy, and aesthetics. Floor plans are arranged based on functional requirements. The elevations adopt a clean and streamlined design approach.

A summary table of the main structures and buildings at the low-mileage end of the tunnel is seen in Table 2.4-53.

Table 5. 47.List of Structures and Buildings at the Tunnel Entrance (Low-Mileage End)

No.	Name of Structures and Buildings	Building Area	Structure	Unit	Quantity	Notes
1	Fire Water Tank and Pump Room	102.95 ㎡	Frame	Unit	1	One above-ground floor and one basement level

No.	Name of Structures and Buildings	Building Area	Structure	Unit	Quantity	Notes
2	Power Distribution Room	392.59 ㎡	Frame	Unit	1	One above-ground floor building

① Fire Water Tank and Pump Room

The fire water tank and fire pump room adopt a single-story frame structure with a total building area of 102.95m² and a total floor height of 3.9m (measured from the outdoor ground level to the structural roof). The functional layout includes the fire water tank and the fire pump room.

② Power Distribution Room

The power distribution room is a single-story frame structure, designed to meet the power supply demands within the tunnel upon completion. The total building area is 392.59m², and the main structural height is 5.40m (measured from the outdoor floor level to the structural roof). Its functional layout includes the high-voltage and low-voltage distribution rooms, weak-current equipment room, weak-current power room, control centre, and spare parts room.

5) Architectural Fire Protection Design

According to the “Code for Fire Protection Design of Buildings”, this project is classified as a Class II building in terms of fire protection, with a fire resistance rating of Grade II. The distance to surrounding buildings meets the requirements for fire lanes and fire separation distances.

The fire resistance rating of the building is Grade II.

② Each room of the building is equipped with a direct external exit to ensure safe evacuation. The building area of each unit does not exceed 2,500m², and each structure constitutes an individual fire compartment.

③ Exterior finishes are made of non-combustible or flame-retardant materials.

6) Selection of Major Building Materials

① Architectural Finishing Requirements:

Exterior Finishes: The fire performance rating of exterior insulation materials shall not be lower than Class B1; the fire performance rating of floor insulation materials shall not be lower than Class B2.

② Building Materials:

This project falls under Category I for indoor pollution control. Primary architectural finishing materials must be non-toxic, non-radioactive, and free from the emission of harmful gases. Admixtures used in concrete products must comply with national standards.

Table 5. 48. Construction Materials and Methods

No.	Name	Materials Selected	Application Location
1	Roofing	Roofing with Self-Protected Membrane Single-layer waterproof membrane; Class II waterproofing	Roofing

	Ceiling (Type 1)	Cement mortar and porcelain-like coating ceiling	Canopy
	Ceiling (Type 2)	Mixed mortar and porcelain-like coating ceiling (Note: For the substation ceiling, no plastering is applied. Instead, the base surface is cleaned and sanded smooth, followed by putty application and finished with white latex paint.)	Interior Ceilings
2	External Walls	Cement mortar external wall finishing with 40mm thick inorganic insulation mortar (Type I insulation material)	External Wall Finishing
3	Interior Walls	Mixed mortar and enamel-like coating interior walls	Interior Wall Finishing
5	Floor	Cement mortar floor with waterproof coating applied to the inner walls and substrate of cable trenches	All Floor
6	Ramp	Cement serrated ramp	All Ramp
7	Skirting	Cement mortar skirting	All skirting shall be 150mm in height
8	Apron	Cast-in-place concrete apron	All aprons shall be 900mm in wide

5.19.2. Structural Engineering

(1) Project Overview

The total building area of this project is 495.54m², comprising two individual buildings: the fire pump room and the power distribution room. The fire pump room covers an area of 102.95m², while the power distribution room covers 392.59m². The fire pump room is a one-story underground structure, with a one-story aboveground evacuation stairwell. The underground section has a total length of 11.8m, a total width of 7.4 m, and a height of 4.85m, with a roof soil cover thickness of 3.35m. The evacuation stairwell is a one-story frame structure, with dimensions of 7.1m by 3.05m and an eave height of 3.6m. The power distribution room is a single-story aboveground structure, with an overall width of 12.9m, a length of 37.6m, and an eave height of 5.1m.

(2) Technical Standards

1) Design Reference Period: By БНбД 20-01-11, the structural design reference period for this project is 50 years.

2) Design Service Life: 50 years.

3) Structural Safety Level: As per Clause 9.1 of БНбД 20-01-11, the structural safety level of the building is classified as Level 3, with a structural reliability factor $\gamma_n = 1.0$.

4) Structural Seismic Fortification: According to БНбД 22-01-21, the seismic fortification category of the building structure is Category 3.

5) Seismic Fortification Intensity: Grade 7 (0.15g).

6) Site Category: Category Ⅰ, subject to confirmation upon completion of the geotechnical survey.

7) Basement Waterproofing Grade: Grade Ⅱ, with an impermeability rating of P8.

(3) Principal Loads and Values

1) Permanent Loads (P_d)

Self-weight of structure: unit weight of reinforced concrete γ = 25kN/m³;

Basement overburden load: unit weight of soil γ = **18kN/m³;

Basement Water Pressure: Groundwater level is taken as the anti-floating design water level, calculated as static water pressure.

Basement Lateral Earth Pressure: Calculated according to the at-rest earth pressure during the service stage.

2) Long-term Loads (P_l)

Equipment load: Based on the actual weight of installed equipment.

Effects from thaw settlement of permafrost and foundation deformation.

3) Short-term Loads (P_t)

Basic wind pressure: ω_0 = 0.85kN/m^2 (50-year recurrence interval); basic snow load: S_g = 0.50 kN/m^2 (50-year recurrence interval).

Fire pump room floor overload design criteria: 20kN/m^2.

Non-accessible roof variable load: standard value = 0.5kN/m^2.

4. Special Loads

Seismic action: calculated for Intensity 7 (0.15g)

(4) Structure Design Principles

1) The safety grade and design service life of concrete structures shall comply with the provisions of Building Structures and Foundation Reliability—general Requirements (БНбД 20-01-11).

2) Concrete structure design shall take into account the level of construction technology and the feasibility of actual project conditions.

3) The concrete structural design scheme shall meet the following requirements:

① Select a reasonable structural system, component forms, and layout.

② The arrangement of the structure's plan and elevation shall be regular; the mass and stiffness of each part shall be uniform and continuous.

③ The load transfer path of the structure shall be simple and straightforward; vertical members shall be continuous, aligned, and well-connected.

④ Statically indeterminate structures shall be adopted; key components and critical load transfer points shall have redundant constraints or multiple load paths.

4) Structural design and calculations shall be based on geological survey data and relevant national codes, standards, and regulations.

5) In addition to meeting process design requirements, the precise dimensions of the

structure shall consider construction tolerances, measurement errors, equipment installation, structural deformation, and construction process needs. These values shall be determined concerning geological conditions, burial depth, loads, structural types, construction sequences, and measured values from similar projects.

6) Structural design shall be carried out according to the structure type, intended use, load characteristics, construction process, and other relevant conditions. The structure or its components shall meet the requirements for strength, stiffness, stability, and durability, as well as technical requirements such as waterproofing and fire resistance.

7) The durability of concrete structures shall be designed based on the design service life, environmental category, and load level of the structure.

(5) Basic Foundation Design

For this project, in the absence of a detailed geotechnical investigation report, the bearing capacity of the foundation bearing layer for all architectural units shall be taken not less than 300kPa. The foundation design grade of the buildings is Grade 3.

The fire pump room foundation is a cast-in-place integral reinforced concrete slab. The distribution room uses isolated column footings with foundation depth below the frost line.

(6) Structural Plan

Considering the building structure's use, function, load characteristics, and construction process comprehensively, the tunnel fire pump room basement adopts a single-story, single-bay box structure. The basement box structure has a span of 6.95m, a total structural length of 11.8m, and a total structural height of 5m. The top slab soil cover thickness is approximately 3.35m. Preliminary calculations propose the thickness of the basement floor slab, roof slab, and side walls all to be 450mm. The fire pump room's evacuation stairwell uses a single-story frame structure with main spans of 2.7m and 6.8m, and a roof height of 3.6m. The distribution room adopts a single-story frame structure with main spans of 7.8m and 8.4m, and a roof height of 5.1m.

CHAPTER 6. ENGINEERING SOLUTION AND PLANNING- NETWORK

6.1. BACKGROUND

6.1.1. Design principles

In engineering design, pipeline integration design is carried out to comprehensively manage all relevant discipline pipelines and eliminate the conflicts in planar and vertical laying of pipelines. During construction, it is the basis for arranging pipeline construction, organizing construction activities, implementing construction management, and inspecting the accuracy of the construction Figures for all discipline pipelines. During production and operation, it is the primary basis for managing, maintaining, and expanding engineering pipelines. It is significantly essential to carry out a scientific, reasonable, and systematic design for under-road pipeline integration. In this design, the following design principles are adopted:

(1) The regional pipeline framework is constructed depending on the municipal pipeline system.

(2) The specifications for all discipline pipelines are met to the maximum extent. The minimum cover depth required for discipline pipelines is satisfied to the maximum extent.

(3) Generally, pipeline crossing is to comply with the following principles: Small pipes give way to large pipes, branches give way to trunk pipes, non-gravity flow pipes give way to gravity flow pipes, bendable pipes give way to non-bendable pipes, and designed pipelines give way to current pipelines.

(4) A proper distance is ensured between discipline pipelines and road trees.

(5) Planar and vertical pipeline designs are conducted according to the requirements for phased construction.

(6) The underground resources of urban roads are entirely and orderly explored and utilised.

(7) Current pipelines are connected adequately with new ones, and orderly construction is ensured.

(8) Safety, reasonableness, and economy of pipeline construction are ensured, and allowance is made for long-term development.

6.1.2. Pipeline integration cross-section design

In this design, a total of 8 types of municipal pipelines, namely flood, stormwater, thermal, water supply, sewage, electricity, lighting, and telecommunication, are laid out under the road. The thermal and sewage pipelines are relocated. Refer to lighting engineering for the lighting pipeline and flood engineering for the flood pipeline. According to the road design specifications, Road design ЗЗБНбД 22-004-2016, manhole covers are not allowed under the driving lane. Therefore, in this design, all the pipelines are laid out under the side strip, non-motorway, and sidewalk. The pipelines involved along the current road section have all been confirmed with the

corresponding management departments, and there are currently no significant cases that cannot be implemented due to design constraints. By the relevant municipal pipeline planning and specifications, pipeline cross sections are laid out as follows:

No.	Name	Location and Distribution	Specification
Chainage No.: K0+380-K1+080			
1	Stormwater pipe	Located under the boundaries of the non-motorways and sidewalks on both sides of the road, 13 m from the road centerline	DN500
2	Water supply pipe	Located under the boundary lines on both sides of the road, 16 m from the road centerline	DN600
3	Sewage pipe	Located beyond the boundary line on the left side of the road, 18 m from the road centerline	2×400
4	Electricity pipe	Located under the sidewalk on the right side of the road, 14.5 m from the road centerline	12-hole
5	Communication pipe	Located under the sidewalk on the left side of the road, 14.5 m from the road centerline	6-hole
Chainage No.: K1+080-K1+850			
1	Stormwater pipe	Located under the boundaries of the non-motorways and sidewalks on both sides of the road, 13 m from the road centerline	DN500
2	Water supply pipe	Located under the boundary line on the left side of the road, 16 m from the road centerline	2×DN600
3	Sewage pipe	Located beyond the boundary line on the left side of the road, 18 m from the road centerline	2×400
4	Electricity pipe	Located under the sidewalk on the right side of the road, 14.5 m from the road centerline	12-hole
5	Communication pipe	Located under the sidewalk on the left side of the road, 14.5 m from the road centerline	6-hole
Chainage No.: K1+850-K3+240			
1	Stormwater pipe	Located under the non-motorways on both sides of the road, 12 m from the road centerline	DN500
2	Water supply pipe	Located under the boundary lines on both sides of the road, 16 m from the road centerline	DN600
3	Electricity pipe	Located under the sidewalk on the right side of the road, 14.5 m from the road centerline	12-hole
4	Communication pipe	Located under the sidewalk on the left side of the road, 14.5 m from the road centerline	6-hole
Standard pipeline cross-section of a 60 m wide road			
1	Stormwater pipe	Located under the side strips on both sides of the road, 14.55 m from the road centerline	DN400-DN500
2	Water supply pipe	Located under the side strips on both sides of the road, 17.55 m from the road centerline (pipe position reserved)	DN150
3	Electricity pipe	Located under the sidewalk on the right side of the road, 28.55 m from the road centerline	12-hole
4	Communication pipe	Located under the sidewalk on the left side of the road, 29.05 m from the road centerline	6-hole
Standard pipeline cross-section of a 45 m wide road			
1	Stormwater pipe	Located under the non-motorways on both sides of the road, 18.05 m from the road centerline	DN400-DN500
2	Water supply pipe	Located under the sidewalks on both sides of the road, 21.55 m from the road centerline (pipe position reserved)	DN150
3	Electricity pipe	Located under the sidewalk on the right side of the road, 28.55 m from the road centerline	12-hole
4	Communication pipe	Located under the sidewalk on the left side of the road, 29.05 m from the road centerline	6-hole

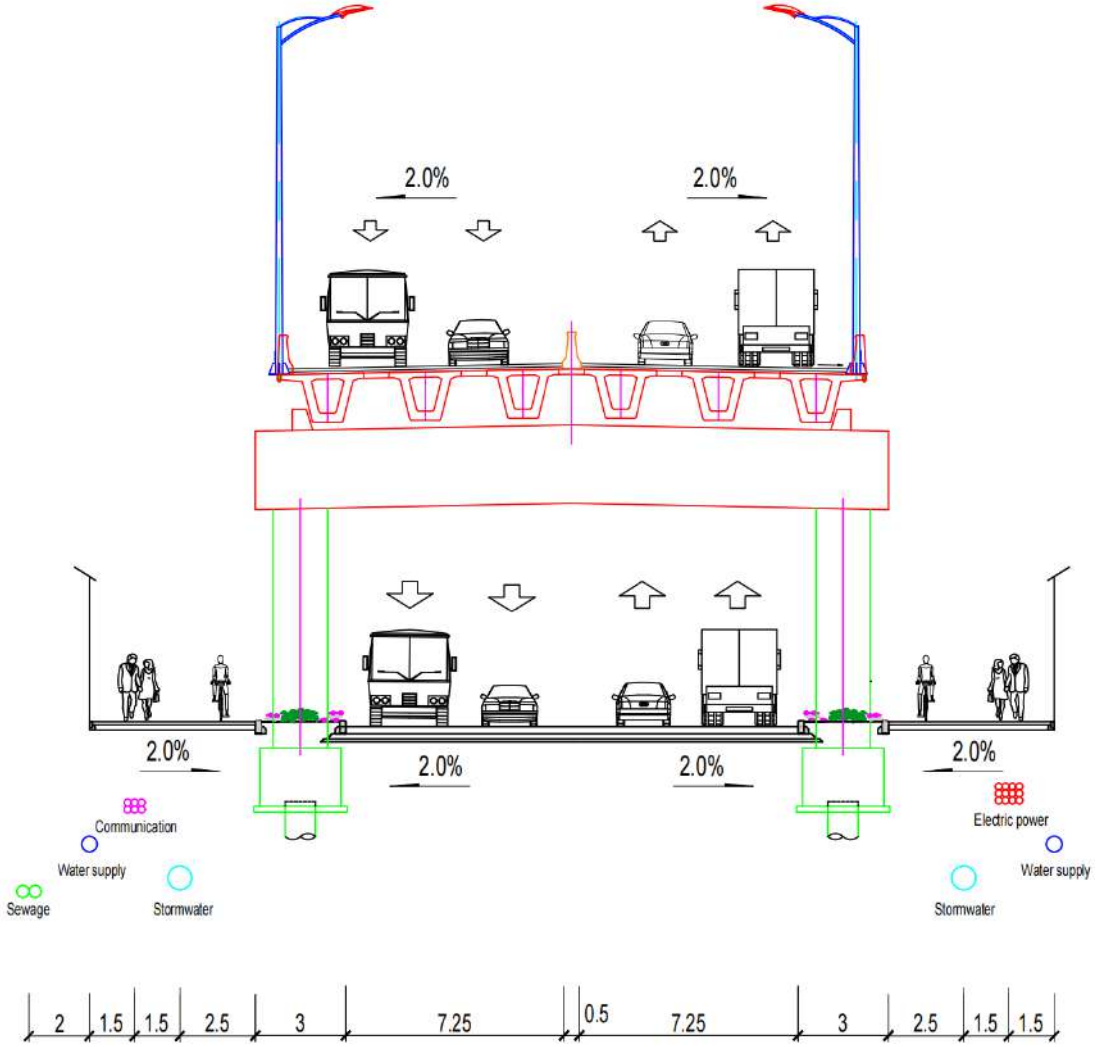


Figure 6. 1. Cross Section of a Standard Section Pipeline at K0+380-K1+080

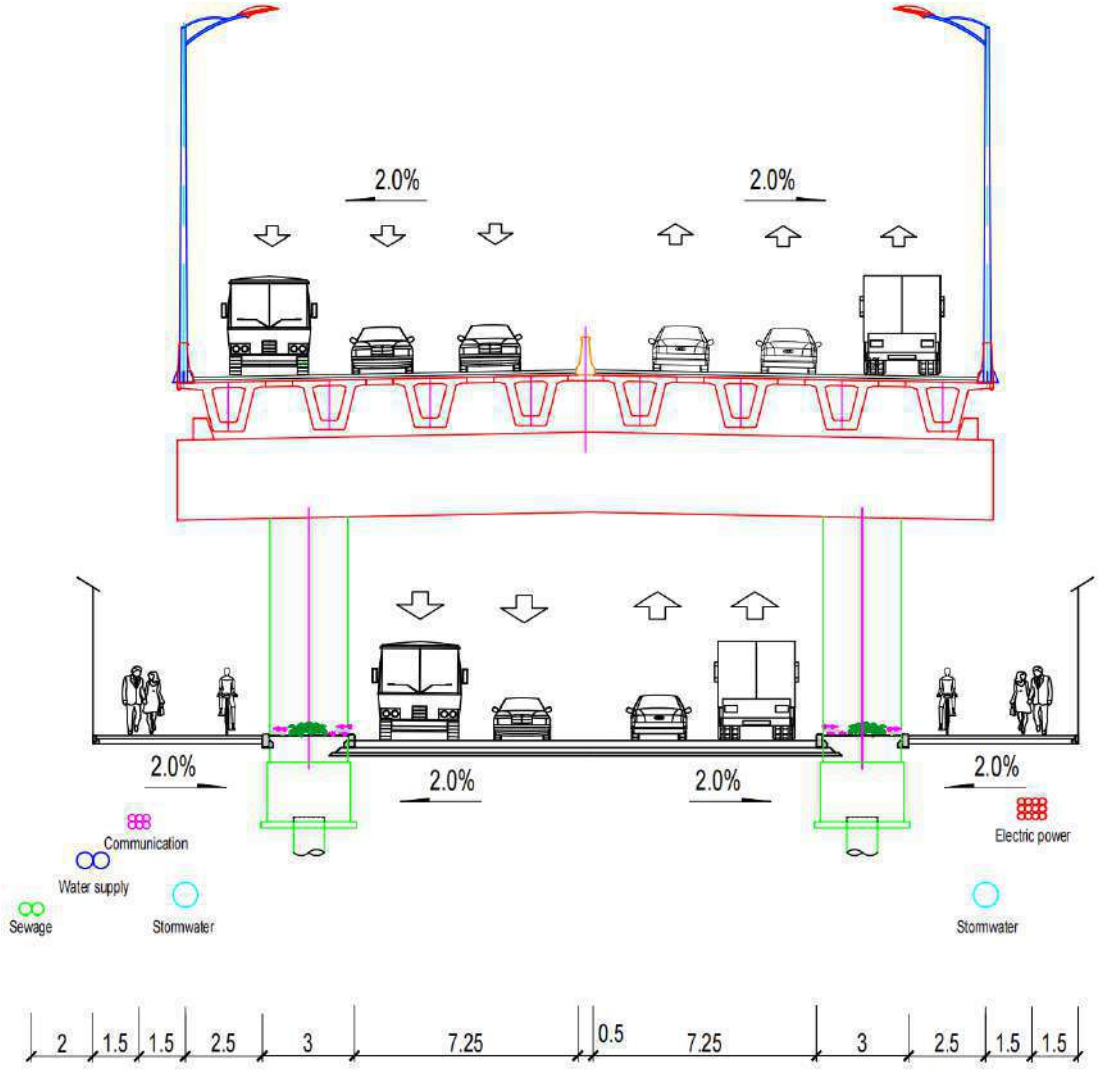


Figure 6. 2. Cross Section of a Standard Section Pipeline at K1+080-K1+850

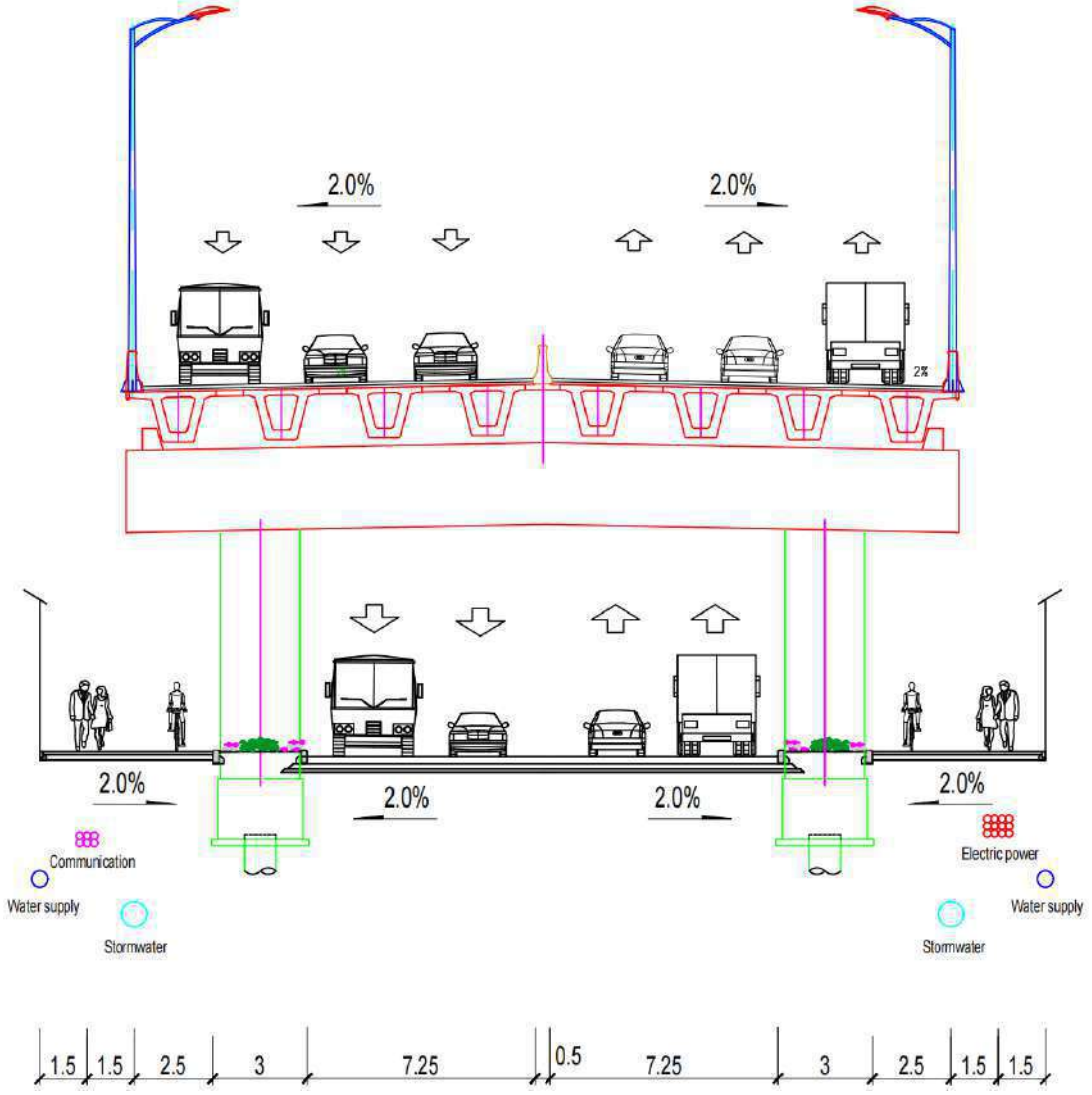


Figure 6. 3. Cross Section of a Standard Section Pipeline at K1+850-K3+240

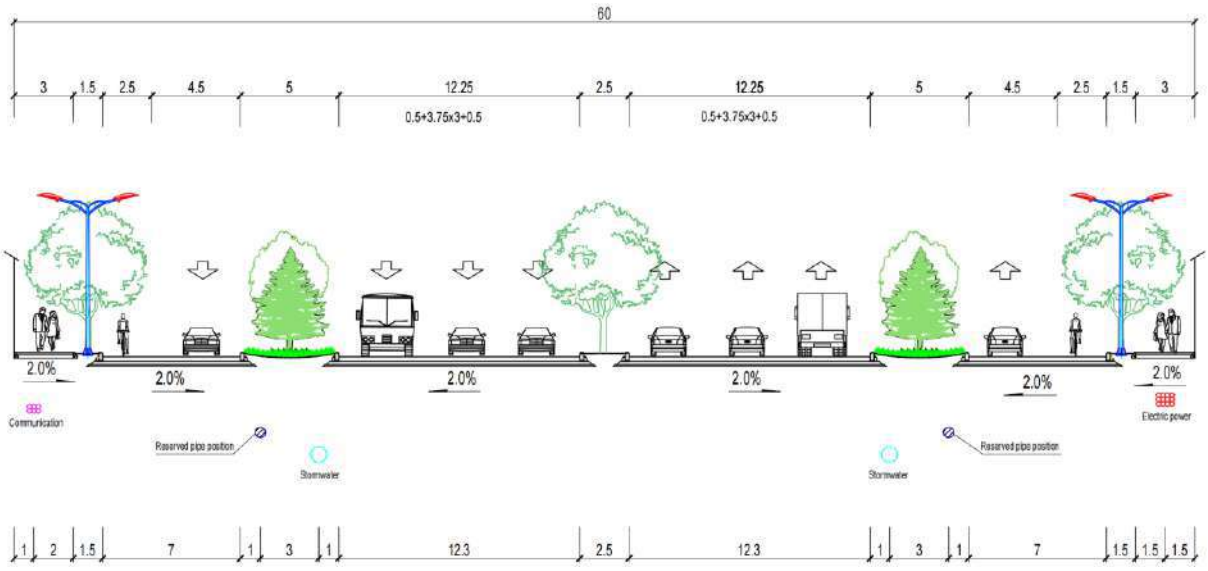


Figure 6. 4. Cross Section of a Standard Section Pipeline of a 60 m Road

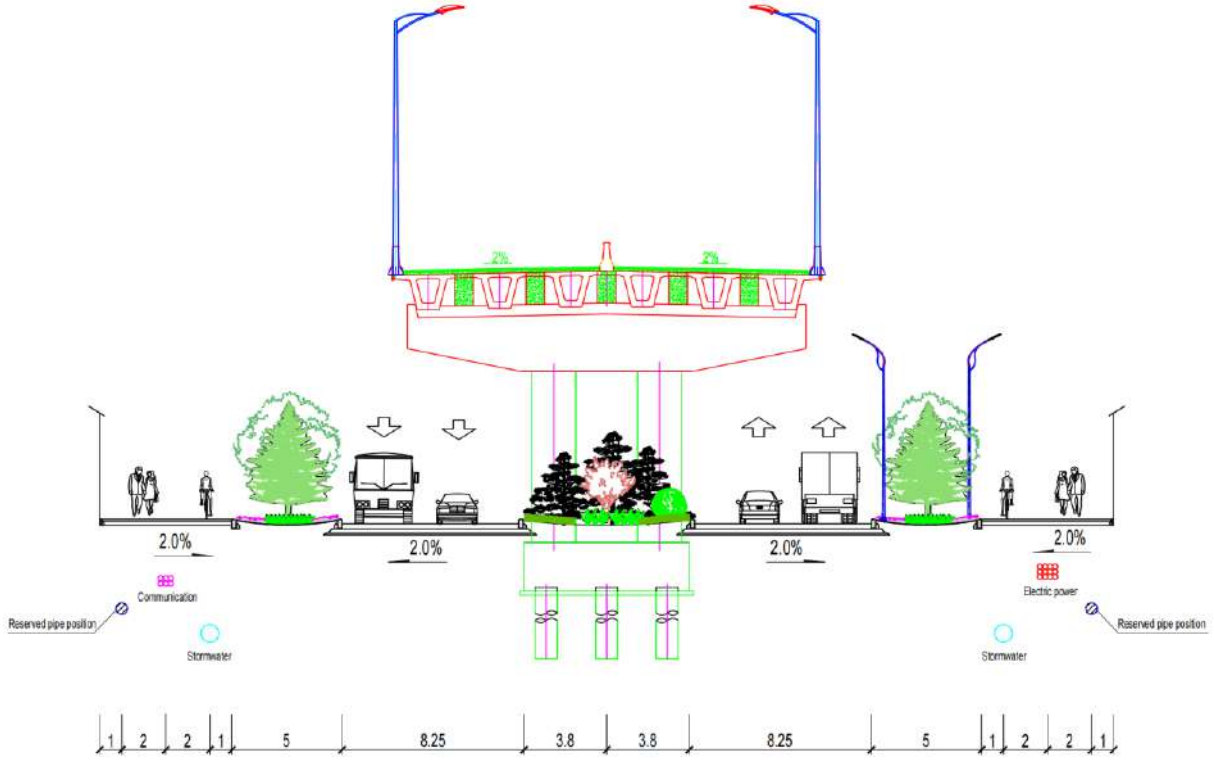


Figure 6. 5. Cross Section of a Standard Section Pipeline of a 45 m Road

6.2. FLOOD CONTROL ENGINEERING

6.2.1. Flood control planning

(1) Construction of flood embankments and reservoirs

Residential areas in the city centre are to be located near main rivers, higher than 1-5% of the observed extraordinary flood discharge for safety guarantee. However, as most of the settlements in Ulaanbaatar are located in the valleys of the Tuul River, Selbe River, Uliastai River, Tolgot River, Bayangol River, and Berkh River, there are high risks of floods.

In the Overall Plan until 2040, 106.75 km of flood embankments will be built at 8 sites to protect the main rivers against floods. It is also planned to restore 118.9 km of flood embankments, increase the discharge of small rivers, and ensure that these rivers flow continuously. Based on surveys and calculations, it is planned to construct 1,402.96 hectares of reservoirs at 14 sites, aiming to create a slightly humid climate environment in a feasible position for each river, including:

① Tuul River: embankment - 37.8 km, lake - 7 sites, with an area of 1,116.5 hectares

② Selbe River: embankment - 21.6 km, floating pond - 3 sites, with an area of 32.16 hectares

③ Uliastai River: embankment - 11 km, lake - 1 site, with an area of 132.5 hectares

④ Tuul Gol River: embankment - 8.1 km, Hovd Reservoir - 1 place, with an area of 24.4 hectares

⑤ Bayangol River: embankment - 6.1 km, lake - 1 place, with an area of 48.7 hectares

⑥ Tashet River: embankment - 9.7 km, lake in Position No. 1 - 48.7 hectares

⑦ Songgen River: embankment - 5.7 km

⑧ Хөлийнголынхамгаалалтындалан - 17.2 km

Flood control channels: The short-term heavy rainfalls around Ulaanbaatar can cause flash floods. When a flash flood breaks out, the flood runs through the river carrying large quantities of sediments and stones, destroying the residential areas and environment along the route, eroding and damaging the bridges and exits, and causing great losses. Urban residential areas may be eroded and collapse due to the wind, rainfall, and human activities. These factors may even cause ground subsidence. To minimize the damage to land in these areas, it is planned to construct interception facilities at 83 sites to stabilize the sediments and stones carried by flash floods, with vegetation planted in a natural manner. 202.2 km of flood control channels will be built at 65 sites and level 2-3 flood purification ponds will be set up at 19 sites to divert floods into rivers, with the purpose of protecting the drinking water source from pollution and reducing the transmission risk of infectious diseases. To prevent flood risks, it is also planned to construct artificial lakes and reservoirs to collect stormwater and spring meltwater. These measures will increase the urban green space, promote the development of domestic tourism, and create a humid, pleasant, and recreational environment.

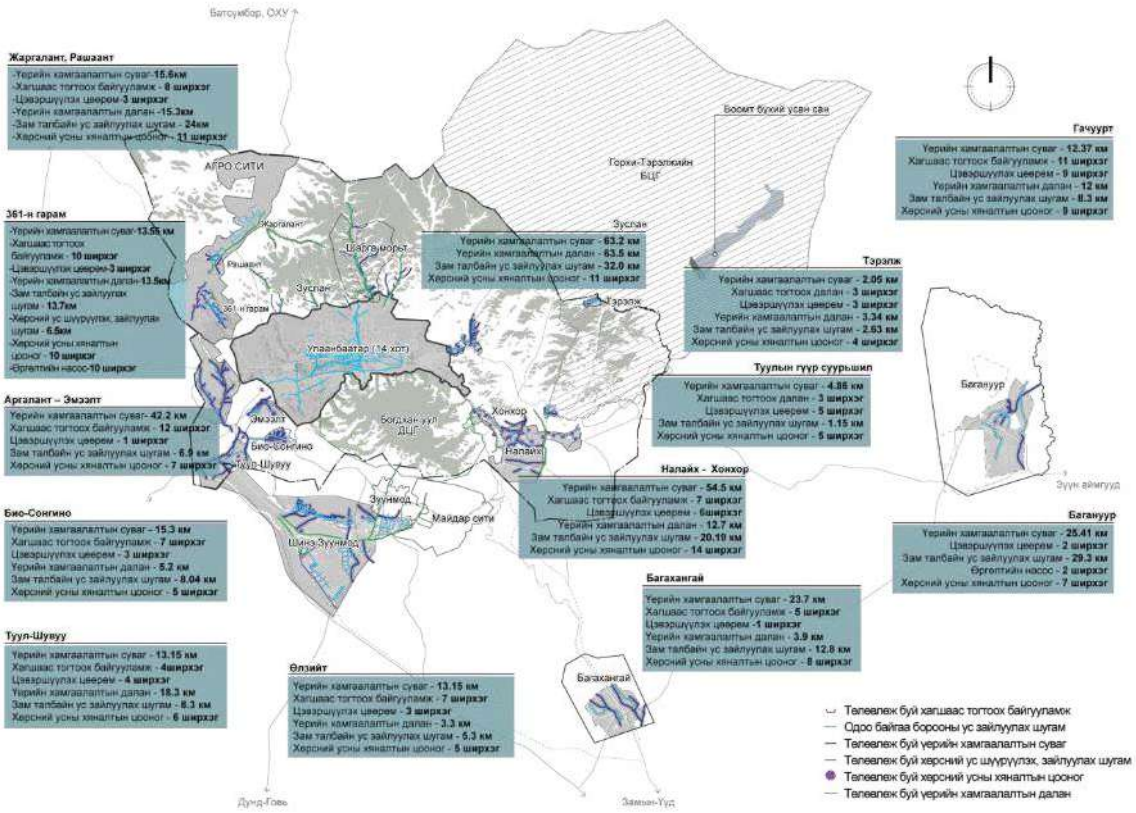


Figure 6. 6. Schematic Diagram of Flood Embankments

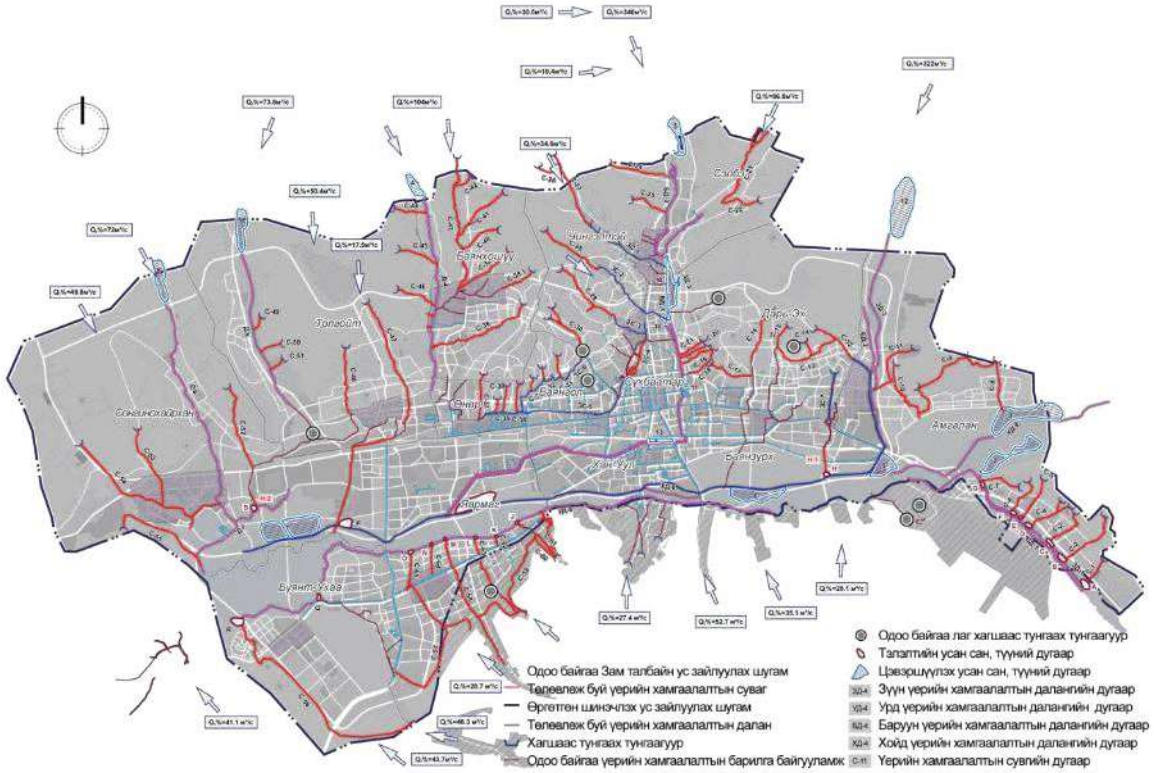


Figure 6. 7.Schematic Diagram of Planned Flood Control Structures

(2) River banks and flood control areas

In urban areas, large and small rivers are having smaller discharges. They are severely polluted and have lost the self-purification capability under natural conditions, which is a consequence of the exploration of mineral resources, tree felling, and damages to vegetation in river protection zones. The "water source protection zone and water supply source sanitation system", which was introduced to prevent the pollution of water sources, reservoirs, and resources and to protect the residents against flood hazards, has not been sufficiently implemented. The type and scope of water source protection zones and sanitation zones will be specified as follows.

According to Article 4.6 of Resolution No. 25 on March 30, 2023 by the Capital Citizens' Representative Assembly, the protection belt of a flood-preventing building is to be 10 m from the periphery of a building, embankment, and channel, and 5 m from the periphery of a stormwater/soil drainage pipeline.

6.2.2. Flood regulation calculation

(1) Calculation formula

According to the Code for Hydraulic Calculations (БНбД 2.01.14-86), in this study, the relationship curve of Q = f (H) is established with the Chezy formula based on cross section

plotting for water levels with various assurance rates:

$$Q = v F$$

where, Q - peak discharge (m^3/s);

V - flood flowrate (m/s);

F - area of wetted cross section (m^2).

The flood flowrate is calculated with the Chezy-Manning Formula:

$$v = C (R I)1/2$$

where, C - Chezy coefficient (depending on the roughness coefficient);

I - water surface slope;

R - hydraulic radius.

The Chezy Coefficient calculation formula is as follows:

$$C = 1/n \cdot (R)1/6$$

The roughness coefficient is n = 0.023.

(2) Maximum daily precipitation and its assurance rate

According to the Code for Hydraulic Calculations (БНбД 2.01.14-86) and field survey in the study area, the intensity of the storm flood in summer is higher than that of the snowmelt flood in spring. Therefore, the calculation focuses on the flood designed for storm. To this end, it is required to calculate and design the maximum daily precipitation first.

Statistical analysis is carried out according to the observation data (maximum daily precipitation) of the Ulaanbaatar Meteorological Station. According to observations, the maximum daily rainfall of the station in August 1982 was 100.3 mm.

Table 6. 1. Maximum Daily Precipitation (Ulaanbaatar Station)

No.	Year	Maximum Daily	Assurance Rate P (%)	Zoning of a Maximum
1	1938	30.2	74.9	1.7
2	39	27.8	74.1	3.3
3	1940	36.8	63.4	5.0
4	41	21.1	51.7	6.7
5	42	21.3	50.0	8.3
6	43	33.2	49.8	10.0
7	44	19.8	46.8	11.7
8	45	21.6	46.5	13.3
9	46	46.5	45.4	15.0
10	47	35.9	44.2	16.7
11	48	27.6	40.5	18.3
12	49	36.2	39.9	20.0
13	1950	26.2	39.7	21.7
14	51	25.5	38.0	23.3
15	52	39.7	37.2	25.0
16	53	23.8	36.8	26.7
17	54	50.0	36.2	28.3
18	55	19.9	34.4	30.0
19	56	29.4	34.2	31.7
20	57	63.4	33.2	33.3
21	58	30.9	32.1	35.0

No.	Year	Maximum Daily	Assurance Rate P (%)	Zoning of a Maximum
22	59	22.7	30.9	36.7
23	1960	39.9	30.2	38.3
24	61	24.1	29.6	40.0
25	62	26.9	29.4	41.7
26	63	37.2	29.4	43.3
27	64	32.1	28.6	45.0
28	65	20.5	28.5	46.7
29	66	74.1	28.0	48.3
30	67	74.9	27.8	50.0
31	68	29.6	27.6	51.7
32	69	28.5	27.4	53.3
33	1970	20.4	26.9	55.0
34	71	28.6	26.2	56.7
35	72	15.8	26.0	58.3
36	73	20.1	25.5	60.0
37	74	19.3	24.7	61.7
38	75	20.8	24.1	63.3
39	76	16.5	23.8	65.0
40	77	28.0	23.0	66.3
41	78	29.4	23.0	68.7
42	79	19.0	22.7	70.0
43	1980	26.0	21.7	71.3
44	81	17.9	21.6	73.7
45	82	44.2	21.6	75.0
46	83	34.4	21.3	76.3
47	84	51.7	21.1	78.7
48	85	27.4	20.8	80.0
49	86	17.7	20.5	81.7
50	87	34.2	20.4	83.7
51	88	24.7	20.1	85.0
52	89	38.0	19.9	86.7
53	1990	23.0	19.8	88.3
54	91	23.0	19.3	85.0
55	92	45.4	19.0	86.7
56	93	46.8	17.9	88.3
57	94	40.5	17.7	90.0
58	95	49.8	16.5	91.7
59	96	21.7	15.8	93.3

(3) Calculation of a maximum discharge

This area is located in the central mountainous region of Mongolia (with moderate ruggedness), characterized by sudden high-flowrate floods following heavy rainfalls. Therefore, the maximum discharge of storm flood in the study basin (rivers, streams, and gullies) is deduced with the following methods.

① For river and stream valleys with a catchment area smaller than 200 km^2, the maximum flood discharge is calculated with the storm intensity method according to the Code for Hydraulic Calculations (BNbD 2.01.14-86).

$$Q_{1\%} = q_{1\%} \times \varphi \times H_{1\%} \times \delta \times p\% \times F$$

where, Q1% - designed peak discharge (m^3/s);

q1% - peak discharge modulus ($L/s \cdot km^2$);

φ - runoff coefficient;

H1% - maximum daily precipitation at a designed frequency (mm);

δ - lake, forest, and marsh regulation coefficient;

p% - coefficient converted at 1% frequency;

F - catchment area (km^2).

② The channel morphological characteristic (Φr) used to determine the peak modulus (q1%) is calculated as follows:

$$Φr = 1000 × L/(Kr × Jr × F1/4 × (φ × H)1/4)$$

where, Φr - channel morphological characteristic value

L - length of a trunk stream (km);

Kr - river network bifurcation ratio;

Jr - channel average longitudinal slope.

③ The slope morphological characteristic (Φxб) used to calculate the slope convergence time (txб) is determined as follows:

$$Φxб = (1,000 × Lxб)1/2/(nxб × Jxб1/4 × (φ × H)1/2)$$

where, Φxб - slope morphological characteristic value;

Lxб - average length of a basin slope (km);

Jxб - average slope;

nxб - slope roughness coefficient.

④ The runoff coefficient is determined as follows:

$$φ = C2·φ0/(F + 1)n6 × (Jc × 50)n5$$

where, C2 - empirical coefficient (1.3 for forest areas and 1.2 for non-forest areas);

φ0 - runoff coefficient when F = 10 km^2 and Jc = 50‰;

n5 - soil structure related coefficient;

n6 - climate zoning related coefficient (0.07 for forest areas and 0.11 for non-forest areas).

⑤ Peak discharge modulus calculation formula:

$$Q1\% = q1\% × F = B1\%/(F + 1)0.4 × δ1 × δ2 × F$$

where, Q1% - design peak discharge at a 1% frequency; q1% - peak discharge modulus at a 1% frequency;

B1% - basic runoff modulus with a 1% flood frequency;

δ1 δ2 - lakeization, forest, and humidification coefficient;

F - catchment area.

4) Calculation results

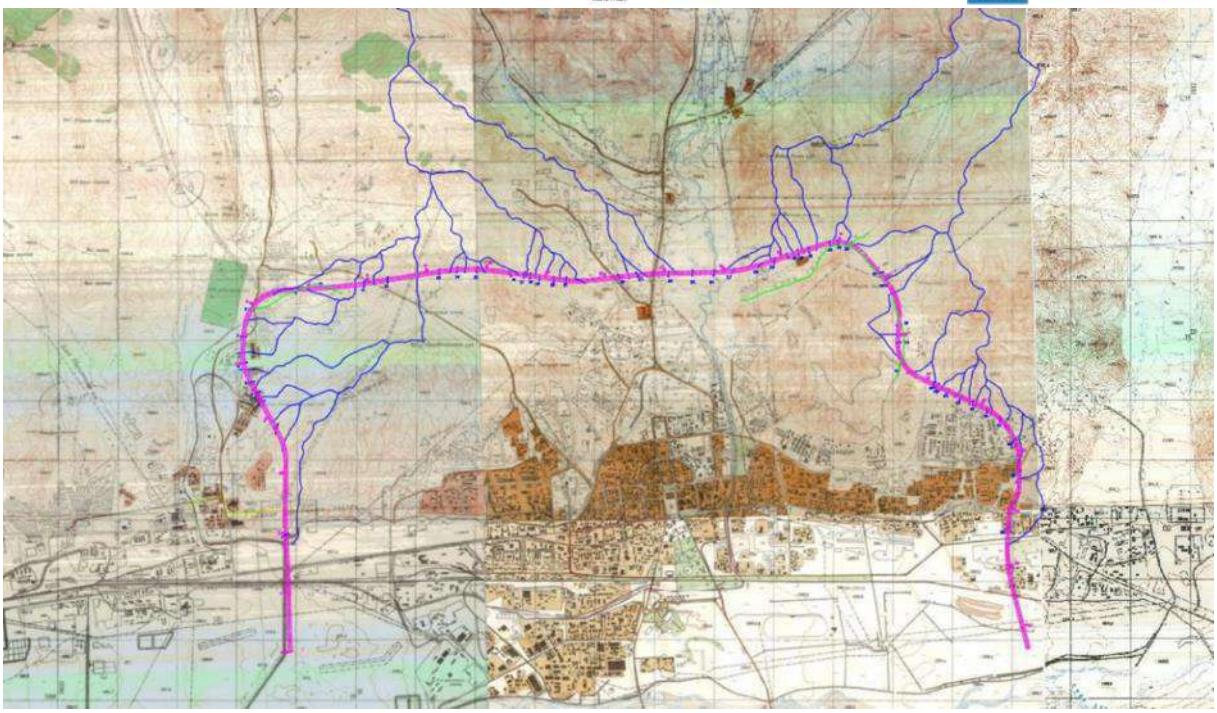


Figure 6. 8. Schematic Diagram of Catchment Analysis along the Line

Table 6. 2. Statistics of Catchment Discharges along the Line

No.	Mileage chainage No.	Catchment area F (km^2)	Catchment length Lr (km)	Discharge Q1% (m^3/s)
1	1+960	0.766	3.104	2.553
2	3+820	0.138	0.641	1.538
3	4+290	0.216	0.934	2.895
4	4+480	0.970	2.741	4.868
5	4+660	0.055	0.385	0.430
6	5+020	2.758	3.945	5.983
7	5+450	0.302	0.864	2.358
8	5+960	1.083	2.122	2.585
9	6+900	0.418	1.184	1.649
10	7+300	0.122	0.498	0.513
11	7+940	0.141	0.636	1.283
12	8+340	0.363	0.926	1.794
13	9+220	0.734	1.468	2.734
14	9+520	0.054	0.342	0.560
15	9+840	0.041	0.278	0.188
16	10+380	0.074	0.563	1.180
17	10+640	1.593	2.490	3.928
18	10+740	0.128	0.809	1.295
19	10+900	0.092	0.538	1.524
20	11+140	0.086	0.516	1.141
21	11+350	0.063	0.336	0.862
22	12+240	5.282	5.258	6.241
23	12+540	0.045	0.530	0.498
24	13+080	0.563	1.673	2.304
25	13+480	Spring water		
26	13+820	304.199	31.741	278.435
27	14+160	0.113	0.781	0.763
28	14+600	0.039	0.265	0.252
29	14+880	0.050	0.402	0.416
30	15+100	0.085	0.703	1.712

No.	Mileage chainage No.	Catchment area F (km^2)	Catchment length Lr (km)	Discharge Q1% (m^3/s)
31	15+290	0.124	0.750	2.337
32	15+480	0.614	1.946	2.450
33	15+840	1.130	2.133	3.678
34	15+980	0.070	0.374	0.487
35	16+180	6.606	5.388	12.138
36	16+880	0.786	1.173	6.837
37	17+140	0.144	0.897	0.829
38	17+840	0.189	0.516	1.815
39	18+120	0.061	0.364	0.492
40	18+460	2.040	2.460	7.845
41	19+140	0.073	0.393	0.703
42	19+190	0.784	1.655	4.755
43	19+390	0.077	0.429	0.652
44	19+640	0.078	0.633	0.710
45	19+840	0.129	0.774	0.864
46	20+100	0.069	0.403	1.144
47	20+380	0.150	0.788	1.234
48	20+810	0.128	0.680	0.456
49	21+350	0.289	1.110	0.674
50	22+320	0.439	1.168	0.459

5) Flood control design

According to the Regional Flood Control Planning and the Hydraulic Analysis Report, flood control design is carried out for once-in-100-year floods. The 50 drainage culverts in the Hydraulic Analysis Report have been optimised to 26, reducing the quantity of culverts and avoiding duplicate development. The combination of "DN800 pipe (minimum size) + 2 × 2 culvert (maximum size)" is adopted to meet the requirement for flood control along the road fully.

The hydraulic structures within the boundaries of the roadbeds on both sides of the flood discharge culverts are included in road construction at this stage. Slope protection is to be enhanced, and anti-erosion measures are to be taken for roadbed sections where flood discharge culverts are constructed.

Table 6. 3. Design for Flood Discharge Culverts along the Line

No.	Chainage No.	Size of a Flood Discharge Culvert (mm)
1	K2+300	Current river
2	K4+175	DN1500
3	K4+725	DN1500
4	K4+860	2000×2000
5	K5+045	DN1000
6	K5+400	2000×2000
7	K6+807	DN800
8	K7+300	2000×2000
9	K11+124	2000×2000
10	K11+350	DN1500
11	K11+565	DN1000
12	K11+788	DN1000
13	K12+650	Current river
14	K12+988	DN1000
15	K13+460	DN1500
16		Current Selbe River
17	K14+325-K15+625	1500×1500

No.	Chainage No.	Size of a Flood Discharge Culvert (mm)
18	K15+925	1800×1000
19	K16+230	DN1500
20	K16+360	DN1500
21	K16+600	1800×1000
22	K18+235	DN1500
23	K18+525	DN1000
24	K18+910	2000×2000
25	K19+510	DN1000
26	K19+590	2000×2000
27	K19+780	DN1000
28	K21+210	DN1500
29	K21+760	DN1000

6.3. Stormwater engineering

6.3.1. Design principles

(1) The general requirements for urban stormwater drainage and flood discharge are met, with the infrastructure including current pipelines and trenches utilized to the maximum extent to reduce or avoid the construction of stormwater pump stations.

(2) A drainage system for separate collection of stormwater and sewage is established, and the near-term development is combined with the long-term planning.

(3) The stormwater is vertically collected based on the planned road network and locally drained to the downstream receiving water body according to current topography, so as to reduce the length of the transfer pipe.

(4) The planar layout and vertical elevation of stormwater pipes are closely combined with road and sewage works, with adequate space reserved for laying the water supply pipe, electricity path, and communication path. Road slopes are reasonably utilized to reduce the cross sectional size of channels, lower the construction cost, and ensure smooth connection between pipes.

(5) The catchment area is properly zoned according to planned land use, current terrain and land planning, and current villages on road sides.

(6) Full account of water drainage of current villages after the road is completed is taken and smooth connection is ensured between the village drainage system and the urban stormwater system.

(7) Full account of the connection between the near-term development and the long-term planning of the stormwater system is taken and smooth stormwater drainage is ensured for near-term development and the long-term planning.

6.3.2. Planning for a stormwater system

Water accumulates on roads and squares as a result of increased energy consumption due to population growth, heat emitted by air conditioners, cars, and factories, decreased coverage

of vegetation, reduced water-absorbing surfaces, and the construction of high-density buildings. Among the 1065 km of hardened pavement within the city, a length of 209 km has been covered by the stormwater drainage pipe network, among which 22 km has been expanded and upgraded. The current 161.6 km of first-class and second-class roads will be protected by developing an 81.5 km stormwater drainage pipeline network.

According to the Overall Development Plan of Ulaanbaatar until 2040, 267 km of first-class highways and 23.2 km of second-class highways will be constructed, with a stormwater drainage trunk line constructed at 332 km.

Within Ulaanbaatar:

22 km of stormwater pipes will be expanded and upgraded.

Seven highway viaducts designed to withstand floods will be constructed.

413.5 km of stormwater drainage pipelines under highways will be constructed.

2 booster pump stations will be built.

2 stormwater purification facilities will be built.

8 lift pumps will be installed.

In recent years, technologies for collecting and using stormwater have been developed rapidly in many countries. For a country with a small land area like Mongolia, underground water and surface water resources are in short supply, making it necessary to collect and recycle stormwater. The following measures will be implemented from 2025 to 2040, including:

Stormwater is collected through a centralised system, purified and supplied to households.

The government and the private sector will cooperate to implement the sponge city technology gradually, build walkways that can absorb stormwater, and recycle the water absorbed.

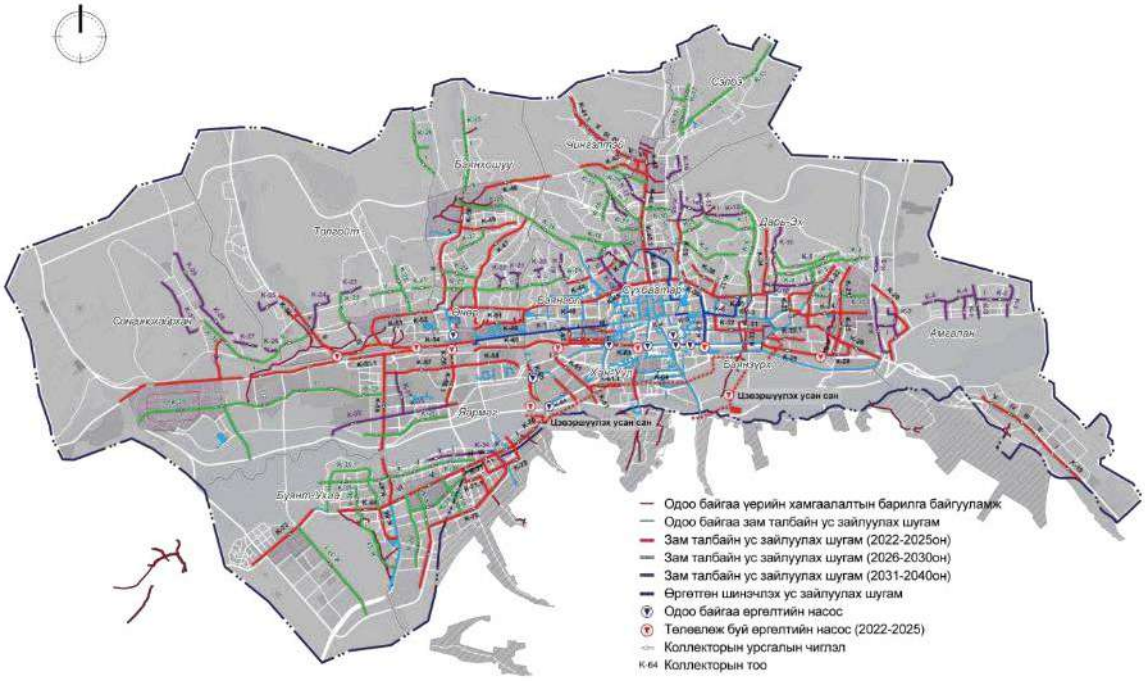


Figure 6. 9. Schematic Diagram of a Stormwater System

6.3.3. Design of stormwater pipeline system

(1) Design standards

According to Design Project and Calculation Norms for Drainage of Rainwater and Snowmelt from Urban and Rural Areas, Streets, and Plazas (БД 40-302-13) and the Overall Plan of Ulaanbaatar City until 2040, in this design, stormwater pipes are designed for once-in-10-year storms, with the development of sponge facilities.

(2) Design scope

The design scope of stormwater engineering is the same as that of the road discipline, with stormwater pipelines laid along the full large ring. The design includes the stormwater pipes under the roads, the road-crossing culverts connecting the current water systems in the plots on road sides, the temporary drainage channels, the stormwater pipes at the crossings along the roads, and the reserved crossing pipes.

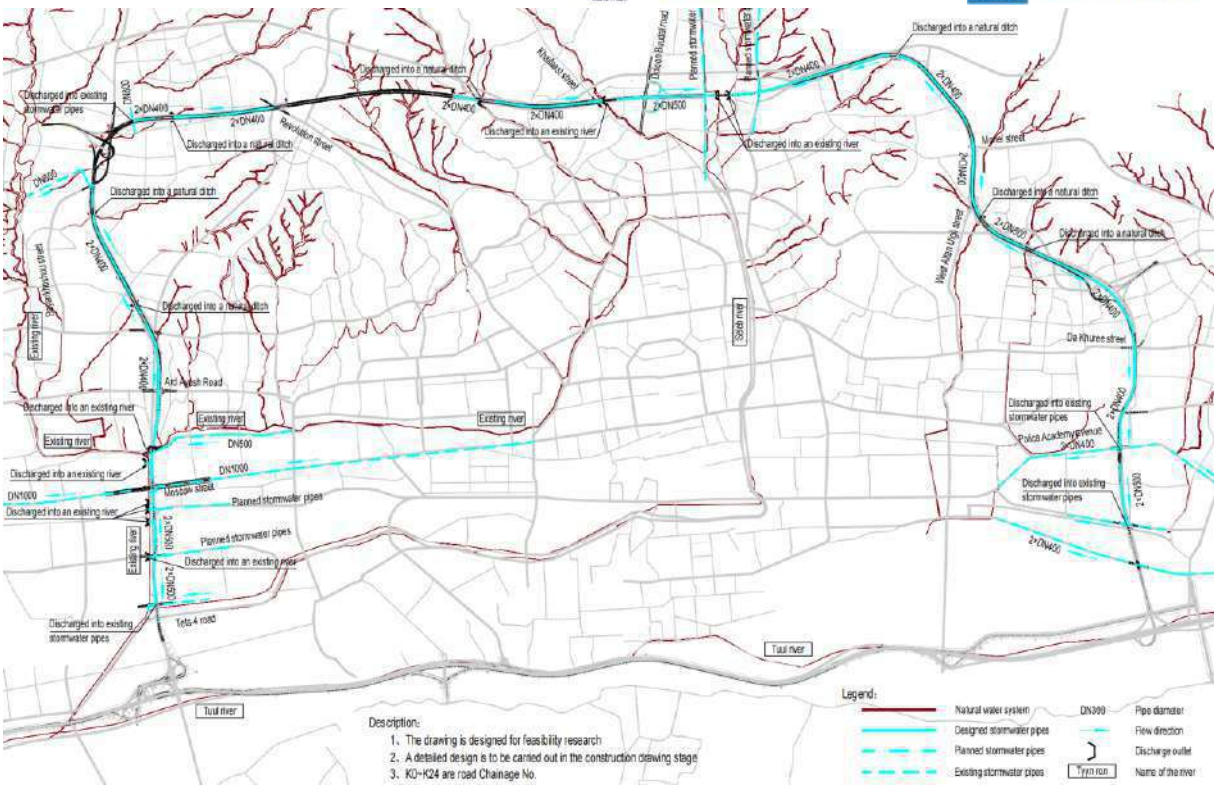


Figure 6. 10. Stormwater System

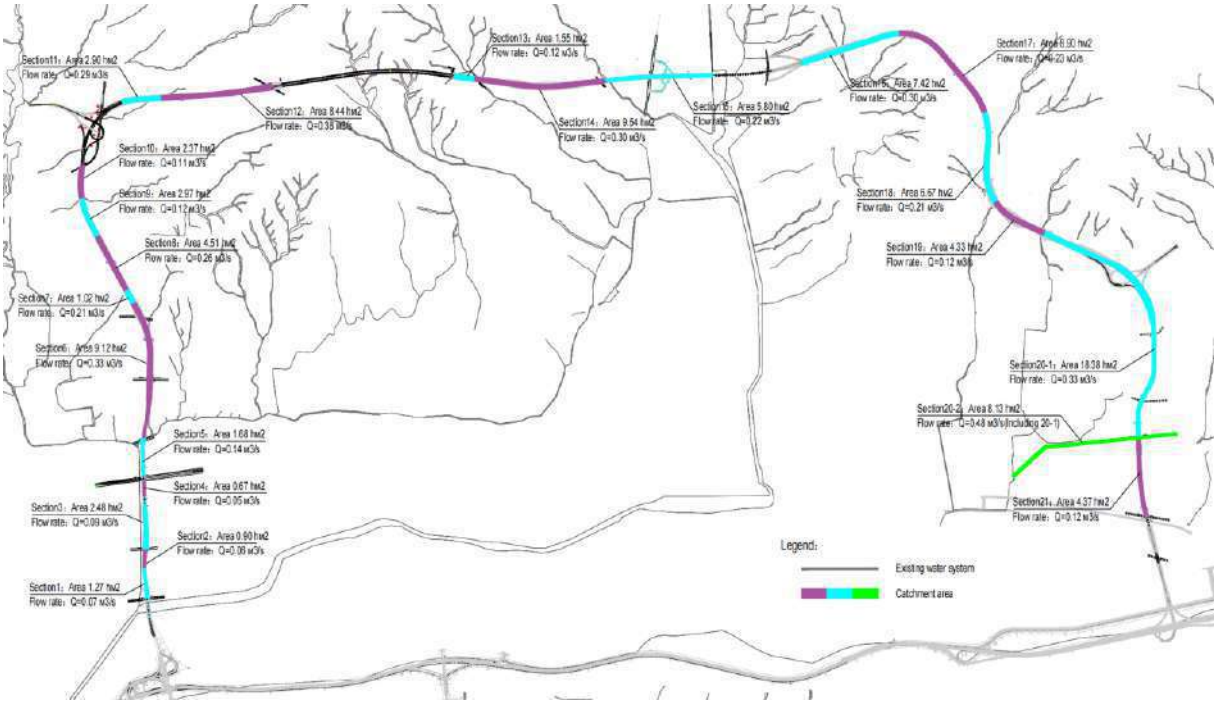


Figure 6. 11.Stormwater Catchment Zoning for Roads

(3) Design calculations

The design of road stormwater pipes mainly serves stormwater drainage on the road and in the surrounding areas.

A proper storm formula is used depending on the actual precipitation of Ulaanbaatar City.

This method determines the maximum flood discharge for areas smaller than 15 km^2 without requiring correction, using parameters such as the catchment area, precipitation intensity, and precipitation coefficient. This method is widely used internationally. The maximum rainfall discharge is determined using the rational method as follows.

Calculation of a maximum runoff of storm flood:

$$Q = \frac{C \cdot I \cdot F}{z}$$

Here: Q – Maximum rainfall flood discharge, $м^3/s$

C – Precipitation coefficient.

I – Average precipitation intensity, mm/hour,

F – Catchment area, ha,

z – Unit transfer coefficient (taken as 360 in the international system).

Calculation of average storm intensity:

$$I = \frac{p_d}{t_c}$$

Here:

p_d – Precipitation layer, mm / Climate and geophysical parameters are taken as 120 mm from BND 23-01-09

t_c – Flood hourly intensity of the catchment area, hours

Calculation of flood intensity over time in the catchment area:

$$t_c = 0.0078 \cdot L^{0.77} \cdot S^{-0.395}$$

Here: The furthest point of the catchment area from the drainage outlet, m,

S – Average slope of the catchment area

Hydraulic calculation of stormwater pipeline:

$$v = \frac{1}{n} R^{\frac{2}{3}} I^{\frac{1}{2}}$$

Here:

R - hydraulic radius (m)

I - hydraulic slope

n - pipe roughness coefficient

b - main calculation parameter of a stormwater pipe

Flowrate:

Table 6. 4. Minimum Flowrate of a Pipe in the Stormwater Drainage Pipeline Network for Roads at Maximum Pipe Filling

Diameter (mm)	Minimum flowrate at H/D filling (m/s)			
	0.6	0.7	0.75	0.8

150-250	0.7			0.65
300-400		0.8		
450-500			0.9	
600-800			1.0	
900			1.1	
1000-1200				1.2
1500				1.3
Over 1000				1.5

In a stormwater pipe with a frequency of P = 0.33 year, the minimum flowrate shall be 0.6 m/s.

With the design flowrate satisfied, a drainage channel is usually laid in parallel with the ground.

(4) Specific design for stormwater engineering

1) Stormwater collection

On the slope of an embankment, the stormwater is "scattered" (scattered out of the slope under gravity without a centralized drainage structure). In a cutting, a trapezoidal side ditch is installed on the road side to collect the stormwater from the slope, which is then longitudinally drained to a natural water system along the road. In a road section where the stormwater is caught on the top of the cutting slope, an interception ditch is installed at the slope crest to catch the stormwater to the roadside ditch. Stormwater pipes mainly collect the stormwater from the pavement and bridge deck, and do not cross or disturb the roadbeds and road areas.

2) Zoning of catchment areas

In the engineering, both the planning and the near-term current situations are to be considered when zoning catchment areas. The catchment areas selected for stormwater discharge calculation will include those considered for both the near-term current situations and long-term planning.

Table 6. 5. Road Stormwater Calculations

Plot	Distance L (m)	Average slope S	Flood intensity tc (h)	Precipitation Pd (mm)	Storm intensity I (mm/h)	Runoff coefficient C	Catchment area F (hm^2)	Unit conversion	Maximum runoff Q (m^3/s)
1	358	0.0063	5.34	120	22.46	0.9	1.27	360	0.07
2	233	0.004	4.59	120	26.12	0.9	0.9	360	0.06
3	520	0.004	8.52	120	14.08	0.9	2.48	360	0.09
4	193	0.004	3.97	120	30.20	0.9	0.67	360	0.05
5	250	0.009	3.52	120	34.09	0.9	1.68	360	0.14
6	1750	0.046	8.27	120	14.51	0.9	9.12	360	0.33
7	130	0.024	1.44	120	83.09	0.9	1.02	360	0.21
8	680	0.024	5.16	120	23.24	0.9	4.51	360	0.26
9	480	0.005	7.34	120	16.35	0.9	2.97	360	0.12

Plot	Distance L (m)	Average slope S	Flood intensity tc (h)	Precipitation Pd (mm)	Storm intensity I (mm/h)	Runoff coefficient C	Catchment area F (hm^2)	Unit conversion	Maximum runoff Q (m^3/s)
10	1020	0.029	6.55	120	18.33	0.9	2.37	360	0.11
11	470	0.045	3.03	120	39.59	0.9	2.90	360	0.29
12	1270	0.042	6.70	120	17.92	0.9	8.44	360	0.38
13	310	0.01	3.99	120	30.11	0.9	1.55	360	0.12
14	1570	0.025	9.68	120	12.40	0.9	9.54	360	0.30
15	1280	0.027	8.02	120	14.96	0.9	5.80	360	0.22
16	1170	0.027	7.49	120	16.03	0.9	7.42	360	0.30
17	1500	0.015	11.43	120	10.50	0.9	8.90	360	0.23
18	1100	0.013	9.53	120	12.60	0.9	6.67	360	0.21
19	710	0.004	10.83	120	11.08	0.9	4.33	360	0.12
20.1	3200	0.025	16.74	120	7.17	0.9	18.38	360	0.33
20.2	1680	0.008	15.99	120	7.50	0.9	8.13	360	0.15
20	4880	0.019	25.83	120	4.65	0.9	26.51	360	0.48
21	930	0.007	10.69	120	11.22	0.9	4.37	360	0.12

In this design, stormwater pipes have a pipe diameter of DN400 - DN500. Stormwater connection pipes have a pipe diameter of DN200. Stormwater is locally drained to a natural ditch or river. The pipe diameter of stormwater pipes is to be checked by the designer in the construction Figure phase, using hydraulic software to simulate and calculate waterlogging and peak cutting.

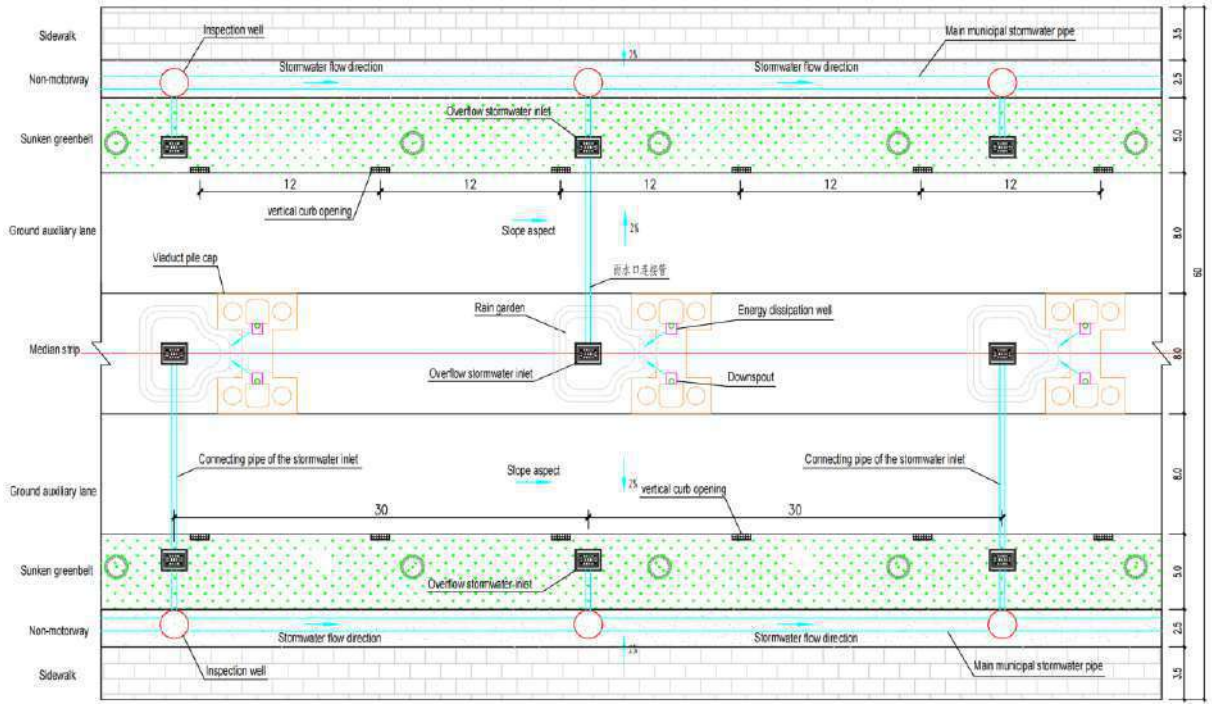


Figure 6. 12. Layout Plan of Standard Stormwater Facilities of a 45 m Wide Road

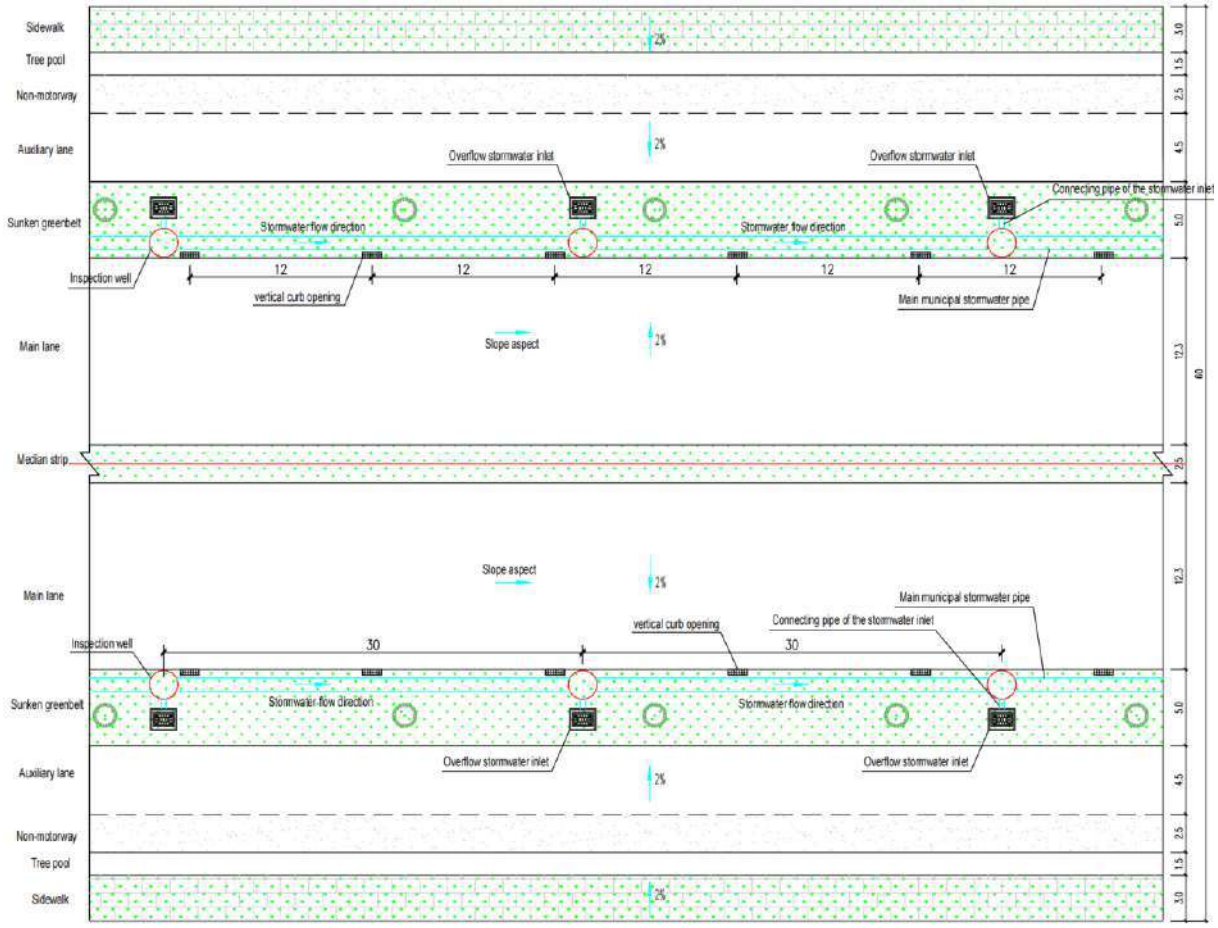


Figure 6. 13.Layout Plan of Standard Stormwater Facilities of a 60 m Wide Road

(5) Stormwater pipes and pipe foundation

① Requirements for a pipe

The materials used for drainage pipes are to meet certain requirements to ensure normal drainage.

Drainage pipes are to have sufficient strength to withstand external loads and an internal water pressure. External loads include the weight of soil and the dynamic load from vehicle movements. Internal water pressure can be induced by siltation of the gravity-flow pipe or during desilting. Pipes must have sufficient strength to prevent cracking during transportation and construction.

Drainage pipes are to be resistant to erosion and wearing by impurities in sewage. These pipelines are also to be resistant to corrosion, especially corrosive industrial waste.

Drainage pipes are to be impermeable. The seepage of sewage will contaminate the groundwater or corrode other pipelines and building foundations.

Drainage pipes are to have neat and smooth inner walls to minimize the resistance of water flows.

Drainage pipes are to be taken locally if possible, considering the possibility for

prefabrication and quick construction to reduce the costs for transportation and construction.

② Selection of pipes

In this design, various pipes for drainage pipes are compared and selected, which usually include the following four types:

Table 6. 6. Comparison and Selection of Drainage Pipes

Pipe Item	Reinforced concrete pipe	Reinforced concrete pipe with a socket	FRP sand inclusion pipe	HDPE pipe
Segment length	Usually 2 m	Usually 2 m	6 m - 12 m	6 m
Joint	Rubber ring joint, wire mesh cement mortar joint, or collar joint	Rubber ring joint, wire mesh cement mortar joint, or collar joint	Rubber ring flexible joint	Electrofusion joint or socket-type rubber ring flexible joint
Foundation	Concrete foundation	Sand bedding foundation	Sand bedding foundation	Sand bedding foundation
Pipe diameter	d300 - d2400	d300 - d3400	DN300 - DN2400	DN300 - DN2000
Roughness coefficient n	0.014	0.014	0.01	0.01
Hydraulic performance	Relatively poor, high along-the-path resistance	Poor, high along-the-path resistance	Good, low along-the-path resistance	Good, low along-the-path resistance
Anti-corrosion performance	Good	Good	Good, not requiring internal and external corrosion protection	Good, not requiring internal and external corrosion protection
Construction speed and level of difficulty	Short pipeline, lots of joints, complicated pipeline foundation; mature and widely applied construction process, quick construction	Short pipe, lots of joints; simple pipeline foundation, quick construction	Long pipeline, few joints, simple pipeline foundation, quick construction	Long pipeline, few joints, simple pipeline foundation, quick construction
Adaptability to unfavorable foundations	Less adaptable to unfavorable foundations than plastic pipes	Less adaptable to unfavorable foundations than plastic pipes	Highly adaptable to unfavorable foundations Well sealed joints, adaptable to differential foundation settlement	Highly adaptable to unfavorable foundations Well sealed joints, adaptable to differential foundation settlement
Transportation and lifting	Heavy and bulky, difficult to transport and lift	Heavy and bulky, difficult to transport and lift	Light, easy to transport and lift	Light, easy to transport and lift
Other advantages and disadvantages	Difficult to operate when the groundwater level is high; high auxiliary costs for construction; low total construction costs; strong pressure resistance of pipe	Lowest total construction costs; strong pressure resistance	Highest total construction costs; large-diameter pipe that is fragile and easily deformed	The total construction costs for large-diameter pipes are high. The pipe is fragile and easily deformed. The total construction costs for small-diameter pipes are similar to (slightly higher than) those of reinforced concrete pipes.

In principle, when selecting the material of a drainage pipe, it is necessary to take into account the reliability, advancement, and economy of the technology adopted and construction quality. Therefore, based on the engineering and geological characteristics of the foundation, a

technical and economic comparison is conducted among the reinforced concrete pipe, reinforced concrete pipe with a socket, HDPE pipe, and FRP sand inclusion pipe, ensuring the selected pipe is both technically feasible and economically reasonable.

Regarding small-diameter drainage pipes, reinforced concrete pipes have several disadvantages, including high energy consumption, a short service life, and poor performance in energy saving and environmental protection. Consequently, their comprehensive cost is not advantageous compared to plastic pipes, which are gradually replacing them. With the diameter increase, the cost of laying plastic pipelines rises. The unit price of this pipe is significantly higher than that of reinforced concrete pipes, resulting in lower cost performance. Therefore, large-diameter plastic pipes can hardly be widely used in construction unless there is a sharp decrease in the price. Small- and medium-diameter plastic pipes are the new pipes that have emerged in recent years. At present, they are extensively used with the promotion of the Ministry of Construction for their technological advancement, flexibility, resistance to subsidence, economic viability, and energy-saving and environmental protection performance.

In particular, the roughness coefficient of the HDPE pipe is merely about 64-71% of the reinforced concrete pipe. That is, with the same hydraulic slope, the discharge allowable by an HDPE pipe can be equivalent to that allowable by a reinforced concrete pipe with a higher grade of pipe diameter.

In sum, considering the extensive use of HDPE pipes in current drainage pipeline network construction, the use of stormwater pipes, the actual requirements for laying drainage pipeline network in this design, and the cost performance of relevant pipes, the following pipes for drainage pipelines are selected: For pipelines with a diameter less than DN500 (included), HDPE reinforced wound pipes are used; for pipelines with a diameter greater than DN500, reinforced concrete pipes (Grade II or III) are used.

In this design, the pipe diameter of the stormwater gravity pipeline is ≤ 500 mm. Therefore, HDPE pipes are used. The pipes used shall conform to the technical requirements in relevant standards, with mechanical performance satisfying the requirements in relevant codes. When the burial depth is ≤ 6.0 m, the ring stiffness shall be 8 KN/m^2, that is, not lower than Grade S2. When the burial depth is > 6.0 m, the ring stiffness shall be 12 KN/m^2. Pipe joints are connected by rubber ring socket and spigot.

The stormwater gravity pipe with a pipe diameter of > 500 mm will be formed with Grade II reinforced concrete pipes. The joints are connected by elastic rubber seal ring socket and spigot. The rubber ring used is to be supplied by the manufacturer, which is resistant to acid, alkali, and corrosion, with physical properties meeting the relevant technical codes.

(6) Pipe foundation

① When the bottom of the HDPE reinforced wound pipe is seated in an undisturbed soil

layer, the bed shall be replaced with a 15 cm thick medium-coarse sand bedding. When the pipe bottom is seated in a recently backfilled soil layer, the bed shall be replaced with a 20 cm thick medium-coarse sand bedding. ② When the bottom of the Grade II reinforced concrete pipe foundation is seated in an undisturbed soil layer, the bed shall be replaced with a 10-20 cm thick medium-coarse sand bedding. When the pipe bottom is seated in a recently backfilled soil layer, the bed shall be replaced with a 20 cm thick medium-coarse sand bedding. The trench of the stormwater inlet connecting pipe is vertically excavated. A medium-coarse sand layer is laid from 15 cm below the pipe bottom to the road trough, with a minimum compactness of 95%.

The pipe foundation is to sit on an undisturbed soil layer with good soil quality or a treated soil layer. The connection of branch pipes and the treatment of the inspection well foundation are similar to the trunk pipe. The foundation bearing capacity of the pipe is to satisfy the standard road load and be not less than 100 kPa.

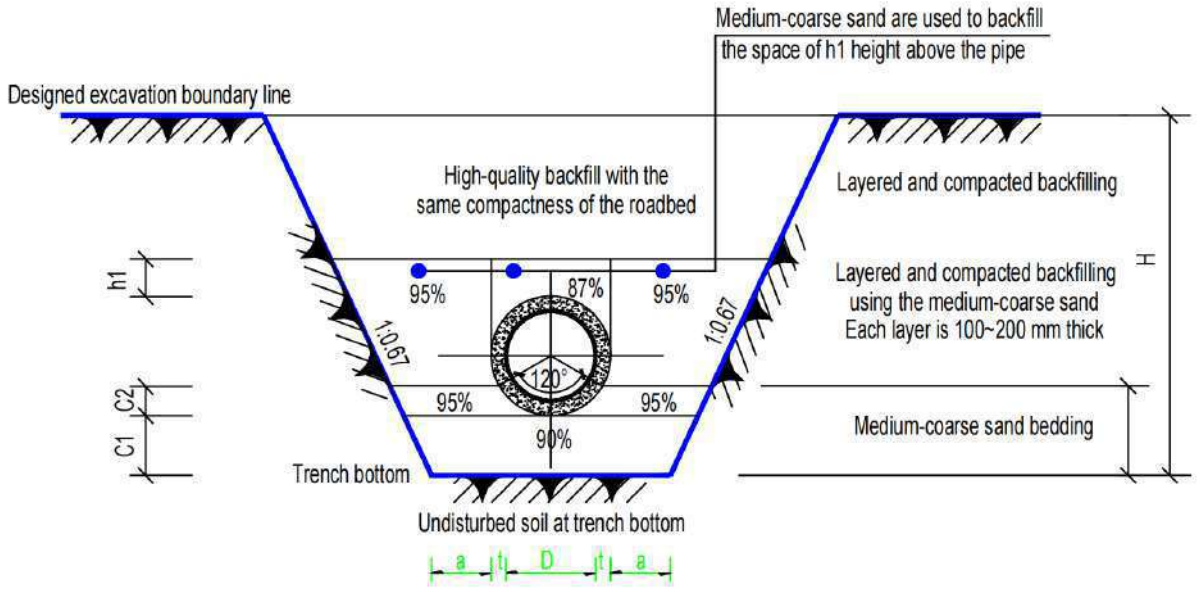


Figure 6. 14. Cross Section of Pipe Excavation (1)

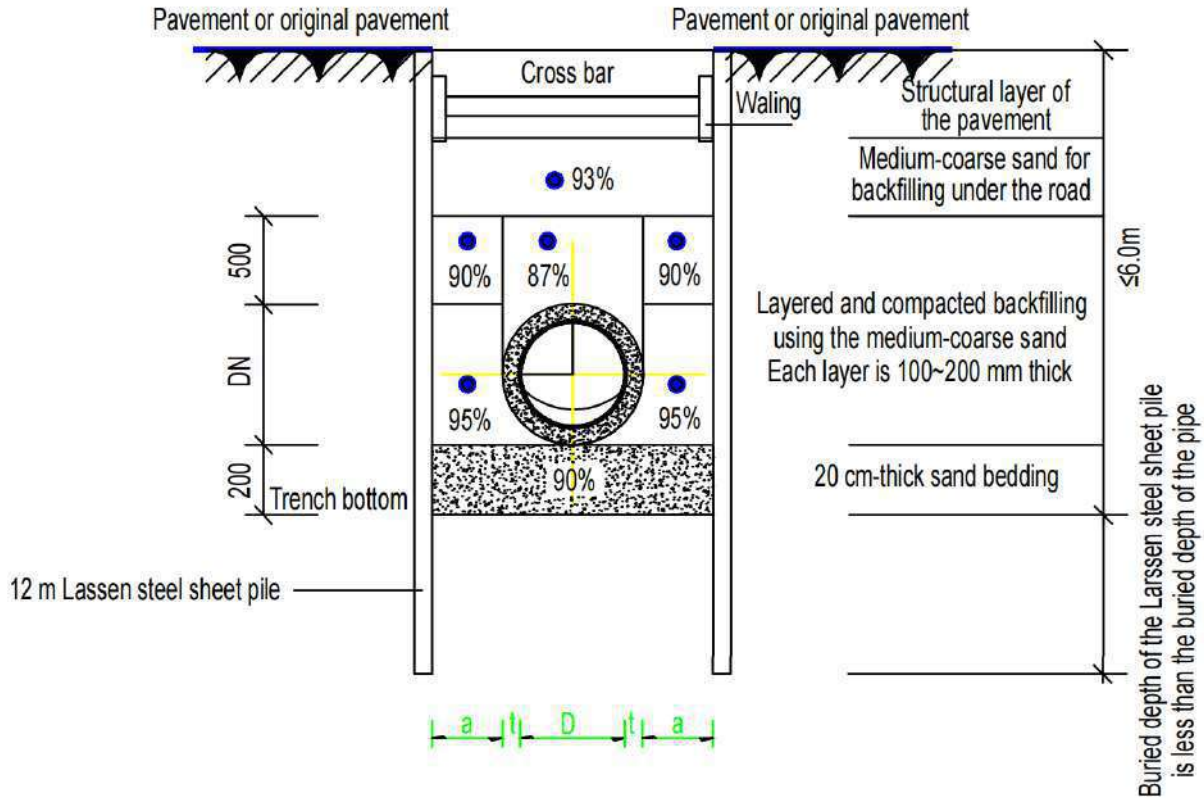


Figure 6. 15. Cross Section of Pipe Excavation (2)

(7) Stormwater structures

Inspection well: When the pipe diameter of the downstream pipe is d ≤ 600 mm, a Φ1000 mm circular stormwater inspection well is used. When the pipe diameter of the downstream pipe is d > 700 mm, the inspection well can be circular or square. The passage is 1000 mm long, with a width equal to the maximum diameter of the pipe. When the diameter of the drainage pipe is 700-1,400 mm, the height of its working part is to be equal to the maximum diameter of the pipe. When the diameter of the transmission pipe is ≥ 1,500 mm, it is not necessary to specify the height of its working part. For an inspection well that connects to the transmission pipe (when the diameter of the transmission pipe is ≤ 900 mm), the width of the cleaning platform is to be half of the maximum diameter of the pipe.

A flow trough is to be set at the bottom of the inspection well.

Stormwater inlet: The stormwater inlet can be a horizontal grid stormwater inlet (for an asphalt/concrete pavement) or a vertical grid stormwater inlet (for a low-lying areas or curb edge) or both, depending on the road form. The grid is made of ductile iron (bearing capacity ≥ D400).

6.4. DESIGN OF SPONGE FACILITIES

6.4.1. Concept overview of a sponge city

Urban flooding has received increasing attention in recent years and the pollution and

hazard of initial stormwater is being taken seriously. The thinking of "emphasizing ground facilities over underground facilities and development over protection" is gradually changing. The various drawbacks of the conventional stormwater infrastructure have been exposed:

(1) Waterlogging in old urban areas;

(2) Poor quality of the water environment due to severe urban diffused pollution;

(3) Failure of conventional development models to effectively respond to floods.

To solve the disadvantages with conventional stormwater systems, China proposed to "building sponge cities that enable natural storage, natural infiltration, and natural purification", with the goals of "keeping the shoes dry when it rains slightly, preventing waterlogging when it rains heavily, protecting water bodies against blackening and foul-smelling, and alleviating the effect of a heat island" by giving full play to sponge functions.

The concept of a sponge city reflects a systematic engineering that includes the low impact development stormwater system (the source), urban stormwater pipe and channel system (the process), and excess stormwater drainage system (the terminal). This concept is mainly manifested in "infiltration, retention, impounding, purification, recycling, and drainage".

(1) Infiltration: By simulating natural stormwater infiltration, the infiltrating stormwater is used to make up the groundwater, to conserve water sources; on the other hand, the infiltration of stormwater can lower the runoff coefficient, reduce the volume of surface runoffs, and delay the occurrence of waterlogging.

(2) Retention: Sunken green measures, such as rain gardens and bioswales, are taken to retain surface runoffs, with the stormwater scattered at the source to reduce the pressure on the downstream pipe network systems and river-lake water systems.

(3) Impounding: Gray artificial measures (such as storage and regulation tanks) and green natural measures (natural water systems) are implemented to collect and store stormwater, to reduce the pressure on the downstream systems using water storage spaces to store and regulate water on the one hand, and recycling stored stormwater on the other hand;

(4) Purification: The measures include constructing sewage treatment facilities and pipe networks, renovating river courses, building along-the-bank ecological low-gradient slopes, carrying out bay dredging, and purifying urban water resources.

(5) Recycling: Sewage recycling facilities are constructed to replenish the groundwater with infiltrating stormwater;

(6) Drainage: Excess stormwater drainage systems are installed to properly and efficiently drain the excess stormwater that cannot be drained at the source, to prevent waterlogging.

6.4.2. Objectives of sponge city construction

(1) Total annual runoff control rate

The designed roads are expressways. The following targets for total annual runoff control are set for roads of different classes:

Table 6. 7. Targets for Total Annual Runoff Control of Roads

Road class	Width of the side greenbelt	Total annual runoff control rate %	
		Newly constructed	Renovated (expanded)
Branch	No greenbelt	-	-
	< 2 m	-	-
	≥ 2 m	≥ 60	≥ 55
Secondary trunk road	< 2 m	-	-
	≥ 2 m	≥ 55	≥ 50
Trunk road	< 2 m	-	-
	≥ 2 m	≥ 60	≥ 55
Expressway	≥ 2 m	≥ 65	≥ 60

(2) Annual runoff pollution control rate

According to China's Technical Guide for Sponge City Construction, among the urban runoff pollutants, SS is often correlated to other pollutant indicators. Generally, SS can be used as the annual runoff pollution control indicator.

(3) Design standards

Comprehensive control measures (engineering and non-engineering measures) are adopted to ensure that the project area can effectively respond to once-in-50-year storms at a minimum. That is, when a once-in-50-year storm or a more minor storm occurs:

① Urban trunk roads and above remain open to traffic, i.e. the waterlogging on the roadway does not exceed 15 cm.

② On other roads, the waterlogging does not exceed 25 cm. The scope of waterlogging is restricted to one block and the duration of waterlogging does not exceed 2 hours.

③ The exit and entrance roads to sensitive facilities, including schools and hospitals, as well as important and critical areas, remain open to traffic, i.e. the waterlogging on the roadway does not exceed 15 cm. No waterlogging occurs at the exit from and entrance to any main building.

④ The ground floors of residential buildings and industrial and commercial buildings remain free of water ingress. The excess stormwater will not threaten the life and property safety of the public.

Comprehensive control measures are to be taken against storms beyond the return period for waterlogging design. Measures are to be taken to ensure that the exit and entrance of underground spaces, including subway stations, large sunken squares (malls and the like), underground parking lots, and underground pedestrian passages, are elevated from the standard waterlogging level on the periphery.

6.4.3. Construction of a sponge city system

A complete sponge city system includes the low-impact development (LID) system, urban drainage system, and flood control and waterlogging drainage system. The small sponge system is designed for light rainfalls, incorporating measures for infiltration, retention, impounding, purification, recycling, and drainage to control 70% of the total annual runoff (corresponding to a precipitation of 26.8 mm). The medium sponge system, i.e. the urban drainage system, is constructed for a once-in-5-year return period. By creating the low-impact development system, the medium drainage system can handle rainfalls more effectively with the same pipe diameter. The extensive sponge system is designed for extreme storms, comprising a primary drainage system that includes the surrounding river, drainage sluices, and pumps, as well as a secondary drainage system located outside the surrounding river, designed to handle once-in-50-year rainfalls.

In sum, by constructing the small, medium, and large sponge systems, the project can work efficiently, regardless of light rainfalls or extreme storms.

Refer to the "stormwater engineering" section for the urban drainage system and flood control and drainage system. This section mainly analyses the construction of the small sponge.

6.4.4. Feasibility analysis

The feasibility analysis of the project's sponge is carried out from six perspectives: "infiltration, retention, impounding, purification, recycling, and drainage".

Infiltration: In municipal road projects, stormwater is usually stored and absorbed by sunken side medians and laid with water-permeable materials on sidewalks and non-motorways.

As a result, "infiltration" is significant in a road sponge project. According to relevant geological survey data, stormwater infiltration can be carried out in most areas with the undisturbed soil layer or after simple replacement of the bed. In local areas, the groundwater level is high. When the groundwater depth is less than 1 m, caution is to be exercised when installing stormwater infiltration facilities.

Retention: For a 43 m wide road, the greenbelt on one side is 3.5 m wide. The green space is broad enough to carry out biological retention measures, which retain, store, and absorb the stormwater.

Impounding, purification, recycling, and drainage: Ulaanbaatar suffers from a shortage of water resources, and its water supply depends on external sources. The stormwater is a relatively clean, fresh water source. Its impounding, purification, and recycling is especially essential in this region. In this area, the stormwater can be purified and reduced through the low-impact development facility and then drained via the stormwater pipe network system to peripheral storage tanks for impounding and recycling. The excess stormwater is drained to

rivers.

6.4.5. Design ideas

A conventional stormwater collection and drainage system is usually a "quick drainage" system based on the following process: pavement stormwater → stormwater inlet → stormwater inlet connecting pipe → inspection well → municipal pipe network. This design is based on the concept of a sponge city to transform the conventional stormwater collection and drainage system, delay the entry of stormwater into the pipe network, and purify the initial stormwater to some extent.

The continuous greenbelt (side median) is designed as a sunken green space to collect the stormwater from the motorway, sidewalk, and non-motorway pavements, aiming to meet the total annual runoff control rate. The non-motorway and sidewalk are paved with permeable materials and sloped towards the continuous greenbelt. The ground runoff enters the greenbelt while the excess stormwater flows into the stormwater pipe through overflow stormwater inlets.

The scope of this design does not include the greening of road setback. The following sponge measures are taken:

(1) The sidewalk is paved with permeable material and the non-motorway is paved with permeable cement concrete.

(2) The greenbelt is sunken to store and absorb runoffs from the motorway, sidewalk, and non-motorway.

(3) Environment-friendly stormwater inlets are installed for motorways at crossings and bus stops and in areas where runoffs are severely polluted.

(4) Ecological tree pits are used.

(5) Permeable bricks are paved with the datum point and face set according to the floor plan, engineering scale, and the specification, shape, and size of the permeable brick.

(6) Permeable bricks are paved starting from the datum point, according to the design Figure and taking the baseline of the permeable brick as reference. When laying the permeable brick pavement, reference lines shall be stretched horizontally and vertically, with a datum point set at every 3 m - 5 m.

(7) When paving permeable bricks, the worker is not allowed to stand on the levelling layer, mix mortar or stack materials on paved brick surfaces.

(8) When paving permeable bricks, firmness and levelness are checked at any time, and the surface is finished in time. It is not allowed to level the brick surface by filling mortar or raising up the brick bottom. Permeable bricks are cut using a cutter.

(9) The joint width of permeable bricks is not to exceed 5 mm on the outside of the curve and is not to be less than 2 mm on the inside. The joint width of permeable bricks on a vertical

curve is 2 mm - 5 mm.

(10) 10 × 20 cm flush curb edging is paved on the edge of the sidewalk.

(11) After permeable bricks are paved, the surface is knocked till it is compacted. The impurities and debris are timely removed from the brick surface. It is not allowed to leave cement mortar on the surface. After the surface course is paved, vehicles are not allowed to enter the construction area until the required strength is reached.

(12) After the handover for use, the permeable brick pavement is to be regularly maintained (preferably 2 times per 1 year) to ensure a normal permeation function.

(13) If the permeation function of the permeable brick pavement is degraded, the pavement can be restored by flushing the brick surface with pressurised water flows or cleaning the permeable brick surface with the vacuum absorption method.

(14) Permeable bricks are to be of uniform specifications, types, and colours according to the design, and free of cracks, missing edges, missing corners, or local discolouring by pollution. Joints are flat, straight, and uniform. The texture is to continue smoothly in all directions (up, down, left, and right). Permeable bricks are dark grey, and tactile bricks are dark green (with an RGB value of (R63G93B73) for dark green).

6.4.6. Permeable paving

In the project, all sidewalks are paved with permeable bricks. The pavement structure is as follows, from top to bottom:

6 cm sidewalk permeable brick (20 cm × 10 cm × 6 cm)

3 cm 1:3 cement mortar

15 cm graded crushed stone

Total thickness 24 cm

The roadbed plain soil is compacted, with a minimum compactness of 92% (the criterion for heavy compaction).

Technical requirements for sidewalk permeable bricks:

Permeable bricks have a dimension of 20 cm × 10 cm × 6 cm (side length × side length × thickness). Their physical properties are to meet the requirements in the following table:

Table 6. 8. Dimensions and Properties of Permeable Bricks

Item	Requirements
Compressive resistance	The average compressive strength is not less than 40 MPa, and the minimum value of a single brick is not less than 35 MPa
Flexural resistance	The average flexural strength is not less than 4 MPa, and the minimum value of a single brick is not less than 3.2 MPa
Wear resistance	The wear resistance length is not greater than 35 mm

Water retention	Not less than 0.6 g/cm^2
Permeability coefficient	The permeability coefficient at 15°C is ≥ 2.0 × 10^{-2} cm/s

6.4.7. Sunken green space

The greenbelts on both sides of the roadway of the road are designed as sunken green spaces. The water inlets are 5 cm lower than the edge of the designed motorways. The surface courses of greenbelts are not more than 15 cm distant from the edge of the motorways. The stormwater in the roadway is caught into the sunken green space through the curb opening set at intervals. An overflow stormwater inlet is installed at the end of each drainage unit to drain the stormwater that cannot immediately infiltrate into the municipal stormwater pipe system. In the sunken green space, the bottom elevation of the base of the overflow stormwater inlet does not exceed the pavement of the neighboring motorway.

After entering the sunken space, the stormwater runoff is retained in the sunken green space, filtered and intercepted by the vegetation, and infiltrates under the ground, etc. In this process, the surface runoff slows down, the runoff volume is reduced, and the peak flow is regulated and impounded, with the amount of stormwater infiltration into soil increased and the stormwater purified. The green space are grown with plants that are highly adaptable, fast-growing, have large biomass, and are both moisture-loving and flood-tolerant.

6.4.8. Environment-friendly stormwater inlet

In this design, environment-friendly stormwater inlets are installed for motorways at crossings and bus stops and in areas where runoffs are severely polluted.

6.4.9.Overall scheme for a sponge city in this design

A conventional stormwater collection and drainage system is usually a "quick drainage" system with the following process: pavement stormwater → stormwater inlet → stormwater inlet connecting pipe → municipal stormwater inspection well → municipal pipe network. This design is based on the concept of a sponge city to transform the conventional stormwater collection and drainage system, delay the entry of stormwater into the pipe network, and purify the stormwater to some extent.

Based on the climate, soil, land use, and catchment conditions of the project area, the following design scheme is proposed for a sponge city in this design:

The side greenbelts are designed as sunken green spaces to collect the stormwater from the motorways, aiming to meet the total annual runoff control rates for the motorway and the side greenbelt. Both the non-motorways and sidewalks are paved with permeable material and sloped towards the continuous greenbelts. The design for permeable paving meets the total

annual runoff rates for the non-motorway and the sidewalk. The excess stormwater will flow into the stormwater pipe through overflow stormwater inlets.

The stormwater drainage system follows the process below: stormwater from the motorway → curb opening water inlet system → side median sunken greenbelt → permeable hose → overflow stormwater inlet → stormwater inlet connecting pipe → municipal stormwater trunk pipe; stormwater from the auxiliary lane, non-motorway, and sidewalk → side median sunken greenbelt → permeable hose → overflow stormwater inlet → stormwater inlet connecting pipe → municipal stormwater trunk pipe.

The integrated stormwater utilization measures will not change the standards for stormwater pipe systems in conventional designs. Ordinary double-grid stormwater inlets are installed in low-lying areas of the road and at crossings to prevent potential waterlogging.

6.4.10. Stormwater integration cross section design

(1) 60 m road: 60 m = 3 m (sidewalk) + 1.5 (tree pit) + 2.5 m (non-motorway) + 4.5 m (auxiliary lane) + 5 m (sunken greenbelt) + 12.25 (motorway) + 2.5 m (median strip) + 12.25 (motorway) + 5 m (sunken greenbelt) + 4.5 m (auxiliary lane) + 2.5 m (non-motorway) + 1.5 (tree pit) + 3 m (sidewalk). In this design, all overflow stormwater inlets are located in the side medians. See the following Figure for details:

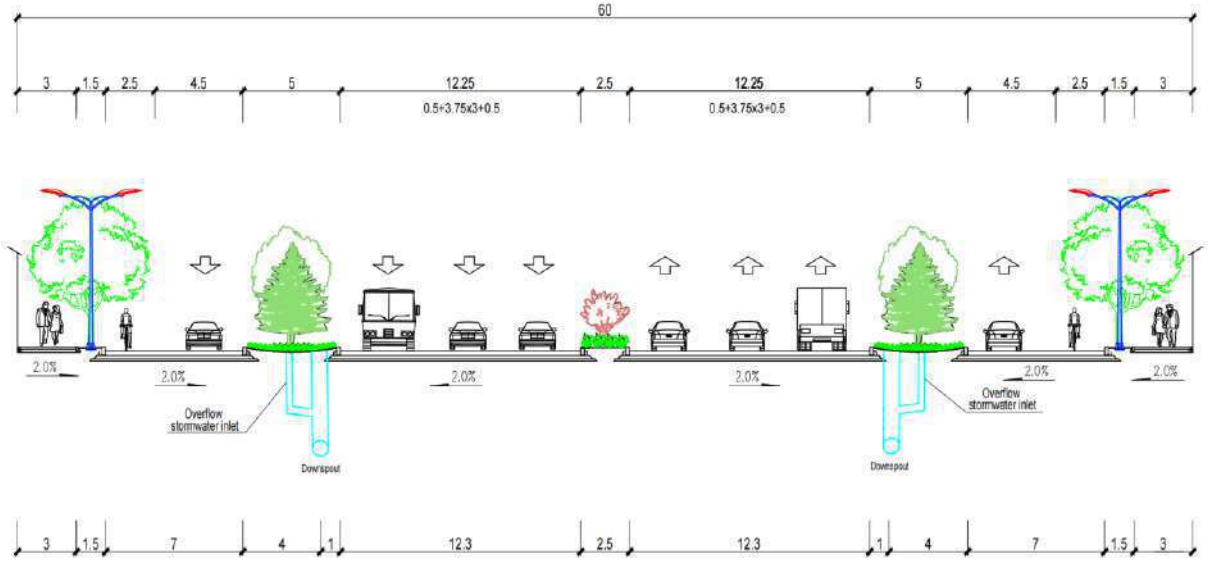


Figure 6. 16. Standard Cross-Section Design of Sponge Facilities of a 60 m Road

(2) 45 m road: 45 m = 3.5 m (sidewalk) + 2.5 m (non-motorway) + 5 m (sunken greenbelt) + 8 m (ground auxiliary lane) + 8 m (median strip) + 8 m (ground auxiliary lane) + 5.0 m (sunken greenbelt) + 2.5 m (non-motorway) + 3.5 m (sidewalk). In this design, all overflow stormwater inlets are located in the side medians. See the following Figure for details:

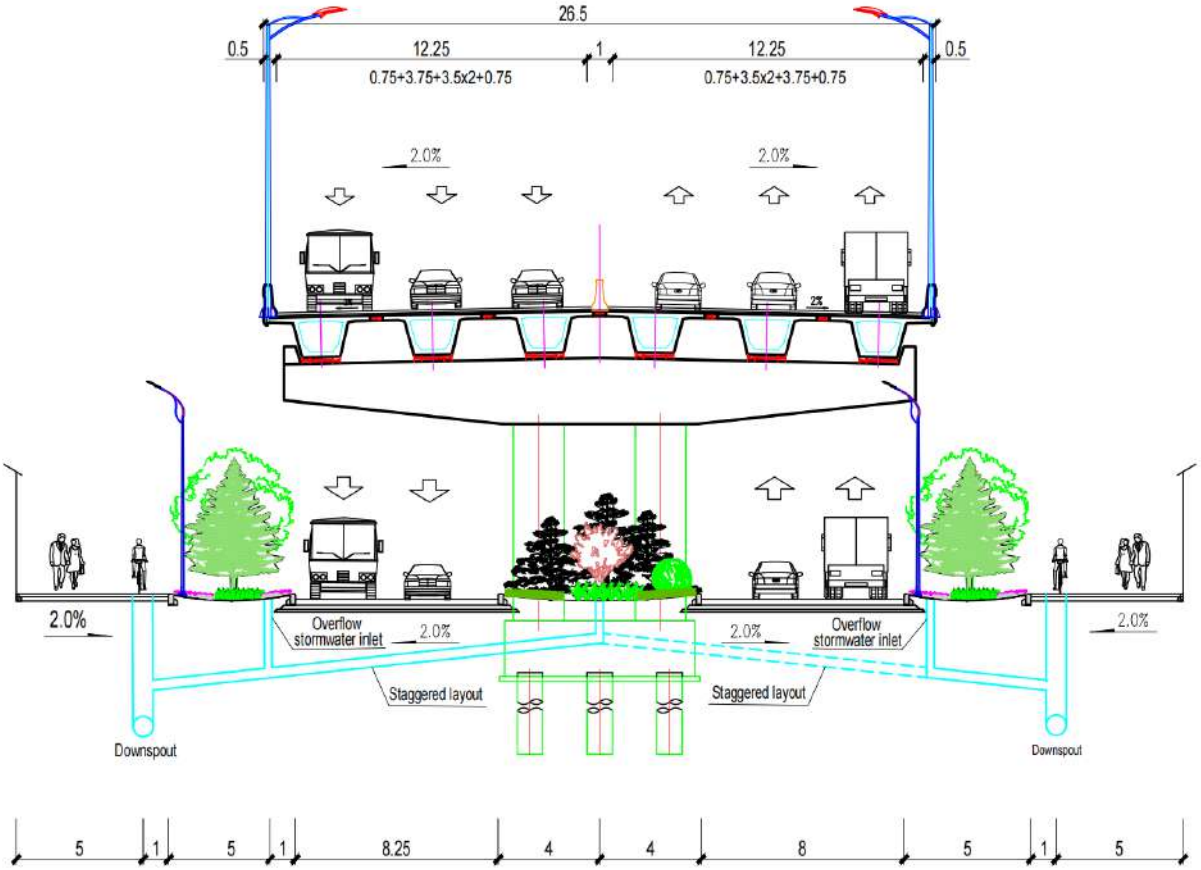


FIGURE 6. 17. STANDARD CROSS-SECTION DESIGN OF SPONGE FACILITIES OF A 45 M ROAD

6.5. HEATING ENGINEERING

6.5.1. Design basis

The relocation and reinforcement of the heating pipe network and facilities on both sides of the designed New Ring Road and along the route are calculated and developed according to the following documents:

(1) Resolution of the Mongolian Law on Urban Development "On Approving Mongolia's Long-Term Development Document: Vision 2050" (2020 No. 52)

(2) Law on the Use of Urban Water Supply and Sewage Treatment Systems

(3) 2020 Overall Development Planning and 2030 Vision of Ulaanbaatar, 2013

(4) Overall Plan Concept of Urban Development of Ulaanbaatar (until 2040, 2021)

(5) Rules on the Formulation, Approval and Evaluation of Architectural Design, Resolution No. 204 of the Government of the Republic of Mongolia in 2009

(6) Urban and Rural Planning and Construction 30-01-04

(7) External Water Supply Networks and Facilities BNbD 40-02-16

(8) External Sewage Treatment Networks and Structures BNbD 40-01-14

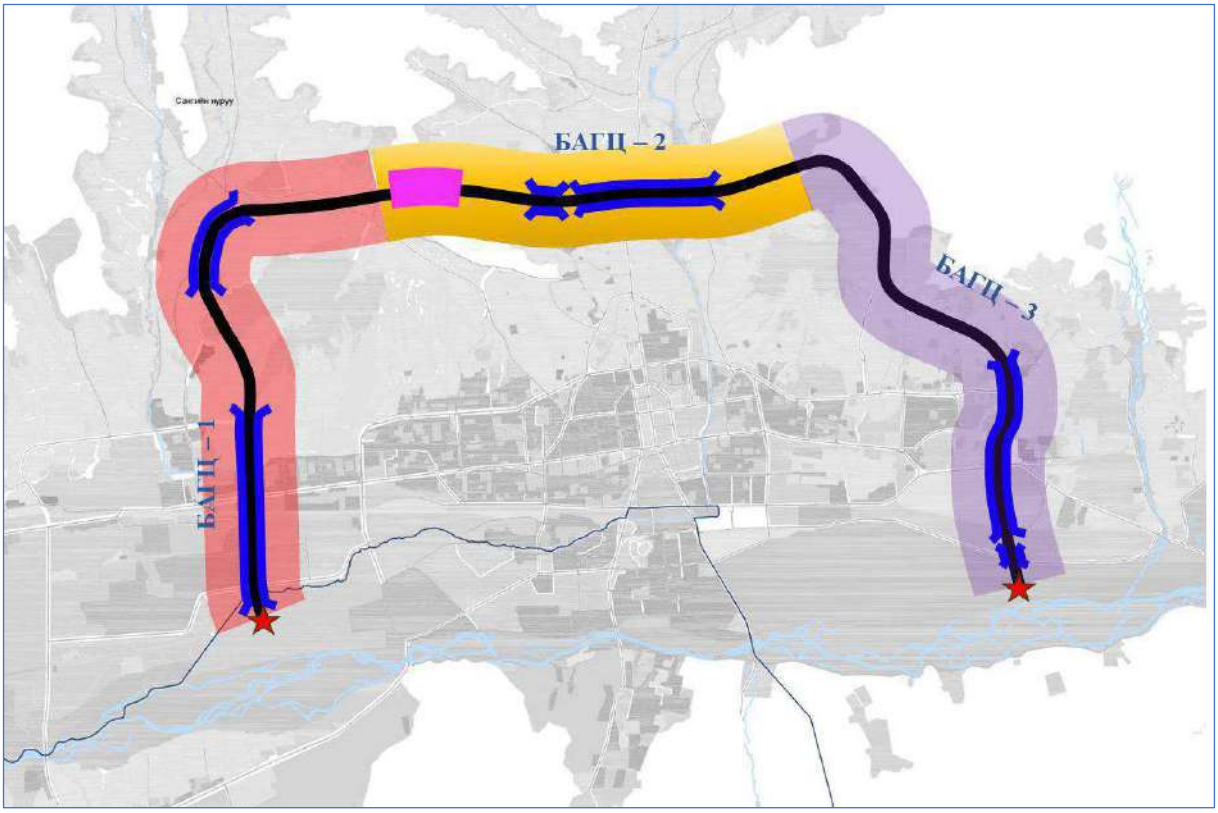
6.5.2. Design of the heating pipe network system

6.5.2.1 Design scope

According to the plan, the New Ring Road will pass Khan-Uul District, Zones 3 and 4, Bayangol District, Zones 20 and 29, Songino Khairkhan District, zones 6, 7, 8, 9, 10, 16, 23, 28, 30, 39 and 40, Chingeltei District, zones 15, 16, 18 and 22, Sükhbaatar District, zones 14 and 16, and Bayanzürkh District, zones 2, 5, 13, 21, 26, 27, 29, 31, 32 and 36. The project totally covers 6 districts including 31 zones of Ulaanbaatar. It is estimated that the road axes are 150 m in two ways, totally 300 m. The route covers an area of 8.4 hectares along the full length. The heating pipe network planning solution will specify the preliminary plans for the movement, relocation, and reinforcement of the pipes and structures included for the planned road route.

6.5.2.2 New plan for reinforcing and relocating the regional heating pipe network

According to the implementation plan, the planned New Ring Road is divided into 3 sections. In the feasibility study, the plan for the heating pipe network also includes 3 packages.



Section 1: From the road to TTP-4 to the planned tunnel start point - 8.6 km of road

Section 2: From the tunnel start point to Bayanzürkh District, Zone 21 - 6.2 km of road

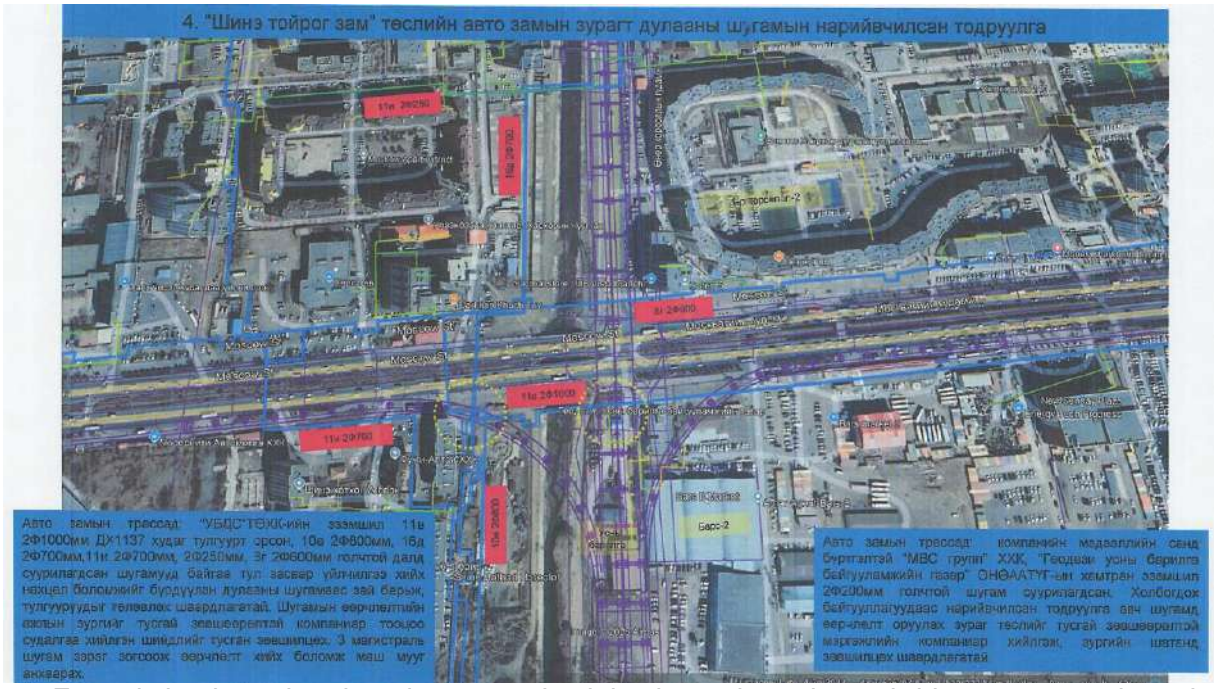
Section 3: From Khoroo Crossing of BZD-21 Street to Dunjingarav Crossing

Exposed pipes with diameters of 2Φ800 and 2Φ1,000, respectively, are laid at the start point of No. 2 planned route of the New Ring Road and the crossing with Road No. 4 of the Thermal Power Plant to supply heat to the 10b trunk line. The road section of the pipe network is designed as a bridge structure. In the construction phase, the exposed pipe network needs protection and installation.

Table 6. 9. Heating Pipelines under Highway Bridges of Section 1

District Heating Line Information						
Lot Number	**Line name:**	**Pipe diameter**	**Length, m**	**Material, lifespan**	**Condition of use**	**Proposed planning solution**
Lot-1	11K Main Line	2x250мм	2x60	Steel pipe	In use	Reinforcement in coordination with the roadwork design drawings
	11K Main Line	2x500мм	2x50	Steel pipe	In use	Reinforcement in coordination with the roadwork design drawings
	11K Main Line	2x400мм	2x170	Steel pipe	In use	Reinforcement in coordination with the roadwork design drawings
	ОСНААУГ-ын ХҮТ-16-ийн шугам	2x250мм	2x110	Steel pipe	in use	Reinforcement in coordination with the roadwork design drawings

Depending on designs of the road and bridge structure, it is planned to relocate and reinforce totally 4 heating pipelines along and crossing plot No. 1. The heating pipelines are totally 800 m long. In addition, it is recommended to relocate the heating pipelines into chennels.



For existing large heating pipe networks, it is planned to adopt a bridge structure along the planned expressway route according to the "UBDS" TJSC specifications. It is also intended to reserve the existing heating pipelines to ensure their safe operation during expressway construction.

Based on the road design, "UBDS" (a utility company) and "OSNAAUG" (a utility and construction company) need to provide additional explanations to formulate the Figures for reinforcing and relocating the heating pipes.

For section 2, as most sections are located in the Mongolian yurt area, there are no centralised heating pipe networks.

Table 6. 10. List of Heating Pipelines within the Road of Section 3

Data of Heat Supply Pipelines						
Lot number	**Pipeline name**	**Pipe diameter**	**Length, m**	**Material and service life**	**Operational condition**	**Planning proposal / Design recommendation**
Lot-3	ОСНААУГ-ын ХҮТ-17-ийн шугам	2x150мм	2x75	Steel pipe	In use	To be relocated according to the road construction design plan
	ОСНААУГ-ын ХҮТ-18-ийн шугам /5 шугам бүхий суваг/	2x150мм	2x50	Steel pipe	In use	To be relocated according to the road construction design plan
	ОСНААУГ-ын ХҮТ-17, хувийн хэрэглэгчдын хамтран эзэмшлийн шугам	2x400мм	2x80	Steel pipe	In use	To be relocated according to the road construction design plan
	ОСНААУГ-ын ХҮТ-17, хувийн хэрэглэгчдын хамтран эзэмшлийн шугам	2x80мм	2x80	Steel pipe	In use	To be relocated according to the road construction design plan
	Нутгийн буян болон бусад хэрэглэгчдын хамтран эзэсшлийн шугам	2x500мм	2x150	Steel pipe	In use	To be relocated according to the road construction design plan

Depending on the designs of the road and bridge structure, the heating pipelines of a total of 5 sites along section 3 will be relocated and reinforced. The heating pipelines are a total of 800 m long. In addition, it is recommended to migrate the heating pipelines to underground trenches.

For existing large heating pipe networks, it is planned to adopt a bridge structure along the planned expressway route according to the "UBDS" TJSC specifications. It is also intended to reserve the existing heating pipelines to ensure their safe operation during the highway construction.

Based on the road design, "UBDS" (a utility company) and "OSNAAUG" (a utility and construction company) need to provide additional explanations to formulate Figures for reinforcing and relocating the heating pipelines.

According to the overall planning and taking into account the existing road network layout, geological location, natural factors, socio-economic factors, and urban conditions, the planning for heating pipe networks will be optimised to ensure that the heating systems are safe and dependable, embodying the new concepts of modernization, advancement, environmental protection, and energy conservation. Meanwhile, the existing heating facilities will be utilized to the maximum extent to save the investment and reduce the engineering cost.

6.5.3. Heating planning

6.5.3.1 Planning for the centralized heating system

(1) Planning for heat sources

The population of Ulaanbaatar City will reach 538,000 households by 2040, among which, 342,700 households (63.7%) will have the access to the centralized heating system. By 2040, the centralized heating system will provide heating services to totally 44,312,048 m^2 of social infrastructure, industrial and technological parks, public buildings, and residential buildings.

By 2040, the centralized heating system of Ulaanbaatar City will connect totally 5,521.85 Gcal/h of building heat loads. The 4 heat sources of the centralized heating system will be expanded to meet the demand for urban heating. Following the international development trend, the fuels used for the heat sources above will be changed to gas fuels. This program will be implemented in phases. By 2040, centralized heating will be entirely supplied by the heat sources of gas fuels, accounting for 20% of the total heating supply (as shown below). The heat sources of the currently operating DCS-2 and DCS-3 have aged and cannot ensure reliable operation. When upgrading these boilers, it is required to upgrade the heat sources with fuels including gas fuels and improved fuels that have less impact on the environment.

The following measures will be implemented to meet the growing heat demand of the urban centralized heating system. According to the objectives and tasks set in the National Energy Policy, a 15% reserve of thermal capacity is to be maintained. To bridge the gap between the thermal capacity required by 2040 and the current thermal capacity, measures are to be implemented, including increasing the heating capacity of heat sources and optimizing the heating system for energy conservation.

By conducting insulation for existing buildings that do not meet the thermal requirements, 292 Gcal/h of heat energy can be saved.

By implementing measures such as billing based on heat consumption, 310 Gcal/h of energy can be saved. The energy consumption of new buildings will be gradually reduced by 20-30%. The relevant specifications will be modified.

It is planned to solve the problems of the hot water supply system of new and old buildings by combining solar water heaters with night power energy storage systems. With the implementation of this measure, a load demand of 147 Gcal/h will be satisfied.

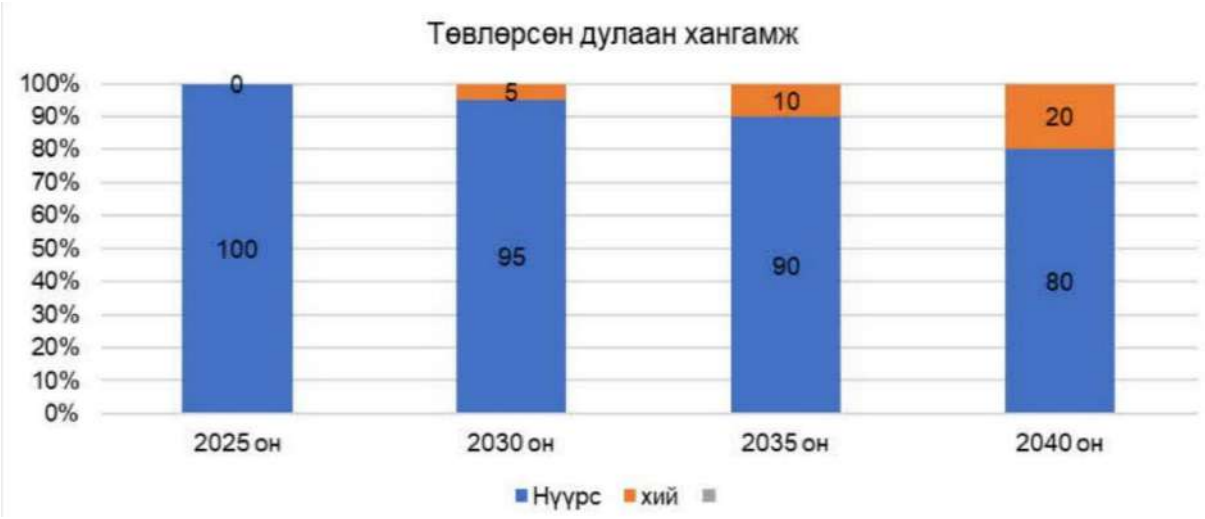


Figure 6. 18. Percentages of Centralized Primary Energy Fuels

(2) Planning for the heating pipe network

As of 2024, the centralized heating pipe network had a total length of 379 km, among which 27% (90.7 km) of the trunk heating pipes had been used for more than 30 years. Therefore, most of the urban heating pipe networks are under high risks and it is urgently needed to upgrade and expand these pipe networks. Among municipal heating pipes in Ulaanbaatar City, 71% are under the ground and the rest 29% are above the ground. Among the heating pipe networks in Ulaanbaatar City, the heating pipes used for 30 years or more are severely aged.

When connecting the lately developed residential areas of Ulaanbaatar City to the centralized heating system, it is needed to increase the transmission capacity of the trunk heating pipes and build new heating pipes to enlarge the scope of coverage of the heating network. By 2040, totally 241.4 km of pipes will be upgraded and expanded. The scope of coverage of the heating network will be enlarged by constructing 63 km of pipes.

6.5.3.2 Planning for the regional heating system

By 2040, the regional heating system will supply heat to 459,884 people from 146,928 households. By 2040, the total building heat load satisfied by regional heating will be 941.2 Gcal/h (1,095 MW.h).

The heat sources used in currently operating regional heating system will be substituted by boilers using gas fuels and improved fuels. In the new regional heating system, heating furnaces advantageous in a complete combustion process and low emissions of hazardous gases will be used as the heat source. In addition, resources such as coalbed methane, natural gas, and hydrogen will be utilized, in combination with incinerators, solar energy storage in renewable energy, ground-source heat pumps, etc. By 2040, 60% of the energy for the regional heating system will be fuel gas. 24% of the energy consumed in regional heating will come from improved fuels while 15% from renewable energy sources. Heating boilers have been connected

to the central fuel gas supply system. For boilers located far away from main fuel gas pipelines, fuel gas will be supplied by truck transportation, with fuel gas reserved and used in the fuel storage depot of a boiler building.

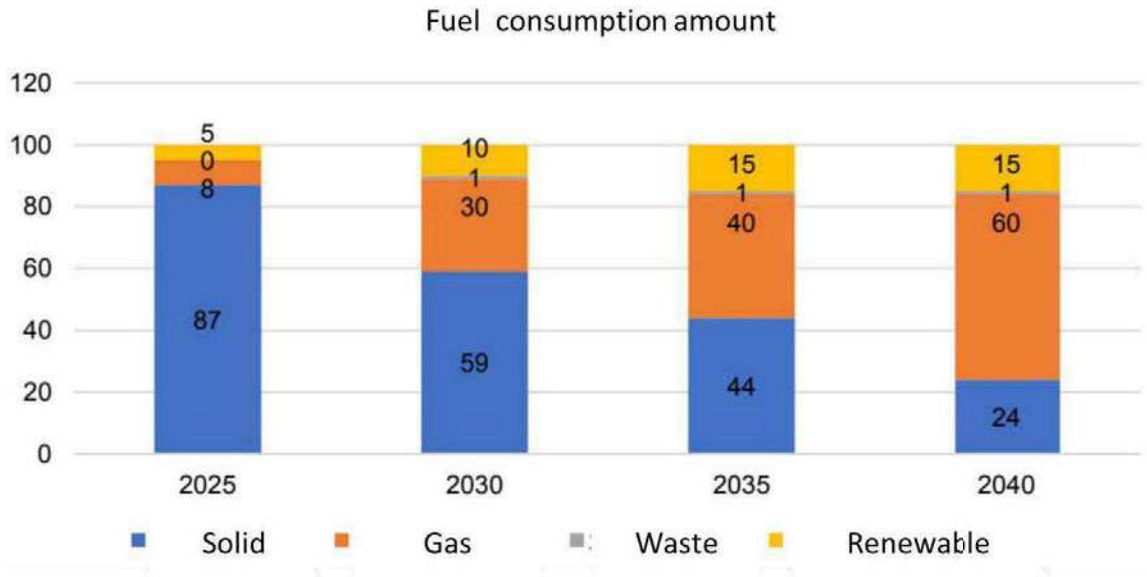


Figure 6. 19. Energy Supply for the Regional Heating System

The pipe networks of some existing heating systems will be upgraded and expanded to enlarge the scope of coverage. For some heating systems, the primary heating and hot water supply systems will remain normal operation in case of change of the heat source. In these systems, renewable energy heat sources such as the solar heat system and heat pump can be used easily. Therefore, a low temperature can be adopted or the water supply temperature in the secondary loop does not exceed 70°C. By 2040, some heating pipe networks with a diameter of 400-150 mm and length of 39 km will be constructed.

A centralized or regional heating system cannot be planned in highly undulated areas of Ulaanbaatar City. In these areas, current household heating will then rely on independent energy sources.

By 2040, 151,571 people from 48,425 households will have access to heating using independent heating energy sources. By 2040, the total heat load of a building containing an independent heating system will be 204 Gcal/h. By 2040, independent heating users will have the access to the integrated natural gas pipe network. Their demand for heating will be satisfied by fuel gas boilers. Depending on the size of a building, the heat pump, solar heat source, and heat storage unit installed in the building can provide energy for heating and a specific amount of domestic hot water. The capacity of the power supply system in residential areas will be increased. It is also planned to use electric furnaces, heat pumps, and other efficient heat sources to satisfy 43% of the heating demand of independent users.

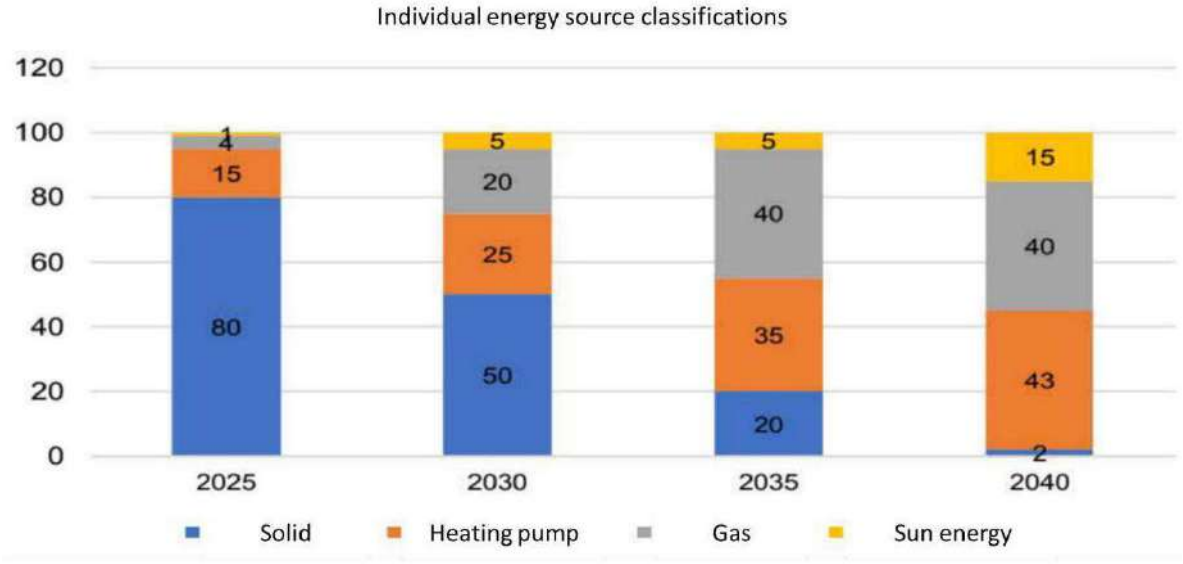


Figure 6. 20. Energy Supply for the Independent Heating System

Heating medium: Based on experience of previous projects and international cases, hot water should be used as the heating medium for urban heating networks supplying heat to civil buildings. Therefore, hot water will be used as the heating medium in the project.

When used as the heating medium, hot water has the following advantages:

High thermal efficiency, easy regulation, high capacity for heat storage, high thermal stability, and long transmission distance.

6.5.4. Laying method

The heating pipe network can be laid in three forms: overhead laying, laying in underground pipe trenches, and buried laying.

These laying methods have their unique advantages and disadvantages. The laying method for the heating network in the project will be selected based on the characteristics of the project, the specific requirements of the municipal planning authority, and according to technological and economic comparisons. The three methods for laying the heating network are briefly introduced below.

(1) Overhead laying

Overhead laying requires a shorter construction period. The insulating structure is simple, and the system is easy to maintain and manage. However, with overhead laying, the insulating performance is poor, and the envelope structures are vulnerable, leading to relatively high costs for year-round maintenance and management. The heat loss is also high. In addition, overhead lying on road sides will impair the urban beauty and is unfavourable for urban development and construction.

(2) Laying in underground pipe trenches

The pipe trench can effectively isolate soil pressure, ground loads, and rainwater erosion, protecting the insulation layer of the pipe from external forces that could cause extrusion or deformation, and also protects the pipe against seepage. Pipes laid in pipe trenches are protected from the sharp stones and corrosive materials in the soil, thus reducing the risks of mechanical damage and chemical corrosion. In a pipe trench, spaces are reserved to allow the pipe to move freely in case of thermal expansion and contraction, avoiding the concentration of stress due to soil friction and reducing the need for using compensators. In road sections where excavation is prohibited, including traffic arteries and densely populated urban areas, pipes laid in pipe trenches can be maintained much more efficiently than buried pipes. The heating pipe can be laid in the same trench as the water, electricity, and communication pipelines. With unified monitoring and maintenance, the underground space can be utilised more efficiently.

(3) Buried lying

Buried laying of pipes has a lower construction cost and faster construction speed. However, pipe maintenance can be difficult in areas, including road crossings.

Based on a comprehensive comparison, all heating pipes in this engineering design will be laid in pipe trenches.

6.5.5. Pipe material and thermal insulation

6.5.5.1 Selection of pipe material: In the project, pipes with a pipe diameter of DN ≥ 250 will use double-sided spiral submerged arc welded steel pipes, fabricated of coiled plates and Q235B carbon steel; pipes with a pipe diameter of DN < 250 will use seamless steel pipes, with a material grade of 20# steel. The deviation in wall thickness of steel pipe is 0-0.5 mm. For buried pipes, in addition to the internal pressure, it is also required to consider the effect of soil pressure, ground loads, pipe weight, internal pressure, the minimum wall thickness resisting temperature changes, the minimum wall thickness resisting local buckling, and pipe rigidity.

6.5.5.2 Selection of insulation material: In this project, PU is used as the insulation material for pipes. A prefabricated, sprayed, and wound insulated pipe consists of a medium-transmitting working steel pipe/piece, a PU-sprayed rigid polyurethane plastic foam insulation layer, and a wound-type PE outer casing pipe. The product structure is shown below.

6.5.5.3 Selection of outer casing pipe: In the project, high-density PE outer casing pipes are used for buried pipes. For overhead pipes, galvanised steel sheets are used for the outer casing pipes.

6.5.6. Installation method

The pipe network shall be installed and designed with economic feasibility, safety, reliability, and technological advancement. The entire system shall be analysed and calculated by the

stress classification method. A buried heating pipe may fail for two reasons: the strength and the stability. Regarding the stability of a large-diameter buried heating pipe, two instability modes are additionally considered: local instability and ovalization. For these modes, new strength conditions are established and satisfied. For straight pipe segments, shakedown analysis is carried out to prevent cyclic plastic failure and instability. For tees, bends, reducers, and angles in the pipe, the purpose is to avoid fatigue failure. For valves, it mainly aims to prevent damage to internal structural components due to excessive axial stress.

Cold installation can be considered when the results of the strength calculation are accepted. A compensator can be used to protect the bends, angles, large branching tees, and valves on the leading pipe network from fatigue failure.

6.6. WATER SUPPLY ENGINEERING

6.6.1. Design principles

(1) Satisfy users' demand for water volume and pressure.

(2) Carry out the design based on the approved Overall Urban Development Planning and Special Planning for Water Supply.

(3) Carry out the design from a global perspective. Take into account of both near-term and long-term water supply and focus on near-term development.

(4) When crossing rainwater and sewage pipes, water supply pipes shall be laid above these pipes.

(5) At least two water transmission trunk pipes are needed to form a loop for safe water supply.

6.6.2. Planning for water supply

(1) Planning for water supply

By 2040, 100% of Ulaanbaatar's population will have access to the centralised water supply system.

Ulaanbaatar has considered the demand of its residents for living and industrial water use for a planning period until 2040. It is estimated that each ordinary residential household will have a water consumption of 180 L, and each improved residential household will have a water consumption of 100 L. By 2040, the water consumption of Ulaanbaatar will double, reaching 526,100 m^3 per day.

Table 6. 11. Water Supply in Ulaanbaatar

User	Consumption m^3/d (2023)	Consumption m^3/d (2040)	Type of Water Source, Supply Volume m^3/d		
			Groundwater	Surface Water	Purified Water
Household water consumption	174,029.6	351,920.9	246,344.6	105,576.3	
Power plants	50,000.0	100,000			100,000
Office buildings		25,901.8		20,721.4	5,180.4
Factories in the food industry	10,680.4	29,224.1	26,301.7	2,922.4	
Factories in non-food industries	11,837.0	19,018.4	1,901.8		17,116.6
Total consumption	246,547.0	526,065.2	274,548.2	129,220.1	122,296.9
Percentage		100	52	25	23

According to the concept of the 2040 Overall Planning, water resources will be supplied from the following three sources:

Groundwater: 52%

Surface water: 25%

Purified water: 23%

By 2040, groundwater sources are estimated to satisfy 274,500 m^3/d (52%) of the total demand for water consumption. The existing 7 groundwater sources will be utilised, and the purified water from the lower right corner of the city will be used for drinking and the food industry. At present, it is no longer planned to include new wells in addition to the deep wells currently in operation. The water source and sanitation system will be strictly implemented. An intelligent water conservation system will be planned to improve the groundwater makeup zone and increase groundwater resilience.

By 2040, surface water sources are estimated to satisfy 129,200 m^3/d (25%) of the total demand for water consumption. To start utilising surface water in 2040, it is necessary to prepare, amend, and approve the project feasibility study by 2030, with the construction drawings designed at the same time.

By 2040, purified/recycled water sources are estimated to satisfy 122,300 m^3/d (23%) of the total demand for water consumption. It is planned to implement the wastewater recycling/purification/reuse systems in the medium term. First, these systems will first be applied to car washes, green facilities, roads, and squares. It is planned to recycle wastewater, grey water, and condensate from the cooling system of power plants and further set up centralised rainwater and grey water collection, purification, and recycling systems in large residential areas and at hotels. Within the scope of use of purified water, two water purification plants with a treatment capacity of 500,000 m^3/d each, four reservoirs with a total treatment capacity of 2,000 m^3/d, and 150 km of purified water pipes will be put into operation. With the non-refundable assistance of the Millennium Account and under the framework of the Wastewater Recycling Project implemented first, purified water will be used for technical applications of thermal power

plants from 2026. This includes the first large-scale plant with a wastewater treatment capacity of 50,000 m^3/d and a purified water pipe network in Mongolia and the use of reclaimed water in the energy sector.

(2) Protection of water resources

According to Order No. A/02/01, jointly issued by the Minister of Environment and Tourism and the Minister of Construction and Urban Development on January 3, 2018, the boundaries for water supply source, sanitation protection zones and makeup zones were determined. At present, it is urgently needed to implement these provisions for the sanitation restriction zones and banned zones of the seven water sources currently in use and water sources of thermal power plants and relocate the users who were not permitted to settle in these zones.

A total of 208 deep wells at 7 water source sites will be brought into unified management, where uniform monitoring systems will be set up. The activities above have been included in the 2020-2024 Work Plan of the Governor of the Capital City.

By 2020, it is necessary to relocate 3,698 units in the drinking water source protection zone in 2025 or in the near term. In addition, it is also essential to carry out greening in drinking water source areas. The total area of relocation and restoration is about 100 hectares. The seven water source sites currently in operation will be continuously monitored and inspected, with laboratory analysis conducted regularly to eradicate violations.

In the follow-up planning phase, surface water will be utilised in addition to deep water sources. In the Overall Development Planning until 2040, the environmental planning authority is formulating the Blue Infrastructure Plan. Based on updates in 2021, it is proposed to set up protection belts for 62 perennially flowing rivers and streams, 229 springs, 38 lakes, and 19 marshes, and include them in protection zones. In addition, to solve the issue of settlement of 2036 hectares of land in the constructed areas of Ulaanbaatar, construction activities will be restricted, and engineering preparation measures will be implemented.

As the use of surface water is expected to commence between 2035 and 2040, it is necessary to establish and utilise protection belts at Port No. 1 of the Tuul Water Complex and in a surrounding area of 10 km^2. Moreover, it is essential to prohibit the distribution or transfer of land ownership to household users in water receiving areas. Drainage pipes and monitoring wells will be built.

(3) Water supply pipe network

In Ulaanbaatar, there will be 13 new reservoirs with a total capacity of 45,500 m^3 put into operation;

The 4 reservoirs currently in operation will be expanded to 32,000 m^3.

164 km of purified water pipe network will be built;

The 50 km of pipe network that cannot meet the demand for use will be upgraded.

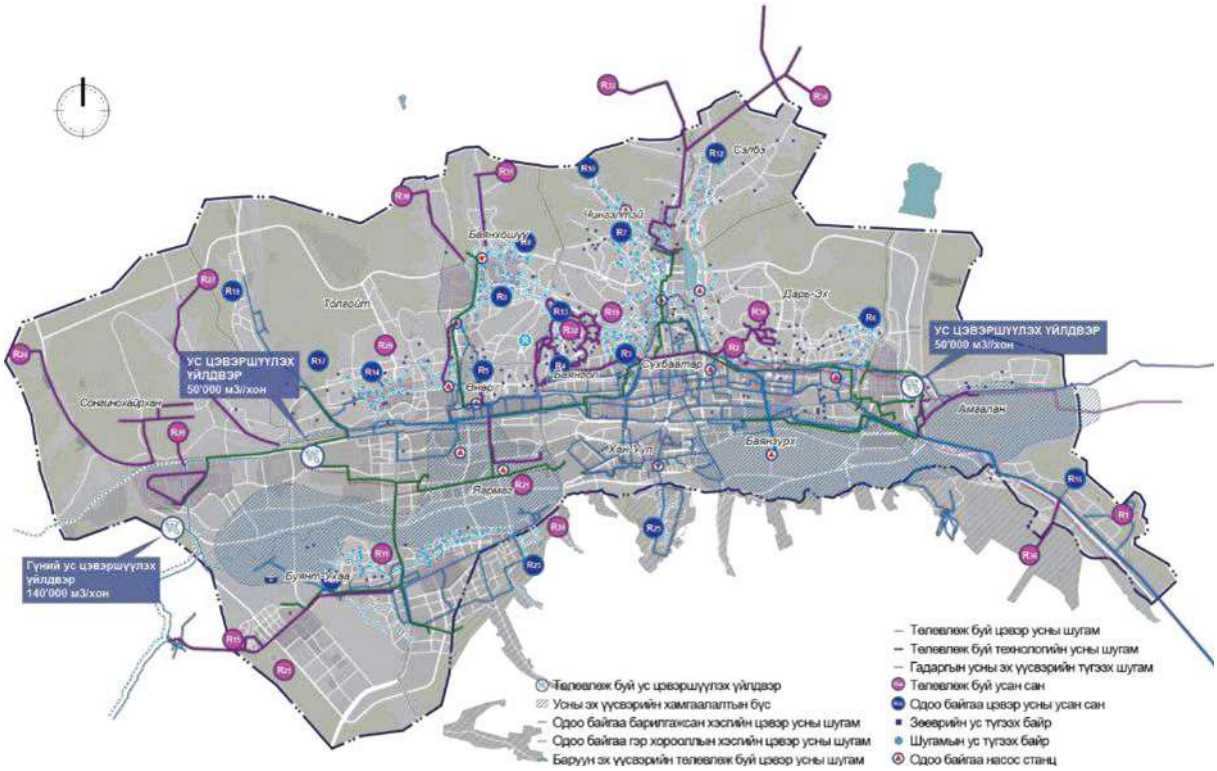


Figure 6. 21. Schematic Diagram of Water Supply System

6.6.3. Design of water supply pipe system

(1) Design standards

According to the WATER SUPPLY. EXTERNAL NETWORK AND FACILITIES (БНбД 40-02-16) and the Overall Plan of Ulaanbaatar until 2040, the new water supply pipeline will have a diameter of DN600 and a nominal pressure of 1.6 MPa. The relocated pipelines will be consistent with the existing ones. The 11 water intake wells along the road have all been relocated outside the boundary line of roads.

(2) Design scope

The design scope of water supply engineering is similar to that of the road discipline, including the relocation of the water supply pipelines along the full length of the new ring road and the DN600 water supply pipe in the start section (K0+380~K1+850).

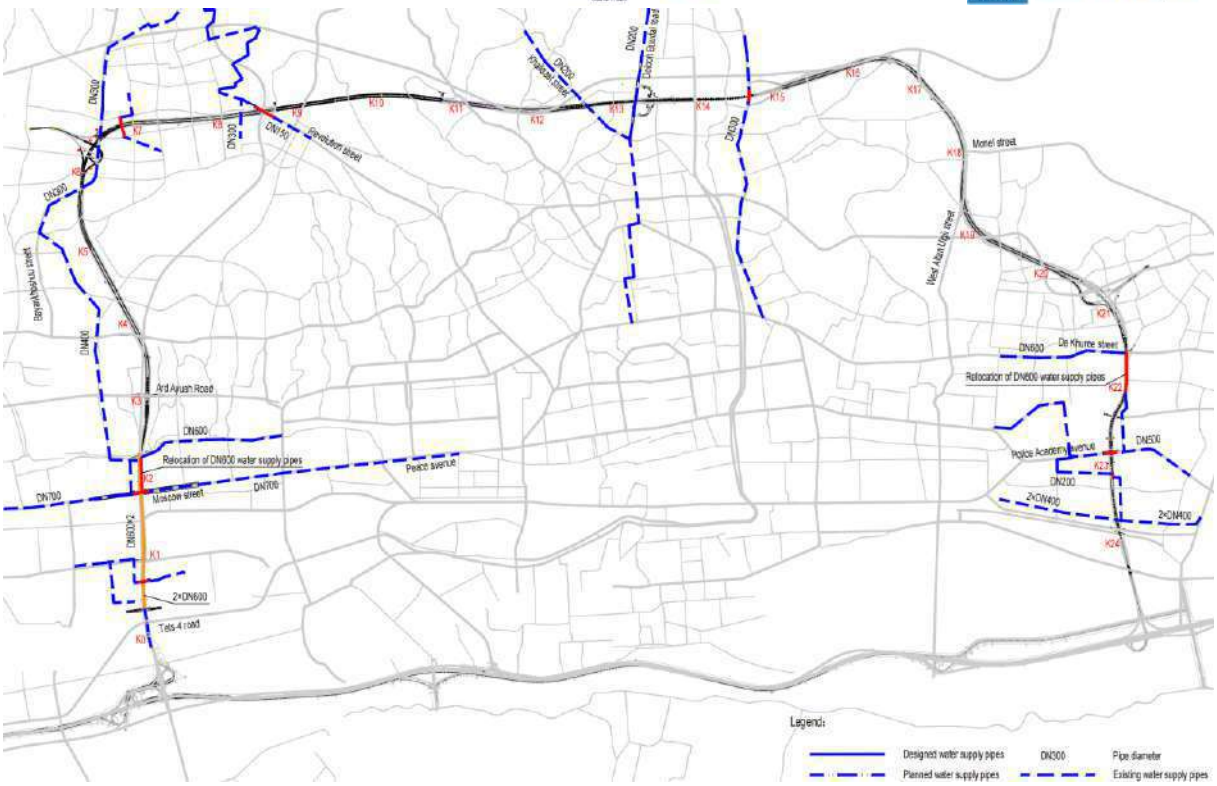


Figure 6. 22. Diagram of Water Supply System

(3) Design calculations

The flow rate of the pipe network is calculated as the economic flow rate to determine the pipe diameter. The water supply pressure shall satisfy the required water head for service at the user pipe access of the most unfavourable point for most of the areas. In residential building areas, the value of the free water head shall conform to the requirement in the Design Code for Building Water Supply and Drainage (БНбД40-06-16). In a single-floor building, the water head shall be at least 10 m above the ground level. In a multi-floor building, an additional water head of 4 m shall be designed for every additional floor. The free water head of the water distribution point in the pipe network and at the hydrant outlet of the centralised water supply point in a shantytown shall not be lower than 10 m.

① The water head of the pipe network is calculated according to the Hazen-Williams formula:

$$i=10.67q^{1.852}/C^{1.852}D^{4.87}$$

where,

Q: Segment discharge (m3/s)

D: Calculation pipe diameter (m)

C: Coefficient related to the pipe roughness coefficient

② Pipe diameter of pipe network

$$D = \sqrt{(\frac{4Q}{\pi V})}$$

where,

D: Transmission pipe diameter (m)

Q: Transmission pipe discharge (m^3/s)

V: Transmission pipe flowrate (m/s)

C. Water head loss of transmission pipe:

$$h = 1.1iL$$

where,

H: Water head loss of transmission pipe (m)

1.1: Local head loss, calculated as 10% of the frictional head

i: Frictional head loss coefficient per unit length (m/m)

L: Transmission pipe length (m)

When conducting hydraulic calculations of the maximum hourly water supply volume, 70% of the water supply volume is assured for an interrupted water supply during an accident and the maximum hourly water supply volume shall be checked and calculated by considering the fire water discharge. A low-pressure firefighting system is adopted in this area. According to the specifications, the number of fires during the same period is 3 times. The one-time fire-fighting water consumption in the urban area is 35 L/S. The one-time firefighting water consumption in the shantytown is 5 L/S.

(4) Water supply pipe material and foundation

① Principles for selection of pipe material

Pipe materials shall be selected based on the following principles: The pipe material shall withstand the designed internal pressure and external loads. The pipe material used shall ensure good sanitation conditions for water transmission, easy construction, reduced workload of maintenance, reliable performance, and a long service life. The inner wall of the pipe shall be smooth while the water transmission capacity remains the same. The engineering costs are relatively low and the pipes can adapt to local engineering geological conditions. Based on the factors above, the general considerations are as follows:

For pipes with a pipe diameter of ≤ DN200, the common trend is to use plastic pipes with lower prices, good anti-corrosion performance, and reliable use.

For pipes with a pipe diameter of DN300-DN1000, ductile iron pipes, steel pipes, and PE pipes are ideal choices, but their prices are relatively high. Prestressed reinforced concrete pipes are cheaper, which are rarely used in large and medium-sized cities now.

② Comparison of pipe materials

With the emergence of new materials, technologies, and processes, the materials of water supply pipes have been developed rapidly from several kinds to a dozen of kinds nowadays. For the moment, grey cast iron pipes, steel pipes, and ductile iron pipes are the representative types of pipes currently used in water transmission and distribution pipe systems. From the perspective of the application result, grey cast iron pipes are made of grey cast iron, which is less intense and tough and cannot bear high external loads. In addition, as these pipes are rigidly connected, incidents of pipe burst and leakage have frequently occurred in water supply pipe networks. Globally, grey cast iron pipes have been phased out in developed industrial countries since the 1960s, and ductile iron pipes have become a common choice. In applications, steel pipes offer advantages in easy installation and high strength, and both pipe materials and fittings are easy to machine. However, they have the shortcomings of low toughness, vulnerability to deformation and corrosion, and strict requirements for lining and external corrosion protection. In some cases, cathodic protection is also needed, leading to a relatively high construction cost. As a new type of pipe material, PE pipes have been gradually used in urban water supply systems, primarily for pipes with medium and small diameters.

A. Ductile iron pipe

Ductile iron pipes, also known as malleable iron pipes, are a new type of pipe material that has gradually developed in Western industrial countries since the 1950s. Before the casting of molten iron, magnesium or rare earth magnesium nodulizer is added to transform acicular graphite to nodular graphite. Ductile iron thus gets its name. Acicular graphite produces a cleavage effect on the iron matrix, making it brittle and easy to crack. Nodular graphite, however, can eliminate such a destructive effect and make the matrix rough. Therefore, regarding material properties, nodular graphite has the advantages of high strength, high elongation, and corrosion resistance. Its service life can be as long as 30-50 years. With the same diameter, the thickness of a nodular graphite pipe is just 1/2 that of a gray cast iron pipe.

B. FRP pipe

FRP pipes are fibreglass-reinforced thermosetting resin plastic pipes. It is a new type of pipe that emerged in the 1970s, categorised into centrifugally cast FRP pipes and filament-wound FRP pipes based on their manufacturing processes. Filament-wound FRP pipes are further divided into continuously wound pipes and reciprocally wound pipes. For the three pipe-making processes above, quartz sand can be added in the production process to increase the structural stiffness.

The wall of an FRP pipe usually comprises two parts:

Structural layer: composed of orthophthalic unsaturated polyester resin or modified orthophthalic unsaturated polyester resin.

Surface reinforcement layer: The inner and outer surfaces of the wall are composed of

alkali-free chopped glass fibre surface mat and corrosion-resistant and high-strength resin.

Depending on use conditions, different resins and filaments can be used to satisfy the required design structure of FRP pipes. However, the construction costs of pipes differ greatly.

FRP pipes are advantageous in terms of resistance to corrosion, light weight, easy transportation and installation, low friction efficiency, and high transportation capacity.

In actual applications, FRP pipes are mainly used in sewage transmission and water intake projects.

C. Steel pipe

Steel pipes have high mechanical strength to resist significant external loads and internal pressure. They are highly adaptable to complicated terrains. Such pipe materials and fittings are easy to machine. However, steel pipes can be easily corroded, which requires anti-corrosion treatment on the inner and outer surfaces and even cathodic protection when necessary. Therefore, steel pipes shall be used under exceptional circumstances, including river crossing, railway/highway crossing, and sections with extremely complicated topography.

D. Plastic pipe

At present, PE pipes are widely used in production in Mongolia. These pipes are easy to machine and install, non-scaling, light, and have smooth surfaces. However, most of these pipe materials are brittle and cannot withstand external pressure and impact. These pipes have a relatively large coefficient of expansion, which is an apparent weakness. Therefore, PE pipes are usually used for plant process pipes and indoor water supply pipes.

In recent years, PE pipes have been popular in the industry. PE pipes are also called ultra-high molecular weight polyethylene pipes, featuring an extremely high molecular weight, high tensile breaking strength, light weight, high wear resistance, resistance to low temperatures and corrosion, smooth inner wall, and high tensile elongation at break. PE pipes can be laid without a foundation, making construction easier. The overall construction costs are slightly lower than those of ductile iron pipes, but the service life is much longer than that of steel pipes and ductile iron pipes, reaching 50 years or more. These pipes are easy to install. Currently, the diameter of this pipe material can reach DN1000 or higher, demonstrating its strong vitality in work.

In sum, PE pipes will be used for the pipes of the Project. The pipe materials and fittings shall comply with relevant standards. Pipe joints are welded, and all pipes are laid on treated subgrades. The foundation is composed of a 20 cm sand cushion layer. The valves, tees, etc. in wells must have C20 concrete buttresses. Rubber gaskets shall be inserted between the buttress and the pipe to protect the pipe from damage.

The foundation of the water supply pipe and the inspection well shall sit on an undisturbed soil layer with good soil quality or a treated soil layer. The foundation bearing capacity shall not be less than 100 kN/m^2.

(4) Water supply structures

Air release valve pit: In this design, a 1,200 × 200 mm reinforced concrete rectangular valve pit is used.

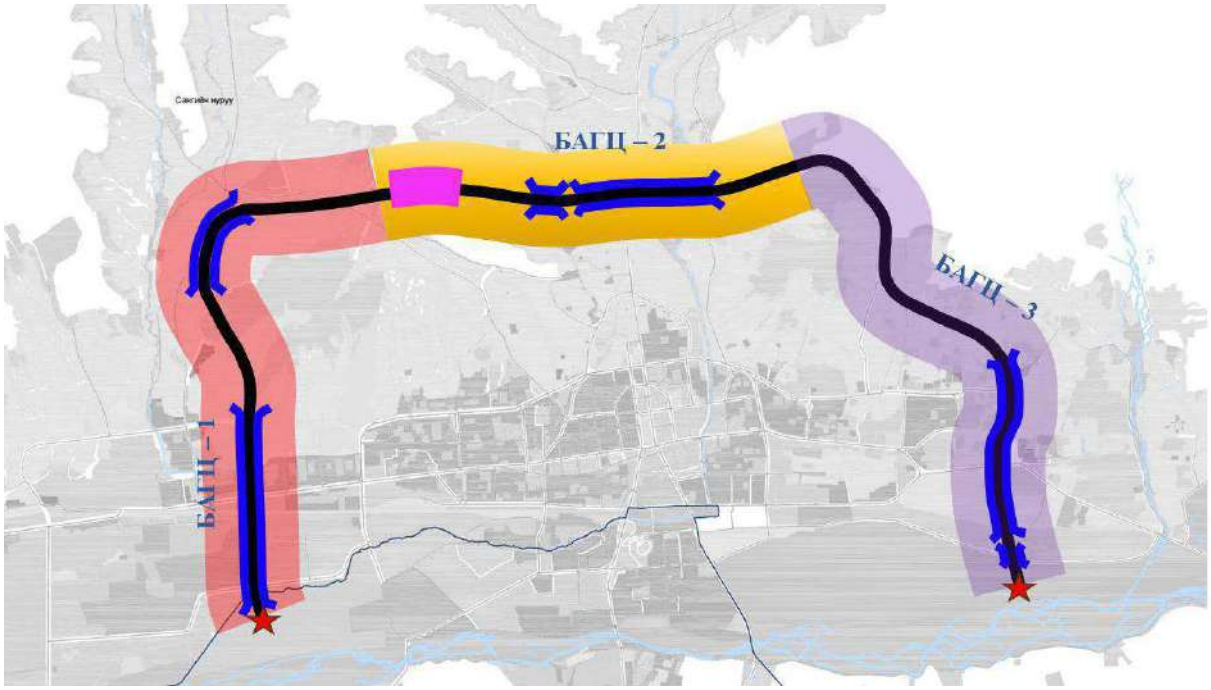
Valve: When the diameter of the water supply pipe is DN300, a gate valve is used. The gate valve on a water supply pipe with a diameter of DN200 or less has a valve bushing. The gate valve on a water supply pipe with a diameter of DN300 has a valve pit. When the diameter of the water supply pipe is larger than DN300, a butterfly valve/butterfly valve pit is used.

6.6.4 Scope of Influence

The planned route of the First Ring Road traverses the territories of residential areas 3 and 4 (Khan-Uul District), residential areas 20 and 29 (Bayangol District), residential areas 6,7,8,9,10,16,23,28,30,39,40 (Songino Khairkhan District), residential areas 15,16,18,22 (Chingeltei District), residential areas 14 and 16 (Sukhbaatar District), and the residential regions 2,5,13,21,26,27,29,31,32,36 (Bayanzurkh District) in Ulaanbaatar. The affected area, spanning 31 residential areas across six districts of Ulaanbaatar, is estimated to cover 300 meters in total (150 meters on either side of the road's centerline), with a total area of 8.4 hectares along the entire route. The water supply system planning solution will manage advanced plans for relocating, shifting, and upgrading the pipeline networks and structures that lie within the planned highway route.

6.6.5. Planning for Relocation, Shifting, and Upgrading of Water Supply Pipeline Networks

Consistent with the plan to execute the First Ring Road's direct route in 3 sections, the planning for water supply and sewage treatment components has been divided into 3 sections based on technical and economic principles.



Section 1: From TEC-4 Road to the start of the planned tunnel – 8.6 km highway

Section 2: From the tunnel starting point to Residential Area 21 (Bayanzurkh District) – 6.2 km highway

Section 3: From Residential Area 21 (Bayanzurkh District) to Dunjingarav Pass

Table 6. 12. Water Supply Pipelines Crossing the Route of Section 1 Highway

Water Supply Pipeline Information						
Section Number	Pipeline Name	Pipe Diameter	Length, m	Material, Installation	Operational Status	Planning Solution Recommendation
Section 1	BYK-2 Potable Water Pipeline	200mm	70	Cast iron pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Potable water pipeline from Station VK3 to BUK2	200mm	70	Cast iron pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Khar Horin Potable Water Pipeline	400 mm	70	Cast iron pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Former 700 Pipeline	700 mm	70	Cast iron pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Bayangol River Potable Water Pipeline	600mm	70	HDPE pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Residential Area 1 Potable Water Pipeline	600mm	70	Cast iron pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Residential Area 1 Sewer Pipeline	600mm	70	Cast iron pipe	In operation	Upgrade according to the highway's construction design plans; relocate and shift the affected sections along the roadway.
	Bayanhoshuu Upper and Lower Reservoir Pipeline	2x350mm	80	HDPE pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Bayanhoshuu Upper and Lower Reservoir Pipeline	280mm	80	HDPE pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Bayanhoshuu Upper and Lower Reservoir Pipeline	280mm	110	HDPE pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Bayanhoshuu Upper and Lower Reservoir Pipeline	2x350mm	110	HDPE pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Bayanhoshuu Sewer Pipeline	Φ225 mm	110	Pipe, Φ225 mm, X10-X11	In operation	Upgrade in alignment with the highway's construction design plans
	270th Water Tap Pipeline	Φ63/25	272	Pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Service Center Pipeline	Φ100 mm	153	Iron	In operation	Upgrade in alignment with the highway's construction design plans

The route of **Section 1** includes a total of 14 potable water pipeline networks, positioned both perpendicularly and parallelly. It is planned to upgrade the perpendicularly located potable water pipeline networks by constructing iron culverts. It is planned to relocate and shift the

Residential Area 1 sewer pipeline, which is located perpendicularly or parallelly to the highway route. A total of 1,395 meters of potable water pipeline networks run along the Section 1 route. There are also 4 residential area water taps located along the highway route. A feasibility study is required to assess options for relocating these water taps in coordination with site planning and the road route.

Upgrades to the potable water pipelines must align with the highway's construction design plans, requiring additional clarification from USUG to finalise the design drawings.

Table 6. 13. Water Supply Pipelines Intersecting Section 2 Highway Route

Water Supply Pipeline Information						
Section Number	Pipeline Name	Pipe Diameter	Length, m	Material, Installation	Operational Status	Planning Solution Recommendation
Section 2	Supply pipeline from Khailaast Water Reservoir	300mm	85	Pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Return pipeline from Khailaast Water Reservoir (left segment)/	200mm	85	Pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Return pipeline from Khailaast Water Reservoir (right segment)/	200mm	85	Pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Daryaa River potable water pipeline	300mm	80	Corrugated pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Daryaa River potable water pipeline	110mm	80	Pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Residential Area 1 Potable Water Pipeline	600mm	70	Cast iron pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Service Center Pipeline	Φ100 mm	153	Iron	In operation	Upgrade in alignment with the highway's construction design plans

The route of **Section 2** includes a total of 7 potable water pipeline networks, positioned both perpendicularly and parallelly. It is planned to upgrade the perpendicularly located potable water pipeline networks by constructing iron culverts. A total of 650 meters of potable water pipeline network runs along the Section 2 route. Additionally, there are 4 residential water supply points located along the highway route. A feasibility study is required to assess options for relocating these water taps in coordination with site planning and the road route. Upgrades to the potable water pipelines must align with the highway's construction design plans, requiring additional clarification from USUG to finalize the design drawings.

Table 6. 14. Water Supply Pipelines Intersecting Section 3 Highway Route

Water Supply Pipeline Information						
Section Number	**Pipeline Name**	**Pipe Diameter**	**Length, m**	**Material, Installation**	**Operational Status**	**Planning Solution Recommendation**
Section 3	Gachuurt source pipeline	700 mm	85	Concrete	In operation	Upgrade in alignment with the highway's construction design plans
	5th Water Tap Pipeline	Φ50/63mm	140	Pipe	In operation	Shift and relocate in coordination with the highway construction design
	Upper source pipeline	600mm	550	Cast iron pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Sharhad drainage pipeline	110mm	300	Pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Yalalt potable water pipeline	500mm	85	Cast iron pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Janzhan potable water pipeline	200mm	140	Pipe	In operation	Upgrade in alignment with the highway's construction design plans
	Upper source pipeline	Φ2x400 mm	160	Concrete	In operation	Upgrade in alignment with the highway's construction design plans

The route of **Section 3** includes a total of 7 potable water pipeline networks, positioned both perpendicularly and parallelly. It is planned to upgrade the perpendicularly located potable water pipeline networks by constructing iron culverts. A total of 1460 meters of potable water pipeline network runs along the Section 3 route. There are also 5 residential area water taps located along the highway route. A feasibility study is required to assess options for relocating these water taps in coordination with site planning and the road route. Upgrades to the potable water pipelines must align with the highway's construction design plans, requiring additional clarification from USUG to finalize the design drawings.

6.7. SEWAGE ENGINEERING

6.7.1. Design principles

(1) For the sewage system, catchment zoning and system layout shall be based on local topographical conditions so that the drainage direction of the pipe is consistent with the slope to reduce the burial depth of the pipe. By fully utilizing the local topography, the construction costs of pipes can be reduced.

(2) The flowrate in the trunk pipe shall be controlled to an extent that no silting occurs at the maximum design filling, so that the sewage can flow into the urban sewage trunk pipe under gravity.

(3) Pipe elevation shall conform to the integrated pipeline planning.

(4) Pipes shall be laid under the sidewalk and non-motorized vehicle lane whenever possible, ensuring smooth traffic on the motor vehicle lane while avoiding any impact on off-road

sites.

(5) The sewage from a plot is preliminarily treated in the septic tank and then drained to the municipal sewage pipe.

(6) The drainage system is separated.

6.7.2. Planning for sewage system

It is estimated that, by 2040, 84% of the total population will have access to the centralised sewage treatment system. The total sewage volume will reach 526,100 m^3/d.

Based on the city's geological location, the areas suitable and unsuitable for buildings, water supply to the population and uniform coverage of the sewage treatment system as well as the system capacity, possible conditions for future planning, and the objectives of ensuring reliable, economic, and efficient operation, the sewage treatment system is planned in 3 areas. Including:

(1) When re-planning the development of the central area, connections will be established by expanding and upgrading the centralised treatment system.

An under-construction 250,000 m^3/d sewage treatment facility near the central sewage treatment facility will be put into use.

The central treatment facility currently in operation will undergo technical upgrades and be put into operation.

The treatment capacity of Moringen Sewage Treatment Plant will be expanded from 20,000 m^3/d to 60,000 m^3/d.

A new purification facility with a treatment capacity of 5,000 m^3/h will be built at the Automobile Trading Centre.

The Harzhaya Sewage Treatment Facility will be expanded to a domestic sewage treatment facility with a treatment capacity of 20,000 m^3/d.

(2) Construction and renovation of sewage pipe network

Renovated sewage pipe network: 13.5 km

Expanded sewage pipe network: 12.88 km

Upgraded soil infiltration pipe network: 22.8 km

Constructed sewage pipes: 230 km

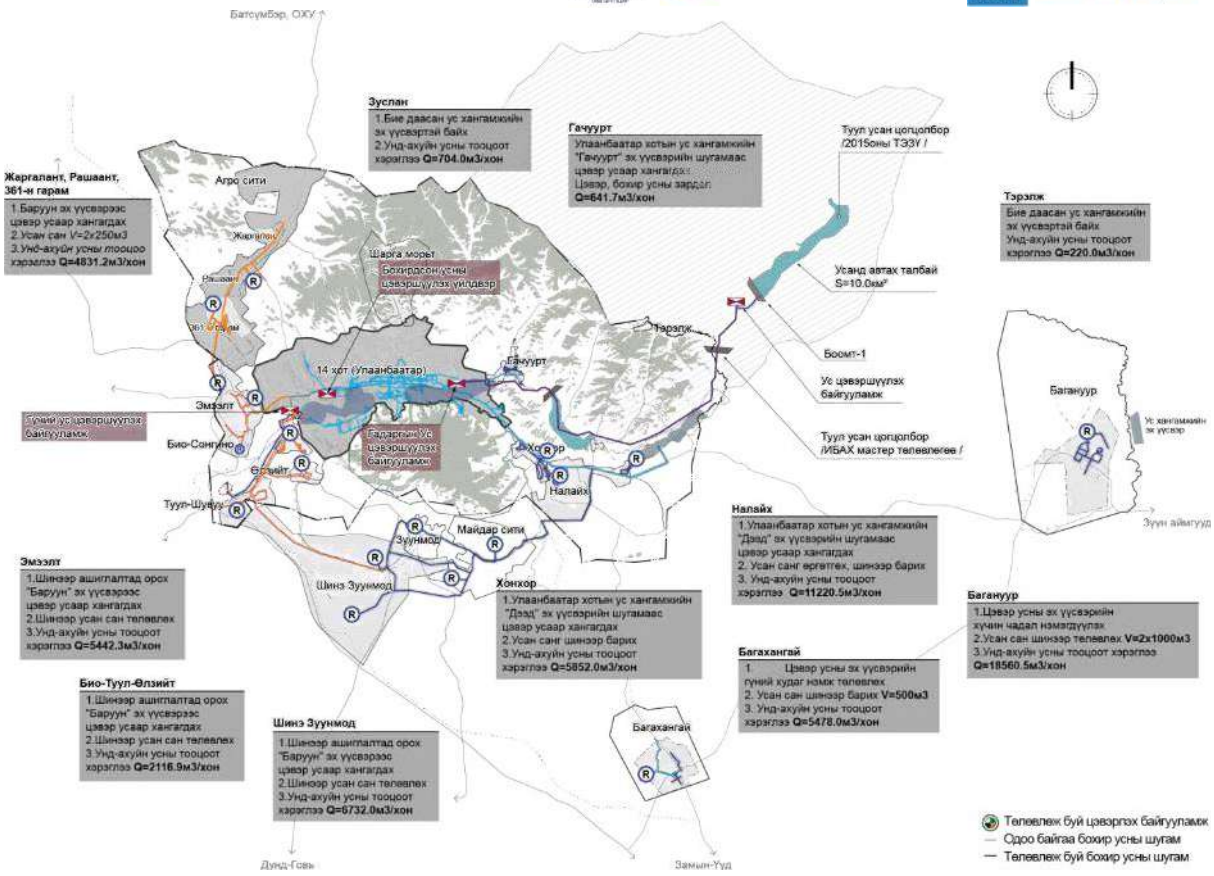


Figure 6. 23. Schematic Diagram of Total Sewage Volume

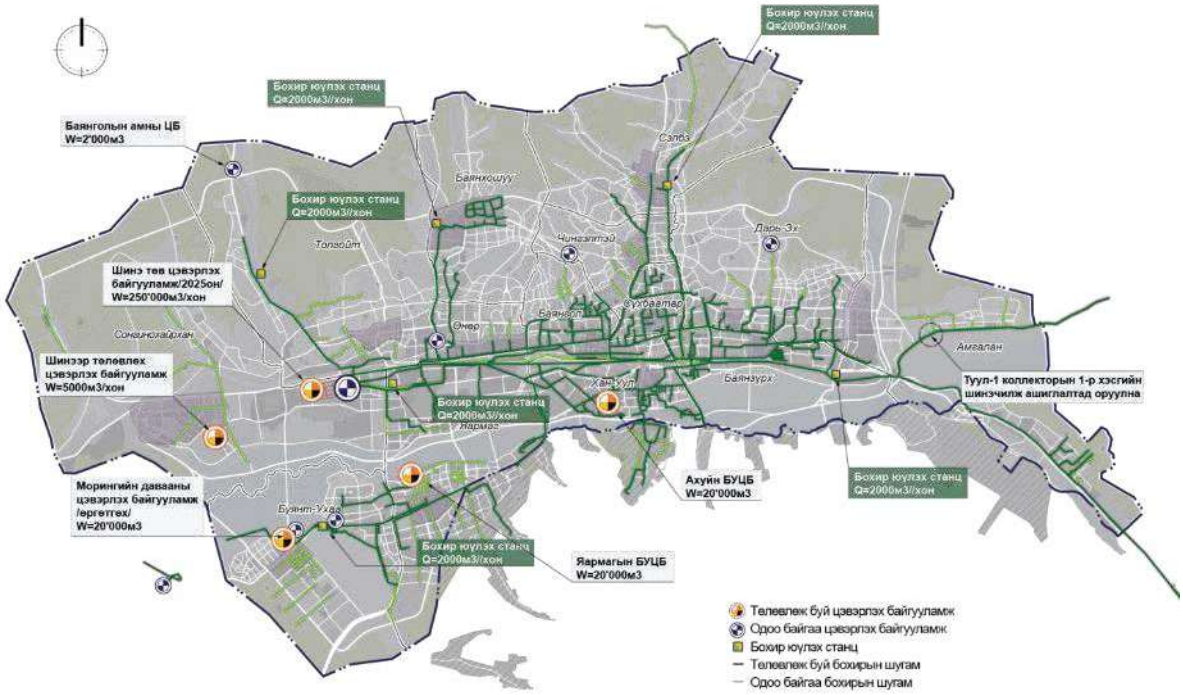


Figure 6. 24. Schematic Diagram of Sewage Treatment Plant and Sewage Pipe network

6.7.3. Design of sewage pipe system

(1) Design standards

According to the АРИУТГАХ ТАТУУРГА. ГАДНА СҮЛЖЭЭ БА БАГУУЛАМЖ (БНбД 40-01-14) and the Overall Plan of Ulaanbaatar until 2040, this design does not involve constructing new sewage pipes. The relocated sewage pipes will be designed based on existing scale.

(2) Design scope

The design scope of sewage engineering is similar to that of the road discipline. The sewage pipelines along the full length of the ring road will be relocated.

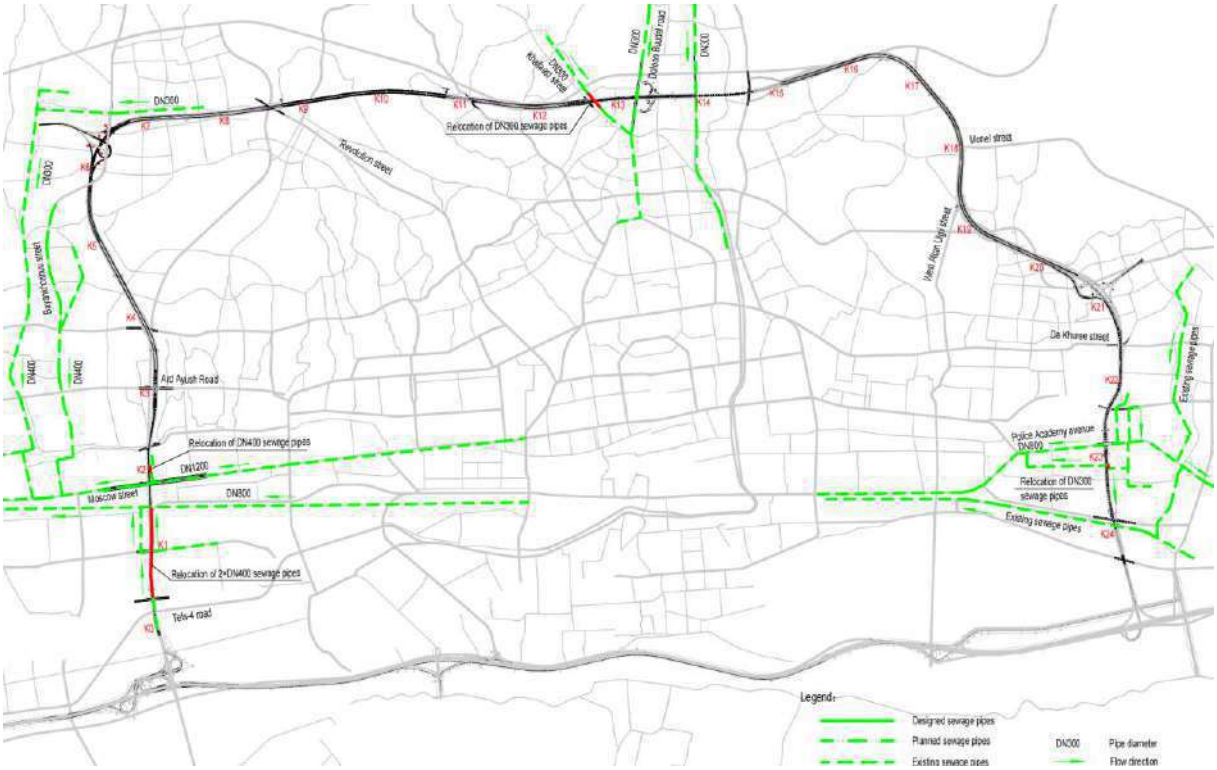


Figure 6. 25. Diagram of Sewage System

(3) Design calculations

Calculation of sewage volume:

A proper estimate of the sewage volume is the basis for determining the scale of sewage treatment facilities and sewage pipes, which affects the engineering investment of the entire project.

Calculation of the sewage pipe:

$$C = \frac{1}{n} R^{\frac{1}{6}}$$

$$V = C\sqrt{RI}$$

$$Q = A.V$$

$$Q = \frac{1}{n} AR^{\frac{2}{3}} I^{\frac{1}{2}}$$

where,

Q: Design discharge of sewage segment

A: Area of wetted cross-section

V: Design flow rate

R: Hydraulic radius

C: Flowrate coefficient

I: Hydraulic slope; equal to the pipe bottom slope for gravity flows

n: 0.009-0.011 for HDPE pipes, UPVC pipes, PE pipes, and FRP pipes

Gravity-flow sewage pipes shall be calculated for non-full conditions. The design maximum filling shall be valued as follows:

Table 6. 15. Minimum Flowrate of a Pipe in the Domestic Drainage Pipe network for Roads at Maximum Pipe Filling

Diameter (mm)	Minimum Flowrate at H/D Filling (m/s)			
	0.6	0.7	0.75	0.8
150-250	0.7			0.65
300-400		0.8		
450-500			0.9	
600-800			1.0	
900			1.1	
1000-1200				1.2
1500				1.3
Over 1000				1.5

(4) Sewage pipe material and foundation

① Requirements for pipe material

The materials used for drainage pipes must meet certain requirements to ensure normal drainage.

Drainage pipes must have sufficient strength to withstand external loads and internal water pressure. External loads include the weight of soil and the dynamic load from vehicle movements. Internal water pressure can be induced by siltation of the gravity-flow pipe or during desilting. Pipes must have sufficient strength to prevent cracking during transportation and construction.

Drainage pipes must be resistant to erosion and wearing by impurities in sewage. These

pipes shall also be resistant to corrosion, especially corrosive industrial waste.

Drainage pipes must be impermeable. The seepage of sewage will contaminate the groundwater or corrode other pipelines and building foundations.

Drainage pipes shall have neat and smooth inner walls to minimise the resistance of water flows.

Drainage pipes shall be taken locally if possible, considering the possibility of prefabrication and quick construction to reduce the costs for transportation and construction.

② Selection of pipe material

In this design, various pipe materials for drainage pipes are compared, which usually include the following four types:

Table 6. 16. Comparison of Pipe Materials for Drainage Pipes

Pipe Material Item	Reinforced Concrete Pipe	Reinforced Concrete Pipe With Socket	FRP Sand Inclusion Pipe	HDPE Pipe
Segment Length	Usually 2 m	Usually 2 m	6 m - 12 m	6 m
Joint	Rubber ring joint, wire mesh cement mortar joint, or collar joint	Rubber ring joint, wire mesh cement mortar joint, or collar joint	Rubber ring flexible joint	Electrofusion joint or socket-type rubber ring flexible joint
Foundation	Concrete foundation	Sand cushion foundation	Sand cushion foundation	Sand cushion foundation
Pipe Diameter	d300 - d2400	d300 - d3400	DN300 - DN2400	DN300 - DN2000
Roughness Coefficient n	0.014	0.014	0.01	0.01
Hydraulic Performance	Relatively poor, high along-the-path resistance	Poor, high along-the-path resistance	Good, low along-the-path resistance	Good, low along-the-path resistance
Anti-corrosion Performance	Good	Good	Good, not requiring internal and external corrosion protection	Good, not requiring internal and external corrosion protection
Construction Speed and Level of Difficulty	Short pipe, lots of joints, complicated pipe foundation; mature and widely applied construction process, quick construction	Short pipe, lots of joints; simple pipe foundation, quick construction	Long pipe, few joints, simple pipe foundation, quick construction	Long pipe, few joints, simple pipe foundation, quick construction
Adaptability to Unfavorable Foundations	Less adaptable to unfavorable foundations than plastic pipes	Less adaptable to unfavorable foundations than plastic pipes	Highly adaptable to unfavorable foundations Well sealed joints, adaptable to differential foundation settlement	Highly adaptable to unfavorable foundations Well sealed joints, adaptable to differential foundation settlement
Transportation and Lifting	Heavy and bulky, difficult to transport and lift	Heavy and bulky, difficult to transport and lift	Light, easy to transport and lift	Light, easy to transport and lift

Pipe Material Item	Reinforced Concrete Pipe	Reinforced Concrete Pipe With Socket	FRP Sand Inclusion Pipe	HDPE Pipe
Other Advantages and Disadvantages	Difficult to operate when the groundwater level is high; high auxiliary costs for construction; low total construction costs; strong pressure resistance of pipe material	Lowest total construction costs; strong pressure resistance	Highest total construction costs; large-diameter pipe that is fragile and easily deformed	The total construction costs for large-diameter pipes are high. The pipe is fragile and easily deformed. The total construction costs for small-diameter pipes are similar to (slightly higher than) those of reinforced concrete pipes.

In principle, when selecting the material of a drainage pipe, it is necessary to take into account the reliability, advancement, and economy of the technology adopted and construction quality. Therefore, for the project, based on the geological characteristics of the foundation, we compared the reinforced concrete pipe, reinforced concrete pipe with socket, HDPE pipe, and FRP sand inclusion pipe in terms of technical feasibility and economic reasonableness, ultimately selecting the pipe material that is both technically feasible and economically reasonable.

Regarding small-diameter drainage pipes, reinforced concrete pipes have several disadvantages, including high energy consumption, a short service life, and poor performance in energy saving and environmental protection. Consequently, their comprehensive cost is not advantageous compared to plastic pipes, which are gradually replacing them. With the diameter increase, the cost of laying plastic pipes rises. The unit price of this pipe material is significantly higher than that of reinforced concrete pipes, resulting in lower cost performance. Therefore, large-diameter plastic pipes can hardly be widely used in construction unless there is a sharp decrease in the price. Small- and medium-diameter plastic pipes are the new pipe materials that have emerged in recent years. At present, they are extensively used with the promotion of the Ministry of Construction for their technological advancement, flexibility, resistance to subsidence, economic viability, and energy-saving and environmental protection performance.

In particular, the roughness coefficient of the HDPE pipe is merely about 64%-71% of the reinforced concrete pipe. That is, with the same hydraulic slope, the discharge allowable by an HDPE pipe can be equivalent to that allowable by a reinforced concrete pipe with a higher grade of pipe diameter.

In summary, given the extensive use of HDPE pipes in current drainage pipe network construction, the actual requirements for laying drainage pipes in this design, and the cost performance of relevant pipe materials, HDPE reinforced wound pipes are used for sewage drainage pipes in this design.

The pipes used shall conform to the technical requirements in relevant standards, with

mechanical performance satisfying the requirements in relevant codes. When the burial depth is ≤ 6.0 m, the ring stiffness shall be 8 KN/m^2, that is, not lower than Grade S2. When the burial depth is > 6.0 m, the ring stiffness shall be 12 KN/m^2. Pipe joints are connected by rubber ring socket and spigot.

Pipe foundation: When the bottm of the HDPE reinforced wound pipe is located in an undisturbed soil layer, the bed shall be replaced with a 15 cm medium-coarse sand cushion. When the pipe bottom is located in a recently backfilled soil layer, the bed shall be replaced with a 25 cm medium-coarse sand cushion. The pipe foundation shall sit on an undisturbed soil layer with good soil quality or a treated soil layer. The foundation bearing capacity shall not be less than 100 KN/m^2.

(5) Sewage structures

Inspection well: For a pipe with the maximum diameter of 600 mm, the length and width of the inspection shall be 1,000 × 1,000 mm. For a pipe with a diameter of 700 mm and larger, the length of the inspection well shall be the diameter + 400 mm and the width shall be the diameter + 500 mm. When a circular inspection well is used, the diameter of the inspection well depends on the pipe diameter: 1,000 mm when the pipe diameter is ≤ 600 mm, 1,250 mm when the pipe diameter is 700 mm, 1,500 mm when the pipe diameter is 800-1,000 mm, and 2,000 mm when the pipe diameter is 1,200 mm. When the pipe diameter does not exceed 150 mm and the well depth does not exceed 1.2 m, the diameter of the inspection well is 600 mm. When the installation depth of the pipe exceeds 3 m, the well diameter shall not be less than 1,500 mm.

The height of the working part of the shaft shall be 1,800 mm from the working platform to the pavement. When this height is less than 1,200 mm, the shaft width can be D + 300 mm but not less than 1,000 mm. The inspection well trench platform shall be located on the top horizontal surface of the pipe with the largest diameter. When the pipe diameter in the inspection well is 700 mm and larger, it is required to set up a working area on one side of the trench and a waste cleaning platform on the other side that shall be at least 100 mm wide. When the pipe diameter is larger than 2,000 mm, the working area is on the support, and the trench opening is 2,000 × 2,000 mm.

A flow trough shall be set at the bottom of the inspection well.

6.8. POWER PIPELINE ENGINEERING AND LIGHTNING

6.8.1. Power pipeline engineering

(1) Design basis

1) Mongolian Code for Electrical Equipment and Facilities БД-43-101-03

2) Regulations for Power System Construction ЗХД-1.13-01-2006

3) Overall Plan of Ulaanbaatar until 2040

In addition to the project duty book and technical conditions provided by the road engineering.

(2) Technical Standards

Based on the Overall Plan of Ulaanbaatar until 2040 and the Mongolian Code for Electrical Equipment and Facilities БД-43-101-03, as well as the future power demand of surrounding plots along this road and the requirements for relocating additional power cables and underground power pipelines. In consultation with the power supply bureau, the capacity of the power network channel facilities is designed for a 12-duct configuration.

(3) Design Principles and Objectives

1) Design Principles

① Safety First Principle

Comply with the national Regulation on Electrical Installations БД-43-101-03 and relevant safety standards to ensure proper insulation, lightning protection, grounding, and other safety measures. Avoid flammable and explosive areas, maintain a safe distance from gas and heat pipelines, and use pressure-resistant, corrosion-resistant materials to prevent short circuits, leakage, and other risks.

② Reliability Principle of Power Supply

Conduct rational planning for cable capacity and the number of circuits based on regional load forecasts to meet future electricity demand. Reserve interconnection interfaces at critical nodes to enhance emergency switching capabilities during faults. Coordinate with municipal power grid planning to ensure efficient integration with substations and distribution stations.

③ Intensive and Standardisation Principle

Prioritise duct laying to minimise the impact of direct burial on road structures. Standardise pipe specifications, chamber dimensions, and identification systems for easier maintenance. Optimise the use of road cross-sectional space and coordinate with water supply, drainage, and communication pipelines.

④ Environmental Coordination Principle

Avoid passing through ecologically sensitive areas to minimize construction damage to greenery and groundwater.

2) Design Objectives

① Build a Safe and Resilient Power Supply Network

Achieve high power supply reliability, rapid fault response and repair times, and ensure stable electricity for residents and industries.

② Promote Efficient Integration of Municipal Facilities

Synchronise the design and construction of power pipelines with road engineering to reduce

repeated excavations and improve comprehensive implementation efficiency.

③ Support Sustainable Urban Development

Adapt to future load growth, reserve redundancy in trunk lines, and accommodate regional development and new energy integration.

④ Green and Low-Carbon Implementation

Use environmental pipe materials to significantly reduce lifecycle carbon intensity compared to traditional methods.

(4) Project Overview and Scope

The road grade of this project is a Grade I arterial road, with sidewalks classified as Grade II. The total length of the main road is 24,793 meters, including 13679 meters length of road section, 9,034 meters length of bridges, 2,080 meters length of tunnels. The road surface is asphalt pavement, with a design speed of 100 km/h for the main road (80 km/h in local sections). The main road is a six-lane dual carriageway. The power pipeline design for this project includes road sections, bridge sections, and tunnel sections.

(5) Design Content

1) Power pipelines;

2) Power manholes.

(6) Power Pipeline Design

1) Quantity of Power Pipelines

Based on the Overall Plan of Ulaanbaatar until 2040 and the Regulation on Electrical Installations БД-43-101-03, as well as the future power demand of surrounding plots along this road and the requirements for relocating an additional 10kV and 0.4 kV power cables and underground 10kV and 0.4 kV power pipelines. In consultation with the power supply bureau, the capacity of power network channel facilities is designed for a 12-duct configuration, adopting a 4x3 arrangement of 12 Φ150mm pipes.

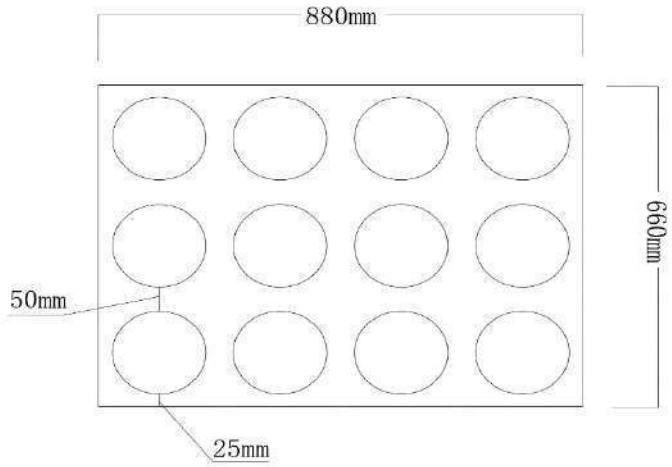


Figure 6. 26. Schematic Diagram of Power Pipe

2) Comparative Analysis of Power Pipe Materials

There are various types of power pipe materials, including plastic materials: PVC pipes, HDPE pipes, PE pipes, MPP pipes; Metal materials: Galvanized steel pipes, stainless steel pipes, cast iron pipes; Composite materials: Plastic-coated steel pipes, fiberglass-reinforced plastic (FRP) pipes; Concrete materials: Concrete pipes/cement pipes; Other special materials: Corrugated pipes (metal or plastic). Due to performance and cost considerations, plastic materials such as PVC pipes and HDPE pipes are currently the most widely used.

Table 6. 17. Comparison Table of PVC Pipes and HDPE Pipes

No.	Comparison Item		PVC Pipe	HDPE Pipe
1	Material Properties		Rigidity: Relatively high, requiring more joints to adapt to terrain variations. UV Resistance: Can be used outdoors with stabilizers, but prolonged exposure may cause aging. Chemical Resistance: Resistant to weak acids and bases but sensitive to certain solvents.	Flexibility: Excellent, allowing curved pavement and reducing joint requirements. Impact Resistance: Maintains toughness even at low temperatures, resisting brittleness. Corrosion Resistance: Resistant to acid-bases, and organic solvents, suitable for chemical environments.
2	Physical Properties	Temperature Adaptability	0°C to 45°C (softens at high temperatures, becomes brittle in cold).	-50°C to 60°C (short-term high-temperature resistance up to 80°C).
		Pressure Bearing Capacity	low-pressure application	High-pressure resistant
3	Installation & Maintenance	Connection Methods	Adhesive or threaded connections (simple but prone to aging and leakage).	Hot melt connections (leak-free but requires specialized equipment).
		Construction Costs	Lower material cost, but more joints may increase installation time.	Higher equipment cost but lower labor expenses (flexibility reduces joints).
4	Lifespan & Environmental Protection	Lifespan	20-50 years (may shorten under UV or chemical exposure).	Over 50 years (resistant to stress cracking and corrosion).
		Environmentally	Contains chlorine, incineration may release dioxins, and recycling is complex.	Recyclable with low production pollution.
5	Costs Comparison	Material Cost	PVC is generally cheaper than HDPE.	
		Comprehensive Cost	HDPE may be more economical due to longer lifespan and lower maintenance	

In summary, PVC pipes have poor temperature adaptability, cannot withstand low temperatures, and have low pressure-bearing capacity. Their adhesive or threaded connections are prone to aging and leakage. In contrast, HDPE pipes have a temperature applicability range of -50°C to 60°C, can withstand high pressure, and feature leak-free hot melt connections. Their lifespan is longer than that of PVC pipes, while the comprehensive cost is comparable. Considering factors such as Ulaanbaatar's winter minimum temperature of -40°C, this project recommends the use of HDPE pipes (High density polyethylene pipe) for power pipelines.

The HDPE pipes have a ring stiffness of ≥10.5 kN/m² (road load), and all other performance indicators must comply with the technical standards approved by relevant Mongolian authorities

for electrical protection. The pipes are connected by heat fusion, with pipe saddle spacing set at 2.0 meters for pedestrian walkways and 1.5 meters for street crossings to meet compressive strength and environmental pressure resistance requirements. The conduit saddles should be provided by the manufacturer.

3) Power Pipelines Layout

This project consists of three sections: roads, bridges, and tunnels.

① Power pipelines layout for road and overpass sections

According to the comprehensive planning and considerations of special pipelines, the laying of power pipelines under sidewalks can not only meet the safety distance requirements from water supply, sewage, and stormwater pipes but also significantly reduce investment and construction difficulty by eliminating the need for steel pipes or concrete encapsulation under sidewalks. Additionally, laying the power pipelines under sidewalks facilitates future cable installation and maintenance without disrupting the movement of motorized and non-motorized vehicles, thereby minimizing traffic impact.

For a 60-meter-wide road section and a 45-meter-wide road (overpass) section, a 12-hole power conduit is laid along the east (south) side sidewalk of the designed route. The soil sealing over the pipeline is ≥1.0 m. The power pipeline adopts HDPE pipes (high-density polyethylene pipe) specifically designed for power applications, with an inner diameter of Ø150 mm and a wall thickness of 10 mm.

The conduit laying scheme adopts a 3×4 arrangement, and the laying method is detailed in the burial method of a main power pipeline (Type A) of the drawing "Detailed Cross Section for Laying of a Power Conduit".

A. Road-crossing power pipeline

The road-crossing pipe adopts 12×Ø150 HDPE pipes, fully encapsulated in C20 concrete with Ø10 rebar for protection, and a soil sealing of ≥1.0 m. The laying method is detailed in the concrete encapsulation and burial method of a main street crossing pipeline (Type B) of the drawing "Detailed Cross Section for Laying of a Power Conduit".

B. Lateral street-crossing power pipeline

The lateral road-crossing power pipeline includes two types:

One type adopts 12×Ø150 HDPE pipes, fully encapsulated in C20 concrete with Ø10 rebar for protection, and a soil sealing of ≥1.0 m. It is laid at intersections. For urban road sections, it is laid every 1000 m, for sections in Mongolian yurt, it is laid every 2000 m.

The laying method is detailed in the burial method of a main telecommunications pipeline (Type B) of the drawing "Detailed Cross Section for Laying of a Power Conduit".

Another type adopts 6×Ø110 HDPE pipes, fully encapsulated in C20 concrete with Ø10

rebar for protection, and a soil sealing of ≥1.0 m. Along the entire road, it is laid every 250 m. The laying method is detailed in the burial method of a street crossing branch pipeline (Type C) of the drawing "Detailed Cross Section for Laying of a Power Conduit".

The specific locations of these power pipelines are detailed in the drawing "Typical Layout Plan of a Telecommunications Pipeline".

② Power pipelines layout for elevated bridge sections

This project includes 2 railway-crossing elevated bridges with accompanying ground-level side roads, and 1 river-crossing elevated bridge without side roads. None of these bridges have pedestrian walkways, leaving no space for power pipe laying. Using directional drilling or pipe jacking methods to cross the railway on the side roads is costly, technically challenging, and inconvenient for future maintenance. Instead, the power pipelines will be suspended using angle steel supports under the box girder flanges. The angle steel supports will be suspended at 1 m intervals, and the power pipes will use Ø150 hot-dip galvanized steel pipes. Communication pipes exceeding 80 m in length will include a 1 m break to facilitate future cable installation. Fireproof sealing shall be applied at pipe breaks.

③ Power pipelines layout for tunnel sections

The power pipe is laid beneath the inner maintenance access of the right tunnel (south side). The pipe adopts 12xØ150 HDPE pipes, secured with pipe clamps at 2 m intervals. For pipes exceeding 80 m in length, a maintenance well is installed to facilitate future cable installation. Fireproof sealing shall be applied at pipe breaks.

④ For 10 kV and lower-voltage power cables, the bending radius of 3-core cables must be no less than 15 times the cable's outer diameter. Each conduit should reserve a steel pulling iron (steel) wire to facilitate future cable installation.

⑤ The clear laying distance between power pipelines and other adjacent pipelines shall comply with the relevant provisions of БД-43-101-03-Electrical installation regulations 2.3.35-2.3.45. For existing pipelines relocating that do not meet the spacing requirements, priority should be given to adjusting the laying method of communication pipelines. Specific practices are detailed in the drawing "Scheme for crossing telecommunications pipelines with other pipelines".

⑥ The longitudinal slope of the designed power pipeline is generally align with the road longitudinal slope, with a minimum longitudinal drainage slope of 0.2% for the power pipeline and 0.2% for lateral street crossing branch pipelines.

(6) Electric Well Design

1) Electric wells shall be designed in the following configurations based on project requirements: straight-through type, T-junction type, cross-junction type, and manholes. TBUH-

3-type wells with 12-hole shall be used, suitable for pipe system installation depths of 100 cm-120 cm. Considering friction, straight-through type electric wells should be set at 80m intervals for straight sections; For turns greater than 45°, corner-type electric wells must be installed. For turns less than 45°, right-angle type electric wells may be used, but the spacing between working wells should be reduced. T-junction type electric wells shall be installed at lateral street crossing branch pipelines, and cross-junction type electric wells shall be installed at intersections.

2) A sump pit shall be installed in the electric well with a bleeding gradient of no less than 0.5%. The sump pit dimensions shall be 0.5 m × 0.5 m × 0.5 m. Accumulated rainwater in the sump pit shall be manually pumped out.

3) The material of electric wells shall meet load-bearing and environmental requirements.

(7) Grounding

1) Two -40×4 galvanized flat steels shall be laid along the power conduit as horizontal grounding electrodes. Vertical grounding electrodes (φ50, L = 2,500 mm angle steel) shall be installed at approximately 100 m intervals and welded to the horizontal grounding electrodes.

2) The grounding device for electric well utilizes the welding of main reinforcements within the well to form a natural grounding electrode, which together with an artificial grounding electrode constitutes a combined foundation grounding electrode. The grounding resistance shall not exceed 10 ohms. After completion of the electric well, the grounding resistance shall be measured. If the requirement is not met, a 50×5 hot-dip galvanized steel pipe shall be welded to the embedded parts of the cable supports on both sides, with the top buried at a depth of 0.8 m, until the requirement is satisfied. Simultaneously, a -40×4 hot-dip galvanized flat steel shall be installed along the wellface at the upper embedded parts of the support columns, connecting the cable support columns, ladders, U-shaped pull rings, and other exposed conductive metal parts for equipotential bonding, ensuring the grounding resistance does not exceed 10 ohms.

(8) Safe Operation and Protective Measures

1) The concentration of toxic or combustible gases (e.g., H_2S, CH_4) in electrical manholes must not exceed safety thresholds. All inspection operations shall strictly follow the procedure: "Ventilate → Test → Enter". Personnel must be equipped with gas detectors and explosion-proof lighting.

2) Accumulated water in electrical manholes must be promptly drained using portable submersible pumps. In cases where conduit collapse results from force majeure events (e.g., natural disasters), a temporary power supply plan shall be activated. This entails utilizing pre-installed spare conduit pipes to enable swift cable path switching during failures.

6.8.2. Lighting engineering

(1) Design basis

1) Road and Street Lighting in Cities, Counties, and Other Settlements-Technical Requirements MNS 6846:2020

2) Planning of Street and Road Lighting in Cities, Counties, and Settlements БД 30-102-11

3) Design Standards for Outdoor Lighting in Cities, Towns, and Rural Settlements СН 541-82

4) General Requirements for Lighting Equipment UCS 1901B

5) Technical Standards for Lighting and Decoration UCS 1902A:2022

6) Mongolian Code for Electrical Equipment and Facilities БД 43-101-03

As well as the project duty book and technical conditions provided by the road engineering.

(2) Technical standards

The road lighting design shall comply with the illumination standards specified for arterial roads (1B) with asphalt pavement in road lighting parameters of Хот, тосгон бусад суурин газрын авто зам, Road and Street Lighting in Cities, Counties, and Other Settlements-Technical Requirements MNS 6846:2020, 1.

(3) Design principles and objectives

1) Design principles

① Safety First: Meet standards for illuminance, uniformity, glare control, etc. Ensure traffic safety and reduce nighttime traffic accident risks; prevent and deter criminal activities; protect buildings and public property; enhance residential security; guard against destructive acts.

② Economic Rationality: Optimize lifecycle costs.

③ Energy Efficiency and Environmental Protection: Adopt low-energy-consumption, low-carbon-emission technologies and advanced control systems.

④ Advanced Technology: Ensure compatibility with future smart upgrades (e.g., IoT control).

⑤ Minimize Light Pollution: Prioritize glare reduction and other light pollution mitigation measures in design.

⑥ Environmental Coordination: As a key component of urban and residential landscapes, street lighting should align with architectural aesthetics and harmonize with the surroundings.

⑦ Ease of Maintenance: Incorporate convenient, safe, and efficient post-construction inspection and maintenance into the design.

2) Design objectives

① Develop a scientific and rational road lighting technical solution that meets functional requirements while balancing cost-effectiveness and energy efficiency.

② Assess project feasibility.

③ Propose the optimal implementation plan and risk prevention and control strategies.

(4) Project overview and scope

The road grade of this project is a Grade I arterial road, with sidewalks classified as Grade II. The total length of the main road is 24,793 meters, including 13679 meters length of road section, 9,034 meters length of bridges, 2,080 meters length of tunnels. The road surface is asphalt pavement, with a design speed of 100 km/h for the main road (80 km/h in local sections). The main road is a six-lane dual carriageway. The current road lighting design covers the road and bridge sections, while tunnel lighting design is detailed in the tunnel chapter.

(5) Design content

1) Road lighting system;

2) Road lighting with power distribution system;

3) Road lighting control system;

4) Grounding system.

(6) Road lighting system design

1) Lighting standards

As a Grade I arterial road with asphalt pavement, the design follows General Technical Requirements for Road and Street Lighting in Cities, Towns, and Other Settlements MNS 6846 2020. The lighting standards for this project are as follows:

Table 6. 18. Lighting Indicators for Roads

Road classification	Road category	Average luminance, $\bar{L}$, (cd/m²), not less than	Luminance uniformity		Average illuminance $\bar{E}$h., (lx), not less than	Threshold increment TI (%), not more than	Illuminance uniformity, Uh, not less than
			Overall luminance uniformity U_0, not less than	Longitudinal luminance uniformity Ul, not less than			
Expressway	1А	2,0	0,4	0,7	30	10	0,35
	1Б	1,5	0,4	0,7	20	10	
Main road	1В	1,0	0,4	0,7	15	15	
	1Г	1,0	0,4	0,6	15	15	
Collector road	2А	0,8	0,4	0,6	10	15	
	2Б	0,8	0,4	0,5	10	15	
Rural road	3А	0,6	0,35	0,4	6	15	0,25
	3Б	0,4	0,35	0,4	6	15	

NOTE:
1. This requirement applies to asphalt-paved roads. If the road has a concrete surface, the average illuminance should be reduced by approximately 30%.
2. All numerical values in the table apply when the road surface is dry.
3. Main roads with large buildings, city centers, commercial district streets, capital city boulevards, and ring roads shall meet first-class lighting standards.
4. In public places and areas with a high likelihood of crime, lighting shall be sufficient to allow facial recognition.

Table 6. 19. Lighting Indicators for Pedestrian Zones

Classification of pedestrian walkways	Illuminance [$\bar{E}h$], lx, not less than	Illuminance uniformity [Uh], not less than
Я3-1	20	0,3
Я3-2	10	0,3
Я3-3	6	0,2
Я3-4	4	0,2
Я3-5	2	0,1
Я3-6	1	0,1

The average horizontal illuminance ($\bar{E}h$) on the surface of pedestrian walkways adjacent to the roadway shall be no less than 50% of the illuminance of the nearby road. The uniformity of illuminance (Uh) on the pedestrian walkway surface shall be no less than 0.3.

The surround ratio (SR) between the illuminance of the roadway surface and the adjacent roadside area shall be no less than 0.5.

Note: For rural roads, this requirement may be omitted.

2) Lamp and Light Source Selection

① Lamps

The lamps should have excellent airtightness and be suitable for outdoor environments, with a protection rating of IP65. The protection rating of the electrical chamber should not be lower than IP53, and the lamps should have a Class I electric shock protection grade, complying with China Compulsory Certification. The lamps should exhibit strong corrosion resistance, a novel appearance, smooth and elegant lines, a lightweight yet sturdy structure, and reasonable light distribution to reduce glare. Each lamp type should have its electrical circuit installed within the lamp. The manufacturing process of the lamps should comply with relevant standards.

② Light Sources

Currently, the light sources available for road lighting mainly include high-pressure sodium lamps and LED lamps. Both types of lamps are used to varying degrees in road lighting, with LED lamps becoming more prevalent in recent years.

Table 6. 20. Comparison of High-Pressure Sodium (HPS) and LED lamp Source Options

Light Source Type	High-pressure sodium lamp (belonging to the third-generation gas discharge light source, emitting light through arc-excited sodium vapor)	LED lamp (fourth-generation semiconductor solid-state light source, based on electron-hole recombination luminescence in a PN junction)
Working Principle	Sodium-mercury vapor inside the arc tube emits light under high-voltage arc excitation, requiring a ballast and trigger.	Semiconductor materials emit light directly when energized, with no filament or gas involved, requiring a driver circuit to control current.
Luminous Efficacy lm/W	Theoretical luminous efficacy of the light source: 100-140 lm/W, but actual lamp efficiency is only 40%-45% (due to significant reflection losses).	Luminous efficacy of the light source: 120-150 lm/W (mass production level), with lamp efficiency reaching 80%-90% (directional luminescence).

Light Source Type	High-pressure sodium lamp (belonging to the third-generation gas discharge light source, emitting light through arc-excited sodium vapor)	LED lamp (fourth-generation semiconductor solid-state light source, based on electron-hole recombination luminescence in a PN junction)
Lamp Efficiency	Due to 360-degree luminescence, about 70% of the light requires a reflector for adjustment, resulting in an effective utilization rate of about 30%-40%.	Directional luminescence achieves an effective utilization rate of over 80%, with more flexible light distribution design.
Light Distribution	Requires reflectors to adjust light direction, prone to scattered light pollution.	Achieves precise light distribution through lenses or reflectors, reducing spill light and offering higher uniformity.
Color Temperature K	Warm yellow light with a color temperature of 2000-2500K, offering strong penetration through haze.	Wide color temperature range (3000-6500K), customizable for cool white or warm white light, providing better visual comfort.
Color Rendering Property Ra	Low color rendering index (Ra 20-40), poor color reproduction, making roads appear dim.	High color rendering index (Ra 70-85), close to natural light, rendering object colors more realistically.
Spectrum	Spectrum concentrated in the yellow light region (around 589nm), with minimal blue and violet light components.	Adjustable spectrum with higher blue light ratio; partial products can combine multiple monochromatic lights to meet special requirements.
Visible Light Composition	High proportion of yellow light, suitable for rainy and foggy conditions, but lacks blue and green light, resulting in lower visual clarity.	White light covers the full visible spectrum, with more blue and green light components, providing bright vision but weaker penetration in foggy weather.
Lifespan (10,000 hours)	Theoretical lifespan: 20,000 hours.	Theoretical lifespan: 50,000-100,000 hours (L70 light wane standard).
Actual Lifespan (10,000 hours)	Actual lifespan: ~4,000 hours (affected by voltage fluctuations and startup frequency).	Actual lifespan: 30,000-50,000 hours (highly dependent on heat dissipation design).
Flicker	There is noticeable flickering (100Hz) under frequency power supply, which may cause visual fatigue.	DC drive is flicker-free, suitable for dynamic lighting needs (e.g., sports venues).
Starting Performance	Requires 3-5 minutes to start and needs cooling time for restart (difficult hot start).	Instant start, supports frequent switching, with no delay.
Fog Penetration Ability	Yellow light wavelength (589nm) has strong fog penetration, making it suitable for scenarios like highways and ports.	White light's short-to-medium wavelength blue light is easily scattered by fog, resulting in poor fog penetration.
Impact of Grid Quality	Sensitive to voltage (requires 180-245V); voltage fluctuations may cause the lamp to be put out or reduce efficacy.	Wide voltage adaptation (90-265V) with high stability.
Electromagnetic Interference	Inductive ballasts may generate electromagnetic interference, requiring additional protection.	Properly designed drive circuits can avoid interference, complying with EMC standards.
Advantages	Strong fog penetration, low initial cost, mature technology.	Energy-saving (50%-70%), long lifespan, good color rendering.
Disadvantages	Low energy efficiency, flickering, slow start-up, contains mercury pollution.	High initial cost, poor fog penetration, high heat dissipation requirements.

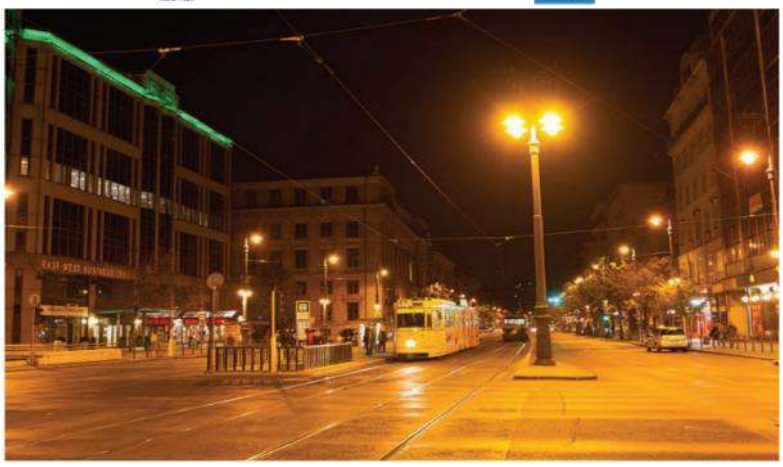


Figure 6. 27. Effect Drawing of High-pressure Sodium Lamp

Figure 6. 28. Effect Drawing of LED lamp

In summary, high-pressure sodium lamps are suitable for scenarios requiring high fog penetration (such as highways), but they have low energy efficiency and high maintenance costs. LED lamp sources offer comprehensive advantages and are suitable for urban roads, commercial areas, and other scenarios with high requirements for light quality and energy efficiency. Considering the specific conditions of this project, high-efficiency LED lamps are adopted as the light source in the design.

The luminous flux of LED streetlamps is not less than 130 lm/W, with a surface temperature ≤100°C, a color temperature of 3000K to 5000K, and a light distribution curve following the butterfly-type luminous intensity. Each branch circuit of the LED streetlamps is protected by a fuse, meaning a fuse shall be installed on the phase line of each lamp, positioned on the incoming side of the LED lamp.

3) Lamp poles

The dimensions of the lamp poles are Φ50×133×219, with a wall thickness ≥3.5 mm. The structure adopts a tapered flange pole, with a foundation size of 150×80×60. The material of

lamp poles can be selected from weathering steel (no coating required), hot-dip galvanized steel (compliant with ISO 1461 standards), hot-dip galvanized iron (compliant with BS EN ISO 1461 international standards), ordinary steel (requiring anti-corrosion coating treatment as per standards). If ordinary steel is used, anti-corrosion spray treatment is mandatory, and mixing different colors is prohibited. This project selects and uses light gray (RAL 7035, RGB 197, 199, 196).

4) Streetlamp layout plan

For a 60-meter-wide road cross-section, two lighting schemes can be adopted. The first scheme involves symmetrically installing streetlamps on both sides of the main road, while the second scheme involves installing a single streetlamp in the central median strip of the main road. A comparison of the two schemes shows that while the lighting effects are the same, the second scheme saves one lamp pole and reduces the corresponding cable compared to the first scheme. Therefore, the second scheme is recommended.

For a 45-meter-wide road cross-section in bridge form, two lighting schemes can be adopted. The first scheme involves installing a single streetlamp on the central crash barrier of the main road, while the second scheme involves symmetrically installing streetlamps on both sides of the main road crash barriers. A comparison of the two schemes shows that while the lighting effects are the same, the first scheme requires a lamp pole height of 15 meters to meet the requirements, which is relatively tall and less aesthetically pleasing. The second scheme, with streetlamps symmetrically installed on both sides of the main road crash barriers, effectively outlines the bridge's profiles on both sides at night, providing excellent guidance and enhancing driving safety on the bridge. Therefore, the second scheme is recommended.

Based on the 2 standard road cross-sections, simulation calculations using DIALux 4.13 confirm that the road surface luminance, illuminance, uniformity, and other metrics all meet specified lighting standard values outlined in General Technical Requirements for Road and Street Lighting in Cities, Towns, and Other Settlements MNS 6846:2020. For specific numerical values, please refer to the DIALux simulation results and drawings.

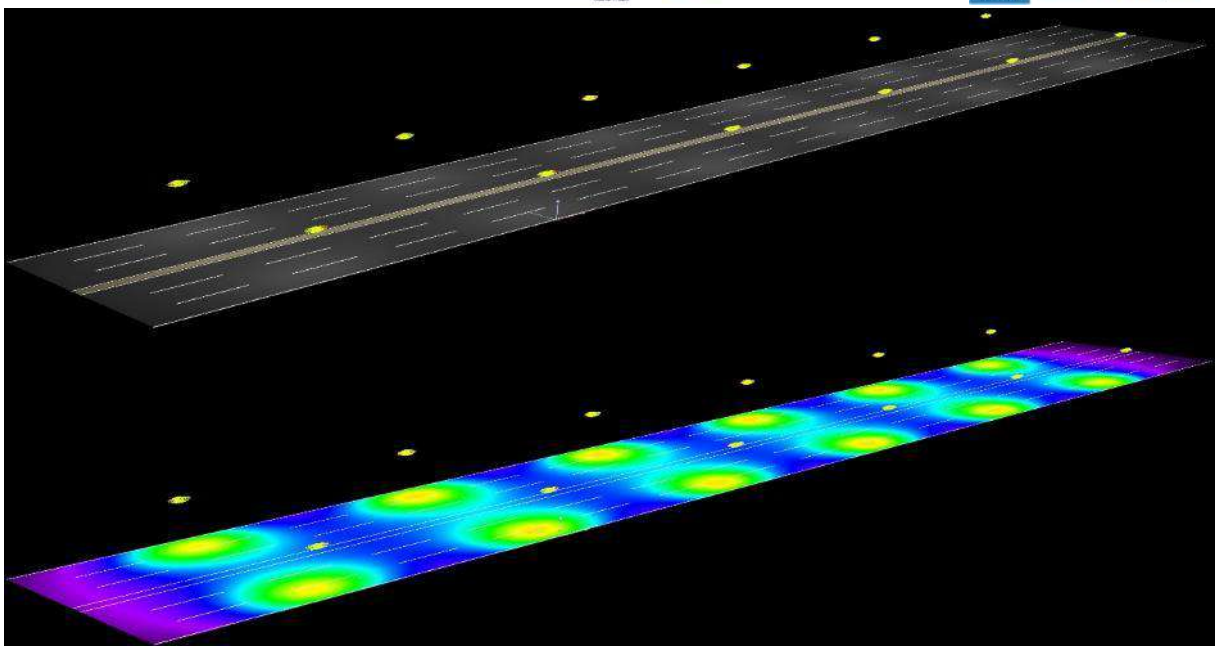


Figure 6. 29. DIALux Simulation of a 60-meter-wide Road

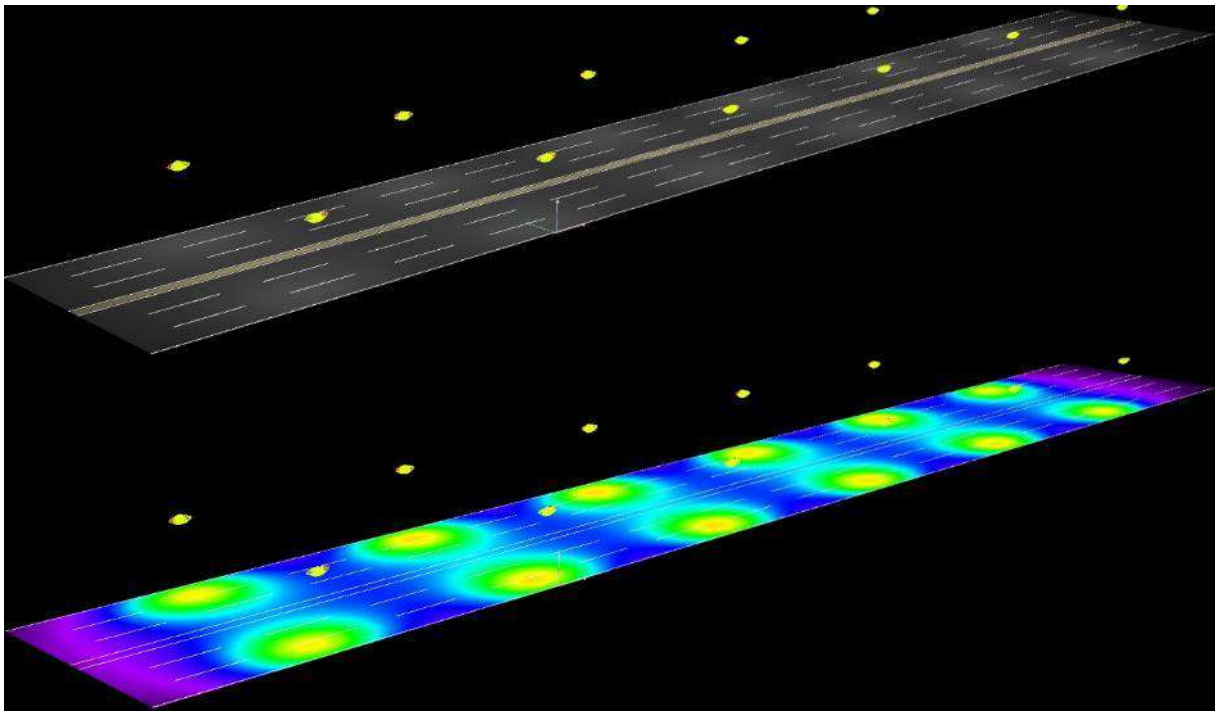


Figure 6. 30. DIALux Simulation of the Overpass Section on a 45-meter-wide Road

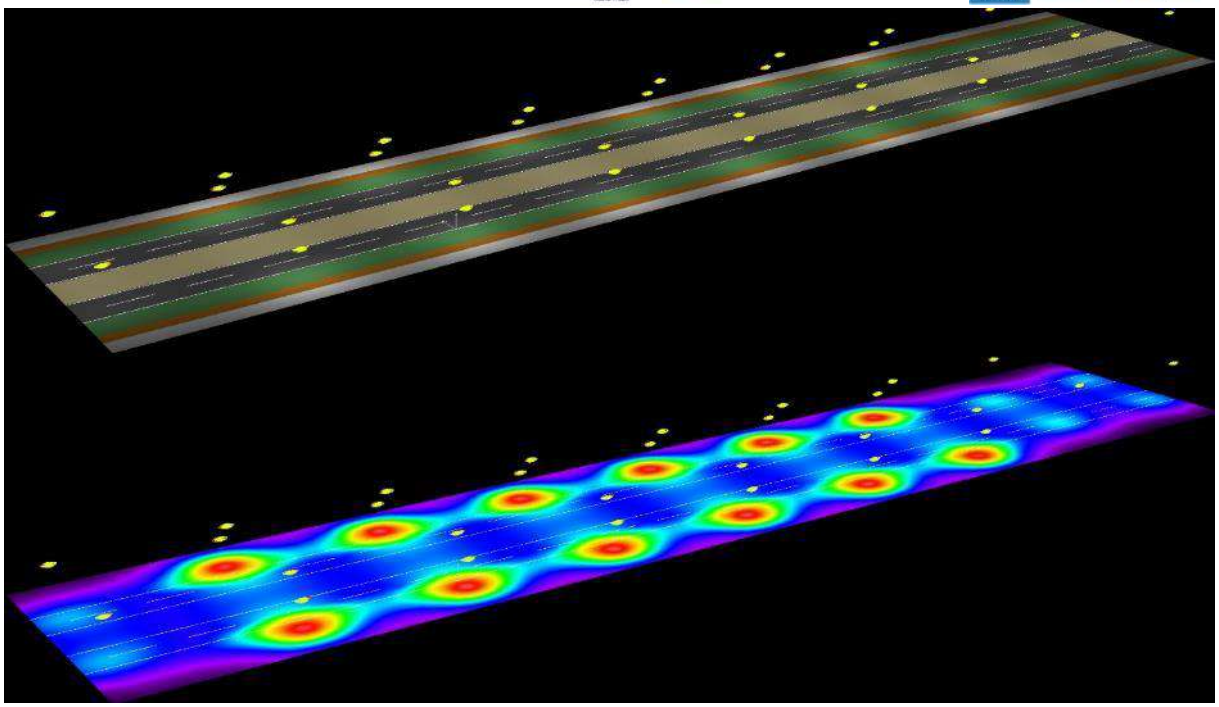


Figure 6. 31. DIALux Simulation of the Side Road, Non-motorway, and Sidewalk Sections on a 45-meter-wide Road

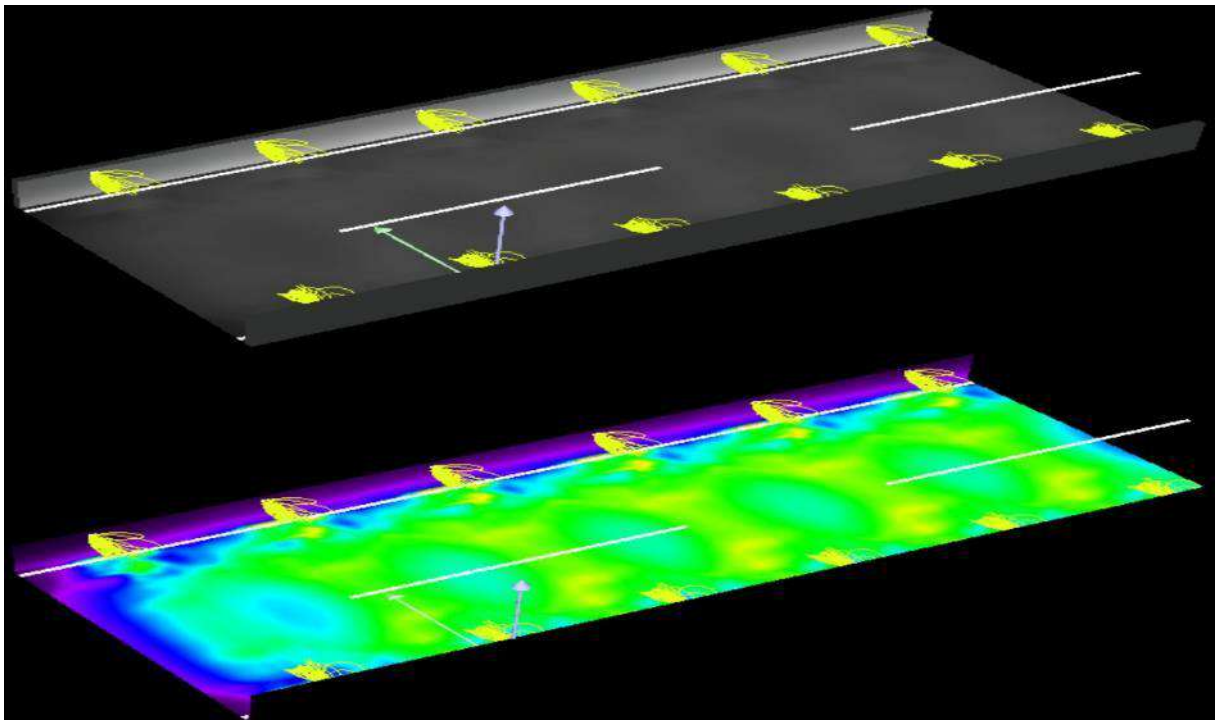


Figure 6. 32. DIALux Simulation of a Typical Ramp

Based on the simulation results, the streetlamp layout plan is as follows:

① Streetlamp layout plan on road section 1 (60m-wide road lighting cross-section): For motorized vehicle lane: 10m single-pole double-arm lamps installed in the central median strip, with pole centers 1.75m from curb stones. Lamps equipped with 100W+100W LED lamps, 15°

elevation angle, 1.5m arm length, 10m mounting height, and approximately 30m spacing. For side road, non-motorway, and sidewalk: 8m single-pole double-arm lamps symmetrically arranged on both sides of facility strips, with pole centers 0.75m from curb stones. Lamps equipped with 65W+20W LED lamps, 10° elevation angle, 1.5m arm length, 8m mounting height, and 30m spacing.

② Streetlamp layout plan on road section 2 (45m-wide road lighting cross-section):

For motorized vehicle lane on an overpass: 10m single-pole single-arm lamps symmetrically arranged on crash barrier locations (foundations cast integrally with the bridge structure). Lamps equipped with 100W LED lamp, 15° elevation angle, 1.5m arm length, 10m mounting height, and 30m spacing.

For ground non-motorway and sidewalk: 8m single-pole single-arm lamps symmetrically arranged on side strips, with pole centers 0.5m from curb stones. Lamps equipped with 70W LED lamp, 15° elevation angle, 1.5m arm length, 8m mounting height, and 30m spacing.

For ground side road: ceiling lamp installed on bridge undersides. Lamps equipped with 80W LED lamp, 15° elevation angle, 1.5m arm length, 8-13m mounting height, and 30m spacing.

③ Transversal layout plan of lamps on typical ramp: For ramp lane, low-level lamps embedded symmetrically in crash barriers on both sides, 1.2m mounting height, equipped with 5W LED lamps, 0° elevation angle, and 4m spacing.

③ Transversal layout plan of lamps on typical ramp: For ramp lane, low-level lamps embedded symmetrically in crash barriers on both sides, 1.2m mounting height, equipped with 5W LED lamps, 0° elevation angle

④ Enhanced lighting at intersections: Install 15-meter high poles with 3×300W LED lamp sources at the intersections of this road and the arterial road; install 13-meter high poles with 2×300W LED lamp sources at intersections with other grade roads.

(7) Power supply and distribution system for lighting

The lighting power load grade for this project is designed as a Class III load. Considering factors such as voltage loss due to long-distance low-voltage power cable transmission and low-temperature effects, fuse sensitivity verification, the economic efficiency of power supply and distribution system, and reserved power loads (e.g., landscape lighting, traffic monitoring equipment, bus stops, toll stations, etc.), The maximum power supply radius for this project is designed at 650 meters taking into account factors such as reliability and investment. Accordingly, an 80 kVA box substation is installed every 1,300 meters, totaling 18 substations along the entire route.

The box substations are located on the outer side of sidewalks or at road intersections that do not obstruct traffic visibility. The high-voltage incoming line operates at 10 kV, sourced from

the nearby urban power supply network. The box substation includes high-voltage incoming lines and distribution equipment, transformers, low-voltage distribution equipment, lighting control units, and electricity metering devices.

The load capacity of the box substations covers landscape lighting (5 kW), traffic monitoring (5 kW), toll stations (5 kW), and bus stops power consumption (5 kW) within their supply range. The transformer load rate is maintained at approximately 70%. The lighting load estimation table and the basic information table for the box substations are as follows:

Table 6. 21. Configuration Table of Lighting Box substation

No.	Box substation Number	Location	Power Supply Range	Power Supply Radius (m)	Lighting Load (kW)	Reserved Load (kW)	Installed Power (kW)	Box substation Capacity (kVA)	Load Rate
1	TM01	K0+620	K0+000~ K1+240	620	24.7	25	49.7	80	69.0%
2	TM02	K1+830	K1+240~ K2+480	650	27	25	52	80	72.2%
3	TM03	K3+100	K2+480~ K3+720	620	19	25	44	80	61.1%
4	TM04	K4+340	K3+720~ K4+960	620	26.34	25	51.34	80	71.3%
5	TM05	K5+580	K4+960~ K6+200	620	19.8	25	44.8	80	62.2%
6	TM06	K6+820	K6+200~ K7+440	620	26.42	25	51.42	80	71.4%
7	TM07	K8+085	K7+440~ K8+730	645	26.91	25	51.91	80	72.1%
8	TM08	K11+440	K10+810~ K12+070	630	26.91	25	51.91	80	72.1%
9	TM09	K12+700	K12+070~ K13+330	630	23.8	25	48.8	80	67.8%
10	TM10	K13+960	K13+330~ K14+590	630	28.35	25	53.35	80	74.1%
11	TM11	K15+220	K14+590~ K15+850	630	18.83	25	43.83	80	60.9%
12	TM12	K16+480	K15+850~ K17+110	630	15.54	25	40.54	80	56.3%
13	TM13	K17+740	K17+110~ K18+370	630	15.54	25	40.54	80	56.3%
14	TM14	K19+000	K18+370~ K19+630	630	15.54	25	40.54	80	56.3%
15	TM15	K20+260	K19+630~ K20+890	630	21.49	25	46.49	80	64.6%
16	TM16	K21+520	K20+890~ K22+150	630	23.67	25	48.67	80	67.6%
17	TM17	K22+800	K22+150~ K23+450	650	20.02	25	45.02	80	62.5%
18	TM18	K24+100	K23+450~ K24+750	650	24.68	25	49.68	80	69.0%

① Protection level of the outdoor box substation shall not be lower than IP54.

② Reactive power compensation: The power factor of LED lamps shall be no less than 0.9.

③ Power metering: Active energy meters and reactive energy meters shall be installed at the low-voltage main incoming line of the box substation. Separate metering shall be provided

for landscape lighting, traffic monitoring, toll stations, bus stops power consumption, etc.

2) Laying of lighting power supply pipeline

① Cable selection and laying method

Considering factors such as streetlamps load, long-distance power transmission, voltage loss, and low-temperature effects, the main supply lines for road lighting shall use YJV-0.6/1kV-5x25mm^2 and YJV-0.6/1kV-5x16mm^2 cables installed through cable protective tubes.

② Cable burial depth shall be no less than 1.0 meters below ground surface when installed under sidewalks and median strips, with PVC φ100 protective tubes. For installation under roadways, the burial depth shall be no less than 1.2 meters below ground surface with SC100 hot-dip galvanized steel protective tubes.

③ Cables passing through streets, intersections, and at transformer entry/exit points shall be protected by SC100 hot-dip galvanized steel pipes, which must undergo anti-corrosion treatment.

④ The branch wires from the main supply line to the overhead lamps shall adopt BVV-(3×2.5) insulated conductors. To ensure balanced three-phase load distribution, the lamps shall be connected in the phase sequence of L1, L2, L3.

⑤ The connectors for streetlamp fixtures shall be completed inside the burglar-proof door of each streetlamp. A 0.5-meter margin shall be reserved for cables inside the burglar-proof door of every streetlamp.

⑥ For lighting fixtures installed on side roads beneath bridges, the cables shall be installed along the underside of the bridge using PVCφ50 hot-dip galvanized steel pipes.

⑦ For lighting fixtures installed on the bridge and low-level ramp lamps, the cables shall be installed inside the crash barriers using PVCφ50 hot-dip galvanized steel pipes.

(8) Lighting control system

Urban road lighting is an essential component of public infrastructure. With the increasing number of streetlamps on urban roads and rising energy consumption, power supply has become increasingly strained. Meanwhile, the maintenance of urban lighting systems and the high maintenance costs (such as manual control and streetlamp inspections) pose significant challenges for city management. Authorities require more efficient management and energy-saving solutions to promote scientific urban lighting management and green energy conservation.

Currently, streetlamp illumination control relies on traditional manual and automatic methods. Automatic control adopts devices such as longitude and latitude time controllers and photoswitches. However, this approach lacks flexibility, cannot provide real-time status updates for every streetlamps, and fails to enable single-lamp control, monitoring, or brightness

adjustment based on actual conditions, thereby limiting effective energy savings. Such monitoring and management methods for urban lighting remain relatively simplistic and inefficient, resulting in subpar service quality and energy-saving performance, which no longer meet the demands of modern urban lighting systems.

The streetlamps along the entire route of this project adopt Power Line Communication (PLC) technology to achieve intelligent single-lamp monitoring. The control system consists of upper-computer management software, centralized controllers, and terminal controllers (single-lamp controllers and dual-lamp controllers). The centralized controllers are installed in the low-voltage distribution cabinets of supply transformers, while the terminal controllers are installed on the lighting terminals. The schematic diagram of system composition is as follow.

Figure 6. 33. Schematic Diagram of Power Line Carrier Streetlamp Control System

The centralized controller communicates with the monitoring center via wireless communication networks such as GPRS/CDMA/WCDMA/4G, and interacts with terminal controllers through power line carrier communication (PLC). By receiving, executing, and forwarding commands from the upper-computer management software, the centralized controller controls each terminal controller to manage the switching and dimming of every streetlamps. This enables intelligent control and refined management of streetlamps, maximizing energy savings. Additionally, the centralized controller can monitor the real-time working status of lamps and provide fault alarms through network monitor terminal controllers. Furthermore, the system can be expanded to include additional functions such as road environment monitoring and alarming assistance as needed. For switching lamp control of streetlamp circuit, the master control mode relies on the intelligent monitoring terminal installed in the low-voltage distribution room of the box substation, with photoelectric control and manual

operation as backup. After configuring local longitude, latitude, and date, the intelligent monitoring terminal operates automatically, using a database-supported control output to switch streetlamps on and off based on daily sunrise and sunset times, adjusted by preset advance or delay times. The streetlamp's matching driver power is connected to the single-lamp controller, which adopts PWM signals to control the driver power's output, enabling remote on/off control and dimming.

The centralized controller for the entire road lighting system is integrated into the cloud monitoring center (including streetlamp monitoring servers, computers, mobile devices, etc.) for unified control, where conditions permit, a monitoring workstation can be established within the streetlamp management department. The streetlamp control center communicates with intelligent monitoring terminals via wireless methods such as GPRS, CDMA, or 4G, while the intelligent monitoring terminals and the controlled streetlamps can adopt power line carrier communication, eliminating the need for communication control wiring. This enables intelligent management of the road lighting system from the monitoring center or via authorized mobile apps and system installed on administrators' mobile phones.

The lighting monitoring terminal adopts Digital Signal Processing (DSP) technology to collect, compute, process, store, and display data such as current, voltage, active power, and power factor in field through AC sampling. It also executes data transmission and lighting control commands from the monitoring center. In the event of faults, theft, or data exceeding limits, the system can actively trigger alarms to ensure the safe and reliable operation of the road lighting system. If communication is interrupted, it can automatically operate based on the stored latest switching schedule.

The system mainly has the following functions:

1) Automatic and Manual Remote Control Functions

The system can divide all monitoring terminals into several groups according to the lighting control requirements of different roads. Each group can be controlled using time control or a combination of time and light control for branch circuits and single lamp. Manual remote operations are also supported, such as switching branch circuits on/off or adjusting the switching status and brightness of single lamp or lamp assembly.

The monitoring center can automatically perform timing monitoring based on pre-set time intervals, or manually query and selectively check data from specific monitoring terminals at any time, including voltage, current, power, branch switch status, single lamp brightness, and switch status.

For energy-saving purposes, when traffic flow drops to 1/5 of peak levels, the streetlamp power is reduced by 30%; when traffic flow drops to 1/3 of peak levels, the streetlamp power is reduced by 50%; during late-night hours, streetlamps are turned off alternately (while ensuring

compliance with uniformity requirements).

Figure 6. 34. Effect Drawing of Single-Lamp Controller Every Other Light On

2) Abnormal inspection data alarm

When the monitoring terminal initiates an alarm or the monitoring center detects abnormal data during patrol inspections, the monitoring center will automatically trigger a voice alarm, save the data to disk, display the corresponding location and fault type on the map, and forward the information to the relevant personnel's mobile phones.

3) Monitoring equipment theft alarm

If the monitoring terminal equipment is tampered with or stolen, the monitoring center's computer will immediately trigger an automatic voice alarm, save the data to disk, display the corresponding location and equipment type on the map, and forward the information to the relevant personnel's mobile phones.

Alarm contents include: lamps on during the day, lamps off at night, bulb failure, ballast failure, controller failure, distribution box door opened, voltage/current exceeding limits, terminal power outage, circuit failure, cable theft or human-induced damage,

4) The control system can also automatically calculate the lighting rate, query and print reports, and support remote real-time query and control functions.

(9) Grounding system

1) This project adopts a TN-S grounding system, and the neutral point of the distribution transformer shall be directly grounded.

2) The grounding main line (PE line) introduced to the streetlamps shall be provided with multiple grounding. The multiple grounding device shall adopt hot-dip galvanized angle steel

grounding electrodes L50×50×5 l=2.5m, with the top buried at a depth of 1.1m, which shall be welded to -40x4 hot-dip galvanized flat steel and streetlamp foundation through no fewer than two main reinforcements lamp-pole anchor bolts to form an integrated connection. The grounding resistance shall be ≤10Ω (≤4Ω when soil moisture > 30%). If the measured grounding resistance does not meet the requirement, artificial grounding electrodes shall be installed.

3) The box substation shall be ring-type grounded. The grounding device shall adopt hot-dip galvanized angle steel grounding electrodes L50×5 l=2.5m, with the top buried at a depth of 1.1m and a horizontal spacing of 5m. The grounding electrodes is connected with -40x4 hot-dip galvanized flat steel with the measured grounding resistance less than 4Ω.

(10) Energy Saving

In the hardware design of road lighting systems, full consideration is given to energy management and efficiency improvement requirements, ensuring energy-efficient design and creating favorable conditions for system energy-saving management. A combination of centralized and decentralized control is adopted for the lighting distribution and control system. The centralized controller can automatically adjust lighting levels based on pre-set user programs or real-time dimming strategies from the control center. To achieve energy-saving management, all urban streetlamps are integrated under the unified control of the streetlamp monitoring center. The lighting design primarily adopts the following technical measures to realize energy savings:

1) Select high-efficiency, energy-saving LED lamp sources and accessories with long service life. The overall lamp efficacy shall exceed 130 lm/W, with an efficiency of no less than 70%.

2) The corrected and compensated power factor of each LED lamp source set shall be no less than 0.9.

3) The design standards shall be scientifically and reasonably selected, suitable for local conditions, and comply with national codes and road design standards to achieve energy-efficient design.

4) Optimize cable cross-section selection to reduce initial investment, minimize line losses, and save operational management costs.

5) Adopt high-efficiency, energy-saving distribution transformers to significantly reduce technologic and load losses, addressing the outdated technology and high energy consumption of old transformers.

6) Select an advanced and rational intelligent lighting system to achieve scientific streetlamp management and green energy conservation.

(11) Application of Smart Streetlamp Technologies.

1) Smart Streetlamps

Smart streetlamps serve as the optimal entrance and service port for smart cities. With vast numbers and dense distribution, streetlamps are among the most intensive urban infrastructures, making them ideal for information collection and dissemination. In the future, Smart streetlamps will become a crucial source of Internet of Things (IoT) data. As an integral component of smart cities, Smart streetlamps enhance urban and municipal service capabilities and act as a key entrance, facilitating the implementation of smart municipal and urban initiatives in the realm of urban lighting.

Smart streetlamps gather urban data through integrated sensors, which will generate the big data required for smart cities in the future. This data is uploaded to the cloud, where it forms a big data. It can interact with intragovernmental traffic systems, policing administration systems, financial management systems, and purchase management systems, providing diverse data support for big data applications in smart cities. After analysis and processing, the data can be displayed on LED displays mounted on the streetlamps, offering various services to citizens.

Smart streetlamps can leverage LED lamps and intelligent control platforms to integrate WIFI base stations, cameras, infrared sensors, radar, electronic displays, charging piles, and other devices into an information carrier, which enables data monitoring, environmental monitoring, vehicle surveillance, security monitoring, lamp-pole display screens and underground pipe network monitoring, urban flood disaster warnings, regional noise monitoring, and emergency alarms for citizens.

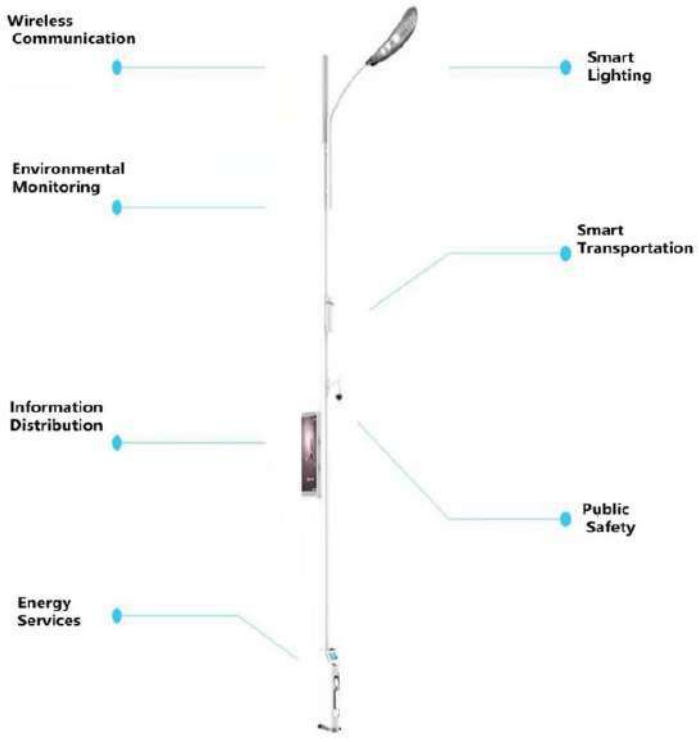


Figure 6. 35. Schematic Diagram of Smart Streetlamps

2) Existing Issues

Returning to the basic functions of streetlamps, the focus should be on road lighting and intelligent lighting, i.e., how to collect operational management data through intelligent control to achieve adaptive lighting and energy savings, thereby ensuring traffic safety and maintaining normal functional lighting for roads. Additional functional vectors should only be considered secondarily.

① Functional configuration issues

On congested urban roads, it is inappropriate to install charging piles. Nor is it necessary to install traffic monitoring, pollution monitoring, air quality monitoring, meteorology, medical assistance, and other functions on every streetlamp pole. It is necessary to tailor solutions based on the unique characteristics, application environment, and scope of each function, taking into account practical circumstances, rather than indiscriminately promoting large and comprehensive yet impractical functions. In reality, such functions are often flashy but of little practical value.

② Interdepartmental coordination issues. Currently, urban lighting management is handled by specialized administrative agencies with clearly defined responsibilities. However, many functions of multifunctional lamp-poles fall under the jurisdiction of various sectors such as public security, transportation, telecommunications, and healthcare. This involves the interests, daily operations, maintenance and management of multiple departments. It is often difficult for operators and the involved departments to reach a consensus on business coordination. A comprehensive solution is essential to address this challenge. However, many functions of multifunctional lamp-poles fall under the jurisdiction of various sectors such as public security, transportation, telecommunications, and healthcare. This involves the interests, daily operations, maintenance and management of multiple departments. It is often difficult for operators and the involved departments to reach a consensus on business coordination. A comprehensive solution is essential to address this challenge.

③ Post-maintenance issues:

Due to the uniqueness of the streetlamp profession, existing maintenance teams are only equipped to handle conventional streetlamps and lack the necessary maintenance management experience for the upkeep of new intelligent streetlamps. Additionally, as road supporting facilities, streetlamps inevitably require repairs. Given that intelligent streetlamps incorporate multiple functions spanning various specialised fields, maintenance teams often struggle to respond promptly to unexpected malfunctions, potentially leading to safety hazards. These issues imperceptibly increase the difficulty of daily management and maintenance of streetlamps. In the long run, a dedicated maintenance team for intelligent streetlamps, or

outsourcing to a designated unit or third-party company for unified maintenance, would help reduce costs.

3) Recommendations

Given the substantial investment, complex functionalities, multiple involved departments, and challenges in post-maintenance associated with intelligent streetlamps, it is recommended to implement the project in phases.

First, focus on basic lighting by establishing a smart lighting system (already designed in this project).

Second, since the project includes reserved load, additional wireless WiFi systems and video surveillance systems can be added later without dismantling the lamp-poles, based on local conditions.

Finally, a comprehensive upgrade to achieve full smart streetlamp functionality can be implemented once conditions are mature.

(12) Others

All electrical equipment must comply with current Mongolian standards with advanced technology. Products that are officially banned by the state shall not be used. All products must operate reliably in ambient temperatures ranging from -40°C to 60°C and provide climate adaptability certification.

6.9. TELECOMMUNICATION PIPELINE ENGINEERING

(1) Design basis

1) Technical Specifications and Installation Standards for Communication Pipe Manhole Facilities MNS 6668:2017

2) Overall Plan of Ulaanbaatar until 2040

In addition to the project duty book and technical conditions provided by the road engineering.

(2) Technical standards

By the Overall Plan of Ulaanbaatar until 2040 and the Technical Specifications and Installation Standards for Communication Pipe Manhole Facilities MNS 6668:2017, the capacity of telecommunication network channel facilities shall be designed based on a (6+0) configuration, adopting a 3x2 arrangement of six Φ110mm pipe systems.

(3) Design principles and objectives

1) Design principles

① Normative and compliance principles

Strictly adhere to relevant Mongolian standards and comply with the requirements of the municipal road master planning and underground pipeline special planning. Ensure pipeline

routing, burial depth, spacing, and other parameters meet mandatory technical specifications, maintaining a safe distance from existing pipelines.

② Prospective and scalability principles

Based on the "moderately advanced" concept, a redundancy of 20%-30% in pore capacity is reserved to accommodate future access demands such as 5G base stations, IoT devices, and smart lamp-poles. Utilise modular design to facilitate later expansion and upgrades, adapting to technology evolutions like Fibre to the Home (FTTH) and quintillion optical networks.

③ Coordinated and harmonised principles

Conduct synchronous design and construction with the New Ring Road engineering, coordinating spatial arrangements for power, water supply, drainage, and gas pipelines to avoid conflicts and reduce secondary excavation costs.

④ Economic and Intensive Principles

Compare and select pipe materials to achieve the highest cost-performance ratio while ensuring safety and applicability.

⑤ Safety and reliability principles

Ensure compliance with compressive strength and cold resistance requirements. Reinforce critical nodes with steel pipes or even concrete encapsulation—guarantee leak-proof requirements for pipeline joints.

2) Design objectives

Build modern communication infrastructures

Establish an optical network arterial road covering the entire road section, providing a physical carrier for intelligent transportation, e-government, and other applications to support digital economic development.

Achieve efficient utilisation of municipal resources.

Through the "unified planning, one-time construction" strategy, integrate Ulaanbaatar communication demands, reduce repeated road excavations, and extend pipeline service life.

c. Meet public service needs. Ensure Fibre to the Home (FTTH) coverage in new residential areas and commercial complexes, supporting civilian applications and bridging the "digital divide."

(4) Project overview and scope

The road grade of this project is a Grade I arterial road, with sidewalks classified as Grade II. The total length of the main road is 24,793 meters, including 13679 meters of road section, 9,034 meters of bridges, and 2,080 meters of tunnels. The road surface is asphalt pavement, with a design speed of 100 km/h for the main road (80 km/h in local sections). The main road is a six-lane dual carriageway. The telecommunication pipeline design for this project includes road

sections, bridge sections, and tunnel sections.

(5) Design content

1) Telecommunication pipelines;

2) Telecommunication wells.

6.9.1. Capacity of Telecommunication Facilities

The capacity of information and communication telecommunication facilities is planned to include six pipes of Φ110mm (denoted as 6+0), in compliance with MNS 6668:2017 Technical Specifications and Installation Requirements for Communication Duct Telecommunication Facilities and Ulaanbaatar's Master Plan through 2040.

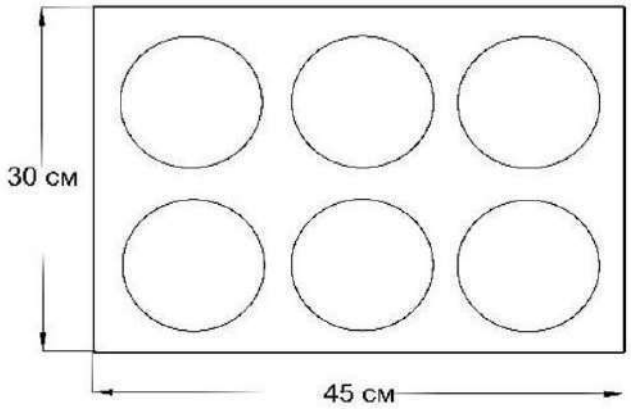


Figure 6. 36. Schematic Diagram of Communication Pipeline Pipes

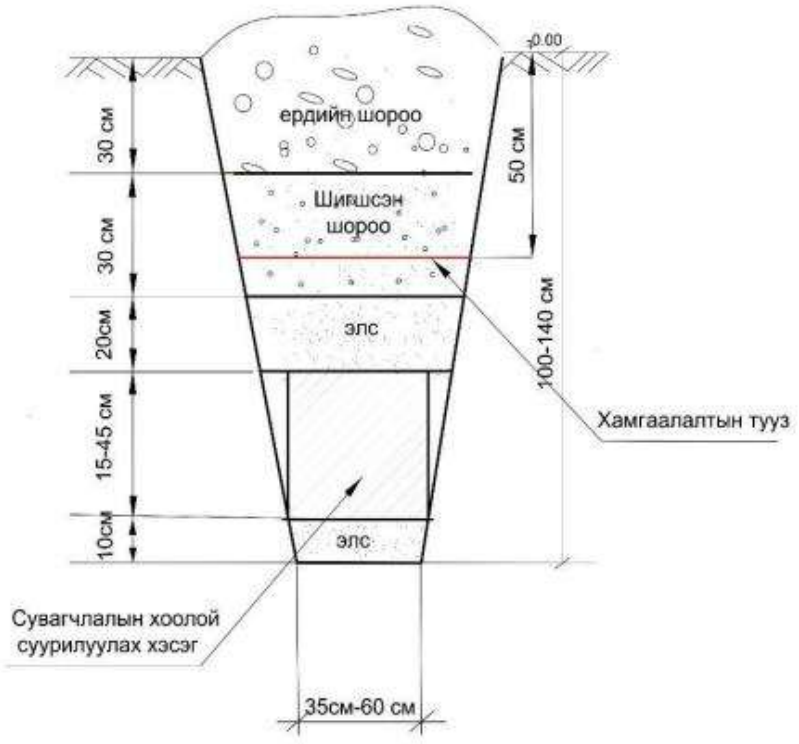


Figure 6. 37. Cross-Section of Planned Telecommunications Under Main Road

Compliance with the following criteria from MNS 6668:2017 Technical Specifications and Installation Requirements for Communication Duct Telecommunication Facilities is mandatory:

9.3 For new highway construction, expansion, or major repairs within urban or rural areas, cross-connections to the road must be installed every 2 km. /According to the technical specifications of Information and Communication Network LLC, cross-cutting is required every 1 kilometer/

9.5 When installing telecommunication facilities alongside highways, the number of pipes must be at least 6.

The planned bridge section of the new ring road must adhere to MNS 6597:2021 General Requirements for Installing Communication Cable Pipelines Across Highways, Railways, and Through Bridge Structures.

13.1. Communication cable pipelines must be installed within bridge structures using one of the following two methods: Specifically:

a) Installation via telecommunication ducts placed beneath a concrete slab, routed through the bridge's pedestrian walkway or the median of curved road segments

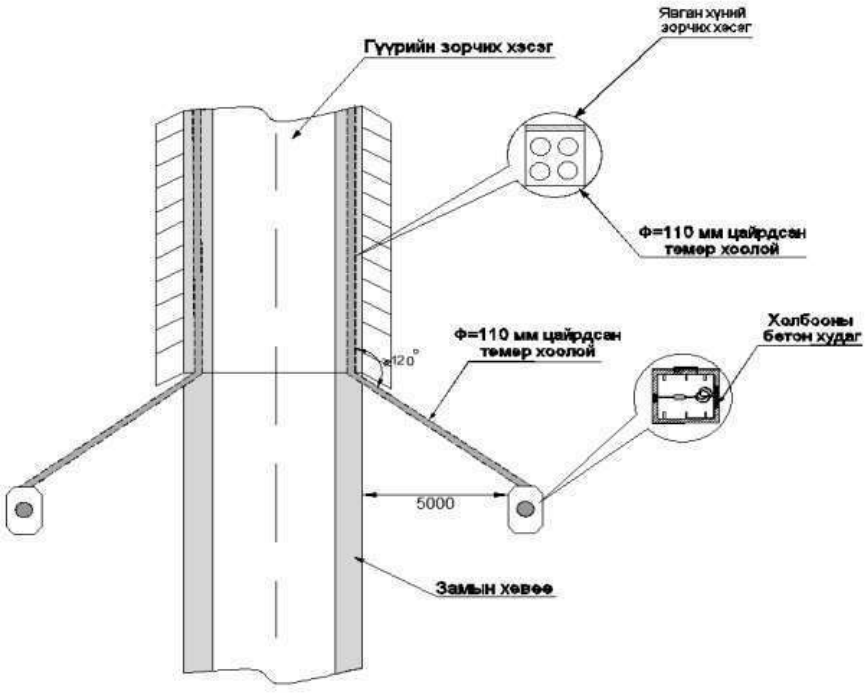


Figure 6. 38. Schematic Diagram of Telecommunication Duct Installation Under the Bridge's Pedestrian Curved Road

b) Installation through a single pre-embedded pipe within the bridge structure

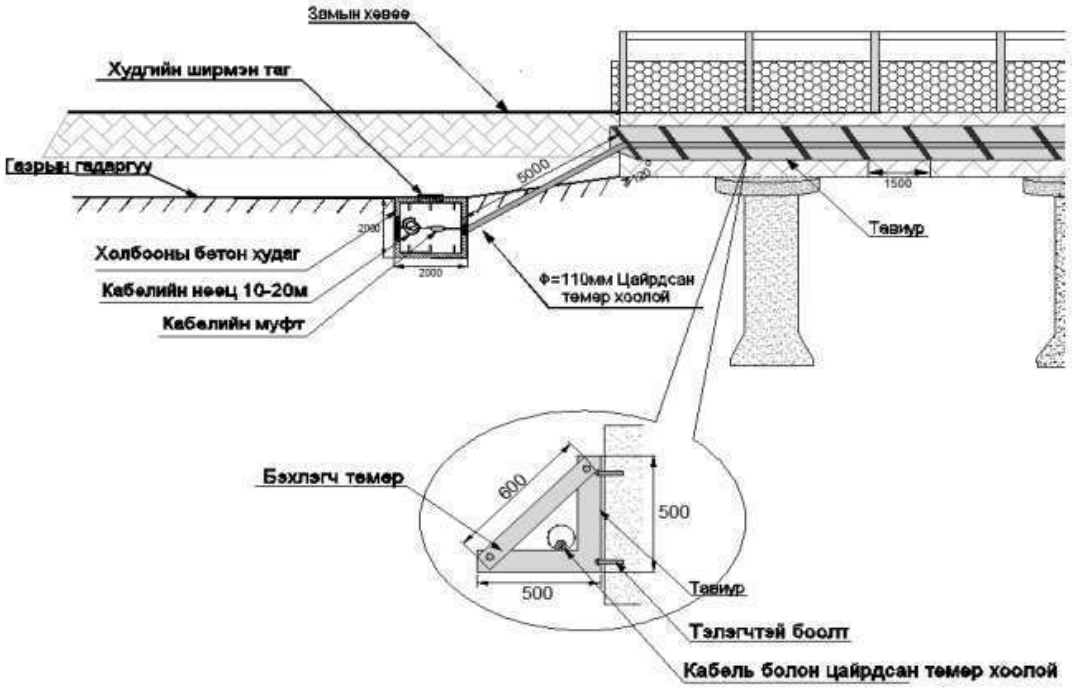
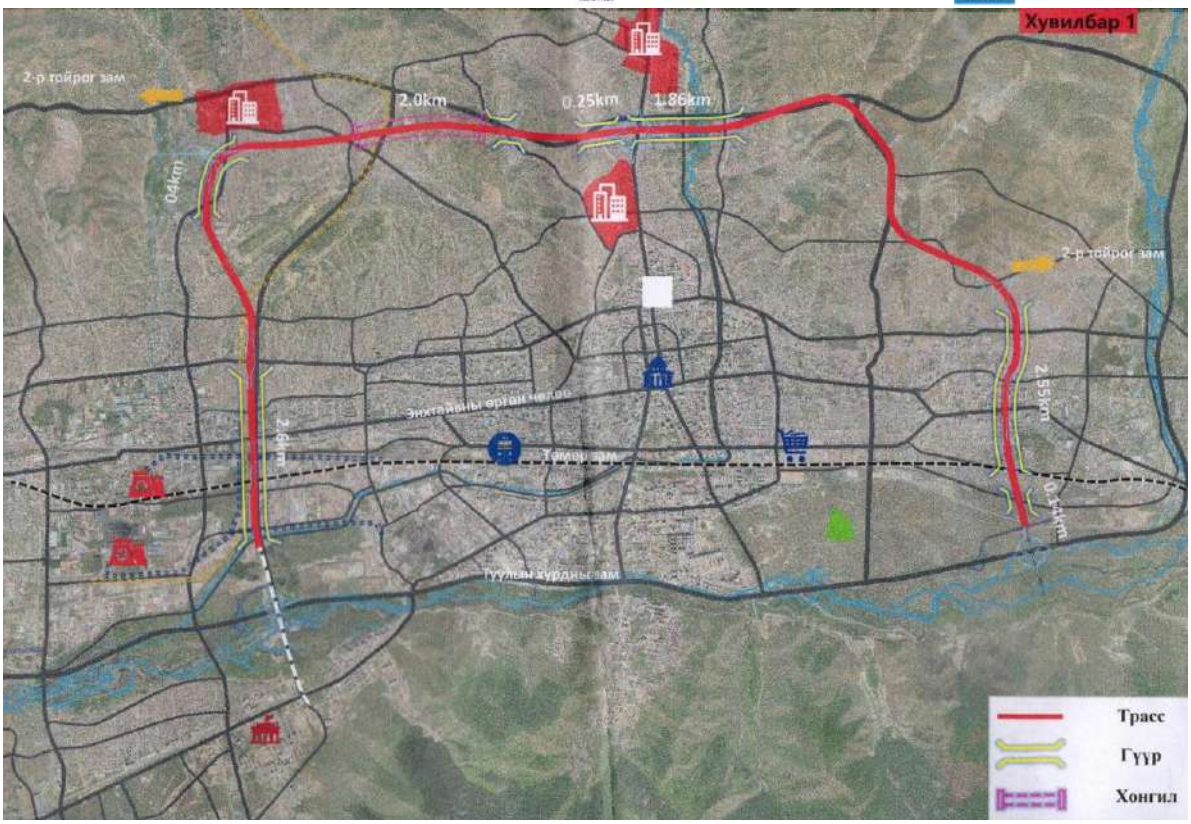


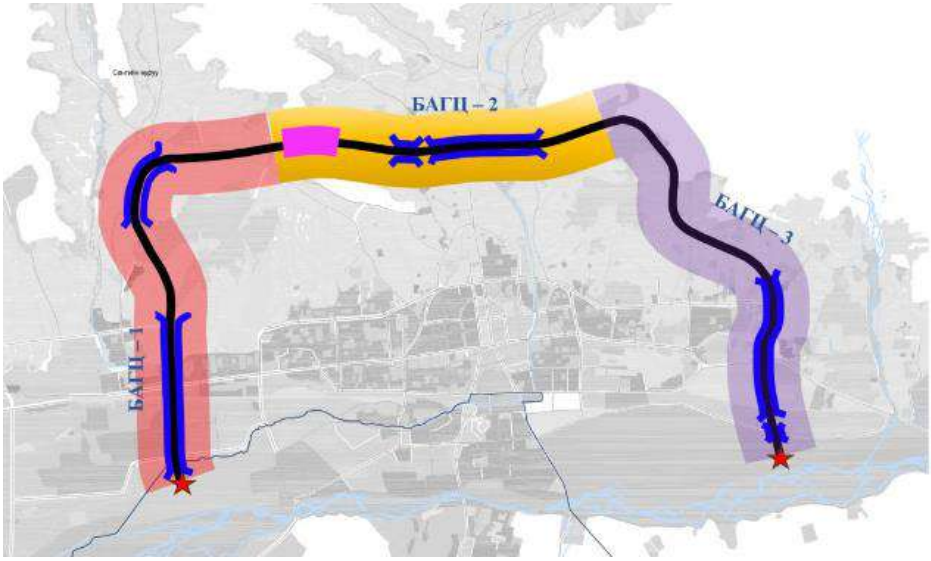
Figure 6. 39. Schematic Diagram of Installation Through a Single Pre-Embedded Pipe in Bridge Structures

6.9.2. Highway Planning

The road length is 24.793km, the length f the subgrade section is 13.679km, the length of the bridge section is 9.034km/5pcs, the length of the tunnel section is 2.08km, and the entire line is equipped with 7 interchanges and 12 separated interchanges.



The total length of the 1st standard section is 8.6 km, including 4.571 km of ground road section and 4.029 km of bridge section; the total length of the 2nd standard section is 6.900 km, including 2.505 km of ground road section, 2.315 km of bridge section and 2.08 km of tunnel section; the total length of the 3rd section is 9.293 km, including 6.603 km of ground road section and 2.690 km of bridge section.



The planned new ring road includes the following types of infrastructure:

(1) 60-meter-wide highway

(2) Multi-level highway

(3) Tunnel

(4) Bridge

For the planned 60-meter-wide highway segment, (6+0) capacity telecommunication ducts must be installed beneath the main road, with interconnections and road cross-connections required every 1 km.

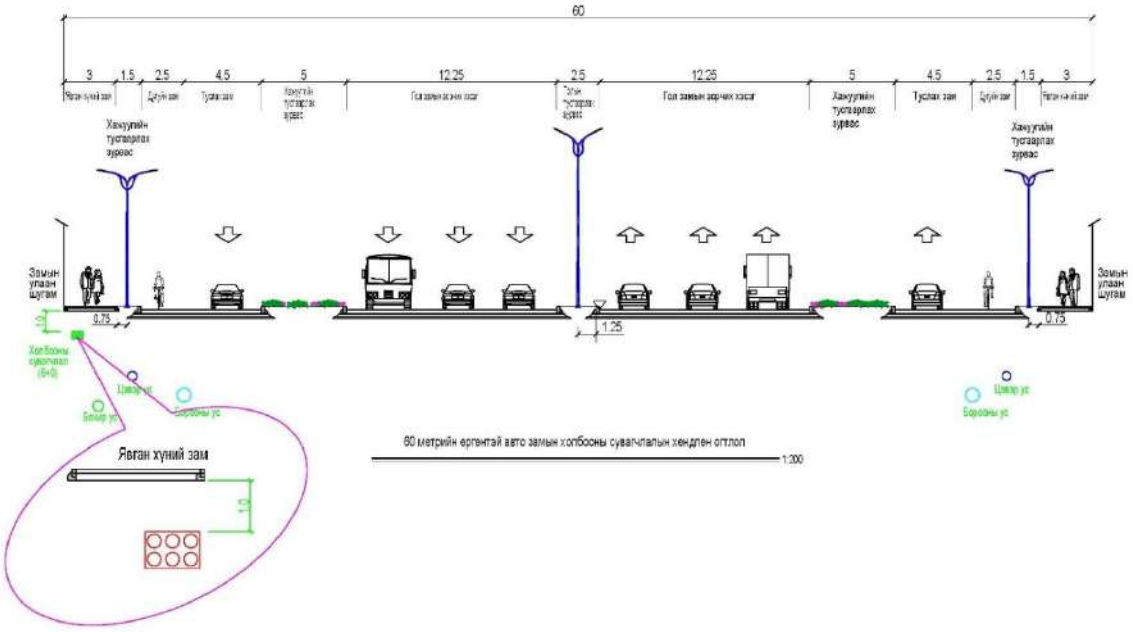


Figure 6. 40. Cross-Section of 60-Meter-Wide Road

For the multi-level highway segment, (6+0) capacity telecommunication ducts must be installed beneath the main road (adjacent to the lower-level highway), with interconnections and road cross-connections required every 1 km.

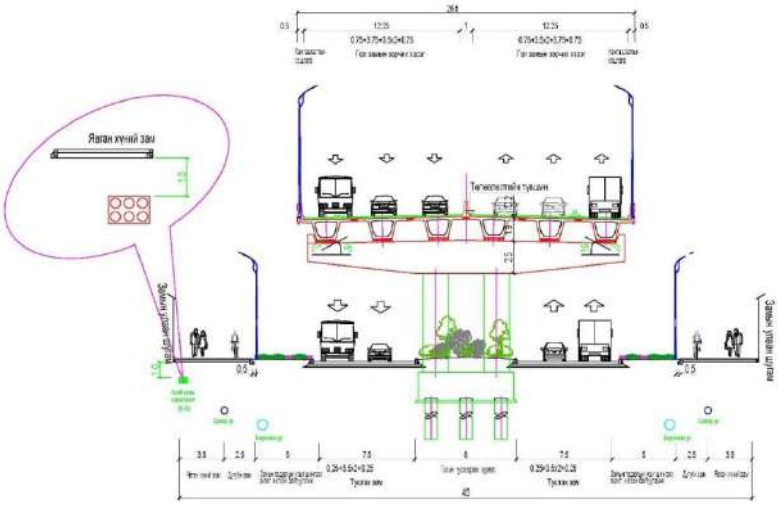
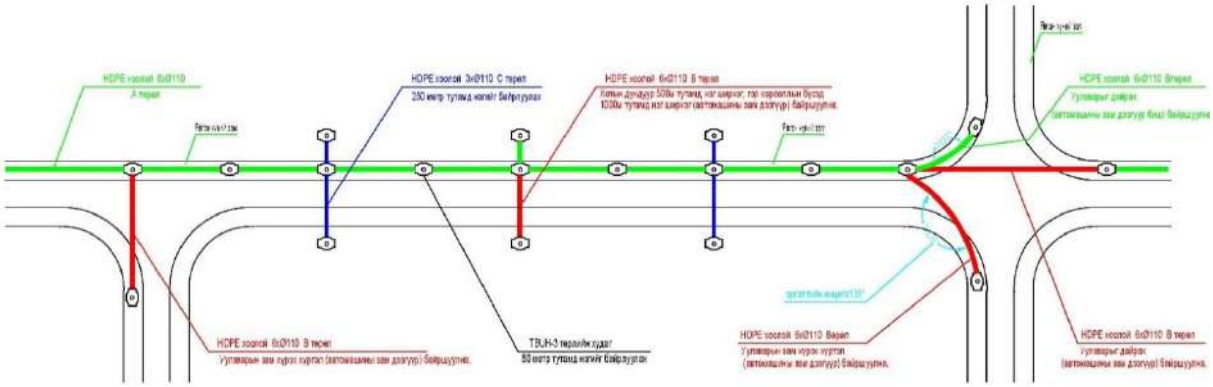


Figure 6. 41. Cross-Section of Multi-Level Road

A 2-km-long drainage system is planned for a segment of the new ring highway. As autonomous vehicles have entered the Mongolian market and demand for such vehicles is growing, the tunnel section must include a planned autonomous driving system.

As Mongolia currently lacks national standards or regulations for this system, international standards and norms must be adapted to Mongolia's specific conditions and formally approved.

Telecommunication ducts are categorized into three types: parallel to the highway, cross-connections, and interchange access points. Cross-connections to the highway are planned every 500 meters for central urban highways and every 1,000 meters in residential areas.



6.9.3. Planning of Tunnel Information and Communication Networks

Relevant Standards, Rules, and Regulations

International standards (e.g., ISO 26262, ISO 21448 - SOTIF, UNECE Regulation No. 157)

Tunnel safety standards (e.g., NFPA 502, PIARC guidelines)

Since GPS and other positioning systems typically fail to operate reliably inside tunnels, alternative technologies are necessary. In environments where positioning systems are inoperable, technologies like LiDAR (3D scanning), radar, and cameras are employed. Beyond fixed-line connections, next-generation 5G networks will form the fundamental infrastructure for advanced technologies like the IoT (Internet of Things), autonomous vehicles, and remote-controlled devices. In Mongolia, 5G trial stations have been operational since 2022, and as of now, Unitel Group's 5G network is deployed in the capital. Thus, implementing 5G networks in tunnel systems represents a technologically and economically viable solution.

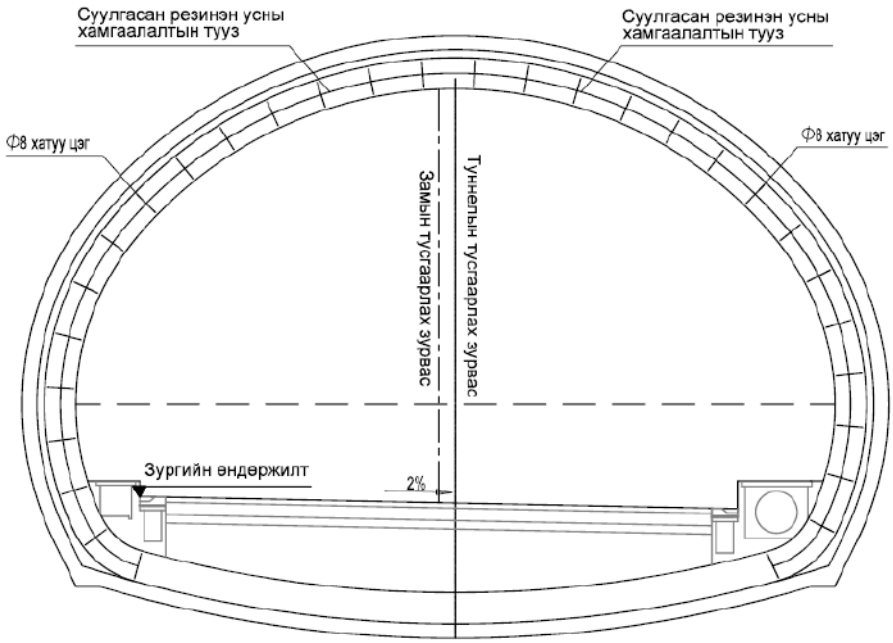


Figure 6. 42. Tunnel Cross-Section

Telecommunication ducts will be installed beneath the main road, adjacent to the sidewalk segment within the tunnel. Manholes will be positioned every 120 meters to facilitate cable installation.

6.9.4. Planning of Information and Communication Networks

The following components of information and communication networks are planned alongside the First Ring Road: Specifically:

(1) Pipeline networks requiring relocation, transfer, and protection

In an official letter dated June 9, 2025, from Information Communication Network LLC, it is specified that technical specifications for protecting and relocating communication duct telecommunication facilities must be secured during the design phase. Per the clarification from this entity, the planned ring road route intersects existing telecommunication facilities at 10 points and runs parallel for 900 meters at one location. Within the residential segment, a 2,000-meter aerial pipeline runs both perpendicularly and parallelly.

Costs for relocation, transfer, and protection works are estimated as follows: constructing new 6+0 telecommunication ducts (linked to the 60-meter-wide road) at 10 locations; relocating 20 cables from existing 4+0 ducts and 2,900 meters of aerial cables to the planned ducts. Parallel pipelines will be relocated and installed in newly built ducts.

Costs for relocation to ducts are calculated in accordance with Clause 4 of Regulation BD 81-106-16, which governs the use of reference values for unit capacities of buildings and structures. Costs for cable installation via telecommunication ducts in the communication

pipeline network segment are estimated using the reference price for installing 24-core fiber optic cables (FO-24).

Budget for Pipeline Network Relocation and Transfer Works

No.	Work Name	Capacity	Unit of Measurement	Quantity /m/	1m Budget Reference Value /million MNT/	Investment /million MNT/			
						Price Increase Coefficient	Excavation	Design Cost	Total
Communication Duct Telecommunication Facility									
1	Telecommunication Duct	6+0	m	600	0.1754	1.85	194.69	1.60	196.29
2	Cable Installation via Telecommunication Duct	FO-24	m	50900	0.0053	1.85	499.07	135.70	634.77
TOTAL							**693.77**	**137.30**	**831.07**

(2) Newly Planned Information and Communication Telecommunication Facilities

The new ring road project includes a total of 32 km of planned telecommunication facilities, with 11.1 km (Section 1), 8.9 km (Section 2), and 12 km (Section 3) allocated for 6+0 capacity telecommunication ducts.

No.	Type Name	Section 1	Section 2	Section 3	Total
1	Telecommunication Facilities Parallel to the Highway	56679	45475	61246	163400
2	Telecommunication Facilities Crossing the Highway	11100	8906	11994	32000
3	Communication Ducts /pieces/	104	83	112	299

6.9.5. Budget Epetnditure Estimate

Telecommunication facilities must be planned alongside the proposed ring road. Budget expenditure estimates, calculated in accordance with Regulation BD 81-106-16 (governing reference values for unit capacities of buildings and structures), include the construction of a communication pipeline network with (6+0) capacity main ducts and reinforced concrete ducts (Φ110mm).

The price index for engineering pipeline networks is set at 1.85, supplementary to the coefficients outlined in Order No. 44 (dated September 12, 2024) by the Capital City Construction, Building, and Land Management Authority.

The cost of design drawings is calculated using the reference prices for design work outlined in BD 81-16-20, supplemented by reference prices for design work involving information, communication pipeline networks, and their associated facilities.

No.	Work Name	Capacity	Unit of Measurement	Quantity /m/	1m Budget Reference Value /million MNT/	Investment /million MNT/			
						Price Increase Coefficient	Excavation	Design Cost	Total

Communication Duct Telecommunication Facility									
1	Section 1	6+0	m	11300	0.1754	1.85	3666.74	30.13	3696.86
2	Section 2	6+0	m	9000	0.1754	1.85	2920.41	23.99	2944.40
3	Section 3	6+0	m	12200	0.1754	1.85	3958.78	32.53	3991.30
TOTAL							**3958.78**	**32.53**	**3991.30**

When installing telecommunication ducts in tunnels, bridges, and similar structures, excavation and design costs for telecommunication facilities may vary based on the length of curved sections.

6.9.6. RFID Equipment

RFID (Radio Frequency Identification) is a technology that uses radio frequencies to identify objects. Passive RFID windshield tags are widely utilized in access control systems, including car parks and restricted entry points. A passive RFID tag is attached to the vehicle's window, with a unique ID number generated and stored in a database. This tag identifies vehicles in road traffic and is used for monitoring at car parks, toll collection points, and inspection stations. Additionally, real-time reading of vehicle tags on the road enables verification of key vehicle information, including taxes, permits, insurance, and violations.

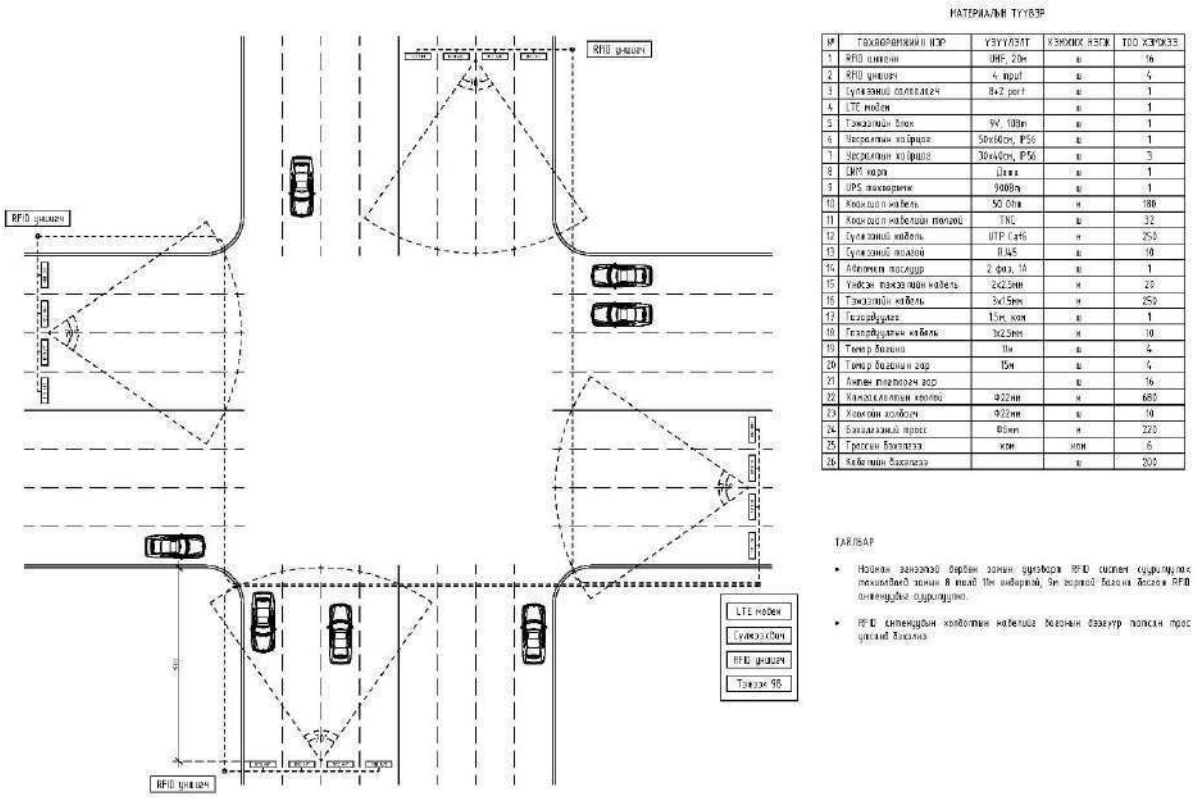
Automated Vehicle Monitoring Station

The automated vehicle monitoring station reads the encrypted code on RFID tags of approaching vehicles and transmits the data to a central registry via a fixed-line network. This enables automatic verification of details (e.g., taxes, insurance, and license plate restrictions) for all vehicles passing through the intersection.

RFID antennas, readers, and data transmission equipment--capable of reading tags from all exit directions--will be installed at road intersections. RFID antennas can read and identify tags from a distance of up to 20 meters.

Data Exchange Component

Data transmission can utilize mobile communication technologies (2G, GPRS, EDGE, EVDO, 3G, 4G) and high-speed wireless network technologies. Based on the network connection, data retrieval from the registry station can be adjusted to occur either per vehicle entry or at timed intervals. When camera data retrieval from the station is required, high-speed wireless network technology will be employed.

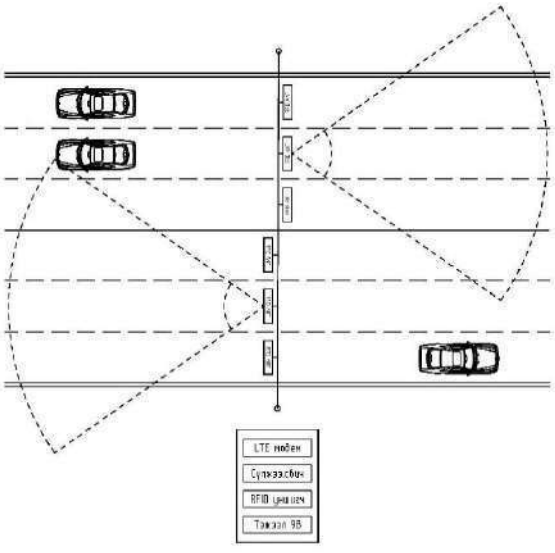


МАТЕРИАЛЫН ТУУВЭР

№	Техвөрөнгийн нэр	Үзүүлэлт	Хэмжих нэгж	Тоо хэмжээ
1	RFID антен	UHF, 20м	ш	16
2	RFID унших	4 input	ш	4
3	Сүлжээний солилцуур	8+2 port	ш	1
4	LTE модем		ш	1
5	Тэжээлийн блок	9V, 10Вт	ш	1
6	Чөлөөлөлт хайрцаг	50х60см, IP56	ш	1
7	Чөлөөлөлт хайрцаг	30х40см, IP56	ш	3
8	СИМ карт	Дата	ш	1
9	UPS тэжээлийн	900Вт	ш	1
10	Коаксиал кабель	50 Ohm	м	180
11	Коаксиал кабелийн толгой	TNC	ш	32
12	Сүлжээний кабель	UTP Cat6	м	250
13	Сүлжээний толгой	RJ45	ш	10
14	Аблоомэл хоолдуур	2 фаз, 1А	ш	1
15	Үнэлэн тэжээлийн кабель	2х2.5мм	м	20
16	Тэжээлийн кабель	3х1.5мм	м	250
17	Газардуулга	1.5м, коп	ш	1
18	Газардуулгын кабель	1х2.5мм	м	10
19	Төмөр багана	11м	ш	4
20	Төмөр баганын зэр	15м	ш	4
21	Антен тогтоогч зэр		ш	16
22	Хамгаалалтын хоолой	Ф22мм	м	680
23	Хоолойн холбоос	Ф22мм	ш	10
24	Бэхэлгээний пресс	Ф8мм	м	220
25	Грессин бэхэлгээ	коп	коп	6
26	Кабелийн бэхэлгээ		ш	200

ТАЙЛБАР

- Нэвтэн зөвшөөрөл бүхий зөөврөөр RFID систем суурилуулах техникийн зөвшөөрөл 8 нэгэл 10м өндөрлөй, 9м зөөрөй багана бүхий RFID антенуудыг суурилуулна.
- RFID антенуудын холболтын кабелиуд баганын дээгүүр толсон прос цусний бэхэлгээ



МАТЕРИАЛЫН ТУУВЭР

№	ТЕХВӨРӨНГИЙН НЭР	ҮЗҮҮЛЭЛТ	ХЭМЖИХ НЭГЖ	ТОО ХЭМЖЭЭ
1	RFID антен	UHF, 20м	ш	6
2	RFID унших	4 input	ш	2
3	Сүлжээний солилцуур	8+2 port	ш	1
4	LTE модем		ш	1
5	Тэжээлийн блок	9V, 10Вт	ш	1
6	Чөлөөлөлт хайрцаг	50х60см, IP56	ш	1
7	Чөлөөлөлт хайрцаг	30х40см, IP56	ш	1
8	СИМ карт	Дата	ш	1
9	UPS тэжээлийн	900Вт	ш	1
10	Коаксиал кабель	50 Ohm	м	100
11	Коаксиал кабелийн толгой	TNC	ш	12
12	Сүлжээний кабель	UTP Cat6	м	50
13	Сүлжээний толгой	RJ45	ш	10
14	Аблоомэл хоолдуур	2 фаз, 1А	ш	1
15	Үнэлэн тэжээлийн кабель	2х2.5мм	м	20
16	Тэжээлийн кабель	3х1.5мм	м	50
17	Газардуулга	1.5м, коп	ш	1
18	Газардуулгын кабель	1х2.5мм	м	10
19	Төмөр багана	11 калибрийн	ш	1
20	Антен тогтоогч зэр		ш	16
21	Хамгаалалтын хоолой	Ф22мм	м	200
22	Хоолойн холбоос	Ф22мм	ш	10

ТАЙЛБАР

- Зөвшөөрөл бүхий зөөврөөр RFID систем суурилуулах техникийн 11 калибрийн баганыг бүхий RFID антенуудыг антен хооронд 3м зөөрөй суурилуулна.
- RFID антенуудын холболтын кабелиуд баганын дээгүүр толсон прос цусний бэхэлгээ

Figure 6. 44. Standalone Equipment for Two-Way Roads

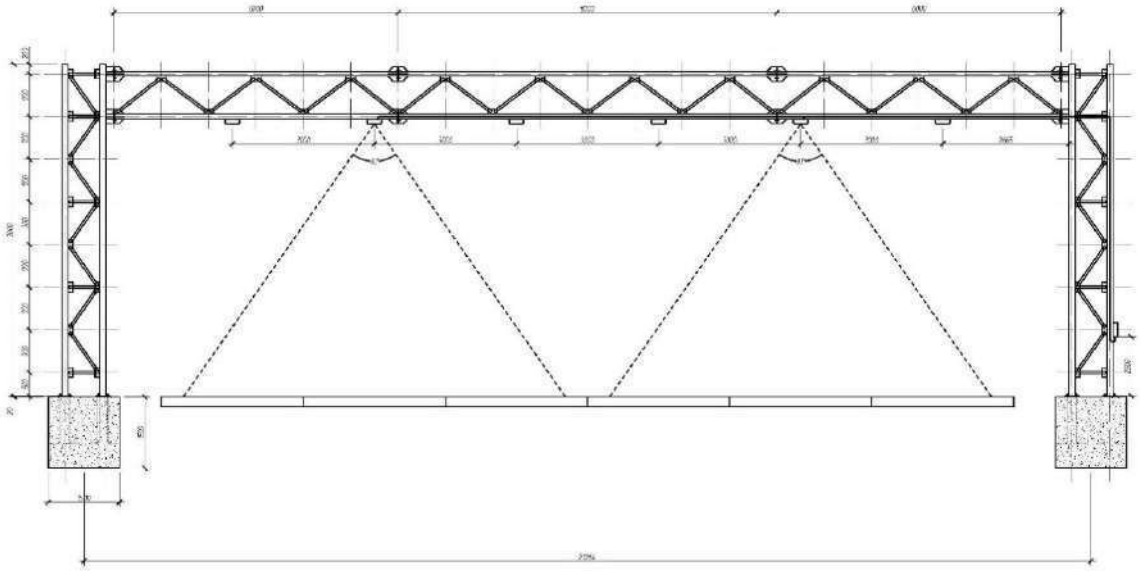


Figure 6. 45. Cross-Section of Mounting Frame for Four-Way Intersections

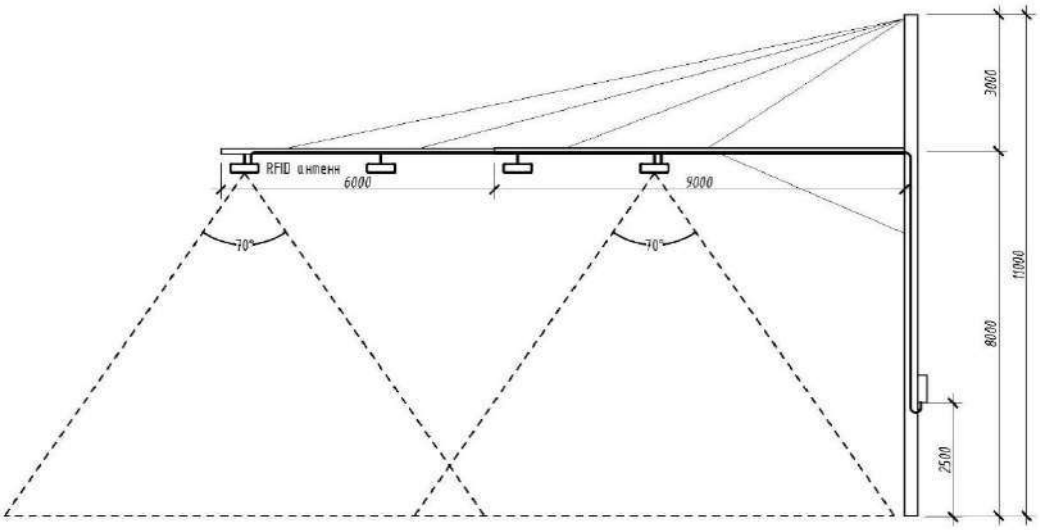


Figure 6. 46. Cross-Section of P-Shaped Mounting Frame for Two-Way Roads

Specification	Description
Operating Frequency	UHF (Ultra High Frequency): 860 – 960 MHz (IEC/ISO 18000-6C / EPC)
Reading Range	Up to 20 meters (varies by antenna and tag type)
Interface	RS232 / RS485 / Wiegand / TCP/IP / CAN / USB
Protection Class	IP65 / IP67 (suitable for outdoor environments)
Working Temperature	-40°C ~ +65°C
High-Speed Reading	Capable of reading up to 200 tags per second

RFID readers (automated vehicle monitoring stations) are planned for each intersection along the proposed road, including 9 units for four-way intersections and 28 units for two-way roads.

No.	RFID Reader	Section 1	Section 2	Section 3	Total
1	For Four-Way Intersections	5	1	3	**9**
2	For Two-Way Roads	7	14	7	**28**

6.9.7. Road Monitoring Cameras

The Traffic Management Center utilizes 45 cameras installed on Ulaanbaatar's major roads to collect quantitative data on vehicle speed, density, and road congestion, supporting traffic flow management. As part of the new ring road project, 16 new cameras will be installed at 22 planned intersections.

Table 6. 22. Technical Specifications of High-Mount PTZ Traffic Cameras

Specification	Description
Resolution	**4MP – 8MP**
Optical Zoom	**25× – 45× Optical Zoom**
Digital Zoom	16× – 32×
Auto-Tracking	Automatically tracks moving vehicles
Viewing Angle (Pan/Tilt)	– **Pan**: 360° endless
	– **Tilt**: –15° ~ +90°
	– Speed: 200°/sec ~ 400°/sec (preset mode)
Night Vision / IR Range	**100m – 250m (IR LED or infrared laser)**
WDR (Wide Dynamic Range)	**120–140dB** (balances light-dark contrast)
Network	– RJ45 Ethernet
	– PoE++ (IEEE 802.3bt) or 24VAC
	– ONVIF Profile S, G, T
Video Encoding	H.264 / H.265 / Smart Codec
Supports AI Functions	– Object classification (vehicle type)
	– Intrusion / line-crossing detection
	– Speed estimate (optional)
Working Temperature	-40°C ~ +70°C
IP Protection	**IP66** (water and dust resistance)
IK Rating	**IK10** (impact resistance)
Anti-fog / Heater	Built-in automatic anti-condensation defogger
Supports SD Card	128GB – 256GB (local storage)

Installation Conditions and Recommendations

Conditions	Description
Installation height	15 – 20 m (frame type: cast/galvanized iron)

Conditions	Description
Anchoring	Pole mount (U-mount + bracket), vibration-damped
Power Supply	24V AC / PoE++ (60–90W)
Grounding	All camera mounts must include SPD protection and be grounded
Network Connection	– CAT6 within 100m
	– Fiber + PoE switch for distances over 100m
In case of power outage	UPS or battery backup with 30-minute runtime

Number of Road Monitoring Cameras

	Section 1	Section 2	Section 3	Total
Road Monitoring Camera	6	5	5	**16**

6.9.8. Toll Collection System

Globally, toll collection points are categorized into two main types: traditional and electronic. Electronic toll collection points utilize three core technologies: RFID (radio frequency identification), LPR/ANPR (camera-based license plate recognition), and DSRC (navigation device recognition). Japan and Singapore have transitioned from RFID technology to ANPR systems. EU countries are adopting next-generation technologies like ANPR and GNSS-DCRS. Countries including the USA, Canada, Brazil, Turkey, and India continue to use RFID technology. Croatia, under its 2017-2030 road transport policy, has partnered with private sectors to develop electronic toll points, while Sri Lanka is replacing RFID technology on the E03 expressway with electronic toll points featuring ANPR solutions (including prepaid options).

For the First Ring Road, toll collection points can be implemented using one of two approaches: Specifically:

(1) Toll collection using RFID or automated vehicle monitoring stations

By installing RFID-based automated vehicle monitoring stations at each intersection linked to the ring road, vehicle entry/exit points and distance traveled can be recorded, with time and distance-based data transmitted to the Road Toll System.

(2) Toll collection via license plate recognition using ANPR (Automatic Number Plate Recognition) cameras

Cameras for the automatic license plate recognition toll system will be mounted on RFID antenna frames, with fiber optic connections to the control center. OCR software calculates the distance traveled to determine the toll, with data transmitted to the Road Toll System for payment processing.

6.9.9. Components of the ANPR System

Technical Equipment:

No.	Equipment	Quantity / Location	Description
1	ANPR cameras	At each entry/exit point	For license plate recognition /To ensure reliable operation and capture plates on both sides of the road, 2 cameras are planned per location/
2	Server	Centralized hub	Data collection and management
3	Network	Along the route	Connecting cameras to the centralized hub
4	Backup component	At the centralized hub or alternate location	For uninterrupted operation of cameras and servers

Software solutions

Toll management system

Vehicle records, account information

Mobile app / web application

OCR license plate recognition system

Network Operations Center (NOC) system

Reporting system (toll, transaction, error)

API integration (banks, payment gateways, national registry, transport)

Network and Connectivity

Optical cable – primary network connection

4G/5G/Starlink backup – for network outages

VPN/IPSec – secure connection

Security and Monitoring

Camera monitoring (CCTV)

Transaction monitoring system

Data backup

Data encryption

Technical Specifications of ANPR Toll Collection System

Technical Specifications of ANPR Cameras

Specification	Description
Resolution	2MP – 5MP (1080p – 2592×1944), IR / optimized for LPR
Lens	6-22mm motorized varifocal, LPR-optimized
IR illumination	Up to 30-50m, with automatic IR adjustment
FPS	25-60 fps (60fps suitable for high-speed roads)
WDR	120dB or higher (balances light-dark contrast)
Algorithm	Embedded AI: License plate recognition, type classification, direction detection
IP Protection	IP66 or higher, IK10 (vandal-resistant housing)
Network	RJ45 Ethernet, PoE+ powered
Protocols	Supports ONVIF, RTSP, HTTP, TCP/IP, MQTT

Network Structure

Tier	Description
Backbone connection	Fiber optic (SM G.652D, 12-24 core)
Substations (Nodes)	Switch/PoE Nodes installed every 3-6 km
Switch	Managed L2/L3 switch, supports VLAN, IGMP, QoS, PoE+
Fiber to Node	Switch with SFP ports, supports redundancy loop
Switch to Camera	Cat6 UTP, PoE connection for cameras within 100m
Power Supply	With UPS/AVR protection; solar system optional

Server Technical Specifications

Specification	Description
CPU	Intel Xeon Silver/Gold or AMD EPYC (16-32 core)
RAM	64GB – 128GB DDR4 ECC
Storage	50TB – 200TB RAID 5/6 (HDD + SSD hybrid)
OS	Linux-based (Ubuntu Server, CentOS) or Windows Server
GPU (for on-device AI processing, if required)	NVIDIA RTX A5000 or Tesla T4
Network Interface	10Gbps Ethernet, redundant NIC
Virtualization	Support for VMware/Hyper-V is preferred

Software Requirements

Specification	Description
LPR Engine	AI/machine learning-based, 95%+ accuracy
Vehicle registry	Create records by license plate, categorize (type, direction, speed, time)
Integration with toll system	Integration with bank/card APIs, QR/NFC, MNT systems
UI/Web Portal	Monitoring dashboard, reports, transaction tracking
Notifications	SMS/Email/Push notifications (for deficits, violations, etc.)
Data Security	Role-based access, audit log, encryption
Offline cache	Local storage for connection loss scenarios

Additional Standalone Equipment

Equipment	Quantity, requirement
Edge NVR / Gateway	Per substation, for local video storage
UPS / Power Backup	Per camera/node, 30-60 minutes of backup power
Key management system	Ability to log all transactions is preferred
Monitoring station	1-3 operator workstations, multi-screen monitoring room

Investment Estimate

No.	Equipment	Quantity	Unit price (million MNT)	Total (million MNT)
Main equipment				
1	Automatic license plate recognition cameras (ANPR)	128	3.5	448.0
2	Mounting frames, brackets	128	0.8	102.4
3	UPS (1 per location)	64	1.8	115.2

No.	Equipment	Quantity	Unit price (million MNT)	Total (million MNT)
Main equipment				
4	Cables, connections, installation	64	4.5	288
Total				**953.6**
Control center and server				
1	Main server (Application, DB, Storage)	1 redundancy unit	150.0	150.0
2	Backup server	1 redundancy unit	80.0	80.0
3	Firewall + VPN	1	25.0	25.0
4	Network equipment (Router, Switch)	1 package	30.0	30.0
5	UPS / server room	1 redundancy unit	20.0	20.0
6	Server location, data center setup	1	35.0	35.0
Total				**340.0**
Software, license				
1	ANPR camera system	1 package	60.0	60.0
2	Toll management (accounting, e-payment)	1 package	90.0	90.0
3	Data exchange API system	1 package	40.0	40.0
Total				**190.0**

Quantity per package

No.	Equipment	Unit of Measurement	Section 1	Section 2	Section 3	Total
1	ANPR cameras	pcs	54	36	38	**128**
2	Mounting frames	pcs	27	18	19	**64**
3	Fiber optic cable FO-48	km	10.32	8.28	11.16	**29.76**

6.9.10. Tunnel Monitoring Camera System

A monitoring camera system must be installed in the planned 2 km tunnel segment of the ring road to monitor pedestrian and vehicle movement continuously, implement emergency response measures, and ensure safety compliance.

(1) Overall system solution

Thermal cameras will be installed every 100 meters inside the tunnel for fire and smoke detection, while PTZ cameras will be placed every 250-300 meters to monitor emergencies and support response actions.

(2) Technical specifications of the tunnel monitoring system

Thermal Camera

Specification	Description
Detection technology	Uncooled VOx thermal sensor
Temperature measurement range	–20°C ~ +550°C (for fire and vehicle overheating detection)

Specification	Description
Detection range	50 – 150 m (varies by tunnel width)
Resolution	320×256 or 640×512
Lens	7mm – 13mm (sized to tunnel length and width)
Frame Rate	≥ 25 fps
Detection	Fire, temperature anomalies, motion detection
Input/output	ONVIF, RTSP, Modbus TCP, Alarm output
IP Rating	IP66 – IP67 (suitable for dusty environments)
Power	PoE+ / 12VDC
Enhancement	AI algorithm with vehicle, pedestrian, and smoke detection (optional)

PTZ Camera

Specification	Description
Resolution	2MP – 4MP (1920×1080 ~ 2560×1440)
Zoom	25× – 40× Optical Zoom (for tunnel depth visibility)
Rotation	360° continuous, –15° ~ +90° tilt
Auto Tracking	Automatically track and monitor movement
IR range	≥ 150m IR LED or laser IR
WDR	120dB or higher (balances light-dark contrast in the tunnel)
Protocol	ONVIF, RTSP, HTTP API
Connection	RJ45, PoE++ or 24V AC
IP Rating	IP66, IK10 (dust, dirt, and impact resistant)

Video recording and management system (VMS + NVR/Server)

Specification	Description
VMS software	Real-time preview, playback
	Integration with detection and fire alarm systems
	AI event (fire, vehicle breakdown, movement, etc.)
	Support for all ONVIF-compliant devices
Video server/NVR	Supports 64–128 channels
	32–64TB HDD RAID 5/6
	Dual NIC (failover)
	H.265+/Smart AI compression
Notifications	SMS/Email, pop-up alert, direct camera access
Specification	**Description**

Network solution (within 2 km)

Equipment	Specification
Managed PoE Switch (Industrial)	• 8/16 ports, 802.3at/af PoE+
	• -40°C ~ +75°C working temperature
	• VLAN, IGMP, QoS, Loop protection

Equipment	Specification
Fiber Backbone	• G.652D SM Fiber, 1/10 Gbps uplink
	• Ring topology (redundant loop)
Switch location	1 PoE switch or node installed every 250–400 meters

Detection and alarm system integration (optional)

Equipment	Function
Fire, smoke/temperature detector	Early notification of fire occurrence
Lighting control	Coordinated with cameras to increase lighting
Emergency display / guide panel	Inform drivers of traffic jams or emergency segments

Power supply and protection

Equipment	Specification
UPS / Battery Backup	Capable of powering all cameras for 30 – 60 minutes (3–5 kVA)
Surge Protection (SPD)	Installed on each camera and switch, 10–20kA
Protective housing	IP66 housing, DIN rail, anti-condensation defogger (for tunnel)

Centralized monitoring station

Specification	Description
Operator workstation	2–3 monitors, multi-camera monitoring
Video wall (optional)	2×2 or 3×3 55” LED/LCD wall
Remote access	VPN / Secure Web interface (HTML5/HTTPS)
Connection to the Emergency Management Agency, transport, and road authorities	Event-triggered API, report submission

Main project objectives

Detect fire, smoke, and overheating -- thermal cameras

Monitor traffic conditions -- PTZ cameras

Deliver rapid alerts during emergencies

Vehicle-specific warnings, integration with traffic control systems

Investment estimation for the camera system

No.	Camera type	Quantity	Location
1	Thermal cameras	20 units	Every 100 meters
2	PTZ cameras	6–8 units	Every 250–300 meters

Standalone equipment price

No.	Equipment	Quantity	Unit price (million MNT)	Total (million MNT)
Tunnel monitoring system				
1	Thermal cameras	20	9.0	180.0
2	PTZ IP cameras (30x zoom, IR)	8	4.2	33.6
3	PoE Switch (managed, fiber uplink)	4	1.4	5.6
4	NVR recorder (64 channels, redundant)	2	7.0	14.0
5	Network server, storage system	1	10.5	10.5

6	Excavation, installation	1	80.0	80.0
Total				**323.7**

Quantity per package

No.	Equipment	Unit of Measurement	Section 1	Section 2	Section 3	Total
1	Thermal cameras	pcs	-	20	-	20
2	PTZ cameras	pcs	-	8	-	8

6.9.11. Flood Level Detection System

A system to detect flood water levels and issue alerts is planned for the First Ring Road. It will be installed at the base of bridge structures, road underpasses, intersections, tunnel entrances/exits, and water retention areas.

The flood level detection and warning system comprises the following components:

(1) Sensor layer (Edge Layer):

Water level sensors

(2) Connection and data transmission layer:

Such as LoRa / NB-IoT / 4G modems

Smart data loggers with UPS power supply

(3) Data reception and processing layer:

Central server or Cloud (e.g., AWS, Azure)

Real-time monitoring web/mobile apps, data dashboard

(4) Emergency notification layer (optional):

Sirens, alarm systems (loudspeakers, alerts)

LED information displays

Technical Specifications of the Flood Level Detection System

Water level sensor equipment (Flood Level Sensor – 31 units)

Specification	Description
Technology	Ultrasonic, radar, or pressure (piezo) sensors
Measurement range	0 – 5m or 0 – 10m (varies by location)
Accuracy	±0.5 cm – ±1 cm
Output	RS485 (Modbus RTU), 4–20mA, NB-IoT, LoRa, ZigBee
Operating temperature	–40°C to +80°C
IP Rating	IP68 (for permanently submerged locations)
Wireless connection	NB-IoT, LoRaWAN, or 4G LTE (selected based on location)
Power consumption	≤ 1W (ultra low-power operation)
Maintenance-free installation	In water retention ditches, bridge foundations, road culverts

Data transmission solution (Telemetry/IoT Gateway)

Specification	Description
Protocol	MQTT / HTTPS / Modbus TCP
Network	NB-IoT / LoRaWAN / 4G LTE
Transmission interval	1 – 15 minutes (configurable)
Battery	Lithium battery with 3–7 years of operational life (continuous use)
Solar power supply (optional)	10–20W solar panel + 10Ah battery (for unstable locations near water)
Protection	IP66/67 housing, SPD module for overvoltage protection

Alarm subsystem (optional – location-specific)

Equipment	Description
Sirens + Flash Beacon	Light + sound alarm when high water levels are detected
Trigger logic	Activates when water level exceeds a specified threshold
Connection	Controlled via gateway transmission or directly via local relay

Centralized Monitoring Server and Software

Specification	Description
Data Platform	Web-based SCADA or IoT Dashboard (customizable)
Server	Intel i7 / Xeon, 16–32GB RAM, 1TB SSD
OS	Linux / Windows Server
UI-User Interface	• Map-based interface
	• Real-time water level display
	• Automatic alerts for threshold breaches
	• Reports and graph analysis (CSV, PDF export)
Notifications	SMS / Email / Push notifications (via API integration)
Data Logging	Ability to store water level data for 1 – 5 years
API integration	Ability to integrate with smart city dashboards and Emergency Operations Center

System communication network (Network Design)

Type	Advantages
NB-IoT (Low Power WAN)	Low cost, excellent power efficiency, wide coverage
LoRaWAN (Private or Public Gateway)	Free radio network, 1 gateway = 10 km coverage
4G LTE	Real-time data, suitable for large datasets

Additional Standalone Equipment

Equipment	Description
Solar Panel Kit	20W solar panel, 12V battery, MPPT controller (for unstable areas near water)
Pole Mount Kit	Designed to mount sensors + gateway on poles
Lightning Protection	SPD (Surge Protection Device) for all equipment installed near water

Key Advantages of the System

Automatic level monitoring -- 24/7 monitoring with no human intervention

Real-time alerts -- direct data transmission to relevant organizations

Report generation -- tracking flood history by time and location

Alerts -- enabling rapid road closure decisions

Self-sustaining power solution -- solar-powered operation

Water Level Sensor Locations

	Road type	Location	Quantity
1	Bridge structures	Base of bridge structures	6
2	Highway segment	Highway underpasses, intersections	22
3	Tunnel	Entrances, exits, water retention areas	3
Total			**31**

Investment Estimation for Water Level Detection System

No.	Equipment	Quantity	Unit price (million MNT)	Total (million MNT)
Flood level detection and warning system				
1	Water level sensors	31	3.1	96.1
2	Data logger / data collector	31	2.8	86.8
3	Solar power system/UPS	31	2.1	65.1
4	LED information display / VMS/	31	2.0	62.0
5	Alarm, notification device	31	2.5	77.5
6	Server, software	1	7.0	7.0
Total				**394.5**

Quantity per package

No.	Equipment	Unit of Measurement	Section 1	Section 2	Section 3	Total
1	Water level sensors, mounting hardware, alarms, notification devices	pcs	12	11	8	31

Table 6. 23. List of Standalone Equipment to be Installed at Planned Highway Intersections, by Location

Intersection number		Intersection location	RFID		CCTV	Toll system ANPR cameras
			4-way intersection	2-way road		
Section 1	1	KM0+390	1		1	8
	2	KM0+993	1		1	8
	3	KM1+603		2		4
	4	KM1+487		2		4
	5	KM1+850	1		1	8
	6	KM2+300	1		1	8
	7	KM3+054	1		1	8
	8	KM5+794		1		2
	9	K6+366		1	1	2
	10	KM6+480		1		2
Section 2	11	KM8+587		2	1	4
	12	KM11+124		2	1	4

	13	KM12+620		2	1	4
	14	KM13+232	1	2	1	12
	15	KM13+979		2		4
	16	KM14+658		4	1	8
Section 3	17	KM20+835		2	1	4
	18	KM22+856	1		1	8
	19	KM23+817		2	1	4
	20	KM23+874	1			8
	21	KM24+337	1		1	8
	22	KM24+793		3	1	6
	Total		**9**	**28**	**16**	**128**

6.9.12. Highway Lighting Control and Monitoring System

The centralised monitoring system connects to the central monitoring network via wireless communication networks (GPRS/CDMA/WCDMA/4G) and to terminal controllers via electrical converter links (PLC). Centralised control manages each terminal controller by receiving, executing, and transmitting commands from computer-based master control software. It monitors the on/off status and illumination of individual highway lights, implements intelligent lighting control and advanced management, and optimises power usage. The network monitoring terminal controller monitors lamp operating status and can execute fault alarm functions. Furthermore, the system can incorporate functions like road segment monitoring and alarm support to meet functional requirements. Control of highway lighting network activation/deactivation is based on intelligent monitoring terminals installed in the low-voltage distribution room of pole transformers, following main control protocols, photoelectric control, and standby mode.

The intelligent monitoring terminal operates automatically after configuring the latitude, longitude, and date of the specific area. Database-supported monitoring data enables automatic control of highway light activation/deactivation based on preset sunrise/sunset times or unexpected conditions. Highway lamps are powered by a control power supply, connected to individual lamp controllers via the power supply, and use PWM control to regulate driver power output, enabling remote on/off and dimming control.

The highway lighting centralised monitoring system includes electronic monitoring centre controls (e.g., highway lighting monitoring servers, computers, mobile devices). The monitoring center and intelligent terminals can use GPRS, CDMA, or 4G wireless channels, leveraging connections through intelligent terminals and controlled highway lighting power lines. No dedicated communication monitoring lines are required; the highway lighting system can be intelligently controlled by installing the APP and system authorisation on monitoring centre

devices or managers' mobile devices.

The lighting monitoring terminal uses digital signal processing (DSP) technology to capture voltage fluctuations, enabling on-site collection, calculation, processing, storage, and display of voltage, current, active power, and capacity data. It transmits data per the monitoring centre's instructions and thoroughly monitors lighting facilities. Active alarms are triggered for faults, errors, or data exceeding thresholds to ensure safe and reliable operation of the highway lighting system. During communication outages, lamps can operate automatically based on preset emergency on/off time limits. The main functions are as follows:

Technical Specifications of Lighting Control and Monitoring System

Overall system structure

Total lighting capacity: ~270–520 kW (18 units × 15–29 kW)

Monitoring type: Centralized + Local (Local manual override)

Connection types: 4G / NB-IoT / Ethernet / RF Mesh (location-dependent)

Intelligent control functions:

Remote on/off control

Scheduled activation (RTC schedule)

Light intensity adjustment (Dimmer control)

Power consumption and fault monitoring

(1) Intelligent Scheduling Panel Equipment (18 units)

Equipment	Technical specifications
Smart Lighting Controller (Gateway)	• RS485/Modbus / DALI / 0-10V
	• 4G/LoRa/NB-IoT/ Ethernet connectivity
	• 6-12 channel contactor/relay
	• 10-20kA surge protection

	• RTC timer with automatic activation
	• Operating temperature: -40 to +70°C
	• IP65 enclosure, DIN rail mounting
Energy Meter (each panel)	• 3-phase, CT or direct measurement
	• Class 1 or 0.5 accuracy class
	• RS485/Modbus compatible
MCB/MCCB + SPD	• IEC compliant, load-matched
	• Cables and switches rated for 18–30 kW load
	• Type 2 Surge Protective Device (SPD)
Manual Override Switch	• A/B selector or push-button override
	• Switch between automatic/manual control modes

(2) Intelligent Lighting Control Module (Luminaire Controller)

For individual light control per pole (individual control)

Specification	Description
Protocol	DALI-2 / 0–10V / PWM
Communication	RF Mesh, LoRaWAN, NB-IoT
Installation	Zhaga Book 18 or NEMA socket
Functions	Automatic dimming, ballast monitoring, fault feedback
IP Rating	IP66

(3) Centralized Monitoring Server (Central Software + Server)

Specification	Description
Server	Intel i7/i9 or Xeon, 32–64GB RAM, 1–2TB SSD, redundant PSU
OS	Windows Server 2019/2022 or Linux
SCADA / EMS system	Web-based UI
	Real-time monitoring
	Fault/event alerts
	Reporting, dashboard, energy analytics
Connectivity	MQTT, Modbus TCP, SNMP, HTTPS API support
Cloud Sync (optional)	AWS/Azure/OwnCloud integration capable

(4) Communication Solutions

Type	Description
LoRa/LoRaWAN	Cost-effective, 2–5 km coverage, minimal RF interference
4G LTE Router (per smart panel)	Connection to central server via static IP or VPN tunnel
Fiber Ethernet (optional)	If road-adjacent network is available

(5) Additional Standalone Equipment

Equipment	Function
UPS/AVR	30-minute runtime per panel (1–3 kVA)
Ambient Light Sensor (optional)	Activation based on ambient light levels

GPS time synchronization	Unified time reference for timer controls
Indoor and outdoor enclosures	IP65, metal/ABS, DIN Rail mount, heat-resistant

Key Advantages of the System

Power optimization: 30–60% dimming through scheduled activation

Remote monitoring: Control individual panels from operator center

Fault reporting: Alerts for light failures and connection outages

Billing system integration: Power consumption tracking and billing capability

Standalone equipment package

No.	Equipment	Quantity	Primary function
1	Intelligent control terminal (RTU/LCU)	18	Per panel
2	GSM/4G/LTE modules	18	Remote monitoring
3	Smart meter (energy monitoring)	18	Energy monitoring and reporting
4	Load control relay/contactor	36	Load isolation/connection
5	Weather sensor	3-4	In designated areas
6	Cable sensor (input, load)	36	Current and voltage monitoring
7	Central server (cloud or local SCADA)	1	Centralized monitoring
8	Software (Web/mobile)	1	Monitoring and control
9	Surge protection device (SPD)	18	Overvoltage protection

System capabilities

Remote control (online on/off)

Load and power consumption monitoring (via meter)

Power outage alerts and fault detection

Lighting schedules and sensor-based automation

Centralized SCADA control system

GSM/4G/LTE connectivity to central server

Investment estimation for lighting control and monitoring system

No.	**Equipment**	**Quantity**	**Unit price (million MNT)**	**Total (million MNT)**
Flood level detection and warning system				
1	Panel package (RTU + meter + GSM + relay)	18	4.5	81.0
2	Central server and software	1	20.0	20.0
3	Sensors and protection devices (SPD, weather, etc.)	1	8.0	8.0
4	Installation, configuration, and testing	1	12.0	12.0
Total				121.0

Prices may fluctuate by ±15-20% based on manufacturer, protocol (MODBUS, DLMS, IEC61850, etc.), SCADA system type, and network infrastructure.

Quantity per package

No.	Equipment	Unit of Measurement	Section 1	Section 2	Section 3	Total
1	Lighting control panel package (RTU + meter + GSM + relay)	pcs	6	5	7	18

6.10. LANDSCAPE ENGINEERING

6.10.1. Design basis and technical standards

(1) Design basis:

1) Reference Guide to Tree and Cultivated Plant Species (UCS 0802C:2022);

2) Urban and Settlement Landscaping and Green Space Planning (UCS 0801A:2022);

3) Ulaanbaatar City Landscaping Master Plan：

4) Code for the Design of Urban Green Space (GB 50420-2007);

5) Code for Planting, Planning and Design of Urban Roads (CJJ 75-97);

6) Standard for Maintenance of Landscape Greening (CJJ/T 287-2018);

7) Planting Soil for Greening (CJ/T 340-2016);

8) Other relevant codes and standard documents.

(2) Technical standards

1) Road Grade: Grade I arterial road;

2) Main road 100 km/h (locally 80 km/h), auxiliary road 40 km/h;

3) The relationship between the variation of greening design unit sections and vehicle driving on the road: In road greening design, the relationship between the length of greening units (i.e., continuous sections with the same plant configuration pattern) and driving speed directly impacts driving safety and the rhythmic perception of the landscape. According to the Code for Planting Planning and Design of Urban Roads (CJJ 75-97), revised in 2013, "The greening of arterial roads should meet the requirements of driving safety, with simple and continuous and configured plants. The length of greening units should be coordinated with the design vehicle speed to avoid frequent changes that may cause visual fatigue."

4) Plant selection and planting requirements: refer to Catalogue of Tree and Cultivated Plant Species (UCS 0802C:2022). Woody plant selection and design: coniferous trees (e.g., Siberian pine), broad-leaved trees (e.g., white birch), shrubs (e.g., rosaceae plants); Lawn and ground cover plants: ordinary lawn, sports turf, soil protection turf; Planting specifications: coniferous trees: tree height ≥4 m, root ball diameter 1.0-1.2 m; Broad-leaved trees: tree height ≥1.5 m, root ball diameter 1.2-1.5 m.

6.10.2. Design principles

(1) Basic principles of greening planning for urban residential areas

1) People-oriented: Meet the needs of residents as the starting point to create a comfortable, convenient, and safe living environment.

2) Ecological priority: Protect and improve the urban ecological environment, enhancing the stability and sustainability of the urban ecosystem.

3) Act according to circumstances: Select plant species and greening methods rationally based on the city's natural conditions, geographical environment, and climate characteristics.

4) Unified planning: Coordinate with the city's master plan, land use plan, transportation plan, etc., to ensure a unified layout of greening in urban residential areas.

5) Economic rationality: While fulfilling greening functions, minimise landscape construction and management costs to improve afforestation benefits.

(2) Requirements for plant configuration in green spaces of urban residential areas

1) Selection of adapted plants: Select plant varieties that are well-suited to the city's natural conditions, geographical environment, and climate characteristics to ensure healthy growth.

2) Diverse configuration: Utilise a variety of plant varieties to form a multi-layered plant community combining trees, shrubs, and grasses, enhancing both ecological functions and landscape effects.

3) Seasonal variation: Emphasise seasonal changes by selecting plants that bloom, bear fruit, or change colour in different seasons, creating a landscape that offers visual interest year-round.

4) Pests and diseases prevention: Select plant varieties with strong resistance to pests and diseases, and arrange them rationally to prevent the occurrence and spread of infestations.

5) Ecological functions: Select plants with ecological functions, such as absorbing harmful gases, purifying the air, and reducing noise, to improve the overall ecological efficiency of the green space.

6.10.3. General introduction

The master plan for greening in Ulaanbaatar city aims to develop urban horticulture and afforestation. It focuses on creating and maintaining streets and squares equipped with amenities and green spaces that are clean, healthy, safe, and desirable, thereby supporting the city's improvement goals. Citizens who value and are committed to environmental protection will build an economically strong city by utilizing resources efficiently and cost-effectively to achieve equitable social relations.

6.10.4. Overall strategic priorities for greening

The overall goal of greening in Ulaanbaatar City by 2030 is to "jointly create a unique green and ecological city." Through SWOT analysis, seminars, and research, four key strategic priorities for this master plan have been identified, as follows:

Strategic priority 1: Improve the legal entitlements environment and establish effective

implementation mechanisms

Develop a legal environment that aligns with landscape planning and design for urban planning and greening works, standardize management and organization development, and enhance execution capabilities.

Strategic priority 2: Build a sustainable foundation, system, and long-term mechanism for greening development

Establish a sustainable development basis to ensure the long-term sustainability of urban greening. Support afforestation activities, promote ecological idea through education and training, encourage public participation, and clarify the long-term benefits of greening efforts.

Strategic priority 3: Protect and develop green infrastructure, introducing suitable technologies and innovations

Cope with land-use changes, cultivate tree species suited to the urban environment, protect natural resources, and advance research and innovative applications of new technologies. Expand and protect green construction areas, promote tree and plant planting across various areas, introduce advanced standards and successful cases, define minimum standards based on urban planning regulations, and support small-scale greening projects.

Strategic priority 4: Enhance public awareness and participation in green development

By raising residents' awareness of green development, facilitate the effective implementation of urban greening works.

6.10.5. Implementation strategies for the overall greening plan to shape the city's image

Ulaanbaatar is situated among four mountain ranges and five rivers, boasting unique natural landscapes. However, past urban development plans failed to adequately protect and highlight these features, resulting in an indistinct city image. To reshape the city image, the following strategies are proposed based on the planning philosophy of urban planner B. Chimediin:

Optimizing landscape views: Mountain vistas are vital to city residents. Therefore, urban construction should be rationally planned to ensure natural integration of mountain landscapes into the city visions while maintaining aesthetically pleasing and comfortable road planting.

Planning Characteristic Roads: The functions and characteristics of major urban roads should be clearly defined. By planting long-lived trees with historical and cultural value and incorporating celebrations and traditional activities, unique and charming road landscapes can be created.

Developing strategic nodes: Key strategic nodes in the city should be identified and meticulously developed through the construction of large public green spaces and afforested areas. These nodes can be integrated with commercial activities and daily operations to

transform them into iconic urban zones.

6.10.6. Selection of trees and herbaceous plants for road planting

Road planting requires the selection of tree and herbaceous plant species that are adaptable to environmental conditions, adversity resistant, stable in greening effects, aesthetically valuable, and eco-friendly.

(1) Key factors to consider for road planting:

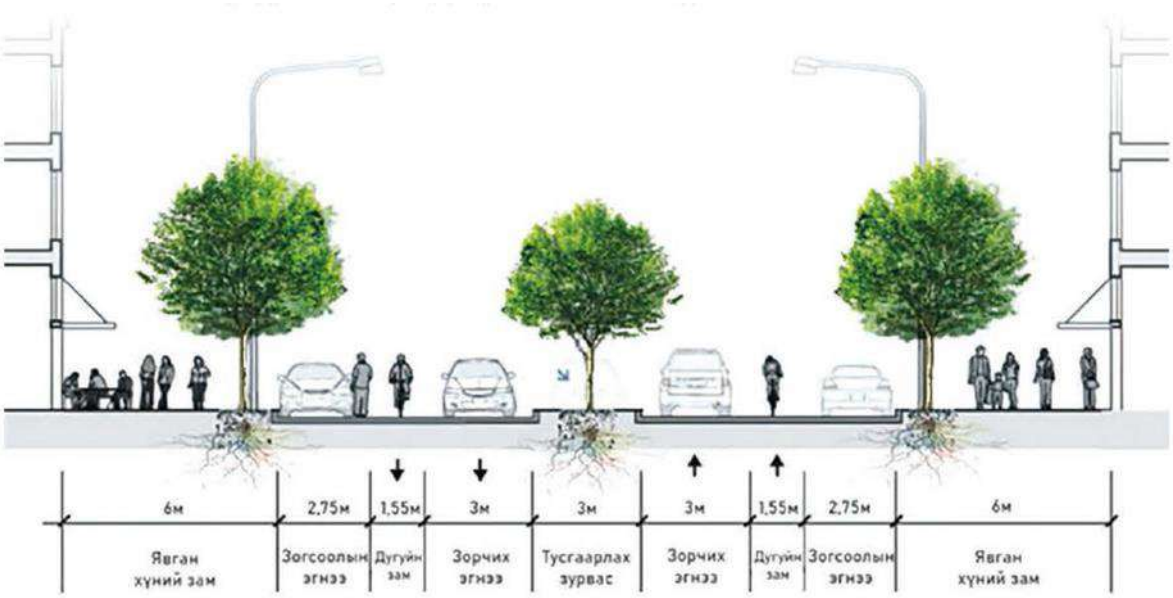


Figure 6. 47. Greening Design along the Highways (Example Diagram)

1) Harsh natural environmental conditions. Examples: Drought, poor soil quality, and disturbances from bricks, gravel, and other construction waste;

2) Sewage and chemical substances. Examples: Saline wastewater, engine oil, gasoline, etc.;

3) Seasonal climate impacts. Examples: Dry summer winds, cold winter winds, and localized strong winds caused by building obstructions;

4) Air pollution factors. Including ozone, sulfides, dust, raise dust, particulate matters, and other pollutants that interfere with normal plant growth;

5) Infrastructure and human disturbances. Such as building obstructions, traffic accident risks, and damage to vegetation caused by pedestrian activities.

(2) Principles for selecting trees

1) Adversity resistant requirements: Deciduous trees should be selected for cold regions, snowy areas, road forks, and urban arterial road greening;

2) Ecological function considerations: Deciduous trees must provide sunlight shading, regulate surface temperatures, purify air, and reduce noise;

3) Limitations of evergreen trees: Evergreen Trees grow slowly, have low canopy heights, offer limited shade in summer, and sunlight obstruction in winter may affect traffic safety.

(4) Principles for selecting sidewalk greening plants need to consider the following factors:

1) Root system and wind resistance requirements: Select tree species with deep root systems, sturdy trunks, large canopies, and strong resistance to lodging to avoid the risk of toppling due to shallow roots, which could endanger pedestrians;

2) Resistance to strong winds and heavy rain. Prioritize deep-rooted tree species to withstand lodging caused by strong winds and heavy rainfall.

3) Preventing root system damage to pavements. Select tree species whose root systems would not uplift and damage side pavements or underground pipelines;

4) Canopy and shading needs. Trees with large canopies and dense leaves help reduce summer temperatures on roads and sidewalks, but care must be taken to avoid excessive obstruction of traffic signs;

5) Enhanced ecological functions. Tree species with large canopies and dense leaves should also provide ecological benefits such as dust filtration, noise reduction, and windbreaking;

6) Adaptability requirements. For narrow sidewalks and poor soil conditions, select tree species that are tolerant of barren soil, drought, strong sunlight, extreme temperatures, and have minimal leaf shedding;

7) Aesthetic design. Prioritize tree species with visually appealing flowers and fruits to enhance streetscape value and attract pedestrian attention;

8) Environment-friendly. Avoid tree species that emit pungent odors, produce allergenic pollen, or easily stain pedestrians' clothing;

9) Safety and maintenance requirements. Pruning should ensure visibility of traffic signs, maintain safe pedestrian passage space, and conduct regular upkeep to ensure both safety and aesthetic appeal;

10) Comprehensive selection criteria

Trees and herbaceous plants meeting the following 10 criteria:

Phenological traits: Early spring leaf expansion, dark green in summer, aesthetically pleasing foliage in autumn, and tolerance to pruning;

Healthy tree form: Straight trunk, evenly distributed branches, and a well-structured canopy;

Ornamental value: Attractive leaves, flowers, and fruit;

Morphological specifications: Trunk height ≥ 1.8 meters, branch angles > 30°, and moderate foliage density;

Transplant adaptability: Easy to transplant with a high survival rate;

Adversity resistance: Adaptable to urban pollution, drought, and extreme weather conditions;

Disaster resilience: Deep root system, wind and snow load resistance, and sturdy branches that resist breakage;

Low maintenance: Strong pest and disease resistance with minimal upkeep costs;

Longevity: Long life cycle.

(4) Selection criteria for herbaceous plants

Select herbaceous plants with short growth cycles, rapid coverage, and low maintenance requirements. Specific criteria are as follows:

1) Avoid plants with strong pungent odors to ensure they do not affect pedestrians or vehicles;

2) Tolerant of pruning with strong regenerative capacity;

3) Highly adversity resistant, capable of withstanding high surface temperatures, dust, and road radiation;

4) Stable phenological characteristics, with both flowers and fruits offering ornamental value;

5) Prefer low-slung herbaceous plants;

6) Select shrubs with dense branches, pruning tolerance, shade resistance, and pest/disease resistance;

7) Small but densely clustered leaves;

8) Small but abundant flowers;

9) Small but highly productive fruits;

10) High transplant survival rate and appropriate specification;

11) Strong coverage capacity and uniform growth.

(5) Selection criteria for ground cover plants

Morphological requirements: Low-slung, creeping growth habit with dense foliage;

Growth characteristics: Rapid spreading rate, forming stable coverage within a short period (5-10 years);

Adversity resistance: Tolerant of poor soils, drought, pests and diseases; resistant to trampling while maintaining ornamental appeal year-round;

Safety: Non-toxic, free of pungent odors, with no environmental pollution from flowers, fruits, or leaves.

(6) Selection criteria for lawn plants

Coverage: Creeping growth habit, low and densely uniform, providing even and aesthetically pleasing ground cover;

Foliage properties: Slim and flexible leaves with a long growing season;

Adaptability: Drought-tolerant, extreme temperature-resistant, and suitable for pruning;

Adversity resistance: Well-developed root system, trampling-resistant, and strong regenerative capacity;

Safety: Thorn-free, non-toxic, hypoallergenic, and harmless to humans and animals.

6.10.7. Selection of woody plants in greening design elements

(1) Selecting plant configuration forms based on landscape functions

Greening design commonly uses the following elements: isolated trees, group trees, street trees, dense woodlands, hedgerows, and flower border edge plantings. Specific configurations include:

Isolated tree/isolated shrub: A single tree or shrub planted alone on a lawn or open space to highlight its individual form;

Group tree: Two or more plants of the same or different species arranged in clusters within green spaces;

Street trees: Trees planted in a single continuous row along both sides of roads or beside buildings;

Dense woodland: Large areas (such as parks) planted with hundreds of trees of the same or multiple species to form forest belts;

Hedgerows: Low-slung, dense shrub belts used to protect flower beds from trampling or to separate internal areas of parks.

Flower border edge planting: Herbaceous plants or low-slung shrubs (height ≤ 0.5 meters) planted along the outer edges of road guardrails or flower beds.

(2) Functions and configuration principles of hedgerows

Hedgerows should serve the dual functions of protecting flower beds and dividing landscape spaces. For single-row planting, a single tree species is recommended, while multi-row planting allows for a mix of different species.

(3) Recommended species for hedgerows

Natural hedges (no pruning required): Low-slung shrubs such as Saxifraga, Stipa, grasses, roses, and Spiraea are recommended;

Formal hedges (requiring pruning): Species with strong pruning tolerance, such as birch, dogwood, smoketree, rosa multiflora, and rosa glabrifolia, are suitable.

(4) Height classification of hedgerows

Divided into three types based on height:

Tall hedges (2-3 m): Used for spatial isolation;

Medium hedges (1-2 m): Used for functional zoning;

Low hedges (0.5-1 m): Used for ornamental margin.

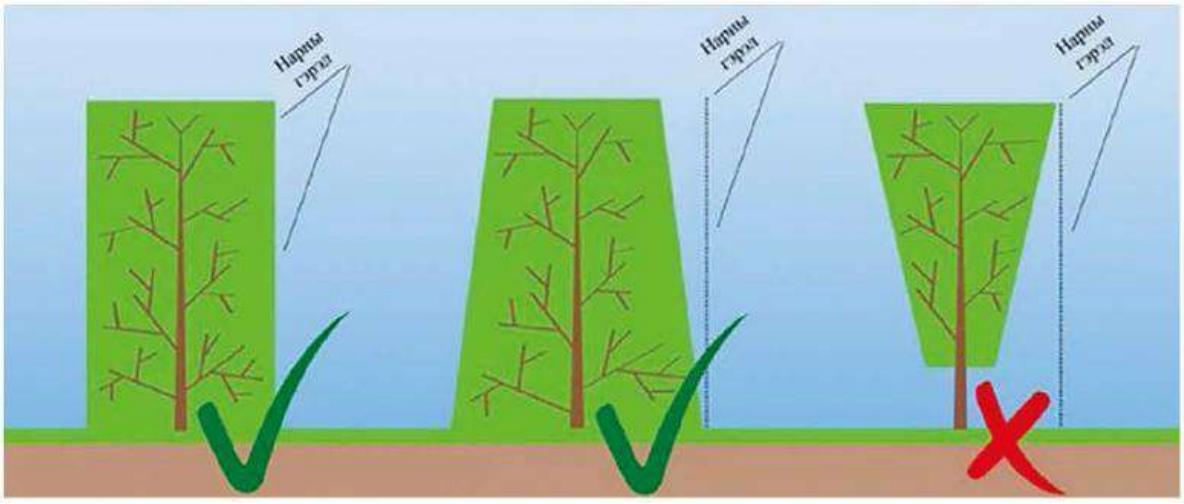


Figure 6. 48. Hedgerows Morphology and Light Exposure of Lower Branches (Example Diagram)

（1）. Analysis of natural conditions in ulaanbaatar

Climate: Average annual precipitation is approximately 200-300 mm, concentrated in summer; winters are long and extremely cold, with frequent sandstorms in spring.

Soil: Dominated by chestnut soil and sandy soil, which are poor in fertility and prone to salinization.

Challenges: Severe wind erosion, water scarcity, and frozen soil affecting root development.

（2）. Plant Selection Sources

Mongolian Green Facility UCS 0802C: 2022 "Species Selection for Trees and Grown plants".

Table 6. 24. Analysis of Main Plant Selection

No.	Plant Name	Height (m)	Purpose	Resistances					Soil Conditions	
	Mongolian & Latin			Heliophilous	Shade Tolerant	Air Pollution Tolerant	Cold Resistant	Wind Resistant	Soil Moisture	Soil Type
1	Pinussylvestris	20-40	o	o		●	o	o	Dry, moist	Other than salt and alkal
2	Siberia Pine	35	oo	o	o	●	o	o	Dry, moist	Other than salt and alkal
3	Padus racemosa	17		o	o	o	o	o	Dry, moist	Rich soil
4	Berberissibirica	1.0-1.5	o	o		o	o	o	Dry, moist	Rich soil
5	Amygdalusmongolica	1.0-2.0		o		o	o	o	Dry, moist	Other than salt and alkal
6	Ulmus pumila	5.0-10	o	o	o		o	●	Dry, moist	All soil
7	Cornussanguinea	4.0	o	o		o	o	o	Moist	Other than salt and alkal
8	Quercus mongolica	20-30	oo	o		o	o	o	Dry, moist	All soil

No.	Plant Name	Height (m)	Purpose	Resistances					Soil Conditions	
	Mongolian & Latin			Heliophilous	Shade Tolerant	Air Pollution Tolerant	Cold Resistant	Wind Resistant	Soil Moisture	Soil Type
9	Syringa villosa	4.0		o		o	o	o	Dry, moist	Rich soil
10	Juniperus sibirica	0.5	oo	o		●	o	o	Dry	Sandy soil
11	Loniceramicrophylla	0.3-1.5		o		o	o	o	Moist	Rich soil
12	Juniperuspseudosabina	0.5	oo	o		o	o	o	Dry	Sandy soil
13	Dianthusdeltoides	0.3-0.4		o		o	o		Dry, moist	Sandy soil
14	Rosa davurica	1.0-2.0		o		o	o	o	Dry	All soil

"o"- Indicates specific growth conditions and resistance; "co" - Indicates potential adaptability;

"●" - Indicates no resistance (for details, refer to Table 2 of the Mongolian National Standard БНбД 30.01.03 on Resistance-Related Parameters of Woody Plants). (Note: For specific data on the resistance of woody plants, please refer to the Mongolian National Standard.)

6.11.7.3. Design strategy for plant sections

When vehicles travel at different speeds, the visual effects of the roadside landscape vary accordingly. Controlling the frequency of changes in plant landscape units helps maintain a stable visual rhythm for drivers, enhancing the guiding function of road greening landscape. When the length of greening units correlates with driving speed as shown in the table below, the roadside landscape can show optimal visual effects.

Table 6.25 Relationship between Greening Unit Length and Driving Speed

Speed Per Hour v (km/h)	v≤40	40<v≤60	60<v≤80
Greening Unit Length L (m)	20<L≤50	50<L≤80	80<L≤110

(1) 60m road section: Wind-break and sand-fixation Shelter belts. The design speed is 80 km/h, with greening units arranged in alternating sections of 80 meters and 100 meters in length.

Functions: Blocks wind and sand, reduces snow accumulation on the road, and isolates external sand sources.

Plant configuration:

Megaphanerophyte layer: Quercus mongolica, Siberian ulmus pumila, Pinussylvestris - Cold, drought and wind-resistant with deep root.

Small trees layer: Prunus padus, Pinus sylvestris - Nitrogen-fixing improves soil and fruit attracts birds.

Shrub layer: Lonicera microphylla, Lilac, Cornus alba, Rosa davurica, Berberis sibirica, Juniperuspseudosabina, Dianthusdeltoides.

Ground cover layer: Carex lasiocarpa- Covers soil surface to suppresses blowing sand.

Structure: A multi-layered planting of trees, shrubs, and grasses is adopted, with densely planted shrubs on the windward side and an increasing height gradient of trees on the leeward side. The proportion of evergreen trees species is controlled in accordance with regulatory requirements.

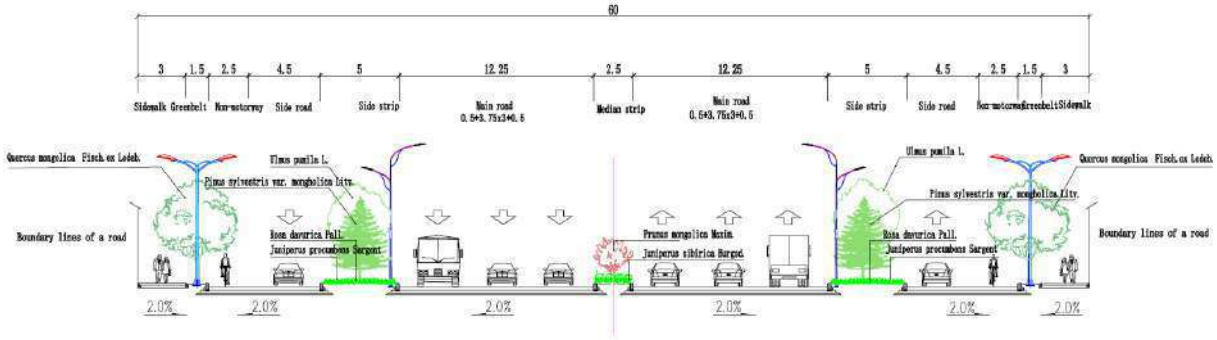


Figure 6. 49. Cross Section of Greening Configuration for the 60m Standard Section

(2) 45m/32m road section: Ecological buffer and landscape display zone. The design speed is 40 km/h, with greening units arranged in alternating sections of 40 meters and 60 meters in length.

Functions: Beautify the urban interface, purify air, and reduce noise.

Plant configuration:

Megaphanerophyte layer: Quercus mongolica, Siberian ulmus pumila, Prunus sibirica, Pinussylvestris - Native species with prominent seasonal fruit and foliage scenery.

Small trees layer: Prunus padus, Amygdalusmongolica - Nitrogen-fixing improves soil and fruit attracts birds.

Shrub layer: Cornus alba, Rosa davurica, Berberis sibirica, Juniperus sibirica, Thymus mongolicus, Juniperuspseudosabina, Dianthusdeltoides - Cold-tolerant flowering plants enhancing seasonal variation.

Ground cover layer: Carex lasiocarpa - Low-maintenance and highly adaptable.

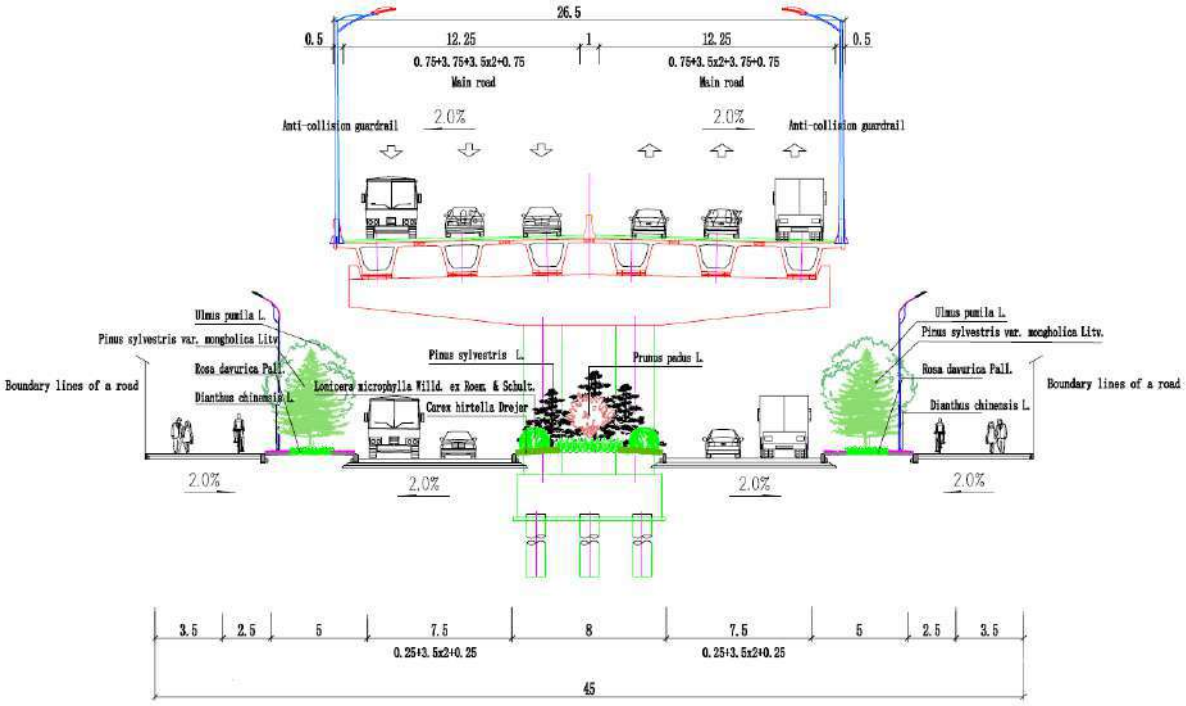


Figure 6. 50. Cross Section of Greening Configuration for the 45m Standard Section

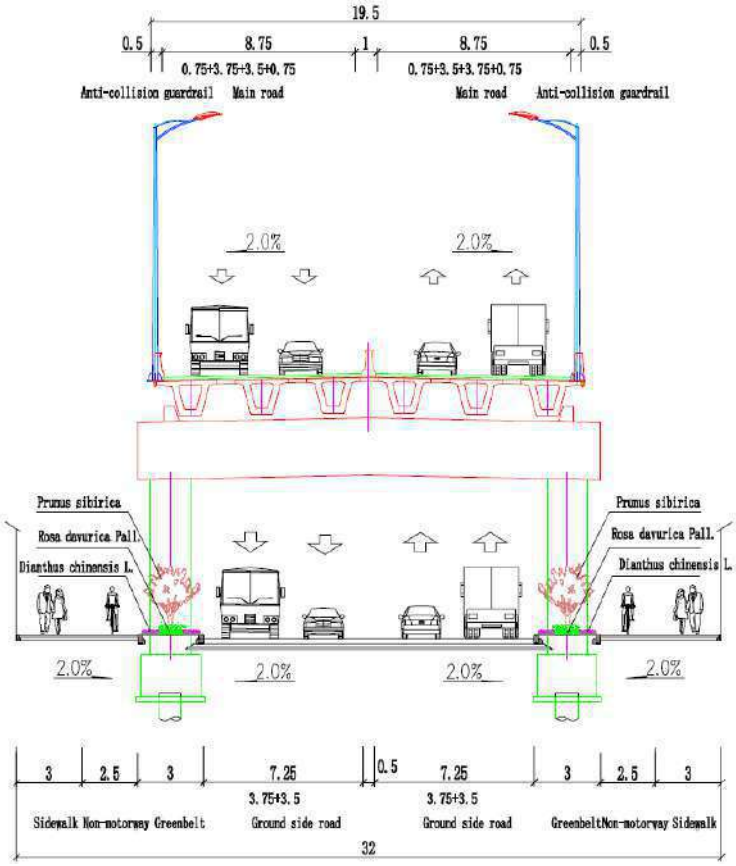


Figure 6. 51. Cross Section of Greening Configuration for the 32m Standard Section (Main Road with Four Lanes Two Ways)

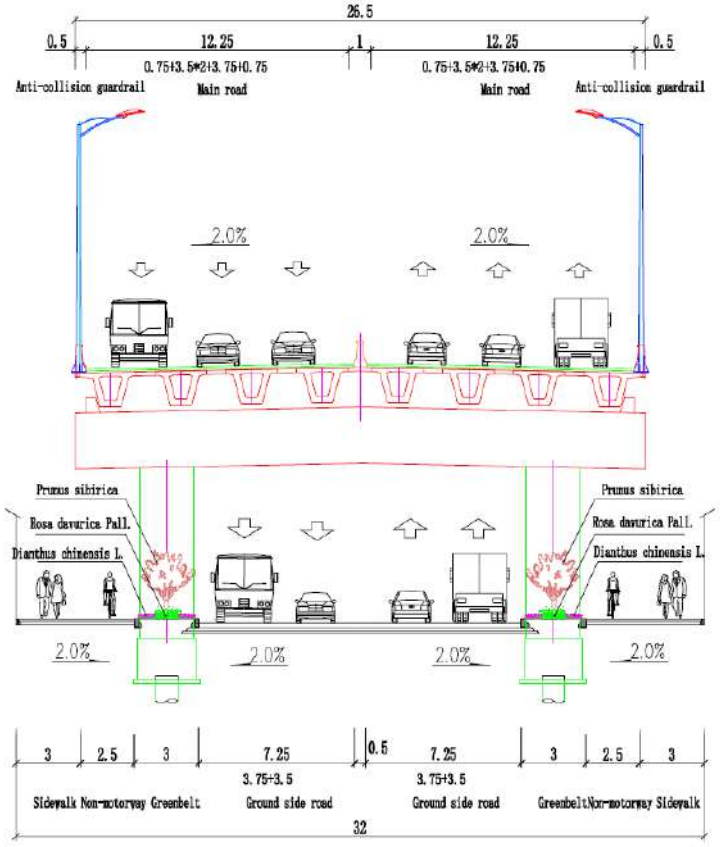


Figure 6. 52. Cross Section of Greening Configuration for the 32m Standard Section (Main Road with Six Lanes in Two Ways)

(3) Interchange nodes: Low-slung and adversity resistant greening

Function: Glare prevention, traffic separation, and adaptation to limited road space.

Plant configuration:

Megaphanerophyte layer: Siberian ulmus pumila, Pinussylvestris - Cold, drought and wind-resistant with deep root.

Shrub balls: Lonicera microphylla - pruning-tolerant and pollution-resistant.

Ground cover layer: Thymus mongolicus, Carex duriuscula - trampling-resistant and fragrant releasing.

Structure: Wavy planting troughs combined with permeable gravel layers to enhance rainwater infiltration.

CHAPTER 7. PROJECT IMPLEMENTATION OPERATION & MAINTENANCE

7.1. PROJECT IMPLEMENTATION SCHEDULE

7.1.1. Overall scheme objective

Based on comprehensive studies of urban development conditions, project construction conditions, regional planning, and design schemes, the overall scheme objective is to complete the construction of the Ulaanbaatar New Ring Road project by December 2027. The project spans a total length of 24.793 km with a width of 32-60 m, comprising 13.679 km of ground road sections, 9.034 km of elevated bridge sections, and 2.08 km of tunnel sections. The construction scope primarily includes road engineering, traffic engineering, bridge engineering, tunnel engineering, water supply and drainage works, power and telecommunications engineering, thermal engineering, as well as landscaping and greening works.

Project direct objectives: Upon completion, the project will enhance urban traffic capacity (projected to improve Ulaanbaatar's traffic flow by 7%-23%) and provide citizens with a greener, more livable urban environment. It will effectively alleviate traffic congestion in Ulaanbaatar and improve road traffic efficiency.

Additional objectives: Upon completion, the project will establish an urban development economic zone around Ulaanbaatar, providing essential transportation infrastructure to facilitate the expansion of urban core facilities and industries. Over the next 5 years, the project is expected to boost economic growth in the surrounding areas significantly. It will greatly improve travel conditions for residents along the route, alleviate urban congestion, enhance residents' sense of social gain, and boost public satisfaction by creating numerous employment opportunities for nearby communities. The completion of the project effectively alleviates traffic congestion and also contributes to reducing traffic-stall-related environmental pollution, improving air quality, and lowering carbon emissions. Furthermore, it will provide a solid foundation for the development of satellite towns along the route, accelerating their construction progress.

7.1.2. Section division status

(1) Overall project condition

The project originates in Ulaanbaatar City with a total route length of 24.793 km, comprising 13.679 km of roadbed section, 9.034 km of bridge sections (5 bridges in total), and 2.08 km of tunnel section, featuring a road width of 32-60 m. The entire route incorporates seven interchanges, 12 grade separations, three footbridges, and seven underpasses.

(2) Section division

This project is divided into three sections, specifically:

Section 1 spans 8.6 km in total length, commencing at the intersection of Power Plant No.

4 Road (ТЭЦ-4 зам) with existing roads. The alignment proceeds northward along Moscow Street, crosses the Mongolian Transverse Railway at chainage K1+600, then turns eastward at Bayankhoshuu Street, terminating at Revolution Street. The route passes through 9 residential areas including District 29 of Bayangol District and Districts 17, 23, 39, 6, 7, 40, 8, and 11 of Songino Khairkhan District. The cross-section width is 32-60 m throughout, comprising 4.571 km of at-grade road sections and 2 bridge sections with a total length of 4.029 Km.

Section 2 spans a total length of 6.900 km, commencing at the Revolution Street near the tunnel portal of this project and extending eastward through Denj 1000 Terminal Road, Khailaast street, Road No. 7, and Dari-Ekh street. At chainage K8+730, the alignment includes construction of a 2.08 km long tunnel through Sambarkhundev Mountain, terminating at the northern side of Агуйтын толгой Hill. The route passes through 10 residential districts in No. 28 District in Songinokhairkhan, District Nos. 12 & 21, 20 & 7, 13, 14 in Chingeltei, District Nos .13, 14 in Sukhbaatar and District No. 21 in Bayanzürkh, maintaining a consistent 45-60 m cross-section width throughout. This package consists of 2.505 km of at-grade road sections, 2.315 km of bridge sections, and 2.08 km of tunnel section.

Section 3 extends 9.293 km in total length, originating at the northern side of Агуйтын толгой Hill (Chainage K15+500) and proceeding southward along Monel street, Da Khuree street, Police Academy Avenue, General's No. IX Street, and Dunjingarav Street. The alignment crosses railway tracks at Chainage K23+850 and terminates with a trumpet interchange connecting to Tuul Expressway. The route traverses 7 residential districts, Districts Nos. 21, 31, 32, 19, 24, 8, and 12 in Bayanzürkh District, with cross-section widths varying between 45-60 m. This package comprises 6.603 km of at-grade road sections and 2.690 km of bridge sections.

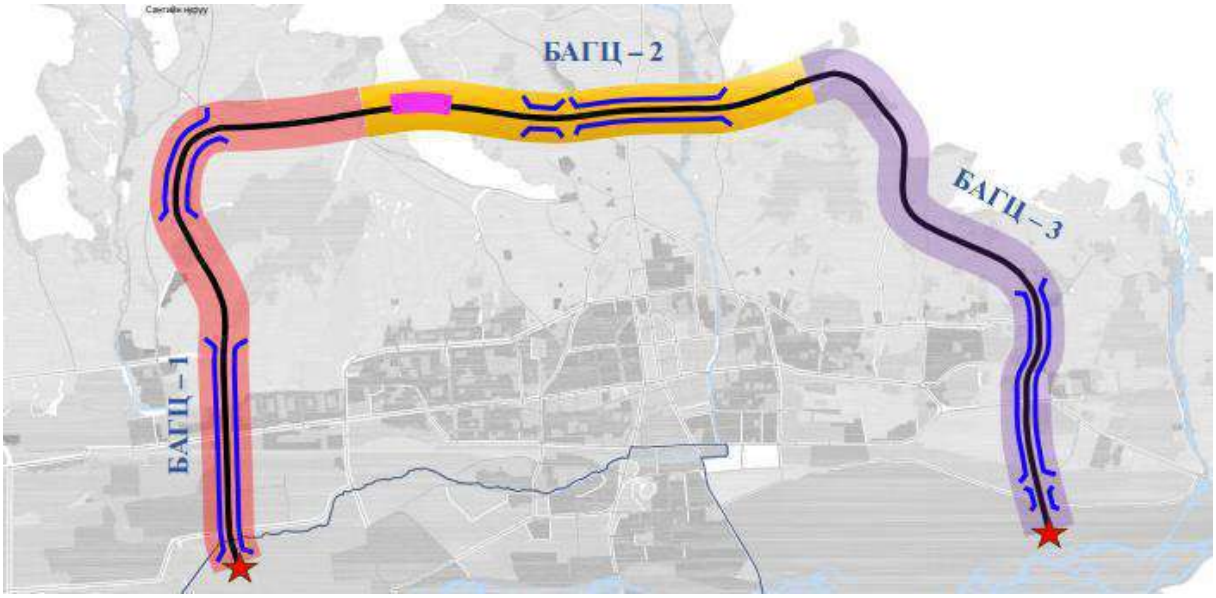


Figure 7. 1. Project Implementation Section Division

(3) Basis for section division

Considering the project's total length of 24.793 km with an extensive alignment and large-scale construction scope, coupled with the employer's stringent timeline requirements, the overall section division strategy was determined based on the following approach:

1) Road length

With a total project length of 24.793 km located adjacent to the main urban area of Ulaanbaatar City - where traffic congestion is prevalent - the project has been divided into three sections (western, northern and eastern sectors of the main city) to ensure controllability and convenience during implementation. Each section maintains a total length within 10 km.

2) Capital scale

Given the substantial total project investment, the section division effectively controls funding scale for each segment, facilitating phased project financing and tendering while enabling detailed cost planning and scheduling during subsequent implementation phases.

3) Implementation complexity

The project, constructed around the main urban area, involves two elevated bridge crossings over railways and one mountain tunnel. The section division strategically distributes these technical challenges across different segments, ensuring overall technical controllability of the project.

4) Project schedule

With a total construction period of only 2 years and further constrained by Ulaanbaatar's climate conditions that limit effective construction time, the adoption of concurrent segmented implementation significantly enhances construction efficiency and ensures project schedule compliance.

7.1.3. Schedule plan

(1) Overall timeline

Pre-construction phase: 2025.1.20~2025.12.30

Construction implementation phase: 2026.1.1~2027.12.30

Commissioning & warranty phase: 2028.1.1~2028.12.20

(2) Detailed schedule

1) Phase-specific breakdown

Pre-construction phase includes the following activities: project official launch, consultant selection, feasibility study report preparation, project feasibility review, tender documentation preparation, and contractor appointment. The critical activities are: feasibility study report preparation and project feasibility review.

Construction implementation phase comprises the following activities: project implementation design, land expropriation and utility relocation, equipment and material

procurement and preparation, project construction, and final inspection and handover. The critical activities include: land expropriation and utility relocation, bridge and tunnel section construction during project execution.

Commissioning & warranty phase includes: project commissioning, operational adjustments, warranty services, and post-project evaluation. The pivotal activity is: project operational adjustments.

2) Analysis of working hours compatible with climatic conditions

Based on the climatic conditions of Ulaanbaatar City, the daytime temperature from April to October (a total of 7 months) can reach above 0°C, meeting the requirements for on-site construction activities. The remaining 5 months are characterized by extreme cold and low temperatures, making on-site construction unfeasible. During this period, indoor engineering activities such as prefabricated component processing, procurement and transportation of construction materials are prioritized. For tunnel excavation, which is conducted within the mountain, the mountain body provides insulation. With conventional construction ventilation and other measures, a construction duration of 10 months (from February to November) can be achieved annually.

Figure 7. 2. Monthly Average Temperature Variation Curve of Ulaanbaatar City

Annual rainfall is mainly concentrated from June to August, with daily precipitation ranging from 21.6 to 29.4 mm. While this may have some impact on on-site construction activities, the overall rainfall is relatively light, resulting in limited effects. Tunnel excavation, being conducted within the mountain structure, is unaffected by rainfall conditions when standard drainage measures are properly implemented.

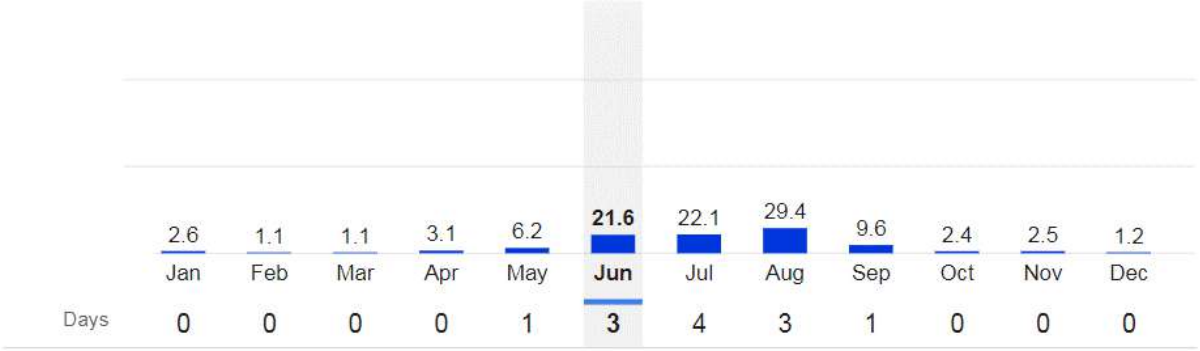


Figure 7. 3. Monthly Average Rainfall in Ulaanbaatar City

During the annual on-site construction period from April to October, daylight hours typically exceed 11 hours per day, sufficiently covering local standard working hours while allowing for additional overtime capacity. For tunnel excavation conducted within the mountain structure, proper implementation of conventional lighting measures eliminates dependence on natural daylight duration.

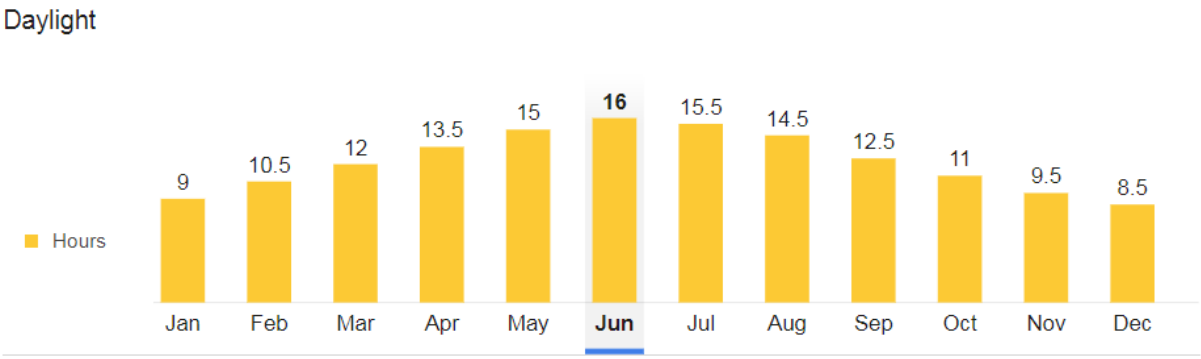


Figure 7. 4. Daily Average Construction Hours in Ulaanbaatar City

Detailed schedule plan

Based on the overall project scale, construction content, and local construction conditions, two additional implementation options have been developed for the client's selection, supplementing the original plan:

Figure 7.1.3-1 Construction periods of Plans A, B and C

Plan Name	Implementation Method	Estimated Construction Period
Plan A (Original Plan)	Concurrent implementation of 3 work sections	2 Years
Plan B	Sequential implementation of 3 work sections	6 Years
Plan C	2-phase approach: 1. Mongolian ger district section first 2. Urban section subsequently	5 Years

Table 7. 1. Detailed Project Implementation Schedule (Plan A)

No.	Phase	Implementation Activities	2024												2025												2026												2027												2028											
			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
D.1	Pre-construction	Project official launch																																																												
		Consultant selection																																																												
		Feasibility study report preparation																																																											
		Project feasibility review																																																											
		Tender documentation preparation																																																											
		Contractor appointment																																																											
D.2	Construction	Detailed project design																																																										
		Land expropriation & utility relocation																																																										
		Equipment, material procurement and preparation																																																										
		Construction (road sections)																																																										
		Construction (bridge sections)																																																										
		Construction (tunnel sections)																																																										
		Inspection & handover																																																										
D.3	Trial Operation and Warranty	Trial Operation																																																								
		Adaptive Adjustment																																																										
		Warranty Services																																																										
		Post-Project Evaluation																																																										

Table 7. 2. Detailed Project Implementation Schedule (Plan B)

No.	Phase	Implementation Activities	2024												2025												2026												2027												2028											
			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
D.1	Pre-construction	Project official launch																																																												
		Consultant selection																																																												
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D.2	Construction	Detailed project design																																																										
		Land expropriation & utility relocation																																																										
		Equipment, material procurement and preparation																																																										
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		Construction (tunnel sections)																																																										
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D.3	Trial Operation and Warranty	Trial Operation																																																									
		Adaptive Adjustment																																																										
		Warranty Services																																																										
		Post-Project Evaluation																																																										

Table 7.2 Detailed Project Implementation Schedule (Plan B) (Continue)

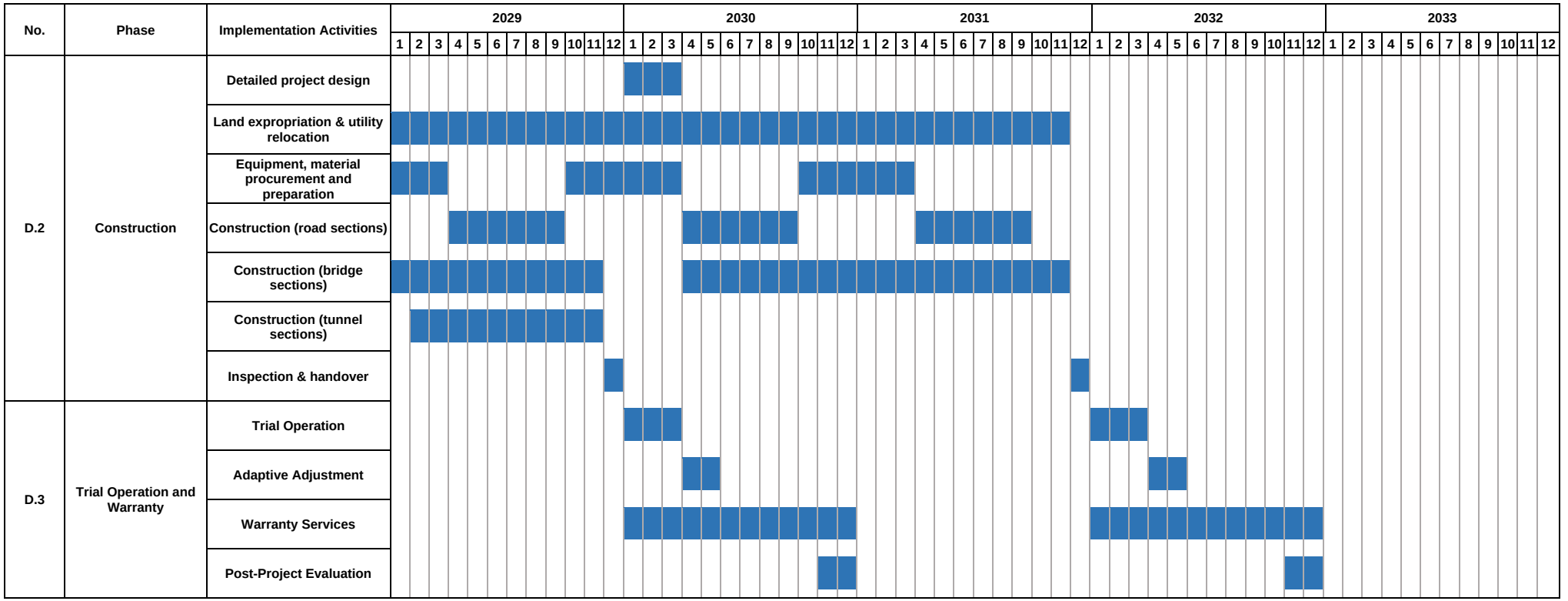
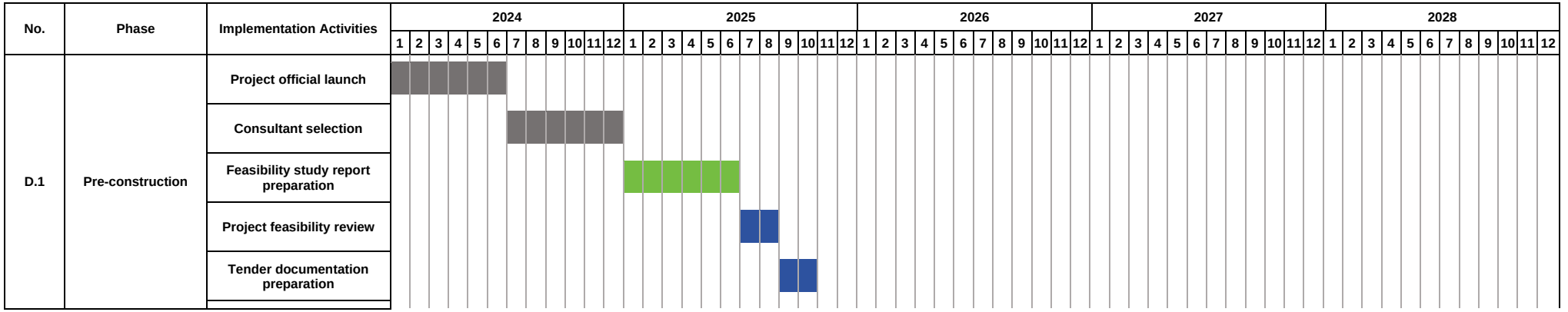


Table 7. 3. Detailed Project Implementation Schedule (Plan C)



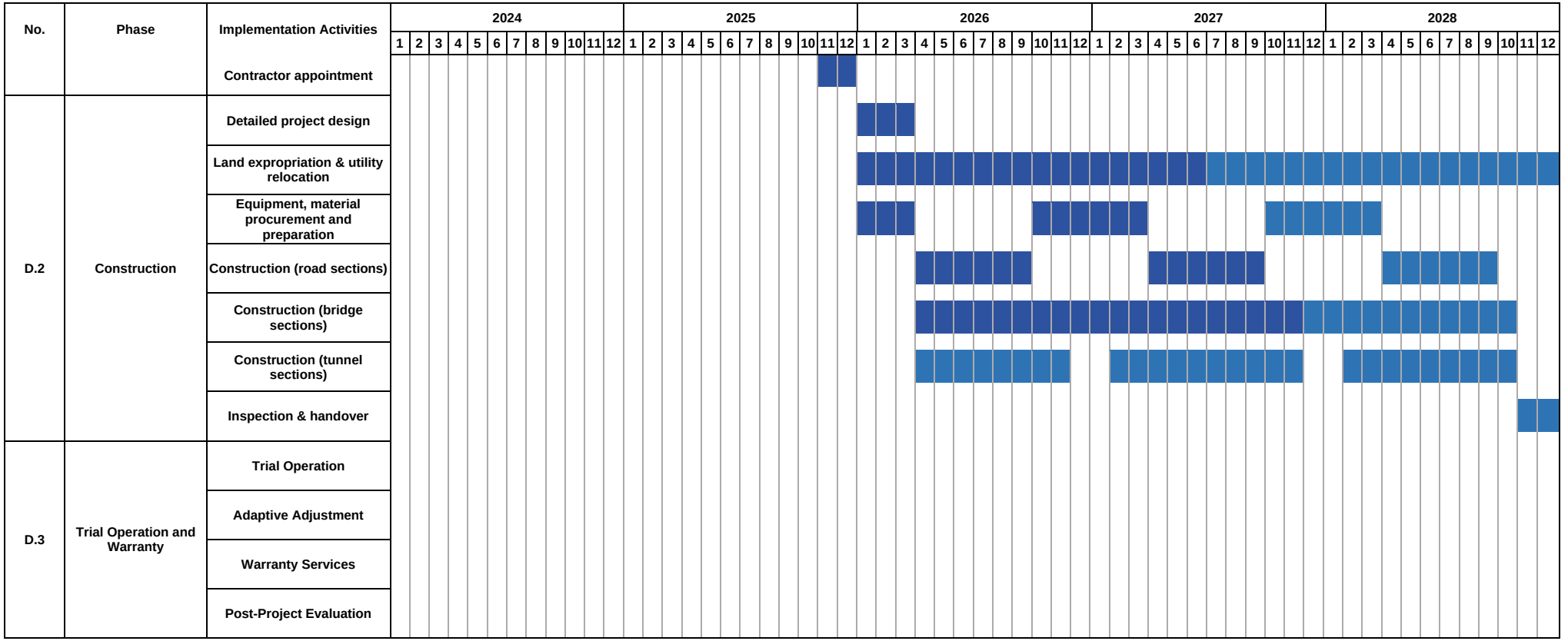
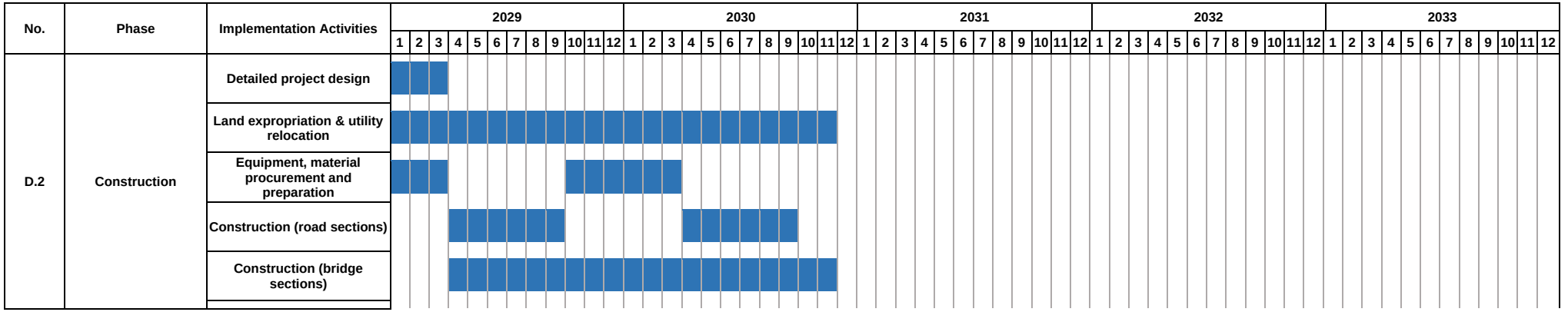
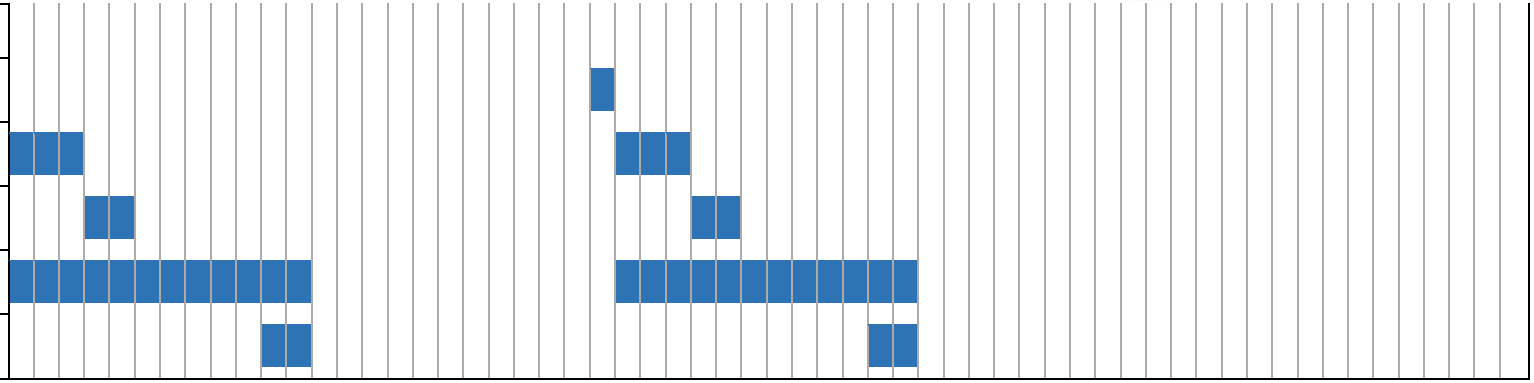


Table 7. 4. Detailed Project Implementation Schedule (Plan C) (Continue)



		Construction (tunnel sections)	
		Inspection & handover	
D.3	Trial Operation and Warranty	Trial Operation	
		Adaptive Adjustment	
		Warranty Services	
		Post-Project Evaluation	



7.1.4. Fund plan

(1) Fund allocation schedule

The total estimated construction budget for this project is 3,282,968,606,712 MNT (approximately $918,569,839.59 ам.доллар USD), comprising construction costs of 2,825,319,285,718 MNT, power line relocation expenses of 16,227,343,503 MNT, land expropriation and resettlement costs of 510,000,000,000 MNT. The funds will be allocated according to the project implementation phases as outlined in the following schedule.

Table 7. 5. Project Funding Allocation Plan

No.	Work Item		Funding Percentage	Togrog (MNT)	U.S. Dollar ($)
Construction Phase			100.00%	3282968606712	918569839.59
1	Power Line Relocation		0.49%	16227343503	4540387.10
2	Land Expropriation & Utility Relocation		15.53%	510000000000	142697257.97
3	Section 1 Construction	Surface Road	7.14%	234322032139	65562963.67
4		Bridge	21.96%	720952039420	201721331.68
5	Section 2 Construction	Surface Road	5.15%	169163806695	47331786.99
6		Bridge	12.03%	395015238468	110524688.99
7		Tunnel	13.85%	454815967115	127256845.86
8	Section 3 Construction	Surface Road	7.76%	254886995421	71317010.47
9		Bridge	16.07%	527585183951	147617566.86

(2)Fund Allocation Schedule

Table 7. 6. Section 1 (2026) Fund Preparation Schedule

No.	Work Item	Funding Percentage		U.S. Dollar ($)	2026											
Construction Phase		100.00%		319038215	January	February	March	April	May	June	July	August	September	October	November	December
1	Power Line Relocation	0.71%		2270193	113510	227019	340529	681058	681058	227019						
2	Land Expropriation & Utility Relocation	10.24%		32659260	1484512	1484512	1484512	2474186	2474186	2474186	2969024	2969024	2969024	3958698	3958698	3958698
3	Project Construction (Road Section)	10.28%		32781480				4589407	5245037	6556296	6556296	5245037	4589407			
4	Project Construction (Bridge Section)	29.72%		94809028				10086067	10086067	10086067	16137707	18154920	12103280	6051640	6051640	6051640
Fund Preparation					1598021	1711531	1825041	17830718	18486348	19343569	25663026	26368981	19661711	10010338	10010338	10010338

Table 7. 7. Section 1 (2027) Fund Preparation Schedule

No.	Work Item	Funding Percentage	U.S. Dollar ($)	2027											
Construction Phase				January	February	March	April	May	June	July	August	September	October	November	December
1	Power Line Relocation	0.00%	0												
2	Land Expropriation & Utility Relocation	5.27%	16824466	3958698	2969024	2474186	2474186	2474186	2474186						
3	Project Construction (Road Section)	10.28%	32781480				4589407	5245037	6556296	6556296	5245037	4589407			
4	Project Construction (Bridge Section)	33.51%	106912308	6051640	6051640	6051640	10086067	10086067	10086067	12103280	16137707	18154920	6051640	6051640	
Fund Preparation				10010338	9020664	8525826	17149660	17805290	19116549	18659576	21382744	22744327	6051640	6051640	

Table 7. 8. Section 2 (2026) Fund Preparation Schedule.

No.	Work Item	Funding Percentage	U.S. Dollar ($)	2026											
Construction Phase		100.00%	325950478	January	February	March	April	May	June	July	August	September	October	November	December
1	Power Line Relocation	0.35%	1135098	56755	113510	170265	340529	340529	113510						
2	Land Expropriation & Utility Relocation	8.04%	26203362	1191062	1191062	1191062	1985103	1985103	1985103	2382124	2382124	2382124	3176165	3176165	3176165
3	Project Construction (Road Section)	7.26%	23665894				3313225	3786543	4733179	4733179	3786543	3313225			
4	Project Construction (Bridge Section)	15.94%	51946603				5526234	5526234	5526234	8841975	9947222	6631481	3315741	3315741	3315741
5	Project Construction (Tunnel Section)	18.35%	59810717				6362842	6362842	6362842	10180548	11453116	7635411	7635411	3817705	
Fund Preparation				1247817	1304571	1361326	17527934	18001252	18720868	26137825	27569005	19962241	14127316	10309611	6491905

Table 7. 9. Section 2 (2027) Fund Preparation Schedule

No.	Work Item	Funding Percentage	U.S. Dollar ($)	2027											
Construction Phase				January	February	March	April	May	June	July	August	September	October	November	December
1	**Power Line Relocation**	0.00%	0												
2	**Land Expropriation & Utility Relocation**	4.14%	13498701	3176165	2382124	1985103	1985103	1985103	1985103						
3	**Project Construction (Road Section)**	7.26%	23665894				3313225	3786543	4733179	4733179	3786543	3313225			
4	**Project Construction (Bridge Section)**	17.97%	58578085	3315741	3315741	3315741	5526234	5526234	5526234	6631481	8841975	9947222	3315741	3315741	
5	**Project Construction (Tunnel Section)**	20.69%	67446127		3817705	7635411	6362842	6362842	6362842	7635411	10180548	11453116	3817705	3817705	
Fund Preparation				6491905	9515570	12936254	17187405	17660723	18607358	19000071	22809066	24713563	7133446	7133446	

Table 7. 10. Section 3 (2026) Fund Preparation Schedule

No.	Work Item	Funding Percentage	U.S. Dollar ($)	2026											
Construction Phase		100.00%	273581146	January	February	March	April	May	June	July	August	September	October	November	December
1	**Power Line Relocation**	0.41%	1135098	56755	113510	170265	340529	340529	113510						
2	**Land Expropriation & Utility Relocation**	12.91%	35317572	1605344	1605344	1605344	2675574	2675574	2675574	3210688	3210688	3210688	4280918	4280918	4280918
3	**Project Construction (Road Section)**	13.03%	35658506				4992191	5705361	7131701	7131701	5705361	4992191			
4	**Project Construction (Bridge Section)**	25.36%	69380255				7380878	7380878	7380878	11809405	13285581	8857054	4428527	4428527	4428527
Fund Preparation				1662099	1718854	1775609	15389172	16102342	17301663	22151795	22201630	17059933	8709445	8709445	8709445

Table 7. 11. Section 3 (2027) Fund Preparation Schedule

No.	Work Item	Funding Percentage	U.S. Dollar ($)	2027											
Construction Phase				January	February	March	April	May	June	July	August	September	October	November	December
1	**Power Line Relocation**	0.00%	0												
2	**Land Expropriation & Utility Relocation**	6.65%	18193902	4280918	3210688	2675574	2675574	2675574	2675574						
3	**Project Construction (Road Section)**	13.03%	35658506				4992191	5705361	7131701	7131701	5705361	4992191			
4	**Project Construction (Bridge Section)**	28.60%	78237309	4428527	4428527	4428527	7380878	7380878	7380878	8857054	11809405	13285581	4428527	4428527	
Fund Preparation				8709445	7639215	7104101	15048643	15761813	17188153	15988755	17514766	18277772	4428527	4428527	

7.1.5. Procurement plan

(1) Procurement overview

The Ulaanbaatar New Ring Road project spans a total length of 24.793 km with a width ranging from 32-60 m, comprising 9.034 km of elevated bridge sections, 13.679 km of ground road sections, and 2.08 km of tunnel sections. The construction scope primarily includes road engineering, traffic engineering, bridge engineering, tunnel engineering, water supply and drainage works, power and telecommunications engineering, thermal engineering, as well as landscaping and greening works.

This procurement package includes:

Pre-construction phase consultant services procurement

The procurement scope is specifically categorized into: feasibility study and design procurement, topographic survey procurement, geotechnical investigation procurement, cost estimation services procurement, and economic analysis services procurement, among others.

Procurement of construction management services, building equipment and building materials during the project implementation phase

The detailed procurement components include construction services procurement, supervision services procurement, testing services procurement, monitoring services procurement, construction machinery procurement, transport vehicles procurement, protective facilities procurement, ready-mix concrete procurement, steel reinforcement procurement, aggregate materials procurement, asphalt mixture procurement, piping materials procurement, and vegetation procurement, among others.

Procurement of trial operation management services during the project's trial operation and warranty phases

The detailed procurement components include the procurement of trial operation management services, maintenance and warranty services, among others.

Policy basis

Procurement activities shall be conducted under Mongolia's Procurement of Goods, Works and Services Using State and Local Property (Revision), implementing independent or combined bidding for various project procurements with general competitive bidding as the principle method, while allowing direct procurement or restricted competitive bidding when necessary, with mandatory open tendering procedures executed in strict compliance with relevant legal provisions, particularly for consulting services where three (3) or more qualified consultants shall be shortlisted for evaluation, with bidding preparation requiring 30 to 60 working days and all operations being conditional upon fulfillment of prescribed application requirements (generally).

Key technical requirements for procurement

1) Centralized procurement and open tendering

The bidding process for major projects must maintain complete open and transparency throughout all stages.

Bulk materials (such as steel, concrete) shall be procured through framework agreements, with supplier selection from the Ulaanbaatar International Building Materials Exhibition.

2) Supplier management

Preference shall be given to enterprises with proven project experience in Mongolia, specifically those having recently completed construction and management of projects with comparable scale and typology, while demonstrating adequate financial capacity, human resources, and equipment availability.

Integrated with Mongolia's "Traffic Congestion Mitigation Program", an investment promotion mechanism shall be established to attract international capital participation.

3) Logistics and project duration coordination

The acquisition or leasing of construction equipment shall be strictly aligned with project milestones, ensuring the first batch of materials arrives on-site before project launch to guarantee all startup requirements are fulfilled.

Utilise municipally reserved logistics corridors and align with local commuting patterns to reasonably schedule construction material deliveries, avoiding conflicts with urban traffic peak periods.

Procurement process arrangement

1) Demand analysis

Based on the project construction schedule, work backward to develop the material list, clarify relevant procurement requirements, refine technical specifications, and specify quantities, parameters, and other details.

2) Tendering implementation

Conduct the tender per Mongolia's procurement procedures to select qualified suppliers. After qualification review, the number of eligible suppliers shall not be fewer than three. Cross-border procurement contracts must simultaneously comply with the acceptance standards of both countries.

3) Contract performance supervision

Use an electronic platform to track procurement progress, with a focus on monitoring the production quality of customized products.

Procurement schedule

Prepare a procurement plan table based on the project's construction requirements:

Table 7. 12. Project Procurement Plan Table

No.	Procurement Item	Procurement Period
1	Consultant Services Procurement	July 2024 - June 2025
2	Construction Management Services Procurement	September 2025 - December 2025

No.	Procurement Item	Procurement Period
3	Construction Equipment Procurement	January 2026 - March 2027
4	Construction Materials Procurement	January 2026 - March 2027
5	Trial Operation Management Services Procurement	September 2027 - December 2027

7.1.6. Construction plan

According to the project schedule, the overall construction period is planned from January 2026 to December 2027, with a total duration of 24 months. The project is divided into three sections to be constructed simultaneously, where Section 1 includes 4.571 km of ground road section and 4.029 km of bridge section; Section 2 contains 2.505 km of ground road section, 2.315 km of bridge section and 2.08 km of tunnel section; and Section 3 includes 6.603 km of ground road section and 2.690 km of bridge section.

The construction content of the ground road section includes: ground attachments clearance, topsoil cleaning, underground pipeline relocation, excavation and backfill of roadbed earthwork, construction of protective engineering, pipeline construction, pavement construction, construction of traffic facilities, construction of lighting facilities, and green planting.

The construction content of the tunnel section includes: excavation and construction of the tunnel entrance, excavation and construction of the tunnel body, excavation of the tunnel body and ancillary construction, and tunnel electromechanical installation.

The construction content of the bridge section includes: ground attachments clearance, topsoil cleaning, underground pipeline relocation, bridge pile foundation construction, construction of bridge piers and abutments, construction of the cast-in-place main beam of the bridge, construction of bridge ancillary works, excavation and backfill of roadbed earthwork, construction of protective engineering, pipeline construction, pavement construction, construction of traffic facilities, construction of lighting facilities, and green planting.

Figure 7. 5. Construction plan for road sections

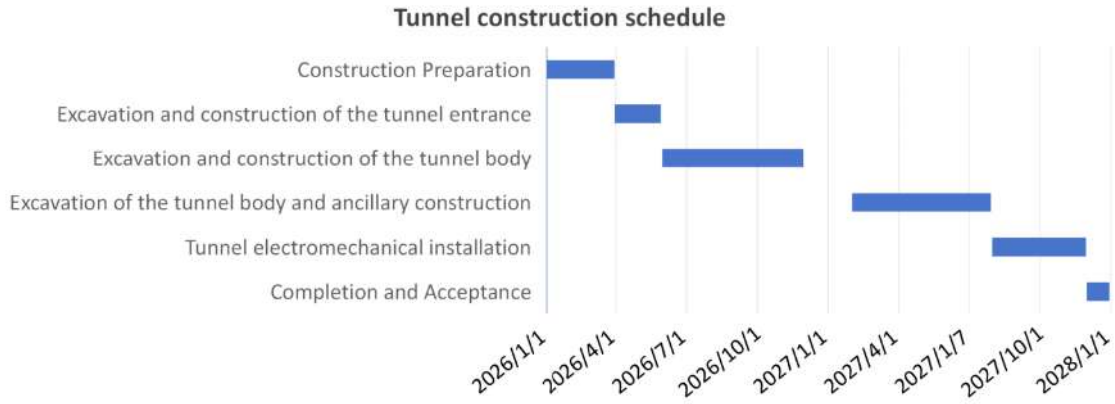


Figure 7. 6. Construction plan for tunnel section

Figure 7. 7. Construction plan for bridge section

7.1.7. Risk response plan

(1) Core risk identification

1) Risk of land acquisition

The project involves the expropriation and compensation of land and houses along the 24.793 km route, requiring precautions against property disputes and resettlement conflicts. Residents along the route may trigger mass incidents due to dissatisfaction with the relocation policies.

2) Traffic diversion pressure

During the construction period, the existing road traffic must be maintained, which may increase the load on the surrounding road network. The average traffic speed in the project-affected area is expected to decrease by 15%-20% during construction.

3) Environmental control challenges

Dust and noise pollution as well as air pollution may intensify.

(2) Risk management framework

Based on the various risks that may occur during project implementation, corresponding risk levels shall be defined according to their impact severity and response requirements, thereby facilitating risk management:

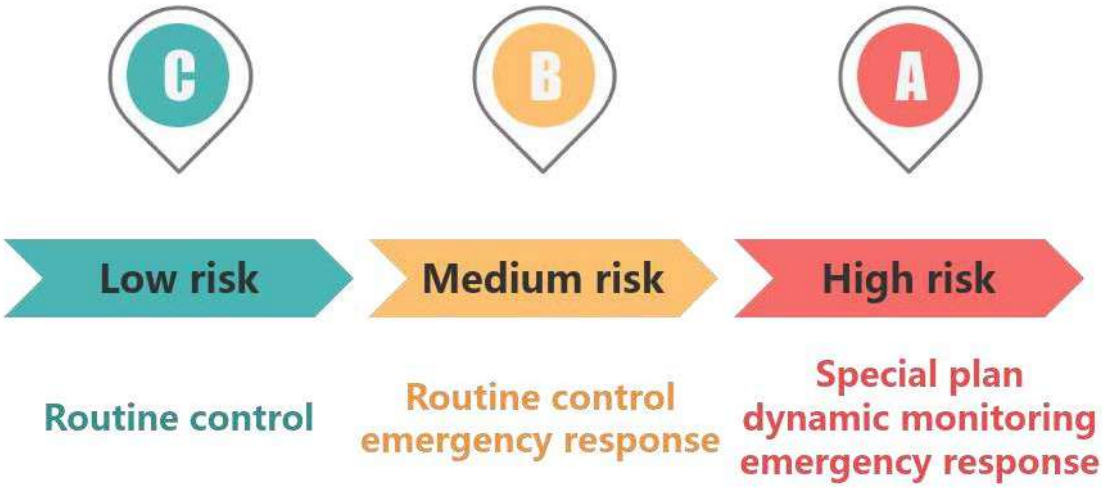


Figure 7. 8. Project Risk Management Framework

(3) Response measures

1) Land expropriation and resettlement

Standardized compensation mechanism: Implement Ulaanbaatar City's unified land replacement standards (2025 updated version), with establishment of a dedicated compensation appeal channel to complete dispute arbitration within 30 days. Housing Security Coordination: Prioritize relocation to newly-built residential areas.

2)Traffic organization optimization

The traffic in the affected areas of the project will be subject to phased construction scheduling, and dynamic management by traffic police will be adopted during peak hours.

3)Environmental risk prevention and control

Real-time pollution monitoring is carried out, with 50 sets of PM2.5/ noise sensors deployed along the line (data directly connected to the municipal environmental protection platform). Green construction techniques are adopted, and the use of ready-mixed concrete and dust suppression nets for coverage is mandatory (reducing dust by 40%).

4)Emergency management mechanism

Establish a cross-departmental emergency command center (with joint presence of transportation, environmental protection and public security departments) to deal with and clear sudden traffic congestion.

(4) Monitor and evaluation

1) Track key indicators

Table 7. 13. Project Implementation Key Indicators Tracking

Indicator	Target Value	Monitoring Frequency
Land expropriation completion rate	≥95%	Monthly

Indicator	Target Value	Monitoring Frequency
Construction zone congestion index	≤120% of baseline level	Weekly
Dust exceedance incidents	≤3 times/month	Real-time

2) Third-party audit

Engage international engineering consulting firms to conduct phased compliance reviews.

7.2. OPERATION AND MAINTENANCE

7.2.1. Operation and maintenance objectives

(1) Integration into road network and functionality

Through the implementation of a reasonable operation and maintenance plan, ensure that the Ulaanbaatar New Ring Road project can be quickly integrated into the urban road network after completion. Road administrators can efficiently perform operation and maintenance tasks, and urban citizens can conveniently utilize the project for travel.

(2) Stable operation and cost savings

Through the implementation of a reasonable operation and maintenance plan, ensure that the Ulaanbaatar New Ring Road project maintains long-term stable traffic flow after commissioning, while minimizing operation and maintenance costs.

(3) Toll collection and revenue generation

Utilize high-definition video cameras installed along the route to record vehicle mileage on the Ulaanbaatar New Ring Road. The system will then issue corresponding toll charges based on the recorded data to achieve project revenue.

7.2.2. Operation and maintenance system configuration

7.2.2.1 Current O&M analysis

(1) Significant expansion in annual road maintenance scale

In 2024, the city renovated a total of 137.1 km of roads, ten times the average annual construction length over the past decade. For 2025, plans include repairing 74 km of roads at 36 locations, including major thoroughfares such as Genghis Khan Avenue and Peace Avenue, as well as a large-scale renovation of 5 km of roads in the Uvurkhangai region.

Some projects face bidding challenges. For example, the Uvurkhangai road overhaul project failed to attract bidders three times, with a fourth tender planned for April 2025.

(2) Current operation and maintenance status

According to the Mongolian Statistical Yearbook, the total national expenditure on construction, capital repairs, and maintenance in 2024 amounted to 9,158,443.7 million MNT. Of this, Ulaanbaatar spent 3,837,076.6 million MNT, with roads accounting for 7.1% (approximately 272,432.4 million MNT) and bridges accounting for 1.3% (approximately 49,882.0 million MNT). The combined expenditure on roads and bridges totaled 322,314.4 million MNT, with operation and maintenance costs representing about 15% (48,347.16 million

MNT).

Table 7. 14. Current Operation and Maintenance Status in Mongolia

22.2 БАРИЛГА УГСРАЛТ, ИХ ЗАСВАРЫН АЖЛЫН БҮТЭЦ, барилгын төрлөөр
STRUCTURE OF CONSTRUCTION, CAPITAL REPAIRS AND MAINTENANCE, *by type of construction*

Барилгын төрөл	*Type of construction*	2020	2021	2022	2023	2024*
		дүнд эзлэх хувь / *share to total*				
Барилга угсралт, их засварын ажил - бүгд	***Construction, capital repairs and maintenance - total***	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Орон сууцны	**Residential buildings**	**33.8**	**33.9**	**37.2**	**38.9**	**35.7**
Орон сууцны бус	**Non residential buildings**	**32.7**	**34.9**	**30.5**	**35.2**	**33.1**
Үйлдвэрийн	*Industrial*	13.1	20.6	14.6	14.8	12.3
Худалдаа, үйлчилгээний	*Trade and services*	2.7	2.5	2.9	3.9	4.1
Эмнэлэг, сургууль, соёлын	*Hospitals, schools, cultural*	11.1	7.8	7.3	9.9	8.9
Бусад	*Other*	5.9	4.1	5.7	6.6	7.8
Инженерийн байгууламж	**General engineering construction**	**30.8**	**28.7**	**29.5**	**22.2**	**27.7**
Эрчим хүчний	*Energy*	1.0	0.5	1.8	4.1	7.6
Холбооны	*Communication*	0.0	0.0	0.0	0.3	0.4
Төмөр зам	*Railway*	15.5	16.8	19.0	4.9	3.5
Авто зам	*Roads*	7.9	5.6	4.3	6.9	7.1
Гүүр, гүүрэн гарц	*Bridges*	0.3	0.4	0.5	0.8	1.3
Далан, суваг, шугам, сүлжээ	*Dams, ditches, cables, networks*	4.7	4.2	2.5	3.0	6.0
Бусад (зам, талбайн бусад ажил)	*Minor work and others*	1.5	1.1	1.4	2.3	1.8
Их засварын ажил	**Capital repairs and maintenance**	**2.7**	**2.5**	**2.9**	**3.6**	**3.5**

7.2.2.2 Workforce and staffing allocation

(1) Operation personnel

Project operation requires the use of high-definition video cameras installed along the route to record vehicle mileage on the Ulaanbaatar New Ring Road. The system will then issue corresponding toll charges based on the recorded data to achieve project revenue. This necessitates the configuration of a specialized team for system hardware and software operations and the establishment of a project toll management department.

Based on operational requirements, the following personnel are estimated to be needed:

1)Remote support staff (approx. 6 persons)

Handle abnormal requests from self-service terminals (such as payment failures, device malfunctions) via a seated system, remotely authorize passage or resolve issues.

2)Maintenance and technical support team (approx. 12 persons)

Conduct daily equipment inspections, troubleshoot faults, and perform system upgrades to ensure stable operation of key devices such as lane controllers and ETC antennas.

Manage backend servers and data centers, optimize toll algorithms, and maintain network security.

3)Audit and data analysis personnel (approx. 6 persons)

Investigate toll evasion (such as ETC interference, license plate obstruction) using surveillance footage and transaction data for evidence collection. Analyze traffic flow data to optimize lane configurations and toll rate strategies.

(2) Maintenance personnel

According to the organisational structure of Ulaanbaatar's road maintenance department, the current staffing comprises 197 employees in total, including: 1 general manager, 3 subject matter experts, 10 administrative office staff, 9 finance department staff and 174 professional technicians and labourers.

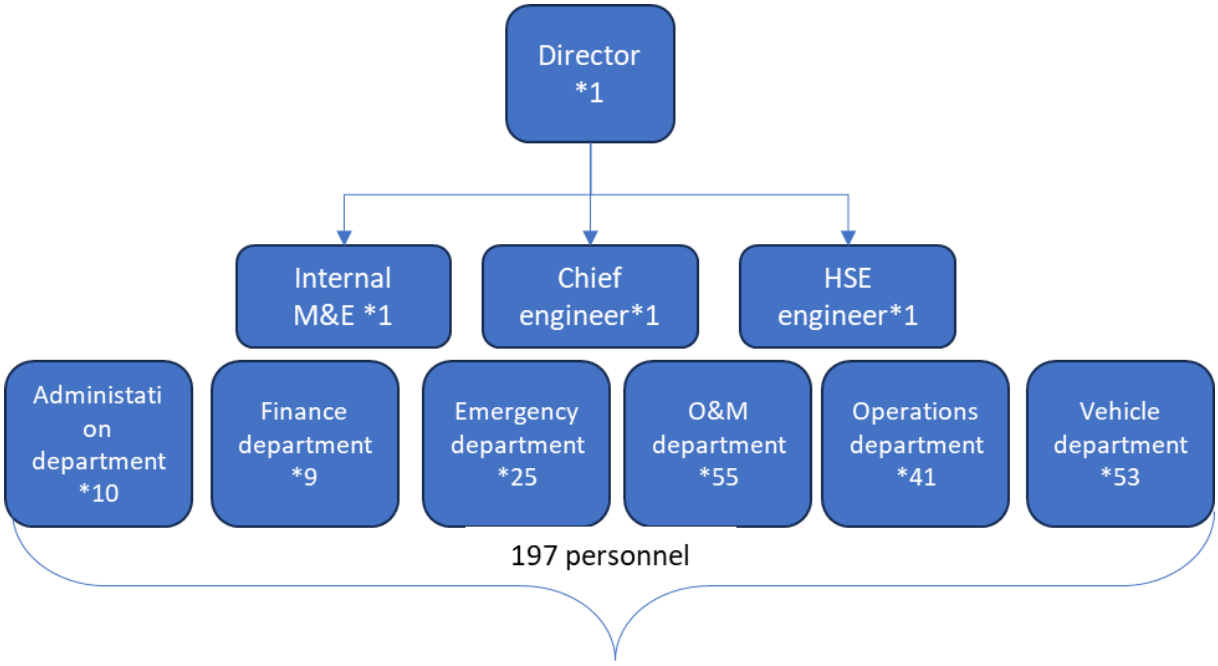


Figure 7. 9. Current Status of Road Maintenance Personnel in Ulaanbaatar

Upon completion of the Ulaanbaatar New Ring Road project, it will add maintenance workloads for 22.72 km of surface roads, 9.034 km of bridges, and 2.08 km of tunnels. It is estimated that additional staffing will be required, including one road specialist, one tunnel specialist, and one bridge specialist, along with six technical professionals and 12 maintenance technicians, totalling 21 personnel. Considering the critical importance of the Ulaanbaatar New Ring Road to the urban road network, it is recommended to establish a dedicated New Ring Road maintenance department with full-time maintenance staff if conditions permit.

Following the corresponding maintenance task plans, an appropriate number of maintenance construction workers shall be prepared to assist technical personnel in executing maintenance implementation tasks. All relevant personnel must undergo professional maintenance technical training before assignment and will be organized into several teams to carry out the project's maintenance work.

7.2.2.3 Mechanical Equipment Configuration

(1) Operation equipment

1) 50 sets of vehicle identification and detection equipment

License plate recognition cameras: Automatically capture license plates and match system data for vehicle classification and toll calculation.

ETC antennas (RSU): Communicate with onboard OBUs to enable electronic non-stop

toll collection.

Vehicle detectors (induction loops/sensors): Detect vehicle positions and trigger barrier gates/license plate recognition systems.

2) 6 sets of automated payment and interaction equipment

Self-service terminals: Integrated functions including card dispensing, QR code payment, and receipt printing, supporting multiple payment methods including ETC cards.

Toll displays and voice guidance: Real-time fare display with operational voice prompts.

3) 6 sets of control and execution equipment

Lane controllers: Coordinate device operations and process toll logic and data transmission.

Automatic barrier gates: Automatically raise/lower based on payment status to permit or block vehicles.

4)1 set of backend management and communication system

Data center servers: Store toll data, vehicle information, and surveillance footage, supporting data analysis and report generation.

Network communication equipment: Connect lane terminals with backend systems to ensure real-time data transmission.

5)6 sets of emergency and safety equipment

Surveillance cameras: Cover toll areas to record transaction processes and abnormal situations.

Alarm devices: Detect forced passage and equipment failures, triggering alerts.

(2) Maintenance equipment

Ulaanbaatar's road maintenance machinery department currently has 51 employees, including managers, operation engineers, mechanical engineers, equipment operators, repair technicians, drivers, and dispatchers. Deployed equipment includes cranes, excavators, scrapers, asphalt pavers, and aerial work platforms.

Figure 7. 10. Current Status of Road Maintenance Equipment in Ulaanbaatar

Upon completion of the Ulaanbaatar New Ring Road project, it will add maintenance responsibilities for 22.72 km of surface roads, 9.03 km of bridges, and 2.08 km of tunnels. To ensure rapid traffic flow as designed by the project, new maintenance equipment must be deployed including guardrail repair vehicles, high-speed crash trucks, rapid clearance vehicles, tunnel aerial platforms, and tunnel cleaning vehicles - all selected for their safety, efficiency and quick-response capabilities to enable fast maintenance operations.

Figure 7. 11. Additional Road Maintenance Equipment Required Upon Project Completion

7.2.2.4 Operation and maintenance regulations

(1) Operation regulations

An automated toll collection system requiring neither vehicle stops nor speed reduction shall be implemented. Standard methods include Radio Frequency Identification (RFID) and license plate recognition (contactless payment). For this project, RFID equipment will be installed at the starting/ending points and all intersection entry/exit locations, interfacing with the existing "Road Traffic Mobile Monitoring System" (RFID system) and connecting to a unified network to achieve comprehensive toll collection across all sections for all vehicles.

(2) Maintenance regulations

The current operation and maintenance system mainly allows citizens to file complaints and provide feedback upon discovering faults in roads and Bridges, and then the road operation and maintenance department conducts repairs.

As the Ulaanbaatar New Ring Road is a high-speed corridor featuring extended elevated bridges and tunnels, it requires a proactive maintenance system with regular inspections and preventive measures. This ensures the roadway maintains optimal operating conditions and uninterrupted traffic flow. The system includes:

1) Routine inspection and maintenance

Daily inspection and maintenance should involve checking and maintaining the appearance changes, structural changes, and construction operation conditions of road infrastructure. The main contents include:

① Whether the appearance of the roadbed, pavement and ancillary facilities is intact, whether there is water accumulation, snow accumulation, ice formation and debris, etc., and whether there are any abnormal conditions that affect the safety of highway traffic:

② Blockages in various drainage facilities:

③ Obvious structural deformations or damages in structures such as Bridges and culverts:

④ The impact of construction operations within the road domain on highway infrastructure and traffic operation:

⑤ The growth conditions of green plants within the road area:

⑥ Night driving safety conditions, anti-glare and reflective effects of traffic safety facilities, etc. Other damages and abnormal situations.

Routine inspection and maintenance should primarily rely on visual observation with proper documentation, while necessary conditions shall be photographed or videotaped, followed by timely maintenance arrangements after inspection recording. The frequency of routine inspection and maintenance shall be twice daily, with increased frequency during rain, snow, ice seasons and frequent natural disaster periods such as typhoons, heavy rains, blizzards, and dense fog.

When routine inspection and maintenance identify abnormal conditions endangering road traffic safety, immediate action shall be taken. For situations requiring delayed treatment, inspection personnel must promptly install warning and protective signs, report the problem, and maintain on-site monitoring until emergency maintenance personnel arrive.

2) Regular inspection and maintenance

A regular inspection and maintenance system shall be established before project commissioning to conduct routine checks on the technical conditions of highway infrastructure. The inspection and maintenance scope shall include verifying the intactness of all infrastructure components and identifying any damages, defects or other abnormalities. Routine inspections shall primarily employ close-range examination methods, combining visual observation with instrument and tool measurements. For pavement and significant structures, automated and informational detection methods should be integrated with manual inspections, with photographic or video documentation required for significant findings.

Table 7. 15. Frequency of road inspection and maintenance

Inspection Items	Inspection Frequency
Roadbed	Monthly
Pavement	Monthly
Traffic Safety Facilities	Quarterly
Bridges	Monthly
Tunnels	Monthly
Drainage Pipeline Facilities	Quarterly
Greening & Environmental Protection Facilities	Quarterly

During rain, snow, ice seasons, and periods of frequent natural disasters such as typhoons, heavy rains, blizzards, and dense fog, the frequency of routine inspections shall be increased. The inspection frequency for electromechanical facilities shall be determined based on

equipment/component types and technical characteristics.

3) Regular inspection and maintenance

A regular inspection and maintenance system shall be established before project commissioning to conduct comprehensive cyclical examinations and testing of highway infrastructure technical conditions. The regular inspection and maintenance shall meet the technical condition assessment requirements for roadbed, pavement, bridge/tunnel structures, and roadside facilities. Pavement inspections shall employ automated detection equipment, while manual surveys with portable devices may be adopted for routes or sections lacking automated detection capabilities. Roadbed, roadside ancillary facilities, greening and environmental protection facilities may utilize either manual surveys or automated detection methods. Bridge/tunnel structures may be inspected through manual surveys or automated detection. Identified issues shall be promptly recorded and corresponding maintenance work arranged accordingly.

4) Special inspection and maintenance

Special inspections for the Ulaanbaatar New Ring Road include dedicated inspection maintenance and emergency inspection maintenance.

① Special inspection and maintenance should be carried out when any of the following situations occur:

A. When further specialized inspections are required following routine, regular, or emergency inspections;

B. When implementing specialized maintenance projects or major rehabilitation projects;

C. During long-term monitoring alerts;

D. When roads exceed their design service life and critical infrastructure requires specialized inspections.

② Emergency inspection and maintenance shall be promptly conducted on road infrastructure following natural disasters, accidents, or other emergency incidents to assess damage conditions. For infrastructure that has sustained damage or poses significant safety hazards, emergency inspections shall be performed as required by evaluation, urgent repair, and traffic maintenance needs, including assessments of load-bearing capacity, disaster resistance capability, and operational safety.

Special road inspections shall investigate the causes of road damage, assess structural integrity, evaluate overall performance and functional conditions of road structures, and provide maintenance/reinforcement recommendations with timely arrangement of repair work.

7.2.3. Operation and maintenance cost estimation

7.2.3.1 Cost estimation

The operational costs for the Ulaanbaatar New Ring Road project primarily involve two major aspects:

(1) Labor, equipment and system operation costs for toll management

Market research on toll collection systems indicates that automated toll collection methods requiring neither vehicle stops nor speed reduction will incur the following annual operational costs, including toll operation costs and traffic management operation costs, as shown in the table below:

Table 7. 16. Road toll operation costs

No.	Year	Type	Cost / by road section (billion MNT)
First Ring Road length/km			**24.793km**
1	2025	Pre-construction Preparation and Planning	
2	2026	Construction and Installation Work of the Project	
3	2027	Construction and Installation Work of the Project	
4	2028	Toll Operation	1.57
5	2029	Toll Operation	1.62
6	2030	Toll Operation	1.68
7	2031	Toll Operation	1.74
8	2032	Toll Operation	1.80
9	2033	Toll Operation	1.86
10	2034	Toll Operation	1.93
11	2035	Toll Operation	2.00
12	2036	Toll Operation	2.07
13	2037	Toll Operation	2.14
14	2038	Toll Operation	2.21
15	2039	Toll Operation	2.29
16	2040	Toll Operation	2.37
17	2041	Toll Operation	2.46
18	2042	Toll Operation	2.54
19	2043	Toll Operation	2.63
20	2044	Toll Operation	2.72
21	2045	Toll Operation	2.82
22	2046	Toll Operation	2.92
23	2047	Toll Operation	3.02
24	2048	Toll Operation	3.12
Total			**47.52**

Table 7. 17. Operating costs of road traffic management

No.	Year	Type	Cost / by road section (billion MNT)
First Ring Road Total length			24.793km
1	2025	Pre-construction Preparation and Planning	
2	2026	Construction and Installation Work of the Project	
3	2027	Construction and Installation Work of the Project	
4	2028	Operation of Road Traffic Management	6.28
5	2029	Operation of Road Traffic Management	6.50
6	2030	Operation of Road Traffic Management	6.73
7	2031	Operation of Road Traffic Management	6.96
8	2032	Operation of Road Traffic Management	7.21
9	2033	Operation of Road Traffic Management	7.46
10	2034	Operation of Road Traffic Management	7.72
11	2035	Operation of Road Traffic Management	7.99
12	2036	Operation of Road Traffic Management	8.27

13	2037	Operation of Road Traffic Management	8.56
14	2038	Operation of Road Traffic Management	8.86
15	2039	Operation of Road Traffic Management	9.17
16	2040	Operation of Road Traffic Management	9.49
17	2041	Operation of Road Traffic Management	9.82
18	2042	Operation of Road Traffic Management	10.17
19	2043	Operation of Road Traffic Management	10.52
20	2044	Operation of Road Traffic Management	10.89
21	2045	Operation of Road Traffic Management	11.27
22	2046	Operation of Road Traffic Management	11.67
23	2047	Operation of Road Traffic Management	12.07
24	2048	Operation of Road Traffic Management	12.50
Total			190.09

(2) Routine maintenance, cleaning and facility upkeep costs

Calculated according to Mongolia's road and bridge maintenance standards with reference to China's tunnel maintenance technical specifications, the project's direct costs over a 20-year operational period are as follows:

Table 7. 18. Direct costs of road operation and maintenance

No.	Year	Road		Tunnel		Bridge	
		Cost (billion MNT)		Cost (billion MNT)		Cost (billion MNT)	
1	2029	Maintenance and repair	4.33	Maintenance and repair	3.69	Maintenance and repair	1.73
2	2030	Maintenance and repair	4.63	Maintenance and repair	3.95	Maintenance and repair	1.86
3	2031	Maintenance and repair	4.96	Maintenance and repair	4.22	Maintenance and repair	1.99
4	2032	**Routine maintenance**	10.17	**Routine maintenance**	6.99	**Routine maintenance**	3.35
5	2033	Maintenance and repair	5.67	Maintenance and repair	4.84	Maintenance and repair	2.27
6	2034	Maintenance and repair	6.07	Maintenance and repair	5.18	Maintenance and repair	2.43
7	2035	Maintenance and repair	6.50	Maintenance and repair	5.54	Maintenance and repair	2.60
8	2036	**Routine maintenance**	13.32	**Routine maintenance**	9.16	**Routine maintenance**	4.39
9	2037	Maintenance and repair	7.44	Maintenance and repair	6.34	Maintenance and repair	2.98
10	2038	Maintenance and repair	7.96	Maintenance and repair	6.78	Maintenance and repair	3.19
11	2039	Maintenance and repair	8.51	Maintenance and repair	7.26	Maintenance and repair	3.41
12	2040	**Routine maintenance**	17.47	**Routine maintenance**	12.00	**Routine maintenance**	5.75
13	2041	Maintenance and repair	9.75	Maintenance and repair	8.31	Maintenance and repair	3.91
14	2042	Maintenance and repair	10.43	Maintenance and repair	8.89	Maintenance and repair	4.18
15	2043	Maintenance and repair	11.16	Maintenance and repair	9.51	Maintenance and repair	4.47
16	2044	**Routine maintenance**	22.89	**Routine maintenance**	15.73	**Routine maintenance**	7.54
17	2045	Maintenance and repair	12.78	Maintenance and repair	10.89	Maintenance and repair	5.12
18	2046	Maintenance and repair	13.67	Maintenance and repair	11.66	Maintenance and repair	5.48
19	2047	Maintenance and repair	14.63	Maintenance and repair	12.47	Maintenance and repair	5.86
20	2048	**Routine maintenance**	30.01	**Routine maintenance**	20.63	**Routine maintenance**	9.89

Total	222.33		174.04		82.40
All	**478.77**				

7.2.3.2 Cost-saving measures

(1) Maintenance management optimisation

Preventive maintenance: Enhance routine infrastructure inspections and monitoring to reduce emergency repairs, e.g., predictive maintenance through big data analytics.

Outsourcing partnerships: Introduce competitive bidding among specialized companies to lower maintenance costs.

Equipment and material reuse: Repair and reuse old equipment and materials to reduce expenditure.

(2) Smart technology applications

Intelligent systems: Deploy ETC, automatic card dispensers, etc., to improve traffic flow and reduce labour; implement IoT-based equipment monitoring for precise maintenance needs.

Digital management: Adopt paperless offices and innovative inspection platforms to cut administrative and labour costs.

(3) Energy & resource management

Water and electricity conservation: Install rainwater harvesting systems and differentiated water supply strategies; use LED lighting with motion sensors to reduce energy use.

Green maintenance: Apply composite modified asphalt and other materials to extend road lifespan and reduce maintenance frequency.

(4) Operational refinement

Budget and procurement control: Strictly manage material procurement through competitive bidding; maintain inventory logs to prevent resource redundancy.

Performance & evaluation: Incorporate cost control into the assessment system, such as implementing quotas for water and electricity consumption management.

Human resource optimisation: Adjust staffing structures, expand service outsourcing to reduce fixed labour costs, and replace third-party services with internal training programs.

(5) Innovative business models

Asset revenue activation: Develop photovoltaic projects or advertising resources on unused land to generate non-toll income.

Emergency service monetisation: Integrate towing and rescue services to create revenue streams.

Through these measures, road operations can achieve dual objectives of cost reduction and efficiency improvement while balancing environmental benefits and service quality.

7.2.4. Maintenance plan

7.2.4.1 Personnel plan

(1) Personnel preparation

Based on the project's maintenance scope and tasks, either supplement the existing road maintenance department with a 21-person technical maintenance team, or establish a dedicated Ulaanbaatar New Ring Road maintenance company to execute comprehensive project operations.

Adopt either full-time staffing or a combination with temporary hires, allocating approximately 4 maintenance construction workers per technical personnel to execute specific maintenance tasks. For critical sections such as major bridges and tunnels, specialized maintenance teams shall implement 24-hour shift rotations.

(2) Personnel training

Full-time maintenance technicians shall undergo qualification-based onboarding training, while temporary construction workers shall receive pre-employment training to meet competency standards or be selected from pre-qualified construction teams with relevant implementation experience.

(3) Personnel dispatch

Adopt a tiered response system integrated with intelligent scheduling for personnel allocation:

Level C alert: 50% workforce on standby

Level B alert: Full deployment with equipment preheating

Level A alert: Activate government-enterprise coordination to mobilize support from major corporations

Utilize the O&M-traffic data integration platform for preemptive personnel deployment and intelligent maintenance scheduling.

7.2.4.2 Cost Plan

(1) Establish cost framework

The project's operation and maintenance funds may be obtained from municipal budget allocations or financing channels. First, submit annual maintenance plans to the municipal government in advance based on the project's O&M requirements to secure approved maintenance funds. Any shortfall can be covered through diversified financing channels for O&M funding.

(2) Refine cost structure

Break down the total annual maintenance costs into detailed components according to specific maintenance activities. Specify exact amounts and compositions of each sub-item to create a clear cost inventory. Conduct corresponding cost preparation and planning in the year preceding maintenance work to ensure effective annual cost implementation.

(3) Cost control

For outsourced maintenance technical services, adopt lump-sum contracting for overall cost control. Implement project-level control systems for tiered cost management of each item.

In compliance with local financial audit regulations, disclose project maintenance costs publicly to ensure cost transparency.

7.2.4.3 Implementation plan

(1) Roadbed maintenance shall preserve optimal load-bearing capacity and stability, with prompt treatment of damages including frost boiling, settlement, and lateral slippage. For specialized maintenance projects of significant scale, in addition to complying with national standards, field trials shall determine specific construction methods and parameters. Continuous settlement monitoring shall be implemented during both construction and operational phases until stability requirements are achieved.

(2) Road shoulders shall maintain smooth, clean surfaces free of debris and weeds, with widths complying with specifications, straight edges without defects, and cross-slopes meeting design requirements that seamlessly connect with pavement surfaces without obstructing drainage. Curb stones shall remain intact without damage. Slope maintenance shall ensure the stability of both slope surfaces and slope bodies, with protective structures meeting all requirements for load-bearing capacity, structural safety, and disaster resistance.

(3) Systematic inspections shall be conducted for side ditches, drainage ditches, and intercepting ditches to ensure facility integrity, unimpeded roadbed drainage, timely removal of sediment deposits, and immediate repair of any structural damages.

(4) Retaining walls shall maintain structural solidity, stability, and integrity to prevent any compromise to traffic safety.

(5) Pavement maintenance shall consistently preserve structural load-bearing capacity and optimal technical conditions, ensuring surfaces remain free of significant damage while delivering comfortable and safe vehicle operation. Common asphalt pavement damages include alligator cracking, block cracking, longitudinal cracks, transverse cracks, potholes, raveling, settlement, rutting, corrugation, bleeding, frost boiling, and patching defects. Routine repairs, preventive maintenance, and rehabilitation measures shall be implemented to maintain surface evenness and integrity.

(6) Sidewalk maintenance shall cover subbases, surface layers, barrier-free facilities, curbs, and steps. Routine inspections must be conducted to promptly repair and address any defects or unauthorized occupancy.

(7) The maintenance scope for bridges and culverts shall include bridge deck systems, superstructures, substructures, ancillary works, and all culvert components. Bridge and culvert maintenance must comply with the following requirements:

1) Maintain clean appearance and fully functional drainage systems.

2) Ensure bridge deck pavements are solid and even, with proper longitudinal and cross slopes and smooth bridge approaches.

3) The structure is undamaged, without abnormal deformation, and has good stability.

4) All components, structures and facilities are complete, functioning normally and arranged reasonably.

5) No erosion on the foundation.

(8) Tunnel maintenance

1) The maintenance scope shall cover tunnel main structures, pavements, and ancillary facilities.

2) Main structure maintenance includes reinforced concrete segments, immersed tube sections, buried sections, open-cut sections, light transition sections, shafts, emergency passages, connecting passages, shear keys, and corbels.

3) Ancillary facility maintenance comprises ventilation towers, drainage systems, drainage pump stations, substations, light transition sections, decorative layers, management centers, and portal facilities. All ancillary facilities shall maintain structural integrity and proper functionality.

4) Tunnel pavement maintenance shall follow road pavement maintenance standards.

7.2.5. Technical response measures

7.2.5.1 Blizzard

(1) Emergency response & operation mode

1) Establish rapid response mechanisms guided by the "snowfall-as-command" principle. Activate emergency rescue plans upon snow accumulation, mobilizing personnel and equipment to sites immediately.

2) Human-machine collaborative operations shall adopt the "machinery-dominant, manual-supplementary" model: Snow removal equipment prioritises clearance of main thoroughfares, bridges, and curves as critical nodes; manual crews supplementarily distribute de-icing agents and anti-skid materials with a maximum single-operation disbursement capacity of 129 tons; advanced chemical de-icers are deployed during extreme low temperatures to enhance snow and ice processing capability in -45°C environments.

(2) Key route protection strategies

1) Reinforce high-risk zones (bridges, steep slopes, shaded sections) with frequent inspections and multi-round de-icing, complemented by warning signage.

2) Implement dynamic monitoring and closed-loop management via "inspection-treatment-feedback" workflows.

(3) Cross-department coordination & public engagement

1) Multi-agency joint prevention and control. Meteorological, traffic police, and road maintenance departments shall implement real-time data sharing, utilizing coordinated early warning systems to preemptively close high-risk road sections, thereby reducing traffic paralysis risks by over 80%.

2) Major enterprises shall participate in heavy machinery snow removal operations, having

donated animal feed, quilts and other relief materials during the 2024 blizzard while organizing employee volunteer assistance.

7.2.5.2. Frozen soil

Ulaanbaatar's frozen soil exhibits maximum seasonal freezing depths of 1.8-2.2 m, with extreme temperatures reaching -40°C in winter and brief summer highs (30°C), undergoing ≥50 annual freeze-thaw cycles. Typical frozen soil consists of silty clay (high frost heave susceptibility, liquid limit >35%).

In view of the local frozen soil characteristics, the project implements the following frost-resistant measures:

① Elevate roadbed design height

② Install anti-frost cushion layers and isolation layers, supplemented with drainage trenches and side ditches when necessary

③ Replace frost-susceptible materials within freezing zones with non- or low-frost-heave materials

Maintenance operations shall systematically verify the integrity of roadbed anti-frost cushion layers and isolation layers, ensure unimpeded drainage conditions, replace frost-heave damaged sections with non-frost-heave materials, and construct drainage trenches with side ditches when necessary during operational phases.

7.2.5.3. Flood

For potential flood risks along the project route, integrated technical responses including inspection, maintenance, reinforcement, and emergency response shall be implemented as follows:

(1) Intelligent inspection and hazard management

"Dual inspection mode (manual + drone)": Conduct comprehensive monitoring of high slopes, bridges, and other key road sections to ensure early detection and timely resolution of hazards.

Dynamic hazard ledger management: Perform thorough inspections of low-lying areas prone to water accumulation, establish a "single-list" ledger, and implement targeted remediation to ensure hazards are "cleared to zero."

(2) Maintenance and optimization of drainage facilities

Drainage system dredging: Regularly clean side ditches, bridge culvert inlets and outlets, remove weeds, and clear silt deposits to ensure unimpeded water flow. Conduct timely maintenance of pipelines and drainage systems before the rainy season.

Engineering system upgrades: Advance the construction of drainage pipelines and stormwater storage facilities to improve a flood prevention engineering system featuring "source reduction, pipeline discharge, and a balance of storage and drainage."

Sponge effect: Establish sponge city facilities to create an urban sponge system with

"infiltration, retention, storage, purification, utilization, and drainage," controlling total surface runoff.

(3) Flood control engineering reinforcement and regional coordination

For riverbank sections, enhance flood control capabilities by reinforcing river flood control systems and upgrading embankment standards.

Multi-department joint prevention and control: Deepen the "Three-Party Road Collaboration" mechanism, integrating resources from transportation, water resources, and emergency departments to form a full-chain responsibility system for hazard inspection and emergency response.

(4) Emergency response and long-term maintenance

Rapid repair mechanism: For facility damage or collapse issues, immediately formulate repair plans to minimize flood season risks.

7.2.5.4. Earthquake

The Ulaanbaatar New Ring Road project has incorporated earthquake resistance and seismic prevention measures during the design phase, and the following technical steps are taken during specific maintenance processes:

(1) Emergency response mechanism.

Activation of plans and command system: Immediately after an earthquake occurs, the emergency response mechanism is activated, and an earthquake relief headquarters is established to coordinate the collaborative efforts of transportation, police, emergency, and other departments. The headquarters sets up specialized task forces for repair, transportation, communication, etc., clarifying responsibilities and establishing a linkage mechanism.

Traffic control and priority passage: Temporary traffic control is implemented on disaster-affected roads, allowing only rescue vehicles to pass; meanwhile, "green channels" are opened to prioritize the passage of emergency personnel, material transport, and injured evacuation. Dynamic adjustment of access permissions is applied to prevent secondary congestion and accidents.

(2) Clearance and connectivity measures

Rapid clearance of critical sections: Adopting a "single-lane priority" strategy, debris is cleared first, and temporary detours are constructed to ensure basic traffic capacity. For severely damaged sections, multi-point simultaneous operations are carried out to shorten clearance time.

Application of graded repair techniques

Minor damage: Quick filling of road cracks and slope reinforcement;

Moderate damage: Partial roadbed grouting and replacement of damaged bridge bearings;

Severe damage: Reconstruction of bridges and tunnels or rerouting.

(3) Post-earthquake hazard inspection

Key inspection targets cover structures including bridges, tunnels, culverts, and slope protection, checking for potential hazards such as foundation voids, road surface subsidence, and slope collapse.

Combination of technical methods: Utilizing drone aerial photography, ground-penetrating radar detection, and other means to assist manual inspections for rapid identification of hidden risk points; establishing a dynamic monitoring mechanism in collaboration with traffic police and maintenance departments.

7.2.5.5 Traffic accidents

Road maintenance following traffic accidents involves multi-party coordination and standardised procedures, with the primary objectives of ensuring road traffic safety, repairing damaged facilities, and clarifying liability allocation.

(1) Rapid multi-department coordination

Establish a rapid response and handling mechanism involving traffic police, insurance companies, and road maintenance departments for traffic accidents, enabling swift liability determination after accidents occur, thereby facilitating road clearance and repair work.

(2) Rapid repair

Utilize rapid clearance vehicles, guardrail repair trucks, and other machinery to achieve quick clearance and maintenance of accident scenes, ensuring fast traffic flow. Potential hazards that may cause secondary disasters (such as fuel leaks or vehicle slide risks) must be prioritized for elimination.

(3) Traffic improvement

Employ big data for intelligent analysis of recorded information, focusing on accident-prone areas to analyze causes. Supplement and maintain corresponding road traffic facilities to reduce the probability of accidents.

7.2.5.6 Large-scale events

For major holiday events in Ulaanbaatar where citizens gather and travel intensively, the following methods are adopted for road maintenance and traffic assurance:

(1) Multi-party coordination for traffic assurance

Establish a joint command center involving event organizers, traffic police, road maintenance departments, and others. Plan traffic organisation and management methods, such as partial traffic restrictions or one-way routes, to ensure smooth road traffic.

(2) Intelligent emergency response mechanism

Utilise drones, smart monitoring, and broadcast systems to develop an effective emergency response and handling mechanism. Quickly and real-time address sudden incidents causing traffic congestion to rapidly alleviate traffic pressure.

(3) Post-inspection and recovery

Conduct comprehensive inspection along the road after large-scale events, promptly

restore damaged facilities caused during the events, inspect and eliminate potential hazards affecting road operation, and perform special inspection and maintenance on key structures such as bridges and tunnels.

7.3. KEY TECHNICAL MEASURES

7.3.1. Key technical measures for road engineering

(1) Alignment design for mountainous section tunnels

The northern route section passes through mountainous terrain with existing elevation differences of 35 m to 80 m. Adopting tunnel construction minimises damage to mountain structures while significantly reducing earthwork excavation, which benefits environmental protection. The original landform is preserved above tunnel roofs to maximize biological corridor retention. The vertical alignment design incorporates active drainage systems, with insulation measures for central drainage outlets at tunnel portals to prevent groundwater freezing. Additionally, the tunnel gradient is designed for outward drainage at both ends to prevent rainwater ingress.

(2) Large-span bridge solution for intersection crossings

According to the survey of existing bridges in Ulaanbaatar, most spans range between 20-30 m, with some newly constructed bridges reaching 40 m spans. For intersections along this project requiring spans exceeding 40 m, precast simply-supported beam solutions prove inadequate. Cast-in-place prestressed concrete continuous girder bridges offer safer and more reliable alternatives.

(3) Intelligent transportation system

Incorporating RFID technology, integrated electronic toll collection (ETC), variable message signs, and AI-based traffic monitoring to optimise traffic signals and lane control in real time.

(4) The connection between the ground pavement system and the central expressway system is a key technical aspect of this project's design, including the selection of entrance and exit locations and the evaluation of existing road traffic conditions, to ensure safe and efficient transitions between the main road and auxiliary lanes.

7.3.2. Key technical measures for bridge engineering

(1) Prestressed concrete strand technology featuring "high strength, low relaxation, corrosion resistance, and precision construction"

Prestressed concrete strands for bridges are the core material of prestressed concrete bridges, whose key technologies directly affect the safety, durability, and load-bearing capacity of bridges. The key technologies of prestressed strands focus on "high strength, low relaxation, corrosion resistance, and precision construction," requiring strict control throughout the entire lifecycle of materials, manufacturing, construction, and maintenance. Intelligent technologies

are integrated to enhance the long-term performance and safety of bridges.

(2) Large cantilever double-cantilever cap beams to address limited space for bridge layout

In this project, elevated bridges are arranged within the limited space of the central median of existing ground roads. Therefore, the substructure adopts a "double-column + large cantilever double-cantilever" concrete cap beam with minimal spatial occupancy. The minimum centre-to-centre spacing of the double columns is only 4.8 m, and the maximum cantilever length on one side of the cap beam reaches 10 m, making the technology relatively complex. For this project, the prestressed cap beams are designed as Class A components, meaning that under the serviceability limit state, tensile stress is allowed in the cross-section but must not exceed the designed tensile stress value, and no cracks are permitted. Calculations confirm that the design meets requirements under both the ultimate limit state and serviceability limit state.

(3) Active noise reduction technology using sound barriers

As this project involves an urban arterial road with high traffic volume, the design requirements for noise barriers are stringent, demanding both effective noise reduction and consideration of aesthetic appeal. After a comprehensive analysis, the design recommends a hybrid solution combining sound absorption and sound insulation for the noise barriers. Based on the project's environmental impact assessment report, noise barriers are implemented at noise-sensitive points along the route. The barriers are installed on the outer side of the elevated bridge guardrails.

(4) Seismic isolation bearings to reduce the seismic response of elevated bridges

The seismic intensity of this project is classified as VII-VIII degrees. In the seismic design of the elevated bridge, the concept of "resilient bridge" has been introduced. To reduce the seismic response of the central elevated bridge under earthquake action, the design incorporates seismic-reduction pot bearings for cast-in-place prestressed concrete box girders and horizontally force-distributing rubber bearings for precast prestressed concrete small box girders. These measures effectively reduce the stress on piers, control the relative displacement between the main girders and pier tops, and comprehensively enhance the bridge's survivability.

(5) Enhancing bridge structure durability

The durability of concrete structures directly impacts the service life and safety of bridges during their operational period, warranting significant attention in design and the implementation of effective measures to strengthen durability design.

1) Improving concrete quality and optimising mix proportions

Starting with raw material control, strict management is applied to key technical indicators, including slump, maximum water-cement ratio, minimum cement content, minimum strength

grade, maximum chloride ion content, alkali content, and impermeability. Durable concrete is employed to enhance compactness and intrinsic damage resistance.

2) Refining structural calculations and reinforcing detailing design to prevent and control concrete cracks

3) Strengthening deck drainage design

The deck pavement uses C40 waterproof concrete with double-layer cold-rolled ribbed steel mesh to improve mechanical performance and prevent cracking. Drainage blind ditches are installed along the inner side of crash barriers for rapid removal of infiltrated rainwater. A novel waterproofing layer combining sprayed hot asphalt and stone chips ensures firm bonding between asphalt and concrete pavements. Drainage designs for scuppers and expansion joints prevent water penetration into beams.

4) Enhancing construction quality control, with strict management of concrete cover thickness.

5) Adopting vacuum grouting technology to ensure dense filling of prestressing ducts.

6) Tightening control over steel components (prestressing tendons, anchors, couplers), employing epoxy coating or galvanization. When necessary, corrosion inhibitors are added to grouting materials to prevent tendon corrosion.

(6) Multi-measure optimization design for prestressed concrete box girder structure of main elevated bridge to reduce construction Period.

The rational arrangement of segment divisions, selection of optimal construction techniques to ensure structural safety while minimizing mutual interference during construction and maximizing schedule compression constitutes a key technical challenge for this project.

1) Selecting optimal construction techniques to reduce prestressing stages, maximize effectiveness of prestressing tendons, minimize material usage while ensuring rational structural stress distribution, and shorten construction duration.

2) Through rational span arrangement, segment division and construction sequencing, maximum construction conditions are achieved. The design adopts principles of "prestressed before conventional", "avoiding long segments", "high before low", and "short before long". The "prestressed before conventional" principle means constructing prestressed box girders first followed by conventional RC box girders, maximizing convenience for tendon stressing and simplifying construction processes. The "avoiding long segments" principle limits segment length to 3-4 spans to prevent multi-stage stressing prolonging schedules, generally controlling stressing stages within 2 times. The "high before low" principle constructs upper bridge levels first. The "short before long" principle first constructs 3-span segments with single-stage stressing, then 4-span segments using wet joint methods. This rational design arrangement effectively guides construction, creating conditions for schedule reduction.

(7) Adopting rational bridge configuration and construction techniques to cross the

ulaanbaatar railway.

Due to special requirements for railway crossings, the construction of main bridge structures must fully ensure the safety of railway traffic below, while considering that future maintenance operations after bridge opening must not affect railway operations. This design employs prestressed concrete continuous girders for the crossing, constructed using the cantilever casting method. The cantilever construction method features: no need for ground-supported formwork or large lifting/transport equipment, with the main equipment being a pair of movable form travelers; suitability for situations where traffic below cannot be interrupted or where limited-formwork methods are inappropriate, avoiding extensive foundation treatment and minimizing impact on ground traffic; mature construction technology with high reliability, capable of adapting to variations in box girder cross-sections.

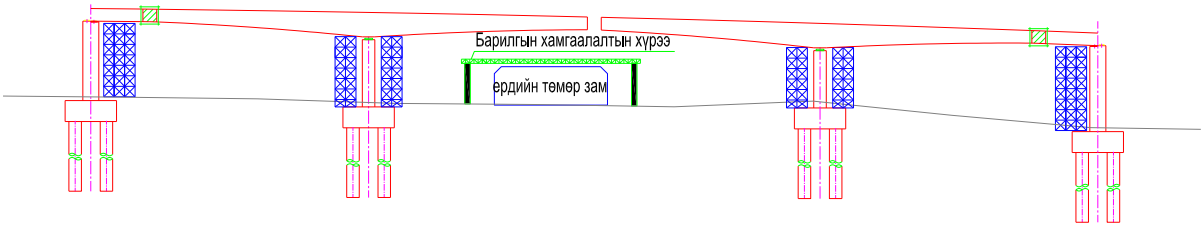


Figure 7. 12. Cantilever Casting Method for Crossing Ulaanbaatar Railway

(8) Limited Formwork Method for Cast-in-Place Prestressed Concrete Continuous Girders at Intersections to Maintain Traffic Flow.

This project involves multiple intersection crossings, where cast-in-place prestressed concrete continuous girders are constructed using the limited formwork method to ensure uninterrupted traffic. The limited formwork method is suitable for locations with low bearing capacity or specific clearance requirements below bridges, avoiding extensive foundation treatment while minimizing impact on ground traffic; featuring mature construction technology with high reliability that accommodates box girder cross-section variations; though with relatively higher costs compared to full scaffolding methods. The support system employs longitudinal and transverse beam structures with designed vehicle passage spaces beneath, where protective plates are installed at the lower edges to prevent falling objects and ensure traffic safety.

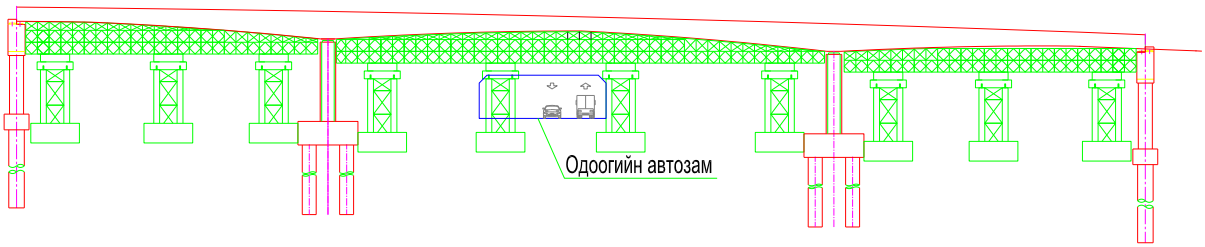


Figure 7. 13. Limited Formwork Method for Intersection Crossings

(9) Multiple work fronts for elevated bridge construction to accelerate project progress.

To expedite project implementation, shorten construction periods and enhance efficiency,

bridge structural construction should adopt simultaneous multi-work front operations. The main construction sequence includes: utility relocation while completing land acquisition and demolition within planned right-of-way → construction access road preparation → enclosed bridge structure construction (including foundations, substructures, superstructures, deck systems etc.) → ground roadworks, landscaping, and traffic sign/marking installation.

7.3.3. Key technical measures for tunnel engineering

(1) Critical civil engineering technologies for tunnels

1) Impact of tunnel construction on buildings near tunnel portals

Based on field surveys and collected data, the tunnel portal section passes directly beneath densely clustered buildings with overburden depths ranging approximately 15-40 m.

Based on the preliminary understanding from the site investigation data, the tunnel portal section and the Grade V portal section pass through rock-dominated strata with relatively intact rock mass and high strength. To ensure the safety of life and property of the residents above the tunnel, during tunnel construction, the stability of the tunnel crown surrounding rock is enhanced by grouting inside the tunnel and strengthening the advance support measures (advance pipe canopy support and double-layer small pipe support). The double-side wall drift method should be used in tunnel construction. By using the intermediate partition wall and temporary supports, the tunnel section is divided into several parts for step-by-step excavation. At the same time, to avoid the impact of blasting excavation on the houses above, mechanical excavation is adopted for the Grade V portal section to minimize the disturbance to the surrounding rock and the impact range, and timely support and invert construction should be carried out. The principles of short advance, multiple cycles, etc., should be followed during construction. Meanwhile, the buildings in this range should be closely monitored to timely understand the impact of tunnel construction on surface structures. In case of any unexpected situation, personnel should be evacuated in time and remedial measures should be taken.

2) Large-span tunnels

Large-span tunnels typically refer to those with an excavation width exceeding 15 m or accommodating three or more traffic lanes. This project features a maximum width of 17.7 m, qualifying as a large-span tunnel. Such tunnels exhibit high flatness ratios, where stress redistribution post-excavation adversely affects tunnel safety, leading to reduced face stability, significant stress concentration at the tunnel base, unstable crown conditions, increased loosening pressure, and relatively lower load-bearing capacity of support structures. Consequently, large-span tunnels impose more stringent requirements on design, construction, and surrounding rock control.

In this design, advanced support measures and face shotcreting are adopted to ensure face stability, while enhancing support structure strength through high-strength shotcrete, high-capacity rock bolts, and immediate steel arch installation after excavation. These measures

control surrounding rock deformation within allowable limits. By integrating ground-penetrating radar, advanced boreholes, and TSP advance detection data with numerical simulations, support parameters are dynamically adjusted to match support stiffness with deformation rates, avoiding "over-stiffness causing cracks" or "excessive flexibility leading to collapses", thereby ensuring construction safety.

3) Tunnel excavation and support technology

During tunnel excavation, different sequential excavation methods are employed based on rock mass classifications: the double-side drift method for Class V rock masses and the ring-cut method with reserved core soil for Class IV rock masses.

Guided by the New Austrian Tunneling Method (NATM) principles, excavation approaches and support parameters are dynamically optimized using real-time deformation monitoring data. The excavation follows the philosophy of "pre-support, strict grouting, short advance, robust support, rapid closure, and frequent monitoring". Primary support combines shotcrete, rock bolts, and steel arches to control deformation, while secondary lining uses cast-in-place concrete.

Given dense surface structures above the tunnel and strict settlement/vibration requirements, mechanical excavation is exclusively used to minimize ground subsidence and eliminate blasting vibrations affecting surface buildings.

4) Advanced Geological Prediction

Advanced geological prediction serves as a critical procedure and technical measure to ensure tunnel construction safety, and should be implemented as an essential construction process. The prediction requires complexity classification to identify key forecast sections, while adhering to dynamic design principles that adjust geological complexity ratings, prediction methods, and technical requirements based on real-time geological findings obtained during implementation.

The methodology integrates geological surveys with exploration, combines geophysical prospecting and drilling, coordinates long-range and short-range approaches, synthesizes surface and underground investigations, and correlates data between pilot and subsequent tunnels. Comprehensive analysis and cross-verification of various prediction results enhance accuracy. Priority shall be given to utilizing pilot tunnels for advanced geological prediction activities.

Building upon detailed survey data and geological prediction outcomes, comprehensive analysis shall be conducted regarding the rock mass classification and construction risks ahead of the tunnel face, with targeted countermeasures and construction plans developed accordingly.

5) Monitoring and Measurement

To obtain mechanical dynamic information and stability status of surrounding rock and

support structures during tunnel construction for timely feedback to guide construction operations and ensure safety. After analyzing measurement data and performing necessary calculations, predictions and feedback are provided to modify support system designs promptly, ensuring construction safety and tunnel stability.

Monitoring primarily includes: internal and external observations, crown settlement measurement, clearance convergence monitoring, surrounding rock pressure measurement, contact pressure between primary and secondary linings, longitudinal displacement tracking, and steel frame internal force assessment.

6) Tunnel insulation

Two insulation schemes were considered: The first places insulation between primary and secondary linings, but since insulation cannot transmit ground pressure, tunnel deformation often compromises thermal performance. Therefore, the project adopted the second approach - surface application, installing insulation on the secondary lining surface. Based on engineering analogies, the insulation extends approximately 1000 m from the portal, covering the entire tunnel length to maintain thermal insulation effectively.

7) Deep burial of central drainage ditches and insulation measures for outlet pipes

Groundwater is the root cause of frost damage to tunnel support structures in cold regions, necessitating unobstructed and freeze-proof longitudinal drainage pipes. Meteorological data from Ulaanbaatar indicates extreme temperatures reaching -45°C. In compliance with tunnel design specifications requiring "deep-buried central drainage ditches when the coldest monthly average temperature falls below -10°C with local cohesive soil freezing depths within a certain range", and based on analogous project experience, the tunnel's freeze-thaw section extends approximately 1000 m from the portal. Consequently, deep-buried central drainage pipes are implemented throughout the entire tunnel, installed below the invert at >2.5 m from the design baseline, with their length matching the insulated lining section. Insulation measures are applied to central drainage outlets at tunnel portals to prevent groundwater freezing at entrance and exit locations.

(2) Critical electromechanical technologies for tunnels

1) Tunnel ventilation

① Ventilation equipment constitutes the primary electricity-consuming system in highway underground road operations. For energy conservation, the number of operating fans is controlled based on required CO and VI thresholds under different operational conditions. Air volume regulation is achieved through staged adjustment of active fan units, enabling 0-100% of rated air volume capacity.

② Fans within single tunnels can operate either individually or in parallel pairs, allowing real-time operational adjustments during service. No fixed fan operation mode is maintained for any given condition, ensuring alternating operation of all tunnel fans.

③ The ventilation control system interfaces with lighting controls, fire alarm/protection systems, traffic monitoring systems, and central control systems for coordinated operation.

2) Tunnel water supply, drainage, and fire protection facilities: Electric heat tracing is a thermal insulation technology that converts electrical energy into thermal energy to provide continuous heating for pipelines, tanks, or equipment. Compared to traditional steam tracing, electric heat tracing offers advantages such as precise energy efficiency, stable temperature control, and simplified maintenance, making it widely used in petrochemical, fire protection pipelines, municipal water supply and drainage systems, and other fields.

① Principle

Based on the Joule heating effect (resistive heat generation), electric heat tracing transfers thermal energy via heating cables to compensate for environmental heat loss, maintaining target temperatures. The heating element consists of electric trace heating cables.

② Installation methods

Flat attachment installation (single or multiple parallel runs, avoiding entanglement).

Spiral wrapping (suitable for large-diameter pipelines to enhance heating uniformity).

③ Application in this project

This project equips each main fire pipeline (D325x5) in the tunnel's fire protection trench with three electric heating cables, installed using the flat attachment method on both sides and the bottom of the pipeline to transfer heat upward, maintaining the pipeline's water supply at the required temperature. The electric heat tracing operates in constant voltage mode, with heating cable parameters of 10 W/m.

Passive insulation layer materials consist of 0.5 mm thick aluminum foil + 5 cm thick polyurethane foam + 8 cm thick rubber-plastic insulation material, wrapped around the entire pipeline circumference.

7.3.4. Key technical measures for landscape greening engineering

(1) Soil improvement

Replace planting pits with humus soil + sandy soil mixed substrate (ratio 1:1) to enhance water and nutrient retention capacity.

Add water-retaining agents (such as polyacrylamide) to reduce irrigation frequency.

(2) Water-saving irrigation

Recommend adopting solar-powered drip irrigation systems utilizing summer rainwater collection pools for water supply.

(3) Wind protection

Newly planted trees shall be equipped with windproof supports and root zones covered with straw insulation layers, with anti-transpirants (such as pine needle extract) sprayed during winter to reduce moisture loss.

CHAPTER 8. SUPPLEMENTARY NOTES

8.1. INTEGRATION OF MONGOLIAN ELEMENTS IN THE DESIGN

The nomadic culture of the Mongolian people has influenced craft creation to a certain extent. Since ancient times, they have refrained from making objects with large volume and heavy weight. Instead, they have poured their creative enthusiasm into household items and livestock tools used in daily life. Such items as cabinets, clothing trims, saddle utensils, Mongolian yurt pillars, rafters, and doors are all reflections of the limited creative space of nomadic peoples. Nonetheless, a large number of historical records indicate that the Mongolians have decorated such constructions as palaces, temples, tents, and Mongolian yurts with patterns and ornaments since ancient times. Among various decorative arts, pattern designs are the most portable, and each of them contains specific symbolic meanings. There are approximately 1,500 types of traditional Mongolian patterns, which can be roughly divided into five categories according to their forms of expression: geometric patterns, animal patterns, plant patterns, natural phenomenon patterns, and religious symbolic patterns. In this design, local Mongolian elements are to be integrated into the scheme.

8.1.1. Bridge Landscape Design

In this design, elements from traditional Mongolian culture are extracted and integrated into the design of the bridge and its lower space. These elements include symbols of nomadic civilization and natural totems such as the structural form of Mongolian yurts, the curved lines of the Morin Khuur, grassland mountains, and galloping horses and the competitive spirit of the Naadam Festival and traditional colors (“Kük” blue (corresponding to the blue sky), grassland green, Buddhist gold, and wool white). For example, a horse-racing relief wall is designed in the underbridge space, depicting horse-racing scenes from the Naadam Festival.

To enhance the urban landscape effect and reflect local characteristic elements, the bridge piers will be "greened" or decorated with graffiti. Meanwhile, the underbridge space will be fully utilised for layout. The following are some engineering design examples, and the specific plans will be refined during the detailed design and construction phases of the next stage.

8.1.2. Street Lamp Shape Design

(1) Street Lamp Scheme 1: Bird Wing-Imitated Shape

Symbolic Meaning of the Saker Falcon (Falco cherrug): Since the era of Genghis Khan, the Saker Falcon has been regarded as a symbol of speed and strength, courage and wit, vitality and dignity, a sacred totem, and boundless dreams. The Saker Falcon is a national pride bird of Mongolia.

Falco cherrug, one of the largest falcon species, ranges from Eastern Europe to Manchuria in northeastern China. It can fly at a speed of up to 320 kilometres per hour, and its

Figure 8. 1. Development and Utilization of Bridge Piers and Underbridge Space

visual accuracy when diving to hunt is 2.6 times that of humans. Therefore, it is praised as “the Snow Leopard of the Sky”.

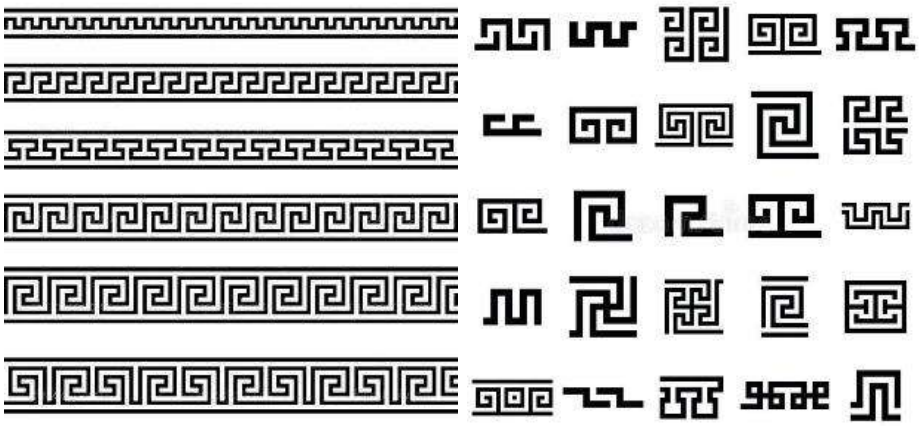
The Saker Falcon feeds on rodent herbivores, small birds, and insects, and plays a role in balancing and regulating the natural ecosystem. It is a bird of prey with exceptional speed, strength, and combativeness, and has been used by humans in hunting activities since ancient times.

Figure 8. 2. Bird Wing-Imitated Street Lamp Shape Scheme

In the lighting pole scheme, it is recommended that the “Tuojiaowen” patterns (corner-bracing motif) be used as decoration at the bottom of the pole. The base of the pole is surrounded by carved “Tuojiaowen” patterns, and traditional Mongolian script is vertically inscribed in the middle of the pole: “State Great Hall of Mongolia-Ulaanbaatar”.

Ulaanbaatar is located in the central part of Mongolia. Formerly known as “Altan Tewshiin Khondii”, it is now situated in an alluvial basin at the confluence of the Tuul River and the Selbe River, with an altitude ranging from 1,300 to 1,350 meters. Surrounded by four major mountain ranges: Bogd Khan Mountain, Songino Mountain, Chingeltei Mountain and Bayanzürkh Mountain, it covers a total area of 4,704.4 square kilometers. In 1639 AD, Ondor Gegeen was received at Shireet Tsagaan Lake and a palace was built, thus forming the predecessor settlement of Ulaanbaatar. Until 1778, the site had undergone multiple relocations before finally settling in its current location. In the early days, Ulaanbaatar was a religious and commercial center, and has been the national capital since 1912. In 1639, a ceremony was held in the Shireet Lake area, where Zanabazar was honored as a religious leader and a palace was built. From this, it gradually developed into the city of Ulaanbaatar. Throughout history, the city has had multiple names: it was called “Urguu” in 1639, renamed “Nomiin Khuree” in 1651, known as “Ikh Khuree” in 1706, referred to as “Niislel Khuree” in 1912, and officially renamed “Ulaanbaatar” in 1924. In the early 20th century, it was also known as “Bogd Khuree”, “Da Khuree” or simply “Khuree”.

Figure 8. 3. Street Lamp Bottom “Tuojiaowen” Pattern Shape Scheme



"Tuojiaowen" pattern is a traditional decorative pattern passed down since ancient times. It symbolizes eternal solidity and unceasing movement, and is therefore often used to adorn the surroundings of objects, signifying protection and blessing. The Tuojiaowen pattern comes in various forms, such as its single-corner, double-corner, and half-corner variants.

(2) Lighting Scheme 2: Symbolic Images of Water Waves, Dripping Water, and Water

Water is an original element that constitutes the universe. It contains profound symbolic meanings and is often regarded as a symbol of life, new birth, and purification. Water is the origin of life, and its fluidity symbolizes movement, change, and the passage of time. Water's purifying properties also link it closely to concepts such as the purification of the mind and spirit, the removal of impurities, the renewal of youth, and transparency and purity.

Figure 8. 4. Street Lamp “Water” Shape Scheme

In this lighting pole scheme, it is recommended that the “Shanwen” (mountain pattern) decorative pattern be used at the bottom of the pole. The base is surrounded by “Shanxingwen” (mountain-shaped patterns), and the upper part is decorated with “Yunwen” (cloud patterns). Traditional Mongolian script is vertically inscribed in the middle of the pole: “State Great Hall of Mongolia–Ulaanbaatar”.

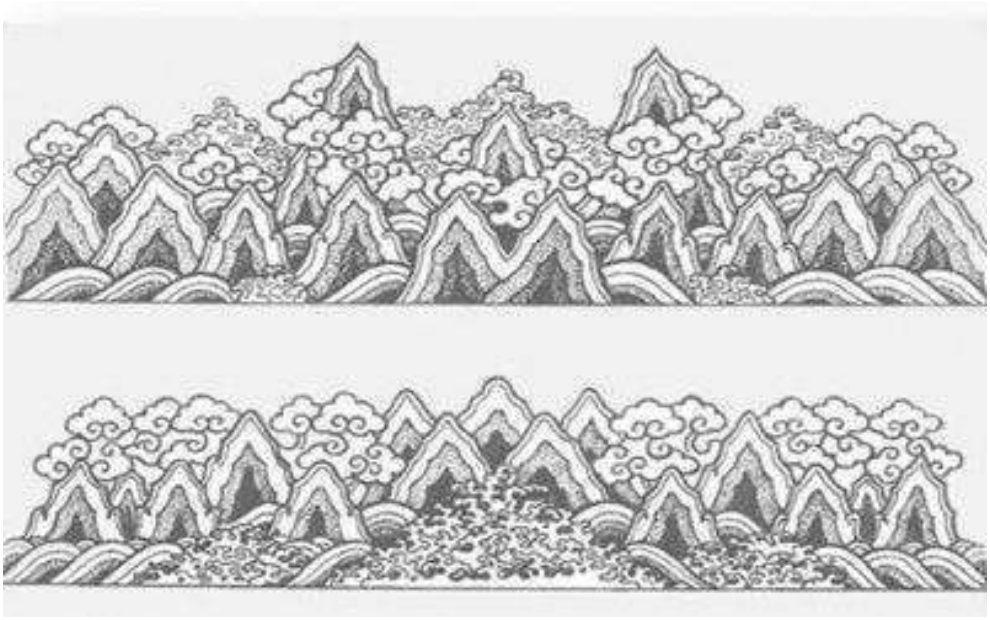


Figure 8. 5. Street Lamp Bottom “Shanwen” and “Yunwen” Patterns Shape Scheme

"Shanwen" pattern is a traditional pattern that features multiple overlaps and continuous drawing, symbolizing nature and Mother Earth.

"Yunwen" pattern includes different forms such as flowing cumulus clouds, cirrus clouds, and thunderstorm clouds. It is an artistic pattern representing the sky. Its implication is that

under the moisture of rain given by the blue sky, all things in nature revive, and all living beings enjoy peace, happiness and auspiciousness. Therefore, the Yunwen pattern not only symbolizes happiness and auspiciousness, but also implies infinite freedom, abundance, and endlessness.

(3) Lighting Scheme 3: Symbolic Images of New Shoots and Leaves

Plant patterns: including flower and leaf patterns that depict flowers and blades, they are widely used in construction decoration, religious paintings, and Buddha statue sculptures, symbolizing purity and noble character. Its patterns are elegant and its colors charming, implying a warm atmosphere, a clear temperament, and the vitality of reproduction and growth.

Leaves are important symbols that symbolize growth, renewal, and the natural cycle of life. New leaves sprout in spring, symbolizing rebirth and youthful vitality. From a broader perspective, leaves imply the natural law of the continuous cycle of life and death.

Figure 8. 6. Street Lamp New Shoots and Leaves Shape Scheme

In the lighting pole scheme, it is recommended that water wave patterns be used as decorative patterns at the bottom of the pole. Water wave patterns surround the base, while the upper part is decorated with "Yunwen" patterns. Traditional Mongolian script is vertically inscribed in the middle of the pole: “State Great Hall of Mongolia–Ulaanbaatar”.

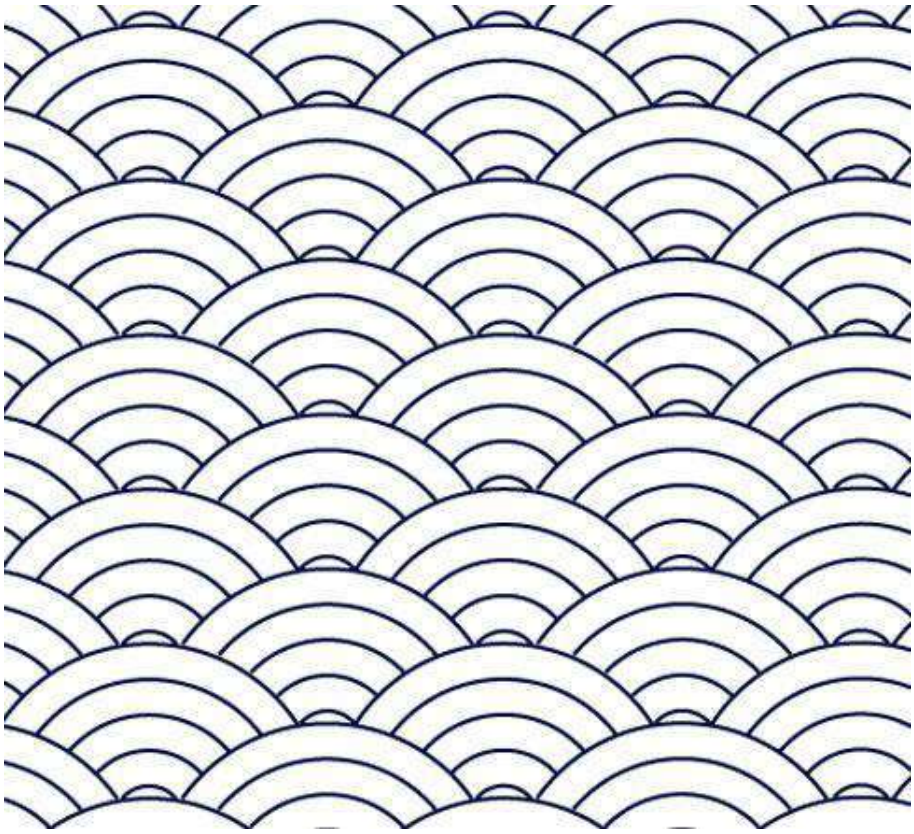


Figure 8. 7. Street Lamp Bottom Water Wave Pattern Shape Scheme

Water wave patterns: manifested as evenly undulating ripples, splashing waves, and layers of flowing water form. This pattern is often used on such decorative items as felt door curtains, stitched carpets, and carpet fabrics. It implies elegance and generosity, purity and tranquility, infinite continuation of rhythm, clarity and purity, the source of life, as well as prosperity.

8.2. TOLL STATION DESIGN

8.2.1. Toll Collection Methods

Internationally accepted toll collection methods mainly include the following types:

(1) Manual Toll Collection (LTC)

Manual toll collection refers to a method in which vehicles must stop, and toll collectors collect cash and issue receipts to complete the toll collection work.

(2) Semi-Automated Toll Collection

Semi-automated toll collection is a transition mode between traditional manual toll

collection and fully automated toll collection. It assists manual operations through partial automation technologies and seeks a balance between cost, efficiency and applicability.

(3) Automated Toll Collection

Automated toll collection refers to a road toll collection method that achieves toll collection without manual intervention through advanced technologies. Its core lies in integrating technologies such as the Internet of Things, AI, and big data to improve the efficiency and support complex billing strategies. Commonly used technologies include Radio Frequency Identification (ETC) and license plate recognition (contactless payment), etc.

Table 8. 1. Comparison and Analysis of Advantages and Disadvantages of Toll Collection Methods

Toll Collection Method	Manual Toll Collection	Semi-Automated Toll Collection	Automated Toll Collection
Principle	Purely Manual Operation	Human-Machine Collaboration (Recognition + Manual Verification)	Fully Technology-Driven (ETC/License Plate Recognition)
Advantages	① Low cost: No technical equipment is required, and the initial investment is extremely low (only foundation tools such as receipts and poles are needed). ② High flexibility: It can handle complex situations (such as cash change, receipt loss, and dispute handling). ③ Strong fault tolerance: Direct manual intervention eliminates the risk of technical failures.	① Efficiency improvement: The passing speed reaches 300-400 vehicles per hour (50% higher than purely manual operation). ② Controllable cost: The equipment investment is only 30%-50% of that of fully automated toll collection. ③ Wide adaptability: It is compatible with both old and new vehicles (such as vehicles with unbound accounts).	① Ultra-high efficiency: The traffic volume of ETC traffic lanes reaches 800-1,000 vehicles per hour, and it supports vehicles to pass at 120 km/h. ② Cost optimization: Long-term labor costs tend to be zero (70% of staff at Shenzhen ETC toll stations have been laid off). ③ Accurate billing: The error rate of AI algorithms is less than 0.1%, and it supports complex billing rules (such as second-based billing).
Disadvantages	① Low efficiency: The passing speed is slow (approximately 100-200 vehicles per hour), and congestion is likely to occur during peak hours. ② High labor cost: 24-hour shifts are required, and labor expenses account for more than 60% of the total cost. ③ Error risk: The error rate of manual timing is approximately 3%-5%, which can easily lead to disputes.	① Human-Machine Collaboration Bottleneck: The speed of manual operations affects the overall efficiency (the operation speed of skilled employees is 1.8 times that of new employees). ② Maintenance complexity: It is necessary to maintain equipment and train personnel simultaneously (such as compatibility issues between cameras and software protocols). ③ Residual error: The system misrecognition rate is approximately 1%-2%, and manual recheck is still required.	① High initial investment: The cost of single-lane reconstruction is approximately $500,000 (such as the free-flow ETC on Guangzhou Airport Expressway). ② Technical dependence risk: Equipment failures or network outages may cause system paralysis. ③ User adaptation threshold: Vehicle owners are required to Pre-install an OBU or bind a payment account, and acceptance among the elderly group is low.
Applicable Scenarios	Small parking lots, temporary road sections	Parking lots, highways	Parking lots, highways, urban roads

The newly built New Ring Road is an urban road, intersecting with multiple urban roads. Based on the above comparison and analysis of advantages and disadvantages, it is not easy to implement manual toll collection or semi-automated toll collection by setting up toll islands and toll stations. At the same time, it may cause congestion at toll stations during peak hours. This design recommends an automated toll collection method that allows toll collection requiring no vehicle stops or speed reductions. Common ones include Radio Frequency

Identification (RFID) and license plate recognition (contactless payment). In this project, RFID devices will be installed at the start points and end points of the road as well as at the entrances and exits of each intersection, with full integration into the existing “Road Traffic Mobile Monitoring System” (RFID System) and a unified network to realize toll collection for all vehicles along the entire road.

8.2.2. Tolling Standards

Common road toll standards include:

(1) Per-Time Tolling (Flat Toll)

A fixed fee is charged each time a vehicle enters the expressway, regardless of the driving distance or time period.

(2) Distance-Based Tolling

Distance-based tolling is a pricing model that charges fees based on actual usage (such as driving distance, electricity consumption, etc.). It is widely applied in fields such as transportation, logistics, and energy. Its core is to calculate fees by accurately measuring users' travel distance and applying tariff rules to achieve fair billing.

(3) Time-Based Tolling

Time-based tolling is a strategy that dynamically adjusts prices based on time, demand intensity, or other factors. It is commonly used in industries such as public services, energy, transportation, and tourism. Its core purpose is to regulate the balance between supply and demand through price levers, optimize resource allocation, and improve efficiency or revenue.

(4) Vehicle-Type-Based Differential Tolling

Different toll standards are applied based on different vehicle types; passenger vehicles are classified by seating capacity, and trucks are categorized by axle count.

(5) Congestion Tolling

It is an intelligent transportation management strategy that reduces traffic flow and eases traffic congestion by charging additional fees to vehicles during rush hours or in congested areas, and regulating travel demand through price levers.

Traffic congestion is severe in the central urban area of Ulaanbaatar and during morning and evening peak hours, while traffic flow is relatively low in remote areas or off-peak periods. After completion, the New Ring Road aims to improve the traffic capacity of major streets, intersections, and crossings in Ulaanbaatar and ease traffic congestion.

This proposal adopts a combination of multiple toll standards, which not only eases traffic congestion in the central urban area but also generates certain benefits, thereby maximizing efficiency.

It is recommended that based on distance-based tolling, adopt vehicle-type-based differential tolling and time-based tolling to guide trucks to detour through prices to reduce traffic impact on the central urban area. At the same time, shift non-essential trips away from

peak hours through price adjustments. To ensure travel for primary commuters, per-time tolling or monthly tolling can be applied for. Post-implementation, additional fees will be levied on vehicles in congested sections based on the conditions of different segments, thereby alleviating traffic congestion.

Road construction involves huge capital investment, including land expropriation, engineering construction, and equipment procurement. During the operation phase, continuous funds are also needed for road maintenance, personnel management, and equipment renewal. The selection of toll standards should take effective cost recovery into account.

The specific toll standards will be refined in the subsequent stage of detailed design.

8.3. UTILITY RELOCATION PLAN

8.3.1. Study on Overhead Line Relocation

Coordination was conducted with Mongolian Power Plants and Ulaanbaatar Power Supply Bureau to confirm the high-voltage overhead lines related to the entire road and the road itself, including high-voltage towers and overhead lines of voltage levels such as 220kV, 110kV, 35kV, 10kV, 6kV, 0.4kV, and 0.22kV. For the specific line quantity, please refer to the official letters from Mongolian Power Plants and Ulaanbaatar Power Supply Bureau in the appendix.

The high-voltage overhead line relocation of this project includes high-voltage towers and overhead lines of voltage levels such as 110kV, 35kV, 10kV, and 6kV, but does not include 220kV high-voltage towers and overhead lines.

The safety clearance for power lines 35kV~110kV must meet the following requirements Parallel to roads Minimum horizontal clearance of 4m and Crossing roads vertically Minimum vertical clearance of 8m. All installations shall strictly comply with Power Facility Regulation **BD43-101-03 and Current Mongolian Standard MNS 65-22:2015.

A preliminary relocation plan has been confirmed, and the budget costs have been calculated. Coordination with Mongolian Power Plants and Ulaanbaatar Power Supply Bureau has confirmed the relocation plan, which includes the following 4 types:

(1) Relocate High-Voltage Towers

It applies to cases where overhead line towers encroach on the road boundary, **including high-voltage towers of voltage levels such as 110kV, 35kV, 10kV, and 6kV.**

High-voltage overhead lines whose spacing from the road does not meet the requirements of relevant specifications will be relocated to other places to meet the safe spacing.

The advantages and disadvantages in terms of its design, construction and economic efficiency are as follows:

Advantages: The road expansion area can be avoided by optimizing the route, and the power transmission efficiency can be improved in combination with the terrain when redesigning the tower positions; the technology is mature, and the construction period is

relatively controllable; and the cost of single-tower relocation is relatively low, which is suitable for local adjustments.

Disadvantages: It is necessary to re-plan the line route, which may involve land expropriation, coordination with other municipal facilities, resulting in high design complexity; old towers need to be dismantled and new towers need to be built, and temporary power outages or the construction of temporary support structures are required during the construction process, which has substantial disruptions to surrounding traffic and residents; and if large-scale relocation is involved, the total cost may be close to that of newly-built lines.

Figure 8. 8. Relocate High-Voltage Towers

(2) Raise High-Voltage Overhead Lines

It applies to cases where overhead lines are above newly-built bridges and the clearance is insufficient, **including high-voltage towers of voltage levels such as 110kV, 35kV, 10kV, and 6kV.**

For high-voltage overhead lines whose vertical spacing from the road does not meet the requirements of relevant specifications, their high-voltage towers will be raised to thereby raising the high-voltage overhead lines to meet the safe spacing.

The advantages and disadvantages in terms of its design, construction and economic efficiency are as follows:

Advantages: By increasing the height of towers or adjusting the sag of conductors, the occupation of floor space is reduced; there is no need to change the line route, resulting in minimal construction workload; and the transformation cost is lower than that of relocation or underground schemes.

Disadvantages: It is necessary to re-check the mechanical parameters of conductors, and it may be necessary to replace them with higher-strength materials, which increases the design

difficulty; the risk of overhead operations is high, requiring support from special equipment, and may be affected by weather; sag may need to be adjusted frequently in the long term, leading to an increase in operation and maintenance costs.

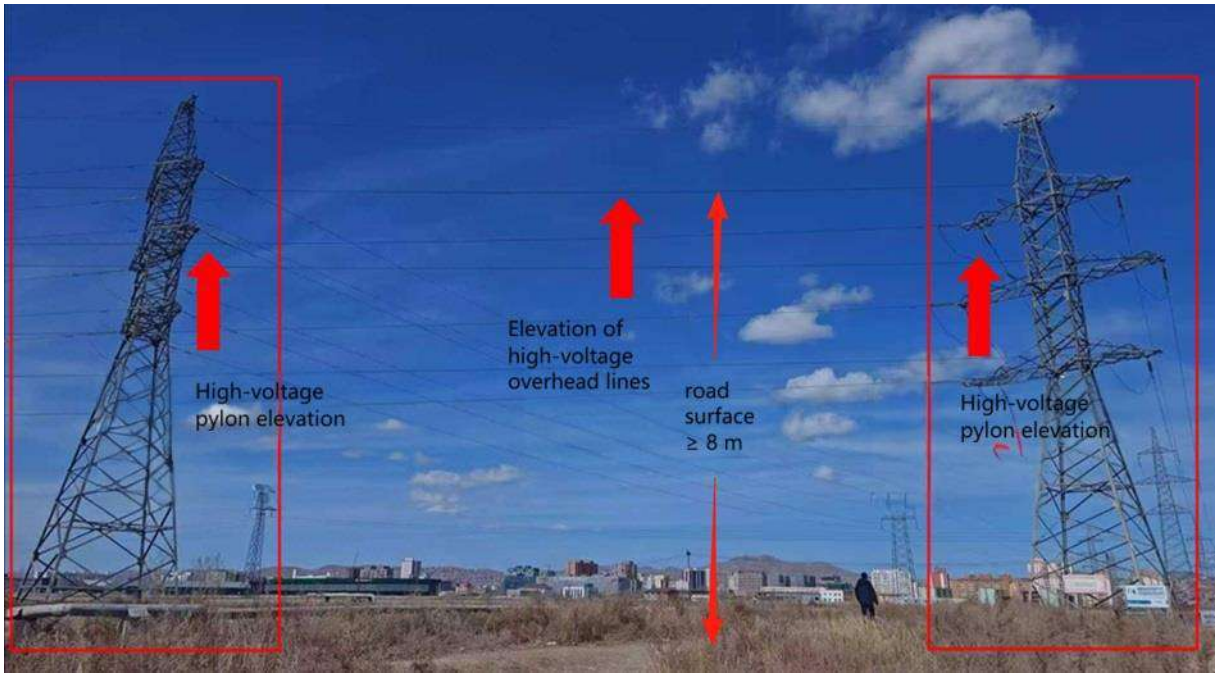


Figure 8. 9. Raise High-Voltage Overhead Lines

(3) Build new towers and merge them with adjacent overhead lines

It applies to cases where space is insufficient due to geographical location restrictions, including **high-voltage towers of voltage levels such as 110kV, 35kV, 10kV, and 6kV.**

High-voltage overhead lines whose spacing from the road does not meet the requirements of relevant specifications will be merged with adjacent overhead lines to meet the safe spacing.

The advantages and disadvantages in terms of its design, construction and economic efficiency are as follows:

Advantages: space intensification: reducing the quantity of poles and towers, optimizing urban space layout, alleviating space pressure after road relocation, enabling centralized route planning, and avoiding conflicts with facilities such as newly-built roads and underground pipelines; shortened construction: completing new line erection at one time, reducing the number of repeated excavations and power outages, and avoiding multiple traffic disturbances caused by phased construction; concentrated utilization of resources: centrally allocating construction machinery (such as tension stringing equipment and cranes), lowering per-unit construction costs; saved initial investment: reducing the consumption of materials such as poles, towers, foundations, and earthing devices, lowering land expropriation or leasing costs, optimizing long-term operation and maintenance costs, reducing inspection routes by 50%, improving fault detection efficiency, and unifying maintenance standards, which can reduce labor training and management costs.

Disadvantages: risk of reduced redundancy: if a single line fails, it may cause power

outages in the coverage areas of original two lines simultaneously, requiring additional configuration of automatic section switches or standby power supplies; and limited construction window: requiring long-term power outages for line switching, which may affect the reliability of power supply to users, it is necessary to coordinate power guarantee plans among multiple departments, there is difficulty in technical connection, and during the dismantling of old lines, accidental breakage may occur due to aging, so corrosion detection and reinforcement need to be carried out in advance. Loss of opportunity cost: loss of the standby capacity advantage of the original double lines, and the need to find another channel for future expansion, which may increase long-term investment.

(4) Underground High-Voltage Overhead Lines

It applies to cases where overhead line towers encroach on the road boundary and the clearance is insufficient, **including only high-voltage overhead lines of voltage levels such as 10kV, 6kV, and 1kV.**

High-voltage overhead lines whose spacing from the road does not meet the requirements of relevant specifications and whose vertical spacing from the road does not meet the requirements of relevant specifications shall be placed underground on-site in the form of power tunnels.

The advantages and disadvantages in terms of its design, construction and economic efficiency are as follows:

Advantages: It can accommodate multiple circuits of cables and reserve space for capacity expansion; a single construction can meet the needs of many years to come and reduce repeated excavations; and it has the optimal long-term economic efficiency.

Disadvantages: High requirements are placed on construction quality; hidden dangers are likely to be left behind; and later maintenance and fault handling are relatively difficult.

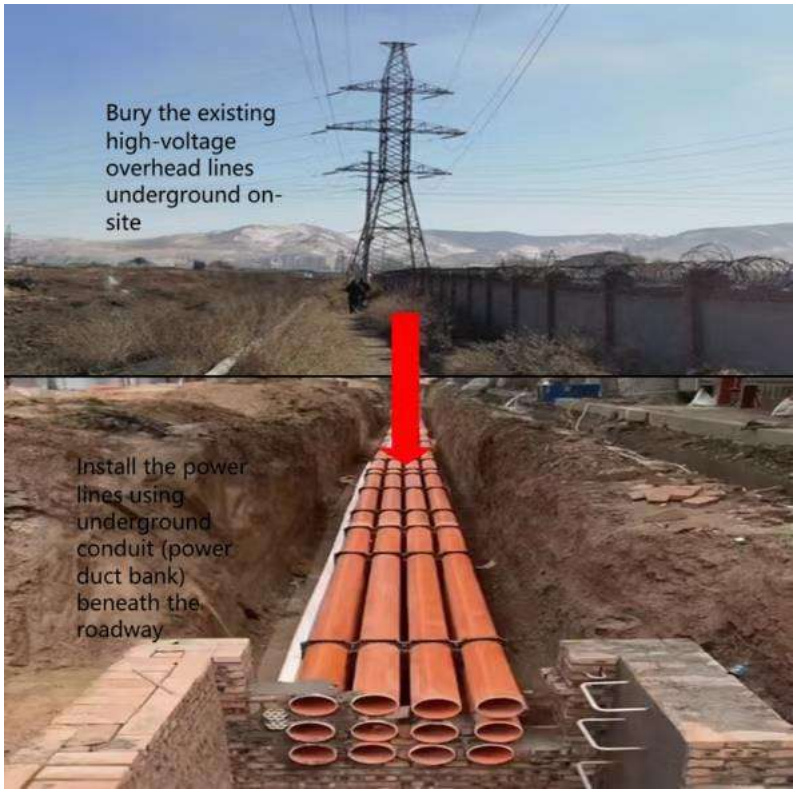


Figure 8. 10. Underground High-Voltage Overhead Lines

CHAPTER 9. CONCLUSIONS AND RECOMMENDATIONS

9.1. General

This project's road design is formulated by the standards, specifications, and indicator requirements specified in Mongolia's current Highway Design Specifications 22-004-2016 and Urban and Rural Planning and Construction Specifications BNbD32.01.24. It incorporates results from engineering geological surveys, mapping, hydrological investigations, environmental status studies, and traffic demand modeling along the route. By the requirements of the Technical and Economic Demonstration, the proposed road falls into the category of Class I arterial roads in the capital's road network.

9.2. Location Analysis

The area along the designed road is densely populated, with infrastructure and engineering pipeline networks, including large residential areas, private real estates of shantytown residents, enterprises and units, high-voltage and low-voltage transmission line networks, urban arterial roads and service roads, drinking water supply points, etc.

The terrain along the route is generally higher in the north and lower in the south, and higher in the east and lower in the west. There are the Chingeltei, Sharkhad, and Dar-Ekh mountains in the northern part of the route. The southwest and southeast ends of the route are flat, and the existing rivers and the Selbe River are distributed along the route.

9.3. Road Route Selection

Three alternative plans need to be considered when selecting the road route: (1) conform to urban development plans; (2) meet the requirements of design specifications, laws and regulations, and relevant standards; (3) do not overlap with existing roads in use; (4) cover a small area for land expropriation and demolition; (5) do not pass through cemeteries or specially managed areas; (6) avoid large-scale facilities such as schools, kindergartens, and hospitals; (7) adopt the form of elevated structures and ground-level auxiliary roads in construction and road network dense areas to reduce land use and at-grade intersections, and follow the above basic principles.

From these three Schemes, Scheme 1, which fully meets the above conditions, lower in costs, and is economically advantageous, has been selected. In accordance with the standards in Highway Design Specifications 22-004-2016, a comparative demonstration has been conducted on the maximum longitudinal slope of the road. Based on a comprehensive consideration of various economic and technical indicators and impacts, the Scheme with a maximum longitudinal slope limit of 4% was finally recommended. Meanwhile, the following indicators of the project have been demonstrated and confirmed: (1) arterial road grade; (2) minimum parameters of plane and profile; (3) transverse dimensions of the cross-section; (4) minimum horizontal curve radius of the arterial road; (5) widening dimensions of the carriageway at small-radius curves; (6) length of the transition section at ordinary curves; (7)

maximum length of the straight section in the profile; (8) volume of bridges and structures, etc.

Design roads, bridges, tunnels, and other artificial structures based on the proposed plane and profile scheme. Within the project scope, the project scale of the selected Scheme 1 is as follows: route length is 24.793km; subgrade section length is 13.679km; bridge section length is 9.034km/5 bridges; tunnel section length is 2.08km; 7 interchanges and 12 grade-separated interchanges are built along the entire line. Three pedestrian overpasses will be implemented in the near term, and four more will be planned for the long term—7 pedestrian Underpasses.

9.4. Crossing Structures

The New Ring Road features 7 interchanges with adjacent roads.

Additionally, it includes 12 grade-separated crossings with surrounding roads, comprising 10 locations with at-grade intersections between frontage roads and crossing roads, and 2 fully grade-separated structures between frontage roads and crossing roads.

For railway crossings, there are 3 intersections along the New Ring Road, specifically: 2 at-grade crossings between frontage roads and railway lines, 1 fully grade-separated structure over railways.

Table 9. 1. Lists of Intersections

No.	Chainage No.	Name of the intersecting road	Grade of the intersecting road	Status of the intersecti on road	Number of lanes on the intersecting road	Type of the intersection	Mode of Crossing
1	K0+200	Road Rehabilitation Project in Selebore	Grade-2 main trunk road	Planned	6 lanes in two directions	Separated interchange	Crossing under for the main road; Fully grade-separated
2	K0+355	No. IV Power Station Road	Grade-2 main trunk road	Existing	2 lanes in two directions	Separated interchange	Crossing over for the main road; level crossing for the ground side road
3	K0+962	Planned road	Grade-2 main trunk road	Planned	4 lanes in two directions	Separated interchange	Crossing over for the main road; level crossing for the ground side road
4	K1+457.982	Ulaanbaatar Railway	Internal combustion railway	Existing	Single line	Separated interchange	Crossing over for the main road; level crossing for the ground side road
5	K1+566.775	Ulaanbaatar Railway	Internal combustion railway	Existing	Double lines	Separated interchange	Crossing over for the main road; level crossing for the ground side road

No.	Chainage No.	Name of the intersecting road	Grade of the intersecting road	Status of the intersection road	Number of lanes on the intersecting road	Type of the intersection	Mode of Crossing
6	K1+817.494	Moscow Street	Grade-1 main trunk road	Existing	6 lanes in two directions	Separated interchange	Crossing over for the main road; level crossing for the ground side road
7	K2+276.092	Planned road	Grade-2 main trunk road	Planned	4 lanes in two directions	Separated interchange	Crossing over for the main road; level crossing for the ground side road
8	K3+024.8	Ard Ayush Road	Grade-1 main trunk road	Under construction	6 lanes in two directions	Interchange	Crossing over for the main road
9	K5+794	Bayankhoshuu Street	Grade-2 main trunk road	Existing	4 lanes in two directions	Separated interchange	Crossing over for the main road; level crossing for the ground side road
10	K6+366	Second Ring Road	Expressway	Planned	6 lanes in two directions	Interchange	Crossing over for the main road
11	K6+480	Bayankhoshuu Street	Grade-2 main trunk road	Existing	4 lanes in two directions	Separated interchange	Crossing over for the main road; level crossing for the ground side road
12	K8+587	Revolution Street	Grade-1 main trunk road	Existing	4 lanes in two directions	Separated interchange	Crossing under for the main road; level crossing for the side road
13	K12+620	Khailaast street	Side road	Existing	2 lanes in two directions	Separated interchange	Crossing over for the main road; level crossing for the ground side road
14	K13+232	Doloon Buudal road	Grade-1 main trunk road	Existing	4 lanes in two directions	Interchange	Crossing over for the main road
15	K13+979	Selbeseregelete Project Road	Grade-2 main trunk road	Existing	2 lanes in two directions	Separated interchange	Crossing over for the main road; level crossing for the ground side road
16	K14+658	Dari-Ekh street	Grade-2 main trunk road	Existing	2 lanes in two directions	Interchange	Crossing over for the main road
17	K20+835	Second Ring Road	Expressway	Planned	6 lanes in two directions	Interchange	Crossing under for the main road
18	K22+856	Police Academy Avenue	Grade-1 main trunk road	Existing	6 lanes in two directions	Interchange	Crossing over for the main road

No.	Chainage No.	Name of the intersecting road	Grade of the intersecting road	Status of the intersection road	Number of lanes on the intersecting road	Type of the intersection	Mode of Crossing
19	K23+817	General's No. IX Street	Grade-2 main trunk road	Reconstructed	4 lanes in two directions	Separated interchange	Crossing over for the main road; level crossing for the ground side road
20	K23+874	Ulaanbaatar Railway	Internal combustion railway	Existing	Single line	Separated interchange	Crossing over for the main road
21	K24+337	Dunjingarav Street	Grade-2 main trunk road	Existing	4 lanes in two directions	Separated interchange	Crossing over for the main road
22	K24+793	Tuul Expressway	Expressway	Planned	6 lanes in two directions	Interchange	Crossing over for the main road

9.5 Pavement Structure

Two schemes, namely asphalt concrete pavement and cement concrete pavement, are compared for the pavement structure of the motor vehicle lane of this road.

The asphalt concrete pavement is composed of the following layers, with an engineering cost of 170,000 MNT per square meter.

Upper Surface Course: 4 cm fine-grained hot asphalt concrete wearing course, BND100/130 (with SBS additive)

Lower Surface Course cm coarse-grained hot asphalt concrete base course, BND100/130

Base Course: 20 cm crushed stone base layer stabilized with 5% cement

Sub-base Course: 20 cm sand and gravel sub-base layer stabilized with 4% cement

Cushion Course: 40 cm gradation-classified crushed stone bedding layer

The cement concrete pavement is composed of the following layers, with an engineering cost of 150,000 MNT per square meter.

Surface Course: 25 cm thick C40 grade cement concrete pavement

Base Course: 20 cm thick crushed stone base layer stabilized with 5% cement

Cushion Course: 40 cm thick crushed stone bedding layer

9.6 Bridge and Culvert Engineering

There are 5 main line bridges in this project, with a bridge length of 9,034m and a bridge width ranging from 19.5m to 45.5m, constructed by prestressed concrete small box girders or cast-in-place prestressed concrete box girders; there are 7 interchange ramp bridges, with a bridge length of 4,989.3m, constructed by precast prestressed concrete small box girders or cast-in-place prestressed concrete box girders; there are 2 ground-level auxiliary road bridges, with a bridge length of 168m, constructed by precast prestressed concrete small box girders; there is 1 overpass bridge, with a bridge length of 100m and a bridge width of 14.5m; 1 overpass bridge is planned for the long term, both have constructed by precast prestressed

concrete small box girders; 1 culverts and 7 passages will be constructed according to the actual situation, 3 pedestrian overpasses will be implemented in the near term, and 4 will be planned for the long term.

9.7. Tunnel Engineering

In accordance with the basic principles of "safety, durability, economy, energy conservation and environmental protection", and based on conditions such as planning, transportation, topography, geomorphology, geological conditions, fire prevention and disaster relief, and environmental protection, the horizontal and vertical alignment of the road is formulated. In combination with Mongolian specification requirements and with reference to Chinese specification requirements, a total of 1 separated tunnel is constructed on the New Ring Road. The total length of the tunnel is approximately 2,080m, with a maximum burial depth of approximately 80m, and it is a shallow-buried tunnel. The tunnel adopts the bamboo cutting type tunnel portal form, and a cut-and-cover tunnel of a certain length is constructed. A total of 2 vehicle cross passages and 5 pedestrian cross passages are constructed along the entire tunnel. Based on experience, the entire tunnel will be constructed using the mining method. Among them, the V-grade surrounding rock section will be constructed using the double-sidewall heading method, and the IV-grade surrounding rock section will be constructed using the ring cut method.

The tunnel ventilation adopts the full jet fan longitudinal ventilation mode; the tunnel fire water supply system adopts a temporary high-voltage water supply system; the tunnel power supply and distribution are equipped with a 10/0.4kV power supply and distribution system, a tunnel lighting system, a power system, a lightning protection and earthing system, as well as power supply and distribution, lighting, and lightning protection and earthing systems for tunnel substations and fire water pump rooms; the tunnel lighting adopts the LED lamp lighting mode; the tunnel monitoring is configured with a tunnel monitoring system at Level A+, including: a central control and management system, a video monitoring system, a lighting monitoring system, a traffic monitoring system, an automatic fire alarm and fire protection linkage system, a ventilation monitoring system, an emergency telephone and wired broadcasting system, a wireless communication system, etc.

A fire pump room and a distribution room are constructed outside the tunnel portal at the low-mileage stake, with a total gross floor area of 495.54 ㎡.

9.8. Pipeline Engineering

(1) To ensure water supply safety, water supply pipelines shall be arranged symmetrically on both sides of the road to improve the redundancy of the water supply system. Relevant standards and specifications shall be strictly adhered to. For the section from K0+325 to K2+308, main water supply pipelines with a DN600 pipe diameter shall be laid under the

pedestrian walkways on both sides of the road, and the water supply pipelines affected along the line shall be relocated. Through specification-based design and standardization arrangement, a safe and resilient water supply network will be constructed.

(2) In accordance with the district planning and the conditions of existing pipelines, all sewage pipelines in this project are existing pipeline relocation, which will be relocated from the road center to under the pedestrian passage, and the design scale will remain consistent with the existing scale.

(3) In accordance with the regional planning requirements and existing drainage conditions, the rainwater pipelines are designed to the standard of a 10-year recurrence interval; the pipe diameters are determined through catchment area and flow calculation. Pipe diameters DN400 and DN500 are mainly used to meet the conventional regional drainage needs, while DN800 is used to cope with scenarios of large flow catchment from other drainage systems in local areas, so as to fully meet the road drainage requirements. Drainage paths adopt the method of connecting to existing rainwater pipes, natural ditches and rivers in the vicinity, so as to reduce the impact of long-distance pipeline laying on the surrounding landscape and municipal facilities.

(4) In accordance with the regional flood control planning and hydrological analysis report, the flood control design shall be implemented in accordance with the standard of a 100-year recurrence interval; the 50 drainage pipes in the hydrological analysis report shall be optimized to 26, and the quantity of pipes shall be streamlined to reduce redundant construction. The combined scheme of “DN800 pipeline (minimum size) + 2×2 culvert (maximum size)” shall be adopted to fully meet the flood control needs along the road. Through science-based layout and standardization arrangement, a safe and resilient flood control network will be constructed.

(5) Adhere to the principles of safety first, power supply reliability, intensification and standardization, and environmental coordination. Based on the planning, existing conditions and specification requirements, 12-hole HDPE Φ150mm power pipes shall be laid under the pedestrian walkway on the east (south) side of the road, and laid through bridges and tunnels along the entire line. To achieve the goals of constructing a safe and resilient power supply network, promoting efficient integration of municipal facilities, and supporting sustainable urban development.

(6) Adhere to the principles of specification compliance and regulatory compliance, forward-looking and expandability, overall coordination, economy and intensiveness, as well as safety and reliability. Based on the planning, existing conditions and specification requirements, 6-hole HDPE Φ110mm power pipes shall be laid under the pedestrian walkway on the west (north) side of the road, and laid through bridges and tunnels along the entire line. To achieve the goals of constructing modern communication infrastructure, realizing efficient utilization of municipal resources, and meeting the needs of people’s livelihood services.

(7) In accordance with the district planning and the conditions of existing pipelines, all thermal pipelines in this project involve existing pipeline relocation, which will be relocated from the middle of the road to outside the motor vehicle lane or the laying depth will be adjusted according to the designed pavement elevation, and the design scale will remain consistent with the existing scale.

9.9. Greening Engineering

(1) Greening Design Requirements: for the 60m road cross-section of the main line of the road with a design speed of 80km/h as an urban expressway, the length of greening design units shall alternate between 80m and 100m, focusing on ecological protection while taking into account windbreak, sand fixation and urban road landscape forests. For the 32/45m road cross-section of the at-grade frontage road adjacent to main road with a design speed of 40 km/h, which is closely connected to the urban interface, the length of greening design units shall alternate between 40m and 60m, taking into account both protective and landscape functions.

(2) Selection of Suitable Trees for Suitable Sites: choose plants that are adapted to local climate and soil conditions. Select coniferous trees such as Pinus sylvestris var. mongolica and Larix gmelinii, as well as broad-leaved trees such as Quercus mongolica and Armeniaca sibirica, which have strong drought-resistant and cold-resistant abilities. Meanwhile, select local woody and herbaceous plants for areas such as road green belts, which can effectively conserve water and soil and enhance the urban image.

9.10. Project Follow-up Implementation Plan and Execution Measures

(1) Follow-up Implementation Plan

The overall time plan of the project is as follows: the preliminary preparation stage: January 20, 2025-December 30, 2025; the construction and implementation stage: January 1, 2026-December 30, 2027; the trial operation and warranty stage: January 1, 2028-December 20, 2028. At present, the project is in the preliminary preparation stage. The selection of consulting consultants has been completed, and the compilation of the feasibility study report is in progress. Subsequent work such as project feasibility review, compilation of bidding plans, and confirmation of contractors will be completed, and then it will enter the construction and implementation stage as well as the trial operation and warranty stage. For subsequent specific plans, please refer to "Table 7.1.3-2 Detailed Project Implementation Schedule" in this report.

Considering that the total length of this project is 24.793 km, the overall route is relatively long, and the project scale is large, while the construction period required by the owner is relatively tight. After a comprehensive analysis of factors such as the overall situation of the project, fund scale, implementation difficulty, and specific construction period, it is recommended that the entire project be divided into 3 sections for simultaneous

implementation. For the specific implementation plan, please refer to the content of Chapter 7.1 of this report.

(2) Execution Measures

Considering that the subsequent implementation of the project will be affected by various factors such as construction conditions, funds, procurement, risks, and operation and maintenance, corresponding execution measures shall be adopted to ensure the smooth progress of the subsequent implementation of the project after analyzing these factors one by one.

1) Construction Conditions

Arrange the project's construction period reasonably according to local conditions such as temperature, rainfall and sunshine duration, so as to ensure that the relevant plans are matched with the local conditions of Ulaanbaatar.

2) Fund Plan

In combination with the content arrangement of each project implementation stage, within the project period, the project funds shall be planned and arranged on a monthly basis, and the specific fund arrangement of the project shall be refined to ensure the implementability of the project.

3) Procurement Plan

Conduct a detailed analysis of all procurement contents of the project, clarify specific procurement technical points in accordance with the relevant procurement policies of Ulaanbaatar, and reasonably arrange the procurement process and procurement time, ensuring the implementability of the project.

4) Risk Response Plan

Identify and classify risks that may occur during the project implementation in advance. After analyzing various risks, propose corresponding response measures and monitoring mechanisms to ensure the controllability of project risks.

5) Operation and Maintenance

Based on the objectives of the project implementation and in combination with the current situation of operation and maintenance organizations in Ulaanbaatar, clarify the operation and maintenance plan of this project, including personnel arrangement and machinery arrangement, and propose corresponding technical response measures for the operation and maintenance costs, implementation plans of the project as well as subsequent possible situations such as snowstorms, frozen soil, floods, earthquakes and traffic accidents.

9.11. OD and Traffic Volume Survey Report

Summarize the main contents of the OD and Traffic Volume Survey Report.

(1) Number of Collected Questionnaire Samples

52 traffic zones were selected within 1km of the New Ring Road and its surrounding areas, with 50 valid questionnaires collected from each traffic zone, totaling 2,600 questionnaires.

(2) Changes in VCR of the Overall Road Network Before and After the Implementation of the New Ring Road

Through comparative analysis of road section saturation, the overall saturation change trends of road sections for 2028, 2030, and 2040 are derived. After the implementation of the New Ring Road, the saturation has decreased by 20.27%, 21.94%, and 25.21% compared with that of the current road network.

(3) Changes in VCR of Key Intersections Before and After the Implementation of the New Ring Road

The construction of the ring road will reduce the traffic pressure in the central urban area. Through the construction of the ring road, changes have occurred in the traffic volume at key intersections and road sections in the main urban area, with reduced traffic volume and an overall decrease in saturation. Through data analysis of intersection saturation, the overall saturation change trends of intersections for 2028, 2030, and 2040 are derived. After the implementation of the New Ring Road, the saturation has decreased by 20.24%, 23.12%, and 25.57% compared with that before the implementation of the New Ring Road.

(4) Changes in Average Operating Speed of the Overall Road Network Before and After the Implementation of the New Ring Road

Through comparative analysis of road section average speed, the overall average speed change trends of road sections for 2028, 2030, and 2040 are derived. After the implementation of the New Ring Road, the average speed has increased by 4.6 km/h, 4.8 km/h, and 5.1 km/h compared with the period before the New Ring Road's implementation.

(5) Traffic Volume Forecast Results of the New Ring Road

The traffic volume forecast results of each section in the final forecast year are shown in the table below.

Table 9. 2. Peak Hour Traffic Volume of New Ring Road Sections in the Final Forecast Year (pcu/h)

Road Section		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Main Road	East to West					2631	3268	2114	2361		
	West to East					3951	4232	3436	3168		
	South to North	2282	3612	4279	3774					2910	1920
	North to South	1988	2538	3373	3065					2624	1598
Auxiliary Road	East to West					2074		1853			
	West to East					1694		1457			
	South to North	2011	1755	1434	1388					188	463
	North to South	1755	1799	1304	989					766	362

9.12. Proposal for the Development of International Technical Document Standards and Operational Manuals

9.12.1. Tunnel Engineering

The current tunnel design standards in Mongolia primarily include the "Railway and Highway Tunnels (Mongolian National Building Code 32-05-07)" and "Railway and Highway Tunnel Structures (Mongolian National Building Code 32-07-10)". The tunnel design standards remain relatively limited, lacking a comprehensive system. They are simplified with fewer clauses, predominantly featuring general or principle-based provisions. Consequently, these standards offer insufficient guidance for tunnel design. Critical aspects of detailed design—such as rock mass classification, portal design, and advance support—are notably deficient. Structural calculations for tunnels are oversimplified, and many referenced standards have been outdated or superseded. The high flexibility in implementation may lead to inconsistent quality and performance.

The primary standards include the Design Specifications for Highway Tunnels (JTG 3370.1-2018), Guidelines for Design of Highway Tunnels (JTG/T D70-2010), Seismic Design Specifications for Highway Tunnels (JTG 2232-2019), and Design Specifications for Highway Tunnels Part 2: Traffic Engineering and Ancillary Facilities (JTG D70/2-2014), among others. China's tunnel design standards have developed distinct advantages through long-term engineering practice and technological accumulation. These standards not only address engineering requirements under complex geological conditions in China but also incorporate advanced international concepts. After years of refinement, China's tunnel design standard system has evolved into a multi-tiered technical framework centred on national and industry standards. This system features a clear hierarchy and comprehensive coverage, accommodating diverse geological and climatic conditions while supporting various tunnel configurations. Specialised standards provide systematic methodologies for safety-critical calculations—including tunnel structures and seismic resistance—significantly enhancing construction safety.

This project involves a separated bidirectional six-lane tunnel with a design speed of 80 km/h and a length of 2,080 meters, classifying it as a long tunnel with a large cross-section.

For the tunnel design in this project, the following normative approach is recommended:

(1) Overall Tunnel Design

Given that China's tunnel design standards have evolved through decades of practice into a multi-tiered technical system with clear hierarchies and comprehensive coverage—centered on national and industry standards—while Mongolia's tunnel design standards remain comparatively limited, the following hybrid approach is advised: Primary Compliance: Railway and Highway Tunnels (Mongolian National Building Code 32-05-07), Railway and Highway Tunnel Structures (Mongolian National Building Code 32-07-10), Detailed Design Enhancement: China's tunnel design standards Design Specifications for Highway Tunnels – Part 1: Civil Structures (JTG 3370.1-2018), Guidelines for Design of Highway Tunnels (JTG/T

D70-2010), Seismic Design Specifications for Highway Tunnels (JTG 2232-2019), Design Specifications for Highway Tunnels – Part 2: Traffic Engineering and Ancillary Facilities (JTG D70/2-2014), Guidelines for Ventilation Design of Highway Tunnels (JTG/T D70/2-02-2014), Guidelines for Lighting Design of Highway Tunnels (JTG/T D70/2-01-2014).

(2) Material Selection

1) Concrete and Ordinary Reinforcement Steel

Recommend locally sourced materials complying with Mongolian national standards.

2) Steel Materials

Existing steel grades in Mongolia: Apply Mongolian standards. Steel grades unavailable domestically: Apply Chinese standards.

3) Other Materials

Material types available in Mongolia: Follow Mongolian standards. Material types not locally available: Adopt Chinese standards.

(3) Load Determination

The determination of tunnel loads—including permanent loads, variable loads, and their corresponding partial safety factors and combination factors—shall comply with: Railway and Highway Tunnels (Mongolian National Building Code 32-05-07) and Loads and Actions (Mongolian National Building Code 20-04-17).

(4) Design of Reinforced Concrete Tunnel Lining Structures

Analysis of Mongolian regulations indicates that construction materials (concrete, reinforcement steel, etc.) are typically domestically sourced or imported from Russia. Furthermore, the Mongolian Railway and Highway Tunnels standard (Mongolian National Building 32-05-07) explicitly mandates the limit state method for structural component calculations. Accordingly, the following implementation strategy is recommended: Load combinations, partial safety factors, combination factors, and material performance parameters shall adopt Mongolian standards. Reinforcement design for lining cross-sections shall employ the limit state method in compliance with the Mongolian standard, Reinforced Concrete Structures with Concrete and Non-Prestressed Steel Reinforcement (Mongolian National Building Code 52-105-10), Empirical refinements based on China's extensive engineering experience shall be incorporated to ensure structural safety.

(5) Structural Seismic Design

Mongolian standards typically require only the first-stage elastic design for ultimate load capacity based on elastic internal forces in most building structures. There is no systematic computational methodology for detailed design under rare earthquakes, with requirements primarily limited to seismic structural measures. China's standards adopt a dual-level fortification and two-phase design approach aligned with the seismic resilience objectives: No damage under minor earthquakes, Repairable damage under moderate earthquakes,

Collapse prevention under major earthquakes. Design Methodology: Phase 1: Elastic seismic design for E1 seismic actions, Phase 2: Plastic seismic design for E2 seismic actions, ensuring sufficient plastic deformation capacity through verification to prevent structural collapse, Recommendation: Tunnel seismic design should reference China's Seismic Design Specifications for Highway Tunnels (JTG 2232-2019) and undergo cross-verification with Mongolia's Seismic Zoning for Building Planning and Design (Mongolian National Building Code 22-01-21).

To address Mongolia's long-term development needs in tunnel engineering, it is recommended to leverage this demonstration project as a benchmark case. By referencing China's tunnel design standards and aligning with international best practices (ISO/AASHTO), Mongolia should initiate the systematic development and refinement of its national tunnel technical standards and code system.

9.12.2. Sponge City

The focal point of "Sponge City" development is establishing a "Low Impact Development Stormwater System", emphasising the use of decentralised small-scale control facilities at the source to maintain and protect natural hydrological functions. This effectively mitigates urban issues caused by increased impervious surfaces, including: Increased peak flood discharge, Elevated runoff coefficients, and heightened non-point source pollution loads. To vigorously advance "Sponge City" construction, conserve water resources, protect urban ecological environments, and promote ecological civilization, China has implemented the following regulations and policies: Urban Drainage and Wastewater Treatment Regulations, State Council General Office Notice on Urban Drainage and Waterlogging Prevention Infrastructure Construction (Guo Ban Fa [2013] No. 23), State Council Guidelines on Strengthening Urban Infrastructure Development (Guo Fa [2013] No. 36), These policies integrate with national standards including: Code for Urban Wastewater Engineering Planning, Design Code for Outdoor Wastewater Engineering, Assessment Standard for Green Buildings, In October 2014, the Ministry of Housing and Urban-Rural Development issued: Technical Guide for Sponge City Construction: Low Impact Development Stormwater Systems (Trial).

The traditional rainwater collection and drainage system primarily follows a "rapid drainage" approach: pavement rainwater → inlets → connecting pipes → municipal inspection chambers → municipal pipeline network. This design fundamentally transforms the conventional rainwater system centered on the Sponge City concept, delaying rainwater entry into pipelines while providing purification to reduce initial rainwater pollution.

Based on the project area's climate, soil conditions, and land-use catchment characteristics, the following Sponge City solutions are implemented: Lateral green belts are designed as sunken green spaces to collect motor vehicle lane runoff, achieving the required annual runoff volume capture rate for both roadways and green belts. Permeable

pavements are installed on non-motorized lanes and sidewalks, sloping towards continuous green belts. These pavements meet the annual runoff volume capture rate requirements for non-motorized lanes and sidewalks, with excess rainwater directed into drainage pipes via overflow-type inlets.

Stormwater Drainage System Flow: Motor Vehicle Lanes: Stormwater → Curb Opening Inlets → Sunken Green Spaces in Lateral Strips → Permeable Soft Pipes → Overflow-Type Inlets → Inlet Connecting Pipes → Municipal Stormwater Main Pipes. Service Roads, Non-Motorised Lanes & Sidewalks: Stormwater → Sunken Green Spaces in Lateral Strips → Permeable Soft Pipes → Overflow-Type Inlets → Inlet Connecting Pipes → Municipal Stormwater Main Pipes.

Stormwater utilisation measures do not alter the design standards of traditional stormwater pipeline systems. Ordinary double-unit inlets (front and rear grates) are installed at road depressions and intersections to prevent water accumulation hazards.

While Mongolia has proposed the Sponge City design concept, it currently lacks supporting policy documents or technical standards. It is recommended to leverage this demonstration project as a benchmark case. By referencing China's Sponge City policies and technical standards while aligning with international practices (ISO/SUDS), Mongolia should systematically develop and refine its national Sponge City regulations and technical codes.