ULAANBAATAR CITY GOVERNMENT OFFICE

INTEGRATED PROJECT MANAGEMENT OFFICE

URBAN PLANNING AND RESEARCH INSTITUTE

"FEASIBILITY STUDY OF THE ULAANBAATAR PUBLIC TRANSPORT (LIGHT RAIL TRANSIT-LRT) FROM GENERAL ARCHIVES TO SUKHBAATAR SQUARE."

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ULAANBAATAR CITY
2025

URBAN PLANNING AND RESEARCH INSTITUTE

FEASIBILITY STUDY FOR INTRODUCING HIGH-CAPACITY PUBLIC TRANSPORT VEHICLE (TRAM) FROM BUYANT-UKHAA SPORTS COMPLEX THROUGH TORGO ROAD COMPLEX PASSING 120 THOUSANDTH INTERSECTION TO SUKHBAATAR SQUARE

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Ulaanbaatar City

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CONTESTS

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CHAPTER 1.GENERAL PROVISIONS

Chapter Subsections:

- Rationale and Justification
- Research Objectives
- Scope of project
- Research Methodology

1.1. RATIONALE AND JUSTIFICATION

The following challenges in implementing a high-capacity public transportation system (Metro) in Ulaanbaatar city, which aligns with the sustainable development concept, supports urban development and prosperity, and ensures safe and comfortable travel conditions for citizens, it is fundamental rationale for conducting this research.
Herein:

- Ulaanbaatar has demonstrated significant population growth - from 560,600 in 1990 to 760,000 in 2000, 1,112,300 in 2010, and currently 1,640,000 inhabitants across 421,600 households in 2024, representing 47.6% of Mongolia's total population.

- Geographically, the city is situated along the Tuul River valley, enclosed by Bogdkhan Mountain to the south and Songino Khairkhan, Chingeltei, and Bayanzurkh mountains to the west, north, and east. Given its territorial and geographical location characteristics, it is a monocentric, linear city. Currently, of the city's 35,206 hectares of developed territory, 17,693.3 hectares are urbanized. The city is characterized by two primary settlement types: zones with centralized engineering infrastructure and partially serviced ger areas along the Tuul River valley.

- The Ulaanbaatar Urban Development Concept 2040 aims to transition from a single-center to a multi-center urban structure. The strategy focuses on decentralizing urban concentration, supporting and limiting urban development, defining development zones, and implementing public transportation development in alignment with urban planning policies.

- As of 2024, the city encompasses 584.6 kilometers of primary and auxiliary road networks, with most sections experiencing high traffic loads, poor road conditions, and significant infrastructure deterioration. The predominant portion of the city's road network (approximately 75%) is located within the developed urban territory.
- Current vehicle registration stands at 679,000, nearly tripling the road network's designed capacity. Public transportation ridership decreases as the number of registered private vehicles increases.

- Urban congestion and overlapping public transportation route networks result in public transportation vehicles average travel speed is between 8-15 kilometers per hour.

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Regulatory Context

The Technical and Economic Feasibility Study for introducing multi-modal public transportation from Buyant Ukhaa Complex to Torgonii Zam Complex, from the 120 thousandth intersection to Sukhbaatar Square has been developed based on the following legal documents.

Herein:

1. Government Action Program of Mongolia for 2024-2028
2. Resolution of the Government of Mongolia from the Meeting on March 27, 2024, Item 12 - Document on the Updated General Development Plan for Ulaanbaatar until 2020 and Development Trends until 2030, approved by the State Great Khural Resolution No. 23 of 2013
3. "Vision 2050" Long-term Development Policy of Mongolia
   - Section 9.2.6: "Fully electrify public transportation to reduce greenhouse gas emissions in the transportation sector"
   - Section 9.3.12: "Introduce multi-modal and intelligent public transportation"
   - Section 9.3.13: "Implement high-capacity passenger transportation along corridors with high passenger flow"
   - Sections 9.3.20 and 9.3.31: "Introduce high-capacity transportation connecting satellite cities based on passenger flow"
4. Ulaanbaatar City Development Concept until 2040, supported by the Government of Mongolia in Meeting No. 35 of 2020
   - Section 4.3.2: "Develop balanced multi-modal transportation"
   - Section 4.4.6: "Design and implement a development model based on public transportation axes"
5. The document on the Updated General Development Plan for Ulaanbaatar until 2020 and Development Trends until 2030, approved by the State Great Khural Resolution No. 23 of February 8, 2013, and the Implementation Action Plan for the same document approved by Government Resolution No. 174 of March 28, 2016, includes Section 2.3.1 stipulating: "Increase public transportation types and improve their coordination".
6. Attachment 1 to the State Great Khural Resolution No. 23 of August 28, 2020, on the Main Directions for Mongolia's Development for 2021-2025, Section 9.3.4 stipulates that multi-modal and intelligent public transportation shall be introduced into service, ensuring passenger hygiene and safety, with public transportation stops. Accordingly, the Capital City Citizens' Representative Khural incorporated a provision in Section 9.21.3 of the Five-Year Development Main Directions for 2021-2025 to expand multi-

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modal and intelligent passenger transportation services, which was approved by Resolution No. 02/10 on December 4, 2020.

7. In the medium and long-term master plan for the capital city's road network, the implementation plan for improving public transportation services includes 11 measures, such as introducing high-capacity, environmentally friendly public transportation systems, supporting a unified transportation policy, and optimizing public transportation networks, routes, and stop planning. Within this framework, the "National Committee for Ensuring Urban-Rural Development Balance, Reducing Centralization, and Decreasing Road Congestion" was established by Government Resolution No. 27 of January 25, 2017. As part of developing and implementing a national program with phased measures, the government emphasized that modernizing Ulaanbaatar's public transportation and introducing high-capacity public transportation would significantly reduce urban road traffic load. During the expanded government meeting on May 19, 2021, the government made a decision to provide annual funding to resolve the critical issues facing Ulaanbaatar, including INTRODUCTION 1-15 challenges, specifically road congestion, expanding main and auxiliary roads and crossings, and addressing the urgent need for public transportation fleet renewal.
8. At the Government of Mongolia meeting on August 25, 2021, a comprehensive plan was discussed to address Ulaanbaatar's traffic congestion and enhance public transportation quality and accessibility. The government resolved to implement a project for introducing high-capacity, innovative transportation vehicles, specifically a light rail system with an elevated guideway. Subsequently, during the meeting on August 31, 2021, the government instructed the Capital City Mayor to develop a preliminary feasibility study for this transportation project.
9. Pursuant to the State Great Khural Resolution No. 106 of December 30, 2021, on the "New Revival Policy", the Urban and Rural Revival section stipulates improving the quality and standards of public transportation in Ulaanbaatar by introducing high-capacity new transportation vehicles, expanding and modernizing primary and main road networks and road infrastructure, establishing multi-level intersections to increase accessibility and reduce road congestion. In the first-stage implementation program of the "New Revival Policy", Section 4.1.3 specifically outlines improving public transportation quality and standards, increasing accessibility, and introducing high-capacity public transportation technologies. The development project list includes the "Urban Public Transportation Renewal and Introduction of High-Capacity New Public Transportation Services with Elevated Guideway Infrastructure" project, aimed at reducing Ulaanbaatar's traffic congestion.
10. Directive No. A/1370 issued by the Governor of the Capital City dated November 15, 2024
11. Technical Assignment No. 240101073 issued by the Capital City Road Development Agency dated December 09, 2024
12. Technical Assignment No. 2501010240 issued by the Capital City Road Development Agency dated February 03, 2025
13. Architectural Planning Assignment for Roads and Road Facilities No. 2025/00-214 issued by the Chief Architect of the Capital City dated February 27, 2025

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1.2. RESEARCH OBJECTIVES

The purpose of this technical and economic feasibility study is to analyze and calculate the requirements and conditions for implementing a light rail system in the public transportation service of Ulaanbaatar city, to determine to create an overview of required investment costs, to define the implementation process in phases, and to propose planning solutions by conducting baseline research for developing a preliminary general plan.

The objective of the project is to:

- To construct a Light Rail Transit (LRT) tram system in Ulaanbaatar city's public transportation network with the aim of improving public transport accessibility, improving urban accessibility, reducing traffic congestion, improving traffic organization, establishing new cultural standards and requirements for public transportation, providing services that ensure citizens' comfort and safety, and aligning with Ulaanbaatar city's master plan, architectural and spatial planning solutions, and socio-economic conditions, while studying and determining road conditions to reduce traffic load.
- To determine the most optimal technological solutions and project implementation alternatives during and after the project design development phase and project formulation stage.

The fundamental issues being addressed to achieve this are:

- To identify environmental constraints and limitations necessary for planning.
- To study and determine on-site conditions through engineering geology, geodesy, and environmental assessment.
- To establish construction areas based on land capacity and vehicular traffic demand requirements.
- To identify current traffic congestion conditions in Ulaanbaatar city and determine congestion reduction conditions following implementation of the planned system.
- To determine throughput capacity, road expansion conditions, and their respective capacities.
- To develop the light rail network to connect and advance urban centers, sub-centers, and primary community micro-centers, while supporting and developing sustainable urban transport with modern engineering solutions for corridors and stations along the network.

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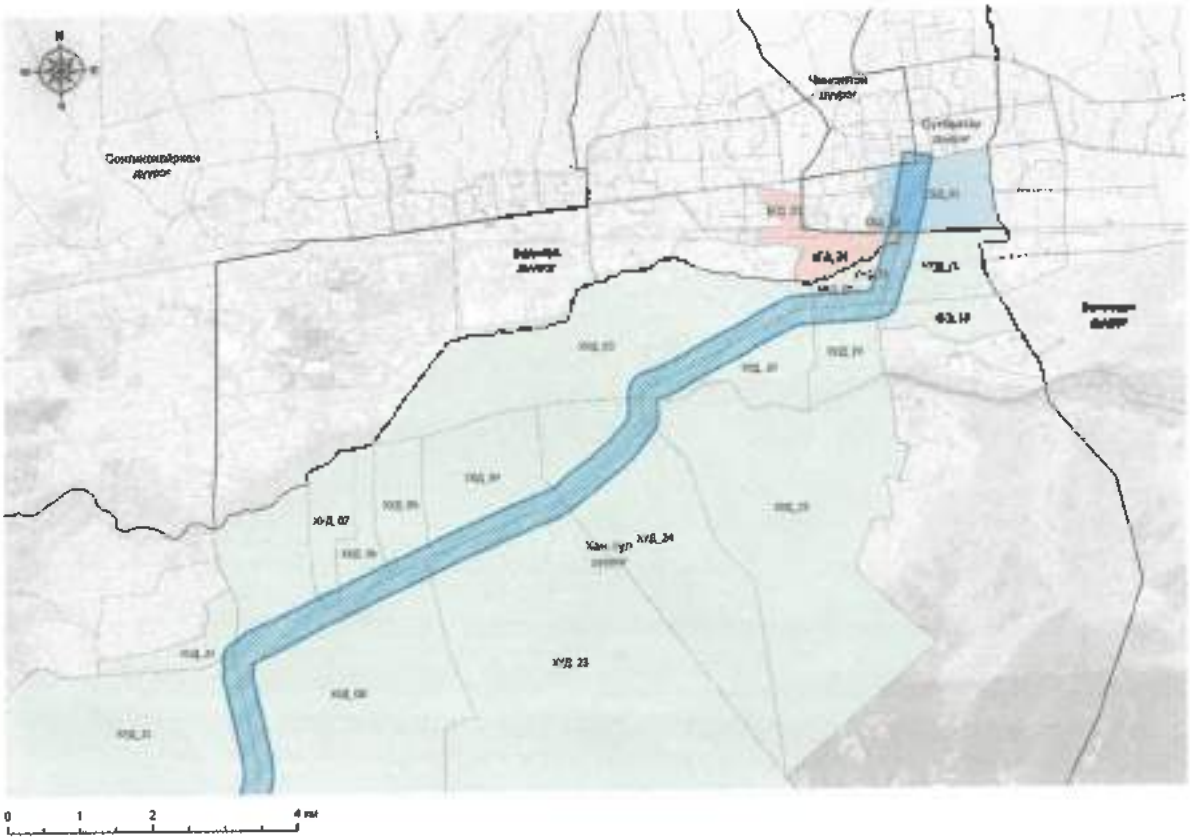
- To develop implementation phase plans and financing solutions.

The project to implement a multimodal public transport system from Buyant-Ukhaa Complex to Torgonii Zam Complex and from 120 thousandthTH INTERSECTION TO SUKHBAATAR SQUARE is located within the territories of the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 15th, 18th, 19th, 20th, 21st, 22nd, 23rd, 24th, and 25th khoroos of Khan-Uul District, the 1st and 2nd khoroos of Sukhbaatar District, and the 3rd and 26th khoroos of Bayangol District. The project covers an area of 1272.83 hectares within a space that is 15.0 km long and 800 m wide, extending from the southern parking area of Sukhbaatar Square to the General Archives Authority.

Project scope



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1.3. RESEARCH METHODOLOGY

A Feasibility Study (FS) refers to the process of determining strategy and future trends through comparative methods based on baseline studies of the project, including technical, technological, capacity, economic, and social benefit calculations.

The feasibility study and design documentation for the high-capacity public transport (tram) project planned for implementation across 3 districts, 21 sub-districts, Naadamchid Road, and Chinggis Avenue in Ulaanbaatar city, are being developed in compliance with the laws, regulations, and standards of Mongolia, as well as the appropriate urban planning and construction norms and regulations, ensuring conformity with the design development standards and regulations.

Norms and regulations used in the development of the Feasibility Study:

- Urban and village planning and construction norms and regulations (CNR 30-01-04) (Construction Norms and Regulations);
- Urban and settlement street and road planning (CNR-32-01-04) (Construction Norms and Regulations)
- Methodological guidelines for developing urban and settlement master plans (UBB 11-202-00) (Urban Building Bureau);
- Methodological guidelines for comprehensive urban planning assessment in urban and settlement areas (UBB 30-201-09) (Urban Building Bureau)
- 1435 mm gauge railway. General technical requirements MNSGB 50090: 2017
- General requirements for design documentation of bridges and culverts for 1435 mm gauge railways MNSGB 10002: 2017
- Railway applications. Track. Acceptance of track maintenance work Part 1: Maintenance work on ballasted track - Plain line, switches, crossings and expansion devices MNS EN 13231-1:2016
- Railway applications. Track. Track geometry quality Part 1: Characterization of track geometry MNS EN 13848-1:2016
- Railway applications. Track. Aluminothermic welding of rails Part 1: Approval of welding processes MNS EN 14730-1:2014 (
- Railway applications. Communication, signaling and processing systems. Software for railway control and protection systems MNS EN 50128: 2016
- Railway applications. Communication, signaling and processing systems. Safety-related electronic signaling systems MNS EN 50129: 2016
- Railway applications - Air conditioning for urban and suburban rolling stock Part 1: Comfort parameters MNS EN 14750-1:2015
- Railway applications - Air conditioning for urban and suburban rolling stock Part 2: Type tests MNS EN 14750-2:2015

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- Railway applications. Definition of vehicle reference masses MNS EN 15663:2015
- Requirements for railway locomotive depot design documentation MNS TB 10004 2016 (Mongolian National Standard Technical Building)
- Urban and village planning and construction norms and regulations (CNR 30-01-04) (Construction Norms and Regulations)
- "Urban settlement streets and roads planning" CNR 32-01-04 (Construction Norms and Regulations)
- "Highway climate and geotechnical conditions" HCGC 2.01.01-2004 (Highway Climate and Geotechnical Conditions)
- "Road signs. General technical requirements" MNS 4597:2014
- "Regulations for the use of road signs, markings, traffic lights, barriers, and guidance devices" MNS 4596:2014
- "Roads and road structures. General requirements for bicycle path planning" MNS 5683:2022
- General requirements for the technical condition of road vehicles MNS 4598:2020
- "Standard prices for road and bridge design and survey works" BD81-104-02 (Building Directive)
- UCS 0901B General requirements for pedestrian path and square planning, paving, and installation
- UCS 0903B General requirements for bicycle path planning and paving
- UCS 1603B General requirements for public transport services, transport services, and vehicles

General research

For conducting on-site surveys: Beginning December 02, 2024, necessary information was collected and analyzed by visiting the planning territory to perform on-site measurements, documentation, and reconnaissance surveys. As a result, information necessary for planning regarding the engineering geological conditions of the planning territory, environmental indicators, and transportation infrastructure and engineering infrastructure in and around the area was determined accordingly.

For conducting statistical research: All statistical information was based on reports and data issued by the Capital City Statistics Department and the National Statistics Office, as well as information from the sections included in the planning.

For conducting comparative research: Similar tram transport solutions being used internationally were examined for each planning unit.

Planning Solution

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For developing planning solutions: Options and solutions were developed based on the guidelines and recommendations provided by the client, the engineering geological conditions of the project site, environmental indicators, opinions of land owners, analysis of current conditions and future prospects of passenger transport demand, and the Ulaanbaatar Development Master Plan 2040. Additionally, after studying Ulaanbaatar city's traffic congestion and future automobile demand, planning solutions were proposed as alternatives based on land acquisition and transport demand modeling.

1.4. STUDY OF LEGAL ENVIRONMENT FOR MULTIMODAL PUBLIC TRANSPORTATION (TRAM)

Currently Valid Laws:

№	Applicable Laws	Relevant Articles and Provisions
1	Construction Law /Revised edition/ 02.05.2016	1.1. The purpose of this law is to regulate relations associated with engaging in construction activities, manufacturing construction materials, executing construction work, exercising oversight, and commissioning. 4.1.33. "Engineering infrastructure" refers to roads, railways, cable cars, underground and above-ground road structures, all types of engineering networks, and structures with both simple and engineered designs and constructions for disaster and accident prevention,
2	Railway Transport Law /Revised edition/ 07.07.2023	1.1. The purpose of this law is to regulate relations associated with the transportation of passengers and cargo by railway, ensuring railway transport safety, constructing infrastructure, and owning, possessing, and using infrastructure and rolling stock. 3.2. This law does not regulate relations associated with the construction and operation of metro, tram, magnetic and similar special design public transport railways. 31.1. When newly constructing or renovating railway infrastructure, it shall not intersect at the same level with roads or other types of infrastructure, and the direction and gradient of existing railway infrastructure shall not be altered. Explanation: "Other types of infrastructure" as specified in Article 31.1 of this law refers to metro, tram, magnetic and similar special design public transport railways.
3	Road Transport Law 04.06.1999	3.1.11. "Public transport" refers to passenger transportation and taxi services that are operated according to public service routes and schedules established by the authorized organization, or are organized in a structured manner; 7.1. The Governors of aimags, soums, the capital city, and districts shall exercise the following powers regarding road transport: 7.1.4. regulate and organize public transport, cargo, and mail transportation within their respective territories;
	Law on Reducing Traffic Congestion in the Capital City of Ulaanbaatar	1.1. The purpose of this law is to increase conditions for unimpeded movement of citizens, improve the types and accessibility of public

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4	and Converting Ger Districts into Apartment Areas 07.12.2023	transport and use of parking facilities, reduce urban concentration, convert ger districts into apartment areas, and reduce the social and economic impacts arising from congestion and environmental pollution. Article 5. Development of Public Transport in the Capital City 5.1. The capital city shall have multimodal, high-capacity public transport and supporting infrastructure. 5.2. The state shall provide support for the diversification and development of public transport in the capital city in accordance with relevant legislation. 5.3. The capital city shall have long and medium-term planning for sustainable mobility and public transport development, taking into account the capital city's general and detailed master plans, passenger flow demand, traffic intensity on the respective travel sections, and infrastructure. 5.4. Public transport services may be implemented through public-private partnership agreements as specified in the Law on Public-Private Partnerships. 5.5. The capital city shall maintain a fund for public transport development. Explanation: Public transport in the capital city as specified in this law includes, in addition to what is defined in Article 3.1.11 of the Road Transport Law, cable transport and high-capacity passenger transport operations.

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CHAPTER 2. CURRENT SITUATION ANALYSIS

Chapter Subsections:

- Socioeconomic study
- Road network traffic volume study
- Road Traffic Congestion Conditions
- Research on historical and cultural immovable monuments

2.1. SOCIO-ECONOMIC RESEARCH

Socio-economic requirements of the project

The socio-economic necessity and requirements for developing public transportation in Ulaanbaatar city and implementing new transport modes can be analyzed based on urban development, planning conditions, urban concentration, population growth, and road network capacity.

Urban concentration and population growth. During the past 30 years, Ulaanbaatar's population has tripled, increasing from 590,600 in 1990 to 1.59 million in 2020. The capital's proportion of the country's total population has increased from 27.2% to 47.6%. Approximately 95.2% of the city's population resides in the 6 central districts, with an additional 120,000 temporary residents. Migration constitutes the primary factor driving the city's population growth, and this concentration trend is anticipated to continue.

Analysis of urban planning implementation. Ulaanbaatar has developed in accordance with 6 master plans formulated and approved in 1954, 1963, 1971, 1986, 2000, and 2013. The document "Ulaanbaatar City Development Master Plan Amendment until 2020 and Development Trends until 2030," approved in 2013, aims to ensure balanced urban development, restrict unplanned expansion, and enhance land use management. Within this framework, the plan addresses ecological sustainability, economic viability, and population safety while promoting environmentally friendly urban development based on green development principles.

However, during implementation, the planning of roads, schools, kindergartens, and public service facilities has lagged behind, and with increased travel demand, traffic congestion has become the most pressing issue.

Ulaanbaatar's development plan until 2040 aims to create a sustainable, accessible, and efficient city. One solution is to reduce traffic congestion by implementing a light rail project based on modern technology.

Road network load and congestion. In the last 10 years, the number of vehicles in Ulaanbaatar has tripled, with 72.2% of households now owning cars. However, during this period, the road network has expanded by only 19%, which is the main cause of congestion, resulting in citizens spending 2.4 hours daily and 35 days annually in traffic jams.

Poor accessibility of public transport, high route overlap, and long travel times have encouraged citizens to use private vehicles, reducing the tendency to choose public transport by 10%. As a result, road network load has tripled, with congestion occurring on 78% of the city's streets and roads.

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To address this situation, it is necessary to introduce high-capacity, competitive public transport vehicles and reduce private car usage.

Macroeconomic analysis

Mongolia's GDP (at current prices) reached 70.4 trillion MNT in 2023, increasing by 30.8 percent compared to the previous year. The following private sector industries have the highest share in GDP: Agriculture, forestry, fishing, and hunting (100%), Real estate activities (99.89%), and Wholesale and retail trade (99.8%).

Table 1. Gross Domestic Product, 2000, 2010, 2023

Region, Capital	GDP (billion tugrug)	GDP share (%)	GDP annual growth (%)	Population (thousand people)	GDP per capita (million tugrug)	Private sector Value Added share in GDP (%)
2010						
National total	9 755.59	100.0	48.0	2 653 826	3.70	73.4
Western region	493.73	5.1	30.9	362 360	1.36	63.2
Khangai region	1 535.24	15.7	18.2	515 213	2.97	43.2
Central region	1 179.71	12.1	60.3	442 046	2.69	85.4
Eastern region	393.97	4.0	49.0	185 518	2.12	86.7
Ulaanbaatar	6 153.94	63.1	57.2	1 168 691	5.40	77.0
2015						
National total	22 694.78	100.0	3.0	2 990 242	7.7	79.1
Western region	1 506.89	6.6	7.6	386 989	4.0	78.5
Khangai region	3 100.09	13.5	0.6	573 095	5.4	65.5
Central region	2 335.12	10.2	-0.6	477 159	4.9	76.2
Eastern region	1 246.54	5.4	-5.7	2075 19	6.1	85.4
Ulaanbaatar	14 704.13	64.2	4.5	1 345 500	11.1	82.0
2023						
National total	70 441.6	100	30.8	3 396 788	20.8	75.3
Western region	3 549.7	5.0	3.7	413 704	8.5	79.8
Khangai region	7 848.3	11.1	11.2	600 281	13.0	52.5
Central region	9 696.3	13.8	37.1	512 665	18.8	84.7
Eastern region	2 470.0	3.6	1.1	229 357	10.8	82.6
Ulaanbaatar	46 887.3	66.5	38.5	1 540 781	29.0	76.5

Source: National Statistics Office, 1212.mn

Ulaanbaatar city Gross Domestic Product by sector, billion MNT

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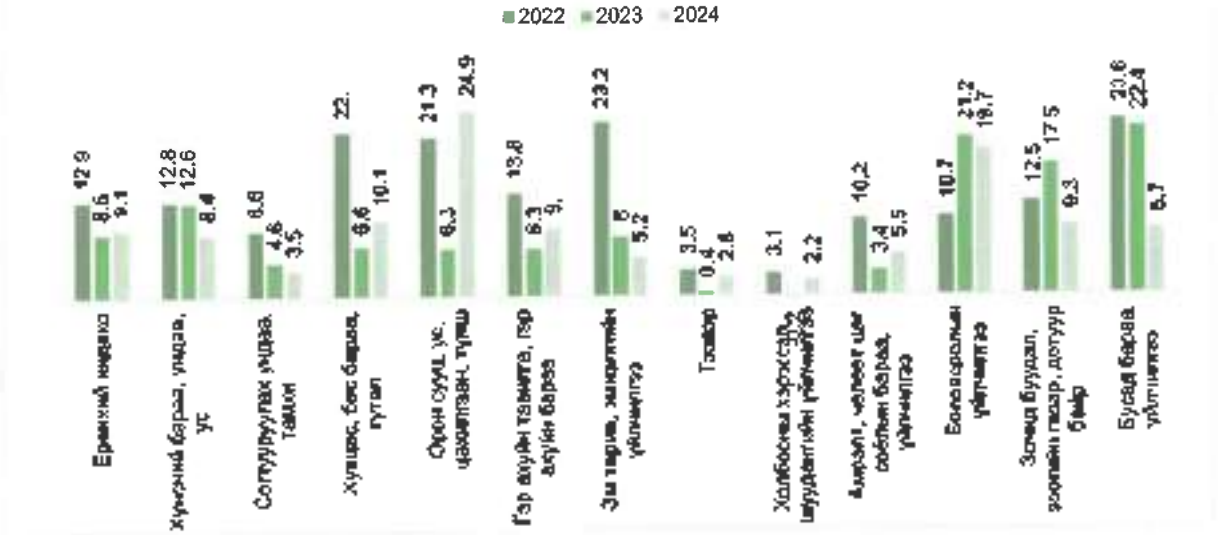
Source: National Statistics Office, 1212.mn

In 2005, Ulaanbaatar city's GDP was 1,762 billion MNT, with agriculture accounting for 0.7 percent, manufacturing 35.3 percent, and services 64 percent. By 2023, it increased to 46,877 billion MNT, with agriculture accounting for 0.18 percent, manufacturing 41.7 percent, and services 58.13 percent. Ulaanbaatar city's Gross Domestic Product decreased by 4 percent in 2020 compared to the previous year due to the pandemic, while in 2023 it increased by 38.5 percent. This growth was primarily influenced by the increase in GDP from the mining sector.

Graph 1. Ulaanbaatar city Consumer Price Index, by quarter, 2022-2024



Source: National Statistics Office, 1212.mn

Graph 2. Inflation rate, 2015-2023

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Source: National Statistics Office, 1212.mn

The inflation rate in Ulaanbaatar city decreased from 14.3 percent in 2010 to 8.6 percent in 2023 and 9.1 percent in 2024, influenced by reductions in food, beverages, and water by 20-27 percent, alcoholic beverages and tobacco by 29-31 percent, and medicine and medical services by 30-56 percent.

Investment is calculated by source as domestic and foreign sources; domestic sources are calculated as the sum of state budget and other domestic sources, while foreign sources are calculated as the sum of loans, grants, and direct investments. Foreign and domestic investments in Ulaanbaatar city serve as the main driving force for urban development, playing an important role in sustainable economic and social development. Due to the concentration of infrastructure, market capacity, and skilled workforce in the capital city of Ulaanbaatar, most of the country's total investment is spent in the capital. For instance, Ulaanbaatar city's share of state budget investment accounted for 58 percent in 2015, 24.6 percent in 2020, and 35 percent in 2023.

Graph 3. Foreign and domestic investment, Mongolia, 2015-2023

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Source: National Statistics Office, 1212.mn

Graph 4. Ulaanbaatar city budget revenue and expenditure, million MNT

Source: National Statistics Office, 1212.mn

The balanced budget of Ulaanbaatar city showed a surplus of 57 billion MNT in 2022 and 289 billion MNT in 2023, while in 2016 it had the highest deficit of 155.2 billion MNT. Ulaanbaatar city's budget revenue reached 2.2 trillion MNT in 2023, increasing by 49.7 percent compared to the previous year. State budget expenditure reached 1.9 trillion MNT in 2023, increasing by 35.4 percent compared to the previous year.

Graph 5. Ulaanbaatar city budget investment, billion MNT

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Source: National Statistics Office, 1212.mn

In 2023, Ulaanbaatar city's investment reached 957.4 billion MNT, with 78.5 percent funded by the state budget and 21.5 percent by the local budget. Ulaanbaatar city's budget investment increased by 8.2 billion MNT (0.9%) compared to the previous year, while local budget investment decreased by 372.2 billion MNT (64.4%). The working-age population accounted for 67 percent of the total population as of 2023, and constituted an average of 71.3 percent of the total population during 2000-2023. The working-age population decreased from 75 percent in 2010 to 67.1 percent in 2023. However, the employment rate, which is the percentage of employed people in the labor force, has increased by 1.2 percentage points since 2010. The World Bank and Asian Development Bank have projected Mongolia's GDP growth to be approximately 5-7% in 2025, driven by factors such as mining sector revitalization, implementation of infrastructure projects, and increased foreign investment.

During project implementation, the increased participation of domestic manufacturers, implementing entities, and subcontractors will have a positive impact on sectoral GDP growth. Following project completion, the development will continue to stimulate economic activity by supporting industrial and service establishments along the project corridor, thereby contributing positively to national GDP performance.

Table 2. Working-age population, by selected years

Type	Subcategory	2020	2021	2022	2023
15+ age population	Total working-age population	1,004,842	1,028,337	1,071,053	1,100,602
	Percentage of total population	67.0%	66.8%	67.1%	67.1%
Economically inactive population	Retired/elderly	152,144	171,259	182,550	203,168
	Student/studying	116,099	115,019	120,384	141,125
	Pregnant/childcare	81,352	81,543	71,747	81,709
	Persons with disabilities	29,027	29,191	18,872	27,480
	Other	89,926	102,770	73,690	81,400
	Total economically inactive population	468,548	499,791	468,242	534,882
	Percentage of total population	31.3%	32.5%	29.3%	32.6%
Economically active population	Employed	517,427	476,806	534,712	549,010
	Unemployed	34,708	41,099	32,022	28,288
	Total economically active population	552,141	518,906	566,734	577,298
	Percentage of total population	36.8%	33.6%	35.5%	35.2%
Unemployment rate, %		6.3	8	5.7	4.9
Labor force participation rate, %		54.1	50.6	54.9	51.9
Labor underutilization rate, %		12.4	16.4	10.1	9
Combined rate of unemployment and potential labor force, %		12.1	15.2	9.6	8.9

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Source: National Statistics Office, 1212.mn

The labor force participation rate is an indicator that shows what percentage of the working-age population makes up the labor force. The labor force participation rate in 2023 was 51.9 percent, with 54.4 percent for males and 45.6 percent for females. As of 2023, the total labor force comprised 49.5 thousand (8.6%) people aged 15-24, 470.1 thousand (81.4%) people aged 25-54, 37.2 thousand (6.5%) people aged 55-59, and 20.4 thousand (3.5%) people aged 60 and above.

The global trend of declining labor force participation rates is also being observed in Mongolia. The decrease in Mongolia's labor force participation rate is partly due to the low birth rate during 1991-2005, with 250-300 thousand fewer children born than the long-term average, who are now citizens aged 18-33 and constitute approximately 34 percent of the labor force. Examining the number of registered unemployed persons from 2007-2023, there has been a continuous decrease, from the highest point of 29.4 thousand in 2011 to 2.6 thousand in 2023. Looking at the labor force participation rates by districts, Baganuur district's labor force participation decreased by 16 percentage points, while Khan-Uul district's labor force participation rate increased by 5 percentage points. Additionally, female labor force participation has decreased due to increased birth rates since 2008. As of 2023, 23 percent of Mongolia's total employed population are professionals, 22 percent are trade and service workers, while 3.2 percent are technicians and associate professionals, 0.6 percent are skilled agricultural, forestry, and fishery workers, and 0.5 percent are armed forces professionals.

Demographic analysis

As of 2023, Mongolia's total workforce composition includes 23% professionals, 22% trade and service workers, 3.2% technicians and associate professionals, 0.6% skilled agricultural, forestry and fishery workers, and 0.5% armed forces personnel.

Graph 6. Working Age Population Projection

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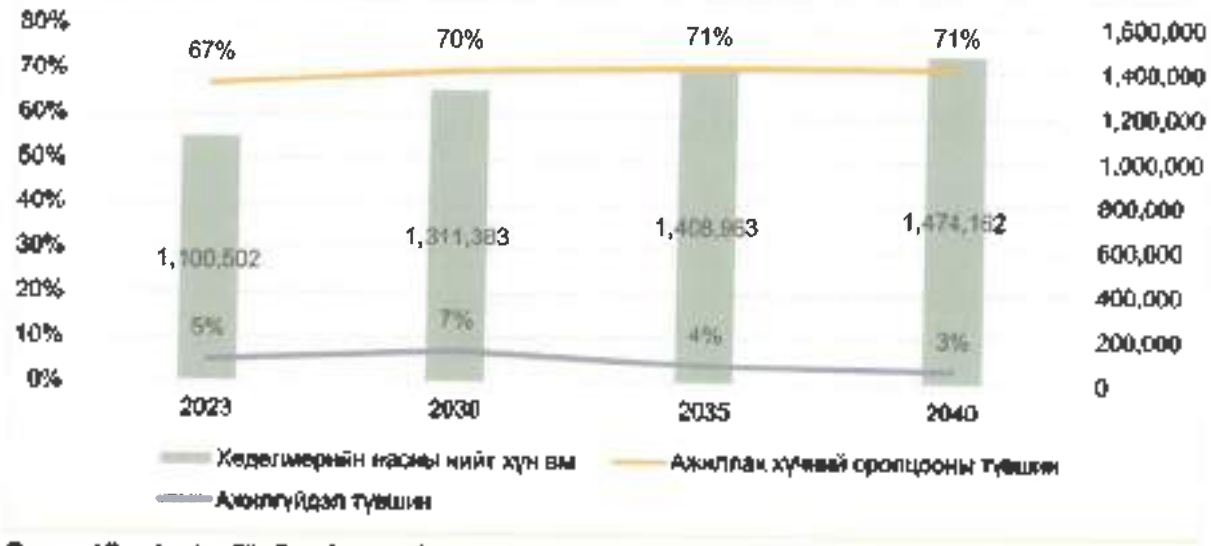
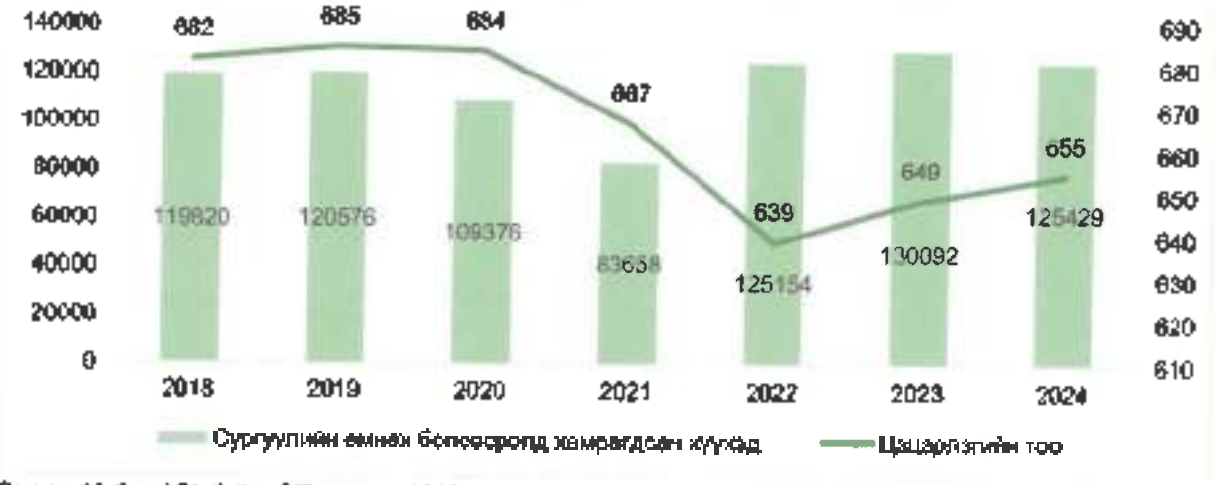


Source: Ulaanbaatar City Development Master Plan until 2040

According to the Ulaanbaatar City Development Master Plan until 2040, the working-age population within the Capital City region is projected to reach 1.474 million, representing a 34% increase from 2023 levels. The unemployment rate is expected to gradually decrease, reaching approximately 3%.

Graph 7 Number of Children in Preschool Education and Number of Kindergartens, 2018-2024



Source: National Statistics Office, www.1212.mn

As of 2024, 125,000 children are enrolled in 655 kindergartens throughout Ulaanbaatar, with 27% of the total enrollment in Bayanzurkh District and 21% in Khan-Uul District. In 2023, 300 public and 349 private kindergartens operated with 4,636 primary teachers and 4,216 assistant teachers.

Graph 8. Number of Full-Time Students in General Education Schools and Number of Schools, 2018-2024

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Source: National Statistics Office, www.1212.mn

In 2024, 398,000 children attend 163 public and 146 private schools in the capital city. Of the total student population, Bayanzurkh District accounts for 25%, Khan-Uul District for 17.4%, and Songinokhairkhan District for 17%.

Table 3 Number of Children of Kindergarten and School Age

Indicator		2023	2030	2040
1-year-old children eligible for nursery/ Daycare center	Total	30,994	38,906	46,299
	Growth		25.9%	18.9%
2-5 year-old kindergarten-age children	Total	149,654	148,250	177,006
	Growth		-0.9%	19.4%
6-17 year-old school-age children	Total	402,349	443,682	451,099
	Growth		10.3%	1.7%

Source: Ulaanbaatar City Development Master Plan until 2040

According to the Ulaanbaatar City Development Master Plan until 2040, the number of kindergarten-age children (2-5 years) is projected to reach 177,000 by 2040, representing an 18% increase from 2023, while school-age children will reach 451,000, a 49.8% increase from 2023 levels.

Demographic Research

The percentage of Ulaanbaatar city's population in Mongolia's total population increased by 4.4 percentage points compared to 2010. During 2010-2023, the population increased by 482.09 thousand, of which 36.9% was due to mechanical growth from migration, and 63.1% was due to natural population growth.

Ulaanbaatar city's population reached 1,640.8 thousand in 2023, an increase of 44.4 thousand (2.8%) from the previous year. From 2010 to 2023, the population grew by an annual average of 37.97 thousand (3.3%).

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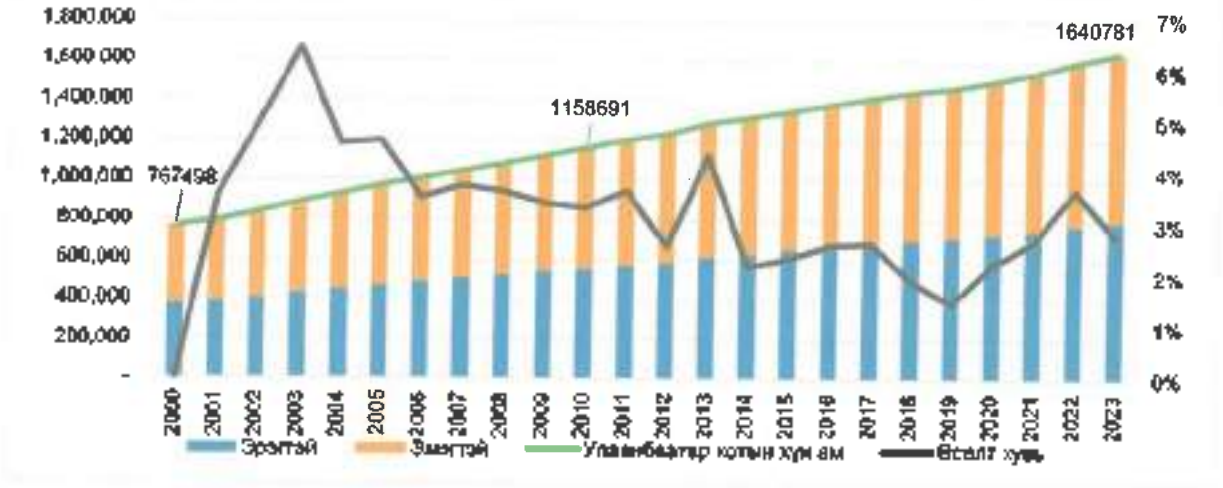
Graph 9. Urban Population Growth by Total Population and Gender Ulaanbaatar City, 2000-2023



Source: National Statistics Office, 1212.mn

Population Growth by Districts

The density and distribution of Ulaanbaatar's population vary significantly due to multiple factors such as the territorial size of districts and khoroos, infrastructure, and economic development. In 2023, 26.62 percent of Ulaanbaatar's total population resided in Bayanzurkh district, while 20.81 percent lived in Songinokhairkhan district. Comparing 2023 to 2003, Chingeltei district's population increased by 9 percent, Baganuur and Bagakhangai districts' population by 19 percent, and Khan-Uul district's population by 211 percent.

Table 4. Population by districts, thousand people, 2003-2023

Year	Baganuur	Bagakhangai	Bayangol	Bayanzurkh	Nalaikh	Songinokhairkhan	Sukhbaatar	Khan-Uul	Chingeltei
2003	24.21	3.70	156.44	177.18	25.15	165.86	108.17	83.13	124.78
2004	25.00	3.77	161.53	187.51	26.10	186.70	114.22	85.43	127.26
2005	25.61	3.86	163.93	200.35	27.09	208.98	119.76	89.80	133.30
2006	26.27	3.91	164.12	215.96	27.86	215.39	125.57	92.78	135.61
2007	26.49	3.94	168.45	225.98	28.71	224.87	132.07	98.57	138.72
2008	26.29	3.79	171.88	238.61	29.57	235.91	135.16	100.34	142.17
2009	26.22	3.83	177.14	253.51	30.62	244.57	136.86	105.53	143.09
2010	26.90	3.85	184.80	264.10	31.42	252.40	136.74	111.42	147.26
2011	26.93	3.74	191.23	282.07	32.39	256.03	137.22	119.31	152.43
2012	27.57	3.69	193.44	296.23	33.04	263.07	132.70	128.03	154.60
2013	28.37	3.85	203.16	306.99	33.76	281.56	135.32	133.07	158.21
2014	28.33	3.90	206.90	308.67	34.55	295.83	138.42	138.37	159.51

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2015	28.42	4.13	205.66	320.86	35.81	307.22	137.63	150.95	154.62
2016	28.97	4.14	214.28	327.12	36.43	315.80	136.57	158.47	158.01
2017	28.79	4.10	221.38	336.93	36.91	322.46	138.05	169.73	159.05
2018	29.51	4.40	226.87	343.62	37.61	321.15	145.34	176.92	157.26
2019	28.57	4.12	225.84	361.69	37.66	327.58	144.41	187.28	146.95
2020	29.34	4.46	231.52	387.68	38.69	335.70	144.62	195.93	151.20
2021	29.43	4.46	236.39	393.89	38.93	341.54	144.54	209.52	150.55
2022	29.34	4.42	246.69	400.80	39.58	342.11	142.44	238.51	144.25
2023	28.93	4.42	252.98	436.82	40.24	341.39	141.54	258.19	136.28
2003/2023	19%	19%	62%	147%	60%	84%	31%	211%	9%
2013/2023	2%	15%	25%	41%	19%	21%	5%	94%	-14%
2018/2023	-2%	1%	12%	27%	7%	6%	-3%	44%	-13%

Source: National Statistics Office, 1212.mn

Table 5. Population density, per square km, by selected years

Administrative unit	2010	2015	2020	2021	2022	2023
Ulaanbaatar	243.76	286.28	339.8	339.8	339.3	346.8
Bayangol	7477.95	6973.99	7850.7	7850.7	8371.9	8578.5
Chingeltei	1627.69	1733.7	1693.2	1693.2	1615.3	1526.1
Sukhbaatar	599.58	660.43	683.9	683.9	683.5	679.2
Khan-Uul	219.32	311.45	404.3	404.3	492.1	532.7
Bayanzurkh	225.5	257.89	295.5	295.5	326.6	351.1
Songino-khairkhan	213.95	256.89	279.6	279.6	284.9	284.3
Nalaikh	49.73	52.08	56.3	56.3	57.6	58.5
Baganuur	35.86	46.82	47.3	47.3	47.3	46.6
Bagakhangai	21.5	29.51	31.9	31.9	31.5	31.6

Source: National Statistics Office, 1212.mn

Nalaikh, Baganuur, and Bagakhangai districts are located 45-110 km away from the city center and have the lowest population density with 31.6-58.5 people per square km.

Population Structure

The sex ratio of the population, measured as the number of males per 100 females, increased from 92.7 in 2010 to 93.6 in 2023. Examining the sex ratio by age group, there are 105 males per 100 females in the 0-14 age group, 91 males per 100 females in the 15-64 age group, and 61 males per 100 females in the 65 and above age group.

Ulaanbaatar city's population remains generally young in terms of age structure. The proportion of children aged 0-14 in the total population has increased by 7.9 percent since 2010, while the proportion of working-age population has decreased by 9.1 percent.

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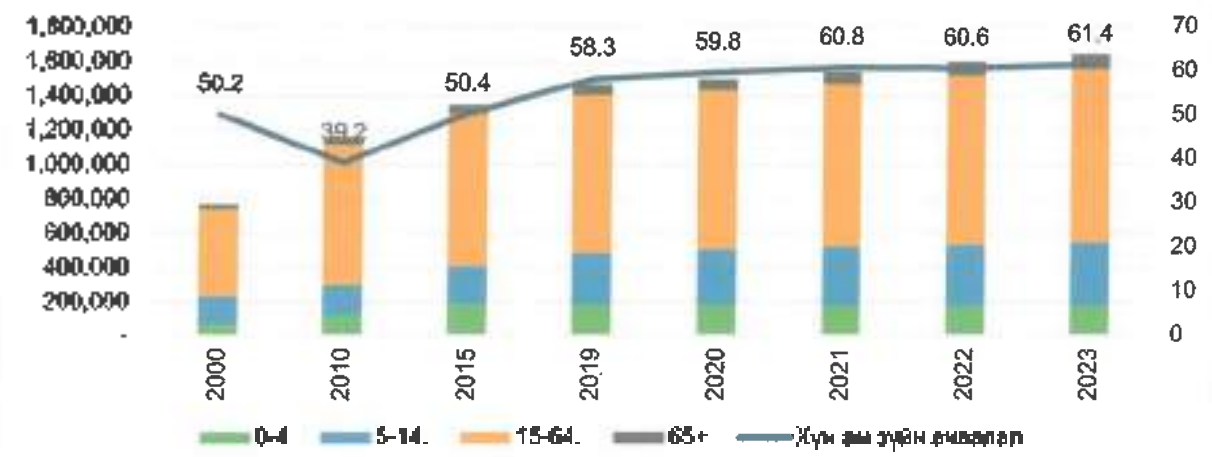
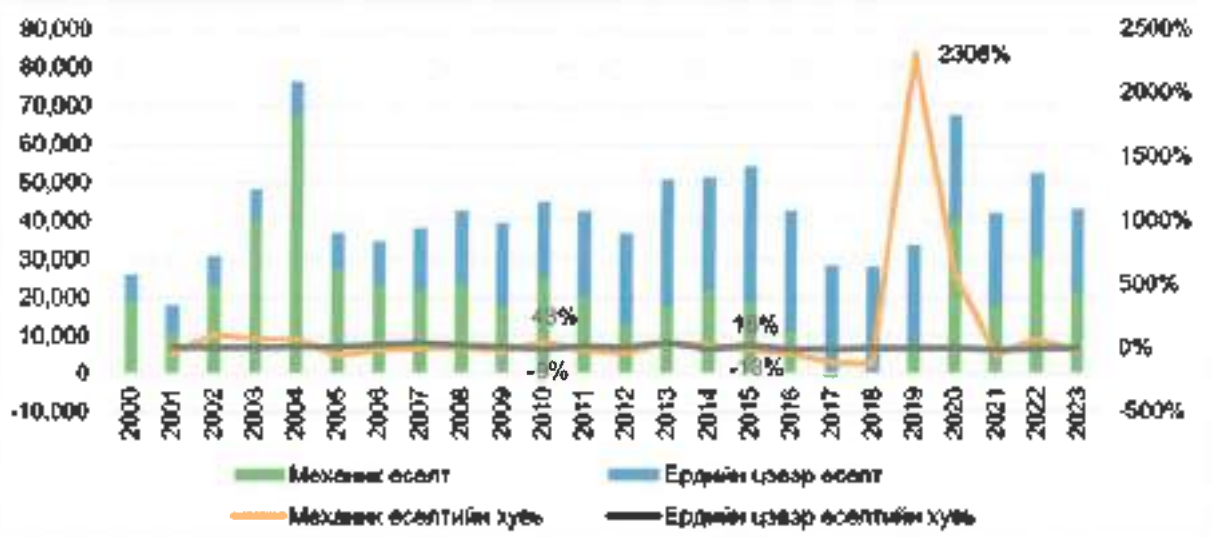
Graph 10. Population age structure, Ulaanbaatar city, 2000-2023



Source: National Statistics Office, 1212.mn

Since 1990, Mongolia's population increased by 63%, while the population of Ulaanbaatar grew by 196%. Due to factors such as employment opportunities, improved living conditions, and access to education, there has been a significant migration from other regions. In fact, approximately 787,000 people have migrated to the capital since 1990.

Table 6. Net and Mechanical Population Growth, 2000–2023



Source: National Statistics Office, 1212.mn

Population Projections

In the population projection of Ulaanbaatar for 2040, the population of 2020 census was used as the base population. The population projections were developed based on three scenarios considering fertility levels, and included estimates of migration flow impacts by gender and age groups. The population projection was calculated for Scenario Z, which takes into account policy influences, and also for the combined 9 scenarios. For

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the scenario that aligns with the population demographic targets outlined in Vision-2050, all calculations were done using the right aging model, applying the Coale-Demeny West model for mortality tables. and conducted using the MOGFAC program.

Table 7. Total Population Projections by Age Group, 2023-2040

Total	2023	2025	2030	2035	2040
0-4	172,708	181,075	191.757	209,840	227,079
5-9	196,018	179,889	182.747	188,266	204,389
10-14	171,553	184,579	181,203	180,138	184,177
15-19	107,974	133,693	188,291	177,858	174,904
20-24	89,592	96,083	139,170	176,651	162,861
25-29	104,146	94,922	102,972	127,164	157,572
30-34	144,107	118,155	98,375	96,492	116,906
35-39	148,641	149,376	119,532	95,092	91,443
40-44	114,197	125,092	149,893	118,835	91,252
45-49	98,449	102,973	126,118	146,958	113,130
50-54	81,930	88,912	102,350	122,037	142,903
55-59	69,223	72,666	87,777	98,213	118,672
60-64	56,277	62,764	70,199	83,182	92,949
65-69	37,278	43,589	58,027	65,537	78,321
70-74	21,004	24,304	38,155	51,489	58,982
75-79	12,789	13,031	19,404	31,080	42,899
80-84	7,979	7,500	8,917	13,756	22,883
85+	4,918	4,343	5,201	6,643	10,863
Total	1,640,781	1,682,937	1,867,089	1,987,207	2,069,807

Source: Ulaanbaatar City Development Master Plan until 2040

According to the Ulaanbaatar City Development Master Plan until 2040, the population in the Capital City area, which is 1.64 million people as of 2023, will be distributed across cities and towns of national and local levels to create jobs. By 2040, it is planned that the cities of Nalaikh and Baganuur, which will attain national level status, will have a population of 200,000 people in 63,800 households, satellite cities of local level will have a total population of 154,000 people in 49,000 households, the towns of Ulaanbaatar will have a population of 51,000 people in 16,000 households, and the 14 districts of Ulaanbaatar city will have a population of 1.685 million people in 538,000 households.

Table 8. Population Settlement in the Capital City Region by Projected Years

No	Cities and Towns of National and Local Levels in the Capital City		2023	2025	2030	2035	2040
1	Cities with National Status	Baganuur /City with National Status/	28,826	32,600	45,000	80,000	100,000
2		Nalaikh /City with National Status/	41,817	42,000	43,963	74,505	100,000
3	Satellite Cities with Local Status	Bagakhangai town	4,422	5,000	10,000	25,000	30,000
4		Agro City Satellite City	7,652	9,906	11,220	15,700	30,000
5		Shargaljuut Satellite City	16,878	19,551	20,000	25,000	30,000
6		Shine Zuunmod City	-	-	5,944	23,158	34,000
7		Emeelt City	2,753	3,855	3,678	5,000	30,000

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	Townships of Ulaanbaatar City	Terelj Town	1,695	2,557	2,573	3,500	5,000
8		Gachuurt Town	7,724	10,293	10,334	10,334	10,000
9		Zuslan (Summer Resort Area)	15,194	15,194	16,000	15,000	16,000
10		Bio Kombinat Town	5,916	6,569	6,605	6,730	8,000
11		Tuul-Shuvuu Town	3,696	4,679	4,913	5,158	5,000
12		Utzii Town	6,378	7,416	7,682	7,381	7,000
	Ulaanbaatar City	Ulaanbaatar Total	1,498,632	1,523,617	1,676,959	1,669,740	1,684,807
13		Angaldai	41,547	47,421	52,839	47,756	42,673
14		Bayangol	166,097	163,691	146,794	131,344	125,686
15		Bayanzurkh	160,369	168,928	183,700	181,055	176,395
16		Bayan-Khoshuu	86,176	83,491	75,491	64,365	52,048
17		Bayant-Ukhaa	48,601	51,006	82,030	122,725	126,826
18		Darl-Ekh	231,485	251,728	237,943	219,222	199,842
19		Uiur	104,573	104,248	103,090	97,216	90,799
20		Songinokhairkhan	25,560	24,109	48,585	55,743	61,315
21		Sukhbaatar	89,714	87,619	109,651	114,212	116,747
22		Selbe	49,310	45,276	58,539	68,787	83,886
23		Tolgoit	94,695	92,381	82,967	80,540	77,369
24		Khan-Uul	229,292	229,329	236,830	227,209	216,702
25		Chingeltei	96,364	97,328	134,288	136,803	90,360
26		Yarmag	72,779	76,061	127,211	142,764	224,062
Total for the Capital City			1,640,781	1,682,937	1,867,089	1,887,207	2,069,807

Source: Ulaanbaatar City Development Master Plan until 2040

2.2. TRAFFIC VOLUME STUDY OF THE ROAD NETWORK

District-Level Analysis of Trip Distribution by Purpose

The results of the travel survey conducted among 15,119 households across 6 districts of Ulaanbaatar city have been analyzed and categorized into 6 classifications, presenting the traffic movement patterns for each district.

Table 9. Traffic Movement Patterns Categorized by District

Work-related Travel

[illegible]		[illegible]						
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		16,[illegible]	[illegible]	11,[illegible]	[illegible]	17,045	[illegible]
	[illegible]	15,242		[illegible]	3,379	[illegible]	14,116	99,234
	[illegible]	[illegible]	[illegible]		5,[illegible]	14,343	11,[illegible]	[illegible]
	[illegible]	18,958	10,757	8,[illegible]		[illegible]	[illegible]	[illegible]
	[illegible]	12,052	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	4,644	12,992		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	37,373	[illegible]	52,496	[illegible]

General Education School and Kindergarten Travel

[illegible]		[illegible]						
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		3,[illegible]	3,809	[illegible]	2,[illegible]	3,[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	3,134	2,726	4,[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]		2,[illegible]	1,[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	3,[illegible]	3,[illegible]		2,[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	3,[illegible]	3,[illegible]	[illegible]		[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	4,[illegible]	[illegible]		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Leisure and Free Time Travel

Travel for Public Services Travel

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		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		1,012	[illegible]	3,825	2,987	4,223	22,946
	[illegible]	[illegible]		[illegible]	52	3,645	[illegible]	[illegible]
	[illegible]	4,805	[illegible]		493	1,780	[illegible]	[illegible]
	[illegible]	4,115	180	982		[illegible]	[illegible]	6,158
	[illegible]	[illegible]	[illegible]	4,596	972		[illegible]	14,723
	[illegible]	5,151	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]		19,021	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Trade and Service Travel

[illegible]		[illegible]						[illegible]
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[illegible]	[illegible]		[illegible]	[illegible]	2,712	3,643	2,956	[illegible]
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	[illegible]	[illegible]	[illegible]		665	[illegible]	[illegible]	[illegible]
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[illegible]		[illegible]						[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		283	[illegible]	1,896	479	1,582	[illegible]
	[illegible]	485		[illegible]	49	615	154	[illegible]
	[illegible]	[illegible]	3,929		987	344	[illegible]	[illegible]
	[illegible]	[illegible]	40	288		[illegible]	256	[illegible]
	[illegible]	1,459	252	[illegible]	173		465	[illegible]
	[illegible]	2,525	1,100	[illegible]	656	222		[illegible]
[illegible]		8,122	4,657	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Higher Education Institution Travel

[illegible]		[illegible]						[illegible]
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[illegible]	[illegible]		[illegible]	[illegible]	457	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	90	566	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]		171	274	558	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]		643	576	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	350		426	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	197	214		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Traffic Analysis Zone

A crucial part of transport modeling is the Traffic Analysis Zone (TAZ). Detailed quantitative data on TAZs plays a vital role in conducting transport modeling and calculations. When establishing TAZs, they are planned as zones based on specific geographical areas and road networks. The division of TAZs is carried out in the following directions:

In this study, Ulaanbaatar city's TAZs were divided into 224 detailed zones. The relevant information for the zoning was categorized into 3 main groups, and the attribute data was calculated and entered accordingly. Herein:

- Demographic information
- Socio-economic information
- Land use information

Division of Traffic Analysis Zones

A total of 40 types of data on the demographic, socio-economic, and land use information of the Traffic Analysis Zones have been converted and integrated into the Geographic Information System (GIS) to conduct a study on the centralization of Ulaanbaatar city based on transportation.

Travel Mode Share

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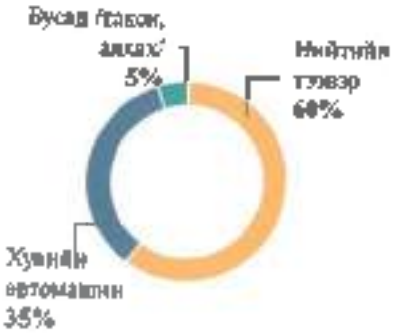
This study investigates which modes of transportation citizens participating in road traffic in Ulaanbaatar choose for their trips. This study is crucial in determining the future transportation demand and indicates the level of development of a city's transportation infrastructure. In recent years, the share of car trips in Ulaanbaatar has increased from 35% to 48%, while the share of public transport trips has drastically decreased from 60% to 34%. According to a survey of 15,000 households conducted in 2022 to develop the origin-destination (OD) matrix of citizens' travel movements, 48% of total road traffic participants use private cars, while 34% use public transport, 12% walk, 1% use bicycles, and 3% use taxis to participate in traffic.

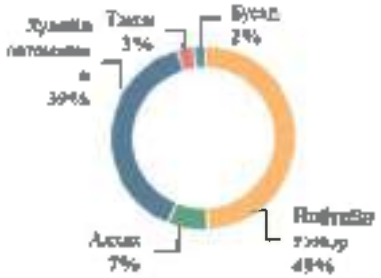
Graph 11. The state of traffic flow / modal split

JICA International Organization Research /2007/

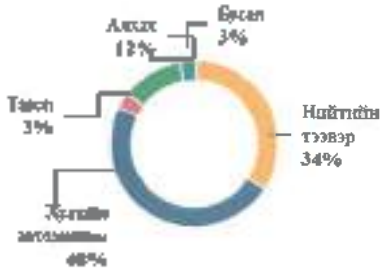


Preliminary study of special road buses in Ulaanbaatar city /2016/

Capital road network development master plan /2017/



Survey of 15,000 households to develop origin-destination (OD) matrix of citizen travel /2022/



Urban Figure 1 Traffic movement between major zoning

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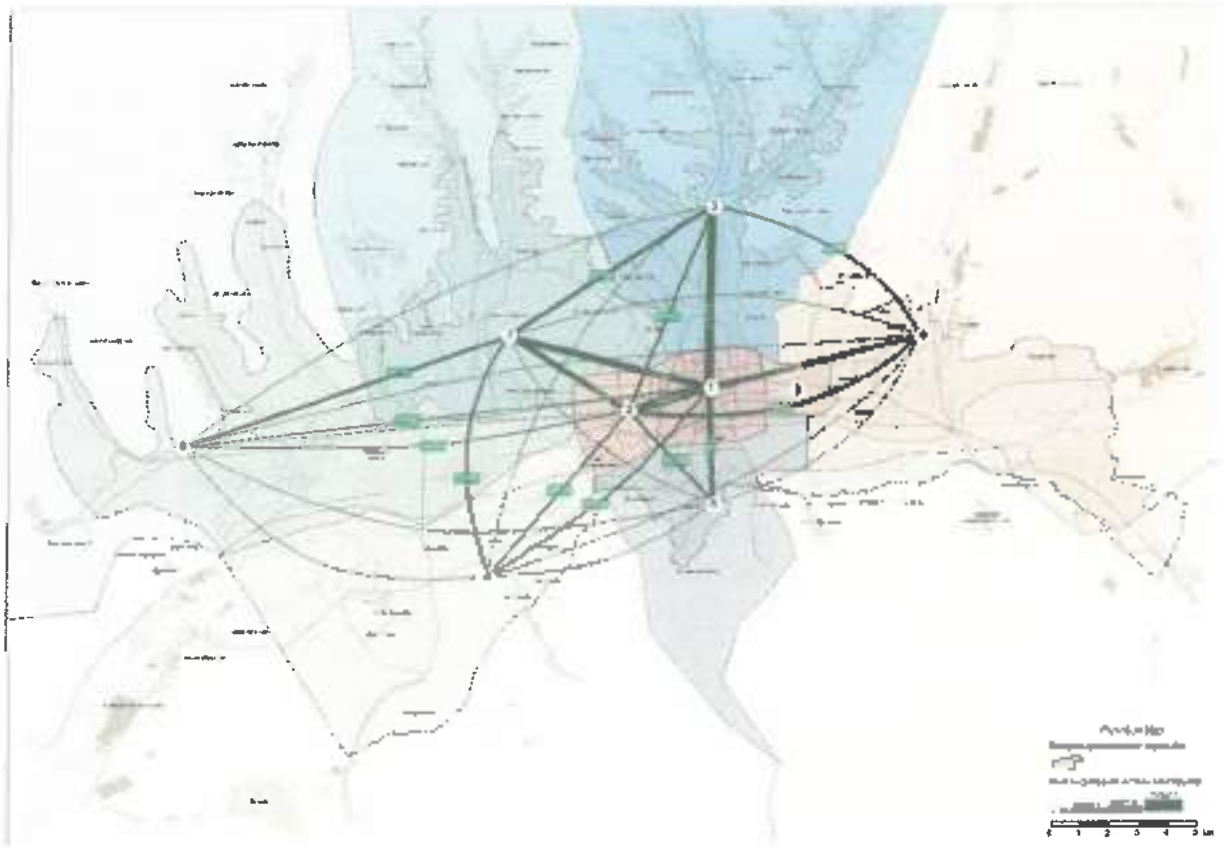

Computational Modeling of Travel Movement by Purpose

A comprehensive survey of 15,119 households across 6 districts of Ulaanbaatar City has generated 10 types of Origin-Destination (OD) matrices. The travel movements were categorized by purpose into 6 classifications and by transportation mode into 3 classifications.

Herein:

- Travel directed to general education schools and kindergartens (Picking up and dropping off children from schools and kindergartens)
- Work-related travel (Going to work, conducting work/business meetings)
- Leisure and free time travel (Visiting relatives, dining out, exercising, meeting friends, spending leisure time, attending entertainment services, receiving beauty services, visiting parks and green spaces, walking)
- Travel for state and social services (Receiving medical services, accessing government services)
- Travel for trade and services (Entering major markets and trading centers, purchasing water, firewood, coal)
- Travel for higher education and training courses (Studying at university, attending training courses)
- Motor vehicle travel (Driving personal car, being driven, motorcycle, taxi, cargo vehicle, moped)

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- Public transportation travel (Bus, trolleybus, microbus, workers' bus, school bus)
- Bicycle and pedestrian travel (Walking, bicycle, scooter)

For each purpose, Origin-Destination (OD) matrices were created within a 224*224 zone framework, and the Production (trip origin) and Attraction (trip destination) modeling was calculated for each purpose. Additionally, OD matrices for each travel purpose were consolidated across the city's 8 main zones and each district, creating and calculating separate OD matrices.

Total traffic movement was considered in terms of outbound and return trips. In Ulaanbaatar's 6 districts, 54% of the movement, or 1,564,814 trips, are heading to their destinations, while 46%, or 1,317,503 trips, are returning home. Breaking down the outbound movement by purpose, 40% (618,788 trips) are for going to work, and 21% (327,593 trips) are related to taking children to and from school and kindergarten.

Additionally, 17% (267,853 trips) are for leisure and spending free time, while 10% (158,435 trips) are for shopping and services. The remaining 6% (99,880 trips) are for accessing government and social services, studying at higher education institutions, and 92,265 trips are for attending training courses. In the following sections, we will examine in detail the movement for each purpose of travel.

Table 10. Total Travel Movement by Purpose

Movement Direction	Travel Purpose	Total Trips	Percentage of Total Trips	Percentage of Outbound Movement Trips
Outbound Movement	Going to Work	618,788	21%	40%
	Taking Children to/from General Education Schools and Kindergartens	327,593	11%	21%
	Leisure and Spending Free Time	267,853	9%	17%
	Trade and Services	158,435	5%	10%
	Accessing Government and Social Services	99,880	3%	6%
	Higher Education and Training Courses	92,265	3%	6%
	Total Outbound Movement	1,564,814	54%	100%
Return Movement	Return Movement (Traveling Towards Home)	1,317,503	46%	
Total (Outbound + Return)		2,882,317	100%	

Travel Movement Research

Based on the transportation planning's 4-stage modeling calculation using citizen travel movement research, it is estimated that 2,882,317 trips are made daily across Ulaanbaatar city. The model of travel movement origins and destinations according to the Transportation Analysis Zones (TAZ) is illustrated in the following diagram. The zones

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with the highest volume of trips are the city center 1st zone, the city center's western and eastern 2nd zones, and the southern 5th zone. The areas with heavy traffic movement are distinctly outlined, and these zones have received 607,060 trips from other city zones.

Total Travel in Ulaanbaatar, by Major Zones and Neighborhoods

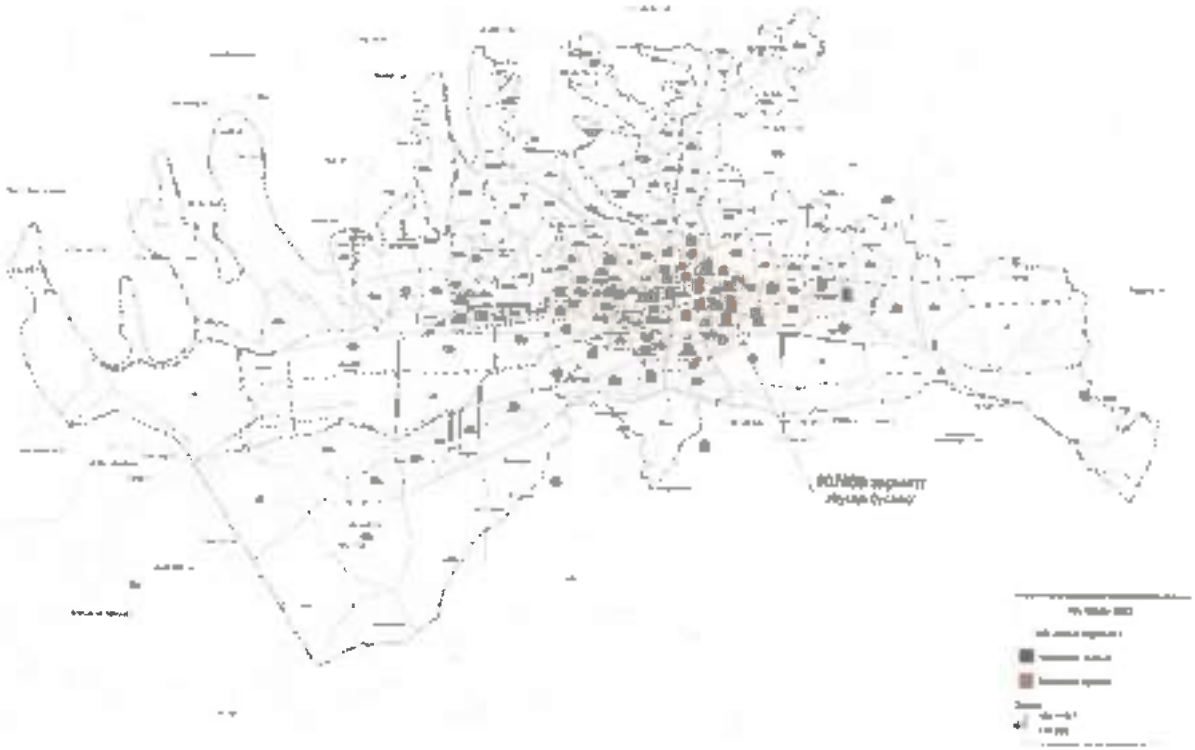

Table 11. Travel matrix, by district

Districts		Destination						Total (Origin)
		BGD	BZD	SBD	SKHD	KHUD	CHD	
Origin	BGD	166,562	80,964	80,105	86,752	63,681	60,368	498,430
	BZD	61,015	339,357	123,705	29,938	68,921	61,807	685,745
	SBD	63,160	102,091	129,007	32,168	48,367	70,585	446,259
	SKHD	72,217	31,478	36,239	218,316	50,932	32,201	443,382
	KHUD	51,658	67,977	57,241	46,049	180,132	33,749	446,807
	CHD	61,342	54,326	92,814	32,391	34,467	74,354	359,693
Total (Destination)		485,953	667,092	521,111	427,615	447,501	333,045	2,682,317

Explanation: The more intense the red color, the higher the travel movement; the more intense the green color, the lower the travel movement.

With reference to the traffic movement distribution across the city's districts, the data reveals the following trip origins: Bayanzürkh District generates 685,745 trips, Bayangol District accounts for 498,430 trips, Songinokhairkhan District contributes 443,382 trips, Sükhbaatar District initiates 446,259 trips, Khan-Uul District produces 446,807 trips, and Chingeltei District generates 359,693 trips.

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Viewing the districts with the most total traffic movements. Bayanzurkh District with 667,092 movements, Sukhbaatar District 521,111, Bayangol District 485,953 movements, Khan-Uul District 447,501 movements, Songinokhairkhan District 427,615 movements, Chingeltei District 333,045 movements each completed.

The total traffic movement matrix has been calculated and consolidated across the city's primary 8 urban zones.

Table 12. Total Traffic Movement Matrix by Major Main Zones

Main zone		Destination								Total (Origin)
		1	2	3	4	5	6	7	8	
Origin	1	310,457	123,444	92,185	57,774	46,094	22,442	77,987	11,545	741,928
	2	143,402	127,795	42,763	41,444	23,492	19,851	69,335	10,616	478,700
	3	122,558	50,845	106,014	28,413	16,073	7,974	42,487	6,421	382,588
	4	69,980	47,296	26,276	101,323	14,327	6,016	14,782	2,882	282,625
	5	49,588	23,830	14,620	13,514	26,255	9,933	15,308	3,592	156,645
	6	24,178	19,763	7,475	5,873	9,819	92,119	25,291	12,545	197,069
	7	95,377	79,125	38,859	15,154	16,530	27,094	219,214	37,632	528,992
	8	12,841	11,941	6,158	2,689	3,804	12,757	40,491	23,117	113,805
Total (Destination)		828,381	463,780	336,353	266,168	156,398	198,192	504,902	108,159	2,882,317

Explanation: The more intense the red color, the higher the travel movement; the more intense the green color, the lower the travel movement.

In the next diagram, we present the traffic movement directions, showing the initiated and completed travel flows across the Main Zones, which represent the city's 8 primary urban zones. The traffic movement between primary zones is characterized by the following key patterns.

Road Network Traffic Intensity Study

Ulaabaatar city's street and road network's cross-axial traffic volume is 347,000 vehicles. The city's main road network's primary axis Peace Avenue in one direction per day has 27,000-42,000 vehicles/24hrs, Naadamchdin Street 27,600-46,000 vehicles/24hrs, Namil Road in one direction per day 17,000-28,000 vehicles/24hrs, Capital Ring Avenue 19,000-32,000 vehicles/24hrs, Bogd Mountain Bypass Road 8,000-10,000 vehicles/24hrs, Great Ring Road Dorjiin Street 23,000-35,000 vehicles/24hrs, Enebish Avenue 27,000-32,000 vehicles/24hrs, Dunjingarav Street 17,000-20,000 vehicles/24hrs.

Ulaanbaatar city's road network's vertical axis traffic volume is 259,500 vehicles. The city's road network's main vertical axis routes include: Chinggis Avenue at Enkhtaivan Bridge 23,000-31,000 vehicles/24hrs, Olympic Street 24,000-32,000 vehicles/24hrs, Ard-

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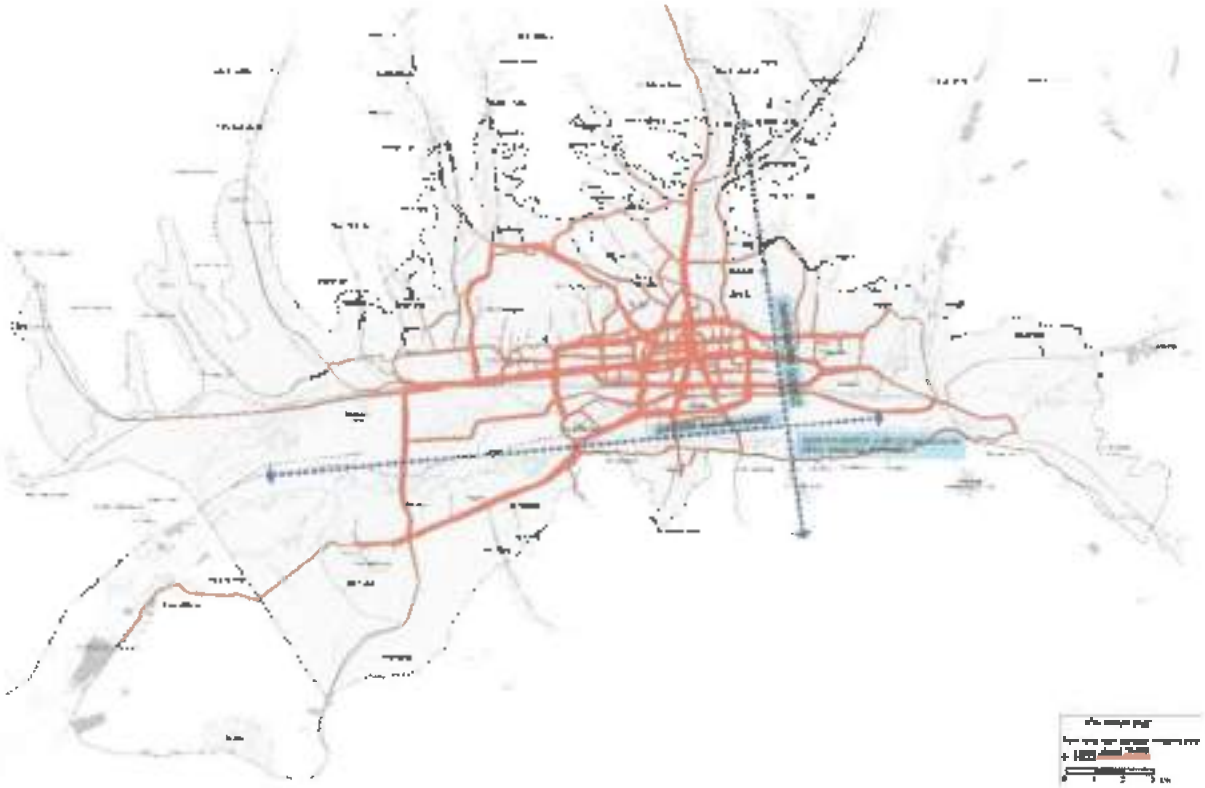
Ayush Avenue 25,000-38,000 vehicles/24hrs, Sonsgolong Street 18,000-25,000 vehicles/24hrs, Workers' Street 25,000-32,000 vehicles/24hrs, Namil Bridge 20,000-32,000 vehicles/24hrs, Great Ring Road Namyajuu Street 22,000-28,000 vehicles/24hrs, Chingeltei Avenue 21,000-36,000 vehicles/24hrs respectively.

Traffic Intensity Modeling along the Road Network Axes of Ulaanbaatar City, 2022



2.2.3. Peak Hour Traffic Load Calculation

The peak hour traffic load on the road network is illustrated in the following figure.

During peak traffic hours on the primary arterial roads of the road network:

- *Peak Hour Traffic Intensity (single direction): 3,500-4,600 vehicles/hour*
- *Volume to Capacity Ratio (VCR): 1.7-2.5*
- *Peak Hour Traffic Speed: <10 km/h*
- *Traffic Service Level (LOS): Level "F"*

Traffic Intensity Modeling along the Road Network Axes of Ulaanbaatar City, 2022

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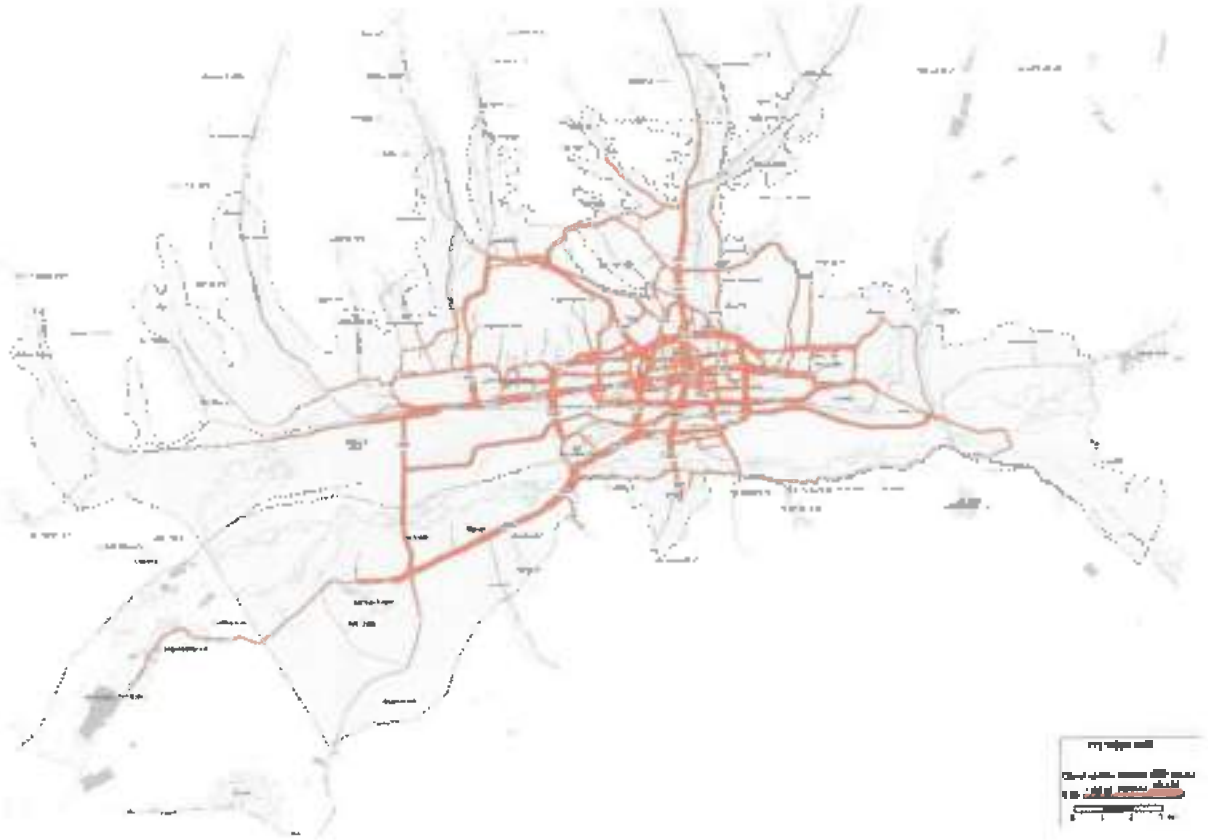

Using the Volume to Capacity Ratio (VCR) to determine the peak hour traffic load on the city's primary arterial roads reveals significant congestion, where roadways and intersections experience extremely high load levels. The traffic movement is characterized by a stop-and-go pattern with extremely low vehicle speeds.

In the specific road network, the traffic demand **exceeds the road capacity by 1-2 times**, representing the most critical traffic conditions possible.

Ulaanbaatar City Road Network's **Secondary Arterial Roads:**

- *Peak Hour Traffic Intensity:* ***2,500-3,600*** *vehicles/24 hours*
- *Volume to Capacity Ratio* ***(VCR): 1.5-2.0***
- *Peak Hour Traffic Speed:* ***<13*** *km/h*
- *Traffic Service Level (Level of Service LOS):* ***"F"*** *level*

Based on the VCR Indicator for Ulaanbaatar City's Secondary Arterial Roads: Substantial load has developed on roadways and intersections, causing vehicle speeds to become extremely low, with traffic moving in a continuous stop-and-go pattern.

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2.2.4. Calculation of Average Speed Indicators in the Road Network

The average speed indicators of the city's road network were calculated through the **Trip Assignment** stage of a 4-stage modeling process. The average speed during peak traffic hours varies significantly, depending on urban zoning, road network density, road classification, function, and purpose. The average speed indicators for the cross-axial main streets in Ulaanbaatar's road network are as follows:

Average Speed Indicators of Ulaanbaatar City's Road Network, 2022

Transverse Axis Main Street and Roads

Peace Avenue and Moscow Street

- Officers' Palace Roundabout - East Cross Road Intersection direction traffic vehicle average speed 8-27 km/h
- East Cross Road - Central Post Office Intersection direction 8-11 km/h
- Central Post Office Cross Road Intersection - West Cross Road Intersection direction 7-15 km/h
- West Cross Road Intersection - Sapporo Cross Road Intersection direction 13-25 km/h

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- Sapporo Cross Road Intersection - Geological Central Laboratory Cross Road Intersection direction 8-16 km/h

Sunny Road:

- 10th Microdistrict - Enkhtaivan Bridge Lower Intersection direction 10-25 km/h
- Enkhtaivan Bridge Lower Intersection - Narantuul Trading Center Intersection direction 7-15 km/h
- Narantuul Trading Center Intersection - Officers' Palace Safety Roundabout direction 12-30 km/h

Enebish Avenue, Ard-Ayush Avenue:

- Sapporo Intersection - Trauma Hospital West Intersection direction 15-30 km/h
- Trauma Hospital West Intersection - Urgoo Cinema Theater Front Intersection direction 12-20 km/h
- Urgoo Cinema Theater Front Intersection - Bayanburd Safety Roundabout direction 12-18 km/h

Naamdachdiin Road:

- Yarmag Bridge to 1st Station direction 6-15 km/h
- Yarmag 1st Station to Aviation Safety Roundabout direction 25-40 km/h

Chingis Avenue:

- Yarmag Bridge - Khan-Uul District Intersection direction 10-30 km/h
- Khan-Uul District Intersection - 120 thousandth Cross Road Intersection direction 7-15 km/h
- 120 thousandth Cross Road Intersection - Central Post Office Intersection direction 6-17 km/h

Average Speed Indicators for Main Street Roads on Vertical Axis

The average speed indicators for traffic intensity on the main street roads of the vertical axis in Ulaanbaatar's road network are as follows.

Olympic Street:

- Foreign Affairs Ministry Intersection – Genden's Cross Road Intersection direction 7-10 km/h
- Genden's Cross Road Intersection - Olympic Bridge direction 10-20 km/h

Namyanjuu Street:

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- East Cross Road Intersection - Infectious Diseases Cross Road Intersection direction 8-20 km/h
- Infectious Diseases Cross Road Intersection - Nerantuul Cross Road Intersection direction 10-25 km/h

City Main Zoning Road Network Average Speed Analysis:

- The average speed in the 1st Main Zone (Ikh toiruu) is 10-25 km/h.
- The average speed in the City's East and West 2nd Main Zones is 10-30 km/h.
- The lowest traffic speed section in the city's Southwest 6th Main Zone is around Yarmag Bridge, with an average speed of 6-15 km/h.
- In the city's Front 5th Main Zone, from 120 thousandth Intersection to Ar Zaisan Intersection, the speed is 8-15 km/h.

2.3. ROAD TRAFFIC CONGESTION CONDITIONS

Time Loss

According to the capital city's research, due to road congestion, one person spends 2.5 hours per day and 35 days per year stuck in traffic.

Labor Productivity Loss

The capital city's business entities and organizations' employees' average monthly salary is 1,312.64 thousand tugrug. A person works eight hours per day, or 40 hours per week. However, they spend 2 hours 30 minutes, or 12.5 hours per week, in traffic congestion. Calculating for a monthly salary of 1,312.6 thousand tugrug, they receive 328.1 thousand tugrug. When dividing this salary by hour, it becomes 8,202.5 tugrug per hour. If capital city residents spend 2.5 hours per day in traffic congestion, it can be explained that they lose productivity equivalent to 20,506.25 tugrug. A capital city resident loses the opportunity to create 6.1 million tugrug of labor productivity due to road congestion.

Table 13. Labor Productivity Loss

No.	Congestion Time per Citizen	Duration	Hourly Labor Cost (thousand MNT)	Productivity Loss (thousand MNT)
1	Per Day	2.5 hours	8.2	20.51
2	Per Week	12.5 hours		102.55
3	Per Month	62.5 hours		512.73
4	Per Year	35 days		6,152.81
5	Lifetime	6.49 years		39,931.72

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Source : Urban Planning Research Institute, 2024

According to the capital's research, 25% of morning traffic congestion is solely due to parents dropping off their children, and 25-30% of evening traffic congestion is related to parents participating in traffic movement to pick up their children. Since work and kindergarten closing times coincide, parents who have finished work get stuck in traffic when going to kindergartens, and consequently pay overtime wages due to being late to pick up their children within the specified time.

Such productivity loss and non-operational expenses caused by road congestion are negatively impacting household living standards. As of September 2020, along the Ulaanbaatar light rail route, 24,560 people traveled one-way daily by public transportation. The lost opportunity cost expressed through these passengers' productivity is 503.7 million tugrug per day, amounting to 183.85 billion tugrug annually.

Lost Opportunity Cost

Registered vehicles in Mongolia by engine capacity: up to 1500 cm³ 404.8 thousand or 36.0%, 1501-2500 cm³ 409.3 thousand or 36.4%, 2501-3500 cm³ 131.3 thousand or 11.7%, 3501-4500 cm³ 42.6 thousand or 3.8%, above 4501 cm³ 137.9 thousand or 12.3%. Average engine capacity calculated at 2,300 cm3. As of 2020, registered vehicles by fuel type: petrol and hybrid vehicles 72.5%, diesel 25.2%, gas 2.1%, electric 0.03%. Total vehicles on the route calculated at 257,791. A vehicle consumes 1.387 liters in one hour of idling (traffic congestion), and 3.45 liters when congested for 2.5 hours. Calculating one liter of A-grade petrol at 2,3888 tugrug comes to 8,238.6 tugrug. This means one driver wastes 8,238.6 tugrug daily in congestion, and 1,730,106 tugrug annually. Total unnecessary expenditure for all vehicles on the route is 446.0 billion tugrug. This lost opportunity cost of vehicle wastage is equivalent to 1.84% of the capital's GDP of 24.2 trillion tugrug in 2020.

Public Perceptions and Behavioral Tendencies Regarding Road Traffic Congestion

A survey indicates that 97 percent of Ulaanbaatar city residents perceive that road traffic congestion has a negative impact on both their work productivity and overall quality of life. To assess the relative significance of traffic congestion among other urban issues, a comparative analysis was conducted using the "Google Trends" analytical tool. The keywords "traffic congestion" and "air pollution," which are commonly associated with urban challenges, were selected for comparison, along with a third term, "child allowance," introduced from a socioeconomic perspective to provide additional insight.

Based on the five-year average of search trends, the keyword "child allowance" ranked first, followed by "air pollution" in second, and "traffic congestion" in third. However, data from the past 12 months shows a shift in public interest, with "child allowance" maintaining the highest search volume, "traffic congestion" moving into second place, and "air pollution" dropping to third. This trend suggests that concerns regarding air pollution are

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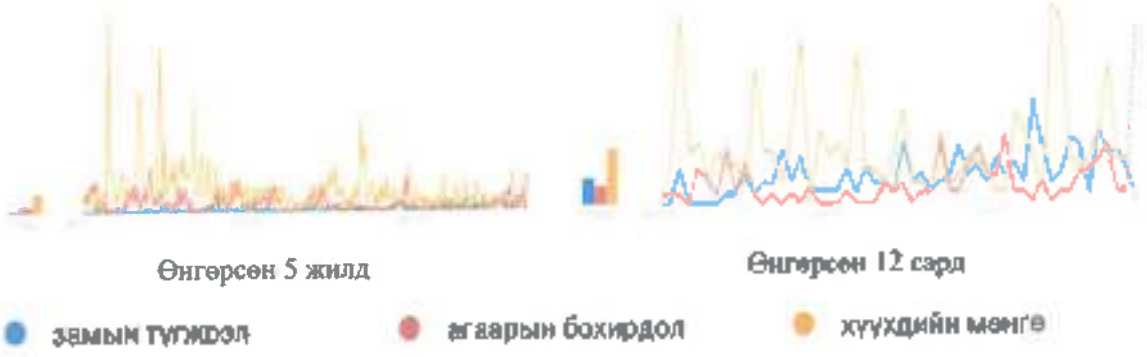
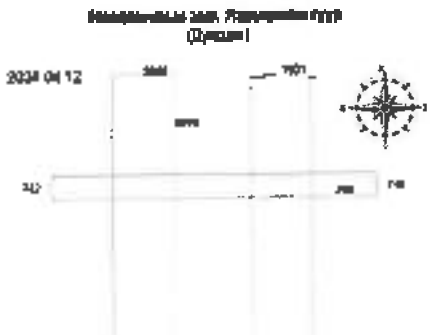
seasonal in nature, while the consistently high search volume for "child allowance" indicates a strong correlation with the public's focus on economic stability and livelihood concerns.

Graph 12 Citizens' Behavior

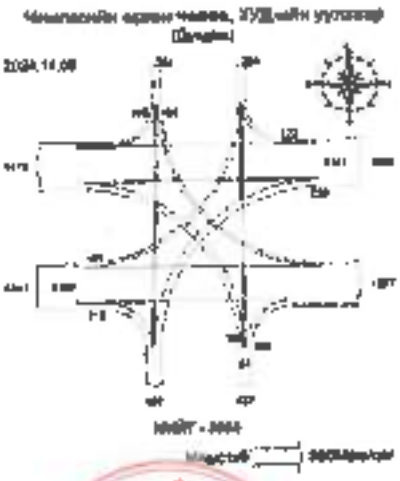


Throughput Capacity of Intersections Along the Alignment



1. Naademchdiin Road, Yarnag Bridge

The traffic load along Naademchdiin Road, particularly at Yarnag Bridge, remains relatively high at all times. On average, 2,006 vehicles pass through the intersection in all directions from north to south, 1,921 vehicles pass through the intersection from south to north, and 742 vehicles pass through the intersection in all directions from east to west.



2. Chinggis Avenue, Khan-Uul District Intersection

The intersection of Chinggis Avenue and Khan-Uul District experiences a high traffic volume during peak hours. The number of vehicles passing through the intersection in the direction from west to east is 264, while the number of vehicles traveling from east to west is 437. The number of vehicles passing through the intersection from west to east is 1441, and the number of vehicles from east to west is 1521.

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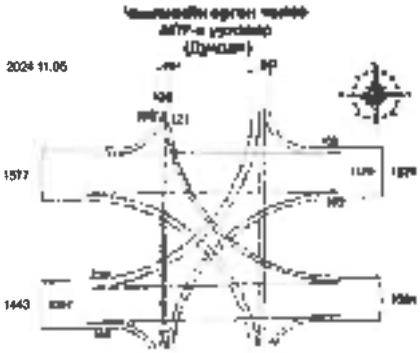
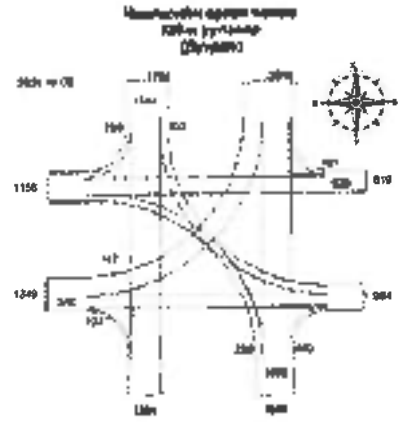


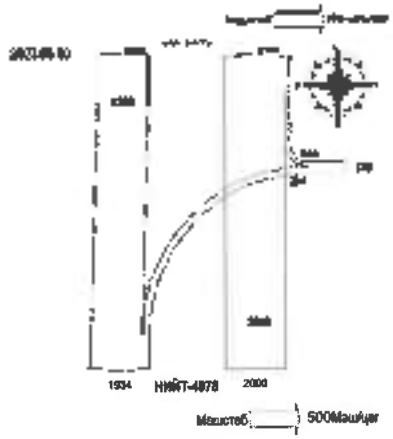
3. Chinggis Avenue, APU Intersection

Chinggis Avenue, at the APU intersection during peak traffic hours, the traffic volume count results show: from south to north in all directions through the intersection, 427 vehicles pass through; from north to south through the intersection, 489 vehicles pass through; from west to east in all directions through the intersection, 1443 vehicles pass through; from east to west in all directions through the intersection, 1526 vehicles pass through.



4. Chinggis Avenue, 120th Intersection

Chinggis Avenue, at the 120th intersection during peak traffic hours, the traffic volume count results show: from north to south in all directions through the intersection, 1726 vehicles pass through; from south to north through the intersection, 1510 vehicles pass through; from west to east in all directions through the intersection, 1349 vehicles pass through; from east to west in all directions through the intersection, 819 vehicles pass through.



5. Chinggis Avenue, Skytel Intersection

Chinggis Avenue, at the Skytel intersection during peak traffic hours, the traffic volume count results show: from north to south in all directions through the intersection, 1700 vehicles pass through; from south to north through the intersection, 2000 vehicles pass through; from east to west in all directions through the intersection, 387 vehicles pass through.

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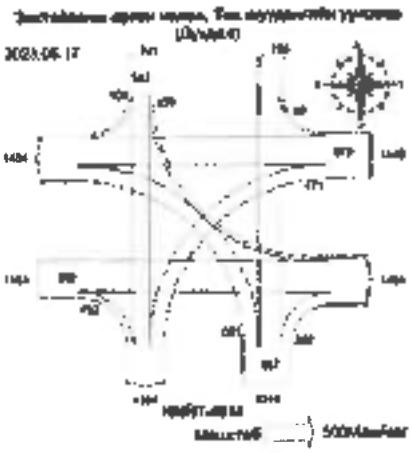

6. Peace Avenue, Central Post Office Intersection

Peace Avenue, at the Central Post Office intersection during peak traffic hours, the traffic volume count results show: from north to south in all directions through the intersection, 741 vehicles pass through; from south to north through the intersection, 1540 vehicles pass through; from west to east in all directions through the intersection, 1184 vehicles pass through; from east to west in all directions through the intersection, 1448 vehicles pass through.

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Naadamchdin Street: The city's main street and Naadamchdin Street's traffic volume from Yarmag Bridge to Yarmag 1st Station in one direction of the road is 13,550-22,600 automobiles traveling per day, the road capacity to traffic volume ratio has resulted in an indicator of 0.99-1.24, and the traffic quality indicator is "E-F" level, with peak hour traffic average speed of 8-17 km/h. From Yarmag 1st Station to Aviation Circle, the traffic volume in one direction of the road is 10,450-16,800 automobiles traveling per day, the road capacity to traffic volume ratio has resulted in an indicator of 0.75-0.92, and the traffic quality indicator is at "D-E" level. To explain the traffic quality indicator: the traffic flow is unstable, with a certain amount of vehicle queues formed in most sections of the road and intersections, and peak hour traffic speed is 12-20 km/h.

According to the baseline research conducted within the framework of the Ulaanbaatar City Development Master Plan for 2040, calculations and studies on the road network load were performed, and the future load was determined. It was calculated that there is a need to create a total of 82.43 km of roads, 6 underpasses, reorganization of 6 intersections, 7 bridges, and a new 70 km road network around the city, which are high-priority main and auxiliary streets. If road network development projects and measures are not implemented, by 2025, the average speed during peak traffic loads will be 5-9 km/h, the traffic volume to road capacity ratio (VCR) value will be 2.1–2.8, 129 km of roads will be heavily loaded or congested during peak hours, and the current road load will increase by 32%.

Chinggis Avenue: This avenue has very little difference in traffic volume between its two directional flows, with traffic volume of 16,200-25,300 automobiles traveling per day in one direction of the road. The road capacity to traffic volume ratio has resulted in an indicator of 1.26–1.98, and the traffic quality indicator is at "F" level. The traffic load is very high, traffic demand exceeds capacity, representing the worst condition, and the average speed during peak traffic hours is 7-15 km/h.

2.4. RESEARCH ON HISTORICAL AND CULTURAL IMMOVABLE MONUMENTS

Mongolia has joined the "Convention Concerning the Protection of the World Cultural and Natural Heritage" and therefore has an obligation to follow international rules and principles established by ICOMOS regarding the preservation, protection, and restoration of cultural heritage, particularly monuments, sculptures, architectural and archaeological monuments, wooden buildings, and historic cities. Therefore, "The International Charter for the Conservation and Restoration of Monuments and Sites" (Venice Charter), "Principles for the Preservation of Historic Timber Structures," "Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage," and the "Burra Charter," which aims to develop theoretical and practical understanding of cultural heritage management, are being implemented in the preservation, protection, and restoration work of monuments, sculptures, architectural monuments, and historic buildings.

In order to address increasingly complex issues in the global preservation, protection, and restoration of historical and cultural monuments, and to increase knowledge, research, detailed study of preservation and restoration principles, and to

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expand their scope, the Second International Congress of Architects and Specialists of Historic Monuments was held in Venice in 1964. To implement the "International Charter for the Conservation and Restoration of Monuments and Sites" adopted at this congress, the International Council on Monuments and Sites (ICOMOS) was established under UNESCO in 1965. ICOMOS is a non-governmental international organization that operates in the field of monument, sculpture, and site protection worldwide, with branch committees working in each country. In addition, ICOMOS provides the UNESCO World Heritage Committee with evaluations of the characteristics of cultural assets proposed for inclusion on the World Heritage List, comperative studies, technical studies, and reports on the preservation status of monuments. ICOMOS develops and enforces rules, regulations, and principles for the protection, preservation, and restoration of monuments, sculptures, and sites at both international and regional levels.

The implementation of international conventions, rules, and principles established by UNESCO, the development of relevant legislation, the search, registration, and documentation of immovable historical and cultural monuments, architectural monuments, historic buildings, archaeological monuments, ethnographic materials, national language, writing, customs, folk art, and artistic works, as well as monitoring their preservation, protection, and use, developing and implementing policies for their traditional development, restoration and repair are responsibilities of the "Ministry of Culture" of Mongolia.

Mongolia began implementing cultural heritage protection policies through legal and regulatory acts since the 1940s, and the approval of "The Law on Protection of Cultural Monument Items of the Mongolian People's Republic" in 1970 was an important step. This law was the first independent legal document that regulated a rather broad range of relationships concerning the protection of cultural heritage.

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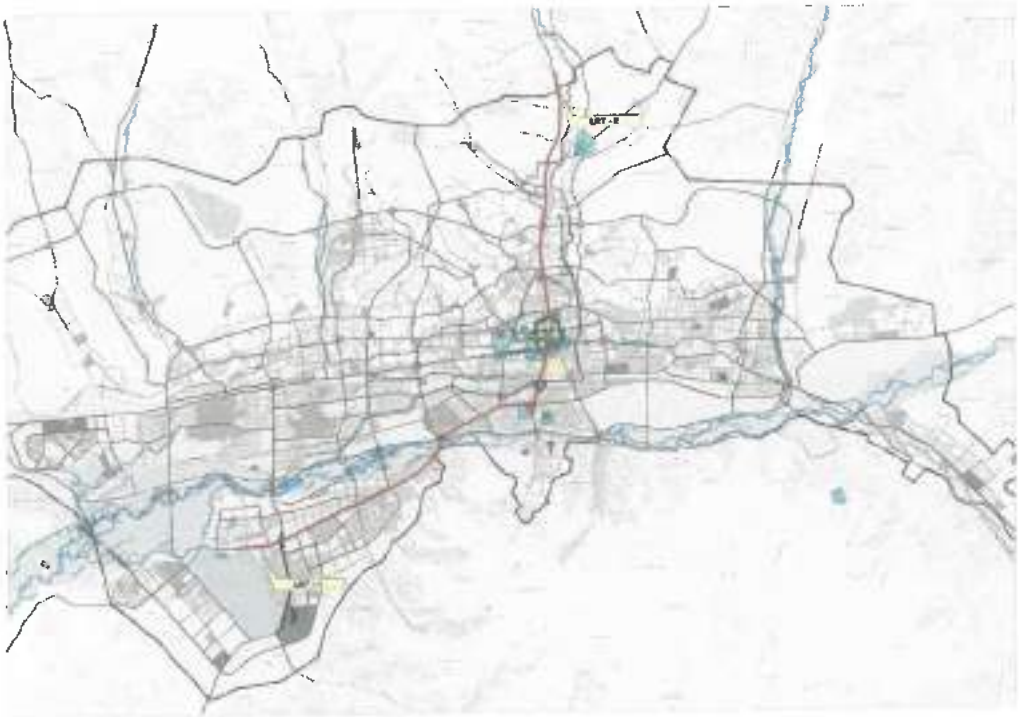
Figure 1. Historical and Cultural Immovable Monuments of Ulaanbaatar



Source: Urban Planning and Research Institute, 2024

Historical and cultural buildings along the planned route with 50-meter protection zones

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Source: Urban Planning and Research Institute, 2024

Table 14. Historic and Cultural Structures Protected Along the Planned Trass

№	Visibility	Building Name	Coordinates
1		Building of the Former Livestock and Agriculture Ministry	N47 59.3 E106 54 57.2
2		National Library Building	N47 54 51.9 E106 54 56.9
3		Khan Uul Monument	-
4		Eldev Ochir Children's Theatre	N47 55 04.9 E106 54 58.0

Based on the cultural heritage registry information that was placed under protection in 2021 along the project route, when examining immovable historical and cultural monument buildings, 14 buildings and structures are affected. When taking the protection limits of these buildings at 50 meters according to regulations, the following are affected:

- 4 buildings and structures
- Buildings and structures planned to be placed under protection in 2040

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- 6 monuments

According to international standards for immovable historical and cultural monuments, if they are state-classified, they are considered as follows:

- Temples and monasteries: 100-200 meters
- Buildings, structures, and monuments: 50-meter protection zones

For the 4-story buildings along Baga Toiruu and Peace Avenue that belong to Chingeltei and Sukhbaatar districts, it is necessary to preserve them without losing their original appearance and to avoid planning new buildings and structures that would affect these buildings.

Table 15. Protected monuments along the planned route

№	Visual Appearance	Monument Name	Registration Number	Coordinates
1		B. Rinchen's Monument	111900175	47.914825 106.915811
2		Monument Dedicated to the Starting Point of Mongolia's Road Network	111900245	47.922614 106.916514
3		P.E. Shchetinkin's Bust Statue	111900095	47.916453 106.917339

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4		S. Zorig's Monument	111900155	47.916572 106.915775
5		Peace Bell	111900235	47.917172 106.917269
6		Yu. Tsedenbal's Monument	111900185	47.915344 106.915225

Archaeological Monuments

Looking at the information about currently protected archaeological monuments including burial mounds and stone structures, there are no monumental complexes along the planned route. However, before obtaining permission to start construction work, it is necessary to conduct exploratory research based on the following provision in the "Law on Protection of Cultural Heritage": *"before allocating land for economic activities such as urban construction, building construction, new road construction, hydroelectric power plant construction, agriculture, mineral exploration and exploitation, preliminary exploration and research must be conducted by professional paleontological, archaeological, and ethnographic research organizations to provide conclusions"* - it is necessary to obtain certification from professional organizations.

Similar international research works conducted:

In our country, buildings constructed before the establishment of norms and regulations for earthquake zone building design are under cultural heritage protection. These buildings need to be evaluated for earthquake resistance, potential risks calculated, and reinforcement required. However, in Mongolia, there are no rules, regulations, or legal framework for evaluating and reinforcing historical and cultural monument buildings. Buildings in Mongolia that are over 50 years old are typically constructed combining four main structural types:

- Wooden structures,
- Stone and brick masonry structures,

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- Cast-in-place column and beam,
- Metal and wooden roof combination structures.

For masonry structures that are common in our country, increasing earthquake resistance and reinforcing damage - for LRT, BRT, and Metro projects - requires detailed study of methods to protect against future vibrations.

Historical and Cultural Reserve Area Metro and Other Railway Vibration Impact Testing and Numerical Analysis - People's Republic of China

Abstract: While the rapid expansion of urban railway transit services is creating comfort for citizens, the issue of metro vibration cannot be neglected. This study examined the spatial distribution characteristics of vibration in the Fayuan Temple historical and cultural site. It involves using the V001 electromagnetic acceleration sensor with a sensitivity of 0.298 V/(m/s²), a measurement range of up to 20 m/s², and the ability to monitor frequency ranges of 0.5-100 Hz. It concerns determining the impact on buildings and structures and vibration reduction schemes. During experiments at the planning site, vibration levels were classified as:

- very high
- generally high
- not excessively high

classified into three measurements. The research work developed a vehicle-track-tunnel-layer-structure dynamic connection model to test the vibration reduction effect of a wire spring floating plate track and a row of columns with constant spacing. The characteristics of three vibration reduction schemes - interior vibration, periodic gravel, and vibration protection reinforcement or building restoration - were compared and a comprehensive solution was proposed. Considering construction conditions, complications, costs, and

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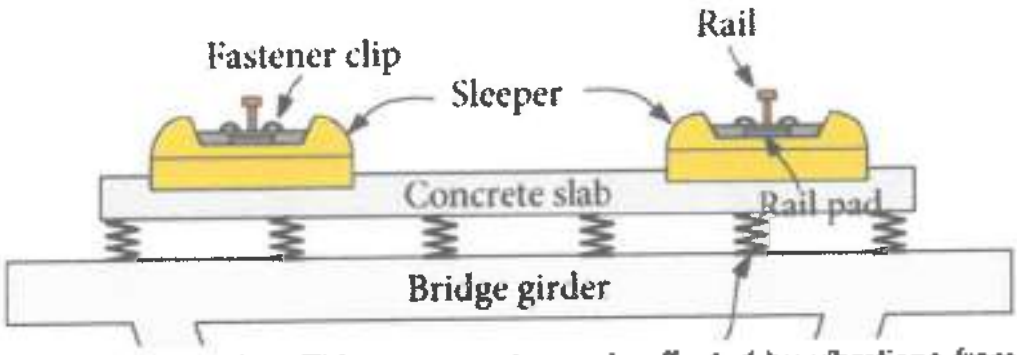
other factors, it was suggested to add periodic mounds. If necessary, anti-vibration reinforcement or building restoration can be additional measures.

Floating Spring Working Mechanism



Research Location: This monument zone is affected by vibrations from Metro Line 4. The distance between metro tracks is 15 m, with a horseshoe-shaped tunnel that is 5.9 m wide and 6.33 m high. The north-south route of Line 4 passes through Caishikou Street, and the ancient buildings in this monument zone are located 16-25 m from the outer edge of the bottom line, and 78-95 m from the tunnel to Nanbangjie Street. Since the metro became operational in 2009, this monument zone, which covers a total area of 13,526 m^2 and houses 435 households, has been significantly affected by vibrations.

Results: Based on on-site measurements, the vibration levels of several buildings in the studied area exceeded standard levels. By analyzing the graph of vibration levels over time and the maximum vibration levels in the vertical direction, it was determined that metro traffic is the main cause of excessive vibration. The area with the highest vibration identified in the study is located between Caishikou Street and Nanbangjie Street, with 40% of the total measured area exceeding the daytime vibration control level of 70 dB, and 60% exceeding the nighttime standard of 67 dB. Based on these results, the study areas were classified as extremely high vibration, ordinarily high vibration, and areas with low vibration impact.

To reduce the impact of vibration, three basic methods were studied: active isolation, attenuation of vibration transmission paths, and passive isolation of affected objects. The study used numerical modeling to analyze the vibration reduction effects of steel spring plate tracks and rows of columns with constant spacing. The results showed that these measures reduced the maximum vibration levels by 6.93–10.81 dB and 6.11–9.98 dB, showing vibration reductions of 9.9–14.0% and 8.7–12.9% respectively.

To reduce the vibration impact on the historical and cultural monument area of Fayuan Temple, a comprehensive solution was developed considering factors such as the area's vibration zoning, numerical modeling results, historical significance of the buildings, and implementation feasibility. This plan recommended using periodic pile rows as the main method for reducing vibration, and suggested that buildings located in areas with

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excessive vibration should have additional vibration isolation reinforcement or undergo restoration measures. It was concluded that in generally high vibration areas, isolation with periodic column rows could meet the requirements for building protection and human comfort.

1. KRRI Vibration Reduction Device

(Korea Railroad Research Institute

The Korea Railroad Research Institute (KRRI) has researched and developed the world's first device to reduce shock and vibration that could damage high-value products such as semiconductors and electronic goods during rail transport. The vibration reduction device created by KRRI is constructed by combining a new type of coil spring with a vibration-absorbing damper. This device supports the weight of the cargo and functions to reduce shock. KRRI has determined that this device is practical and easy to use, economically efficient, and easy to install and remove. Moreover, by using this device, it is possible to reduce shock by more than 80% and vibration by more than 60%. According to KRRI, although the air suspension system used in road transport can reduce shock and vibration by 50%, it is unsuitable for use in railway freight cars due to poor durability and high cost.

The device is used by loading a specially designed cargo platform with a forklift. This research project was implemented by KRRI in collaboration with Korail (the national railway operator of the Republic of Korea), Unison Technology, and the Korea National University of Transportation. The project lasted from April 2018 to March 2022 and was funded by the Science and Technology Support Agency of the Ministry of Land, Infrastructure and Transport of the Republic of Korea. The government provided 4.3 billion won ($3.5 million) in funding, while the private sector contributed 1.4 billion won ($1.1 million). KRRI tested the performance of the device in a laboratory environment for 12 months and conducted field tests in real railway and road conditions for two years on the Cheonan-Uiwang-Busan route. These tests confirmed the effectiveness of vibration reduction in both railway and road environments. Additionally, the durability of the device was tested under various conditions ranging from -60°C to 80°C. The newly developed device will be manufactured by Unison Technology. Dr. Jang Seung-ho, a senior researcher at KRRI, emphasized, "When designing this device, we prioritized economic efficiency to avoid increasing logistics costs. As a result, it has developed into a technology that can be used not only for railways but also for road, sea, and air transport."

Source: https://www.railjournal.com/technology/krri-device-reduces-vibration-to-protect-high-value-freight/

2. Dynamic Response Analysis of Train Vibration Impact on the Prabhutaratna Pagoda in Beijing

Abstract: Train-induced vibration can have dynamic effects on historical buildings, especially structures with high historical and cultural value. Train vibration can create repetitive loads over long periods, potentially causing damage. Therefore, when developing rail transport systems, assessing and reducing vibration impact on historical

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buildings becomes critically important. This study examined the train vibration impact and dynamic state of the ***Prabhutaratna*** pagoda, located in Beijing's outskirts, with approximately 1000 years of history. The study aimed to measure the dynamic characteristics of the pagoda and identify its structurally most vulnerable parts under train loads. During the research, free vibration modes were determined based on dynamic measurement results. Then, a finite element (FE) model of the Prabhutaratna pagoda was developed, and the results of the model were compared with actual measurements. Subsequently, the dynamic response from train movement was studied in detail. The following main conclusions were drawn from the research results.

- The predominant frequency of environmental vibration was below 4 Hz, while the predominant frequency of train vibration was between 8-16 Hz.
- The first, second, and third order natural frequencies of the pagoda in the west-east direction were determined to be 1, 3.25, 6 Hz, and in the north-south direction, 1, 3.25, 6.25 Hz respectively.
- The two most structurally vulnerable locations (A and B) of the Prabhutaratna pagoda were the base of the top section and the right door of the first floor. At location A, the maximum principal stress reached 243.6 N/m², while the maximum tensile deformation reached 3.74×10^{-7}.

These results provide a basis for understanding the potential risks to historical structures due to railway vibration, and for developing protective measures against them.

Theoretical Research: Railway transport is one of the most environmentally friendly modes of transportation in terms of energy consumption, CO_2 and toxic emissions (EC Transport White Paper, 2011). Nevertheless, noise and vibration from train movement remain the main environmental issues facing railway systems (Connolly et al., 2016). In today's era of increasing urban congestion and growing demand for public transport, new railways are being built closer to buildings and structures. Additionally, there continues to be a trend requiring the expansion of railway networks (UIC High Speed Department, 2013).

Environmental vibration from trains consists of quasi-static and dynamic excitations. Dynamic excitation depends on wheel and track irregularities, impact excitation from rail joints and damaged wheel sections, as well as parametric excitation due to sleeper frequency (Thompson, 2009). The wheel axle load is calculated taking into account rail and wheel irregularities, as well as the elasticity of the train and the track's foundation soil. If the train speed is less than the wave velocity in the soil, the track response is dominated by quasi-static loading, while the free-field soil response depends on dynamic behavior (Lombaert and Degrande, 2009).

Historical buildings have high cultural and historical significance. Many studies have been conducted on the dynamic state of these ancient structures, including ruin analysis (Acito et al., 2016), earthquake vulnerability (Casolo et al., 2013; Milani et al., 2017; Sarhosis et al., 2018), and restoration methods (Milani et al., 2018). Research on how railway

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vibration affects the dynamic characteristics of ancient buildings is also being conducted intensively. Repeated loading over long periods can cause structural fatigue damage, risking the loss of structural integrity. Therefore, assessing and reducing vibration impact on historical buildings has become an urgent issue in the development of railway transport systems (Alan et al., 2017; Ma et al., 2016). Related to this issue, Bata (1971) studied the impact of traffic vibration on buildings. In the last 20 years, studies have been conducted to measure and predict vibration from road traffic on historical buildings (Bezeco et al., 1995; Chiostrini et al., 1995; Crispino and D'Apuzzo, 2001; Bongiovanni et al., 2011; Zhang et al., 2017), and with metro development, research on underground railway vibration has also increased. For example, to protect Cologne Cathedral in Germany from vibration from a newly built metro, Hinzen (2014) et al. conducted detailed measurements. In Italy, to protect historical sites, Breccolotti et al. (2011) developed a methodology for predicting vibration levels from railway traffic. In China, Ma et al. (2011, 2016, 2017) studied the impact of metro train vibration on historical buildings in Chengdu, Xi'an, and Beijing. In Iran, Sadeghi and Esmaeili (2017, 2018) conducted experimental and theoretical studies to determine safe distances to protect historical buildings from metro lines in Isfahan.

Historical and Cultural Structures Along the Research Location

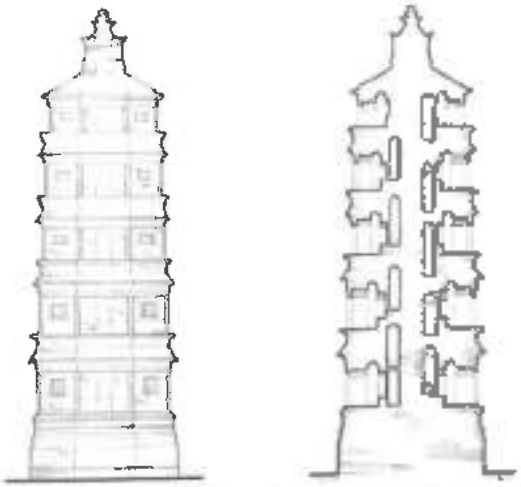

Fig. 2 Vertical and section view of the Fruhlotus-pine pagoda (hand drawn by Zhang Nan)

Fig. 3 Examples of the different principal types of Buddhist pagodas in China: (a) one-storied, (b) multi-storied, (c) multi-eaved, (d) Lamaist stupas and (e) five-pagoda clusters

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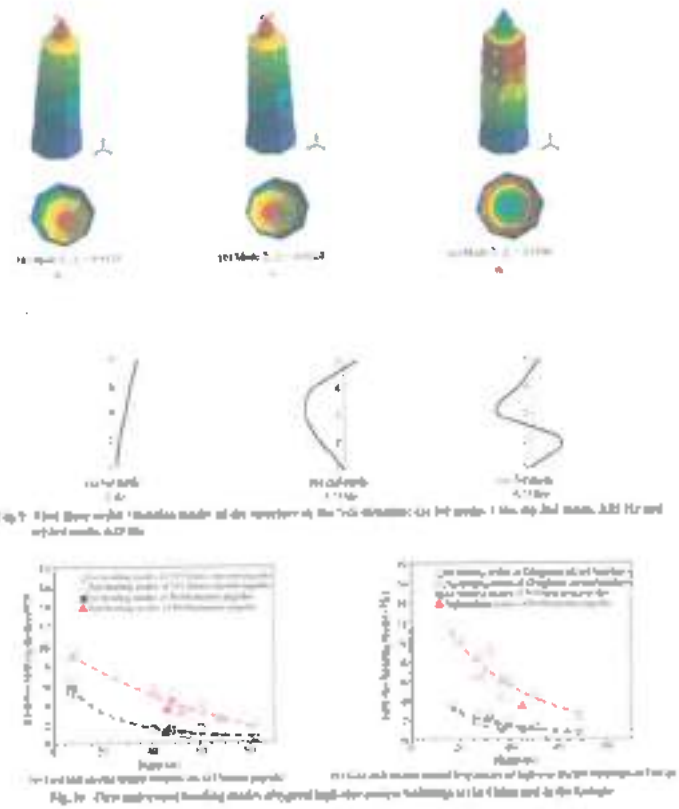

• **Results:** In this study, the dynamic response to environmental vibration and train-induced vibration at the Prabhutaratna pagoda was measured. The characteristics of the pagoda were identified, and a detailed 3D finite element (FE) model was developed and used for high-level modal analysis and vibration response studies. The research results showed:

• The predominant frequency of environmental vibration was less than 4 Hz, while the predominant frequency of train-induced vibration was determined to fluctuate between 8–16 Hz.

• For the first, second, and third natural frequencies: In the West-East (W-E) direction: 1, 3.25, 6 Hz, in the North-South (N-S) direction: 1, 3.25, 6.25 Hz - By FE modal analysis: Modes 1, 4, 7 corresponded to the first 3 measured modes in the W-E direction, Modes 2, 5, 8 corresponded to the first 3 measured modes in the N-S direction, Modes 3, 9 (torsional deformation) and Mode 6 (vertical deformation) were not recorded in measurements due to limited sensor placement.

- The most vulnerable locations of the pagoda (A and B) were the lower part of the top section and the right door of the first floor.

At location A: Maximum principal stress: 243.6 N/m², Maximum tensile deformation: 3.74×10^{-7}, Predominant energy: below 1 Hz (environmental vibration), 9–15 Hz (train vibration). At location B: Predominant energy: below 1 Hz (mainly related to environmental vibration). These results are considered important for developing measures to protect historical buildings from railway vibration impacts.

Source: https://link.springer.com/article/10.1007/s11803-021-2016-9

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CHAPTER 3. TRANSPORT DEMAND ANALYSIS

3.1. PUBLIC TRANSPORT SURVEY

Public Transport Routes

As of the end of 2023 statistical data, public transport had a total of 127 routes in 4 categories: 96 main routes, 15 suburban routes, 4 express routes, and 3 resort routes, with a total route length of 4309.6 km. From 2022, the public transport sector in Ulaanbaatar city began intensive fleet renewal, and by the end of 2023, based on the renewal of the fleet with a total of 800 new buses, changes were made to the public transport route network planning from January 2024. The basic principle of this change was to organize services based on 6 main "M" magistral routes connected by other "Ch" and "U" routes. As of the first quarter of 2024, a total of 1139 vehicles were operating in public transport services daily on 112 routes: 91 main routes, 2 express routes, 16 suburban routes, and 3 resort routes. The table below shows the comparison of the main indicators of the route network for the first quarter of 2024.

Table 16. Public Transport Route Indicators 2024

Indicator			Unit of Measurement	First Quarter of 2024
Number of Passengers			million people	29.4
Number of Public Transport Routes			number	112
Of which	Main routes		number	91
	Of which	State-owned	number	33
		Private	number	58
		Trolleybus	number	0
	Small-sized bus routes		number	2
	Of which	Auxiliary routes	number	0
		Express routes	number	2
	Resort routes		number	3
	Suburban routes		number	16
Length of public transport service routes			km	3696.2
Of which	City bus		km	2035.0
	Articulated		km	24.4
	Trolleybus		km	24.4
	Suburban		km	806.3
	Small-sized bus		km	422
	Resort		km	115.7
	Night transport		km	210.2
Vehicles operating daily on routes			number	1139

Source: (Public Transport Authority, 2024)

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Ulaanbaatar's new public transport planning aims to eliminate route overlaps by focusing on six magistral routes along Peace Avenue, Chingeltei Avenue, Chinggis Avenue to Naadamchdin Road, Ikh Toiruu Street, Namil Road, and Khunnu Street, connected by eight circular routes, with short-turn routes serving other streets. The basic principle of this planning is the transfer principle, and what distinguishes it from previous planning is the separation of magistral or main street routes and the increase in the number of buses operating in service.

Public Transportation Network Diagram 2024

Source: Urban Planning and Research Institute, 2024

Based on the passenger survey conducted on public transportation in Ulaanbaatar, a significant number of passengers utilize public transport services along Enkhtaivan Avenue, Chinggis Avenue, Ard Ayush, Enebishan Avenue, the Great Ring Road, the Small Ring Road, and Chingeltei Avenue. For instance, bus stops such as MUBIS (North), Officers' Palace (North), and 5 Shar (South) serve over 250,000 passengers per month. The survey data on passengers using public transportation in Ulaanbaatar indicates that the number of passengers is higher at bus stops located at the intersections of the road network branches.

Furthermore, the current public transportation network exhibits a high degree of route overlap along the main roads mentioned above while providing services on the existing street network. This can be attributed to the high passenger flow along these roads and the limited route options available within the current road network, resulting in numerous routes passing through these specific streets.

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The main reason for this pattern is that Ulaanbaatar's urban planning has developed radially due to its geographical structure. As a result, citizens' movements are directed from the city's outskirts towards the center, passing through the center, and moving outward from the city center. Furthermore, the majority of state and locally owned organizations, business entities, health and educational institutions, and shopping centers are located in the city center, creating a movement towards the center.

Changes in statistical indicators of the sector during the changes in Ulaanbaatar's public transport network are shown in the table below. Looking at the changes in the route network, the number of passengers transported decreased by 1.4 times in the 1st quarter of 2024 compared to 2014, and by 0.18 times when comparing 2023 to the 1st quarter of 2024. Although the number of vehicles operating on the line per day increased by 6.3% when comparing 2023 to the 1st quarter of 2024, the number of passengers transported decreased.

Table 17. Some Indicators of Public Transport Service (Comparison)

Indicator			Unit of Measurement	2014	2023	Q1 of 2024	2014/2024	2013/2024
Number of Passengers			million people	284.9	139.1	29.4	-142.3%	-18.3%
Number of Public Transport Routes			number	137	127	112	-22.3%	-13.4%
Of which	Main routes		number	70	96	91	23.1%	-5.5%
	Of which	State-owned	number	21	34	33	36.4%	-3.0%
		Private	number	45	58	58	22.4%	0.0%
		Trolleybus	number	4	3	0	0%	0%
	Small-sized bus routes		number	44	4	2	-2100%	-100%
	Of which	Auxiliary routes	number	16	0	0	0%	0%
		Express routes	number	28	4	2	-1300%	-100%
	Resort routes		number	7	3	3	-133.3%	0.0%
	Suburban routes		number	15	16	16	6.3%	6.3%
Length of public transport service routes			km	4,361.3	4,309.6	3696.2	-17.9%	-16.5%
Of which	City bus		km	1,956.2	2423.2	2035	3.9%	-19.1%
	Trolleybus		km	88.9	24	24.4	-264.3%	1.6%
	Suburban		km	939	817.1	805.3	-16.6%	-1.5%
	Small-sized bus		km	1,093.7	743	422	-159%	-76%
	Resort		km	252.1	116.1	115.7	-117.9%	-0.3%
	Night transport		km	31.4	210.2	210.2	85.1%	0.0%
Vehicles operating daily on routes			number	1,377	1067	1139	-20.9%	6.3%

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Source: Urban Planning and Research Institute. 2024

It is imperative that Ulaanbaatar's future Comprehensive Development Master Plan prioritizes the construction of essential roads based on citizens' travel demand, improves the utilization of existing roads, increases the efficiency of public transport along these roads, and enhances management. In the current era of rising car usage in Ulaanbaatar, resolving the critical issues within the city's transportation network is impossible without promoting public transport usage over private vehicles and regulating this through policy.

Public Transport Stops

The public transport service consists of 3 main components: roads, stops, and vehicles. The regulation and planning of bus stops are carried out within the framework of the Mongolian standard MNS 5879:2012 "Public Transport. Route Stops. Classification. Technical Requirements" and the building code "BD 32-101-17" for the planning of public transport vehicle stops. As of 2024, a total of 1,145 stops are being used in the public transport service, of which 68 are registered as terminal stops and 1,076 as intermediate stops.

Location of Public Transport Stops, 2024

Source: Urban Planning and Research Institute. 2024

Since 2022, there has been active work on constructing more enclosed or heated public transport stops. In addition to investments from the capital and district budgets, private sector organizations have made significant investments in this work as part of their social

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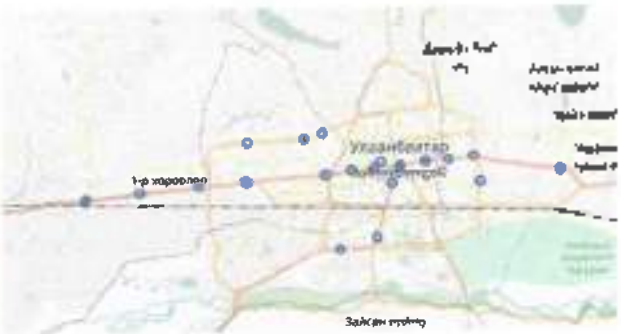
responsibility initiatives. Meanwhile, the improvement of terminal stops is being organized in stages using investments from the capital and district budgets, as well as funding from international projects.

A pressing issue with the current public transport system is that high-traffic bus stops do not have sufficient capacity to meet passenger demand. High-demand stops can be defined as those used by more than 1,000 passengers per day, while very high-demand stops are those used by more than 2,000 passengers per day. The organization of these stops is not capable of handling the high loads. Bus stops are designed to accommodate small passenger flows, which leads to common problems such as difficult queues, obstacles to boarding buses, delays at stops, negative impacts on road traffic, uncertainty for passengers about where the bus will stop, and obstacles to pedestrian movement. Improperly organized bus stops contribute to congestion, as buses often occupy two or more lanes at stops.

As of 2024, there are 20 stops that handle more than 300 passengers during the morning peak hour and 25 stops that handle more than 250 passengers during the evening peak hour. These high-traffic stops are shown on the map. Of the 20 stops with high morning peak hour traffic, 14 are located on Peace Avenue. Similarly, 17 out of the 25 stops with high evening peak hour traffic are situated on Peace Avenue.

Location of High-Traffic Public Transport Stops, 2024

Stops with more than 300 passengers boarding from a single bus stop between 07:00-08:00 on weekdays in May 2024



Stops with more than 250 passengers boarding from a single bus stop between 17:00-18:00 on weekdays in May 2024

Source: Ulaanbaatar City Public Transport Strategy, USUTP Project, 2024

It is very important to consider the intermodal connectivity between different types of vehicles at bus stops. In late 2023, new systems such as bike-sharing, electric bicycles, and electric scooters were introduced, and these vehicles are directly connected to bus stops and routes to access public transport. Passengers use these vehicles to reach bus stops, but sometimes leaving them parked haphazardly at the stops can obstruct pedestrian movement and negatively impact safety, which is common.

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Passenger flow estimation for public transportation

The public transportation route directions and passenger flow estimation are presented based on the results of the Trip Assignment stage. The outcome of the public transportation passenger flow modeling on the road network is illustrated using the one-day passenger flow data along the major roads of Ulaanbaatar's first-class road network, specifically along Peace Avenue.

Peace Avenue, Moscow Street: Passenger flow on a single direction of the roadway

- Officer's Palace Circle to the intersection of Eastern Crossroad: 27,250-32,093 passengers
- Eastern Crossroad to the intersection of Central Post Office: 27,800-35,800 passengers
- Central Post Office Crossroad to the intersection of Western Crossroad: 24,500-43,600 passengers
- Western Crossroad to the intersection of Sapporo's Crossroad: 25,900-42,000 passengers
- Sapporo's Crossroad to the intersection of Geological Central Laboratory's Crossroad: 29,000-42,000 passengers

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Source: Urban Planning and Research Institute. 2022

Chinggis Avenue:

- In the direction from Yarmag Bridge to the Khan-Uul District intersection: **14,000–16,800 passengers**
- In the direction from the Khan-Uul District intersection to the 120 thousandth 4-road intersection: **15,000–25,000 passengers**
- In the direction from the 120 thousandth 4-road intersection to the Central Post Office intersection: **19,000–27,000 passengers**

Enebishiin Avenue, Ard-Ayushiin Avenue:

2. Direction from Sapporo intersection to the western intersection of the Traumatology Hospital: 16,000-29,000 travelers/day

3. Direction from the western intersection of the Traumatology Hospital to the intersection in front of Urgoo Cinema: 15,000-23,000 travelers/day

4. Direction from the intersection in front of Urgoo Cinema to Bayanburd safety roundabout: 16,000-29,000 travelers/day

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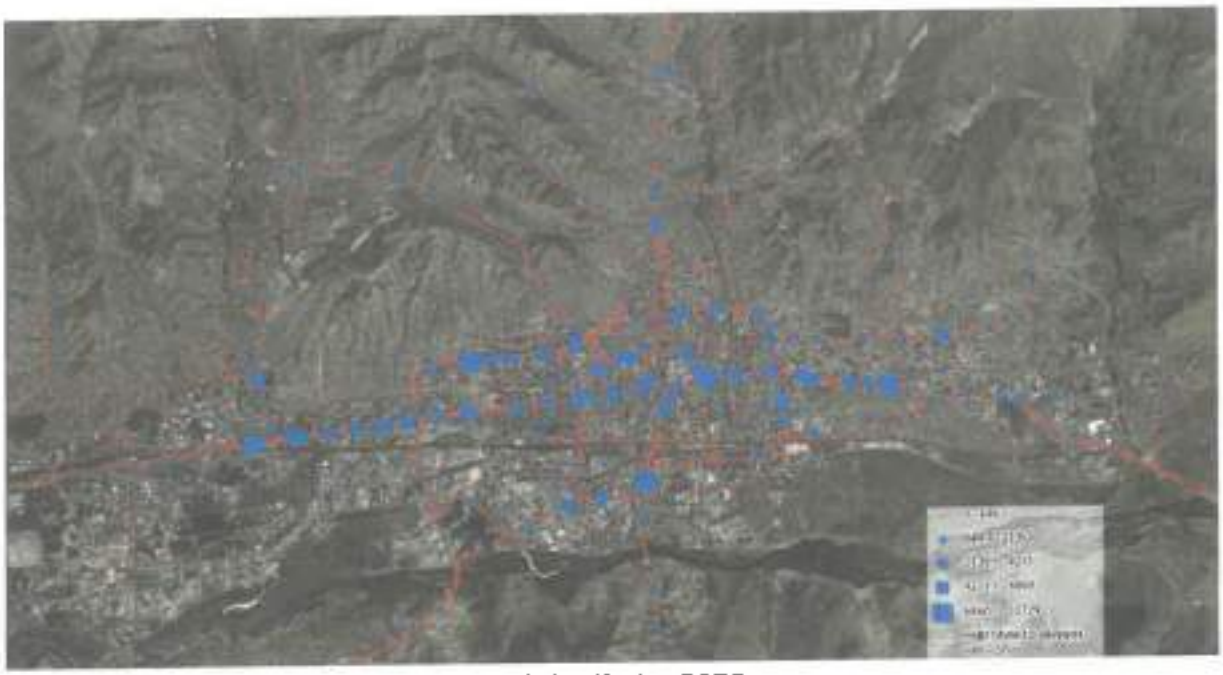
Public Transport Passenger Demand Study

The passenger flow demand for public transport in Ulaanbaatar city has been developed as of 2022, based on a study of citizen demand boarding buses during morning and evening peak traffic hours.

The study of passenger demand for public transport buses was developed by converting the data into GIS (Geographic Information System). The results of the study are shown in the following illustration.

Public Transport Passenger Flow of Ulaanbaatar City Road Network, 2022



Source: Urban Planning and Research Institute, 2022

The following figure shows the morning and evening demand for public transport passenger flow for each bus stop in Ulaanbaatar city. The highest public transport passenger flow directions are Peace Avenue, Ard-Ayush, and Enebishin Avenue. Peace Avenue at Tavan Shar has the highest bus passenger boarding rate.

Peak Hour Passenger Flow of Public Transport

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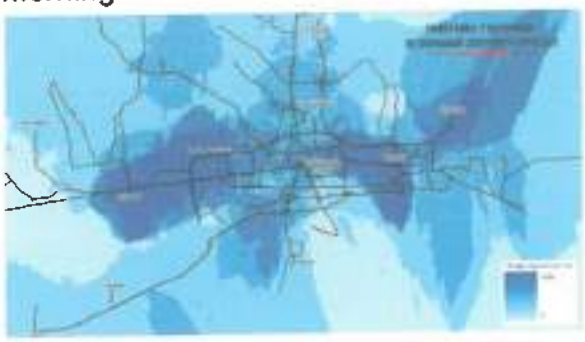
Morning



Evening

Source: Urban Planning and Research Institute, 2022

3.2. PREVIOUS STUDIES ON INTRODUCING HIGH-CAPACITY PUBLIC TRANSPORT IN ULAANBAATAR CITY

List of previous studies on introducing high-capacity public transport in Ulaanbaatar city

Capital City Public Transport Development Investment Program (BRT), Ulaanbaatar City Public Transport Project, ADB (MON-MFF: TA 7156-MON);

1. Public Transport Agency, "Technical and Economic Feasibility Study for Metro Construction in Ulaanbaatar (LRT) (No. 6/20100084)" Su Song Company of Korea, 2011;
2. "Study on Implementation of Public Transport Project in Ulaanbaatar (MRT)" within the framework of technical assistance from Japan International Cooperation Agency (JICA), Value Planning International, Almec Corporation, Oriental Consultants, Marubeni, Nikki Companies, 2011-2013;
3. Ulaanbaatar LRT Project (Preliminary Technical and Economic Feasibility Study for LRT Implementation in Ulaanbaatar), Red Hero and Partners, 2019;
4. "Cable Car Implementation Project in Ulaanbaatar" within the framework of a highly concessional loan from the Government of the French Republic, 2019;
5. Public Transport Service Agency, "Research on Introducing a New Type of High-Capacity Public Transport in Ulaanbaatar City", 2021;
6. Capital City Governor's Office, "Study on Implementing High-Capacity Public Transport Service with Support Bridge Structures", 2021;

Table 18. Previous studies on introducing high-capacity public transport in Ulaanbaatar city

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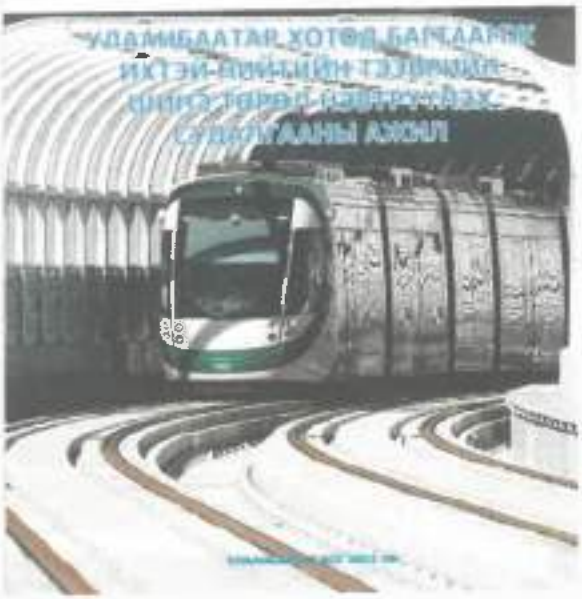
A. "Technical and Economic Feasibility Study for Metro Construction in Ulaanbaatar (LRT) (No. 8/20100084)"	B. "Study on Implementation of Public Transport Project in Ulaanbaatar (MRT)"
C. "Research on Introducing a New Type of High-Capacity Public Transport in Ulaanbaatar City"	D. "Study on Implementing High-Capacity Public Transport Service with Support Bridge Structures"
	

Table 19. Previous studies on introducing high-capacity public transport in Ulaanbaatar city

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Work completed: In 2009-2010	"Urban Transport Development Program" study was developed with Technical Assistance from ADB
2011-2012	With Technical Assistance from ADB, a Preliminary Conceptual Plan for the "Urban Transport Development Program" was developed.
2015.04.30	The Parliament approved the first phase loan agreement for the Ulaanbaatar Urban Transport Development Investment.
2015.05.05	The Government of Mongolia, ADB, and the Capital City Governor's Office signed the first phase Loan Agreement and Project Agreement.
2015.11.29	The Ministry of Finance signed a subsidiary loan agreement with the Capital City Governor's Office.
2015-2017	With ADB Technical Assistance, a technical study to strengthen Ulaanbaatar's transport capacity was redeveloped.
2017.06.04	The Project Implementation Unit was established by the Capital City Governor's Decree No. 158 of 2017, and project implementation began.
2017.10.22	International consulting services were announced for developing detailed engineering designs for the Bus Rapid Transit infrastructure network and supervision of construction works for the first corridor.
2018.06.18	The selection of international consulting services was completed and the final evaluation report was submitted to ADB on June 18, 2018, resulting in negotiations with the partnership of "EGIS International" and "EGIS Villes Transport" firms from the French Republic, though no contract was signed.
2018.06.11	The "Project Steering Committee" membership was renewed by Capital City Governor's Decree No. A/844 of 2018.
2019	The Project Implementation Unit membership was renewed.
2020.02.28	As the financing period for the Asian Development Bank loan expired, it was decided to close the project.

Table 20. Summary of investment calculations from previous studies

Nr	Project Name	Financier	Proposed Option	Date Prepared	Description	Investment Amount
1	Capital City Public Transport Development Investment Program	Asian Development Bank	BRT / Bus Rapid Transit	2009-2020	BRT lines totaling 43.8 km in 3 directions	274.4 million USD
2	Feasibility Study for Metro Construction in Ulaanbaatar	State and Capital City Budget	LRT / Light Rail Transit	2010-2011	LRT lines totaling 49.4 km in 2 directions	4 trillion 917 billion 328 million MNT
3	Study on Implementation of Public Transport Project in Ulaanbaatar	JICA Organization of Japan	MRT	2012-2014	MRT line of 12.73 km in 1 direction	1.5 billion USD / 2.5 trillion MNT

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4	Ulaanbaatar LRT Project (Preliminary Technical and Economic Feasibility Study for LRT Implementation in Ulaanbaatar)	Red Hero Partners LLC	LRT / Light Rail Transit	2019	LRT line of 13 km in 1 direction	2.0 trillion MNT
5	Project for Implementing Cable Car Transport in Ulaanbaatar	Government of France	Cable car / aerial cable transport	2019	Aerial cable lines totaling 10.3 km in 2 directions	60.0 million EUR

3.3. OMPARATIVE STUDY OF PUBLIC TRANSPORT

Comparison of capacity of urban public transport types

The type of public transport and vehicle selection depends on the city's population, urban development planning, geographical characteristics, population movement flow, and specific travel demand of citizens. Urban public transport types have their own advantages and disadvantages, and internationally it is common to compare them in terms of capacity. When comparing capacities, the passenger flow volume that can be transported in one direction per hour is calculated.

In the publication "Changing Course in Urban Transport: An Illustrated Guide" (Robin Hickman, Paul Fremer, Manfred Breithaupt, Sharad Saxena, 2011) jointly produced by the Asian Development Bank (ADB) and German Cooperation Agency (GIZ), the transport capacities were compared by the number of passengers that can be transported per hour on a single lane with a width of 3.5 meters. In mixed traffic, passenger cars transport approximately 2,000, regular public transport buses around 9,000, BRT 20,000-43,000, LRT around 22,000, and MRT 30,000-100,000 passengers.

Comparison of capacity of urban transport types

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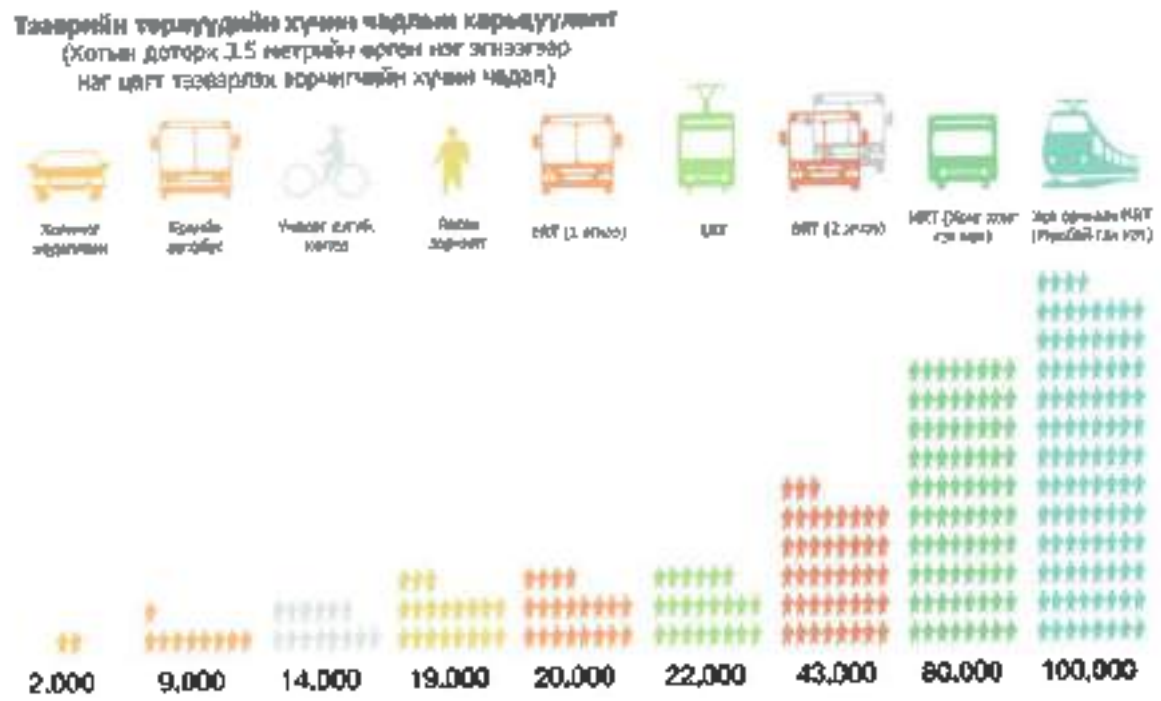

In modern times, when comparing and selecting transport types, reducing negative environmental impacts has become as important as capacity considerations. Research shows the number of passengers that can be transported per kilometer for each ton of CO_2 emissions by transport type, with high-capacity public transport modes demonstrating lower environmental impact by transporting 146.1 thousand passenger-kilometers per ton of CO_2 emissions.

Types of Public Transport

Table 21. Comparative study of public transport rolling stock

Category	MRT (Mass Rail Transit)	LRT (Light Rail Transit)	BRT (Bus Rapid Transit)
Train Form			
Characteristics	-Good transport capacity High construction and operational costs	-Smaller facility and vehicle size, lower construction and operational costs Precise time scheduling	–Cannot implement precise time scheduling, negative impact on environment - Low construction and operational costs
Metro construction cost (MNT/km)	80 billion - 1,2 trillion MNT	30-90 billion MNT	5-10 billion MNT

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Operational cost (km/year)	1 billion 440 million MNT	700 million-1 billion 50 million MNT	500-800 million MNT
City population	Suitable for cities with population over 2 million	Suitable for cities with population of 500 thousand to 2 million	Suitable for cities with population of 200-500 thousand
Number of wagons in a train	6-10 wagons	2-6 wagons	-
Transport capacity	30,000-90,000 people/hour	5,000-30,000 people/hour	500-2,000 people/hour
Construction completion time	Approximately 5-10 years	Approximately 3-5 years	Approximately 2 years

Table 22. Comparison of Regular and Dedicated Lane Public Transport

Parameter	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)
Passenger comfort and convenience	Medium passenger comfort, operates in mixed traffic. High dependency on road conditions. Suitable for transport of passengers with luggage and is compatible with passenger flow.	High passenger comfort with smooth operation, suitable for transporting large volumes of passengers in a major arterial corridor.
Cost-effectiveness and financial viability	Relatively low capital expenditure, can be implemented within existing road infrastructure. Low operation costs; the combination of bus network flexibility and dedicated lanes provides good cost-effectiveness.	Requires high capital investment; requires metal tracks, electrified lines, and other expensive infrastructure work in underground or elevated sections.
Environmental impact	Uses diesel fuel-powered buses. Environmental impact can be significantly reduced by implementing environmentally friendly diesel technology or using electric buses.	Uses electric power which significantly reduces air pollution. However, electricity generation may cause environmental impact depending on the source of power generation.
Passenger travel time and service quality	Travel time is dependent on road infrastructure; dedicated bus lanes improve service quality. However, bus capacity and service frequency can be adjusted according to passenger flow.	Has high carrying capacity, is flexible, and has elastic capacity based on volume and frequency. Provides good control over passenger flow.
Impact on urban development	Has little impact on current road network; can be flexibly implemented with minor modifications to existing infrastructure. Has minimal impact on urban development.	Has significant impact on urban structure and development. LRT routes can influence urban development patterns and enhance urban mobility along corridors.
Service operation and implementation flexibility	Limited technical operation, low cost. Can be flexible in changing routes as needed.	Requires metal tracks, electrified system which increases operation costs. LRT has better operational flexibility in high passenger volume corridors.

Table 23. Comparison of Public Transport Vehicle Types

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Conclusion

By the research on Ulaanbaatar's Urban Development General Plan through 2040, the Yarmagiin area population is projected to reach 323,000, increasing 2.6-fold; workplace capacity is expected to reach 136,000, expanding 3-fold; and commercial/service infrastructure is anticipated to grow to 8.1 million square meters, representing a 4-fold increase. Based on the transportation demand modeling derived from these calculations, the passenger flow projections indicate that public transit ridership along the corridor will reach 101,000 passengers daily in 2040, with peak hour single-direction volume at 11,000; by 2050, these figures are estimated at 121,000 total daily passengers and 13,000 peak hour single-direction passengers. Evaluating transportation demand, environmental impact, public transit service sustainability, operational expenditures, and urban development effectiveness, the analysis suggests that Bus Rapid Transit (BRT) represents a short-term, cost-efficient solution, while Light Rail Transit (LRT) emerges as a long-term, sustainable, and operationally optimized alternative.

№№	Transport type	Vehicle type	Features				
			Description	Capacity / 1 direction/	Average speed	Implementation cities	Cost /1 km/
1	Urban Rail Transit	High capacity metro /Mt RT/	Metal track-based electric transit system. Underground or elevated	40.0-70.0 thousand passengers/hour	40-50 km/hour	London, Moscow, Tokyo, Berlin, New York, etc.	60- 100.0 million USD
2		Light capacity metro	Metal track-based electric transit system. Underground or elevated	20.0-30.0 thousand passengers/hour	60-120 km/hour	Seoul, Minnesota, Alberta, Texas, Sydney, etc.	40-80.0 million USD
3		Tram	Metal track-based electric transit system. At-grade with some underground or elevated sections.	5.0-15.0 thousand passengers/hour	60-80 km/hour	Frankfurt, Paris, London, Ulsan, Hiroshima etc.	20-30.0 million USD
4		Monorail	Uses elevated structure with single track beams.	10.0-15.0 thousand passengers/hour	60-80 km/hour	Tokyo, Sydney, Seattle, Daegu etc.	40-50.0 million USD
5		Light Rail Transit LRT	Uses electrical power with specially designed features. Elevated structure.	5.0-20.0 thousand passengers/hour	80-100 km/hour	Nagoya, Birmingham, Tachon, Vancouver etc.	40-70.0 million USD
6		Automated Light Rail Transit	Driverless automated system with underground or elevated routes.	7.0-28.0 thousand passengers/hour	70-100 km/hour	London, Vancouver, Busan, Incheon etc.	50-60.0 million USD

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7	Road-based Transit	Bus	Regular bus service operating on mixed-traffic roads.	3.0-5.0 thousand passengers/hour	20-40 km/hour	All cities	-
8		Trolleybus	Electric-powered bus operating on road infrastructure with overhead wires.	3.0-6.0 thousand passengers/hour	20-40 km/hour	Ulaanbaatar, Moscow, Hiroshima and other cities	1-3.0 million USD
9		Bus Rapid Transit /BRT/	Bus service operating on dedicated lanes with specialized infrastructure.	5.0-25.0 thousand passenger/hour	30-60 km/hour	Bogota, Beijing, Guangzhou, Curitiba etc.	5-10.0 million USD

3.4. PUBLIC TRANSPORT NETWORK OF THE PROJECT AREA

Public transport routes along the alignment

Table 24. Information on public transport routes serving the planned project alignment

No.	Route number	Route name	Number of service vehicles	Average daily ridership	Average monthly ridership
1	Ut:3	National Archives Square-120 thousandth District-Sukhbaatar Square	18	7800	188858
2	Ch:7	Niseekh – MUBIS - Ard Cinema	30	13060	319898
3	Ch:9	"Niseekh – Narmil Bridge – Tengis Cinema – New 4th District"	15	6324	192643
4	Ch:53	Yarmag – MUBIS	11	3630	90756
5	Ch:54	"Yarmag – 10th District – 3,4th District – Zuragt - Bayankho"	15	6163	144791
6	Ch:78	National Archives Square-Yarmag Bridge-3,4th District	7	2518	64345
7	Ch:79	Tachi-Yarmag 1st Bus Station	6	1576	44296
8	Ch:80	KHASUT-Yarmag 1st Bus Station	6	1746	47806
9	Ch:81	"3,4th District-Yarmag 1st Bus Station"	6	2494	60620
10	Kh:19	CHKHOUNB-Sukhbaatar Square	1	5	73
11	SHU:2	Sukhbaatar Square-Niseekh	2	86	2534
Total					117

Current status study of public transport routes

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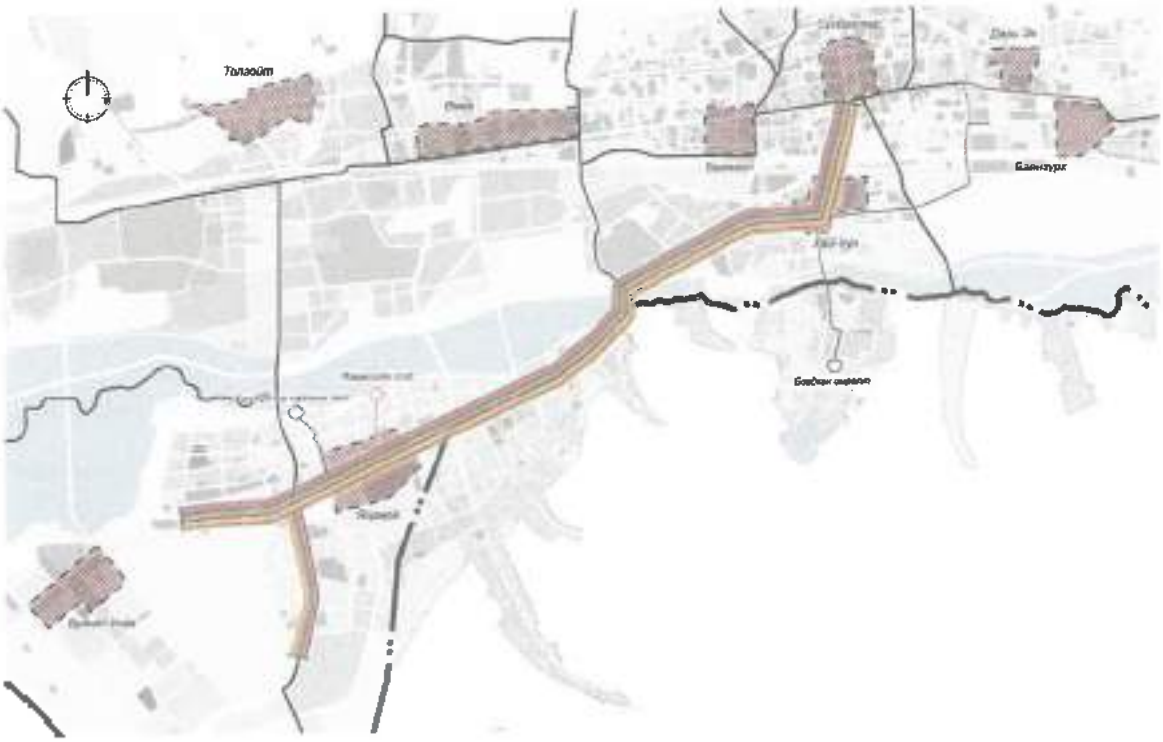

In the Yarmag direction, 117 vehicles on 11 routes are providing service, with an average of more than 45 thousand passengers daily and more than 1.15 million passengers monthly using these routes.

Table 26. Quantitative data

Зорчлогч урсгалын судалгааны бүртгэл

Хүснэгт-1 2024 он

	1-р сар	2-р сар	3-р сар	4-р сар	5-р сар	6-р сар	7-р сар	8-р сар	9-р сар	10-р сар	Файлын тоо
М3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Х19	☐	☐	☐	☐	☐	☐	✓	✓	✓	✓	8
Ч7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Ч9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Ч53	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Ч54	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Ч76	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
Ч79	☐	☐	☐	✓	✓	✓	✓	✓	✓	✓	7
Ч80	☐	☐	☐	✓	✓	✓	✓	✓	✓	✓	7
Ч81	☐	☐	☐	✓	✓	✓	✓	✓	✓	✓	7
ШУ2	☐	☐	☐	☐	☐	✓	✓	✓	✓	✓	5
НИЙТ											90

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Public transport stops along the alignment

For the 2024 data on passenger flow of all 11 bus routes in the Yarmag direction, we used consolidated reports registered in the UB smart system, based only on boarding records. Since only about 10 percent of total passengers scan their cards when alighting, which would reduce the reliability of the study results, this data was not included in the calculations.

Table 26. Number of Public Transport Passengers Along the Route

No.	Bus stop name	Total number of boarding passengers		
		Monthly	Daily	Hourly
1	National Archives Square	5139	171	14
2	New Yarmag District	19065	636	53
3	Buyant Ukhaa-1	10261	342	28
4	Nisqlch Market	5639	188	16
5	"Civil Aviation Authority of Mongolia" (CAAM)	5002	167	14
6	Buyant Ukhaa Sports Complex	27373	912	76
7	118th School	2226	372	31
8	Yarmag 4th Bus Stop	6267	209	17
9	Yarmag Health Center	9677	323	27
10	Yarmag Old Health Center	8558	285	24
11	Hospital Bus Stop	19891	663	55
12	Yarmag 3rd Bus Stop	22653	756	63
13	Yarmag 2nd Bus Stop	23945	798	67
14	Yarmag 1st Bus Stop	56763	1892	158
15	English School	7115	237	20
16	Hunnu Great Store	37589	1253	104
17	Viva City	45654	1522	127
18	MSM	5604	187	16
19	Gem	23497	783	66
20	Tavan Bogd Company	47151	1572	131
21	Service Center	37676	1269	105
22	Central Office of 120 thousandth District	63387	2113	176
23	Bayangol Restaurant Bus Stop	25876	866	72
24	Central Book Store	4624	154	13
25	Sukhbaatar Square Bus Stop	153727	5124	393

There are a total of 23 public transport stops along the project route from north to south, with the highest passenger traffic at Yarmag 1st Bus Stop, Tavan Bogd Company, Central Sports Complex 120 thousandth District, and Sukhbaatar Square Bus Stop. At

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the stops along the planned route, a total of 1,072,578 passengers per month, 21,830 passengers per day, and 1,785 passengers per hour are being served.

Four-step transport planning methodology

The most widely used transport planning methodology internationally is the traditional 4-step model. The traditional 4-step transport planning model consists of four parts: Trip Generation, Trip Distribution, Modal Split, and Trip Assignment.

In the first step, Trip Generation, the transport volume of each transport zone's trip production and attraction points, or the travel demand of citizens, is calculated. When determining the trip generation rate for each transport zone, it is assumed to depend on socio-economic indicators of that area and is calculated using multiple regression analysis. Trip generation rates are usually calculated based on variables such as population, economic production volume, number of workers, number of vehicles, etc. of that area. The results of this model's calculations produce the production (origin) and attraction (destination) models for each transport zone.

In the second step, Trip Distribution, based on the trip generation rates calculated in the first step, the transportation volume between the trip production and attraction points is calculated. In other words, it calculates the OD matrix, which is the most important information for calculating the future outlook of transport demand. Trip distribution is calculated using gravity models, growth factor models, Frater models, intervention-opportunity models, etc. The result of the trip distribution model calculation is the transport flow OD matrix, which represents the transport production-attraction or trip distribution between transport zones. Transport flow monitoring and registration information is important for more realistic assessment of transport production or passenger generation points (O matrix), attraction or passenger absorption points (D matrix), and production-attraction or passenger generation-absorption points (OD) matrix.

In the third step, Modal Split, the distribution of vehicle types or the selection of travel modes is calculated based on the current proportion of transport modes to determine the future share of different transport types. In most studies, a Logit model is developed to calculate the proportion of transport modes based on changes in travel time and costs from the point of origin to destination.

In the fourth step, Trip Assignment, the transport routes for carrying cargo from origin to destination points are calculated, establishing the OD traffic volume and calculating the transport demand for each vehicle choice (road, rail, waterway). Transport planning software has several different types of transportation assignment models.

The traditional 4-step transport planning model and network optimization models are being calculated internationally using software such as TransCAD, Cube, VISUM, VISSIM, EMME, Strada, etc.

Passenger flow demand forecast calculated using Visum software

Using the 4-step transport planning methodology with PTV Visum software, passenger flows at 23 stops along the route were calculated by boarding, alighting, and through passengers on daily and hourly bases. For Ulaanbaatar city, the transport analysis divided the city into 224 zones, and

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developed an origin-destination (OD) matrix based on a total of 40 socio-economic indicators for each zone including population (by age group), number of households, employed people, unemployment, number of vehicles, employed people with vehicles, unemployed people with vehicles, number of kindergarten children (kindergarten capacity), number of children attending kindergarten, number of students (school capacity), number of school children, number of university students, retired people, people using nearby stores, people traveling long distances or to markets, bicycle riders, pedestrians, number of businesses, business sales volume, number of employees, etc.

To create this OD matrix, the travel surveys of 53,000 households conducted in 2017 and 15,000 households conducted in 2022 across Ulaanbaatar city were used as base data.

When calculating passenger flows for boarding, alighting, and through passengers at 23 stops along the LRT route on the PTV Visum transport planning software on daily and hourly bases, planning periods of 2030, 2040, and 2050 were used as references. The Ulaanbaatar transport demand model incorporated information about future roads, transport networks, urban planning, buildings and facilities, and residential areas included in the Ulaanbaatar 2040 Master Plan, while population calculations were based on the National Statistics Office's medium variant 1B scenario for the resident population of Mongolia by number, gender, age group, and aimag/capital city, projecting Ulaanbaatar's population to reach 2.524 million by 2050.

When calculating the number of daily passengers traveling from the Archives to Sukhbaatar Square on the LRT route using the PTV Visum transport planning software, there are projected to be 58,708 trips in 2030, 90,891 trips in 2040, and 110,023 trips in 2050.

For the direction from Buyant Ukhaa Sports Complex to Sukhbaatar Square, the Peak Hour Passenger Demand (PHPD) is calculated to be 6,296 trips in 2030, 9,748 trips in 2040, and 11,800 trips in 2050.

Currently, in the direction from Buyant Ukhaa Sports Complex to Sukhbaatar Square, route M:3 "National Archives - Sukhbaatar Square" operates 18 high-capacity buses on working days, transporting approximately 7,000 passengers on average. Along this route, an average of 46,800 passengers board public transport at all 18 stops on working days across all routes.

By introducing a new high-capacity public transport type, it appears possible to reach the trip volumes calculated on the PTV Visum transport planning software by accounting for increased ridership from other transport modes and from integration into a unified public transport network.

Table 27. Public Transport Trips

Year	2025	2030	2040	2050

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Parameter	endless	endless	Buyant Ukhaa - Sukhbaatar	endless	Buyant Ukhaa - Sukhbaatar	endless	Buyant Ukhaa - Sukhbaatar
	-		LRT - 2	-	LRT - 2	-	LRT - 2
Total daily passengers in the LRT direction from Buyant Ukhaa Sports Complex to Sukhbaatar Square, number of passengers that could shift to LRT once implemented. Including:	588491.6	683070	722479	1065034.7	1127210	1297735.7	1309775
LRT ridership Daily	2029 - 51126	-	84561	-	100073	-	121554
LRT ridership Peak hour	4392	-	5455	-	8456	-	10271
Total transport network's full structural length	29.232	29.232	29.007	27.67	29.007	29.232	29.007
Total transport network total length	2858.128	2858.128	2619.882	2858.128	2619.882	2858.128	2619.882
Average passenger travel distance (km)	5.872	6.06	6.117	6.043	6.144	6.126	6.061
Average passenger travel time	39m 15s	40m 27s	39m 47s	40m 41s	39m 33s	40m 52s	40m 22s
Passenger hour LRT			10929h 14min 40.700006s		16566h 43min 26.700011s		20608h 50min 39.700002s
Passenger KM			375258.126222 km		570455.072544 km		707586.485035 km

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Tram Line 2 /2030/			
№	Station	Boarding	Alighting
1	National Archives Square	521	0
2	Buyant Ukhaa 2 / New Yarmag District	660	9
3	Buyant-Ukhaa Sports Complex	1888	14
4	118th School	3740	14
5	Yarmag 4th Station	1247	21
6	Orgil	1101	17
7	Hospital Station	629	17
8	Yarmag 3rd Station	339	25
9	Yarmag 2nd Station	1858	65
10	Yarmag 1st Station	2135	442
11	316th Kindergarten	463	111
12	English School	605	184
13	Hunnu Department Store	1500	264
14	Vivo City	1212	192
15	MSM	399	1308
16	Erka Company	1515	1217
17	Altargana	663	522
18	Tavan Bogd Company	1398	578
19	New Songoli	1306	577
20	Service Center	1907	1127
21	75th School	3103	483
22	120 thousandth District	3616	3545
23	Sukhbaatar Square	0	21065
	Total	31804	31804

Tram Line 2 /2040/			
№	Station	Boarding	Alighting
1	National Archives Square	801	0
2	Buyant Ukhaa 2 / New Yarmag District	996	13
3	Buyant-Ukhaa Sports Complex	2841	22
4	118th School	5681	25
5	Yarmag 4th Station	1887	33
6	Orgil	1672	27
7	Hospital Station	970	31
8	Yarmag 3rd Station	622	39

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9	Yarmag 2nd Station	2771	103
10	Yarmag 1st Station	3255	696
11	318th Kindergarten	705	174
12	English School	922	290
13	Hunnu Department Store	2284	421
14	Viva City	1904	283
15	MSM	646	2032
16	Erka Company	2381	1860
17	Altargana	1010	797
18	Tavan Bogd Company	2120	935
19	New Songolt	2071	572
20	Service Center	3048	1761
21	75th School	4910	756
22	120 thousandth District	5802	5505
23	Sukhbaatar Square	0	32482
	Total	49176	49176

Tram Line 2 /2050/			
№	Station	Boarding	Alighting
1	National Archives Square	988	0
2	Buyant Ukhaa 2 / New Yarmag District	1244	15
3	Buyant-Ukhaa Sports Complex	3560	25
4	118th School	7020	29
5	Yarmag 4th Station	2340	37
6	Ongi	2078	29
7	Hospital Station	1208	36
8	Yarmag 3rd Station	650	45
9	Yarmag 2nd Station	3430	117
10	Yarmag 1st Station	3957	796
11	318th Kindergarten	860	199
12	English School	1124	332
13	Hunnu Department Store	2793	470
14	Viva City	2272	855
15	MSM	784	2492
16	Erka Company	2840	2218
17	Altargana	1202	650
18	Tavan Bogd Company	2544	1071

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19	New Songolt	2429	1041
20	Service Center	3898	2133
21	75th School	5765	914
22	120 thousandth District	6887	6578
23	Sukhbaatar Square	0	39888
	Total	59578	59578

Graph 13. Daily Trip Distribution by Hour

Peak traffic along the corridor is observed during the morning hours between 07:00-09:00, when 17% of total passengers travel. The evening peak occurs between 17:00-19:00, accounting for 15% of total passenger movements during this timeframe.

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CHAPTER 4. PROJECT AREA STUDY

Chapter Subsections:

- A Social and economic aspects of the planning area
- A Environmental status study of the planning area
- A Road network of the planning area
- A Public transport network of the planning area
- A Land use study

4.1. SOCIAL ECONOMY AND DEMOGRAPHY OF THE PLANNING AREA

Demographic study of the project territory

As of January 1, 2024, 1.640 million people in 465 thousand households, representing 48 percent of Mongolia's population, reside in the capital city of Ulaanbaatar. The planning area covers 254 thousand people in 72 thousand households in Khan-Uul and Bayanzurkh districts. Ulaanbaatar's population has increased by 11.9 percent over the last 5 years, Khan-Uul district's population has increased by 37.9 percent, while the population under the planning area increased by 8.3 percent in 2023 compared to the previous year, and is expected to continue growing due to new residential construction.

Table 28. Population and number of households in the project location

№	District Name	Neighborhoods	Total Neighborhoods	Total Households	Population
1	Khan-Uul	01,02,03,04,05,06, 07,08,15,16,17,18, 19,20, 21,22, 23, 24,25	19	60,154	213,367
2	Bayanzurkh	26, 36	2	11,915	40,953
Total			21	72,069	254,320
Capital City				465,069	1,640,781
Percentage of Capital				15%	15%

Source: NSO (National Statistics Office)

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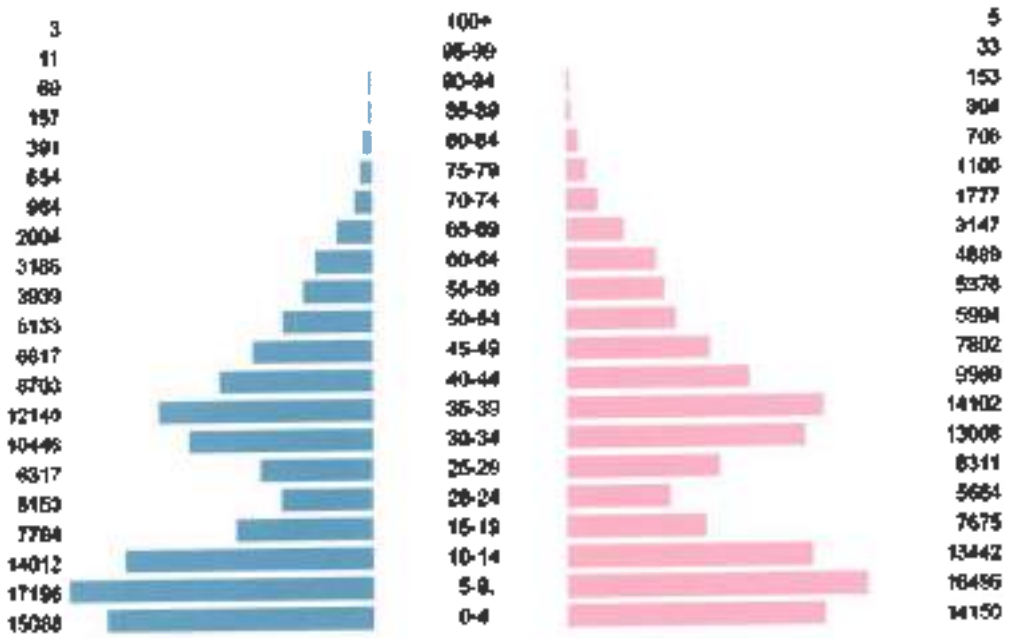
Graph 14. *Population pyramid of the planning area, 2023*



According to the population pyramid, 0-4 year-olds make up 11.5 percent of the total population, 5-9 year-old children 13.2 percent, 10-14 year-olds 10.8 percent, 15-19 year-olds 6.1 percent, 20-59 year-olds 50.7 percent, and those aged 60 and above constitute 7.7 percent of the total population. The population age and gender pyramid gradually widening in the middle section indicates that the population is trending toward maturity. Within the area's population, children aged 0-14 (kindergarten and school age) make up 35.5 percent, people aged 15-59 constitute 56.8 percent, and citizens aged 60 and above make up 7.7 percent.

Housing provision

In the planning area, 217 thousand people from 61.8 thousand households (85.4 percent of the population) live in apartments, while 25.1 thousand people from 6.7 thousand households live in houses, 12 thousand people from 3.5 thousand households live in gers, and 26 people from 15 households live in other types of accommodation.

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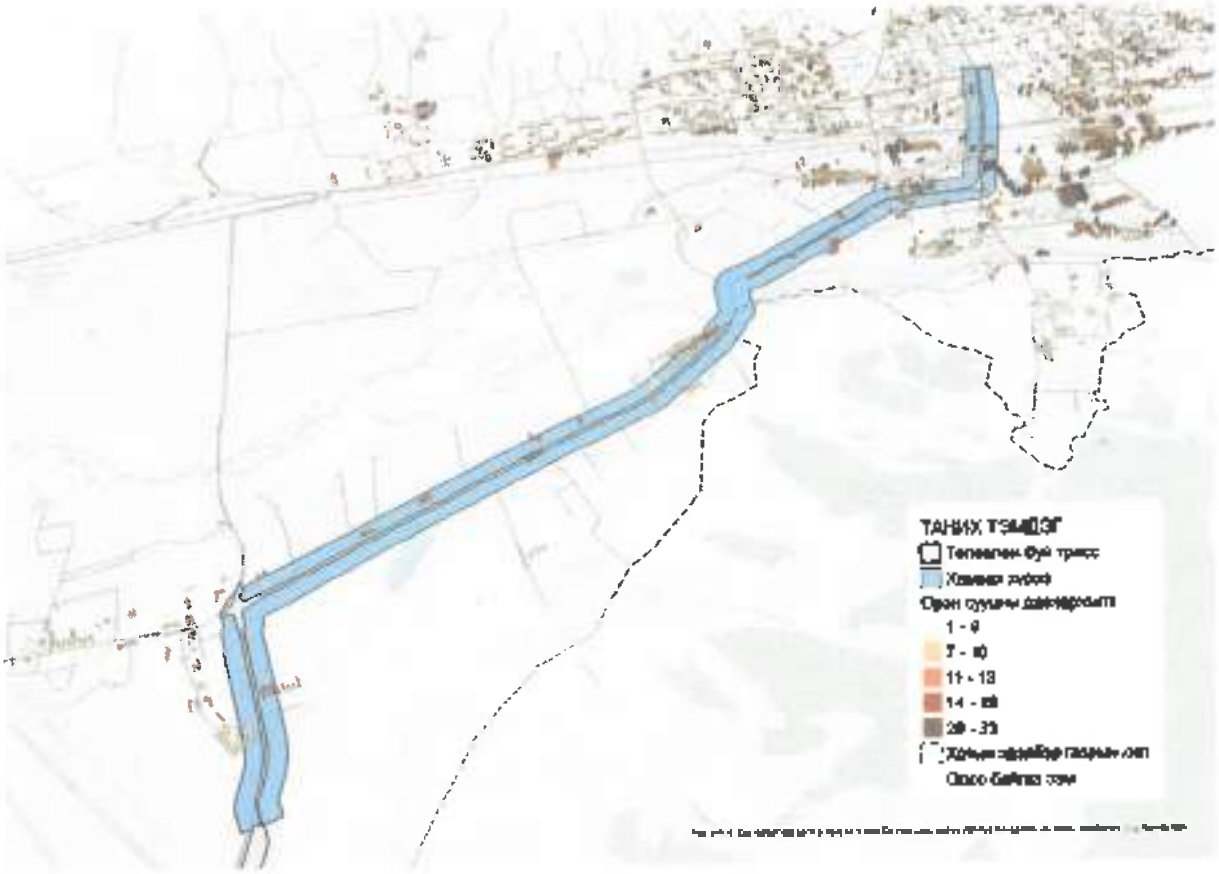
Apartments within the project area coverage



Social infrastructure

Pre-school education institutions

In the project coverage area, 10 public pre-school education institutions are operating for the 2024-2025 academic year. These kindergartens have a total capacity of 3,625 children, but 4,990 children are enrolled, exceeding capacity by 38 percent. 19 private kindergartens have a capacity of 1,601, but only 1,136 children are enrolled, operating at 60 percent capacity.

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Pre-school education institutions within the project area

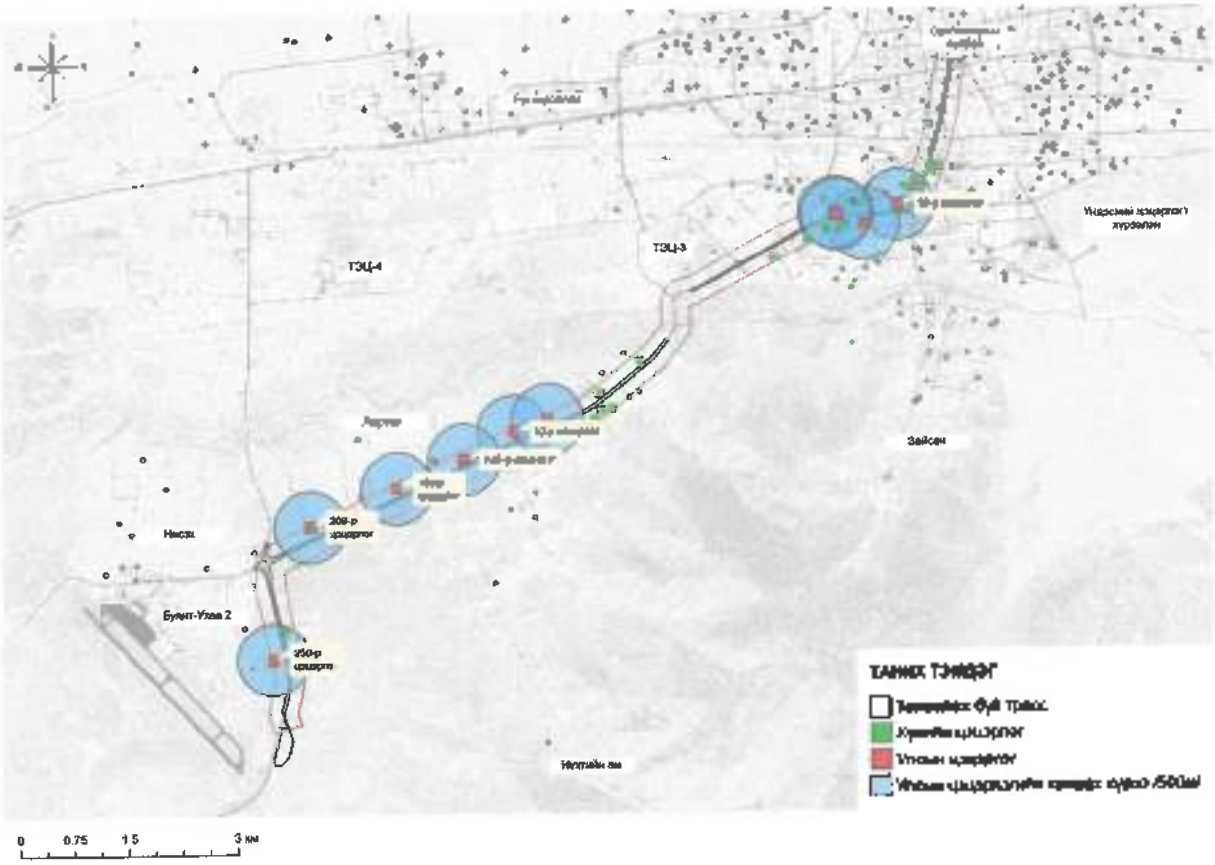

Table 28. *Public kindergartens in the project area*

No	District	District Code	State Kindergarten	Capacity for Accommodation	Number of Children	Provision
1	Khan-Uul	KHUD_01	53th Kindergarten	290	350	121%
2		KHUD_03	28th Kindergarten	505	649	129%
3		KHUD_03	4th Clinic Care	0	0	0%
4		KHUD_04	12th Kindergarten	715	984	138%
5		KHUD_04	312th Kindergarten	200	182	91%
6		KHUD_05	145th Kindergarten	390	370	95%
7		KHUD_06	188th Kindergarten	250	494	198%
8		KHUD_08	209th Kindergarten	350	344	98%
9		KHUD_19	27th Kindergarten	635	897	141%
10		KHUD_21	250th Kindergarten	390	720	185%
Total				3625	4990	138%

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Table 30. Private kindergartens in the project area

No	District	District Code	Kindergarten Name	Number of Children	Capacity for Children
1	Sukhbaatar	SBD 01	Meredin Ger Bul Kindergarten	33	29
2		HUD_01	Baihan Sondor Kindergarten	88	190
3		HUD_01	Choghoolhon Kindergarten	39	26
4		HUD_01	Zaagaltai Baichirhuud Kindergarten	38	89
5		HUD_02	Nandin Bagachuud Kindergarten	129	162
6		HUD_03	Atzai Eulzagatuud Kindergarten	31	40
7		HUD_03	Mongolia Uls Delh French Kindergarten	27	50
8		HUD_04	Tsegmeg Kindergarten	53	41
9		HUD_11	Hustlin Shident Eteris Kindergarten	9	125
10		HUD_15	Baihan Ayalagchid Kindergarten	87	101
11		HUD_15	Kiu Kids Preschool Kindergarten	45	65
12		HUD_20	Baigaluul Eteris Kindergarten	65	60
13		HUD_20	Nomin Kindergarten	60	151
14		HUD_20	Orkhon Bagachuud Kindergarten	74	74
15		HUD_20	Shident Han Uls Kindergarten	66	103
16		HUD_23	British Surgical Department Kindergarten	51	48
17		HUD_24	Ochon Kindergarten	29	41
18		HUD_24	Sutran Kindergarten	63	66
19	Khan-Uul	HUD_24	Ehlne Mongolia Harumatuls Kindergarten	149	150
Total				1136	1601

Preschool Educational Institutions

In the project coverage area, 4 public general education schools are operating in the 2024-2025 academic year. These schools have a total capacity of 4,598 children, but 11,283 children are studying in two shifts, exceeding their capacity by 50%. 10 private schools have a capacity of 7,862, but 3,904 children are studying, utilizing their capacity at 50%.

Table 31. Public Schools in the Project Area

No	District	District Code	Public School	Capacity for Accommodation	Number of Students	Expansion /2 shifts/
1	Khan-Uul	HUD_02	75th School	1228	2343	1.9
2		HUD_03	18th School	1130	3146	2.8
3		HUD_04	34th School	1280	3649	2.9
4		HUD_08	118th School	960	2146	2.2
Total				4598	11283	2.5

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Table 32. Private Schools in the Project Area

No	District	District Code	Private School	Capacity for Accommodation	Total Number of Students
1	Khan-Uul	HUD_01	French Secondary School	45	0
2		HUD_06	Happiness School	270	0
3		HUD_20	Orkhon School	1300	768
4		HUD_20	Anist Khangai School	523	101
5		HUD_20	Onom School	500	651
6		HUD_20	Mongol Business School	474	18
7		HUD_20	Tsagmag Technology School	1250	0
8		HUD_23	British School	600	389
9		HUD_24	Gurvan Tamir School	900	568
10		HUD_24	Shine Mongol Harumafuki School	1300	1411
Total				7862	3904

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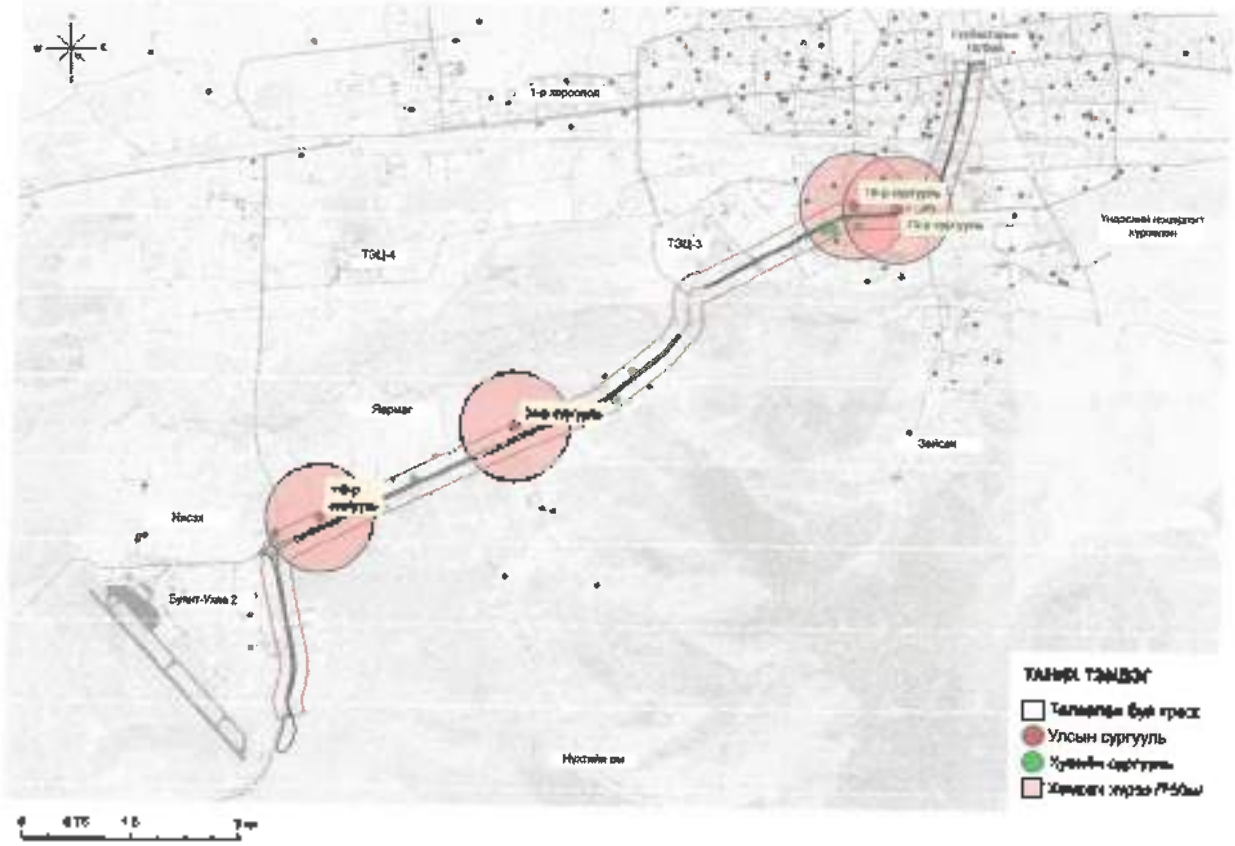

4.2. ENVIRONMENTAL BASELINE STUDY OF THE PLANNING ZONE

Green Space Research

Green spaces serve the purpose of creating an aesthetically pleasing, hygienic, and healthy environment for residents, establishing a favorable microclimate in urban spaces, protecting against various harmful human impacts, and improving the architectural-spatial composition of developed territories.

Within the framework of the technical and economic feasibility study and design of the project "Introducing multi-type public transportation from Buyant-Ukhaa Sports Complex to Torgoni Road Complex, from the 120 thousandth intersection to Sukhbaatar Square" - spanning 15 km - an initial count has been made of 531 pine trees located in a limited-use area along the 3 km stretch from Ulzit Road to Niseikh Circle. These trees need to be preserved within the project scope, but in unavoidable circumstances, they would require careful environmental assessment and evaluation of potential ecological damage if transplantation or relocation is necessary.

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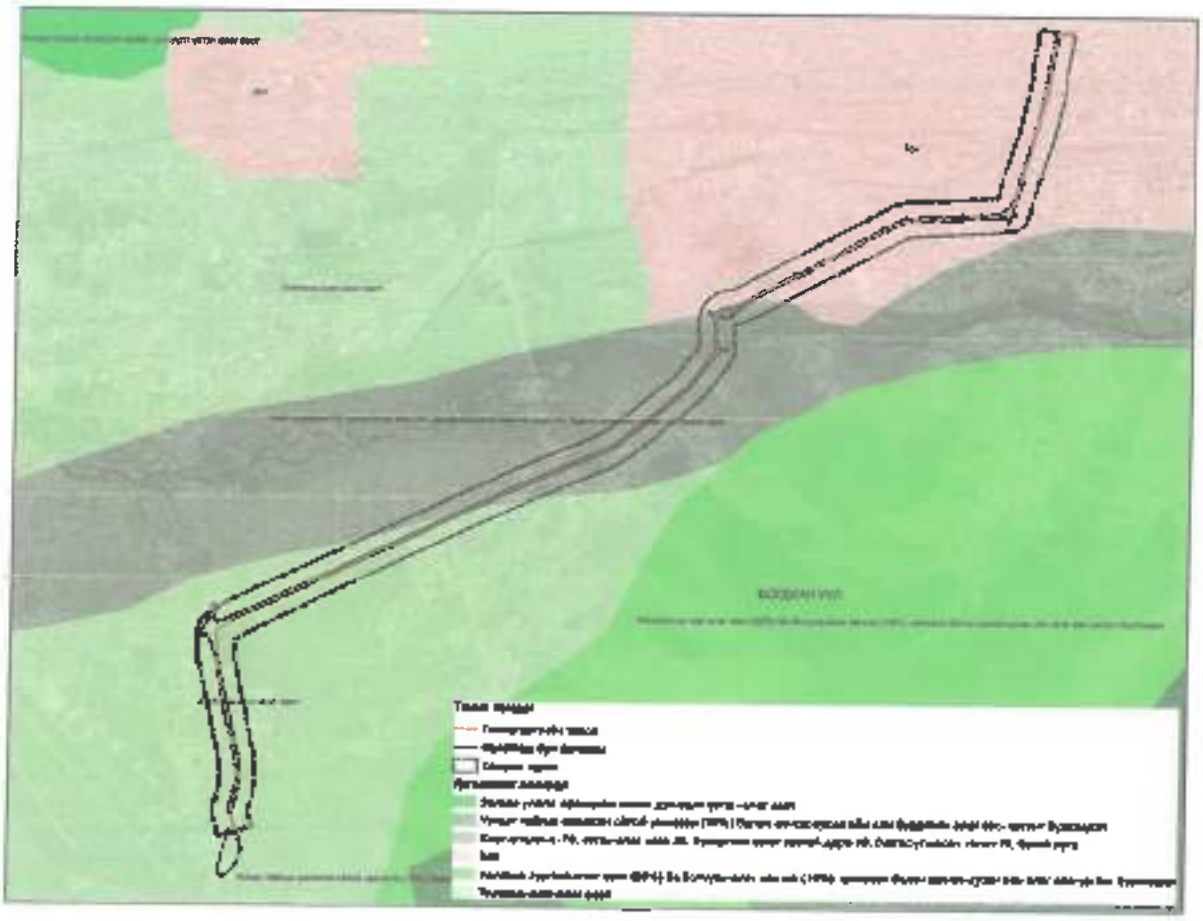
Vegetation Classification

Along the planned route and settled areas, and along the Tuul River basin, the vegetation is characterized by: Feather grass-mixed herb (20%), Wormwood-mixed herb (10%), Coniferous and mixed coniferous-poplar herb-grass communities, Predominantly feather grass-wormwood-mixed herb zones

Soil Classification of the Project Area



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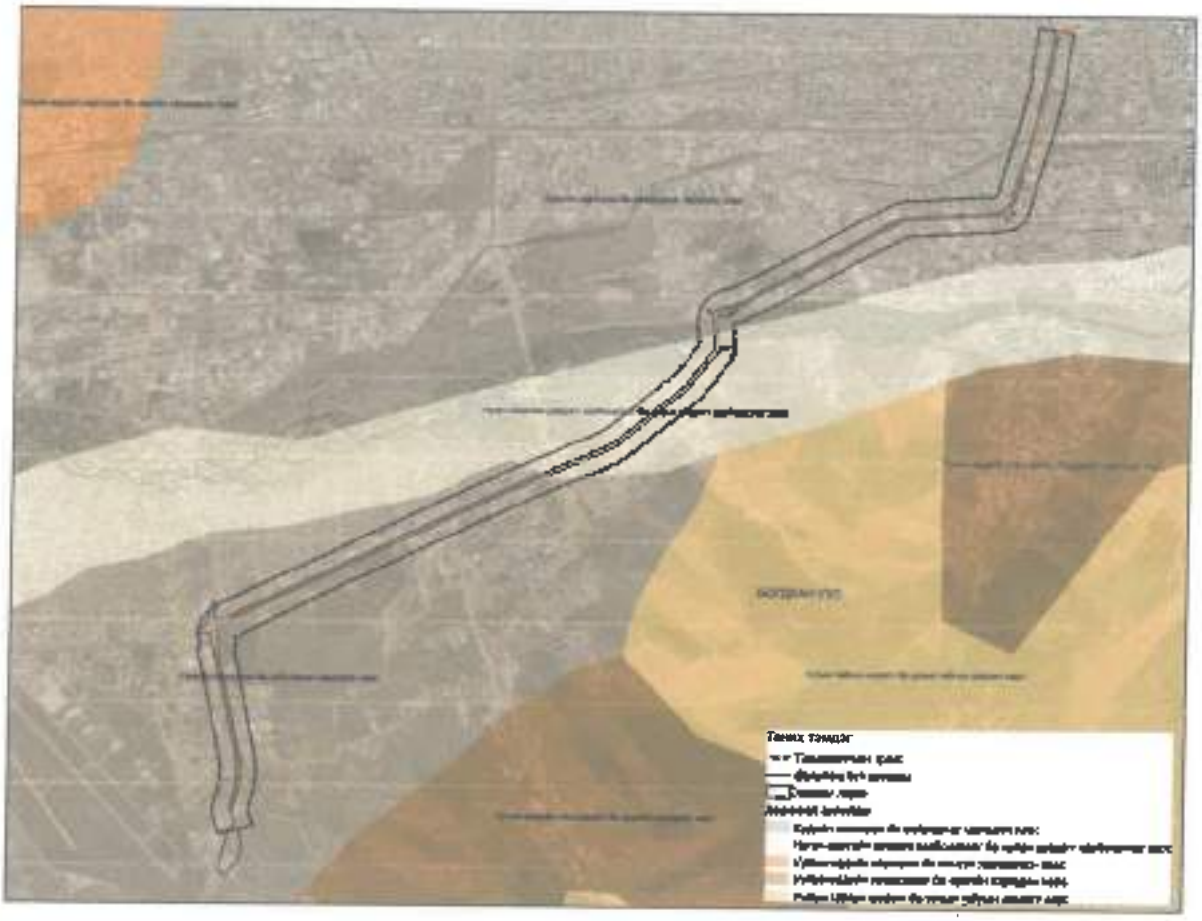
Soil Classification

Along the planned route, meadow-permafrost carbonate and meadow carbonate soils, mountain ordinary chestnut and ordinary dark chestnut soils, ordinary dark chestnut and gravelly dark chestnut soils predominate.

Soil Classification of the Project Area



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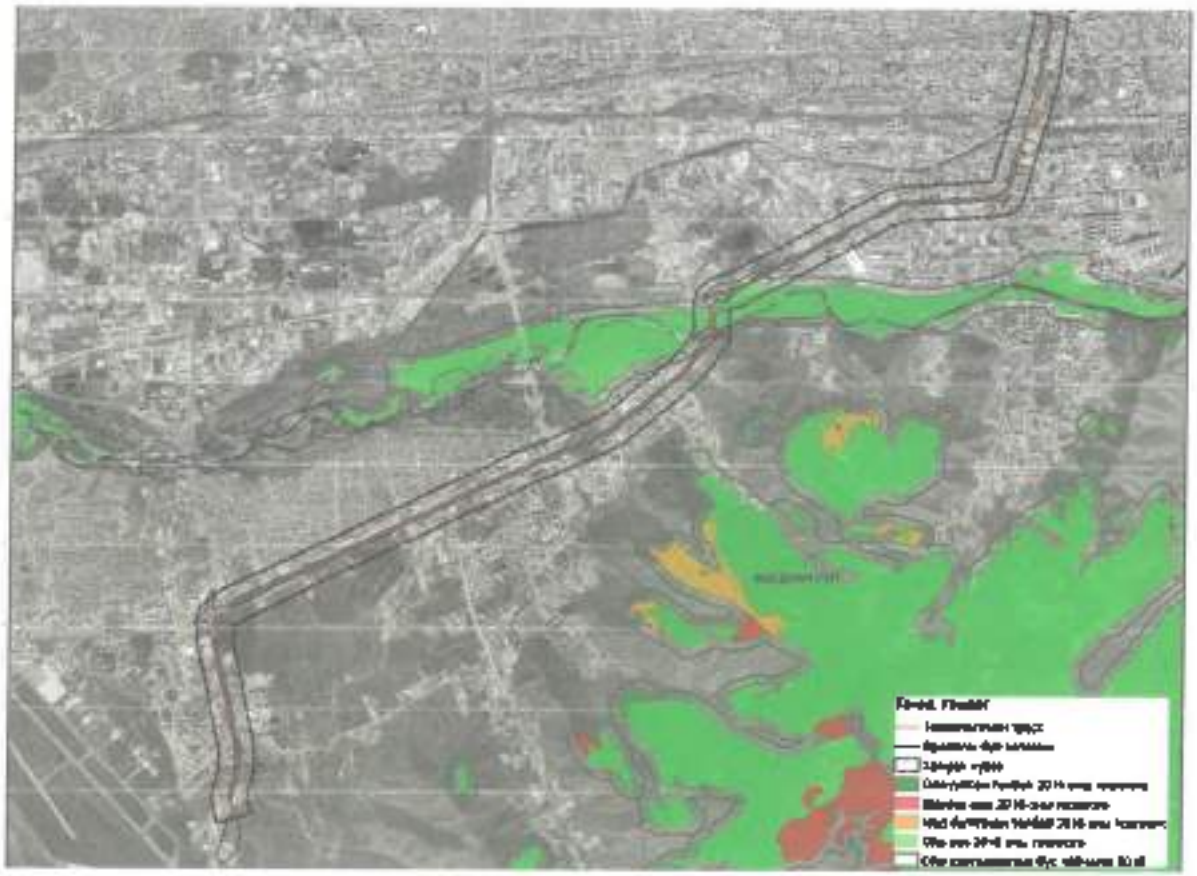
Forest Fund Territories

The forest fund area follows the Tuul River basin and passes through the Yarmag Bridge, therefore it is anticipated that no issues will arise during project implemantation.

Forest Fund Territories of the Project Area



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Specially Protected Territories

The planned route does not overlap with specially protected territory boundaries, but intersects with the restricted zone of Bogd Khan strictly protected area, and it is anticipated that no issues will arise during project implementation.

Specially Protected Territories of the Planning Area

Blue Infrastructure

The project area does not include springs, ponds, lakes, or mineral water sources, but overlaps with water fund territories' ordinary and special protection zones, water supply source restriction and protection zones, and nutrient zone boundaries. Therefore, it is necessary to follow the Water Law carefully.

Blue Infrastructure of the Planning Area

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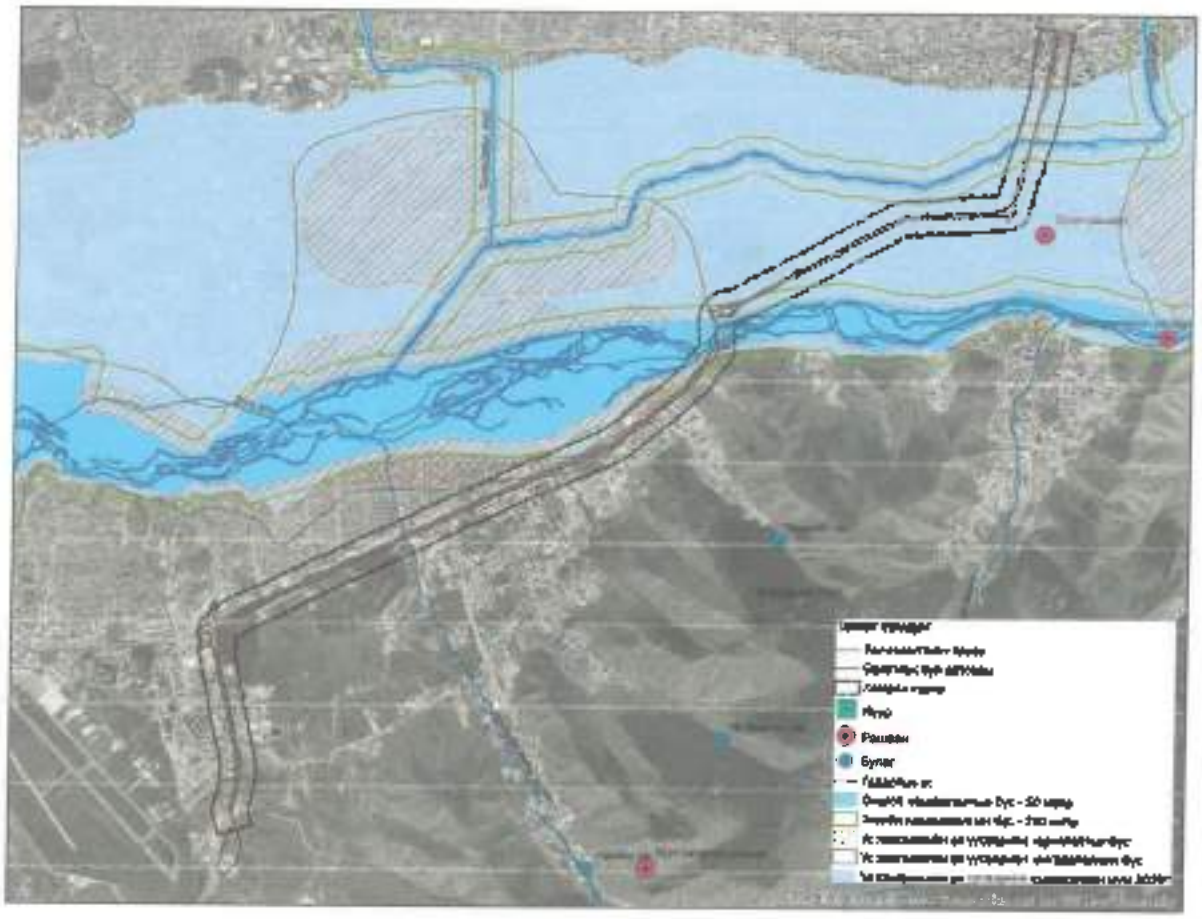

Elevation and Slope

The project for introducing multi-type public transportation from Buyant-Ukhaa Sports Complex to Torgonii Zam Complex, from the 120 thousandth intersection to Sukhbaatar Square, is planned for implementation in Ulaanbaatar City. Ulaanbaatar's surrounding terrain elevation fluctuates between 1,145-2,564 meters above sea level. 95% of the project implementation area falls into highly suitable or suitable categories, while the remaining 5% ranges from limited suitability to completely unsuitable categories.

Land Surface Slope

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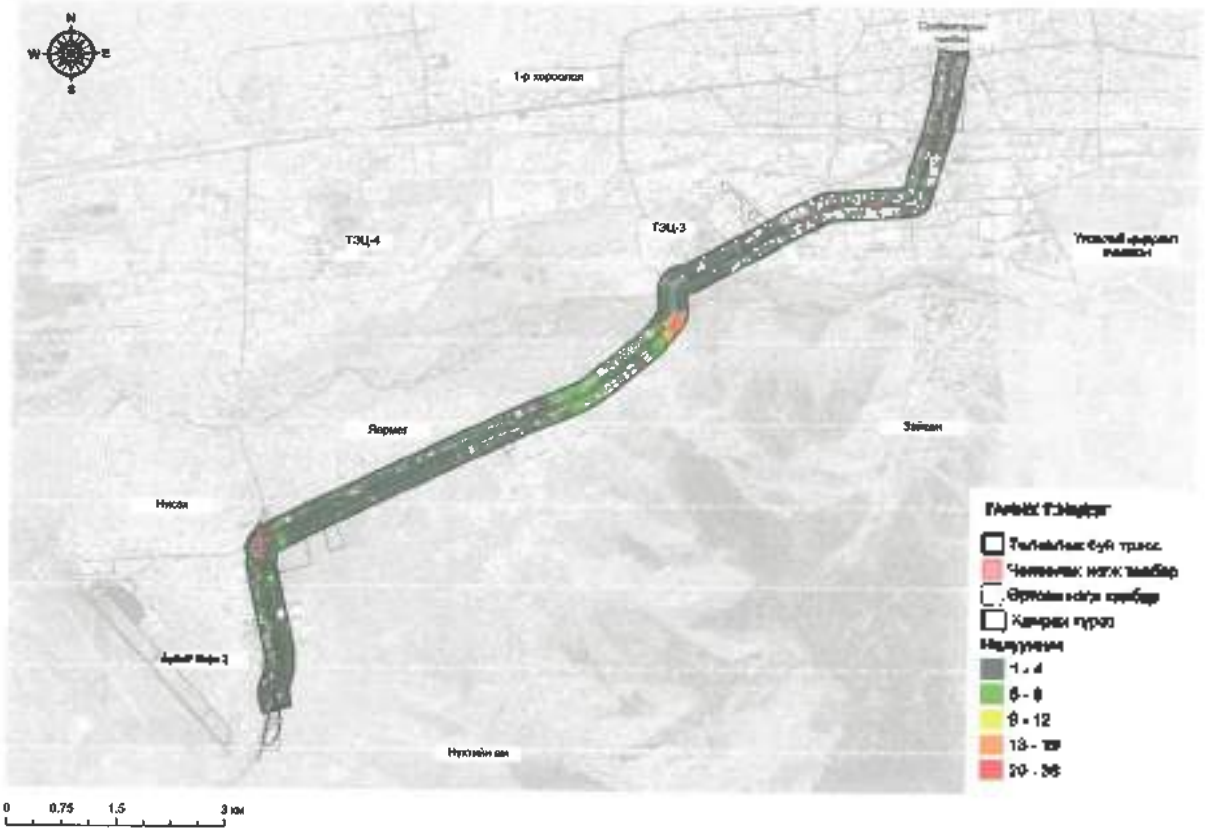

4.3. GEODETIC RESEARCH

With the rapid socioeconomic development of the country, numerous large-scale infrastructure projects including international airports, railways, highways, industrial facilities, and engineered structures are being constructed. Mongolia is now planning previously unimplemented technologies such as metro systems, dedicated transit lanes, multilevel roads, and oil and gas facilities, necessitating engineering and geodetic studies at a new level aligned with modern technology and standards.

Project Objectives

The primary objective is to establish an integrated system along the specified corridor to reduce traffic congestion and improve public transportation efficiency. This will be achieved through implementing dedicated lanes for unimpeded passenger vehicle movement. Additionally, the project aims to reduce delays caused by turning vehicles and passenger boarding by optimally positioning stations and dedicated lanes in the central portion of streets. The fare collection system will be modernized to implement pre-boarding payment, accelerating the boarding process and eliminating payment-related delays. To increase accessibility, platforms will be designed at the same level as vehicle floors, ensuring barrier-free access for wheelchair users and passengers with strollers. Traffic management improvements will include turn restrictions and priority rights for dedicated lane buses at intersections. These integrated planning measures and

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regulations aim to enhance traffic efficiency and make public transportation faster, more accessible, and more effective.

Project Scope and Location

The 1:500 scale topographic mapping work for the "Technical and Economic Feasibility Study and Design Development for Implementing Multimodal Public Transportation from Buyant-Ukhaa Sports Complex to Torgony Zam Complex, and from 120,000 Intersection to Sukhbaatar Square" was conducted along the main road covering a total of 15 km in Khan-Uul District, Ulaanbaatar. The route location is shown in Figure 24.

The geodetic measurement and mapping work was performed by professional organizations with special permits for geodetic production and services, including MSP LLC, Geodata LLC, and Best Network LLC.

Corridor Alignment Map

Project Phases

The 1:500 scale topographic mapping work for the "Technical and Economic Feasibility Study and Design Development for Implementing Multimodal Public Transportation from Buyant-Ukhaa Sports Complex to Torgony Zam Complex, and from 120,000 Intersection to Sukhbaatar Square" was carried out in the following phases:

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- Baseline research and preparatory phase
- Field measurement work
- Topographic map processing

Research of Existing/Previous Geodetic Points

The research encompassed 4 existing GNSS mapping network points established in 2024 along the route from Yarmag Bridge to the National Archives (2 points have been destroyed), and 5 second-order elevation reference points in Ulaanbaatar city, which can be utilized for subsequent field measurement and mapping operations.

Table 33. Center Point Number, Network Type

№	Point Number	Point Type	Point Status
1	255	Elevation Class II	Normal
2	264	Elevation Class II	Normal
3	227	Elevation Class II	Normal
4	515	Elevation Class II	Normal
5	238	Elevation Class II	Normal
6	Gp3000	GNSS Mapping Network	Destroyed
7	Gp3034	GNSS Mapping Network	Normal
8	Gp3062	GNSS Mapping Network	Normal
9	Gp3098	GNSS Mapping Network	Destroyed

Location Map of Leveling II Class Points Included in the Research

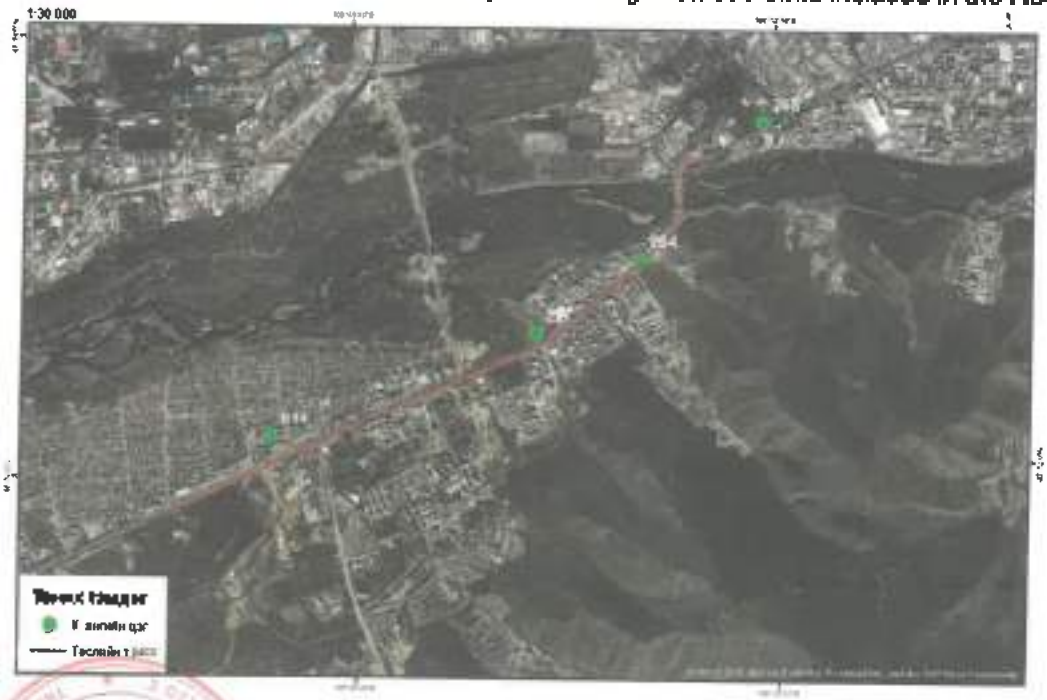

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Table 34. Center Numbers and Network Types of Newly Installed Points as Shown in the Following Table

Center Point Number, Network Type

Д/Д	Point Number	Network Type	Description
1	Gp70	GNSS Mapping Network	Newly Installed
2	Gp72	GNSS Mapping Network	Newly Installed
3	GCT-3034	GNSS Mapping Network	Newly Installed
4	GCT-3034	GNSS Mapping Network	Newly Installed
5	GCT-3034	GNSS Mapping Network	Newly Installed
6	GCT-3034	GNSS Mapping Network	Newly Installed

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Location Map of Newly Installed Points

Personal files containing details such as point names and numbers, nearby/distant photos, environmental overview maps, measurement distances, location notes, and research dates were compiled and attached to the technical report.

Positioning and Elevation Network Measurement and Processing

Coordinate Height Unified System. The work was performed in the ITRF2008 (2005.01.01) coordinate system or WGS-84 coordinate system.

I. Coordinate System: WGS-84 / Conversion Parameters / II. Height System: Baltic Sea / Geoid Height Model / III. Projection: Universal Transverse Mercator /UTM 6 degrees /

Coordinate system data is presented below:

1. *WGS_1984_UTM_Zone_48N*
2. *Projection: Universal Transverse_Mercator*
3. *False_Easting: 500000.0*
4. *False_Northing: 0.0*
5. *Central_Meridian: 105.0*
6. *Scale_Factor: 0.9996*

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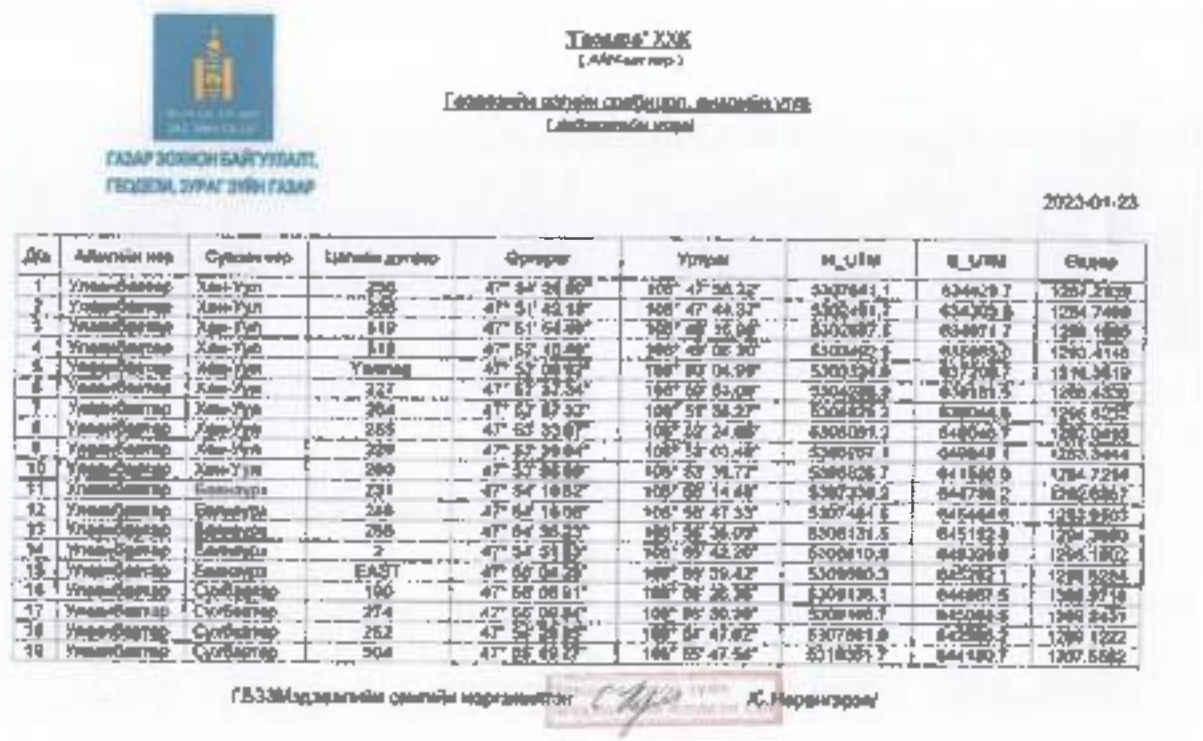
7. *Latitude_Of_Origin: 0.0*
8. *Linear Unit: Meter (1.0)*
9. *Geographic Coordinate System: GCS_WGS_1984*
10. *Angular Unit: Degree (0.0174532925199433)*
11. *Prime Meridian: Greenwich (0.0)*
12. *Datum: D_WGS_1984*
13. *Spheroid: WGS_1984*
14. *Semimajor Axis: 6378137.0*
15. *Semiminor Axis: 6356752.314245179*
16. *Inverse Flattening: 298.257223563*

Based on the project scope and work assignment, the elevation network was measured and implemented to meet the accuracy of leveling III class, based on the elevation II class reference points of Ulaanbaatar city in the Baltic Sea height system. The height values of Ulaanbaatar's III class leveling points were obtained from the Land Management, Geodesy and Cartography Agency's Information Database /Figure 33/

Table 35. *List of II Class Leveling Heights from the Land Management, Geodesy and Cartography Agency's Information Database*



ГАЗАР ЗОХИОН БАЙГУУЛАЛТ, ГЕОДЕЗИ, ЗУРАГ ЗҮЙН ГАЗАР

2023-01-23

Дд	Аймгийн нэр	Сумын нэр	Цэгийн дугаар	Өргөрөг	Уртраг	H_UTM	E_UTM	Өндөр
1	Улаанбаатар	Хан-Уул	296	47° 54' 26.80"	106° 47' 36.25"	5307641.1	634429.7	1287.2629
2	Улаанбаатар	Хан-Уул	295	47° 51' 42.18"	106° 47' 44.37"	5302481.7	634305.8	1284.7469
3	Улаанбаатар	Хан-Уул	519	47° 51' 54.99"	106° 48' 35.94"	5302887.6	633071.7	1288.1886
4	Улаанбаатар	Хан-Уул	518	47° 53' 10.49"	106° 49' 06.30"	5305402.1	632093.3	1290.4148
5	Улаанбаатар	Хан-Уул	Ymnag	47° 53' 08.93"	106° 50' 04.99"	5305324.8	631208.7	1316.3619
6	Улаанбаатар	Хан-Уул	327	47° 53' 37.54"	106° 50' 53.08"	5306288.9	630181.5	1288.4358
7	Улаанбаатар	Хан-Уул	264	47° 53' 37.32"	106° 51' 38.27"	5306276.3	629044.8	1296.6255
8	Улаанбаатар	Хан-Уул	265	47° 53' 32.07"	106° 52' 24.88"	5306091.3	628040.7	1290.0488
9	Улаанбаатар	Хан-Уул	329	47° 53' 39.64"	106° 53' 03.46"	5306337.1	627049.1	1283.3444
10	Улаанбаатар	Хан-Уул	280	47° 53' 38.66"	106° 53' 38.77"	5306328.7	626150.9	1284.7294
11	Улаанбаатар	Баянзүрх	291	47° 54' 19.82"	106° 55' 14.48"	5307738.3	624798.2	1282.6367
12	Улаанбаатар	Баянзүрх	288	47° 54' 19.06"	106° 56' 47.33"	5307484.5	623444.9	1283.9503
13	Улаанбаатар	Баянзүрх	286	47° 54' 36.23"	106° 56' 36.09"	5308131.5	623192.9	1284.3980
14	Улаанбаатар	Баянзүрх	2	47° 54' 51.15"	106° 55' 42.26"	5308610.9	624320.0	1284.1802
15	Улаанбаатар	Баянзүрх	EAST	47° 55' 04.28"	106° 55' 39.42"	5309060.3	624262.1	1288.5384
16	Улаанбаатар	Сүхбаатар	190	47° 55' 08.91"	106° 56' 26.36"	5309135.1	624867.5	1288.9718
17	Улаанбаатар	Сүхбаатар	274	47° 55' 09.84"	106° 56' 30.30"	5309166.7	625084.5	1289.8457
18	Улаанбаатар	Сүхбаатар	252	47° 55' 28.12"	106° 56' 47.62"	5307861.0	625280.2	1289.1222
19	Улаанбаатар	Сүхбаатар	304	47° 55' 49.37"	106° 55' 47.54"	5318351.7	624180.7	1307.5582

ГБЗЗМедээлэлийн сангийн мэргэжилтэн Ж.Нарангэрэл

GNSS network measurement and processing work was performed by determining the location and height values of 5 geodetic point markers. The mapping network work

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was carried out in GNSS static measurement mode. In the processing work, the Permanent Active Reference Station (PARS) used nationwide in Mongolia was utilized. The coordinate values of the PARS were officially obtained from the Land Management, Geodesy and Cartography Agency and used in the calculation work /Figure 5/.

PARS Coordinate Values

Газар зохион байгуулалт, геодези, эрдэс зүйн газрын 2023 оны 01 дугаар сарын 19-ний өдрийн 4/128 тоот албан бичгийн хавсралт

ITRF2008, (2005.01.01) эрчид тэгшитгэн бодсон БАСС -ын солбицол өндөр

Д/д	БАСС	Өргөрөг /градус. минут. секунд/	Уртраг /градус.минут.секунд/	Өндөр /метр/
1	UB01	47 55 16.829637	106 54 31.673268	1277.82834
2	UB03	47 59 22.03082	107 27 27,285189	1498.047564
3	UB04	47 46 18.828526	107 15 23.689866	1424.344971
4	TUV1	47 42 31.490109	106 57 8.737149	1489.872005

GNSS Measurement Processing Results. The final processing of coordinates for newly installed geodetic main network points along the route, showing the results as follows:

Table 36. Network Point Values

Datum:					WGS-84	
Coordinate system:					UTM	
Zone:					48N	
Geoid model					MonGeoid_pcs	
#	Point number	Northing	Easting	Elevation	Latitude	Longitude
1	ГТЦ-3066	5306232.05	840393.944	1281.605	N47°53'38.5820"	E106°52'41.7390"
2	ГТЦ-3068	5304616.626	838975.023	1301.607	N47°52'53.8718"	E106°51'31.7971"
3	ГТЦ-3036	5303856.742	837408.813	1292.922	N47°52'24.0119"	E106°50'15.2273"
4	ГТЦ-3034	5302962.648	835637.203	1297.208	N47°51'58.4206"	E106°48'49.0654"
5	ub01	5309321.087	842601.414	1314.191	N47°55'16.8296"	E106°54'31.6732"

Aerial Mapping Using Unmanned Aerial Vehicle

Aerial photography of the mapping area was conducted using an unmanned aerial vehicle along the route from Sukhbaatar Square to Yarmag Bridge in May 2024, and along the route from Yarmag Bridge to the National Archives in March 2023. For sections with changes, an additional flight was performed in March 2025 to update the orthophoto.

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Aerial photo processing was carried out using Agisoft Metashape Professional 1.5.3 Build 8407 software. After inputting aerial photo ground control point measurements, aerial photographs, and aircraft measurements, the location and elevation were adjusted using GNSS measurements taken at ground control points, ensuring correct positioning of aerial photos. The aerial images were merged to produce an orthophoto at the site scale. This orthophoto fully meets the accuracy of a 1:500 scale map, with a Ground Sampling Distance (GSD) of 0.05 meters.

Topographic Mapping Measurements and Processing at 1:500 Scale

Field topographic mapping measurements were conducted in accordance with the "1:500 Scale Topographic Mapping Work Instruction" (BD 11-106-08), ensuring positional accuracy of 0.05 meters (0.1mm * Scale) and vertical accuracy not exceeding 0.12 meters ((1/4) * Layer Height). The topographic mapping was performed in the WGS84 ellipsoid UTM coordinate system for positioning and the Baltic Sea height system for elevation. Natural and man-made objects on the ground were measured and classified according to their characteristics.

Above-ground and underground engineering network lines were measured and identified within the approved route and depicted on the topographic map. For underground engineering network lines not visible to the naked eye, specialized underground line detection equipment was used for measurement and mapping.

Underground engineering network field measurements and research were conducted in the following sequence:

- Locating manholes, measuring and determining their position and elevation
- Opening manholes, measuring manhole depth and indicators
- Determining and measuring engineering line direction and turns

After locating network line positions and turns, measurements were taken using a Trimble R8 GPS/GNSS instrument. Field measurements were performed with appropriate accuracy and coded for subsequent office processing.

For some inaccessible manholes, depth indicators were obtained from the elevation data in the Urban Development and City Standards Agency's information database.

1:500 Scale Topographic Mapping Office Processing

The engineering network mapping was performed using remote sensing indirect measurement methods, implementing a multi-faceted approach based on knowledge and innovation to increase the economic efficiency of geodetic production.

Network Base Map

- The 1:500 scale topographic map prepared during the general plan, partial general plan, construction project, and research stages was used as the base map for

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network mapping.

Field survey and research will conduct detailed investigation of the following network facilities:

- Exploring main engineering facility trunk lines
- Exploring branch main lines in settlement and industrial zones
- Exploring main utility lines within residential areas
- Investigating engineering network lines entering and leaving residential complexes, industrial, and economic areas

Field Measurement and Research for Underground Engineering Network Topographic Mapping

The measurement work was conducted by surveying using line detection equipment the positioning and routes of electrical power supply high and low voltage cable lines, communication fiber optic and physical cables, water supply, heating supply, communication, and sewage network manholes, tracing the location of water supply, heating supply, communication, and electrical line routes, and detecting the turns, entries, exits, and splice locations of street light poles and traffic light electrical connections. The detected information was positioned and incorporated into the topographic map.

For detailed information on the 1:500 scale topographic mapping to be conducted within the framework of the "Technical and Economic Feasibility Study and Design Development for Introducing Multi-Modal Public Transport from Buyant-Ukhaa Sports Complex to Torgonii zam Complex, from 120 thousandth Intersection to Sukhbaatar Square", please refer to the supplementary report.

4.4. GEOLOGICAL RESEARCH

Geosurvey LLC conducted engineering-geological research along a 15.8 km route in March 2025 within the framework of the "Technical and Economic Feasibility Study and Design Development for Introducing Multi-Modal Public Transport from Buyant-Ukhaa Sports Complex to Torgonii Complex, from 120 thousandth Intersection to Sukhbaatar Square" project.

A total of 33 boreholes were drilled to a depth of 5.0 meters along the route, with 167 linear meters of drilling performed. To determine the physical-mechanical properties of the underlying soil, 69 samples were taken and analyzed at the Soil Research Laboratory of the Geological and Urban Engineering School of the University of Science and Technology.

- *Geomorphologically*, the research area is located in the central part of Mongolia, in the southeastern part of the Khentii Mountain range, on the II terrace alluvial and accumulative surface of the Tuul River. The area has a geographical

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characteristic of Tuul River terrace and flat terrain. Along the route, there are accumulative, transitional, and piedmont surfaces with gentle slopes.

- *Geologically*, the area's geological structure is characterized by Carboniferous (C1-2ou) Orgioch Mountain formation sandstones, covered with deluvial-proluvial (*dpQ2*) clay-sandy gravels, clay-sandy gravels with clay inclusions, alluvial-proluvial (*apQ2*) gravels with sandy inclusions, sandy gravels with sandy inclusions, alluvial (*aQ2*) sandy gravels with inclusions, and technogenic (*tQ2*) fill soils with varying thicknesses depending on the surface slope.
- *Hydrogeologically*, groundwater was detected at depths of 3.1-4.2 meters in boreholes 06, 07, 08, 09, 10, 11, 12 drilled along the RT01 route to a depth of 5.0 meters. The groundwater is unconfined, with a free surface, directly fed by atmospheric precipitation and the Tuul River's adjacent areas. Groundwater level fluctuations depend on annual precipitation, ranging from 0.7-1.3 meters. Chemical analysis was performed on water samples from boreholes where groundwater was detected.

Sample 1: Chemical analysis of a sample taken from a depth of 3.7 m in borehole BRT01BH-08 revealed groundwater of the hydrocarbonate-sulfate class, sodium-calcium group, type II composition, with a neutral environment, fresh and soft water. Pollution indicators were detected within acceptable limits. The water meets the requirements of "Water Technical Conditions for Use in Concrete and Building Mortars UST 3821 - 85", although acid aggressiveness was noted, suggesting the use of high-grade cement would be advisable. The water's chemical composition can be expressed using Curlov's formula:

$$M\ 0.3\ \frac{HCO^3\ 54.7\ \ SO^4\ 38.4}{Na\ 40.7\ Ca\ 32.8\ Mg\ 24.1} \qquad pH\ 6.91$$

Sample 2: Chemical analysis of a sample taken from a depth of 3.5 m in borehole BRT01BH-11 revealed groundwater of the hydrocarbonate-sulfate class, sodium-calcium group, type II composition, with a neutral environment, fresh and soft water, accompanied by pollution indicators. The water from this aquifer does not meet the requirements of "Water Technical Conditions for Use in Concrete and Building Mortars UST 3821–85". The water's chemical composition can be expressed using Curlov's formula:

$$M\ 0.3\ \frac{HCO^3\ 52.7\ \ SO^4\ 32.6}{Na\ 42.4\ Ca\ 33.1\ Mg\ 22.9} \qquad pH\ 6.87$$

Along the research route, no significant physical-geological phenomena or processes have developed. However, in the Yarmag section of the special-purpose road, during spring and summer seasons with precipitation and flood waters, there is a possibility of water entering from the branched streams of the Nukhi Valley mouth. Therefore, it is advisable to design temporary drainage channels on both sides of the road to divert such water.

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- *In terms of engineering-geological conditions*, 6 types of soil were identified along the BRT01 route, categorized into 6 engineering-geological elements. The distribution of soils and rocks in the area is as follows: between boreholes 01-05, alluvial-proluvial sandy gravel deposits; between boreholes 06-13, alluvial deposits; between boreholes 14-26, deluvial-proluvial deposits; between boreholes 27-37, alluvial-proluvial deposits.
  Based on these conditions, the planned road route falls within an area with moderately complex engineering-geological conditions.
- The seasonal soil freezing depth, earthwork complexity, and deformation degree for the soils distributed in the research area are shown in Table 1.

Table 37. Soil Freezing Depth, Earthwork Complexity, and Deformation Degree

No.	Rock name	Soil origin/Rock symbol	Soil condition/Rock symbol: Moisture	Soil condition/Rock symbol: Flowability index	Specific electrical resistance /Ом·м/	Freezing heave coefficient	Earthwork classification grade	Seasonal freezing depth, m
								ПВ
1	Sandy compacted gravel	aQ_2	Low moisture content		570	Non-heaving	III	3.5
			Water saturated		310		III	3.5
2	Sandy compacted pebbles	apQ_2	Low moisture content		550	Non-heaving	III	3.5
3	Sandstone compacted pebbles			solid	620	Heaving	IV	3.5
4	Clay loam containing pebbles	dpQ_2		solid	110	Heaving	II	2.5
5	Clay loam compacted pebbles			solid	820	Strong	IV	3.5
6	Sandstone	$C_{1-2}du$			955	-	VII	-

Table 38. Physical-mechanical and weathering properties of rock soils

Nr.	Rock Name	Indicator	Index	Unit	Numerical Value: maximum	minimum	average
1	Carboniferous Sandstone IGE-6	Natural Density	$\gamma_{ш}$	g/cm³	2.69	2.56	2.62
		Weathering Degree	$K_{вв}$				0.95
		Temporary Resistance to Uniaxial Compression	Rc	kgs/cm²			120
		Hardness Degree					VII

Table 39. Normative and calculated values of soil mechanical property indicators

Nr	Soil name	Flowability index, Liquidity coefficient, W	Cohesion force	Internal friction angle	Deformation modul, Eсоil
			Ccoil	φcoil	

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			MPa	degree	MPa
Alluvial sediment geological-origin complex /aQ2/					
1	Sandy compacted gravel	-/0.028	0.002	43	50
		-/0.130	0.002	43	50
Alluvial-proluvial sediment geological-origin complex /dpQ2/					
2	Sandy compacted pebbles	-/0.026	0.002	43	50
3	Sandstone compacted pebbles	-/0.066	0.01	35	45
Deluvial-proluvial sediment geological-origin complex /dpQ2/					
4	Clay loam containing pebbles	-/0.126	0.038	27	60
5	Clay loam compacted pebbles	-/0.093	0.019	30	67

- ***Permafrost soil*** **was not detected in the study area.**
- **The study area belongs to the VII (PSA 110-142 cm/s2) - VIII intensity zone (two zones differentiated by PSA 143-190 cm/s2 and 191-205 cm/s2) according to the Ulaanbaatar city seismic microzonation map.**

Table 40. Drillhole Catalogue

No	Borehole number	Depth, m	Coordinates		Elevation, m	Groundwater level, m		Drilling date
			X	Y		detected	established	
1	BRT01BH01	5	5308949	643251	1261.27	-	-	2025.03.09
2	BRT01BH02	5	5306512	643113	1257.00	-	-	2025.03.09
3	BRT01BH03	5	5308124	643036	1263.35	-	-	2025.03.09
4	BRT01BH04	5	5307483	642859	1252.64	-	-	2025.03.09
5	BRT01BH05	6	5307057	642743	1252.14	-	-	2025.03.09
6	BRT01BH06	5	5306644	642376	1251.31	-	-	2025.03.09
7	BRT01BH07	5	5306816	641875	1249.56	-	-	2025.03.10
8	BRT01BH08	5	5306748	641384	1248.87	-	-	2025.03.10
9	BRT01BH09	5	5306515	640943	1247.71	-	-	2025.03.10
10	BRT01BH10	5	5306276	640505	1246.18	-	-	2025.03.10
11	BRT01BH11	5	5306040	640064	1245.38	3.10	-	2025.03.10
12	BRT01BH12	5	5305805	639624	1244.95	3.20	-	2025.03.10
13	BRT01BH14	2	5305247	639332	1249.55	-	-	2025.03.10
14	BRT01BH15	5	5305011	639169	1259.15	-	-	2025.03.10
15	BRT01BH16	5	5304683	638940	1267.11	-	-	2025.03.10
16	BRT01BH17	6	5304387	638453	1260.10	-	-	2025.03.10
17	BRT01BH18	6	5304092	638038	1256.32	-	-	2025.03.10
18	BRT01BH19	6	5303874	637524	1256.52	-	-	2025.03.10
19	BRT01BH20	5	5303694	637119	1259.60	-	-	2025.03.10
20	BRT01BH21	5	5303484	636667	1260.47	-	-	2025.03.11
21	BRT01BH22	5	5303267	636214	1260.31	-	-	2025.03.11
22	BRT01BH23	5	5303053	635764	1260.44	-	-	2025.03.11
23	BRT01BH24	5	5302838	635313	1258.87	-	-	2025.03.11
24	BRT01BH25	5	5302623	634862	1254.54	-	-	2025.03.11
25	BRT01BH26	6	5302413	634420	1250.32	-	-	2025.03.11
26	BRT01BH27	5	5302193	633959	1259.60	-	-	2025.03.11
27	BRT01BH31	5	5301851	633716	1272.18	-	-	2025.03.11
28	BRT01BH32	5	5301364	633822	1274.30	-	-	2025.03.11
29	BRT01BH33	6	5300875	633928	1284.03	-	-	2025.03.11
30	BRT01BH34	5	5300383	634005	1289.68	-	-	2025.03.11
31	BRT01BH35	5	5299877	633902	1293.29	-	-	2025.03.10
32	BRT01BH36	5	5299467	634080	1305.73	-	-	2025.03.10
33	BRT01BH37	6	5299082	634118	1310.24	-	-	2025.03.10

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4.5. LAND USE STUDY

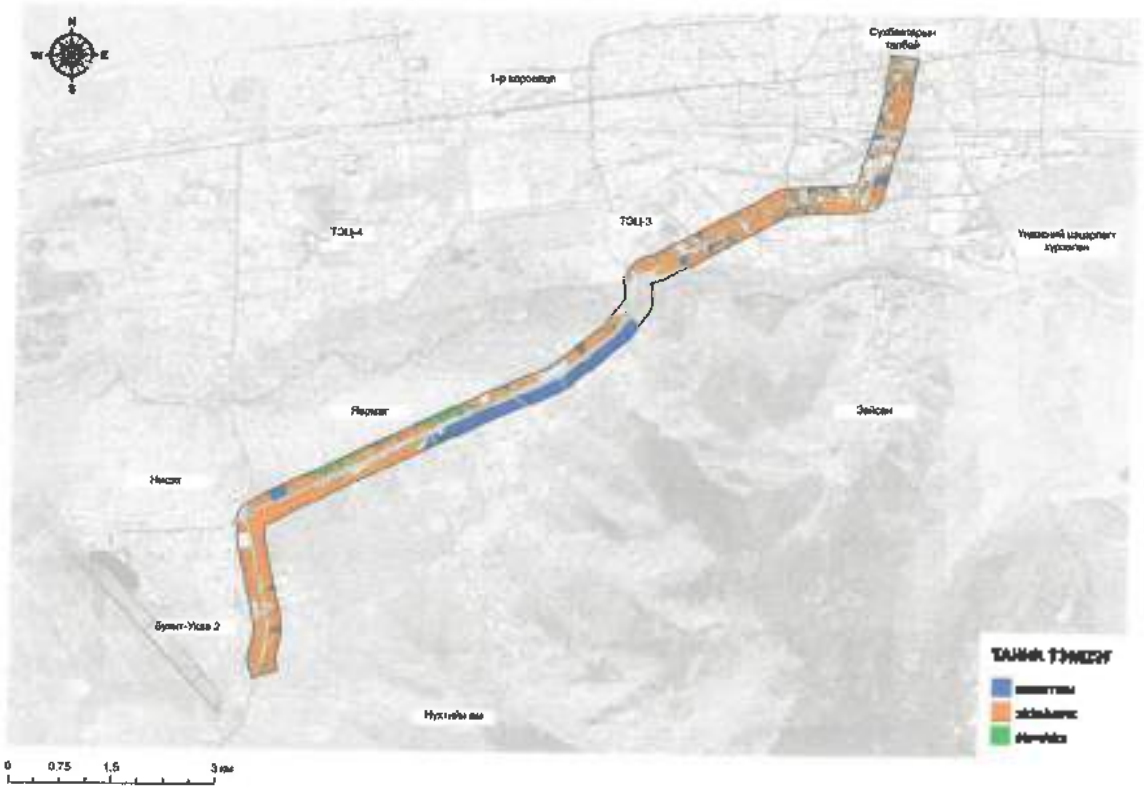
Land Legal Status

Within the planning scope, a total of 383.3 hectares of land across 1136 land units have been allocated for ownership, possession, and use by citizens and business entities. Of these, 15.2 hectares across 405 land units have been allocated for ownership, 291 hectares across 624 land units for possession, and 77.1 hectares across 107 land units for use.

Table 41. Land Legal Status Area Balance

No	Right Type	Number of Land Units	Percentage	Area (ha)	Percentage
1	possession	624	55%	291.0	76%
2	ownership	405	36%	15.2	4%
3	use	107	9%	77.1	20%
Total		1136	100%	383.3	100%

Legal Status of Land Rights in the Project Area



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Land Use Purpose

When examining land use purposes, land has been allocated for 33 different purposes. Of these, 17.2 hectares of land in 452 parcels were allocated for ger districts and residential fenced areas, which accounts for 39.8% of total land allocations. 97.2 hectares of land in 264 parcels were allocated for trade, public service areas, centers, and complexes, accounting for 23.2% of total land allocations. 58.4 hectares of land in 75 parcels were allocated for residential with commercial services, accounting for 6.6% of total land allocations. 59 hectares of land in 61 parcels were allocated for tourism and travel bases, accounting for 5.4% of total land allocations. 151 hectares of land in 284 parcels were allocated for other purposes, accounting for 25% of total land allocations.

Land Use Purposes of the Project Area

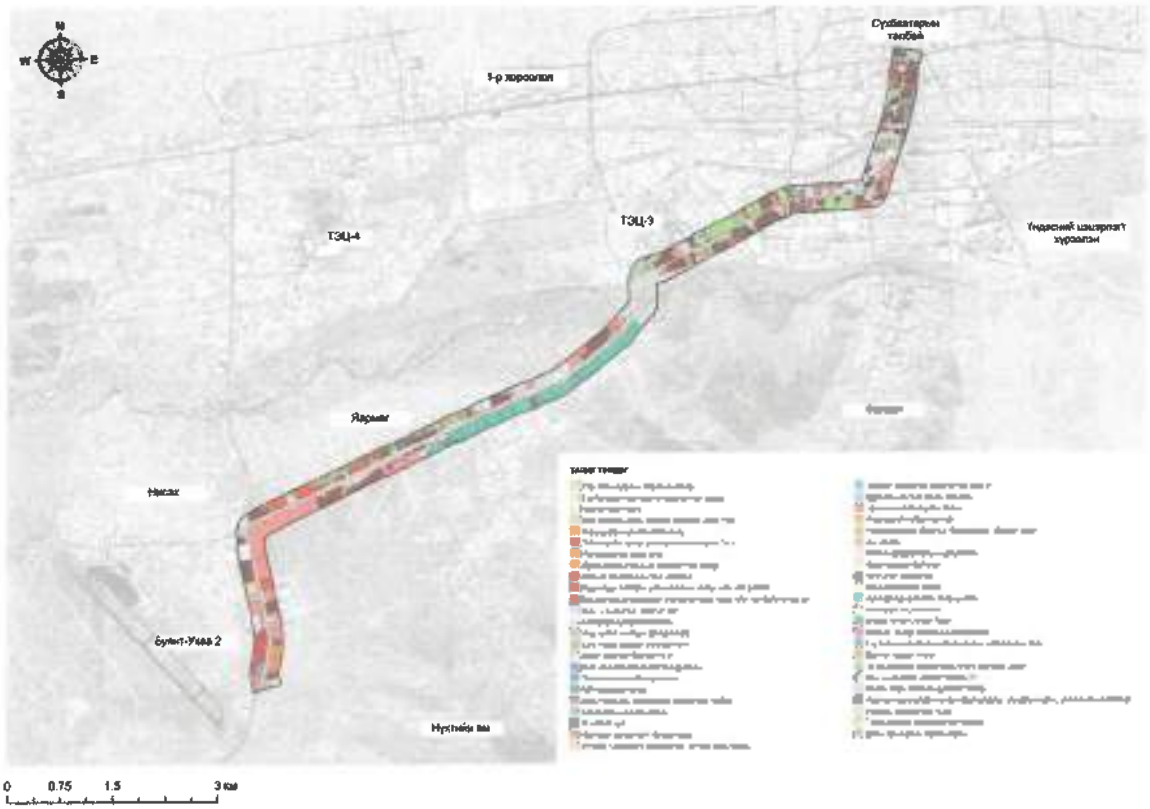

Table #2. *Land Purpose Area Balance*

No.	Land Purpose	Number of units	Percentage	Area (ha)	Percentage
1	4 and fewer story public apartment buildings	3	0.30%	3	0.80%

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2	5-8 story public apartment buildings	12	1.10%	7.3	1.90%
3	9 and more story public apartment buildings	39	3.40%	19.8	5.20%
4	Auto transport vehicle checkpoint area	1	0.10%	0	0.00%
5	Automobile garage	1	0.10%	0	0.00%
6	Business entity	7	0.60%	1	0.30%
7	Official residence	19	1.70%	1.6	0.40%
8	Tourism and resort base	61	5.40%	59	15.40%
9	Physical training and sports facilities	6	0.50%	2.9	0.70%
10	Educational facilities	28	2.50%	12.2	3.20%
11	Foreign country diplomatic representative office, UN organization facilities	1	0.10%	0.2	0.10%
12	Ger and residential housing fence land	452	39.80%	17.2	4.50%
13	Higher education institution facilities	7	0.60%	0.2	0.10%
14	Cultural complex, public apartment complex	3	0.30%	3.2	0.80%
15	Tree nursery land	1	0.10%	0.3	0.10%
16	Museum, theater, cultural monument land	1	0.10%	0.1	0.00%
17	Lake, public facility	1	0.10%	0.2	0.10%
18	Public possession other lands	23	2.00%	25.9	6.80%
19	Public possession green facilities, flower garden, improved area	3	0.30%	6.2	1.60%
20	Iron road protection zone	3	0.30%	0.7	0.20%
21	Religious organization facilities	45	4.00%	21.4	5.60%
22	Art, cultural facilities	1	0.10%	0.1	0.00%
23	Production office	6	0.50%	3.1	0.80%
24	Production buildings, facilities, other lands	39	3.40%	30.3	7.90%
25	Service-integrated apartment buildings	75	6.60%	58.4	15.20%

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26	Food production complex	4	0.40%	2	0.50%
27	Communication, information transmission, receiving station	1	0.10%	0	0.00%
28	Communication, information transmission network	1	0.10%	0.1	0.00%
29	Trade, public service area, center, complex	264	23.20%	97.2	25.40%
30	Temporary residence land, housing	13	1.10%	5.2	1.30%
31	New scientific facility	1	0.10%	0.5	0.10%
32	Health medical facilities	7	0.60%	3.5	0.90%
33	Energy transmission station	7	0.60%	0.2	0.10%
Total		1136	100.00%	383.3	100.00%

Project Area Road Network

The project location extends from the Buyant Ukhaa Complex to the Silk Road Complex, and from the 120 thousandth intersection to Sukhbaatar Square, designed for multi-type public transportation. The project area covers Khan-Uul district's 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 15th, 18th, 19th, 20th, 21st, 22nd, 23rd, 24th, and 25th khoroos; Sukhbaatar district's 1st and 2nd khoroos; and Bayangol district's 3rd and 26th khoroos. It spans from the southern parking area of Sukhbaatar Square to the General Archives Office, covering a 15.0 km long, 800 m wide space with a total area of 1272.83 hectares.

Table 43. Road Classification and Length within the Project Area

Road Classification	Length (km)
1st class main road (vertical axis)	14
1st class auxiliary roads	8.6
2nd class auxiliary roads	3.6
Total	26.2

The majority of the road classification within the project area consists of a 14 km long vertical axis 1st class main road. The 1st class auxiliary roads in the project area have a total length of 8.6 km, while the 2nd class auxiliary roads are 3.6 km long, meaning the vertical axis auxiliary roads cover a relatively small area.

Project Area Road Network

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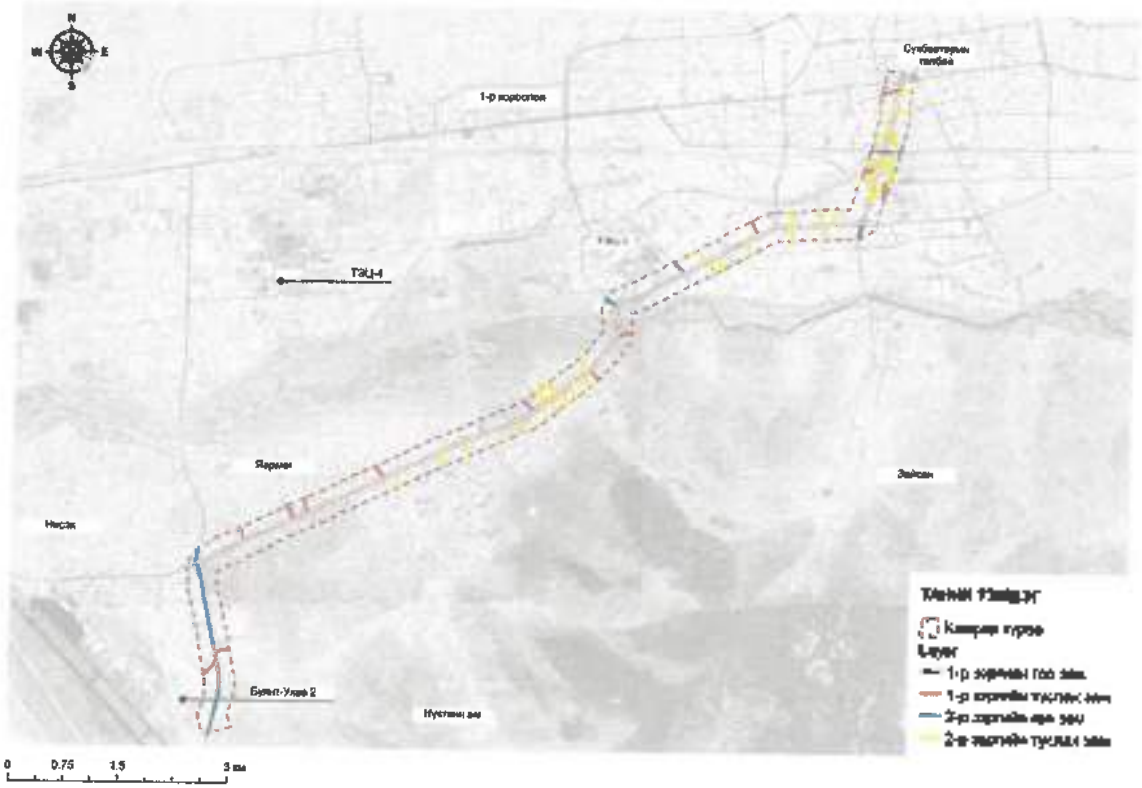

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CHAPTER 5.PLANNING CONCEPT

5.1. INCORPORATION IN THE GENERAL DEVELOPMENT PLAN (2040)

The optimization and improvement of the city's public transportation network is designed to ensure comfortable travel conditions for residents and citizens, while supporting sustainable economic growth and environmental stability of the city. The planning of the city's public transportation network has been developed based on the city's street network planning solutions through 2040.

During the planning period, reaching the 2040 level, by implementing phased upgrades to the public transportation network and public passenger vehicle fleet throughout Ulaanbaatar, daily passenger circulation will reach 1.2 million, increasing capacity by 50% from the current level. The city's public transportation development is based on the following principles:

- Optimize and improve the public transportation network
- Introduce high-capacity public transportation types
- Coordinate with external transportation planning to optimize the use of railway lines passing through the city for public transportation needs
- Further improve and develop large bus services, increase passenger carrying capacity, upgrade the fleet, and improve service quality
- Develop taxi services to meet modern requirements
- Implement modern information technology in public transportation services
- Create conditions for prioritizing public transportation in city traffic

Public Transportation Network Structure (by 2040): By optimizing and improving public transportation service routes and increasing high-capacity public transportation types, network overlap and network length will decrease while capacity and service accessibility will increase. The city's public transportation routes will be planned and developed along the horizontal and vertical axes of the city's street network, eliminating current public transportation route overlaps and reducing travel time by 2-2.5 times. During the planning period (by 2040), the plan includes 42.23 km of metro, 10 km of LRT, 61.15 km of BRT, and 7.1 km of aerial cable transportation network.

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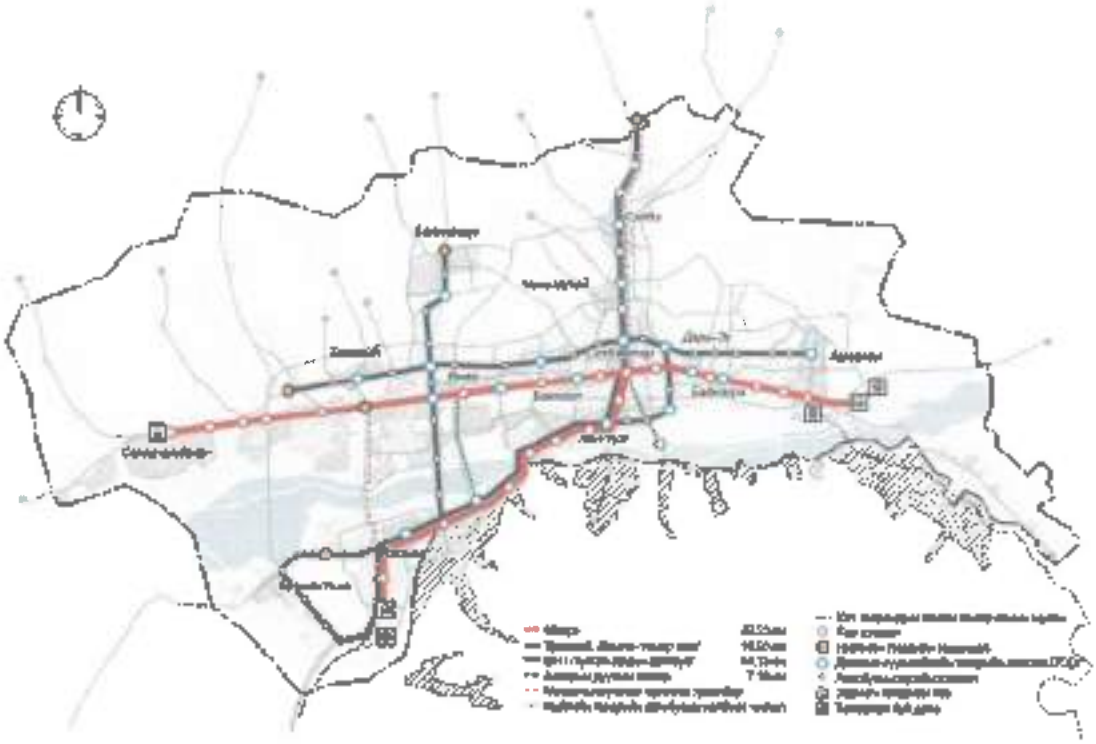

Table 44. Projected Capacity of the Public Transport Network by 2040

No	Type	Length, km	Number of Buses	Passenger Capacity, passengers/hour
1	Metro 1st Line	27.1	20	36000
2	Metro 2nd Line	15	10	36000
3	Intercity Bus Transit (BRT)	61.15	49	13000
4	Light Rail Transit (LRT)	10	8	25000
5	City Center Integrated Transit	7.1	4	3000

Metro

Metro construction research in Ulaanbaatar began in 2007, and based on city traffic calculations, the metro will transport 36,000 passengers per hour in one direction. Two main metro line routes are planned:

1st line: New sub-center - along Peace Avenue - to Ulastai station. 27.1 km long, 20 stations, 100% underground facility.

2nd line: From Sukhbaatar city center to Buyant-Ukhaa city. 15 km long. 10 stations. 100% underground facility.

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Bus Rapid Transit (BRT) The Bus Rapid Transit will run along Ard Ayush Avenue - Great Circle Road - Namyanjug Street - Niislel Khuree Avenue, and additionally along Naadamchid Road, Bayankoshuu Street, and Chinggis Avenue, with 61.15 km, 49 stations, carrying 13,000 passengers per hour in one direction.

Light Rail Transit (LRT) The Light Rail connecting the resort area from Zunjin Shopping Center to Sukhbaatar Square is planned to be 10 km long with 8 stations, carrying 25,000 passengers per hour in one direction.

Aerial Cable Transportation By 2040, two lines of aerial cable transportation with a total length of 7.1 km are planned, with the final project solution to be approved based on detailed technical and economic feasibility studies. This type of transportation aims to reduce traffic congestion and facilitate citizen mobility.

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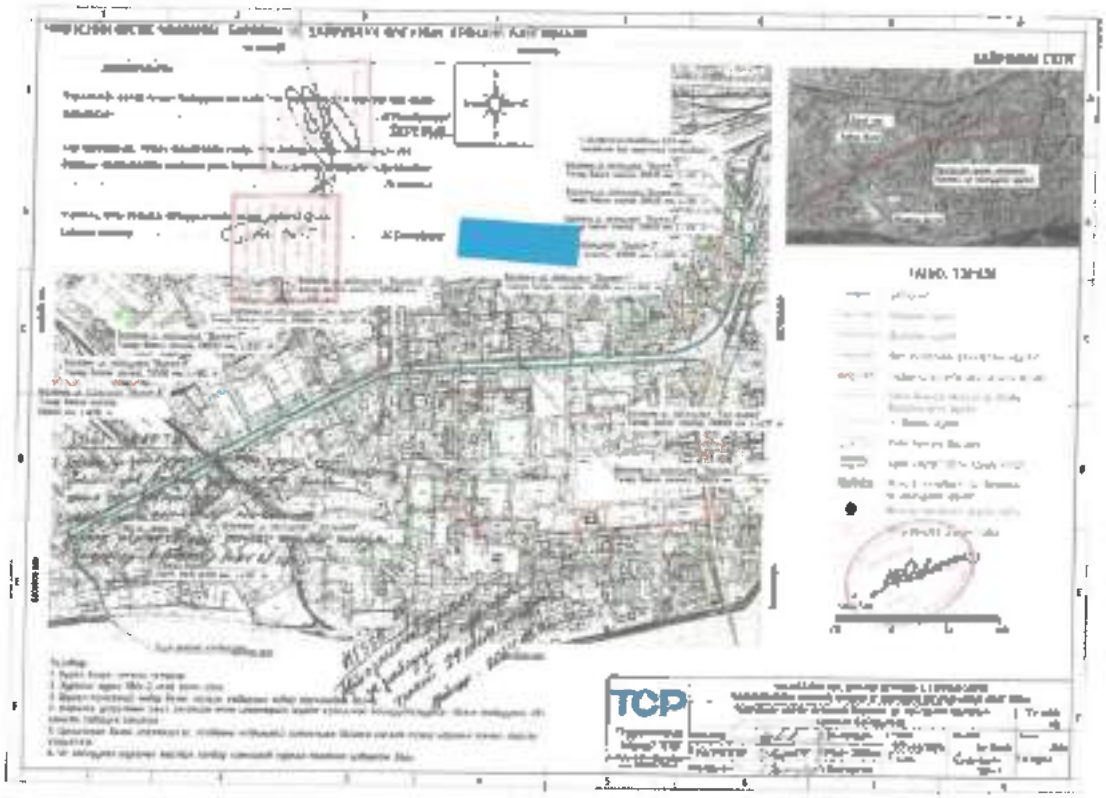
5.2. PROJECT AND PROGRAM RESEARCH

5.2.1. Road and Road Facility Works Planned Along the Project Planning Route

Chinggis Avenue Stormwater Drainage System

According to the Ulaanbaatar City General Manager's Order No. A/97 dated May 14, 2024, and the work implementation contract ZAA/KhTSI-2024-A/97, the "Design, budget and research work for flood protection facility repairs, renovations, and new construction at 24 locations in Ulaanbaatar city territory" was developed by the "Urban Planning Research Institute" SOE. The unified state inspection conclusion for the design and budget of these 24 locations was issued and handed over to the client organization with 3% completion on October 18, 2024. The normative research work being conducted within this project is currently in the consultation and discussion stage with relevant organizations.

Chinggis Avenue stormwater drainage system



Chinggis Avenue Public Pedestrian Walkway Improvement Work

According to the Mayor's Order No. A/510 dated May 6, 2024, the public pedestrian walkway improvement work was developed by the "Urban Planning Research Institute" SOE. The unified

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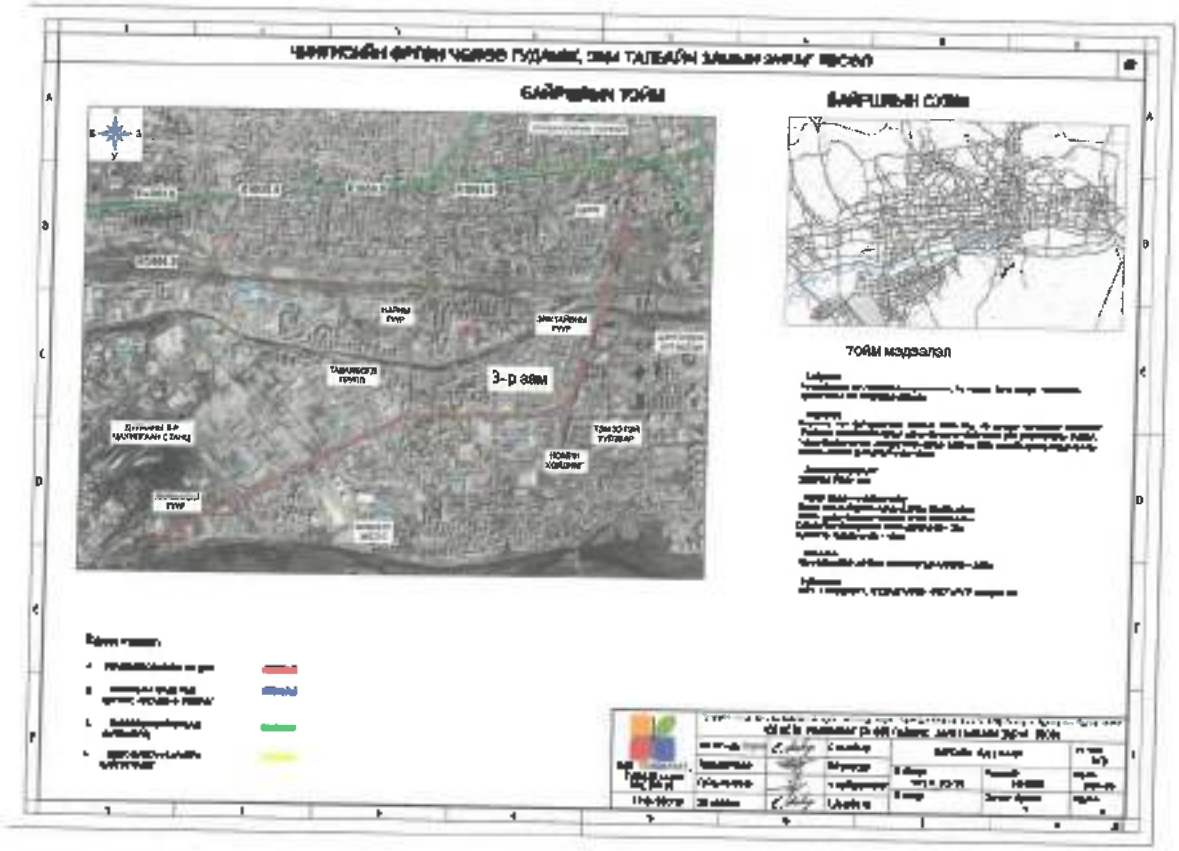
state inspection conclusion for the design and budget of 6 locations was issued and handed over to the client organization with 3% completion on August 22, 2024.

Public pedestrian walkway improvement work



Chinggis Avenue Road Partial Repair and Renovation (From Peace Bridge to Camel Monument, and from 120 Camel Monument to TEC 3 Intersection)

According to the Mayor's Order No. A/685 dated June 12, 2024, the Chinggis Avenue road partial repair and renovation work was developed by the "Urban Planning Research Institute" SOE. The unified state inspection conclusion for the design and budget was issued and handed over to the client organization with 3% completion on November 25, 2024.

800-meter Bridge Over Naadamchid Street Connecting Tuul Road with Nukhtiin Road

According to the Capital City Mayor's Order No. A/523 dated June 30, 2021, the design was developed by "GBET" LLC.

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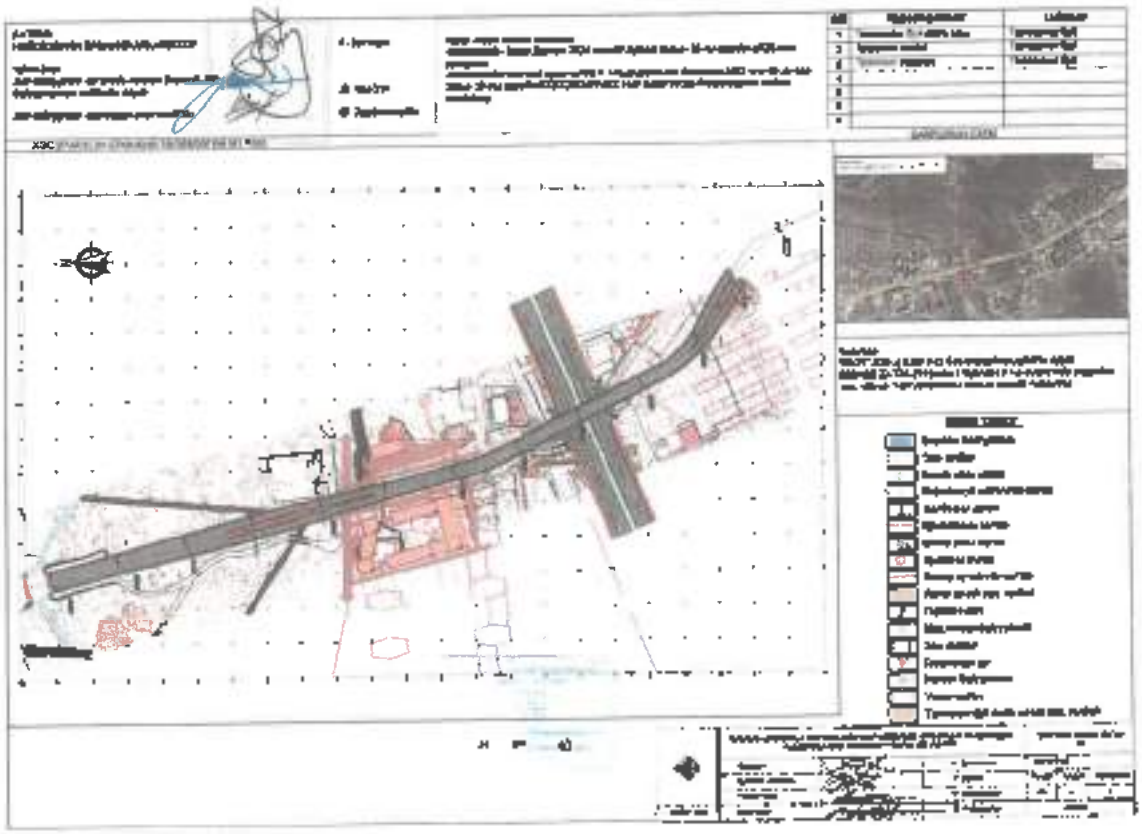
Bridge work design



Chinggis Avenue Expansion and Renovation Design (Khan-Uul District, 3rd and 20th Khoroos, from the east side of Yarmag Bridge to the Workers Street Intersection)

According to the Capital City Mayor's Order No. A/1311 of 2022, the design was developed by "GRC" LLC.

Road work design

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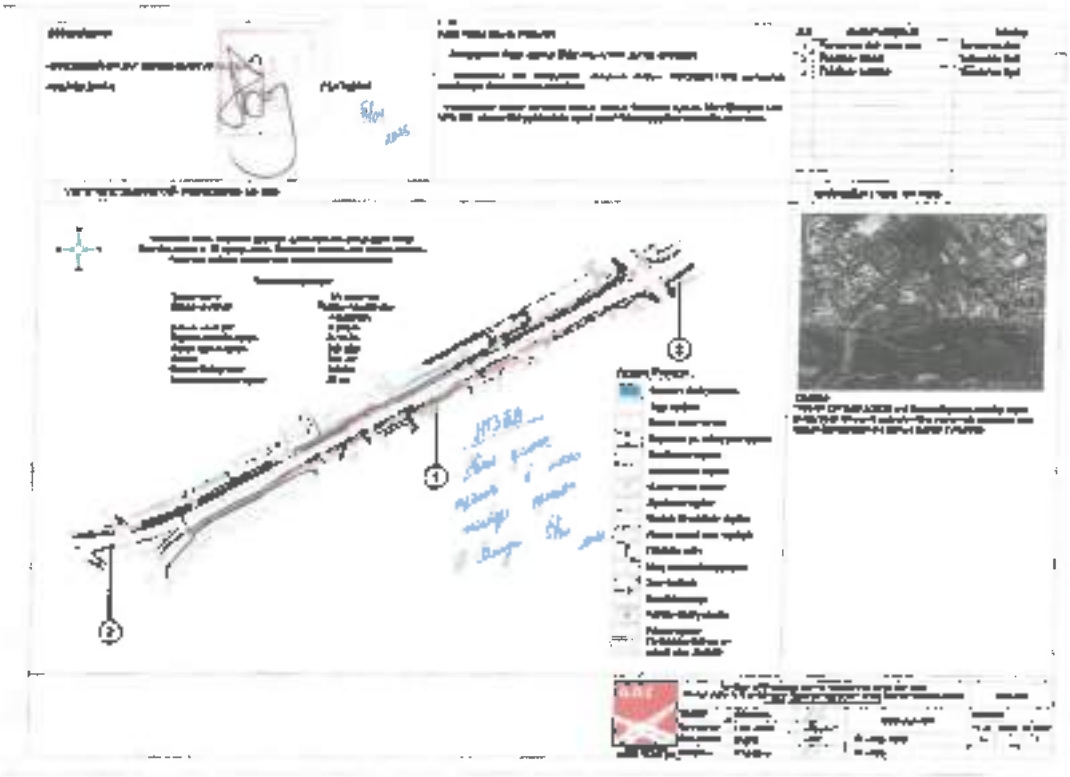

Chinggis Avenue road partial repair and renovation work

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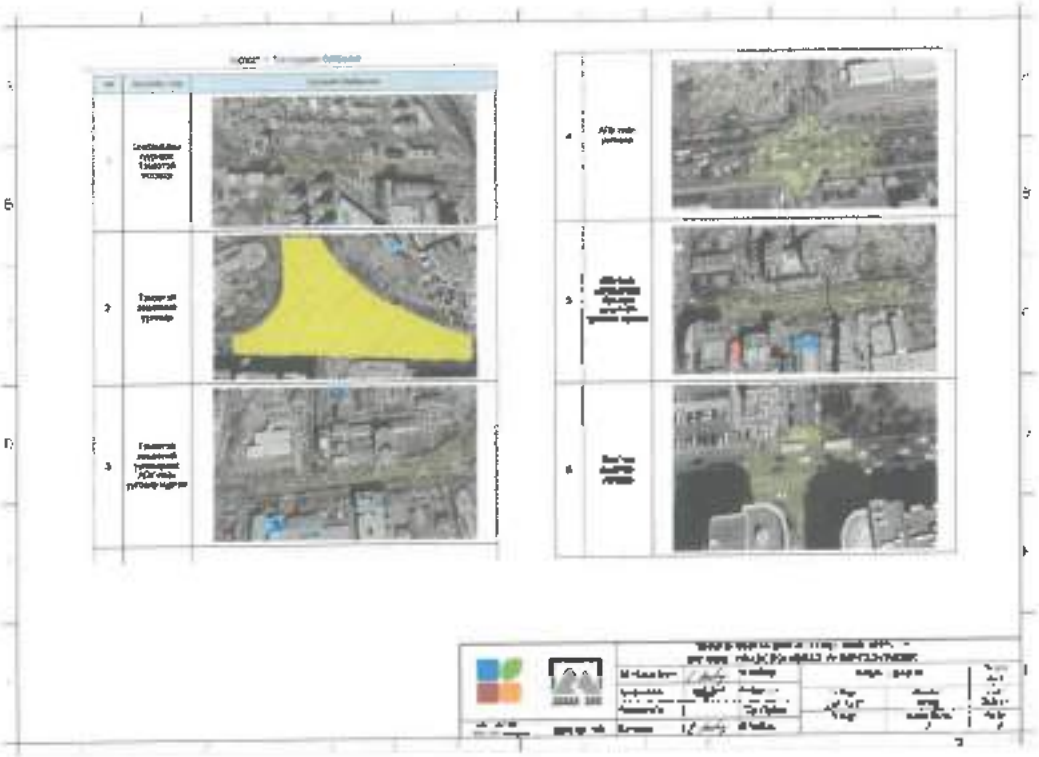

Buildings with Architectural Planning Assignments in the Planning Area

Within the scope of the project area, there are 706 buildings with architectural planning assignments. The foundation area of these buildings covers 143.7 hectares, while the total building area occupies 483.3 hectares.

Buildings with architectural planning assignments in the planning area

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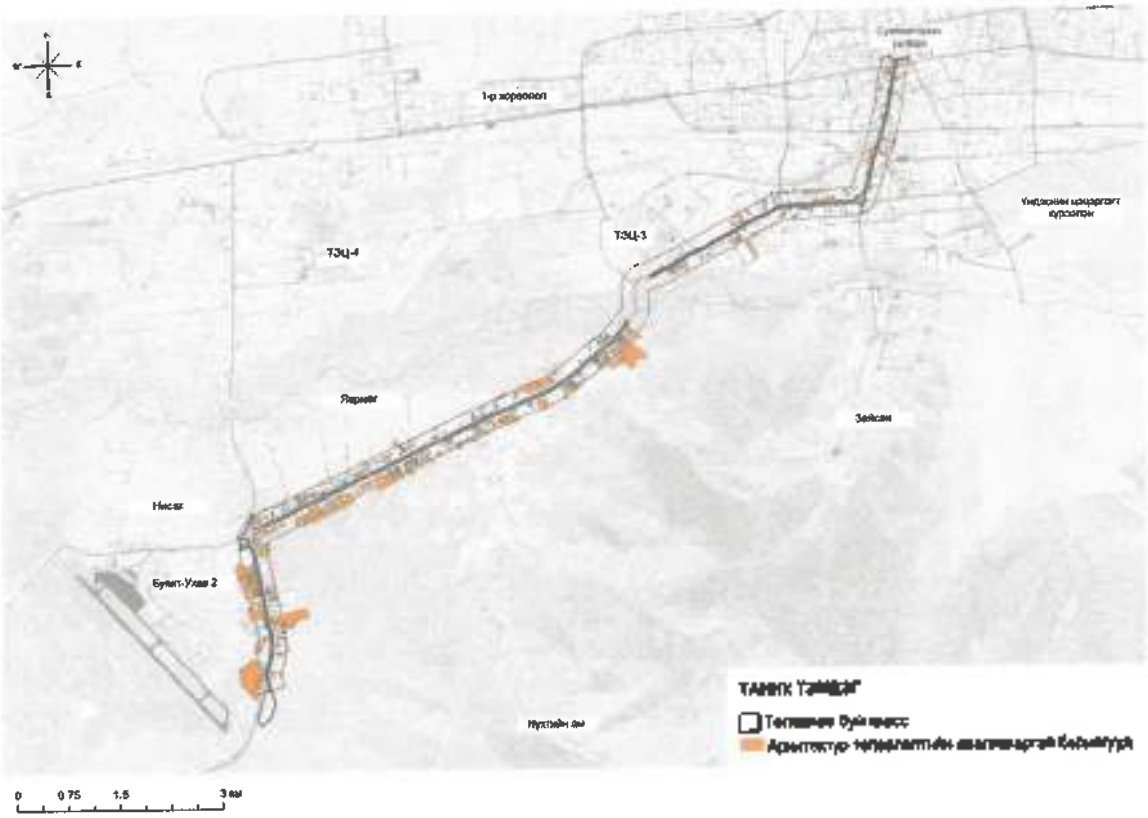

5.3. POLICY DOCUMENT RESEARCH

Vision 2050

"Vision 2050" is Mongolia's long-term development policy approved by the Parliament of Mongolia on May 13, 2020, with the fundamental goal of making Mongolia a leading Asian country in terms of social development, economic growth, and quality of life by 2050. The implementation of the tram project will contribute to achieving the following objectives:

- Creating a human-centered, environmentally friendly, smart city
- Ensuring ecosystem balance and reducing greenhouse gas emissions
- Introducing green technology in urban areas
- Optimizing underground space utilization for transportation, roads, and engineering networks
- Implementing multi-modal, smart public transportation

Ulaanbaatar City Development Master Plan Until 2040

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The evaluation of Ulaanbaatar's Development Master Plan until 2030 highlighted deficiencies such as slow development of satellite cities and imbalanced infrastructure. To address these issues, a new plan based on public input and expert recommendations has been developed and is in the approval stage. The implementation of the multi-model public transportation (tram) project will support the Ulaanbaatar City Development Master Plan 2040 in the following ways:

- Optimizing public transportation routes and increasing high-capacity transit options to reduce network overlap, decrease network length, and increase capacity and service accessibility
- Enabling bus auxiliary routes with shorter circuits to connect passengers from peripheral areas to main routes and distribute to city outskirts
- Increasing high-capacity light rail modes to handle 60% of public transportation trips and enabling an average public transportation speed of 30 km/hour
- Connecting 4 cities from among 14 city centers

20-Minute City National Program

Mongolia's "20-Minute City" strategy is a key component of the government's comprehensive urban and rural revitalization initiative. This innovative approach aims to reduce urban concentration, create self-developing urban centers, and address Ulaanbaatar's pressing issues. Our project supports the following core objectives:

- Addressing Ulaanbaatar's urbanization issues
- Reducing urban concentration
- Creating self-developing urban centers
- Improving accessibility of government services

New Revival Policy

The "New Revival Policy" is a medium-term targeted program aimed at strengthening Mongolia's economic independence, reducing the negative economic impact of the COVID-19 pandemic, promptly addressing development constraints, creating foundational conditions for implementing the "Vision 2050" long-term development policy, and improving economic, infrastructure, and government productivity. Our project supports this program by:

- Improving the quality and standards of public transportation in Ulaanbeetar, introducing new types of high-capacity public vehicles, expanding and modernizing the main road network and road facilities, building multi-level intersections to increase accessibility, and reducing traffic congestion

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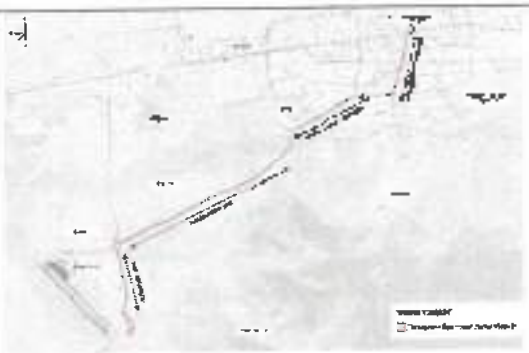
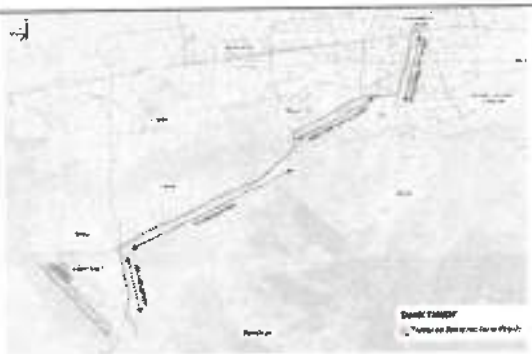
CHAPTER 6. ROUTE SELECTION

- Alternative conditions
- Land acquisition

6.1. ALTERNATIVE CONDITIONS

Table 45. Project route proposals

1		Road length - 14.6 km Single lane expansion - 2.77 km Double lane expansion - 0.52 km Number of lanes - 2 Railway length - 15.3 km Number of stations - 21 Stations with single-level crossings - 21 Stations with service centers - 0 Rolling stock - 16
2		Road length - 13.3 km Single lane expansion - 2.77 km Double lane expansion - 0.2 km Number of lanes - 2 Railway length - 15.3 km Number of stations - 21 Stations with single-level crossings - 21 Stations with service centers - 2 Rolling stock - 16
3		Road length - 13.5 km Single lane expansion - 0 Double lane expansion - 1.2 km Number of lanes - 2 Railway length - 15.7 km Number of stations - 22 Stations with single-level crossings - 22 Stations with service centers - 2 Rolling stock - 16

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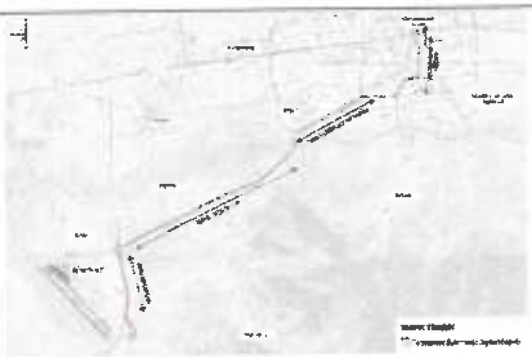
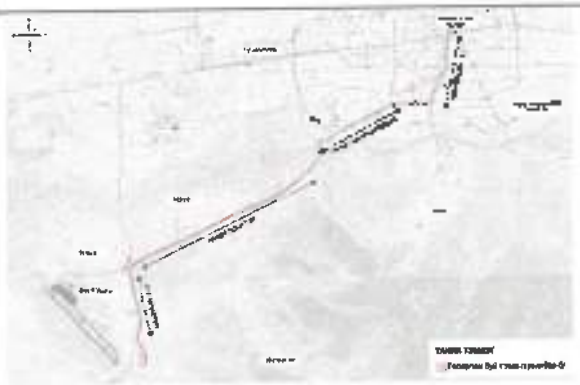
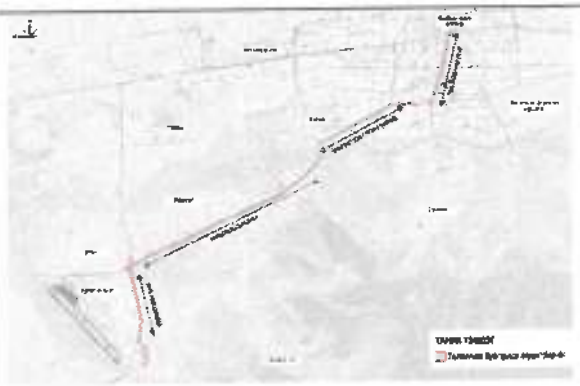
4		Road length - 13.4 km Single lane expansion - 0 Double lane expansion - 1.2 km Number of lanes - 2 Railway length - 15.8 km Number of stations - 23 Stations with single-level crossings - 23 Stations with service centers - 2 Rolling stock - 16
5		Road length - 13.6 km Single lane expansion - 2.77 km Double lane expansion - 0.4 km Number of lanes - 2 Railway length - 15.4 km Number of stations - 22 Stations with single-level crossings - 22 Stations with service centers - 2 Rolling stock - 16
6		Road length - 12.5 km Single lane expansion - 2.77 Double lane expansion - 0.52 Number of lanes - 2 Railway length - 15.2 km Number of stations - 21 Stations with single-level crossings - 21 Stations with service centers - 2 Rolling stock - 16

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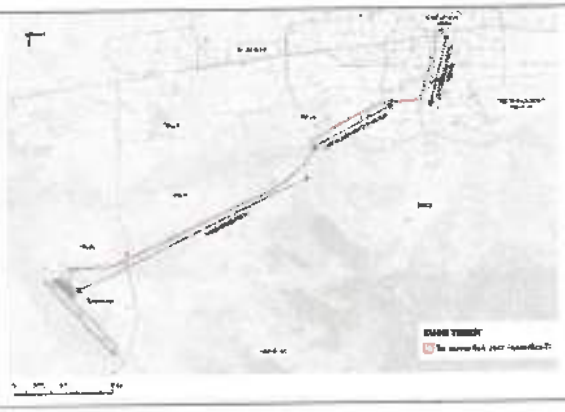
7		Road length - 14.3 km Single lane expansion - 2.77 Double lane expansion - 1.92 Number of lanes - 2 Railway length - 14.6 km Number of stations - 23 Stations with single-level crossings - 23 Stations with service centers - 2 Rolling stock - 16

In selecting the planning route, a total of seven alternatives were developed, compared, and thoroughly studied. These alternatives were evaluated based on several key indicators including primary travel direction, suitability of turns, land acquisition requirements, and engineering infrastructure complexity. Based on this comprehensive assessment, Alternative 1 was identified as the optimal solution and selected for implementation.

6.2. LAND ACQUISITION CALCULATION

LAND LEGAL STATUS

Along the planned route, a total of 28,245 sq.m of land across 59 land units have been allocated for possession and use by citizens and business entities. Of these, 28,131 sq.m across 55 land units have been allocated for possession, and 114 sq.m across 4 land units have been allocated for use.

Table 46 Land Legal Status Area Balance (sq.m)

No	Right Type	Number of Land Units	Percentage	Area (sq.m)	Percentage
1	Ownership	55	93%	28,131	99.6%
2	Usage	4	7%	114	0.4%
Total		59	100%	28,245	100.0%

Land Legal Status (land units affected by the planned route)

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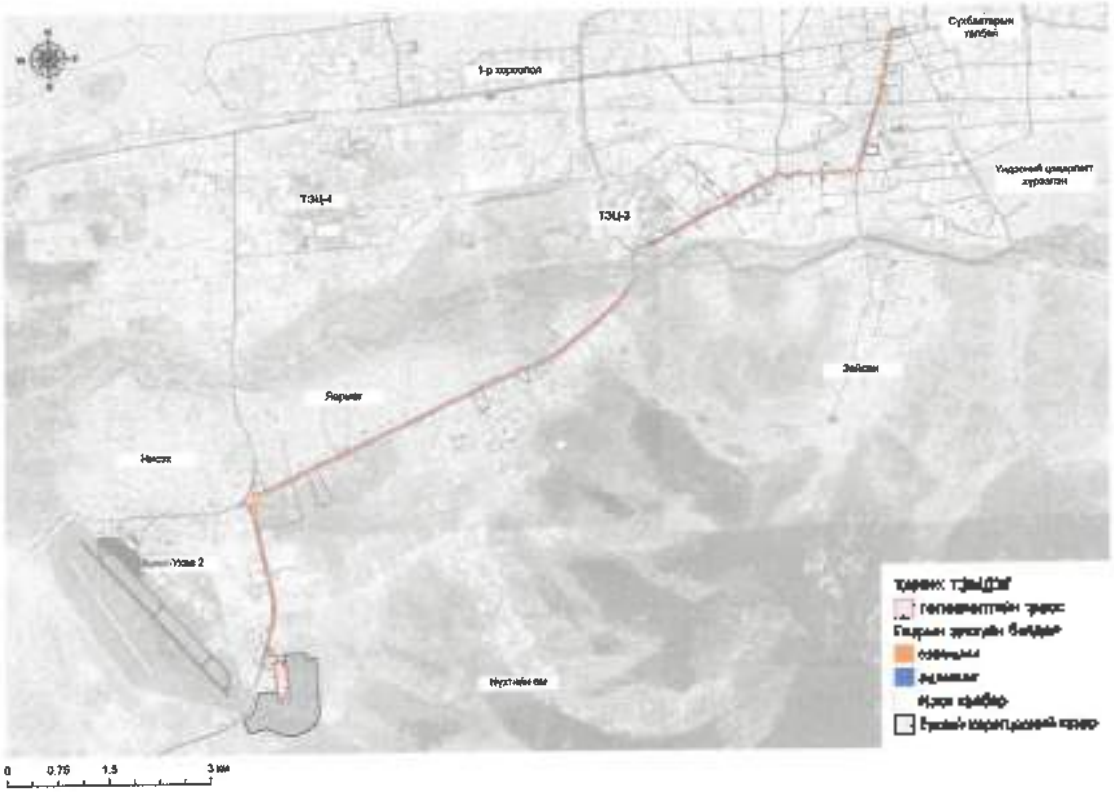

Land Use Purposes

When examining land use purposes, land has been allocated for 16 different types of purposes. Of these, 7,559 sq.m across 28 land units have been allocated for trade, public service areas, centers, and complexes, representing 47% of total land allocations. 1,210 sq.m across 6 land units have been allocated for production buildings, facilities, and other land purposes, accounting for 10% of total land allocations. 630 sq.m across 6 land units have been allocated for residential purposes with commercial services, accounting for 10% of total land allocations. 18,846 sq.m across 19 land units have been allocated for other purposes, accounting for 32% of total land allocations.

Table 47. Land Purpose Area Balance (sq.m)

No	Land Regulation	Number of Regulations	Regulation Percentage	Cumulative Number of Regulations	Cumulative Percentage
1	5-8 Inch Pipeline Residential Buildings	1	2%	461	1.60%
2	8 Bar and Above Residential Buildings	1	2%	57	0.20%
3	Tourism and Recreation Areas	2	3%	85	0.30%
4	Educational Institutions	2	3%	448	1.60%

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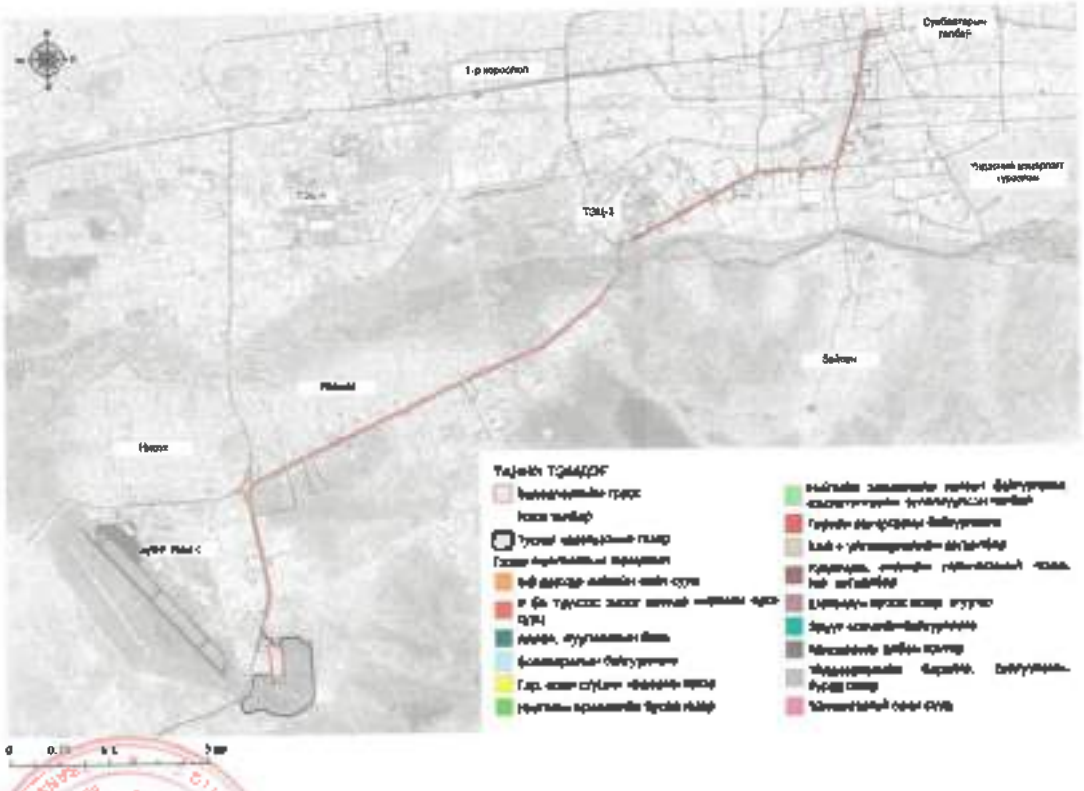
5	Individual Residential Plot Areas	1	2%	2,096	7.40%
6	Public Property Land	2	3%	12,471	44.20%
7	Public Green Spaces, Police Facilities	2	3%	412	1.50%
8	Railway Protection Zones	1	2%	1	0.00%
9	Government Administrative Buildings	2	3%	1,737	6.10%
10	Industrial Office Facilities	2	3%	65	0.20%
11	Industrial Buildings, Facilities, Other Areas	6	10%	1,210	4.30%
12	Service-Oriented Residential Areas	6	10%	630	2.20%
13	Agricultural Complex	1	2%	548	1.90%
14	Trade, Public Service Areas, Central Complex	28	47%	7,559	26.80%
15	Fuel Stations and Storage	1	2%	333	1.20%
16	Operational Safety Regulations	1	2%	139	0.50%
Total		59	100%	28,245	100%

Land Use Purposes (land units affected by the planned route)



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Land Valuation and Land Acquisition

To implement the Land Payment Law and implement urban redevelopment activities, the land valuation zones, grades (zones), base valuations, and land payment amounts were approved by Government Resolution No. 182 of June 20, 2018. Appendix 3 of this resolution provides the base valuation of 1 hectare of land for the 6 central districts of the capital city, and Appendix 4 provides the base valuation for the 3 remote districts, with 16 valuation grades for each specific purpose.

The base valuation of urban, town, and other settlement land is determined by land grade, taking into account location, engineering supply, social, economic, engineering, geological, and environmental conditions.

Table 46. Government Resolution No. 182 of 2018, Appendix 3. Land Valuation Grades (Zones) and Base Valuation of 1 hectare of land in the Bayangol, Bayanzurkh, Chingeltei, Songinokhairkhan, Sukhbaatar, and Khan-Uul districts of the Capital City

Land Valuation Grade (zone) number	Family common use	Budgetary organization official use	Public residential housing	Trade and all types of services	Petroleum product storage, gas stations	All types of parking (garages) construction (above ground, underground)	Public land	Engineering networks and their infrastructure buildings and facilities	Railway, airport buildings and facilities	Railway, airport protection zones	Land allocated to foreign diplomatic or consular representations and international organization offices	Religious buildings, temples, monasteries	Chemical toxic substances, leather, wool, cashmere factories, treatment facilities and hazardous waste production	All types of production (except agriculture)	Agricultural production	Mining extraction operation areas	Mining production areas
0	Base Valuation of 1 hectare of land (million MNT)																
1.	819.0	323.8	967.4	1,280.0	1,408.0	960.0	380.2	967.4	967.4	366.1	760.3	1,309.5	1,408.0	1,408.0	-	-	-

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2.	764.0	220.8	652.8	1,216.0	1,344.0	768.0	259.2	652.8	652.8	249.6	518.4	892.8	1,344.0	1,344.0	-	1,408.0	1,408.0
3.	490.0	178.8	522.2	1,216.0	1,280.0	576.0	207.4	522.2	522.2	199.7	414.7	744.3	1,280.0	1,280.0	-	1,344.0	1,344.0
4.	436.0	132.5	391.6	1.152.0	1,216.0	576.0	155.5	391.7	391.7	149.8	311.0	535.6	1.216.0	1,216.0	-	1,280.0	1.280.0
5.	382.0	132.5	391.6	1,088.0	1,216.0	512.0	155.5	391.7	391.7	149.8	311.0	535.6	1,216.0	1.216.0	-	1.216.0	1.216.0
6.	273.0	117.8	348.2	960.0	1,152.0	448.0	138.2	348.2	348.2	133.1	276.5	476.1	1.152.0	1.152.0	-	1,216.0	1.216.0
7.	245.0	103.0	304.6	896.0	1.088.0	384.0	121.0	304.6	304.6	116.5	241.9	416.7	1,088.0	1,088.0	-	1,152.0	1.152.0
8.	191.0	88.3	261.1	1.024.0	1.024.0	256.0	103.7	261.1	261.1	99.8	207.4	357.1	1,024.0	1,024.0	96.0	1.088.0	1,088.0
9	136.0	58.8	174.1	896.0	896.0	384.0	69.1	174.1	174.1	66.5	138.2	238.0	896.0	896.0	64.0	1,024.0	1,024.0
10.	109.0	88.3	261.1	896.0	1,024.0	320.0	103.7	261.1	261.1	99.8	207.4	357.1	1,024.0	1,024.0	96.0	896.0	896.0
11.	55.0	73.6	217.6	1.024.0	960.0	256.0	86.4	217.6	217.6	83.2	172.8	297.6	960.0	960.0	80.0	1,024.0	1.024.0
12.	27.0	58.9	174.1	768.0	896.0	256.0	69.1	174.1	174.1	66.5	138.2	238.0	896.0	314.0	64.0	960.0	960.0
13.	18.0	58.9	174.1	768.0	896.0	128.0	69.1	174.1	174.1	66.5	138.2	238.0	896.0	462.0	64.0	896.0	896.0
14.	-	29.4	87.0	576.0	768.0	128.0	34.5	87.0	87.0	33.3	69.1	119.1	768.0	105.0	32.0	896.0	896.0
15.	-	29.4	87.0	448.0	768.0	102.4	34.5	87.0	87.0	33.3	69.1	119.1	768.0	84.0	32.0	768.0	768.0
16.	-	23.6	69.6	192.0	384.0	102.4	27.7	69.6	69.6	26.6	55.3	95.2	384.0	76.0	25.6	384.0	768.0

The project route covers zones 1, 2, 4, 5, 6, 7, and 8

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Alternative 1

Land acquisition for Alternative 1 was calculated with widths of 38 meters along Olzii Road, 42 meters along Naadamchid Road, 28 meters along Chinggis Avenue, and 25 meters along Peace Avenue.

The base valuation for land acquisition of 28,245 sq.m across 59 land units affected by the route is 1.4 billion MNT. The valuation for 4,375 sq.m across 7 land units affected by the transformer substation location is 0.56 billion MNT, bringing the total land acquisition compensation to 2.0 billion MNT.

Land Acquisition (Alternative-1)

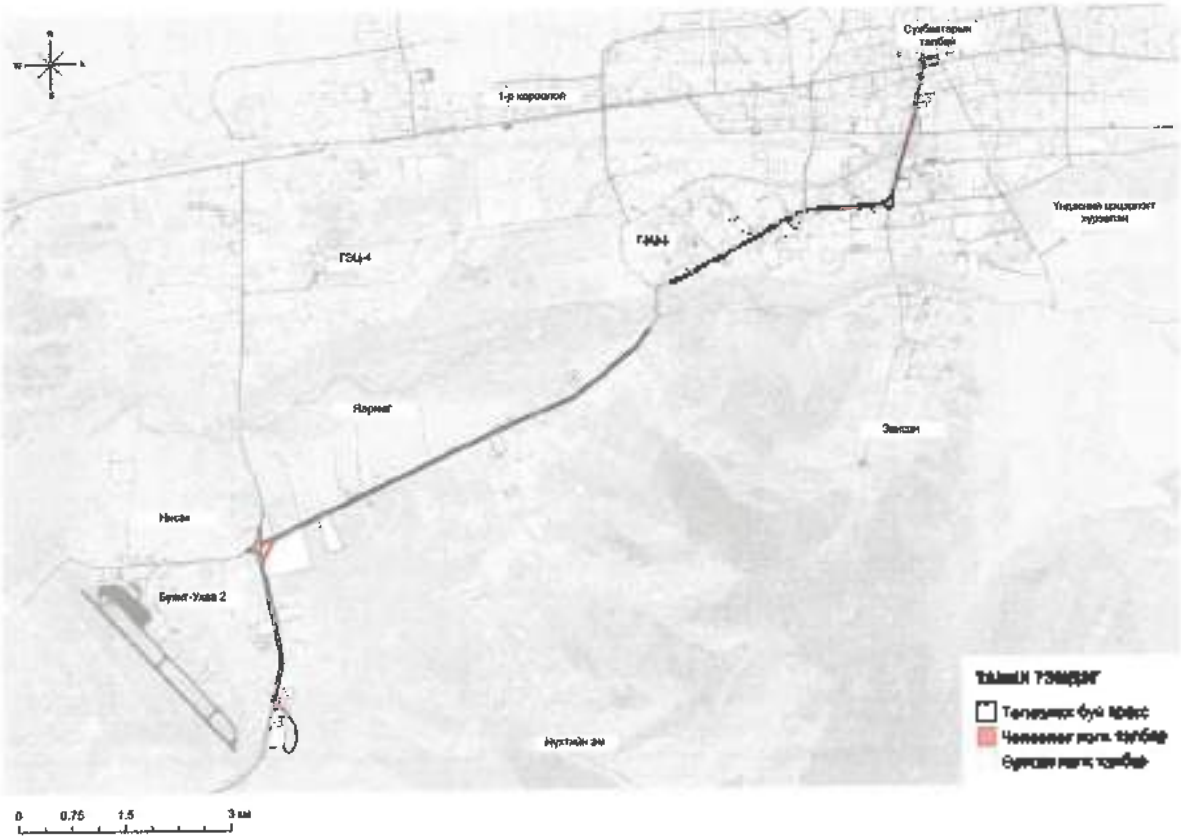

Table 49. Base Valuation of Land Acquisition for Land Units Affected by the Route (Alternative-1)

No.	Alternative-1	Number of land units	Area (sq.m)	Land acquisition cost (million MNT)
1	Route-1	59	28,245	1,437.7
2	Transformer substation	7	4,375	560
Total		62	32,620	1,997.7

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Alternative 2

Land acquisition for Alternative 2 was calculated with widths of 38 meters along Ulzit Road, 42 meters along Naadamchid Road, 28 meters along Chinggis Avenue, and 35 meters along Peace Avenue.

The base valuation for land acquisition of 28,532 sq.m across 62 land units affected by the route is 1.63 billion MNT. The valuation for 4,375 sq.m across 7 land units affected by the transformer substation location is 0.56 billion MNT, bringing the total land acquisition compensation to 2.2 billion MNT.

Land Acquisition (Alternative-2)

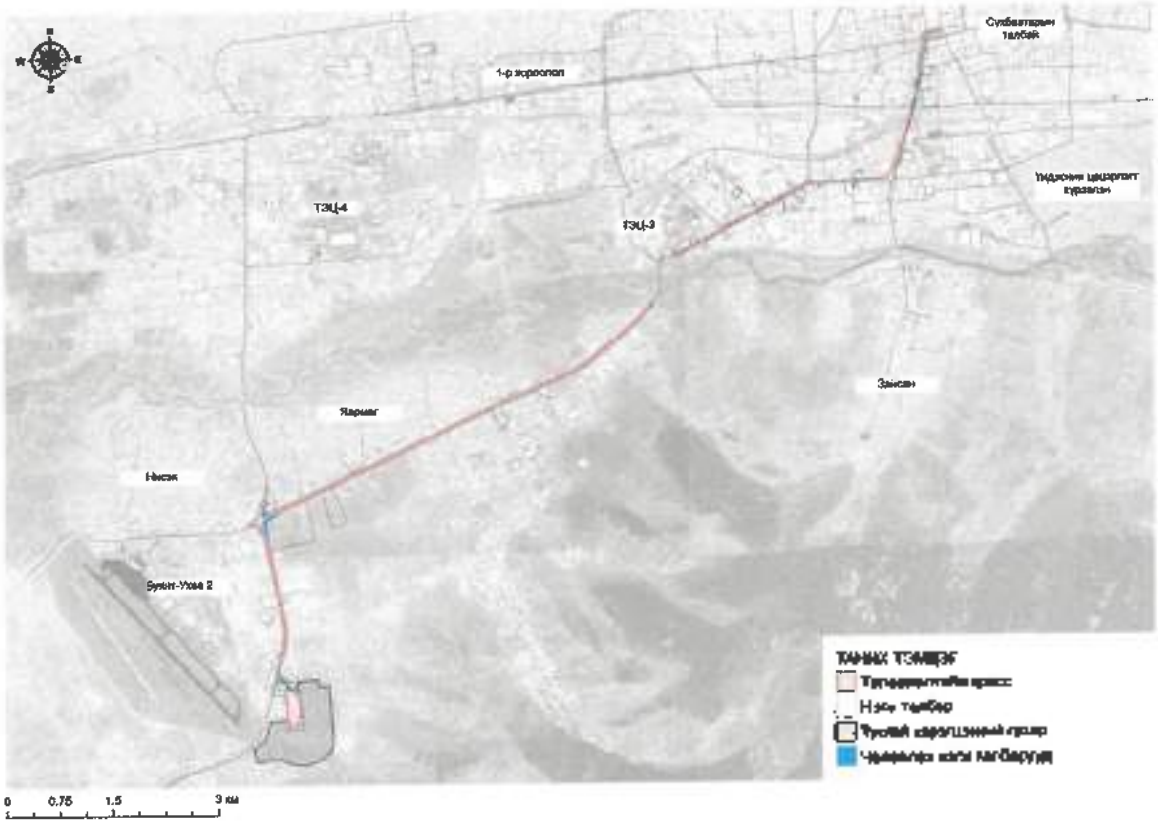

Table 50 *Base Valuation of Land Acquisition for Land Units Affected by the Route (Alternative-2)*

No.	Alternative-2	Number of land units	Area (sq.m)	Land acquisition cost (million MNT)
1	Route-2	62	28,532	1,628
2	Transformer substation	7	4375	560
Total		69	32,907	2,188

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Alternative 3

Land acquisition for Alternative 3 was calculated with widths of 38 meters along Otzlit Road, 42 meters along Naadamchid Road, 28 meters along Chinggis Avenue, and 7 meters along Peace Avenue.

The base valuation for land acquisition of 29,693 sq.m across 58 land units affected by the route is 2.3 billion MNT. The valuation for 4,375 sq.m across 7 land units affected by the transformer substation location is 0.56 billion MNT, bringing the total land acquisition compensation to 2.9 billion MNT.

Land Acquisition (Alternative-3)

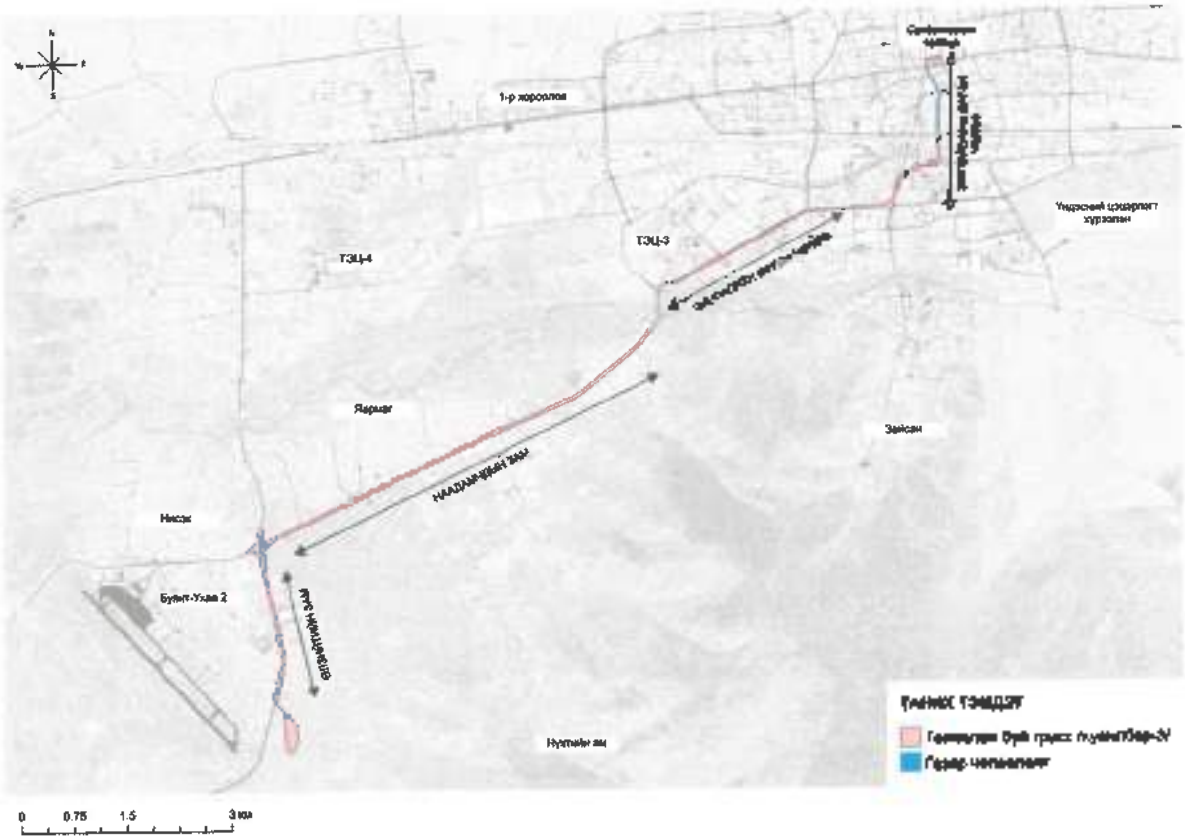

Table 51. *Base Valuation of Land Acquisition for Land Units Affected by the Route (Alternative-3)*

No.	Alternative-3	Number of land units	Area (sq.m)	Land acquisition cost (million MNT)
1	Route-3	58	29,693	2,302
2	Transformer substation	7	4,375	560
	Total	65	34,068	2,862

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Alternative 4

Land acquisition for Alternative 4 was calculated with widths of 38 meters along Olzit Road, 42 meters along Naadamchid Road, 28 meters along Chinggis Avenue, and 7 meters along Peace Avenue.

The base valuation for land acquisition of 29,790 sq.m across 58 land units affected by the route is 1.25 billion MNT. The valuation for 4,375 sq.m across 7 land units affected by the transformer substation location is 0.56 billion MNT, bringing the total land acquisition compensation to 1.8 billion MNT.

Land Acquisition (Alternative-4)

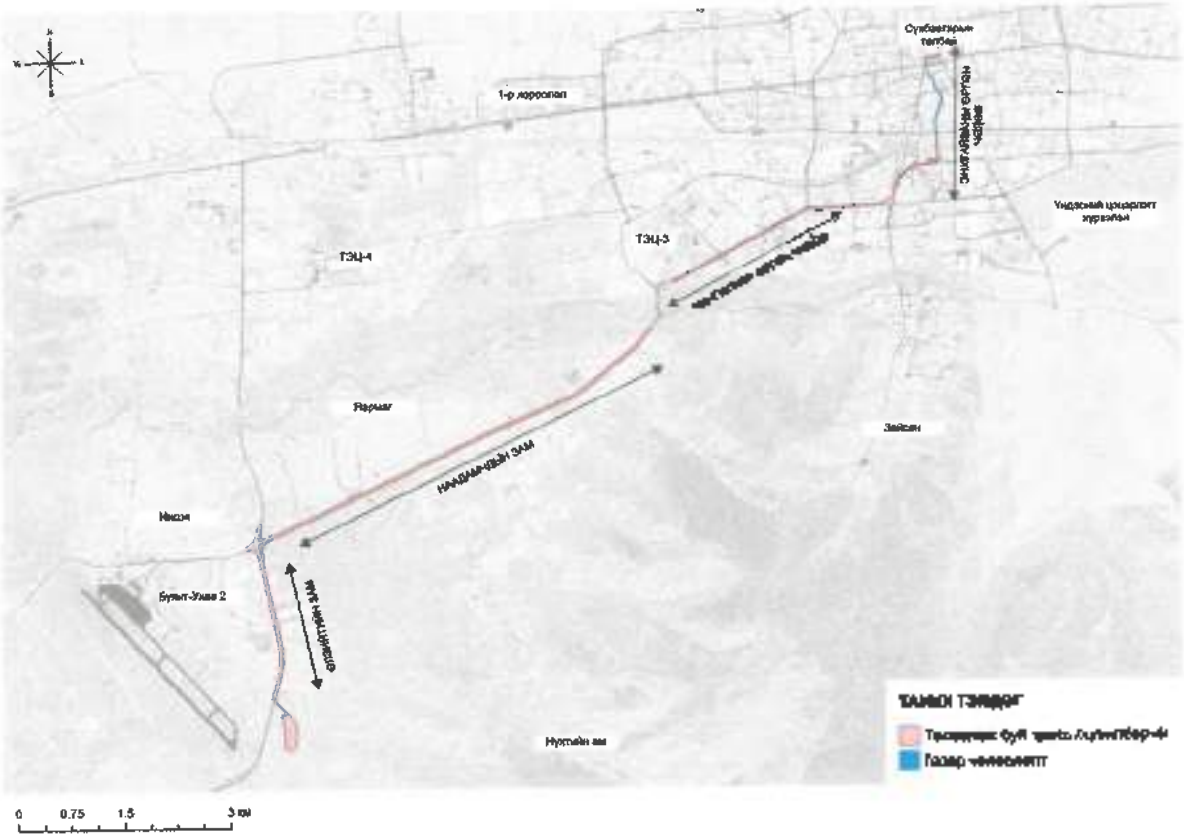

Table 62. *Base Valuation of Land Acquisition for Land Units Affected by the Route (Alternative-4)*

No.	Alternative-4	Number of land units	Area (sq.m)	Land acquisition cost (million MNT)
1	Route-4	58	29,790	1,254
2	Transformer substation	7	4375	560
Total		65	34,165	1,814

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Alternative 5

Land acquisition for Alternative 5 was calculated with widths of 38 meters along Olziil Road, 42 meters along Naadamchid Road, 28 meters along Chinggis Avenue, and 7 meters along Peace Avenue.

The base valuation for land acquisition of 29,291 sq.m across 59 land units affected by the route is 1.23 billion MNT. The valuation for 4,375 sq.m across 7 land units affected by the transformer substation location is 0.56 billion MNT, bringing the total land acquisition compensation to 1.8 billion MNT.

Land Acquisition (Alternative-5)

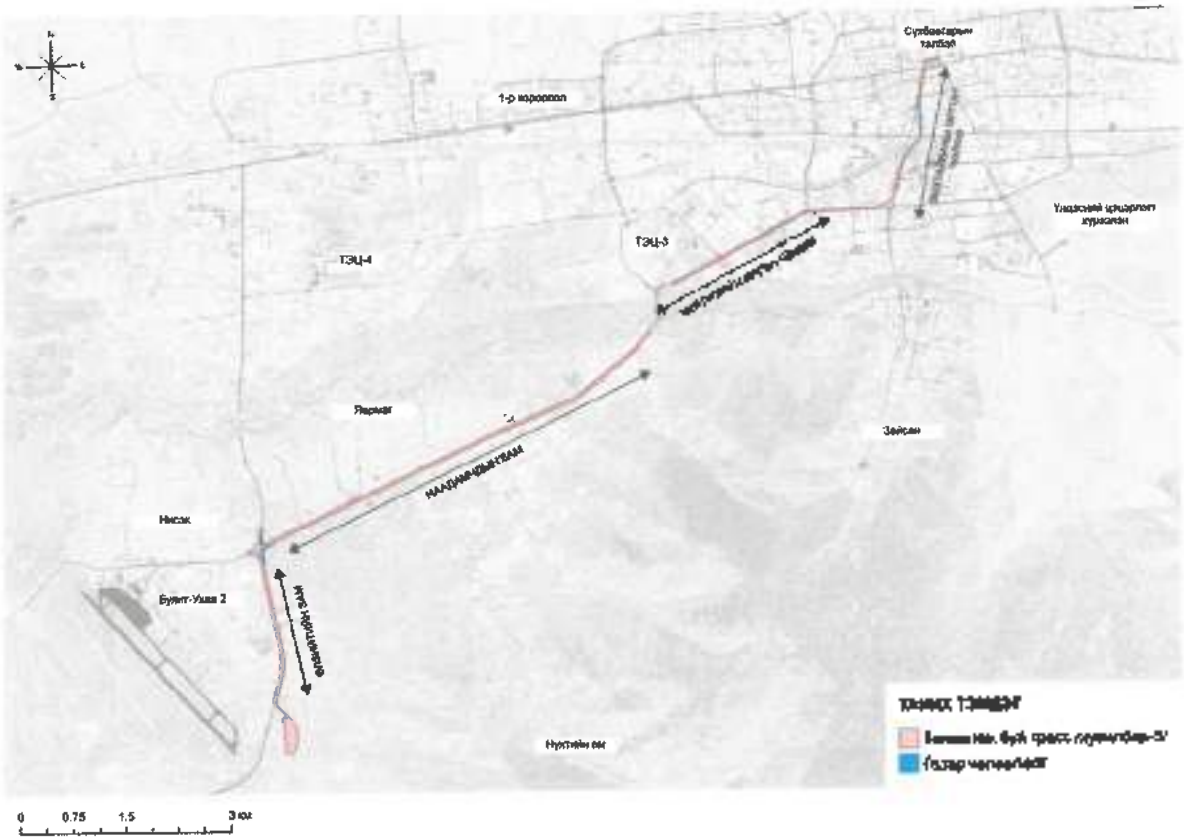

Table 53. Base Valuation of Land Acquisition for Land Units Affected by the Route (Alternative-5)

No.	Alternative-5	Number of land units	Area (sq.m)	Land acquisition cost (million MNT)
1	Route-5	59	26,291	1,232
2	Transformer substation	7	4375	560
Total		66	30,66	1,792

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Alternative 6

Land acquisition for Alternative 6 was calculated with widths of 58 meters along Olzit Road, 42 meters along Naadamchid Road, 28 meters along Chinggis Avenue, and 35 meters along Peace Avenue.

The base valuation for land acquisition of 41,663 sq.m across 73 land units affected by the route is 3.47 billion MNT. The valuation for 4,375 sq.m across 7 land units affected by the transformer substation location is 0.56 billion MNT, bringing the total land acquisition compensation to 4.0 billion MNT.

Land Acquisition (Alternative-6)

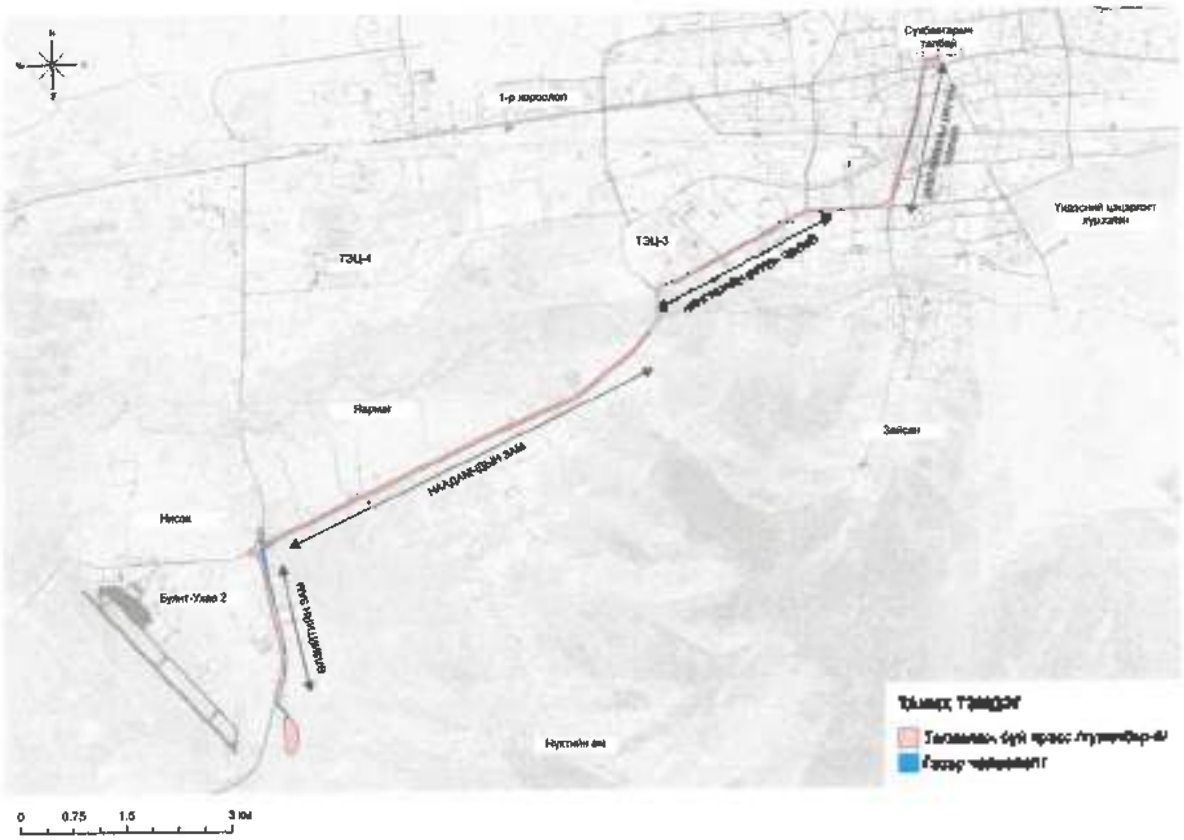

Table 54. *Base Valuation of Land Acquisition for Land Units Affected by the Route (Alternative-6)*

No.	Alternative-6	Number of land units	Area (sq.m)	Land acquisition cost (million MNT)
1	Route-6	73	41,663	3,468
2	Transformer substation	7	4375	560
Total		80	46,038	4,028

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Alternative 7

Land acquisition for Alternative 7 was calculated with widths of 42 meters along Naadamchid Road, 28 meters along Chinggis Avenue, and 35 meters along Peace Avenue.

The base valuation for land acquisition of 17,904 sq.m across 59 land units affected by the route is 1.42 billion MNT. The valuation for 4,375 sq.m across 7 land units affected by the transformer substation location is 0.56 billion MNT, bringing the total land acquisition compensation to 2.0 billion MNT.

Land Acquisition (Alternative-7)

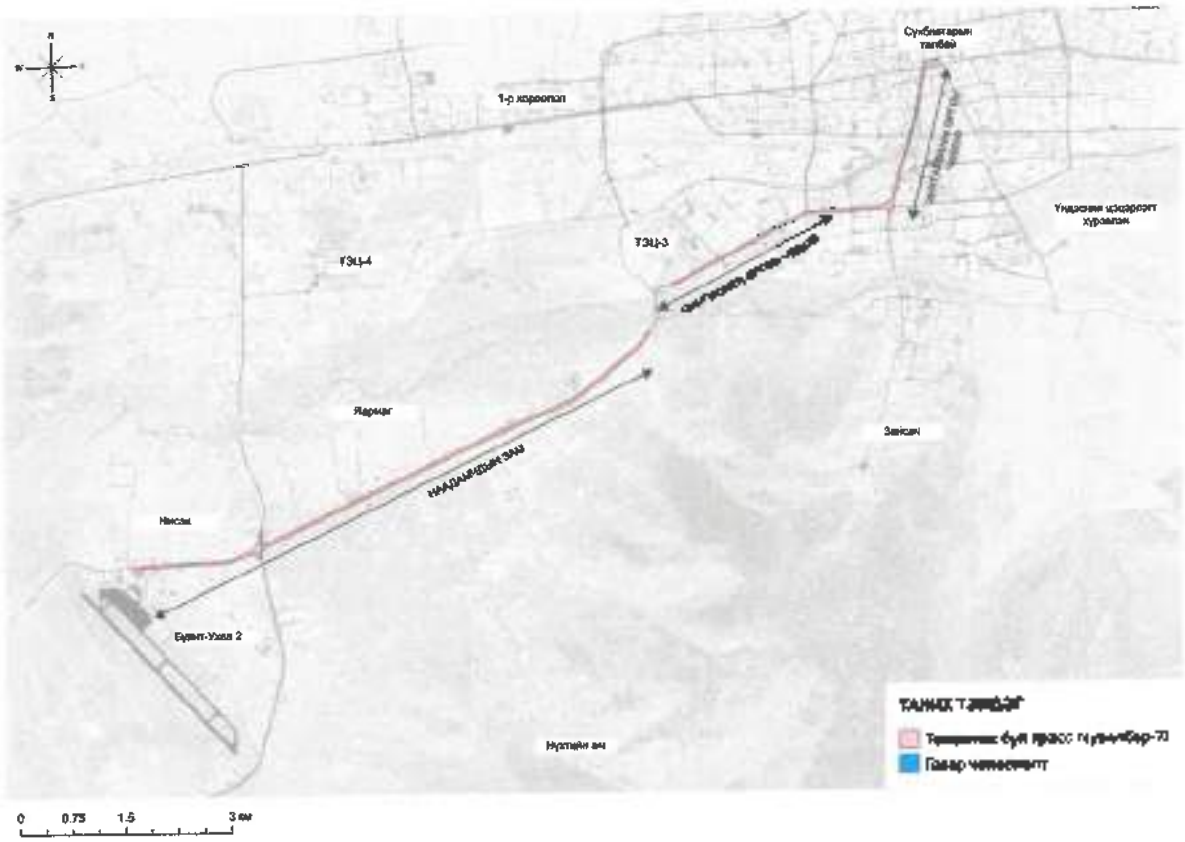

Table 56. *Base Valuation of Land Acquisition for Land Units Affected by the Route (Alternative-7)*

No.	Alternative-7	Number of land units	Area (sq.m)	Land acquisition cost (million MNT)
1	Route-6	59	17,904	1,419
2	Transformer substation	7	4375	560
Total		66	22,279	1,979

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CHAPTER 7. PLANNING SOLUTION

- Planning solution
- Public transportation station planning
- Tramway planning
- Infrastructure planning
- Tramway line planning

7.1. PLANNING SOLUTION

Transportation planning has evolved into an independent scientific discipline, with each transport sector developing according to its specific characteristics. Urban public transportation planning represents a comprehensive activity conducted within the framework of the fundamental goal to gradually establish conditions for transporting citizens in minimum time, at minimum cost, without compromising comfort, and ensuring safety. When planning urban public transportation, it is essential to optimally select both the transport network and transport type, as these directly affect the basic service characteristics.

Comparative studies of urban public transport types and their optimal planning have been documented in research by Russian scientists M.A. Germanovna (2000), S.A. Alexandrovich (2005), Norwegian scientist Gustav Nielsen (2005), Australian scientists Jago Dodson and Paul Mees, Japanese scientist Katsutoshi Ohta, and American scientist Vukan Vuchic ("Urban Transit Operations, Planning and Economics," 2005). Urban public transport types are classified according to the vehicles used in service, infrastructure, capacity, and passenger volume. Assessment of existing public transport types and planning for new implementations are based on passenger demand, transport distance, investment scale, and regional characteristics. In other words, transport types are selected based on these key indicators.

Transport Type Selection:

The selection of urban public transportation types depends on multiple factors including passenger demand, investment scale, and transport distance. Internationally, there are two fundamental approaches to selecting public transport types: one based on current conditions and another based on future trends. When utilizing high-capacity transport types in urban public transportation services, construction and operational costs are high, necessitating detailed calculations of investment returns and payback periods. In other words, when selecting high-capacity public transport types, efficiency calculations must determine the economic and social significance of the initial investment recovery timeframe.

There are experiences where investment return calculations and transport efficiency were compromised by overestimating ticket prices, resulting in fewer actual users and unprofitable operations.

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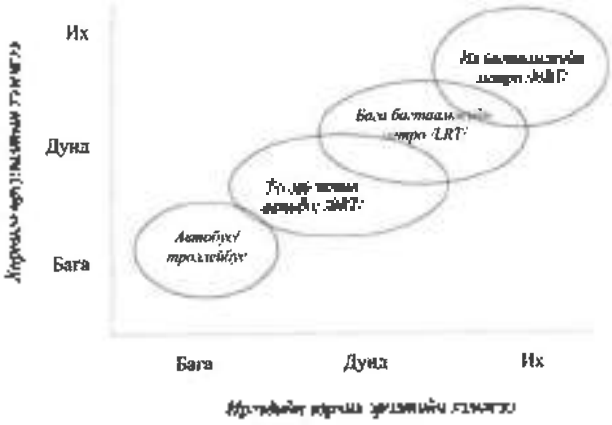

Model of public transport type selection based on investment scale and passenger demand (Kh. Bulgan, Tomoko Abe, 2012)

When selecting public transport types, it is essential to consider passenger travel distance or transport distance, which depends on the city's geographical location and settlement structure - the distance between points generating and absorbing passenger flows. For instance, Asian cities with high population density have shorter transport distances, while European and American cities with lower population density have greater transport distances.

Model of public transport type selection based on travel distance and passenger demand

A major change in contemporary urban planning policy is the focus on minimizing citizens' travel distances. Since the average travel distance of citizens is the foundation of urban traffic congestion problems, it has received special attention in planning and organizational frameworks. For example, the Ulaanbaatar City Master Plan includes

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establishing additional sub-centers to reduce citizen travel distances and optimize mobility.

Urban Planning Solution

The Ulaanbaatar City Development Master Plan until 2040 includes optimizing and enhancing the urban public transport network to ensure comfortable travel conditions for residents and citizens, supporting sustainable economic growth and environmental sustainability. During the planning period, by 2040, the phased renovation of the public transport network and public passenger vehicle fleet throughout Ulaanbaatar will increase daily passenger turnover to 1.2 million, representing a 50% capacity increase from current levels.

Urban public transport routes will be planned and developed along horizontal and vertical axes of the city street network. The planning period includes 42.23 km of metro, 10 km of tram, 61.15 km of BRT, and 7.1 km of aerial cable transport network. With the addition of tram systems, three lines will carry 60% of public transport passenger turnover, with average public transport speed calculated to reach 30 km/hour. This project's scope is incorporated into the planning. Within the planning framework, the key significance will be providing an independent public transport system to address the currently high travel time resulting from spatial constraints and excessive traffic congestion, creating conditions for fast and efficient mobility.

Planned tramway line

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Curve Radius

Curves of 20 m and greater are planned for the main line. Transition curves are planned for all curves. The length of transition curves was determined based on the outer rail elevation measurements and standard norms. The average train speed is calculated to be 25 km/h.

Curve Placement

Due to surface elevation conditions and bridge locations, 37 curves with a minimum radius of 40 m have been designed along the 15.3 km route.

Straight Insertions

The length of straight insertions between the initial points of transition curves, or between circular curves when there are no transition curves, has been designed to be not less than 10 m under normal conditions, according to SP 98.13330.2018 tramway and trolleybus lines SNIP 2.05.09-90 and standard norms.

Longitudinal Section

In the longitudinal section design, the gradient is 40‰ in the direction from Nisah to Sansar Safety Circle. Vertical curves were created when the difference between gradients exceeded 33, with the vertical curve radius set at 2,000 m or greater. The minimum length of vertical curves is planned to be 20 m or more. The longitudinal section parameters have been determined to meet the project criteria. The longitudinal profile of the project is shown below

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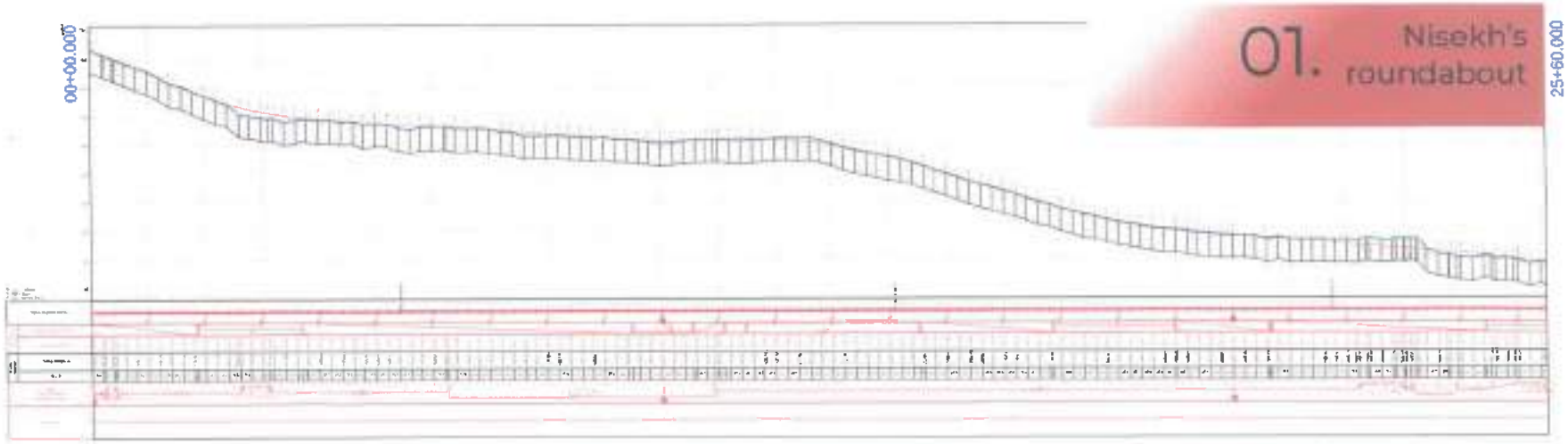

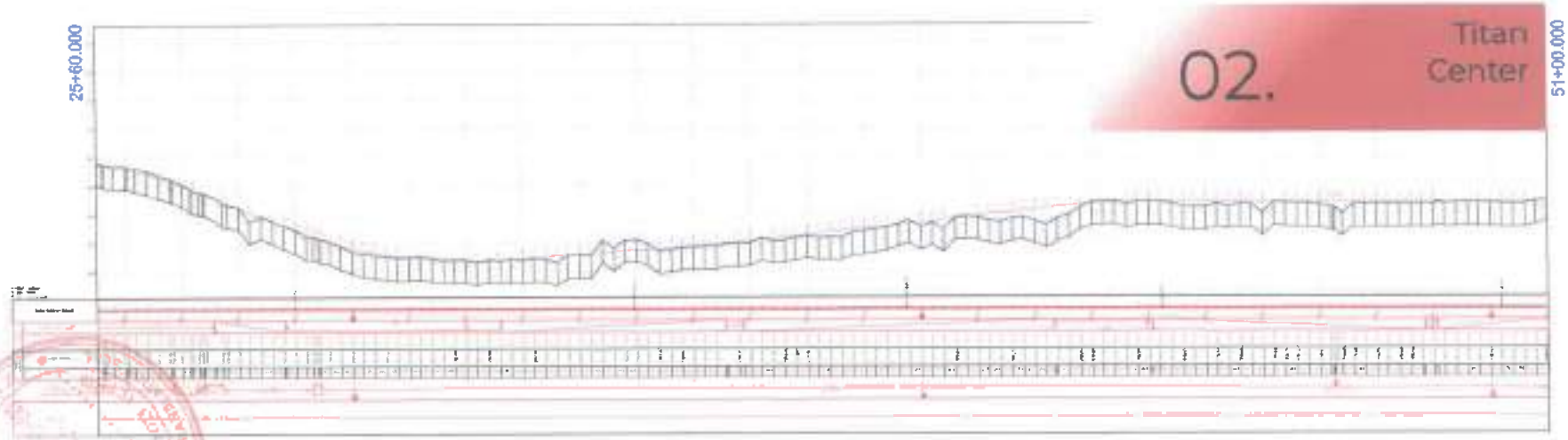

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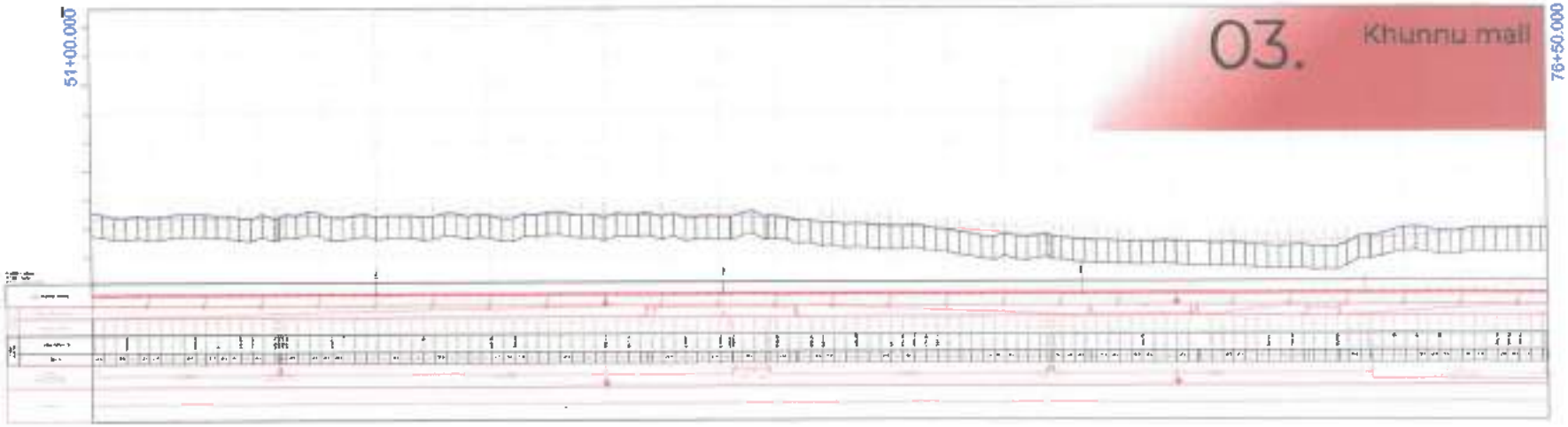

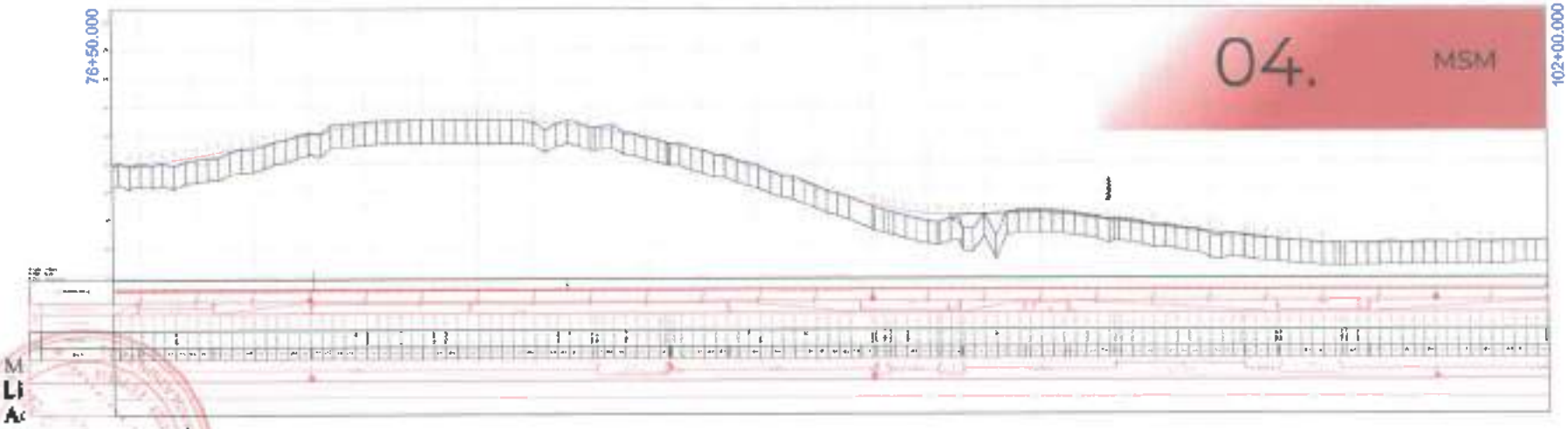

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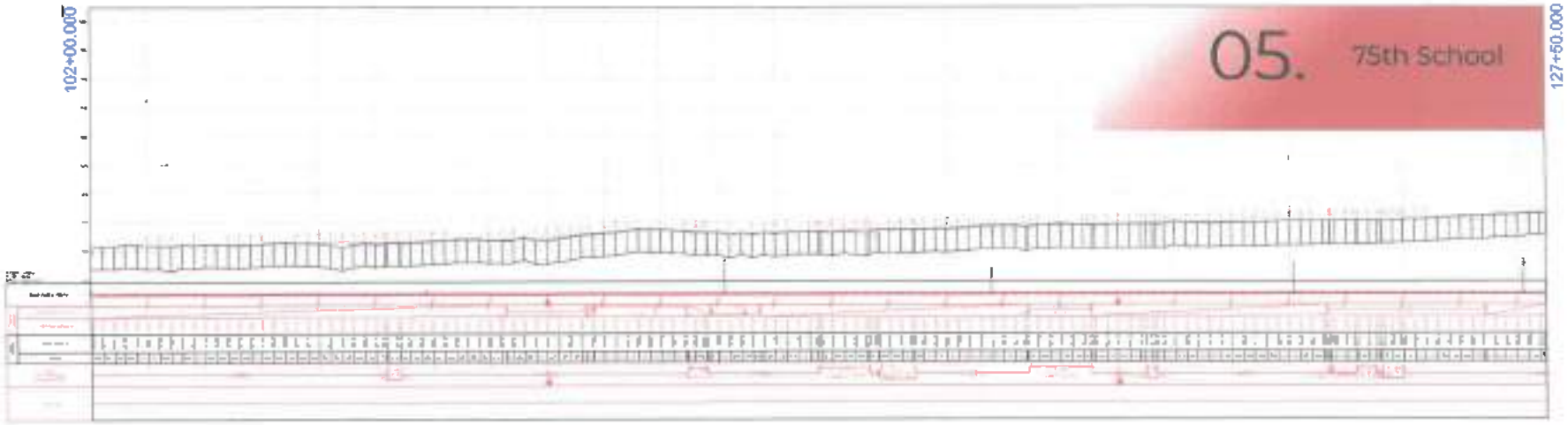

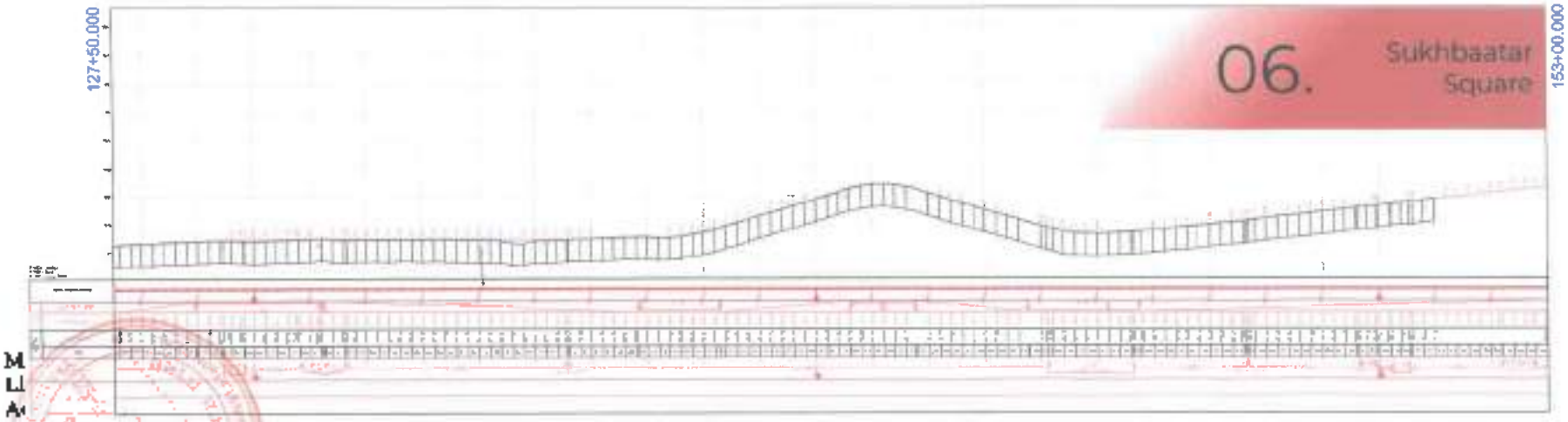

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Longitudinal Section Elements The longitudinal section's adjacent elements were designed to have the minimum algebraic difference in gradient and maximum possible length. The length of the longitudinal section element is not less than half the useful length planned for the reception-departure track in the future. In this project, the minimum useful length of stations is designed to be 100 m in the future and 60 m under current conditions.

Railway Substructure The railway substructure is an integrated system where all components work in coordination with train movement. It requires regular inspection and maintenance and should not cause any unplanned impact on movement. To achieve this goal, high quality in rail calculation, construction, and maintenance is considered most important. While the substructure can be defined by the initial investment, its stability and service life are determined by appropriate maintenance. The main factor in rail calculation is ensuring that the components (rails, sleepers, rail gaskets, fasteners, ballast, etc.) can withstand the dynamic loads from rolling stock. To achieve this objective, the rolling stock load must be compatible with the installed track works. The selection of rail components and their spacing ensures a balance between installation and maintenance costs; generally, the higher the quality of rail installation, the lower the subsequent maintenance costs.

Main Track Embankment The main track will have a cross-section width of 7 m for double-track sections on first-class roads. For straight sections, the width of the upper edge of the embankment must be determined considering conditions for track maintenance, electrical and signaling cables, and related facilities. The movement of maintenance personnel should also be considered. For curved sections, it will be determined based on the effect of rail elevation.

Earthwork The earthwork quantities are taken in total, and all quantities are calculated by area. The pavement layer thickness will be 400-700 mm. The first layer is divided into two parts, upper and lower, each 300 mm thick. Both parts will consist of cement-reinforced crushed stone filling. When calculating soil removal quantities, an additional 1 m width was calculated at the end of the embankment slope for embankments with side drainage ditches, and 1 m width for embankments without side drainage ditches. The ground surface level is based on the results of field measurements. The filling and excavation side slopes are adjusted according to field analysis and slope stability calculations. Protection of side slopes, fences, barriers, auxiliary roads, and land boundary lines are not included and will be determined considering on-site conditions. The location, technical requirements, and bottom level of side drainage ditches are calculated in accordance with reinforced concrete round pipes, reinforced concrete square pipes, station transverse drainage channels, and on-site conditions. The differences and elevations on the cross-section drawings of stations are based on the highest point of each track. Other differences will be determined according to site conditions if drainage ditches and auxiliary roads change.

Main Track General Planning

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1. This is the planning map for Ulaanbaatar city's LRT (Light Rail Transit), containing the following key information: A schematic diagram showing sections along the tramway line from the General Archive Office to Sukhbaatar Square that require pavement and structural changes. This includes green spaces, U-turns, bridges, intersections, and multi-modal transportation types, with technological solutions developed and incorporated into the design. Vehicle and tramway traffic: The scheme indicates road types such as MIXED SECTION, DIVIDED SECTION, TRAMWAY MID PLATFORM SECTION, TRAMWAY SIDE PLATFORM SECTION. These define the traffic mode and road organization for each zone. Intersections are planned at 60-meter intervals, with U-turns planned at 50-meter intervals, a solution aimed at improving traffic safety.

Markings and restriction information: To coordinate vehicle traffic with the LRT line, separation strips, road widths, and marking dimensions have been placed according to standards. Width: 15.3 meters Area (DEPOT): 10 hectares

Table 56 *Route Alignment Parameters*

Element Name	Element Name				Radius	Length (m)	Element Name	
	Station / Chainage	+	X	Y			Left	Right
Straight	0	0+00.000	5299620.525	634088.309	—	24.36		
Curve	0	0+24.36	5299640.846	634074.882	100	19.17	10° 58' 55"	
Straight	0	0+43.52	5299655.790	634062.652	—	217.04		
Curve	0	0+260.56	5299810.699	633910.899	50	51.44		58° 56' 29"
Straight	0	0+312	5299858.229	633898.194	—	312.85		
Curve	0	0+624.85	5300151.205	633976.675	1000	467.51	26° 47' 11"	
Straight	1	1+92.46	5300624.384	633985.560	—	1157.80		
Curve	2	2+249.96	5301765.393	633739.338	150	100.55		38° 24' 28"
Straight	2	2+350.51	5301863.352	633751.226	—	298.49		
Curve	2	2+649	5302121.344	633882.666	160	101.11		38° 37' 22"
Straight	2	2+750.11	5302190.969	633953.352	—	127.21		
Curve	2	2+877.33	5302245.227	634068.406	3000	12.30	0° 14' 05"	
Straight	2	2+889.62	5302250.495	634079.519	—	1781.86		
Curve	4	4+671.49	5303017.221	635687.988	3000	1.58		0° 01' 48"
Straight	4	4+673.06	5303017.899	635689.410	—	699.58		
Curve	5	5+372.62	5303318.581	636321.049	3000	2.91		0° 03' 20"
Straight	5	5+375.53	5303319.830	636323.678	—	801.00		
Curve	6	6+176.53	5303663.414	637047.242	2000	46.67		1° 20' 13"
Straight	6	6+223.19	5303682.937	637089.627	—	213.96		
Straight	6	6+437.15	5303770.180	637284.383	—	261.05		
Curve	6	6+718.2	5303880.468	637543.498	3000	11.59	0° 13' 17"	
Straight	6	6+729.79	5303885.034	637554.150	—	551.78		
Curve	7	7+281.57	5304103.518	638060.638	1136	317.65	16° 00' 56"	
Straight	7	7+599.13	5304266.116	638331.192	—	855.01		
Curve	8	8+454.14	5304610.146	638992.435	585	128.44	12° 34' 47"	

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Straight	8	8+582.58	5304901.780	639082.070	—	0.80		
Curve	8	8+583.37	5304902.406	639082.560	3000	4.53		0° 06' 12"
Straight	8	8+587.9	5304905.971	639085.357	—	350.04		
Curve	8	8+937.94	5305181.186	639301.858	200	50.62	14° 30' 20"	
Straight	8	8+988.56	5305224.512	639327.598	—	67.21		
Curve	9	9+55.79	5305286.073	639354.569	100	46.96	26° 19' 56"	
Straight	9	9+101.75	5305330.888	639362.866	—	282.34		
Curve	9	9+384.09	5305612.898	639349.889	150	217.58		83° 05' 30"
Straight	9	9+601.66	5305787.808	639474.612	—	64.26		
Curve	9	9+665.91	5305778.484	639537.967	350	113.63	18° 36' 03"	
Straight	9	9+779.54	5305815.062	639645.018	—	885.99		
Curve	10	10+685.53	5306233.266	640426.096	3000	27.68	0° 31' 36"	
Straight	10	10+6593.1	5306248.394	640450.347	—	504.08		
Curve	11	11+197.18	5306489.409	640892.532	3000	32.23		0° 36' 56"
Straight	11	11+229.42	5306503.727	640920.881	—	217.25		
Curve	11	11+446.67	5306605.977	641112.579	1500	45.60		1° 44' 31"
Straight	11	11+492.28	5306626.525	641153.137	—	48.22		
Curve	11	11+539.5	5306647.331	641194.563	1500	46.19	1° 50' 27"	
Straight	11	11+586.69	5306669.398	641237.400	—	206.58		
Curve	11	11+793.27	5306766.939	641419.502	250	109.96		25° 12' 04"
Straight	11	11+903.23	5306796.225	641524.573	—	95.70		
Curve	11	11+998.92	5306801.190	641620.138	3000	18.07	0° 20' 43"	
Straight	12	12+17	5306802.183	641638.185	—	303.24		
Curve	12	12+320.24	5306819.741	641940.921	3000	1.01		0° 01' 09"
Straight	12	12+321.25	5306819.799	641941.929	—	44.84		
Curve	12	12+366.1	5306822.380	641986.700	3000	37.14		0° 42' 34"
Straight	12	12+403.24	5306824.269	642023.791	—	8.00		
Curve	12	12+411.24	5306824.660	642031.784	3000	39.00	0° 44' 41"	
Straight	12	12+450.23	5306826.866	642070.726	—	445.09		
Curve	12	12+895.32	5306852.562	642515.063	351.75	36.36	5° 55' 23"	
Straight	12	12+931.69	5306856.549	642551.190	—	112.52		
Curve	13	13+44.21	5306874.653	642662.249	50	57.06	65° 22' 29"	
Straight	13	13+101.26	5306910.751	642702.417	—	406.13		
Straight	13	13+507.39	5307302.362	642810.042	—	953.39		
Curve	14	14+360.78	5308125.243	643036.190	1500	153.33	5° 51' 24"	
Straight	14	14+514.11	5308274.906	643069.202	—	200.21		
Curve	14	14+714.32	5308472.365	643102.281	1500	4.24		0° 09' 43"
Straight	14	14+718.56	5308476.548	643102.988	—	196.52		
Curve	14	14+914.08	5308669.283	643135.836	500	31.79		3° 38' 33"
Straight	14	14+945.88	5308700.426	643142.169	—	27.29		
Curve	14	14+973.09	5308728.925	643148.440	500	31.79	3° 38' 33"	
Straight	15	15+4.88	5308758.069	643154.773	—	155.20		
Curve	15	15+160.08	5308911.061	643180.847	51.75	64.57		71° 29' 39"
Straight	15	15+224.65	5308963.503	643223.915	—	128.64		

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Table 57. Transition Curve Parameters

Point	Angle Vertex	Coordinates		Radius (m)	Transition Curve Position		Distance Between Vertices (m)	Straight Length (m)
					Beginning	End		
	Station / Chainage	X	Y		Station / Chainage	Station / Chainage		
RS	00+000.000	5299520.525	634056.308					
							33.97	24.36
AV1	00+033.969	5299548.866	634069.582	100.00	00+024.356	00+043.523		
							254.90	217.04
AV2	00+288.815	5299630.873	633891.117	50.00	00+260.560	00+311.996		
							579.32	312.95
AV3	00+863.057	5300381.725	634036.211	1000.00	00+824.949	01+092.460		
							1447.86	1157.50
AV4	02+302.207	5301806.444	633728.222	150.00	02+249.961	02+350.512		
							403.30	298.49
AV5	02+701.563	5302168.536	633905.611	150.00	02+649.000	02+750.114		
							185.92	127.21
AV6	02+883.475	5302247.850	634073.969	3000.00	02+877.327	02+889.624		
							1788.80	1781.86
AV7	04+.672.276	5303017.580	635688.699	3000.00	04+671.488	04+673.064		
							701.80	699.56
AV8	05+374.073	5303319.206	636322.362	3000.00	05+372.619	05+375.626		
							825.79	801.00
AV9	06+199.659	5303673.423	637068.321	2000.00	06+176.525	06+223.191		
							237.30	213.86
AV10	06+437.152	5303770.180	637284.993	0.00	06+437.152	06+437.152		
							286.84	281.05
AV11	06+.723.996	5303882.740	637548.828	3000.00	06+718.200	06+729.790		
							717.40	651.78
AV12	07+441.393	5304166.799	638207.592	1136.00	07+281.574	07+599.127		
							1079.31	855.01
AV13	08+518.616	5304851.023	639042.392	685.00	08+454.135	08+582.577		
							67.54	0.80
AV14	08+585.639	5304904.190	639083.957	3000.00	08+583.373	08+587.904		
							377.76	350.04
AV15	08+963.398	5305201.198	639317.384	200.00	08+937.945	08+988.578		
							116.06	87.21
AV16	09+079.131	5305307.499	639363.957	100.00	09+055.789	09+101.747		
							439.69	282.34
AV17	09+517.049	5305745.716	639343.498	150.00	09+384.087	09+601.684		
							254.53	64.25
AV18	09+723.229	5305788.008	639594.487	350.00	09+686.912	09+779.538		

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							957.10	885.99
AV19	10+679.318	5306239.774	640438.252	3000.00	10+665.528	10+693.104		
							533.98	504.08
AV20	11+213.301	5306496.141	640906.670	3000.00	11+197.184	11+229.418		
							256.18	217.25
AV21	11+469.476	5306616.710	641132.699	1500.00	11+446.672	11+492.277		
							93.12	46.22
AV22	11+562.586	5306658.021	641216.169	1500.00	11+536.500	11+589.689		
							286.56	206.58
AV23	11+849.153	5306793.328	641488.784	250.00	11+793.269	11+903.229		
							160.62	95.70
AV24	12+007.961	5306901.659	641628.164	3000.00	11+998.924	12+016.998		
							312.79	303.24
AV25	12+320.747	5306819.770	641941.425	3000.00	12+320.243	12+321.252		
							63.92	44.84
AV26	12+384.668	5306823.449	642005.240	3000.00	12+366.097	12+403.238		
							46.07	8.00
AV27	12+430.736	5306825.632	642051.261	3000.00	12+411.238	12+450.233		
							482.79	445.09
AV28	12+913.522	5306853.621	642533.230	351.75	12+896.325	12+931.687		
							162.81	112.52
AV29	13+076.295	5306879.816	642693.915	50.00	13+044.211	13+101.261		
							438.21	406.13
AV30	13+507.392	5307302.362	642810.042	350.00	13+507.392	13+507.392		
							930.12	853.39
AV31	14+437.516	5308169.231	643056.624	1500.00	14+380.783	14+514.112		
							279.06	200.21
AV32	14+716.441	5308474.456	643102.531	1500.00	14+714.321	14+718.561		
							213.53	195.52
AV33	14+929.976	5308684.955	643138.507	500.00	14+914.077	14+9145.863		
							59.03	27.23
AV34	14+988.993	5308742.396	643152.101	500.00	14+973.094	15+004.880		
							206.35	156.20
AV35	15+197.328	5308947.782	643187.106	61.75	15+160.079	15+224.683		
							166.89	129.54
EoR	15+364.292	5306973.411	643352.016					

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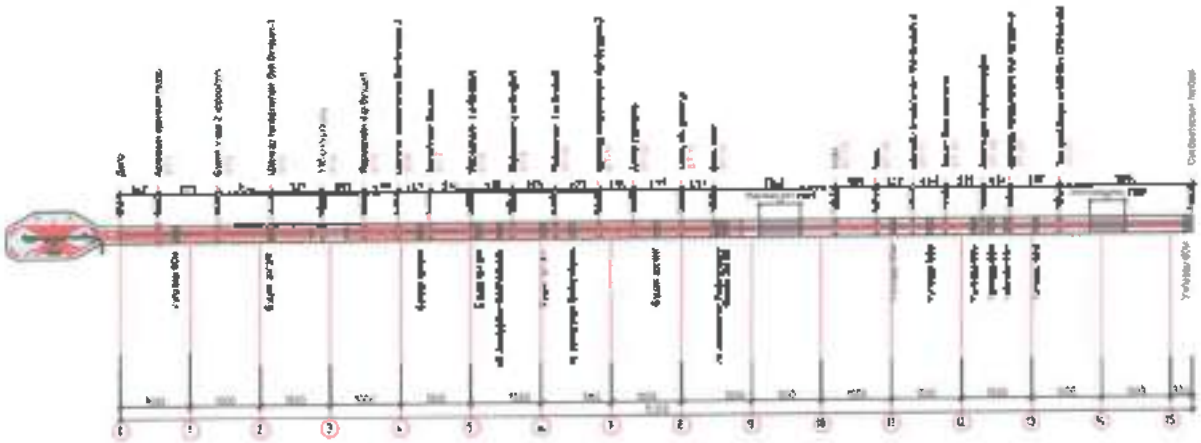

TYPES OF CROSS-SECTIONS ALONG THE TRAMWAY

1. Standard Cross-Section Feature:

Integrated planning of roads, tramway, and green spaces, with a structure that increases the city's green space.

Standard cross-section (width: 47.9 meters)

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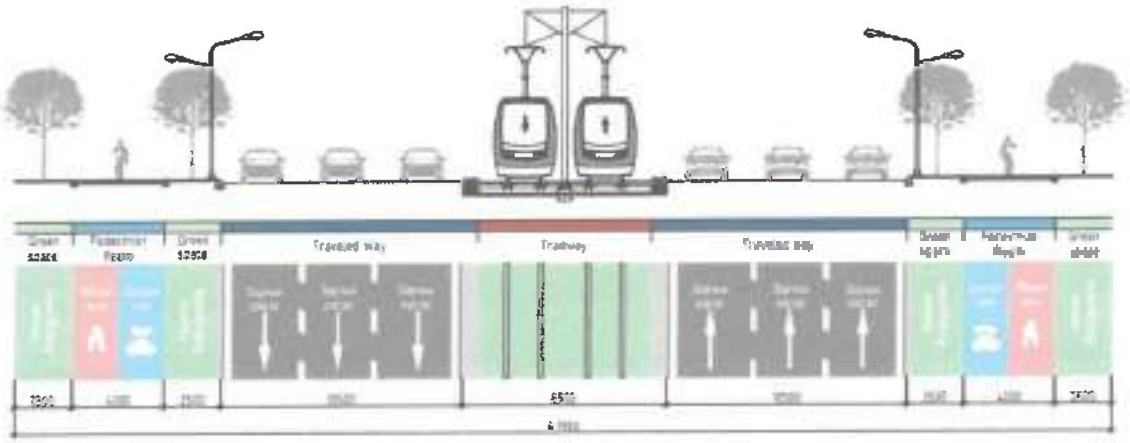
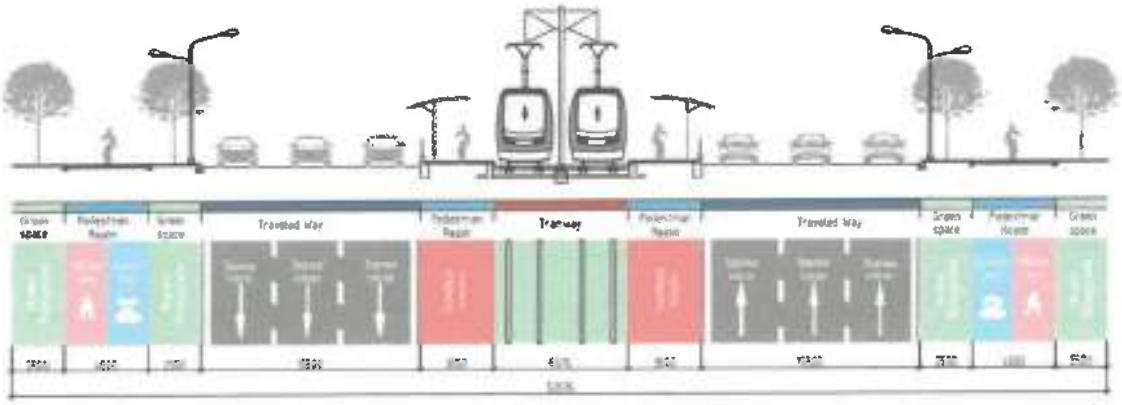
DIVIDED SECTION



2. Cross-Section with Tramway Feature
Specially designed tramway stops with safety considerations. Width: 52.575 meters

Cross-section with tramway

TRAMWAY SIDE PLATFORM SECTION



3. Combined Cross-Section with Road 1 Feature
Structure with flexible traffic flow solutions allowing vehicles and tramways to travel side by side. Width: 41.8 meters

Combined cross-section with road-1

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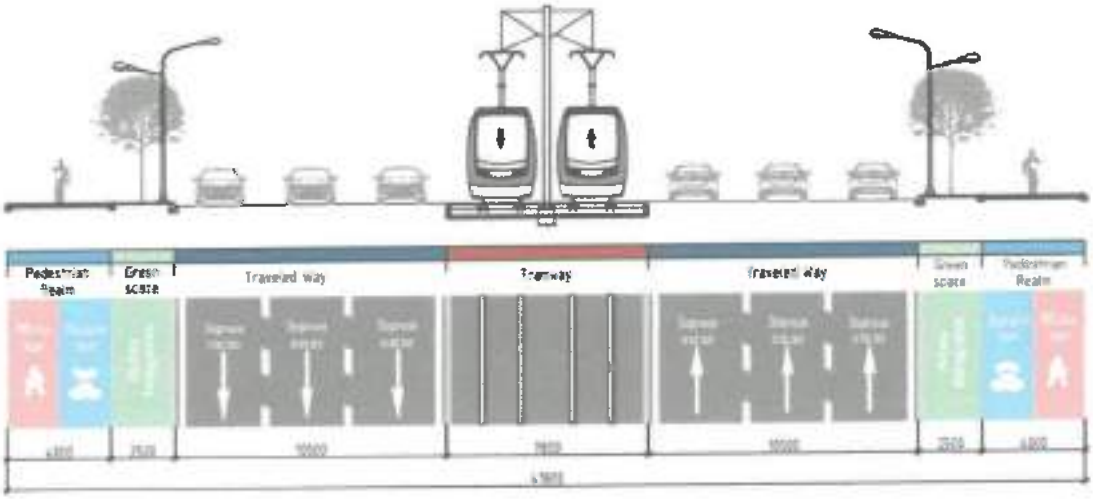
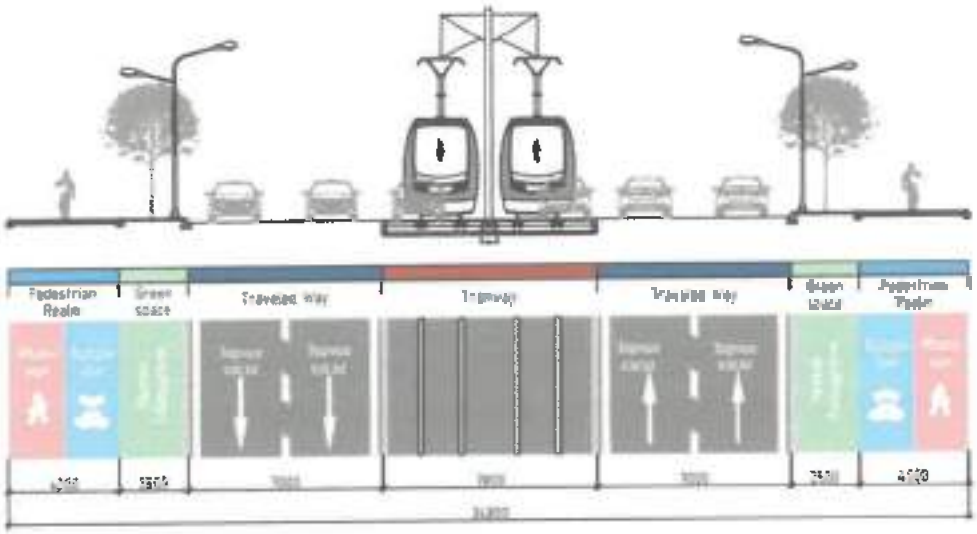


4. Combined Cross-Section with Road 2 Feature

Integrated planning of roads, tramway, and green spaces, with a structure that increases the city's green space. Width: 34.8 meters

Combined cross-section with road-2

MIXED SECTION



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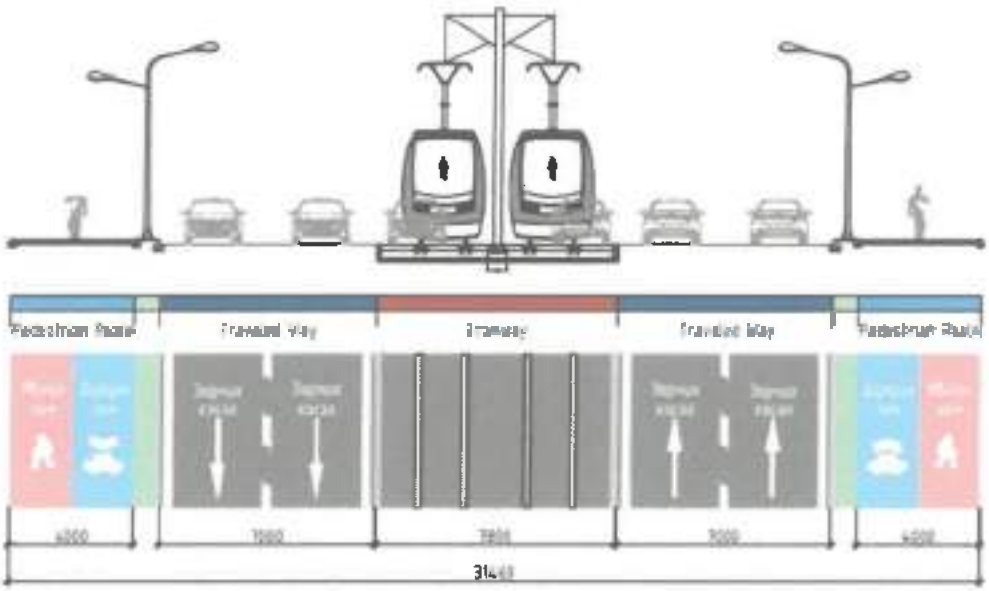
5. Combined Cross-Section with Road 3 Feature

Structure with flexible traffic flow solutions, integrating roads, tramway, and green spaces, allowing vehicles and tramways to travel side by side. Width: 31.46 meters

Combined cross-section with road-3

MIXED SECTION



GENERAL CONCLUSION

These cross-sections along the travel route are integrated planning solutions aimed at managing urban traffic loads and organizing the flow of various types of vehicles. These cross-sections are particularly important for meeting the following fundamental objectives:

Optimal Regulation of Vehicle Traffic Flow:

The widths of travel sections have been determined according to standards, with measures included to increase flow capacity in high-density traffic areas. The high-capacity public transport vehicle, the tram, has been specifically planned for introduction, with traffic organization solutions developed to avoid impeding the flow of travel sections. By planning cross-sections with tram stops, attention has been paid to passenger safety and creating a comfortable waiting environment. Pedestrian paths and bicycle lanes have been specifically planned in all types of cross-sections, ensuring safe and comfortable travel conditions for citizens. Green spaces have been added along pedestrian and bicycle paths, enhancing environmental comfort.

Combined Organization of Multiple Modes:

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Planning that coordinates various types of traffic flows has become a solution that positively impacts citizens' living environment and urban planning. These cross-sections play an important role not only in organizing road traffic but also in improving urban quality of life and environmental conditions. This planning along Naadamchid Road can be concluded to be aligned with the objectives of Ulaanbaatar city's 2040 Development Master Plan and meets the needs and requirements of citizens.

The locations of stops were determined by considering existing bus stops along the project line, designated car parking, and external parking areas of commercial services and public buildings in the surrounding area. There are a total of 21 stations in the planning area.

7.2. PUBLIC TRANSPORTATION STOP PLANNING

The primary element for citizens to access public transportation services is the public transport stop, where passengers board and alight from public transport vehicles. In other words, a public transport stop is a point where public transport vehicles drop off and pick up passengers. Public transport stops are categorized as terminal and intermediate stops. At terminal stops, public transport vehicles not only drop off and pick up passengers, but also begin and end services according to timetables, allow drivers and conductors to change shifts, rest, use facilities, have meals, and clean vehicles.

Internationally, the distance between public transport stops is determined based on the type of transport and the density of settlement areas.

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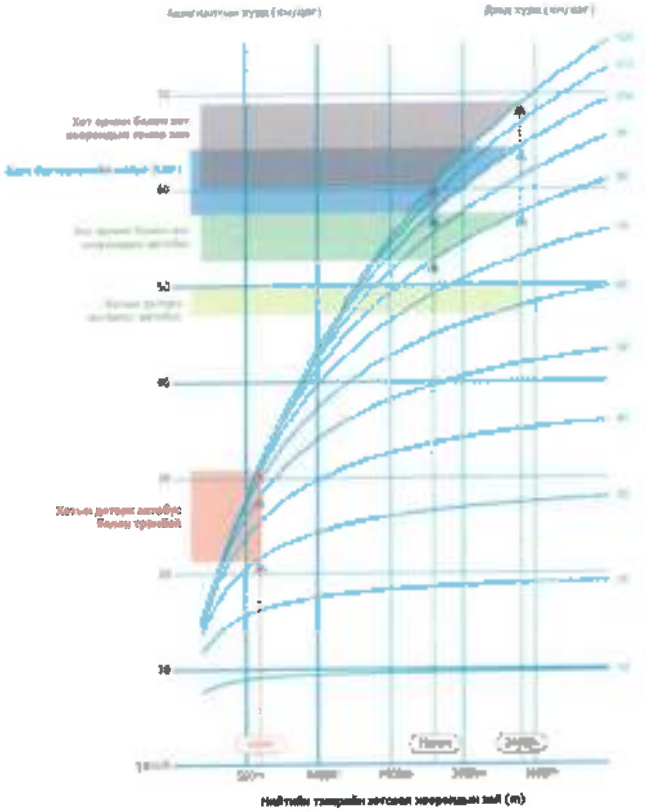

Research on distance between public transport stops depending on transport type (Gustav Nielsen, John D. Nelson, Corinne Mulley, Goran Tegner, Gunnar Lind, Truls Lange, 2005)

Specifically, the distance between public transport stops is planned in relation to vehicle speed: 300-600 meters for urban bus and tram services, 800-2400 meters for urban express bus services, 1800-2400 meters for intercity and suburban services, and also 1800-2400 meters for high-capacity transport types.

A crucial aspect in public transport route planning is stop planning, as the distance between stops directly affects the operational speed of vehicles on that route. In other words, the more stops along a route, the lower the operational speed of the service vehicles. Therefore, when improving network planning, it is essential to precisely calculate stop locations and capacity.

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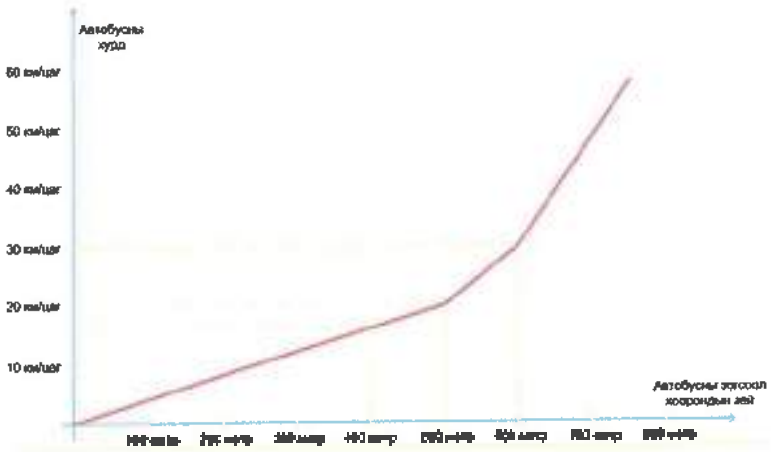
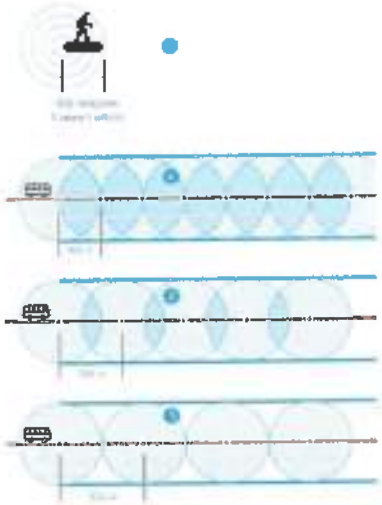


Research on speed depending on distance between stops

Conversely, conditions must be created for citizens to walk to public transport stops to access services. If the average walking speed is calculated at 5 km/hour, a person can travel about 400 meters in 5 minutes. Internationally, a walking distance of 400 meters to access public transport services is considered appropriate, and walking more than 5 minutes is considered unfavorable for passengers. A 400-meter radius should be drawn from planned public transport stops to determine coverage area, and the distance to the next stop should be calculated in relation to population density within that coverage area. Depending on population density within the coverage area, the next stop's coverage area may overlap to ensure balanced stop loading, and the distance between stops is planned as shown in the figure.



According to Mongolian Standard MNS 5879-2012 "Public Transport Route Stops. Classification. Technical Requirements" section 7.5, "The distance between route stops shall be 400-600 meters within the city, and determined based on road conditions and

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settlement structure outside the city." Also, the "Urban Planning and Construction Norms and Regulations" (BNbD 30-01-04) section 6.28 states, "The walking distance to public passenger transport stops shall be planned at not less than 300 meters."

Public transport stop locations are directly related to traffic safety and passenger safety, thus they should be located at least 40-50 meters from road intersections and crossings, provide conditions for disembarking passengers to safely exit behind the vehicle, and be planned together with nearby pedestrian crossings.

The Transit Street Design Guide published by the National Association of City Transportation Officials (NACTO) defines considerations for planning island stops within streets, which have been utilized in the planning. An in-street boarding island located between a transit lane traveling along the center of the street and a general traffic lane on the right side of the roadway creates an in-lane stop, prioritizing trams and buses within the street while allocating space for straight-traveling vehicles. In-street boarding islands recommend careful regulation of pedestrian interaction to access the platform.

Usage and Conditions

- In-street island stops are used on streets with center-running public transport where in-lane stops are appropriate. Particularly on streets with high transit passenger volume or service frequency, center boarding islands significantly improve bus or rail service.
- Platforms can be adapted for level or near-level boarding for various public transport types such as trams and buses.
- Suitable for various service types from local to express services, from buses to light rail.
- Island stops will be located at intersections (with stop signs or traffic signals) with regulations to facilitate safe pedestrian access to the island.

Advantages

- In-street island stops allow for center-running public transport on relatively small streets where full-scale transit stations are unsuitable or unnecessary.
- In-lane stop positions reduce the dwell time of public transport vehicles.
- Island stops provide dedicated space and comfort for public transport passengers while clearly preserving pedestrian space on sidewalks.
- Island stops provide safety not only for public transport passengers but also for pedestrians crossing the street.

The planned alignment includes 23 designated public transport stops.

Public transportation stop planning along the planning route

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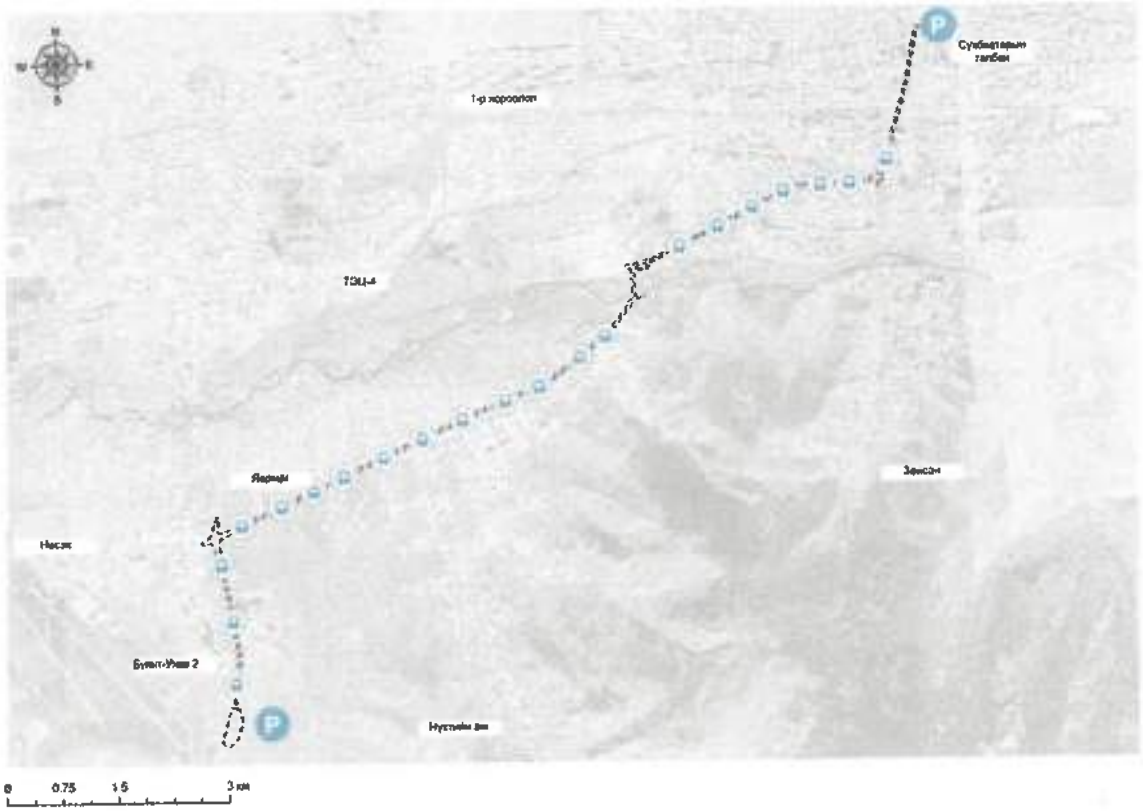

Table 58. ***Distance between planned stops***

No.	Station Name	Distance between stations (meters)	Road Name	Station location and characteristics
1	General Archive Office	350	Olzii Road	Located at the city's northern intersection with Hashin Khondii, Zuunmod direction. Located along the main road on the 2nd level. Serves as the main station for foreign international transport.
2	Buyant-Ukhaa 2 District	865		Located at the city's northern intersection with Hashin Khondii, Zuunmod direction. Located along the main road on the 2nd level. Located near a new educational zone.
3	New Planned Station-1	785		
4	118th School	705		
5	Yarmag 4th Bridge	596		
6	New Planned Station-2	478		Located at the city's northern intersection with Niech, Yarmag direction. Located along the main road on the 1st level. Located near a new educational zone
7	Hospital Station	448		

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8	Yarmag 3rd Bridge	596		
9	Yarmag 2nd Bridge	579		
10	Yarmag 1st Bridge	607		
11	New Planned Station-3	627		
12	English School	495	Naadamchid Road	Located at the city's northern intersection with Nisah, Yarmag direction. Located along the main road on the 1st level. Located near a new educational zone. Western side with ger district.
13	Old Department Store	676		Located at the city's northern intersection with Nisah, Yarmag direction. Located along the main road on the 1st level. Near a new district, city administrative buildings, ger residential district, and commercial service buildings.
14	Viva City	451		
15	MSM	1744		
16	GEM	590		
17	New Planned Station-4	523		
18	Tavan Bogd Company	476		
19	Worker's Cultural Palace	520	Chinggis Avenue	Located along the main road on the 1st level in the city's northern district. Located in the Chingeltei district production zone with specifically designated housing for workers.
20	New Planned Station-5	401		
21	Central Stadium 120 thousandth	696		

In developing the planning solution, two alternatives were considered for stops, with each stop designed to be 3m wide and 60m long.

The placement of each of the 23 planned stops will depend on specific location characteristics, road space, traffic intensity, and pedestrian access. The appropriate design varient from the cross-sections will be selected for each location, with detailed planning to occur during the design documentation phase.

1. Stops Located on Both Sides

Visual representation of stops on both sides

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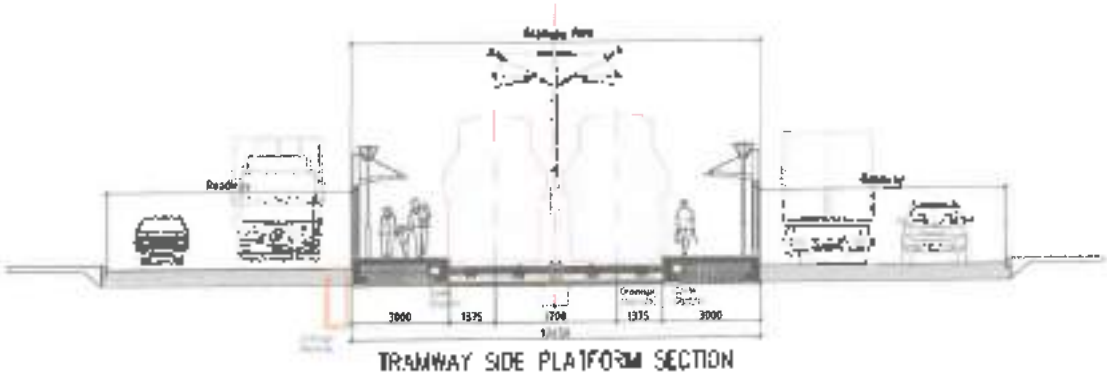

Visual representation of stop planning

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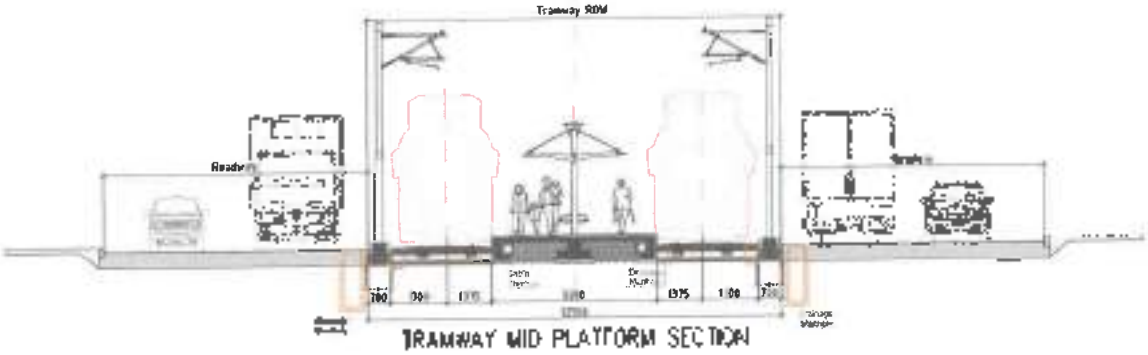
2. Center-Located Stops

Visual representation of center-located stops



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Public-Private Partnership Stop Alternative

There is potential to build 1-2 stops with service facilities on each line through public-private partnerships.

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7.3. TRAM TRAFFIC ORGANIZATION

Trams are public transport systems designed to carry passengers in urban areas, with the distinctive feature of operating on both mixed and dedicated tracks with roads.

- Implementing urban light rail passenger transport can elevate the city to the rank of major international cities, completely transform the city's appearance, and influence urban development to create a more modern city.
- Urban light rail implementation creates a scheduled, high-capacity, comfortable public transport system with several key benefits,
- Significantly reduces private car usage from city outskirts to the center due to business and administrative concentration, helps solve numerous traffic problems
- Modernizing existing public transport stops to create innovative new stations will contribute to new types of urban development.
- Since light rail rolling stock selection is considered crucial for the city's interests, vehicles with distinctive features reflecting Ulaanbaatar's unique character and appearance will be selected.
- Depending on investment, the first line could become operational within 2-4 years.
- Due to relatively low investment and operational costs, ticket prices can be maintained at affordable levels.

Tram capacity is 230-260 people, with the ability to increase train frequency and reduce intervals during peak hours.
It will enable travel from any city outskirts to the center within 30 minutes.

Tram passenger transport offers numerous advantages:

- Electric power source means no noise, air pollution, or greenhouse gas emissions
- Being at the same level as roads results in lower construction costs, no intersection obstacles, and easy integration with bus networks, pedestrian and bicycle paths
- Passenger capacity can be increased according to demand, with capability to carry up to 400 passengers at once
- Lower maintenance costs compared to other transport services

The tram project will not only address central city issues but can also be expanded to cover suburban areas.

Most importantly, the network can be easily expanded until 2050-2060, providing a complete solution for future city traffic.

Ulaanbaatar's implementation of this new public transport system will serve as a good example for cities like Darkhan and Erdenet to introduce tram systems.

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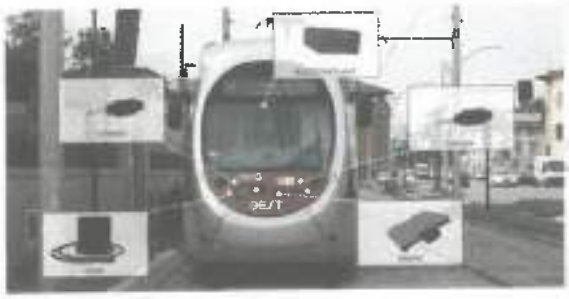
The light rail tram introduces a new public transport system to Ulaanbaatar, which will bring many changes. The selection of rolling stock significantly affects investment, future operation and maintenance costs, traffic safety, and reliability in mixed traffic.

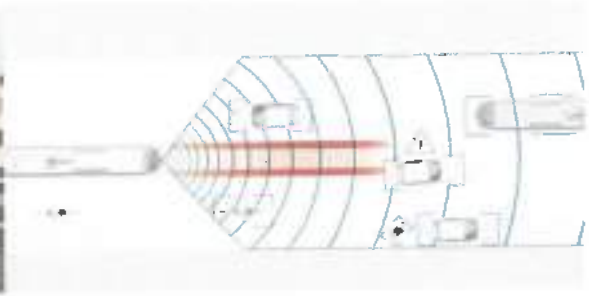
As trams are new to Mongolia, they will operate with minimal risk when running along the green median strip of Yarmag Road, separated from vehicular and pedestrian traffic. However, when entering the city center from Peace Bridge to Sukhbaatar Square, trams will run at the same level as cars, necessitating updates to road traffic regulations and driver education campaigns coinciding with the system's launch.

Safety in tram passenger transport operation is the most critical aspect, requiring human resource training, educational programs, research, and selection of advanced technological solutions. Modern tram manufacturing has incorporated new technologies with significant improvements in passenger comfort and safety. Given the current intensity of Ulaanbaatar's road traffic, the probability of accidents such as collisions in level-grade sections with cars is high, making regulations, unified management, and driver education campaigns crucially important.

While a car traveling at 50 km/h has a stopping distance of 15 meters, a tram at the same speed requires three times that distance—45 meters—to stop.

Ensuring tram transport safety is of paramount importance to all road users and must be prioritized at all stages.





Modern trams are equipped with front-facing image transmitters and recording cameras, Lidar, Radar sensors, and information displays in the driver's cabin. These sensors detect all moving objects in front and to the sides, enabling automatic emergency stops or immobilization for objects the driver may not have seen or anticipated. They also detect road signs and traffic light operations to assist driving, helping to anticipate dangers, prevent accidents, and avoid collisions.

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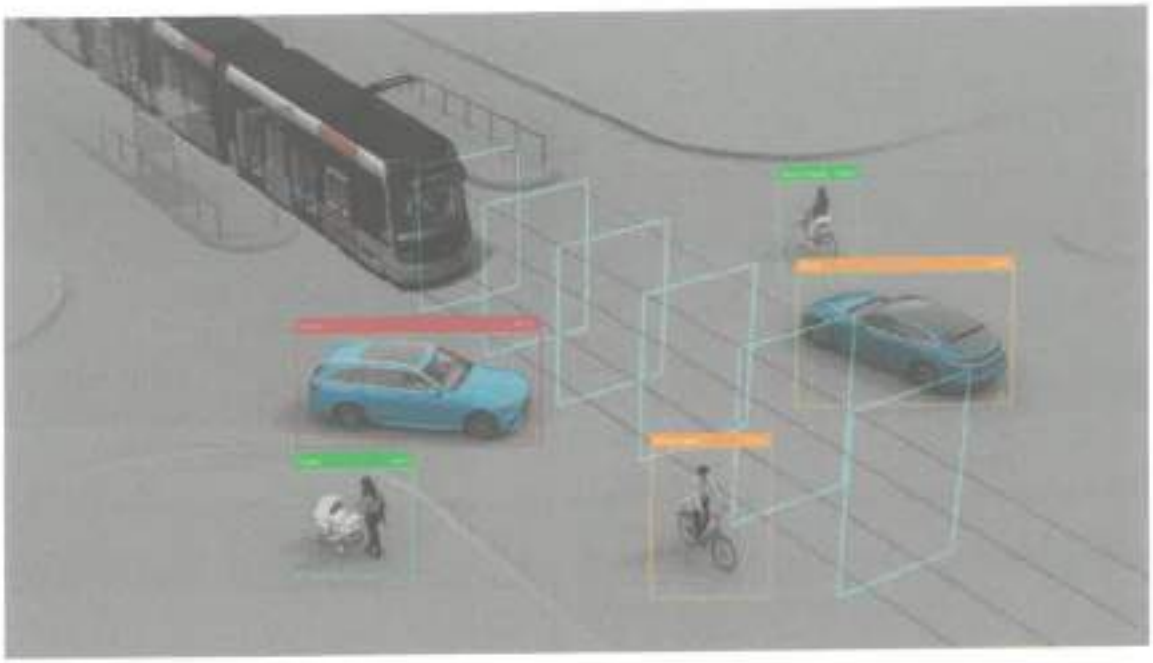
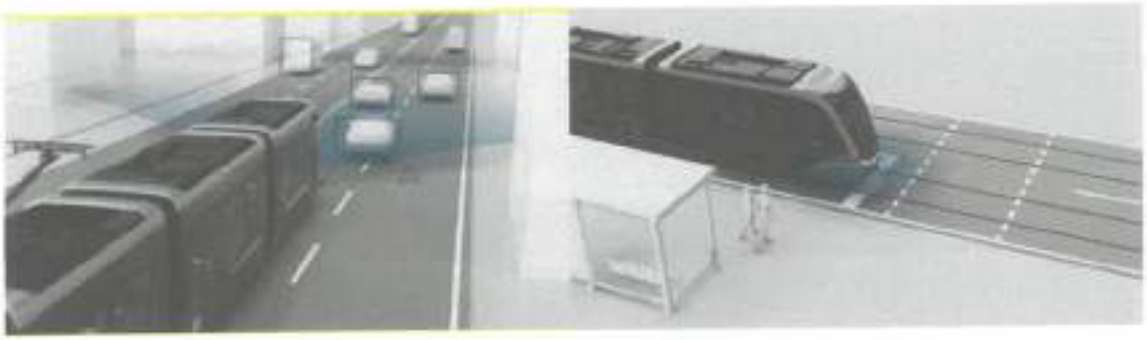


The system also monitors driver attention, facial expressions, movement patterns, and fatigue, providing warnings when incorrect decisions might be made.



Sensors help calculate and detect all objects in the guideway, adjusting speed or stopping the vehicle when necessary. For example, they can detect and alert when a young child suddenly appears at a pedestrian crossing.

Preventing tram traffic accidents is important to avoid significant costs resulting from accidents.

In recent years, there has been a trend away from overhead catenary poles, with underground power conductors being used to reduce operational costs and improve driver visibility.

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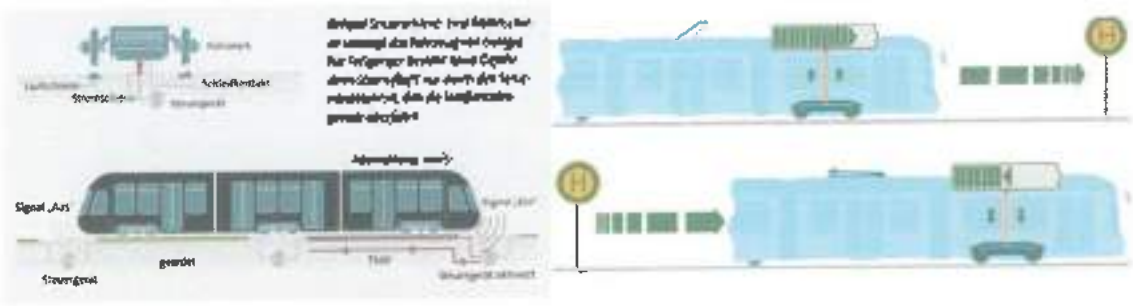
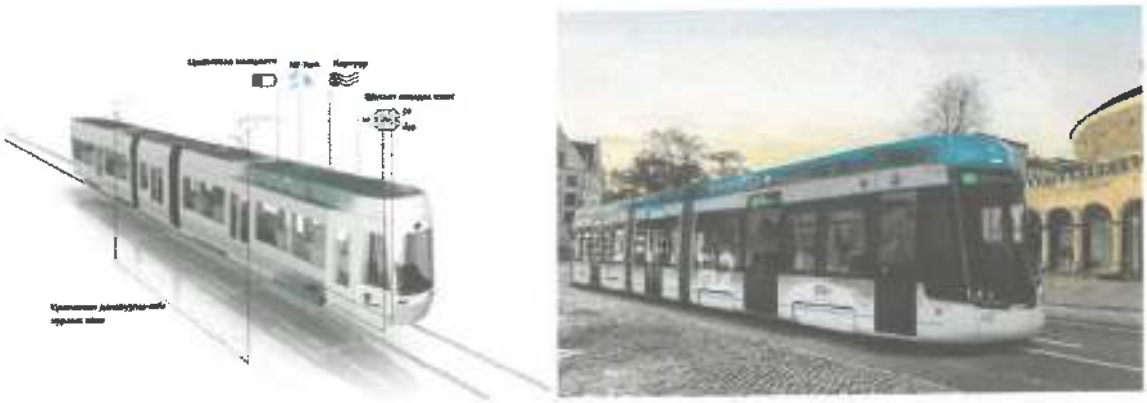


Hybrid systems with battery-stored charge allow operation without catenary systems in cases of sudden power outages or when passing under bridges.



The German city of Görlitz in Saxony is planning to introduce hydrogen trams from 2026, with a budget of 8 million euros and very low operational costs.

Traffic Organization

The main traffic accident risk factors are cars, particularly left turns and intersection crossings.

Prohibiting left turns would cause unpredictable congestion at intersections. Therefore, the working group must determine where, to what extent, and under what conditions left turns or U-turns can be made during the detailed design phase.

Left turns should be permitted at major city thoroughfares with high traffic volume (Category 1 and 2 roads). From the General Archives terminus toward the city center, the following high-traffic intersections should retain left turns:

- Intersection from Naadamchid Road to CHPP Road
- Intersection of Chinggis Avenue and Engels Road (Namy Bridge)
- 120 (Camel Monument) Intersection
- Central Post Office Intersection

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U-turns will be permitted only at specific approved locations and only with traffic light control.

Trams will be regulated by a separate traffic signal system that coordinates with road traffic signals. By granting trams priority at intersections, they will be able to pass through intersections directly without any waiting time.

Equipment installed on trams will transmit information to each roadside pole, alerting the traffic control system of their approach. Following this principle, when a tram approaches an intersection, the system will notify road traffic signals of its arrival, stop vehicular traffic, activate signals for the tram's direction of travel, and allow the tram to proceed through the intersection without stopping.

1. Signals on roadside lighting poles provide information about the tram's proximity to the next intersection.
2. 2 and 3. Trams transmit their position and other information in real-time to intersection traffic light control.
3. Intersection traffic light control determines when the tram will arrive at the intersection and clears it.

Giving priority to public transport vehicles at intersections:

- Will make public transport investment more effective, optimal, and more profitable.
- Will reduce fuel consumption and noise.
- Will increase tram speed and reduce traffic congestion.
- Will transport citizens using public transport faster.
- Will reduce time spent on public transport, among other advantages.

Public transport service will become safer and able to pass through faster than automobiles.

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CHAPTER 8.OPERATIONAL PLAN

Table 59. Operational Traffic Plan

Parameters	Specifications
Line length	15 km
Peak hour passenger demand	6923 people/hour/1 direction
Average distance between stops	700 m
Unit rolling stock	1 set /3 sections/
Passenger occupancy (peak hour)	180%
Total passengers per unit	230 people
Interval between trams	5 minutes
Number of operational units	16
Total line travel time	37 minutes /one way

Table 60. Tram Service Hours and Trip Planning

Indicator			2
Route No.			Tram - 2
Route name			Archives GA - Sukhbaatar Square
Round trip length (km)			30 km
Round trip time (min)			74 minutes
Number of transport vehicles		Daily operating vehicles	16
	Time	Interval	
	6:30	10	8
	7:00	5	15
	10:30	6	12
	16:00	5	15
	20:00	8	10
	21:30	10	8
	22:30	20	4
Performance	Hours		106
	Trips		171.5

Operational traffic organization will be conducted from a unified control center using the SCADA system, and the traffic schedule has been developed with intervals and number of operating rolling stock aligned with passenger movement during peak and off-peak demand periods. The daily operational schedule is preliminarily planned from 06:30 to 23:30. During peak traffic hours, 15-16 units of rolling stock will be in operation, with a total of 172 round trips calculated per day.

8.1. TRAM TRACK PLANNING

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CHAPTER 9.Planning on bridge structures

The planned line from Buyant-Ukhaa Sports Complex to Sukhbaatar Square is 15 km long with 23 stops, and Yarmag Bridge and Peace Bridge are located along this route. The following solutions have been developed as options for integrating the tram route with these bridges.

Yarmag Bridge

Yarmag Bridge is 250.2 m long, 20.5 m wide, with 4 lanes, and together with the old bridge has 8 lanes. The plan fully utilizes two north-south bound lanes with a width of 7 m, designed to pass under the east-west directed estacade.

Tram Route Planning on Yarmag Bridge

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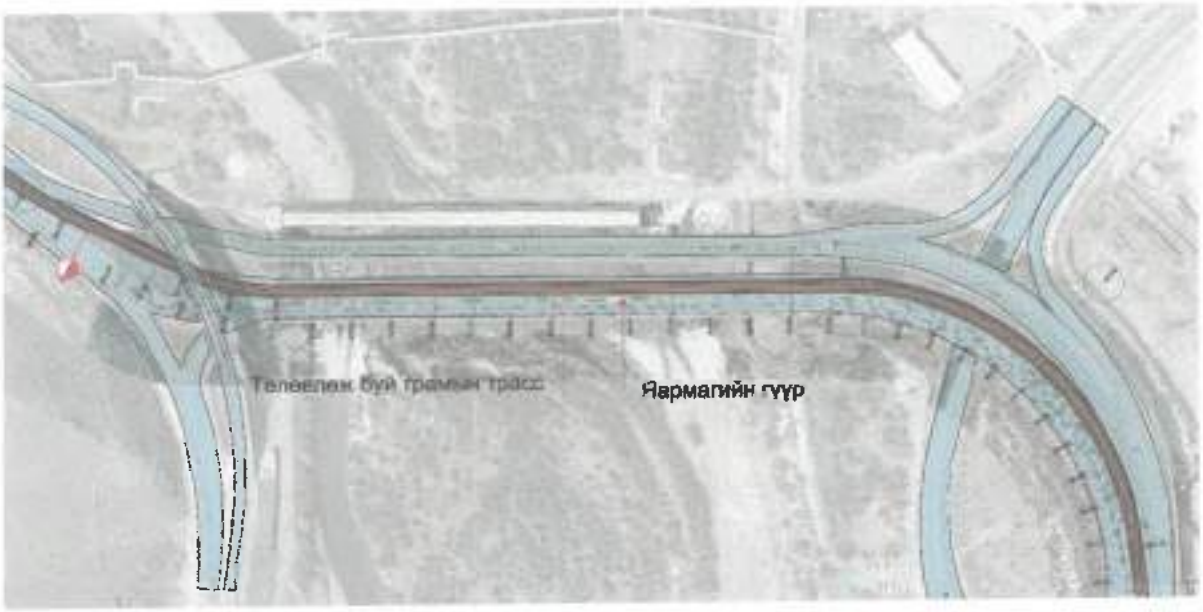

Peace Bridge

Peace Bridge was commissioned in 1958 and serves as the main road connecting the city center with Khan-Uul District, running north-south over the east-west railway and Selbe River. The Namy Road passes underneath it.

Total length: 580 meters, bridge width: 16,8 meters, with two-way vehicular traffic lanes and pedestrian paths.

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In terms of architectural solution and location, this bridge combines neoclassical elements characteristic of socialist-era construction with traditional Mongolian decorative forms. The platform towers on both sides feature classical column ornamentation, which was an important solution symbolizing the power of the government at that time. Peace Bridge is not merely infrastructure but a social, historical, and cultural heritage. This bridge remains a symbol of major construction undertaken during the socialist era, representing the architectural and engineering development of that period.

Therefore, two alternatives have been developed for integrating the tram route with this bridge: either preserving the architectural style and structure, or in case of expansion, reconstructing the towers according to their original design.

Current Situation

Newly Planned Alternative-1

The tram route is planned along the center of the existing bridge in two lanes (7.0 m), relocating the pedestrian path to create two-way traffic with one lane, and the bridge would be expanded on both sides to accommodate one vehicle lane and pedestrian paths.

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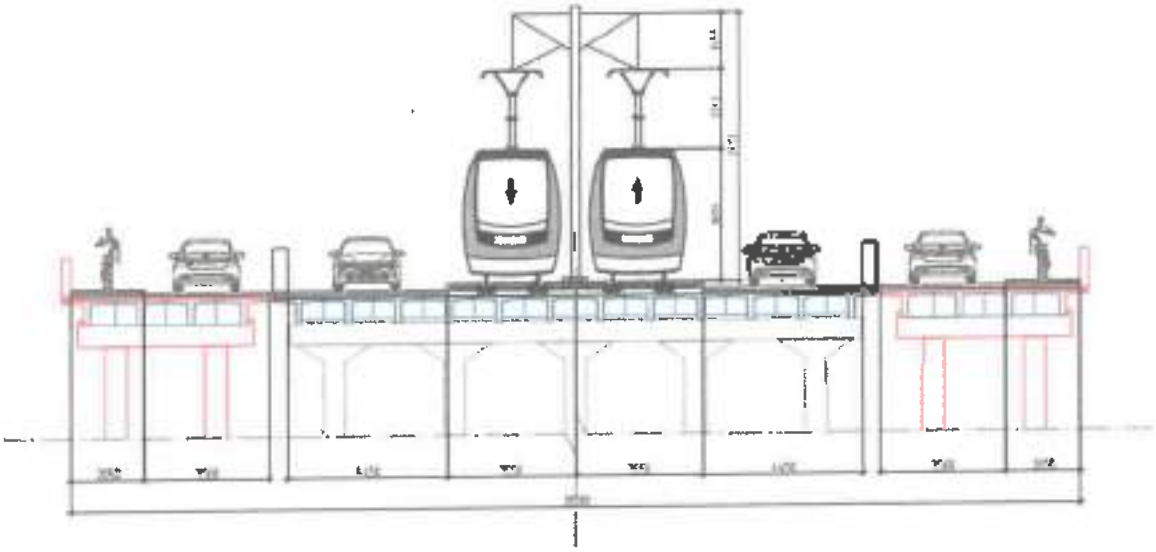
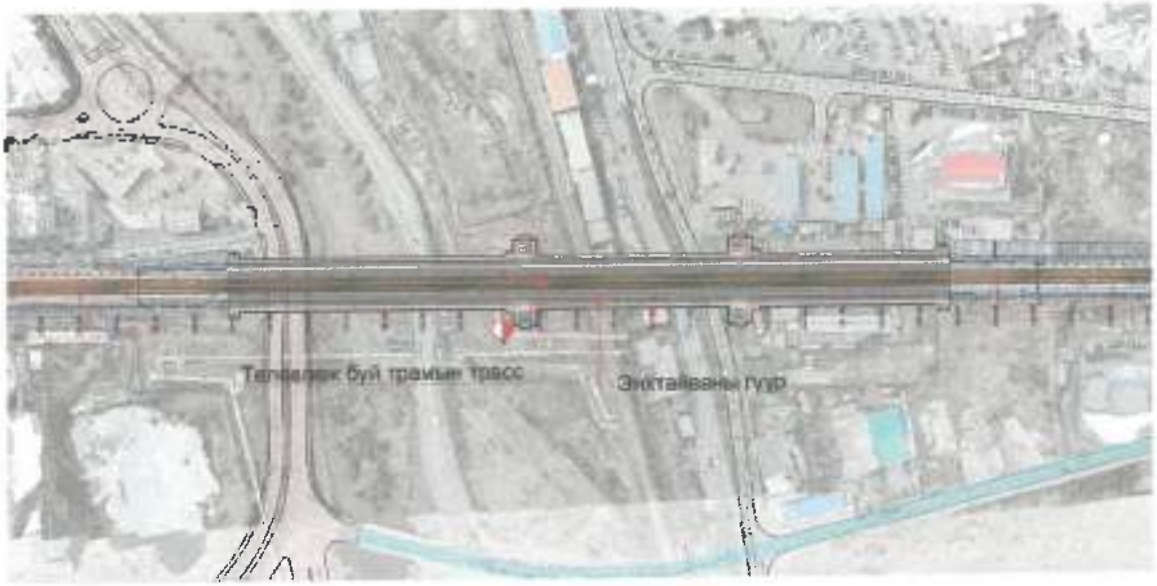
Plan, Expanded Alternative



Visual Representation, Expanded Alternative



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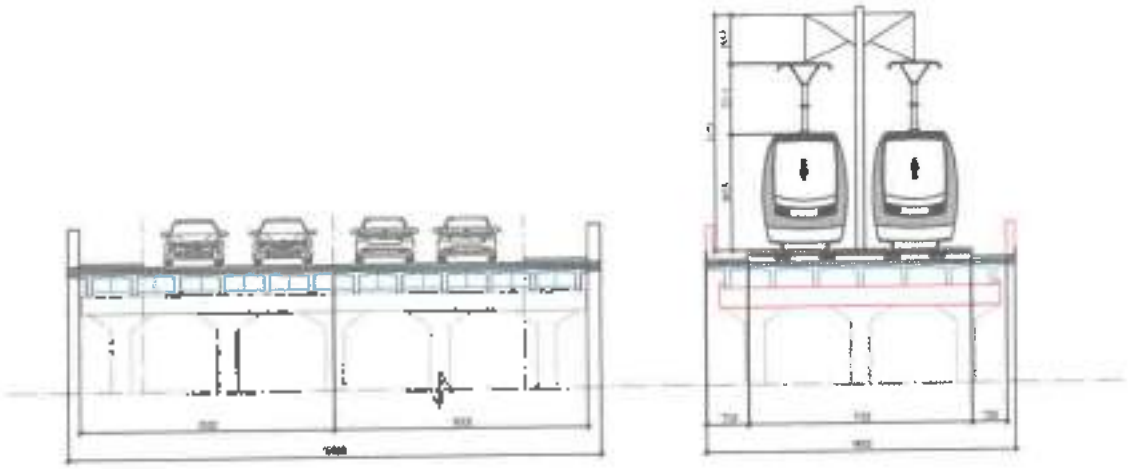
Newly Planned Alternative-2

A new bridge structure for the tram route is planned on the east side of Peace Bridge.



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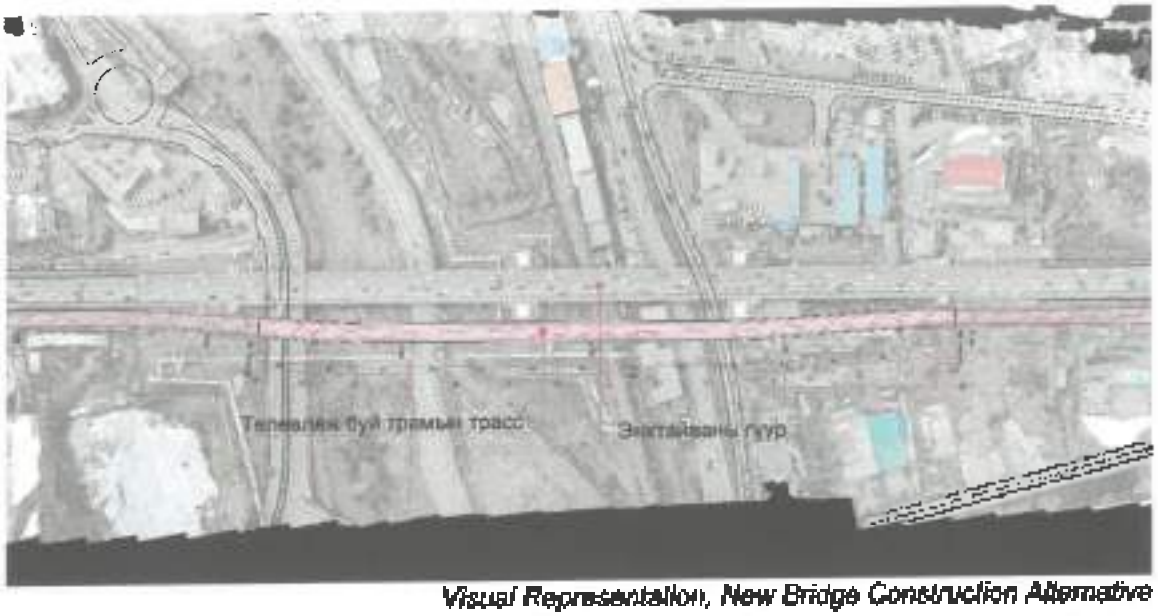
Plan, New Bridge Construction Alternative



Visual Representation, New Bridge Construction Alternative

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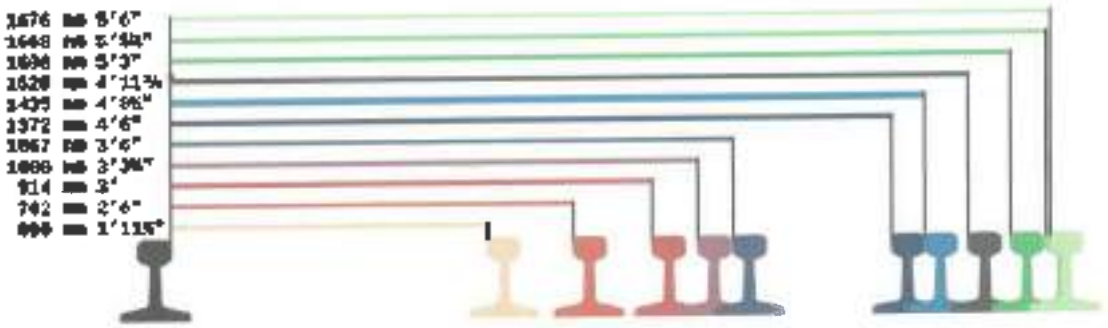
9.1. TRAMWAY PLANNING

Tramway Track Gauge Size and Selection

The tram is one of the earliest urban transport vehicles, emerging in the early 19th century as a result of railway development. The first tramway system is considered to have appeared in England in 1825. Since then, tramway networks have spread and begun to be used in many countries around the world. A tramway track, like a railway, has double rails, and the gauge of the tramway refers to the distance between the two rails. The type of tramway gauge varies depending on many factors such as a country's transport network, economic conditions, geographical location, and vehicle load.

Gauge width



Compared to railways, tramway tracks are placed alongside roads and pedestrian paths in a greater variety of configurations, which is why there are many different gauge sizes.

Table 61. Basic classification of tramway track gauges

Type of Gauge	Width (mm)	Usage
Standard Gauge	1435 mm	Most commonly used globally
Broad Gauge	1524–1676 mm	Russia, India, Spain, Argentina
Narrow Gauge	600–1067 mm	Mountainous areas, specialized trams
Ultra-Narrow Gauge	500 mm or less	Tourist and heritage tramways

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Table 62 *Common global tramway gauge standards*

Type of Gauge	Width (mm)	Countries Used In	Advantages	Suitable for Ulaanbaatar
Standard Gauge	1435 mm	Paris, London, Berlin, New York, Tokyo	International standard, compatible with modern tech, facilitates interconnectivity	Most suitable (LRT, etc.)
Broad Gauge	1524 mm – 1676 mm	St. Petersburg, Helsinki (1524 mm), Mumbai, Buenos Aires (1676 mm)	Suitable for large-capacity trams, stable movement	Currently used, but not globally standard
Narrow Gauge	600 – 1067 mm	Zurich, Geneva, Lisbon (1000 mm), Cape Town, Kobe (1067 mm)	Suitable for road-sharing, narrow streets, lower construction cost	Suitable for downtown tram systems
Ultra-Narrow Gauge	500 mm and below	San Francisco (500 mm, cable car), Dresden	Used for tourism, heritage transport, attracts tourists	Suitable only for tourist-oriented routes

Methodology for Selecting Gauge Size

For selecting the gauge size for Ulaanbaatar's Tramway (Light Rail), the Analytical Hierarchy Process (AHP) methodology developed by researcher Thomas L. Saaty will be used. This method provides the advantage of enabling decision-making based on multiple factors, weighing influential factors, and determining the final selection using an evaluation system. When selecting gauge size, it is necessary to consider fundamental criteria such as technical compatibility, economic factors, passenger comfort, and coordination between transport types.

According to the AHP methodology, the first step is to define the objective. In this case, it is necessary to select which gauge is appropriate for Ulaanbaatar's Tramway, with options such as 1000 mm or 1435 mm gauge. The next step is to establish the main factors that influence decision-making, including technical compatibility, construction cost, expansion possibilities, coordination with other transport types, and maintenance costs. Further classifying these, technical compatibility considers alignment with existing railway systems, construction cost includes initial installation and maintenance expenses, future expansion possibilities consider compatibility with international standards, and transport coordination considers compatibility with other public transportation vehicles.

The most important phase of AHP is the comparison process. In this phase, all factors are compared with each other and evaluated on a scale of 1-9. For example, if one factor is considered slightly more important than another, it receives 3 points, if very important, 7 points, and if of highest importance, 9 points. Based on these scores, mathematical modeling is used to make the most optimal decision.

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The advantage of the AHP methodology is that it allows multiple factors to be considered simultaneously and creates conditions for making decisions based on objective data.

Comparison	High Importance (9)	Medium Importance (5)	Low Importance (1)
Technical Compatibility vs. Cost	5 (Compatibility is critical)	-	-
Future Expandability vs. Multimodal Integration	-	7 (Expandability matters)	-

Table 63. Example of AHP methodology

Evaluation Factor	1000 mm Gauge	1435 mm Gauge
Compatibility with Current Roads	High	Low
Cost	Low	High
Maintenance Standards	Requires adjustment	More standardized
Potential for Future Expansion	Limited	Easy

Table 64. Results of AHP evaluation

Criteria	Weighting (%)	1000 mm Score	1435 mm Score
Technical Compatibility	30%	9	4
Cost	25%	8	5
Future Expandability	20%	3	9
Multimodal Integration	15%	5	8
Maintenance	10%	4	7
Total Score	100%	6.3	7

Calculations using the above methodology show that the standard 1435mm gauge is widely used in many countries, conforms to international standards, is economically efficient, and can have stable maintenance costs. In contrast, while the 1000mm narrow gauge has advantages for combination with roads, it can be difficult for long-term expansion and has weak compatibility with other vehicles.

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Considering international standards compliance, future expansion possibilities, coordination with other transport types, standardized maintenance technology, and operational cost savings, it appears that selecting the 1435mm standard gauge is the most appropriate and optimal solution for Ulaanbaatar city's tramway.

The selection of 1435mm standard gauge for Ulaanbaatar city's tramway aligns with international standards, offering future expansion possibilities, compatibility with other transport modes, standardized maintenance technology, and operational cost savings, making it the most suitable and optimal solution.

9.2. TRAMWAY TRACK TECHNICAL SPECIFICATIONS AND GENERAL REQUIREMENTS

The technical specifications for the tramway track have been determined according to internationally common standard requirements and are included in the table below.

Table 65 General Track Specifications

№	Parameter	Dimension	№	Parameter	Dimension
Infrastructure			Rolling Stock		
1	Number of lines	1	8	Tram width	2650 mm
2	Gauge size	1435 mm	9	Tram length	as calculated
3	Track type	without intersection	10	Axle load	12,5 tons
4	Base type	ballastless, slab track	11	Electrical power	560-700 kW
5	Maximum gradient	40 ‰	12	Capacity	150-240 people
6	Minimum turning radius	50 meters	13	Maximum speed	60-80 km/h
7	Rail	50-65 kg/m, grooved	14	Average speed	30 km/h

When planning tramway curves, the radius should be maximized, preferably between 50 meters (minimum) and 2000 meters (maximum). In challenging conditions due to terrain characteristics, urban road space, and building placement, radii as small as 20 meters may be considered. Such planning must account for the selected rolling stock's wheel pair type and bogie spacing. Transition curves must be included for curves with radii less than 1000 meters on high-speed tramway sections and less than 100 meters on regular tracks, depending on tram operational speed.

When curves are oriented in opposite directions, a straight insertion of at least 10 meters must be placed between the two initial transition curves.

The longitudinal profile gradient in straight sections should not exceed:

- 60‰ on straight tracks
- 2.5‰ at track beginnings, endings, and maintenance areas
- 30‰ on dead-end tracks in narrow, difficult conditions

Tramway gradients should not extend beyond the following lengths: 700 meters for 30‰, 500 meters for 40‰, 350 meters for 50‰, and 250 meters for 60‰.

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Vertical curves should be planned, as with railways, to avoid overlapping with transition curves, bridge supports, and road intersections.

Track Structure Selection and Standardized Cross-Sections

Tramway track superstructure, substructure, and pavement are planned in various ways worldwide, depending on local conditions, urban density, road width, available space, overhead networks, and whether tracks intersect with or share space with roads.

Tramway track foundation structures differ primarily between ballasted with sleepers and ballastless slab foundations. Modern tramway tracks increasingly incorporate the Embedded Rail System (ERS), where rails are installed in continuous concrete slabs without separate fasteners or bolts.

Ballasted foundation tramways are similar to conventional railway structures and are most suitable for areas without mixed vehicular traffic and with minimal at-grade intersections between cities.

Track with Ballasted Foundation

Slab foundation tramway tracks are more suitable for passenger transport within cities, and their main advantage is the ability for roads and tramway tracks to travel at the same level. This type of foundation keeps the upper structure of the track stable and allows for easier, faster maintenance. It also connects tramway tracks with roads at the same level, increases road safety, and makes tramway movement safe and efficient. Slab foundations play an important role in reducing slip, vibration, and noise levels, making tramway track operations in city center areas more efficient. This is suitable for modern urban settlements and simplifies

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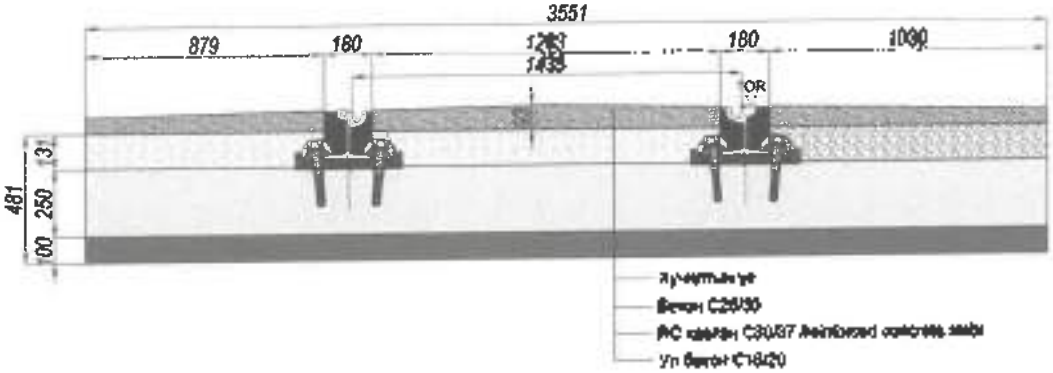
tramway movement in high-density road areas, making it suitable for use in deliberately limited spaces.

Track with Slab Foundation

Figure 1. Main Track Structure Cross-Section



Bridge Structure Track Cross-Section

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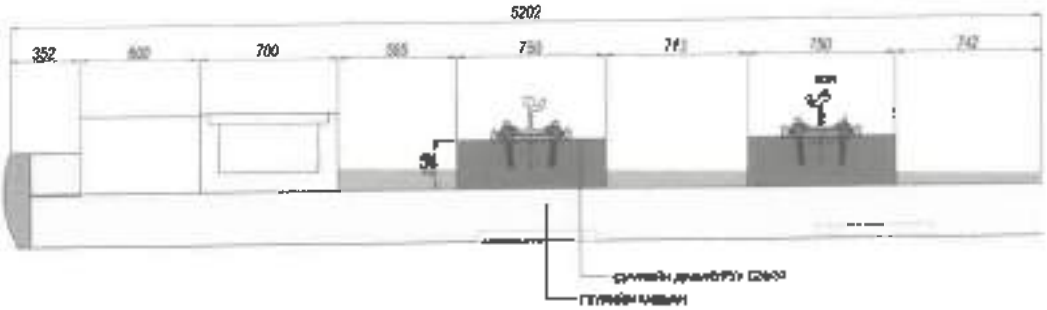
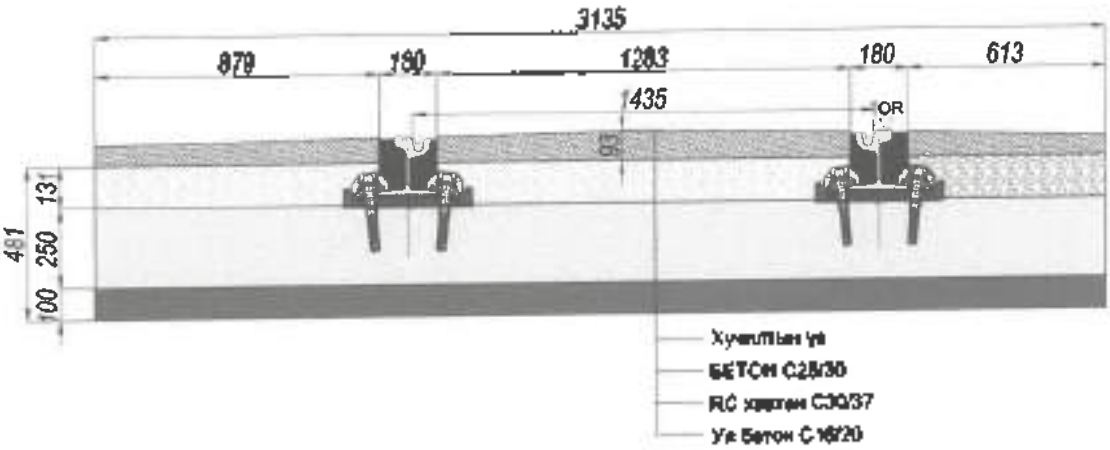
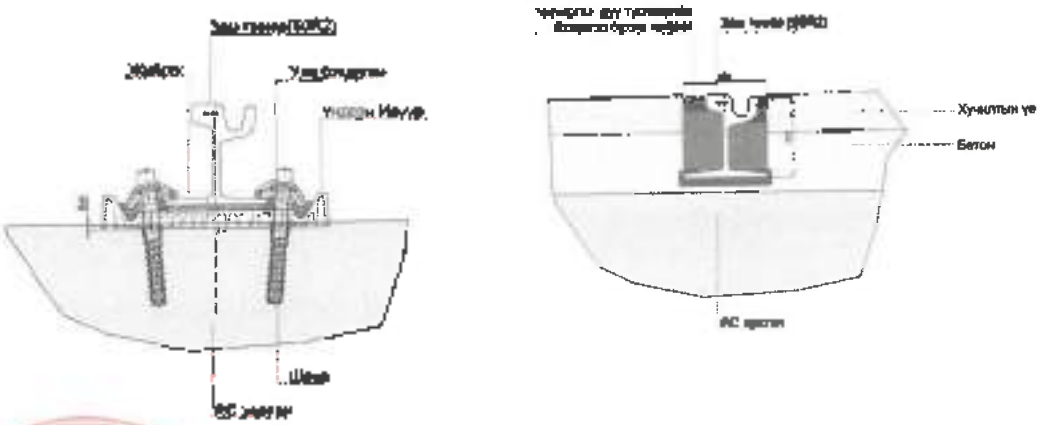


Stop Location Track Cross-Section



Fastening Types



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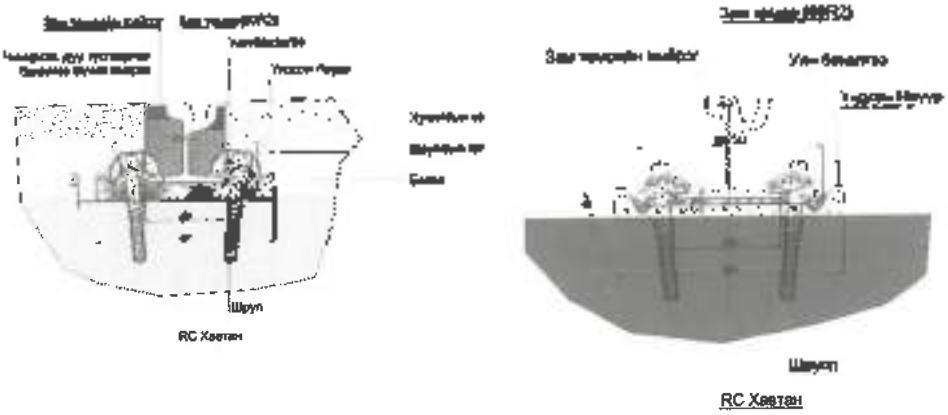

Basic Grooved Rail

Embedded Rail System (ERS)

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When selecting tramway track superstructure materials, load calculations for each component should be considered, with attention to:

- Track purpose
- Train and rolling stock forces
- Surface type
- Hydrogeological conditions
- Base and longitudinal profile
- Protection of underground utilities from corrosion and wear

The tramway track substructure or foundation absorbs the load and pressure from the rails and above, transferring a small portion to the soil. Substructure design requirements consider track stability and durability, including:

1. The track structure must ensure constant stable operation, preventing settlement or deformation that could damage the pavement layer and rail buckling
2. Rails must be securely fastened to the foundation to prevent movement in transverse and vertical directions
3. The foundation structure must prevent surface water infiltration into the subsoil and connect to central drainage systems
4. The entire tramway structure should be flexible, reducing noise when rolling stock passes

When selecting substructure materials, consider:

- Traffic intensity, track speed, and load
- Subsoil characteristics
- Tramway location, whether mixed with or separated from other vehicles
- Longitudinal gradient drainage capabilities
- Superstructure and pavement type

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- Traffic purpose

Tramway pavements can be designed with various materials including asphalt concrete, cast concrete, concrete slabs, blocks, or stone. In modern infrastructure-advanced countries, eco-pavements with green turf have been implemented. These provide excellent vibration and noise reduction, electrical insulation, and environmental benefits while enhancing urban aesthetics.

Various tramway pavement types are shown in the figures below.

Types of Tramway Track Pavement:

Tramway track pavement can be made in many varieties including asphalt, cast concrete, concrete slabs, blocks, and stone. Among these pavements, eco-pavement or green grass pavement is becoming an environmentally friendly solution with good electrical insulation properties and noise reduction. Green pavement reduces vibration and noise, positively impacts urban aesthetics, is more environmentally friendly, and contributes to energy conservation.

Track with Asphalt Pavement

Concrete Slab Paved Road

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Stone Paved Road

Grass Paved Road

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Cast-in-place Concrete Paved Road

When selecting the cross-section and structure of Ulaanbaatar city's tramway track, it's important to consider modern advanced technologies. Therefore, slab foundations without ballast, especially prefabricated concrete slab structures, will be the most appropriate choice. This structure can be assembled in a short time when planning and constructing new tramway lines on roads, and has easy installation features. Additionally, slab foundations increase track stability and durability while helping reduce vibration and noise. This type of structure is also relatively well-suited to weather conditions and hydrogeological situations, playing an important role in reducing long-term usage and maintenance costs. This feature of prefabricated structures contributes to ensuring tramway track construction stability and improving traffic safety.

Tramway Track Cross-Section

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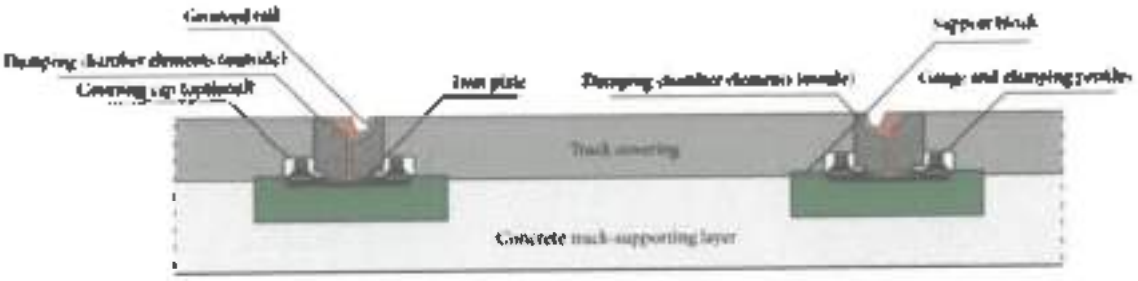

Tram Track Installation Work

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According to the instructions and technical requirements shown in the above image, foundation preparation activities play an important role in creating quality, stable track structures. Therefore, ground soil compaction should be done in compliance with standards and technical requirements to ensure track foundation stability.

For ease and efficiency in track repair and maintenance services, concrete foundations should be manufactured and installed in lengths of no more than 2-3 meters. This allows for correct and quick assembly of the foundation and will help reduce maintenance.

Using geotextile is important to prevent water penetration, swelling, and settling distortion in the ground soil, which will positively impact soil stability. Additionally, laying rubber gaskets along the entire length to reduce track noise and vibration levels plays an important role in traffic safety and user comfort.

Detailed working drawings and plans must clearly specify ground soil slopes and concrete foundation gradients, and water flow and drainage pipes must be placed as required. Properly planning the water drainage system is important for protecting against water accumulation and track damage. Also, correct placement of drainage pipes will make it possible to prevent problems caused by water effects.

Organizing all these processes at a high professional level is the basic condition for ensuring track durability and guaranteeing long-term usage.

Drainage system

A drainage system will be installed along the railway corridor. Surface water from the roadway will be collected through grated channels intersecting perpendicularly at specific intervals along the slope, discharging into existing drainage facilities or appropriately located drainage lines. When using closed drainage systems, the contractor must install sufficient manholes and inspection points to ensure system cleaning, inspection, and maintenance. In cut and embankment sections, trapezoidal side ditches with 1H:1V slopes will be constructed, discharging into appropriate drainage systems.
Slope and embankment protection will be implemented using surfacing materials that comply with domestic and international practices. Structural designs for culverts will be developed in accordance with relevant domestic and international standards. Existing culverts under roadways will be modified for use with the tram line construction while maintaining their current characteristics. Required structural designs and implementation methodologies will be presented to the client. To facilitate construction, maintenance, and renovation, culverts should be standardized with modular structures for easy assembly. Materials and technologies meeting environmental and sustainable development requirements will also be studied and implemented.

Railway Rails

Tramway rails depend on many factors such as structural type, usage characteristics, material properties, technical parameters, production standards, durability period, load-bearing capacity,

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installation and maintenance requirements. Therefore, tramway rail classification emerges considering these factors, and generally distinguishes the following 3 types:

- Special structure rails for tramway tracks (Block rail)
- Grooved rails for tramway tracks (Grooved rail)
- Regular railway rails (Vignole rail)

The length of tramway track rails is usually the standard length of 12.5 meters. This is the most commonly used measurement, and factories produce rails at this length. However, in some cases, depending on tramway track structure, transport conditions, and track configuration, the length can be 6 meters, 9 meters, or up to 18 meters.

Tramway tracks need to be without intersections to ensure maintenance, usage, and passenger comfort, as well as to reduce noise, and temperature stress adjustment work must be performed during initial assembly. Rails are welded using electric welding or aluminothermic welding.

1. Special structure rails for tramway tracks (Block rail) Block rails have solid structures, high load-bearing capacity, and advantages such as low noise. However, this type of rail has disadvantages such as high material input, inflexibility or excessive rigidity, and difficulty in placing on curved track sections. Therefore, using this type of rail is effective in environments with high vehicle loads and low noise.

Block rails are widely used in the following places:

- Urban transport tramway lines - Basically used in places where low noise and normal conditions of tramway movement need to be maintained.
- Metro and light rail (LRT) lines - This type of rail has high load-bearing capacity, suitable for metro and light rail traffic density and load.
- Heavy-duty roads - Used in ports, warehouses, cargo transport zones, and other places where high load-bearing capacity is required.

Block railway rail

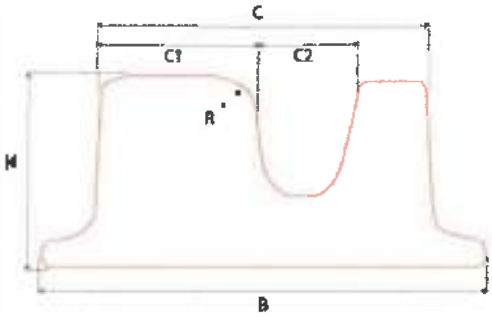

Table 66. Block railway rail dimensions

Rail Type Specifications	Weight, kg/m	Head width, mm	Groove width, mm	Total head width, mm	Base width, mm	Height, mm
		C1	C2	C	B	H

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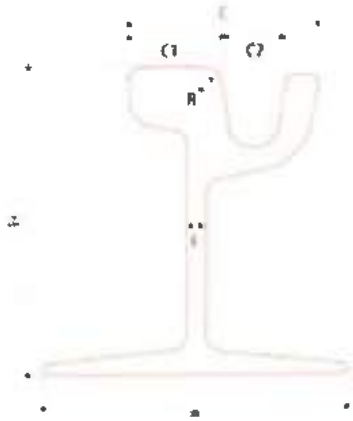
53K2	53.34	56.0	45.0	116.0	156.0	70.0
57K2	57.88	58.0	36.0	115.0	156.0	72.0
58K2	58.29	55.9	41.5	120.0	156.0	72.0

Grooved rail Grooved Rails for Tramway Tracks



Grooved rail is widely used for tramway and trolleybus tracks. This type of rail has a groove in its head section, and the groove serves to correctly position and guide the flange of the tram's double wheels. The groove correctly positions the tram wheel on the rail surface, playing an important role in ensuring stable tramway movement and safety.

Grooved rail is used on tramway tracks considering speed, load, traffic density, etc., and these rails basically have high load-bearing capacity. They are suitable for use on tramway and trolleybus tracks and can be positioned at the same level as roads. This type of rail is more suitable for use in transition and turning sections because the groove helps adjust to the direction of the road and helps keep the wheel direction from getting lost.

Additionally, Grooved rail plays an important role in controlling tramway speed, rolling stock safety, and maintaining proper operation, and also helps reduce track damage and maintenance costs.

Grooved Rail

Table 67. Grooved Rail dimensions

Rail Type Specifications	Weight kg/m	Head width, mm	Groove width, mm	Total head width, mm	Base width, mm	Height, mm	Neck width, mm
		C1	C2	C	B	H	E
51R1	51.37	55.83	42.34	113.00	150.00	130.00	12.00
53R1	52.98	55.83	38.34	113.00	150.00	130.00	12.00

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54R1/54G1	54.26	56.16	41.09	116.82	141.50	152.50	13.00
54G2	54.65	55.91	41.65	116.80	141.50	152.80	13.00
54G4	50.09	58.22	40.63	116.82	141.50	152.52	13.00
55G3	56.27	55.61	40.18	116.82	141.50	152.50	13.00
55R1	56.46	56.00	36.00	113.00	160.00	160.00	12.00
57R1	58.54	51.82	60.46	127.00	150.00	182.00	11.00
58R1	58.97	56.00	42.00	113.00	180.00	180.00	12.00
59R2	58.14	55.80	42.50	113.00	180.00	180.00	12.00
60R1	60.69	56.00	36.00	113.00	180.00	180.00	12.00
60R2	59.75	55.83	36.35	116.00	180.00	180.00	12.00
62R1	62.37	58.03	34.44	116.00	180.00	180.00	12.00
62R2	61.91	56.86	36.98	116.00	180.00	180.00	12.00

Grooved rails are more suitable for use within cities, on roads, and for traveling alongside vehicle traffic. This type of rail allows combined use of tramway tracks and roads, playing an important role in ensuring the flexibility of the road structure and the stability of rolling stock.

Construction and operation costs are average, but in terms of safety, it's considered the best rail. Grooved rail improves road safety and allows tram wheels to maintain the correct direction. Also, when traveling alongside vehicle traffic, the risk of road damage and cracking is reduced, making it a factor in ensuring traffic safety and passenger comfort.

Grooved rails not only keep tramway movement stable and safe but also have relatively low maintenance costs and simplify maintenance operations. This is important for supporting long-term usage and continuous operation of tramway tracks.

Regular Railway Rail or Vignole Rail

1) Vignole rail is the most commonly used standard rail type in the railway sector and is basically used for heavy-load tracks. This rail was first introduced by engineer Charles Vignole in Great Britain in the early 19th century and was named "Vignole" rail after him.
2) The flat base of Vignole rail is wider than its head, and this has been internationally accepted as the most suitable form for railway transport. This type of rail has high load-bearing capacity and works best in heavy transport, high-speed tracks, and high-load conditions. The wide base of Vignole rail improves track stability, evenly distributes loads, and protects the railway structure for a long time.
3) This type of rail is used on most railway lines, and its technical parameters are suitable for tramway tracks, metro, high-speed tracks, and other targeted vehicles. Even with high maintenance costs and technical competitiveness, Vignole rail has become a suitable standard for international use.

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Vignole rail is manufactured in compliance with railway standards in many countries worldwide and is produced according to the technical standards and order requirements of countries such as America (AREMA), Russia (GOST), China (GB/YB), and Australia (AS). It can also be manufactured according to European (EN) and International Union of Railways (UIC) standards.

The Vignole rails customized to these countries' specific characteristics are manufactured to meet the technical requirements, load-bearing capacity, weather conditions, and transport volume of that country, and the proposed standard maintains a uniform quality and reliability worldwide.

Additionally, when manufacturing according to AREMA, GOST, GB/YB, and AS standards, the general structure, operating conditions, and track safety features of each country's railway are considered. However, EN and UIC standards establish the most common and compatible standards for Vignole rails used internationally, integrating international railway networks.

This plays an important role in ensuring the efficiency, durability, high-speed track suitability, and unified quality transport internationally.

Table 68. Vignole Rail Dimensions

Rail Type Specifications	Weight, kg/m	Head width, mm	Groove width, mm	Total head width, mm	Base width, mm	Height, mm
		D	C	B	H	E
50E2	49.97	44.00	72.00	140.00	151.00	15.00
50E3	50.02	48.00	70.00	133.00	155.00	14.00
50E6	50.90	49.00	65.00	140.00	153.00	15.50
54E1 (UIC54)	54.77	49.40	70.00	140.00	158.00	16.00
54E2 (UIC54E)	53.82	51.40	67.00	125.00	161.00	16.00
54E3	54.57	49.40	67.00	125.00	159.00	16.00
54E4	54.31	56.00	67.00	125.00	154.00	16.00
54E5	54.42	49.40	70.20	140.00	158.00	16.00
66E1	66.30	49.21	69.85	140.00	158.75	20.00

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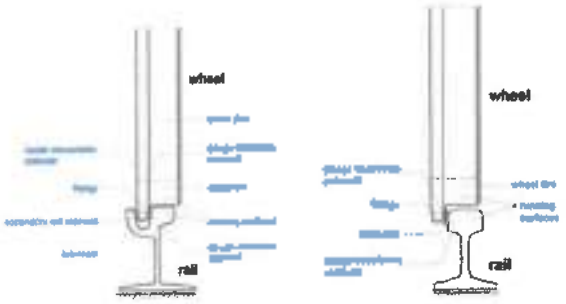
Rail Type Specifications	Weight, kg/m	Head width, mm	Groove width, mm	Total head width, mm	Base width, mm	Height, mm
60E1 (UIC60)	60.21	51.00	72.00	150.00	172.00	16.50
60E2	60.03	51.00	72.00	150.00	172.00	16.50

Vignole rail is the most suitable choice for high-speed and freight railways, with high load-bearing capacity and durability providing long-term usage and track stability, though construction and maintenance costs are high.

Comparison of RailwayRails

	Block rail	Grooved rail	Vignole rail
Suitable location	Low speed, low load sections	City center, road surface, tramway tracks	High-speed tracks, freight railway
Construction cost	Expensive	Moderate	Very expensive
Maintenance cost	Low	Moderate	High
Load capacity	Low	Moderate	High
Speed range	30-50 km/h	30-60 km/h	60-200 km/h

Interaction of Grooved and Regular Rails with Wheels



For Ulaanbaatar city's tramway tracks, Grooved rail will be the most suitable choice, as experience from other cities shows that it ensures safety, load-bearing capacity, and ease of maintenance when traveling alongside roads.

Track base slabs

As mentioned in the track structure selection section, ballastless, sleeper-free construction using prefabricated track-road slabs will be used for the tram track foundation. These prefabricated slabs may have various designs, structures, and purposes. The basic slab with a rail groove is designed for tram tracks where tram traffic is mixed with road traffic and can be used for all types of railway profiles including single and double tracks, intersections, straight sections, and curves.

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Basic slab with rail groove (LC-L)

The basic slab with rail groove can be manufactured in standard dimensions as shown in the table below, with slab dimensions selected according to track gauge, profile, and cross-section. Custom-sized slabs can also be manufactured according to project requirements.

Table 69. Specifications of Basic Slab with Rail Groove

№	Indicators	Dimension
1	Width	2.40m, 2.20m, 2.00m, 1.76m
2	Thickness	0.35m, 0.40m
3	Length	1.0m, 1.5m, 3.0m, 4.0m, 6.0m
4	Rail	49E1, 60R2
5	Gauge width	1000mm, 1435mm
6	Radius	≥660m (6.0m slab), ≥300m (4.0m slab), ≥180m (3.0m slab)
7	Applicable use	All types of tracks

Trapezoidal Basic Slab

Trapezoidal track slabs are designed for installation on sections where the turning radius of the tram line is 60 meters or less. These slabs serve to minimize gaps that occur on the outer sections of low-radius curves.

Trapezoidal slabs are manufactured with a standard length of 1000 mm, with one side increased by 40 mm or 80 mm, creating a rectangular trapezoid shape when viewed from above.

For curves with 60 m ≥ R ≥ 30 m, the outer length is 1040 mm,

For curves with 30 m ≥ R ≥ 20 m, the outer length is 1080 mm.

Trapezoidal Basic Slab (LC-LT)

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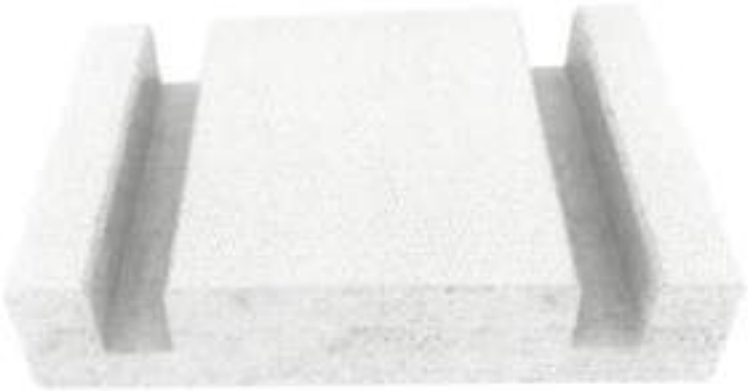

Inter-track Solid Slab

This slab is used between double tram tracks and parallel tracks, manufactured in various widths depending on the distance between track centerlines, while the length and thickness are the same as the basic slab.

Inter-track Solid Slab (LC-LM)

Special Purpose Slabs:

Special design slabs include those with channels and manholes for draining surface rainwater and connecting to drainage systems, as well as slabs designed for placing and routing various cables and wires. These special slabs can be manufactured in the same dimensions as the basic track slabs.

Slab with Drainage Channel (LC-LO)

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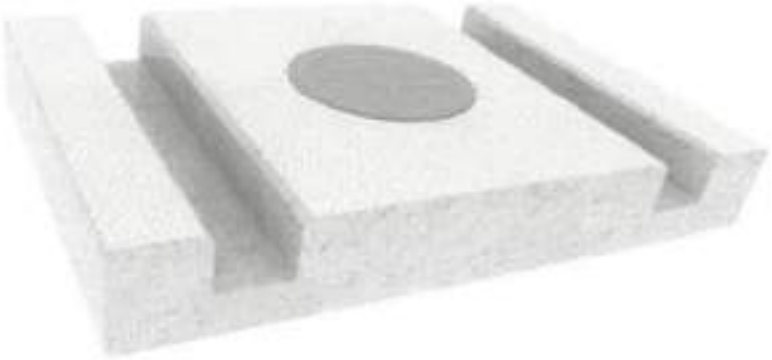
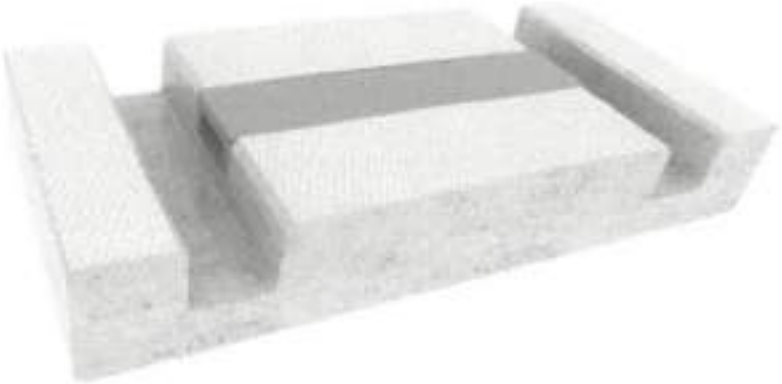
Slab with Drainage Manhole (LC-LW)



Slab with Cable Channel (LC-LK)



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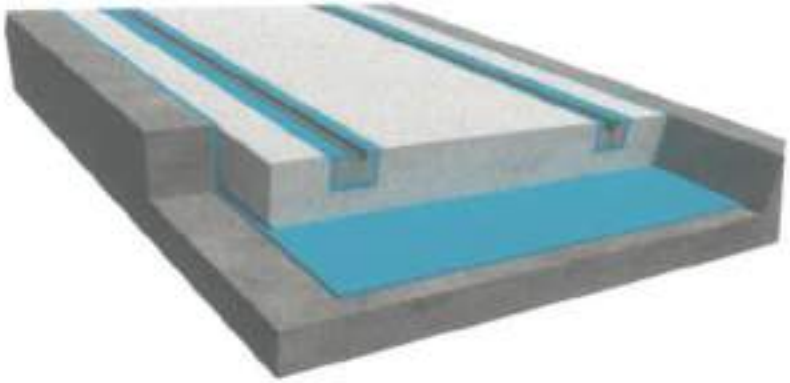
Insulation materials for base slabs

Insulation materials for tram track base slabs serve the primary purpose of softening, evenly distributing, and absorbing loads from rolling stock, reducing vibration and noise, and minimizing negative impacts on the surroundings, which positively affects passenger comfort and residents living near the tracks.

Base slab insulation materials include STM - Slab track mats (vibration insulation pads), Polyrail - rail insulation liquid, Railshim - rail insulation gaskets, Railstrip - rail elastic pads, Railfiller - filler rubber blocks, Railwedge - rail fastening wedges, and Railspacer - materials insulating rails from cables.

Polyurethane Vibration Insulation Pad for Slab Tracks



Polyrail - Rail Insulation Liquid

Railshim - Rail Insulation Gasket

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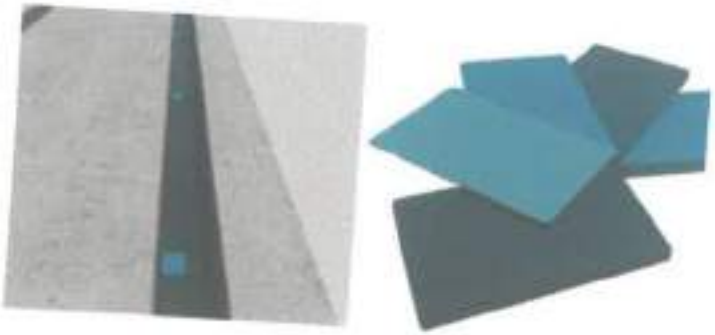
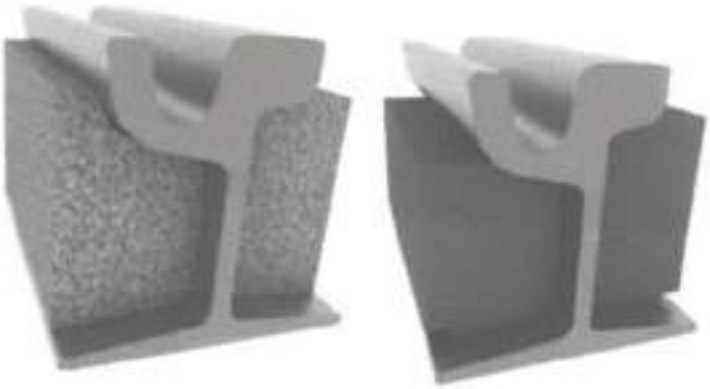


Railstrip - Rail Elastic Pad

Railfiller - Filler Rubber Block



Railwedge - Rail Fastening Wedge

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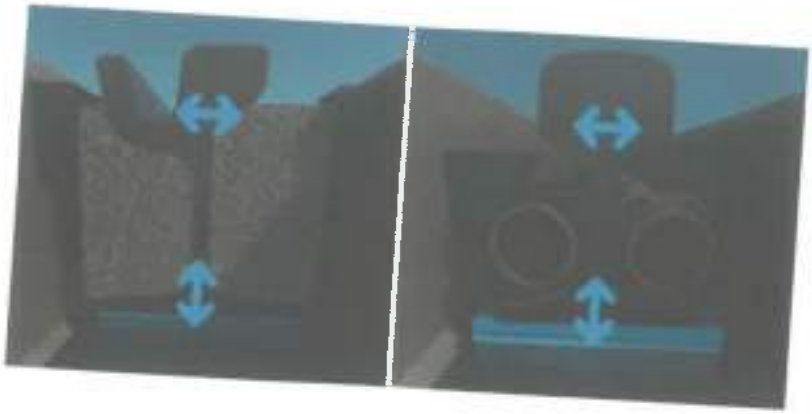
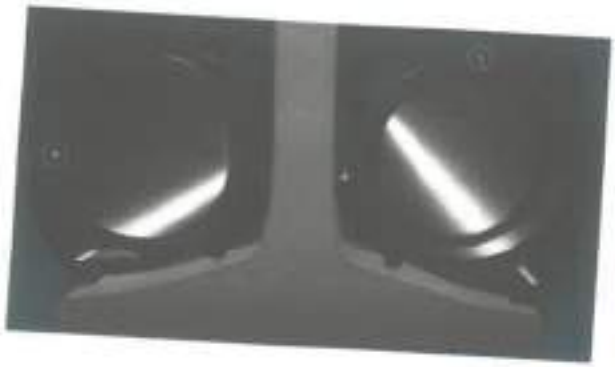


Material for Insulating Rails from Cables



Track Base Plate

Base Type	Main Track Section		Depot Section
indicator	Concrete Track	Grass Track	Ballasted Track
Location	At level crossings with city roads	In green landscaped areas	In depot track sections
Technical Characteristics	Very durable, requires minimal maintenance	Requires regular maintenance of the grass	Easy to maintain, lower construction costs
Urban Aesthetics	Can be colored and maintained to match urban appearance	Environmentally friendly, requires city maintenance	Not compatible with urban aesthetics

Subplate vibration isolation mats

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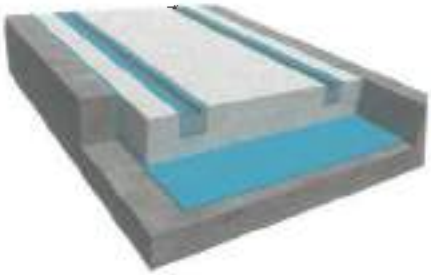
Subplate vibration isolation mats absorb tramway track vibration and noise, keeping negative impacts on the environment to a minimum. This solution affects the surrounding area, especially the comfort of residents.

Ballastless Track /Slab-Track Mats STM/



Ballasted Track /Sub-Ballast Mats SBM/

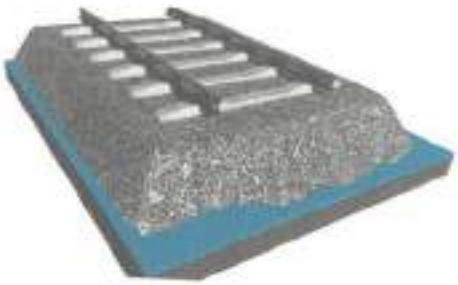
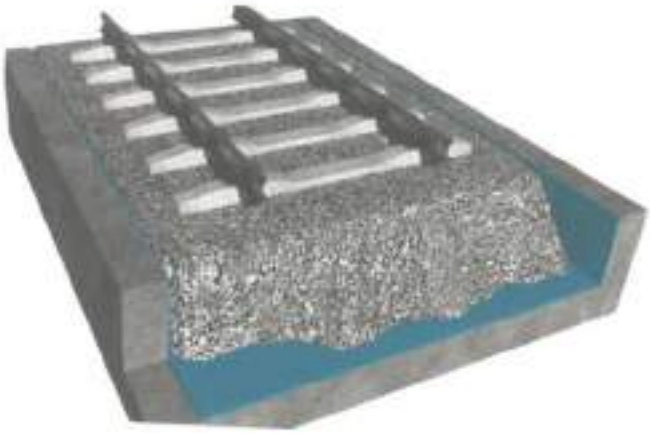


Table 70. STM, SBM Types and Dimensions

Type		Material	Usage	Dimensions mm	Thickness mm
Rubbermat /500.600.700/	SBM	Rubber	For ballasted track	1000×2000	15, 20, 25, 30
Polymat /150.160.180/	STM	Polyurethane	For concrete slab track	1000×2000, 1200×2000	15, 20, 25

Ballast and Concrete Foundation /Sub-Ballast Mats SBM/



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Turnout

Turnouts used in European tramway systems vary depending on the infrastructure, track gauge, and traffic intensity of the city or region. Tramway track gauges are usually 1,000 mm, 1,435 mm (standard gauge), or 1,524 mm, which directly affects the design and size of turnouts. The turnout mark depends on factors such as the size of the city's tramway network, track length, intersections, and number of branch tracks. For example, cities with large tramway networks, such as Leipzig in Germany, Lyon in France, and Barcelona in Spain, have numerous turnouts, while cities with smaller networks use fewer turnouts. Standards followed in Europe regarding tramway turnouts include guidelines and technical parameters developed by the European Committee for Standardization (CEN) and the International Union of Railways (UIC), and these standards define the design, materials, installation, and maintenance requirements for turnouts. In Mongolia, the standard "Railway applications. Track. Switches and crossings, switch installations, crossings and auxiliary parts. Dimensions" MNS EN 13232-1:2016 is followed, which is compatible with European standards. This standard defines requirements such as wheel set and track dimension parameters, geometric design principles for wheel set guidance, etc.

Turnout Diagram

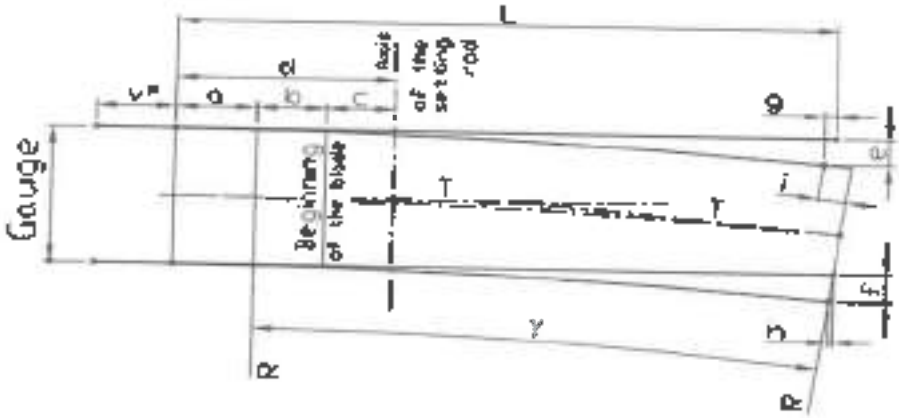

Table 71. *Turnout Marks*

	R=20m		R=25m		R=30m		R=50m	
Rail	R59,R59N,R60, R60N		R59,R59N,R60, R60N		R59,R59N,R60, R60N		R59,R59N,R60, R60N	
Gauge	1000	1435	1000	1435	1000	1435	1000	1435
L	4500	4500	4500	4500	4000	4000	5000	5000
V*	500	500	500	500	500	500	350	350

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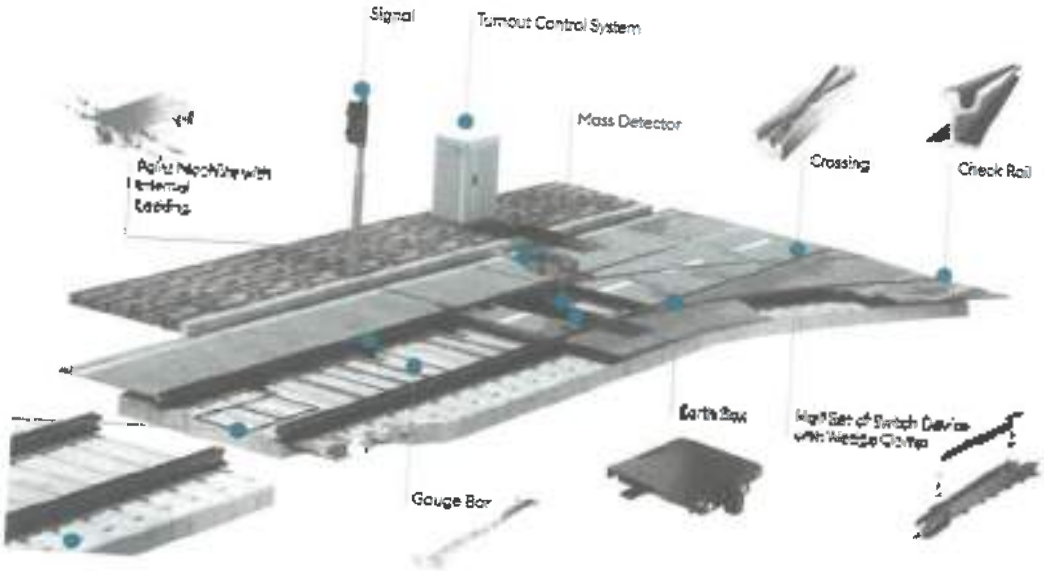
	R=20m		R=25m		R=30m		R=50m	
Y	11°45'11"	11°53'08"	9°21'18"	9°26'18"	7°46'06"	7°47'14"	5°47'14"	5°48'48"
	13,0589g	13,2060g	10,3938g	10,4889g	8,6232g	8,6963g	6,4305g	6,4569g
A	500	500	500	500	0	0	0	0
b	0	0	0	0	400	400	650	650
C	500	500	500	500	400	400	350	350
D	1000	1000	1000	1000	800	800	1000	1000
E	389	385	313	311	282	280	247	247
F	409	413	326	329	271	273	253	253
G	26	25	16	16	11	11	8	8
H	28	29	16	16	12	12	9	9
I	205	298	169	236	166	195	101	146
T	2059	2082	2065	2084	2037	2052	2527	2539

Turnout Components



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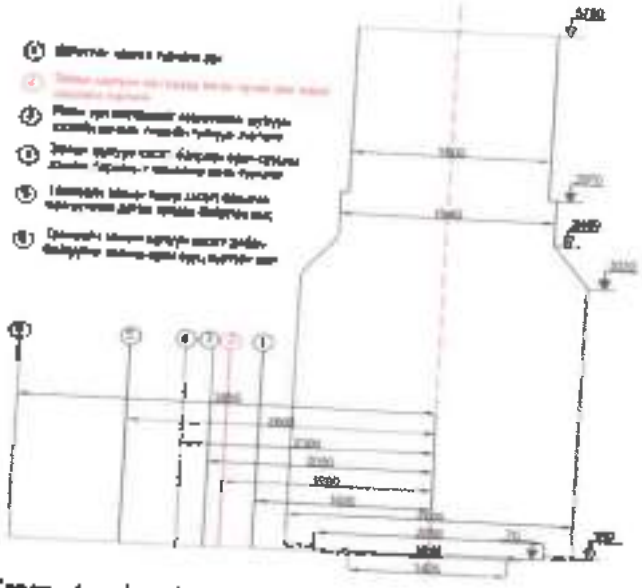
Track clearance

Clearance refers to the limited space established in accordance with traffic safety and technical requirements for the safe positioning of tram track objects, rolling stock, nearby buildings and structures, and cargo. The minimum permissible distance from the centerline of the straight section of the tram track to buildings, structures, and pedestrian paths is shown in the following figure.

Figure 1. Tram Track Clearance Requirements



Tram track clearance dimensions were developed based on the Russian Federation's SP84.13330.2016 standard.

9.3. PLANNING SOLUTION FOR RELOCATING ENGINEERING NETWORKS ALONG THE TRAMWAY ROUTE

Heating Supply System

Within the framework of developing the feasibility study for a new 15 km long tramway route from Buyant-Ukhaa Sports Complex in the 21st khoroo of Khan-Uul District to Silk Road Complex, and from the 120 thousandth intersection to Sukhbaatar Square, the heating supply section was developed after obtaining network clarifications from UBDS TOHK and KHHUG, calculating for 4 tramway route alternatives, and comparing these 4 alternatives with road route, architecture, spatial considerations, land acquisition, and all other factors to select the best, most feasible alternative, which is alternative 1, for which the feasibility study was developed.

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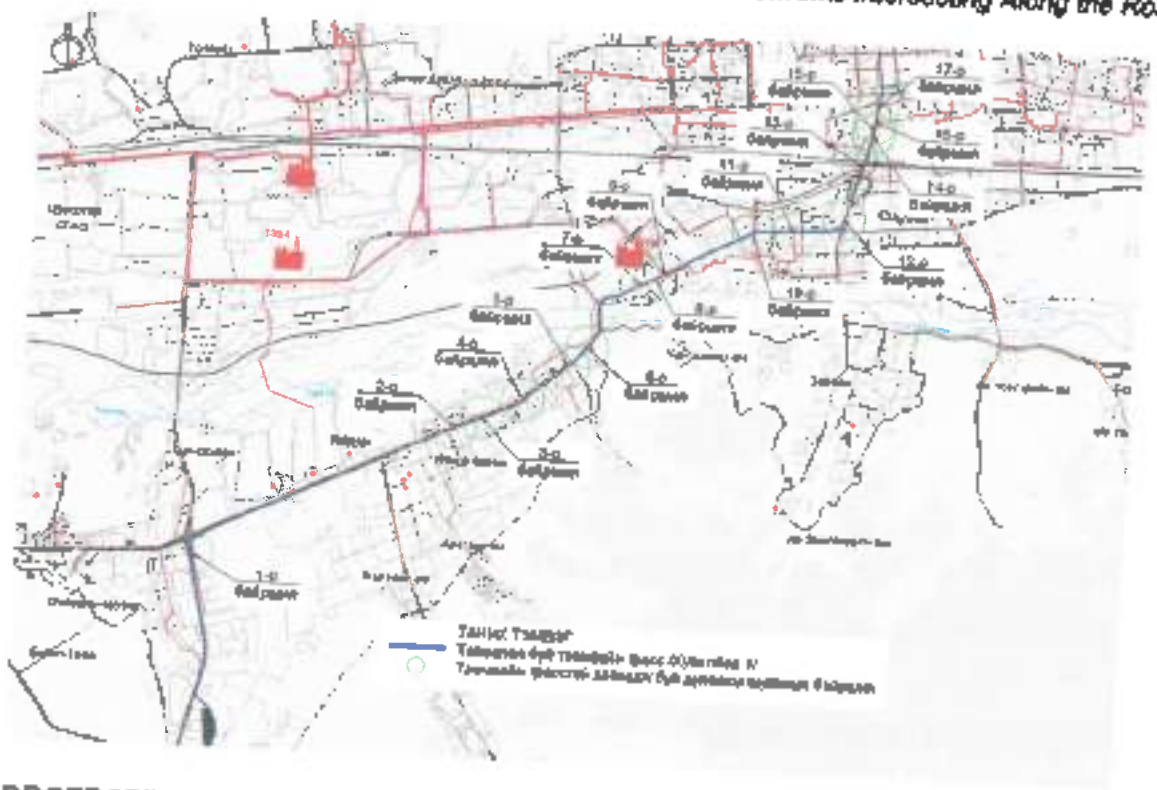
The planned tramway route runs along the center of the road from beside Buyant-Ukhaa 2 district to Yarmag Bridge, and through the middle of Peace Bridge.

Along the planned tramway route, heating network pipes with diameters from 2f150-800m owned by Ulaanbaatar Heating Network TOHK are encountered at 17 locations with a total length of **1675m**, of which heating pipes crossing the route at 13 locations have a total length of **515m**, and heating network pipes located along the route at 4 locations have a total length of **1040m**. Of these, heating network pipes with a total length of **120m** crossing at **2 locations** are currently in access channels. These are at locations 2 and 6. To prevent difficulties that may arise during repair, maintenance, expansion, and renovation work in the course of using the heating network pipes affected by the route, it is planned to relocate pipes that run parallel to the route, reinforce channel slabs, and place crossings in access channels.

Networks Intersecting Along the Route



PROTECTING HEATING NETWORKS WITH ACCESS CHANNELS:

Heating network pipes intersect with the planned tramway route at 13 locations (locations 1, 3, 4, 5, 9, 10, 11, 12, 14, 16, 17), and it is planned to place a total of **515m** of pipeline

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in access channels to facilitate easy repair of any damage that may occur during operation. Planned Channel Cross-sections

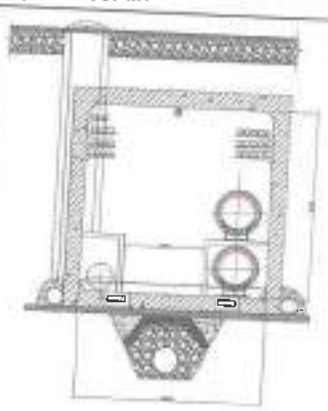
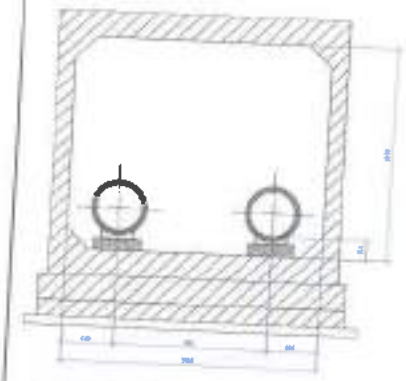
Access Channel-1	Access Channel-2
2.4x2.4h	3.0x2.4h
2φ200-500mm	2φ500-1000mm
	

Table 72. Planning Solutions

No.	Pipe name	Diameter	Length, m	Solution
Location 1	13b New Yarmag	2φ400	50	The heating pipe crossing the tramway route will be relocated by constructing a 2.4x2.4h dimension access channel with protective measures.
Location 2	15g Zuun salaa	2φ400-2φ300	60	The existing access channel will be reinforced with additional protection measures due to high pressure operations.
Location 3	15g salaa pipe	2φ200	50	The heating pipe crossing the tramway route will be relocated by constructing a 2.4x2.4h dimension access channel with protective measures.
Location 4	10j salaa pipe	2φ250	50	The heating pipe crossing the tramway route will be relocated by constructing a 2.4x2.4h dimension access channel with protective measures.

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Location 5	10j salaa	2φ300	55	The heating pipe crossing the tramway route will be relocated by constructing a 2.4x2.4h dimension access channel with protective measures.
Location 6	10j salaa pipe	2φ200	60	The existing access channel will be reinforced with additional protection measures due to high pressure operations.
Location 9	10g main pipe	2φ800	50	The heating pipe crossing the tramway route will be relocated by constructing a 3.0x2.4h dimension access channel with protective measures
Location 10	3d main pipe	2φ700, 2φ400	50	The heating pipe crossing the tramway route will be relocated by constructing a 3.0x2.4h dimension access channel with protective measures.
Location 11	1a neighborhood in Shar	2φ350	40	The heating pipe crossing the tramway route will be relocated by constructing a 2.4x2.4h dimension access channel with protective measures.
Location 12	1e main pipe	2φ800	40	The heating pipe crossing the tramway route will be relocated by constructing a 3.0x2.4h dimension access channel with protective measures.
Location 14	12a main pipe	2φ700	40	The heating pipe crossing the tramway route will be relocated by constructing a 3.0x2.4h dimension access channel with protective measures.
Location 16	16-12a main pipe	2φ300	40	The heating pipe crossing the tramway route will be relocated by constructing a 3.0x2.4h dimension access channel with protective measures.

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Location 17	11e main pipe	2φ800	50	The heating pipe crossing the tramway route will be relocated by constructing a 3.0x2.4h dimension access channel with protective measures.

RELOCATION AND REINFORCEMENT OF HEATING PIPELINE NETWORK:

According to the plan, the heating pipeline network intersects with the planned tram route at 4 locations - positions 7, 8, 13, and 15. These heating pipelines are located along the tram route. It is planned to relocate a total of 800m of heating pipelines with diameters of 2φ150 and 2φ800mm by shifting them 3-8 meters to the east, and to reinforce the covering slabs of 240m of heating pipeline with diameter 2φ150mm.

Table 73. Planning Solutions

No	Pipe name	Diameter	Length, m	Solution
Location 7	10g branch pipe	2φ150	550	It is planned to relocate the 550m of 2φ150 pipe running along the planned tramway route by 8.0m.
Planned line				
Location 8	10g branch pipe	2φ150	240	It is planned to reinforce the channel and cover of the 240m of 2φ150 pipe running along the planned road expansion.
Planned line				

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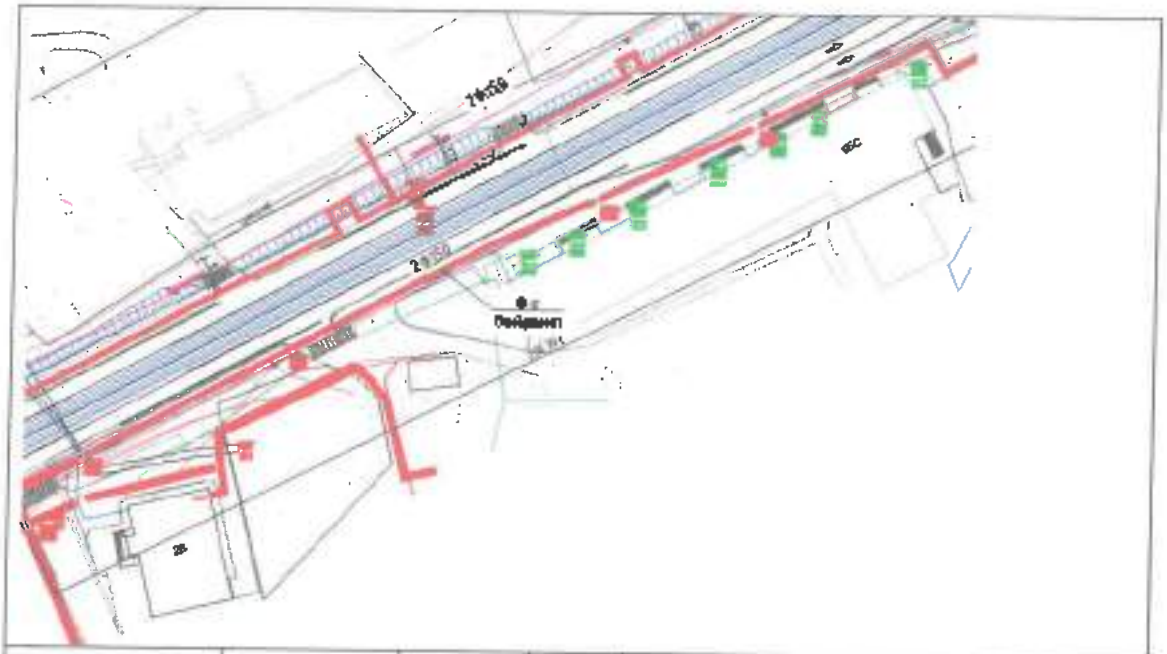
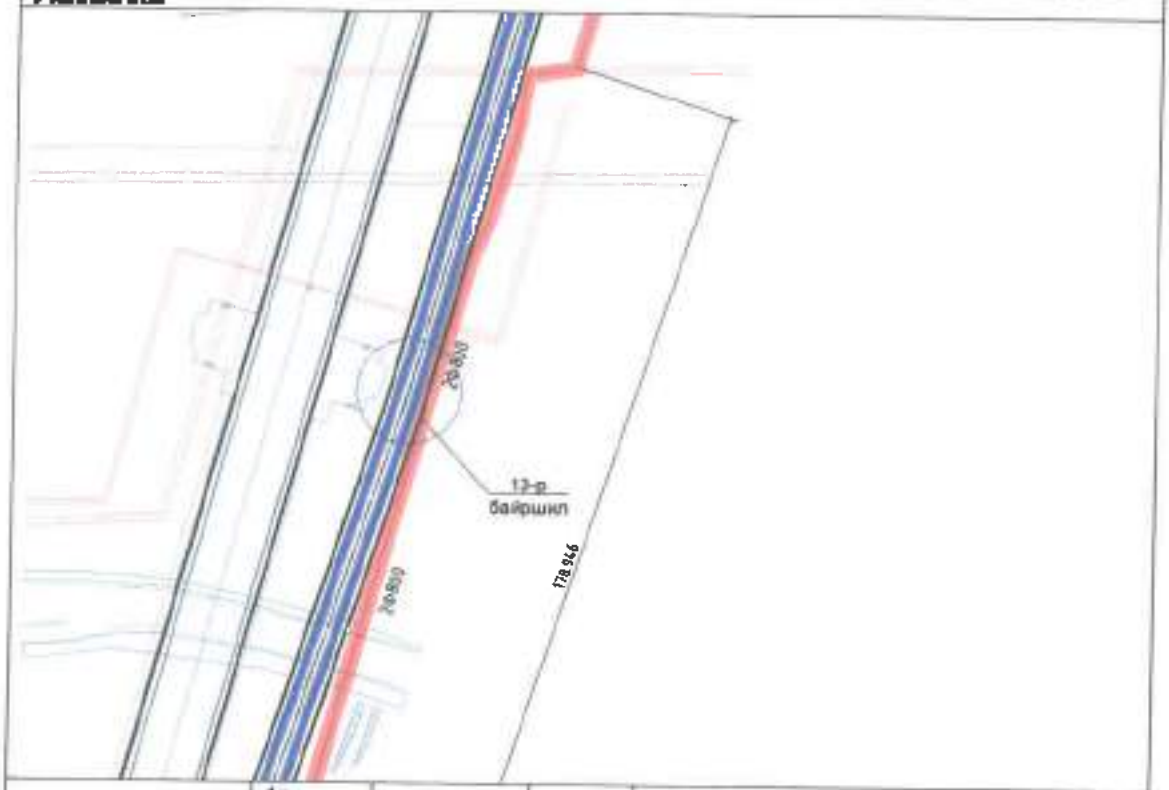


Location 13	1a branch line	2φ800	180	It is planned to relocate the 180m of 2φ800 pipe running along the planned tramway route by 3.5m.

Planned line



Locatio 15	1a branch line	2φ800	70	It is planned to relocate the 70m of 2φ800 pipe running along the planned tramway route by 5.0m.

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DEPOT BUILDING HEATING AND VENTILATION

The depot building will have a complete heating and ventilation system that meets the requirements of BNbD 41 01 11 norms, rules, and standards.

Heating system:

1. Install a heat meter at the inlet node of the heating system to monitor consumption
2. Properly insulate the heating system pipelines
3. Install adjustment valves on each heating device
4. Fully automate heating and hot water supply

Ventilation system:

1. Plan mechanical exhaust and supply ventilation systems
2. Fully automate the ventilation system

Plan smoke extraction and pressurized air supply systems for fire events. The smoke protection system will operate with automatic alarm in case of fire, at which time the exhaust system valve will open, the smoke extraction fan will operate to remove smoke. After this, the pressurized air supply fan will operate to provide pressurized clean air to the tunnel.

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Current Status of Engineering Preparation Measures and Planning Solutions

Along the newly planned 15 km tramway route from Buyant-Ukhaa Sports Complex in the 21st khoroo of Khan-Uul District to Torgoni Road Complex, and from the 120 thousandth intersection to Sukhbaatar Square, the existing rainwater collector K-4 pipeline intersects at 15 locations, with a total length of 1240 m along the tramway route. The existing rainwater drainage line has been constructed according to road elevation planning, and due to limited space for relocation, it can be renovated along its existing route.

From the Buyant-Ukhaa complex to Peace Bridge section of the tramway route, working drawings have been prepared for both sides of the road, and according to Ulaanbaatar city's 2040 Development Master Plan, 26,200 m of new rainwater drainage lines are planned. This needs to be implemented in coordination with the tramway construction work according to the working drawings. The total length of rainwater lines is 26,200 m.

Networks Intersecting Along the Route

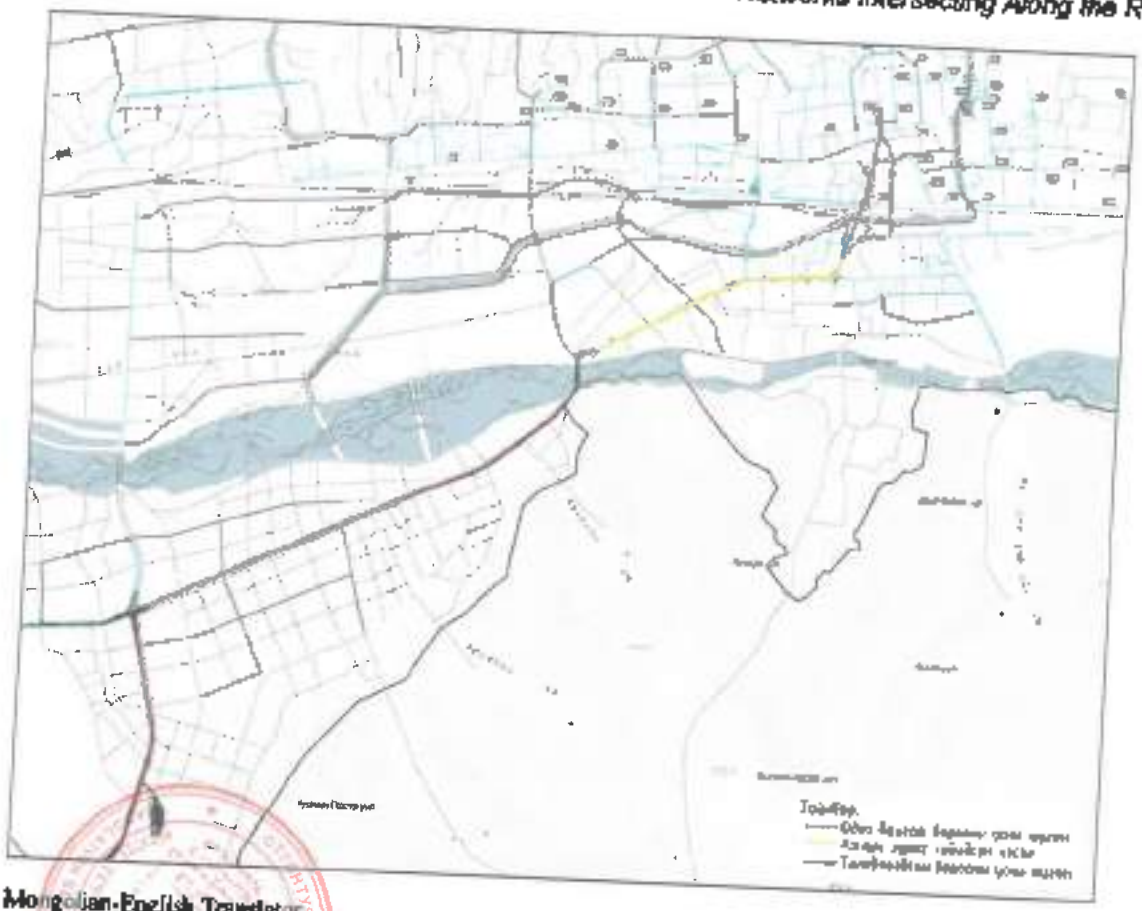

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Table 74. Planning Solutions

№	Line name	Length, m	Solution
1. Existing rainwater drainage lines			
1	Collector K-4	840	Lines along the tramway route will be renovated along their existing route
2	Collector K-4	300	Lines intersecting with the planned tramway route will also be renovated along their existing route
2. Rainwater drainage lines with completed working drawings			
3	New	7200	Will be implemented in coordination with the tramway according to completed working drawings
3. Newly planned rainwater drainage lines			
4	New	19000	Will be implemented at the working drawing stage in coordination with the tramway according to Ulaanbaatar city's 2040 Development Master Plan

Current Status of Water Supply System and Planning Solutions

The 15.0 km long tramway route newly planned from Buyant-Ukhaa Sports Complex in the 21st khoroo of Khan-Uul District to Silk Road Complex, and from the 120 thousandth intersection to Sukhbaatar Square has been developed with four alternatives.

Along this route, water supply lines with diameters from φ110-500 mm owned by USUG and OSNAAG are located in 12 locations in both crossing and parallel positions.

Clean Water Networks Intersecting Along the Route

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Water Supply System Protection and Planning Solutions

Clean water lines cross the tramway route at 17 locations and run parallel at 8 locations.

Therefore, the following measures are planned:

1. Plan full access channels: At locations 1, 3, 8, 9, 13, 17, 20, 21, 22, 24, lines with diameters φ200-φ700mm are planned to be protected by placing 495.0 linear meters in access channels.
2. Plan combined access channels with other engineering networks: At locations 3, 10, 11, 25, lines with diameters φ200-φ500 are planned to be protected by placing 359 linear meters of clean water lines together with other engineering networks in a single channel.
3. Use reinforcement lining method: At locations 14, 15, 16, 18, 19, 23, protect 301 linear meters of φ500mm diameter clean water lines using the reinforcement lining method.
4. Adjust existing access channels to road elevation: At locations 4, 5, 6, 7, repair access channels for existing φ200mm diameter clean water lines of 226 linear meters to coordinate with tramway elevation.
5. Relocate clean water lines running parallel along the route: At location 2, relocate 218 linear meters of 200mm diameter lines away from the tramway route.
6. At location 12, relocate 422 linear meters of clean water lines located in heating channels running parallel along the tramway route together with the heating supply lines.

Table 75. Planned Channel Cross-sections

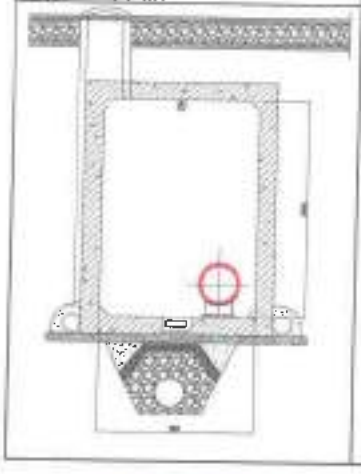
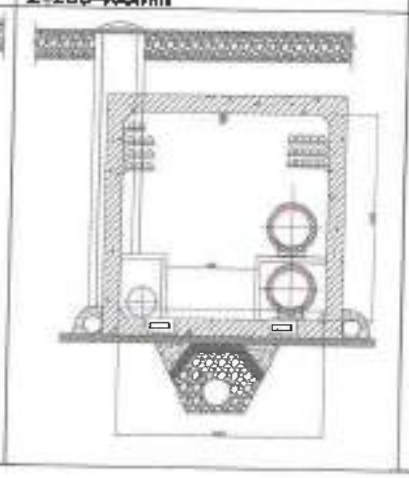
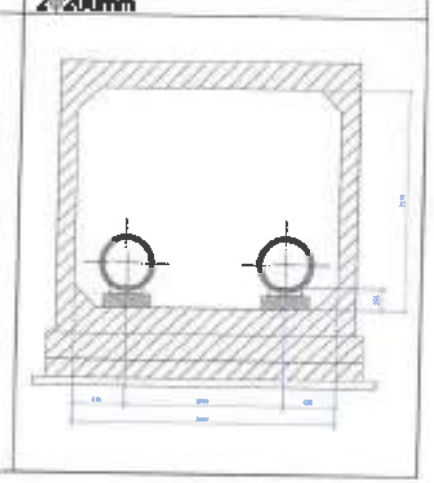
Access Channel-1	Access Channel-2	Access Channel-3
1.8x2.4h	2.4x2.4h	3.0x2.4h
2φ200-400mm	2φ200-400mm	2φ200mm
		

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Table 76. Water Supply Planning Solutions

Name of Linear Facility	Capacity, Pipe Diameter	Unit	Quantity	Solution
Location 1 with access channel	Φ325x6	m	64	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel together with other engineering networks.
	1.8x2.4	m	54	
Location 2	Φ225x20.5	m	98	Relocating the clean water pipeline that runs along the track
Location 3 with access channel	Φ225x20.5	m	286	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel. For the section running along the track
	1.8x2.4	m	114	
Location 4	Φ219x6	m	52	Adjusting the existing access channel to coordinate with the road elevation
Location 5	Φ219x6	m	59	Adjusting the existing access channel to coordinate with the road elevation
Location 6	Φ219x6	m	56	Adjusting the existing access channel to coordinate with the road elevation
Location 7	Φ219x6	m	59	Adjusting the existing access channel to coordinate with the road elevation
Location 8 with access channel	Φ219x6	m	48	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel.
	1.8x2.4	m	46	
Location 9 with access channel	Φ426x6	m	51	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel.
	1.8x2.4	m	51	
Location 10	Φ426x6	m	54	Planning a complete access channel together with other engineering networks
Location 11	Φ273x6	m	81	Planning a complete access channel together with other engineering networks
Location 12	Φ114x4	m	422	Relocating the clean water pipeline together with heat duct running along the track
Location 13 with access channel	2Φ426x6	m	32	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel.
	1.8x2.4	m	32	
Location 14	Φ630x6	m	41	Using reinforcement lining method
Location 15	Φ530x6	m	87	Using reinforcement lining method
Location 16	Φ630x6	m	33	Using reinforcement lining method
Location 17 with access channel	Φ325x6	m	38	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel.
	1.8x2.4	m	38	
Location 18	Φ530x6	m	39	Using reinforcement lining method
Location 19	Φ530x6	m	71	Using reinforcement lining method
Location 20 with access channel	Φ325x6	m	44	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel.
	1.8x2.4	m	44	
Location 21 with access channel	Φ426x6	m	31	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel.
	1.8x2.4	m	31	
Location 22 with access channel	Φ273x6	m	47	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel.
	1.8x2.4	m	47	

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Location 23	Φ159x5.0	m	30	Using reinforcement fring method
Location 24 with access channel	Φ325x9. 720x8.0	m	38	Planning to protect the clean water pipeline that intersects with the planned tram track in a 1.8x2.4h sized access channel.
	2.4x3.0	m	38	
Location 25	Φ530x6	m	42	Planning a complete access channel together with other engineering networks

Clean water pipelines located along the track are mostly steel pipes. In recent years, reinforced polyethylene HDPE pipes have been used more frequently, but steel pipes are still used in heat ducts. Currently used steel pipes are corroded and deteriorated, with reduced nominal diameter due to scale formation, infiltration and exfiltration processes exceeding acceptable levels, and high risk of pipeline rupture, which has led to the use of plastic pipes in recent years with good results.

Analysis of previously developed project drawings and construction cost estimates shows that although there is a small price difference depending on the pipe material, the final price is approximately the same due to transportation and construction work. When selecting materials for intersecting water transmission pipelines, the following conditions should be considered:

- Pipe material wear conditions
- Pipe installation and operation conditions
- Pipe supply conditions
- Pipe price and technological requirements

Table 77. Comparison of advantages of water supply removal and reinforcement pipelines

Indicators	HDPE, Reinforced polyethylene plastic pipe	Steel pipe	DICL, Cement-lined ductile iron pipe	GRE, Glass-reinforced plastic pipe
Diameter, mm	5-1600	10-1400	65-1600	25-1000
Length, m	12m	6-12m	6m	12m
Maximum pressure, Bar	16(25)	64	40	250/75
Connection method	Hot welding	Electric welding	Coupling	Coupling/Adhesion
Advantages	No deformation in flexibility due to mechanical action	Durable	Durable	No deformation in flexibility due to mechanical action
	Manufactured in Mongolia and widely used	High pressure resistance	High pressure resistance	High pressure resistance
	No special measures required for corrosion protection	-	No special measures required for corrosion protection	No special measures required for corrosion protection
	Water permeability capacity does not change during operation	Widely used, installed in heat ducts and requires earthwork	Water permeability capacity does not change during operation	Water permeability capacity does not change during operation

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	Low weight, low transportation cost and installation cost	Installation is performed using electric welding. Experienced in installation	Relatively short installation time, heavy weight requires large working area with machinery	Low weight, low transportation cost but limited installation experience
	Long service life of over 60 years	Used for 20-30 years. Service life varies depending on water quality	Longer service life compared to steel pipes +50 years	Potential service life of +100 years with proper protection measures

Table 78. Comparison of disadvantages of water supply removal and reinforcement pipelines

Indicators	HDPE, Reinforced polyethylene plastic pipe	Steel pipe	DICL, Cement-lined ductile iron pipe	GRE, Glass-reinforced plastic pipe
Diameter, mm	5-1600	10-1400	65-1600	25-1000
Length, m	12m	6-12m	6m	12m
Maximum pressure, Bar	16(25)	64	40	250/75
Connection method	Hot welding	Electric welding	Coupling	Coupling/Adhesion
Weaknesses and disadvantages	At pressures above 16 bar, wall thickness increases resulting in heavy weight	Heavy weight, high transportation cost but relatively short service life	Heavy weight resulting in low transportation cost	Started being used in Mongolia only since 2018
	Requires protection from external and soil effects	Requires additional measures for corrosion protection	Concrete lining may be damaged from external effects or during installation	-
	-	Permeability decreases during operation	-	-
	Requires special welding machine	Requires highly skilled welders for high-pressure pipes	-	Requires special adhesive materials

When comparing the hydraulic conditions and the advantages and disadvantages of water transmission pipelines, using reinforced plastic HDPE pipe would be appropriate, but steel pipes must be used in heat ducts due to technological requirements. Therefore, for reinforcement and relocation lines in standalone sections, pipes meeting MNS ISO 4427:2007 standard requirements should be used.

To prevent difficulties during maintenance and renovation of these networks, sections crossing horizontally are planned to be placed in access channels, and reinforcement and relocation is planned.

The water supply and sewage networks to be constructed within this project should be coordinated with the tram track elevation and completed in advance as preparatory work. During the design stage, it is necessary to consult with user and supplier organizations

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and clarify network details at intersections with engineering networks such as roads, communications, electricity, etc.

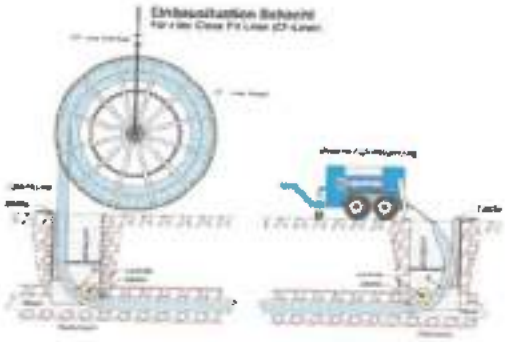
CLEAN WATER PIPELINE RENOVATION TECHNOLOGY:

Technologies for renovating old pipelines include excavation renovation and trenchless lining methods. For trenchless lining, there are perforation methods, and USUG uses the following two perforation methods to renovate old clean water pipes (See Figure. There is no experience in renovating sewage pipes using the perforation method).

1. Trenchless lining method CIPP (Cured In Place Pipe)
2. Close Fit or pipe-in-pipe insertion method

CIPP (Cured In Place Pipe) method

Close fit method



Source: Ulaanbaatar Water Supply and Sewerage Authority.

Note: "Ulaanbaatar Water Supply and Sewerage Authority"'s method for renovating clean water pipelines

Sewage System Planning Solution

The newly planned 15 km tram track from Khan-Uul District's 21st khoroo, Buyant-Ukhaa Sports Complex to Torgonii Road Complex, from the 120 thousandth intersection to Sukhbaatar Square has been developed with four options.

Along this track, sewage pipelines with diameters of Φ160-1400mm intersect at a total of 23 locations, running both perpendicular and parallel.

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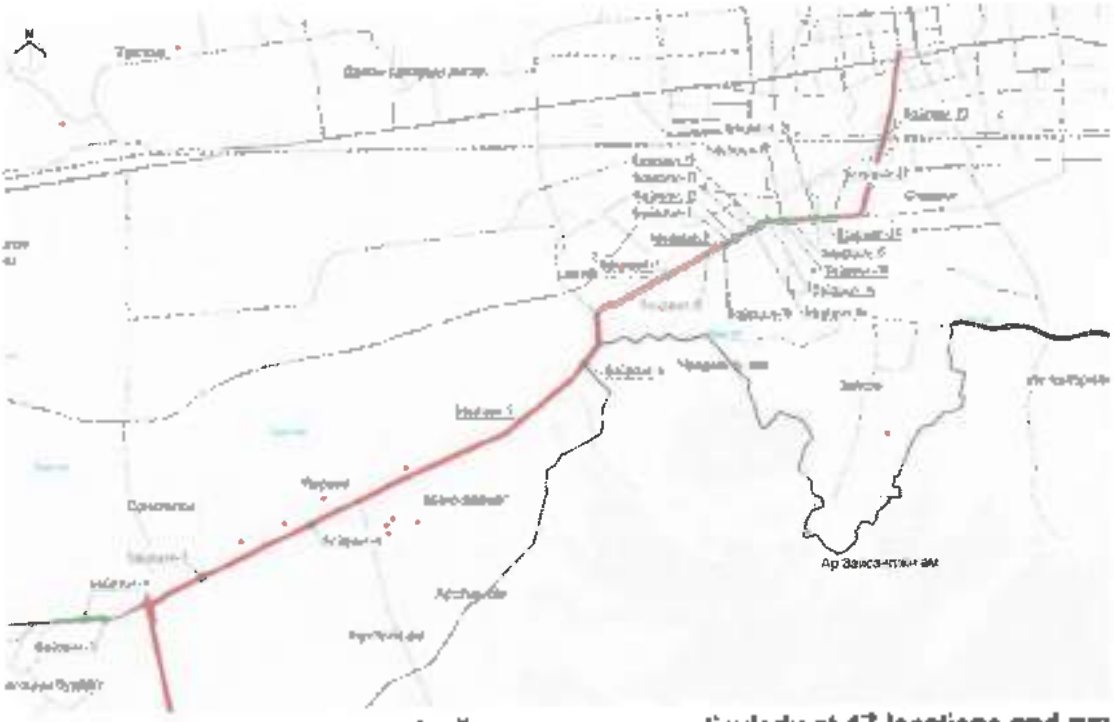
Sewage network crossing along the track



Along the tram track, sewage pipelines cross perpendicularly at 17 locations and run parallel at 6 locations.

Therefore, the following measures are planned:

Plan complete access channels: At locations 2,5,7,9,10,11,12,13,15,17,22,23, sewage pipelines with diameters of —ф160-1400mm will be protected in 519 linear meters of access channels.

Plan complete access channels together with other engineering networks: At location 6, a —ф300mm diameter sewage pipeline will be protected together with other engineering networks in a 42 linear meter access channel.

Use reinforcement lining method: At locations 8,19,20,21, sewage pipelines with diameters of —ф300-800mm and 214 linear meters will be lined using SPR technology.

Adjust existing access channels to coordinate with road elevation: At locations 3 and 4, sewage pipelines with diameters of —ф300,800mm and 148 linear meters will be repaired in coordination with road elevation.

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Relocate sewage pipelines running along the track: At locations 1,14,16,18, sewage pipelines with diameters of —ф300-800mm and 1188 linear meters will be relocated away from the tram track.

Table 79. Sewage System Planning Solution

Name of Linear Facility	Capacity, Pipe Diameter	Unit	Quantity	Solution
Location 1	Ф300	m	661.0	Relocating the sewage pipeline running along the tram track
Location 2	Ф300	m	35.0	Protecting the sewage pipeline that intersects with the planned tram track in an access channel
Location 3	Ф300	m	65.0	Taking measures to adjust the existing access channel to coordinate with road elevation
Location 4	Ф160	m	83.0	
Location 5	2Ф160	m	69.0	Protecting the sewage pipeline that intersects with the planned tram track in an access channel
Location 6	Ф300	m	42.0	Complete access channel together with other engineering networks
Location 7	Ф400	m	64.0	Protecting the sewage pipeline that intersects with the planned tram track in an access channel
Location 8	Ф600	m	39.0	Reinforcement lining using SPR technology
Location 9	Ф1400	m	82.0	Protecting the sewage pipeline that intersects with the planned tram track in an access channel
Location 10	Ф200	m	37.0	
Location 11	Ф400	m	46.0	
Location 12	Ф300	m	27.0	
Location 13	Ф530	m	60.0	
Location 14	Ф800	m	195.0	Relocating the sewage pipeline running along the tram track
Location 15	Ф800	m	31.0	Protecting the sewage pipeline that intersects with the planned tram track in an access channel
Location 16	Ф530	m	207.0	Relocating the sewage pipeline running along the tram track
Location 17	Ф500	m	39.0	Protecting the sewage pipeline that intersects with the planned tram track in an access channel
Location 18	Ф400	m	125.0	Relocating the sewage pipeline running along the tram track
Location 19	Ф500	m	40.0	Reinforcement lining using SPR technology
Location 20	Ф300	m	68.0	
Location 21	Ф300	M	67.0	
Location 22	Ф300	m	43.0	Protecting the sewage pipeline that intersects with the planned tram track in an access channel
Location 23	Ф1000	m	30.0	

Clean and Sewage Pipeline Renovation Technology:

In Ulaanbaatar, accidents involving road subsidence and collapse due to old pipelines are rare but do occur. If old pipelines are not renovated, the following issues may arise:

1. Road subsidence and collapse accidents due to old pipeline failures caused by tram weight

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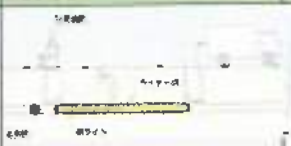
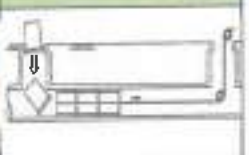
2. Sewer backups due to blocked old pipelines, making it impossible for citizens to use the sewage system. Also, unpleasant odors may contaminate the living environment
3. Soil contamination near pipelines due to sewage leaking from cracks and damaged sections of old pipelines
4. Potential disruption in the reliable and continuous supply of clean water to consumers
5.

Therefore, to prevent issues before they occur, renovating aged and damaged pipelines would ensure uninterrupted sewage services and complete public utility service.

The lining method is planned for use in difficult excavation and renovation areas (replacing pipelines), particularly in downtown areas with heavy traffic and green spaces.

There are trenchless pipe lining methods for pipeline renovation. In Ulaanbaatar, the pipe insertion lining method is used for clean water pipelines. USUG is interested in using the insertion lining method in the future to renovate sewage pipelines installed under high-traffic roads. As shown in the table, insertion lining methods include inversion, pneumatic installation, pipe connection, and lining methods.

Table 80. Pipeline Lining Renovation Methods

Method	Inversion Method	Pneumatic Installation Method	Pipe Connection Method	Lining Method
Scheme				
Features	The material containing rubber that hardens with heat, light, etc. is inverted into the pipe from the trench using pressure (water, air pressure), and is hardened with hot water, steam, or light	The material containing rubber that hardens with heat, light, etc. is inserted from the trench into the pipe, inflated with water pressure and gas, and hardened with hot water, steam, or light	Hard polyvinyl chloride material is bonded inside the pipe, and the space between the existing pipeline repairs is filled with clay, etc. to install the pipe. Can be installed while sewage flows through the pipe.	A pipe with a smaller diameter than the existing pipeline is inserted using pump or push method, the space between is filled with filler material to repair the pipe. Can only be used for medium and large diameter pipes.

SPR Method (automatic)

Source: https://www.eslontimes.com/system/items-view/254/

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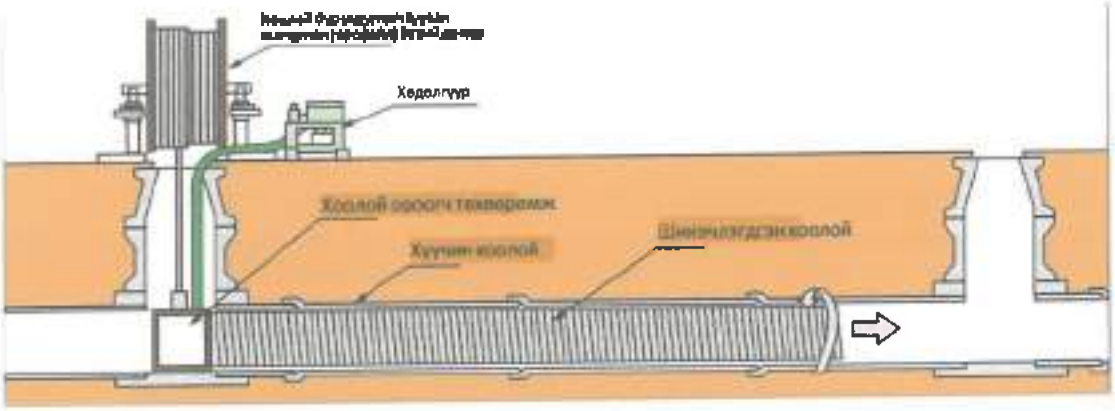
The pipeline insertion lining method usually requires temporarily stopping the water to prevent sewage from entering the section being renovated. The Japanese SPR method (Sekisui Kagaku Kogyo Co., Ltd., Adachi Kensetsu Kogyo Co., Ltd., see Figure 1 on the next page) allows work to be done without stopping the sewage at the water limit level of the pipe.

The SPR method is classified as a pipe connection lining method within the pipeline lining renovation methods. The pipe connection lining method involves inserting pipe-forming material inside the old pipe to form a new pipe, and filling the space created between the old pipe with filler material such as mortar. Figure 2 shows the pipe connection lining method of the SPR method. As shown in the figure, in terms of equipment and materials to be used, there are pipe winding equipment, pipe-forming tape material or profile, rollers, motor equipment, etc. In the case of pipe work in this country, the pipe building equipment and pipe-forming materials will be transported from Japan.

Pipe Connection Lining Method of SPR Method



Source: https://www.eslonbimes.com/system/items-view/71/

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The SPR method is widely used in countries such as the USA, Germany, Singapore, Taiwan, and China. The SPR method was used in JICA's Private Sector Proposed Localization Project Implemented in Ho Chi Minh City, Vietnam in 2013. In that project, a pipe with a diameter of φ1300mm was lined and renovated, and a training seminar was organized to localize this method.

The project was successfully implemented, and in May 2019, it was decided to line and renovate a total of 2.7 km of sewage pipeline using the SPR method in Ho Chi Minh City.

The main advantages of the SPR method are described below:

1. Rich experience with work performed in Japan, the method has proven to be reliable.
2. The pipe work can be carried out while sewage is flowing, and the work can be completed in a short time
3. The pipe work requires a very small area of 2.5m, so it has little impact on traffic, etc.
4. Extensive experience has been accumulated from work performed abroad, mainly in Europe and America.

The main conditions for pipe work are also described below. However, in cases where the pipeline is excessively curved up and down, the lining renovation method cannot be used, and the pipe must be renovated using the replacement method. Our situation is suitable for this method as we will be using it on a currently properly functioning network.

- Diameter: φ250-5000mm
- Water level at 30% of the diameter or less than 60 cm. Flow velocity less than 1.0m/s
- Can be used for bent and long pipe works

Based on the above, it is possible to implement a pipeline renovation project using the SPR method through loan assistance in Mongolia. As mentioned above, since USUG is using the lining renovation method to renovate clean water pipelines, there are no capacity issues, but it is necessary to pay attention to the issues of pipe work management and supply of materials and equipment related to the SPR method. It is a method that has not been used in Ulaanbaatar city until today, and especially since the SPR method can perform pipe work without stopping sewage, special management instructions will be required. Also, based on the condition of deteriorated pipelines in Ulaanbaatar city, it is planned to use lining renovation and other excavation methods.

Planning for the water supply system at the tram's terminal:

Fire extinguishing time - Fire water will be planned based on an average of 30-60 minutes. It is appropriate to plan a simple fire extinguishing system with a flow rate of q=20.0L/s and an automatic fire extinguishing system. In the cold season, it is necessary to prevent pipelines and equipment from freezing. To prevent fire hazards, it is important to accurately calculate water needs and ensure reserves. For this purpose, it is necessary

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to optimally plan centralized and reserve water supplies and ensure readiness for use when needed.

Current Status of Electrical Supply System and Planning Solution

Since 0.4 kV, 10 kV, 35 kV electrical transmission overhead and cable lines are located along the route of the new tram line, these need to be adjusted, protected, and relocated to comply with safety requirements.

10-35 kV Electrical Transmission Overhead Lines

While the standard height of 10 kV, 35 kV overhead line support poles is 10-18 m, the height of the tram contact wire is 5.5-6.5 m. Therefore, the following measures are planned to prevent intersection with overhead lines:
Adjust the height and distance of the line according to standards: o 10 kV line ,Ö/ at least 2.5-3 m away from the tram contact wire. o 35 kV line ,Ö/ 3.5-4 m away from the tram contact wire.
Explore the possibility of relocating high-voltage lines in another direction.
If relocation is not possible, increase the height of the electrical transmission line poles.
Consider the option of replacing with underground cable lines.

0.4 kV Electrical Transmission Cable Line

The 0.4 kV electrical transmission line is usually in an underground channel system or directly buried underground. The following adjustments will be made in the area overlapping with the tram infrastructure work:
Place cable lines in protective trays, channel systems to protect from mechanical damage.
Explore the technical possibility of relocating cable lines that pass under the tram track in another direction.
Check the reliable operation of electrical supply in the tram infrastructure area and upgrade if necessary.
The route from Buyant-Ukhaa Sports Complex to Torgoni Road Complex, from the 120 thousandth intersection to Sukhbaatar Square is 15 km long in total. The following electrical lines and networks have been found along the route:

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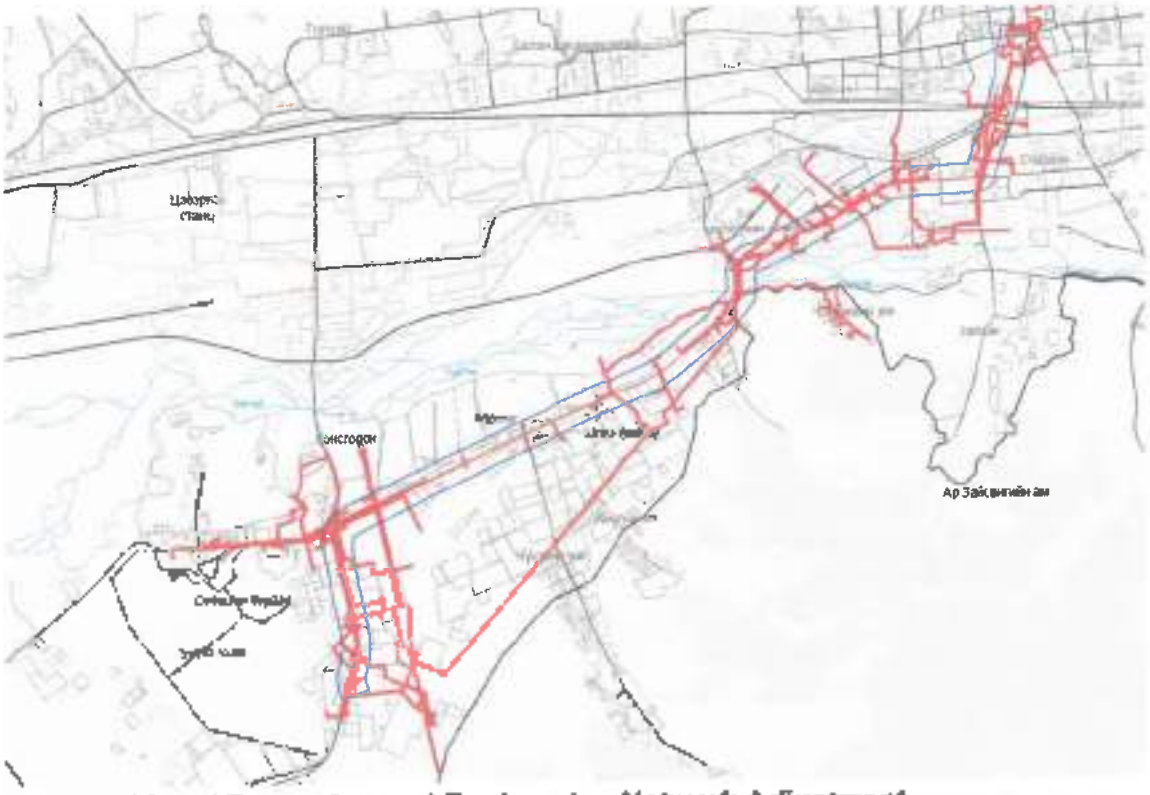
Electrical lines and networks along Route-1



Impact of Road Expansion and Engineering Network Adjustment

Within the framework of the planned road expansion and renovation work along the tram route, engineering networks (overhead and cable lines) that cross the road and are located within the route may be affected, thus requiring relocation of the networks and placement in protective trays.

The table includes only electrical networks that cross the road and are within the tram route.

Planning

Since electrical channels crossing the road are installed at depths of less than 1.0m in some sections, according to the recommendations provided by the National Electricity Distribution Network JSC, they will be tightened with cable testing equipment and lowered to a depth of 1.2 meters to not be affected by the tram track route, and installed in a protective cable channel.

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Table 81. Planning Solution

Line Type		Unit	Affected by Road Expansion	Planning
Cable line		m	17,384	Relocate, move, place in cable channel under the road
Overhead line	35kV	Location	2	Relocate, move, change the location of intersections along the route
	6 kV	Location	1	Relocate, move, change the location of intersections along the route

It is necessary to plan a survey, engineering solution, and protective measures for the electrical transmission network along the 15 km long tram route from Buyant-Ukhaa Sports Complex to Torgonii Road Complex, from the 120 thousandth intersection to Sukhbaatar Square. It is important to conduct a detailed study of the electrical transmission overhead and cable lines along and intersecting the route, make necessary adjustments, and ensure the safety of the project and reliable operation of electrical supply.

Table 82. Planning Solution

Line Type		Unit	Affected by Route	Planning
Cable line		m	20,325	Relocate, move, place in cable channel under the road
Overhead line	35kB	Location	6	Relocate, move, change the location of intersections along the route
	6 kB	Location	2	Relocate, move, change the location of intersections along the route
	10 kB	Location	3	Relocate, move, change the location of intersections along the route

Current Status of Information Communication Infrastructure

Information communication lines along the LRT route

In the planning area of the route from Buyant-Ukhaa Sports Complex to Torgonii Road Complex, from the 120 thousandth intersection to Sukhbaatar Square, 315 communication wells, 35.7 kilometers of channeling facilities, 148 aerial poles, and 52.6 kilometers of cable lines have been found.

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Table 63. Quantity of Information Communication Lines

№	Facility Name	Unit	Quantity
			BRT
1	Communication well	piece	315
2	Channeling facility	meter	35738
3	Aerial pole	piece	148
4	Cable line	meter	52584

Information Communication Infrastructure Planning for the High-Capacity Public Transport Project in Ulaanbaatar City

The Light Rail (tram) project will serve two main directions. The second direction is 15 km long in total from Buyant-Ukhaa Sports Complex to Torgoni Road Complex, from the 120 thousandth intersection to Sukhbaatar Square.

Traffic lights and control panels, RFID antenna poles at the following locations are within the tram track route and need to be relocated to the side of the road:

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- *Traffic lights - 2 pieces*
- *Traffic light control panel - 1 piece*

Buyant-Ukhaa 2 Residential Area

- *Traffic lights - 4 pieces*
- *Traffic light control panel - 1 piece*
- *RFID pole - 2 pieces*

Yarmag 4th Station

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- *Traffic lights - 4 pieces*
- *Traffic light control panel - 1 piece*

Hospital Station

Traffic lights - 4 pieces

Traffic light control panel - 1 piece

Yarmag 3rd Station

- *Traffic lights - 4 pieces*
- *Traffic light control panel - 1 piece*

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Yarmag 2nd Station

- *Traffic lights - 4 pieces*
- *Traffic light control panel - 1 piece*

Yarmag 1st Station

- *Traffic lights - 4 pieces*
- *Traffic light control panel - 1 piece*
- *Surveillance camera pole - 1 piece*

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Hunnu Mall

- Traffic lights - 4 pieces
- Traffic light control panel - 1 piece

Viva City

- Traffic lights - 4 pieces
- Traffic light control panel - 1 piece
- RFID pole - 2 pieces

PLANNING

Since communication channels crossing the planned route are installed at depths of less than 80cm in some sections, according to the recommendations provided by Information Communication Network LLC, wells will be installed on both sides of the road, the channel level will be lowered to 1.2 meters, and the channel will be protected with L2 trays to allow for future expansion.

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Along the new tram line route, 0.4 kV, 10 kV, and 35 kV overhead and cable power lines are present, which need to be regulated, protected, and relocated to meet safety requirements.

10-35 kV Overhead Power Lines

The standard height of support poles for 10 kV and 35 kV overhead lines is 10-18 m, while the height of tram contact wires is 5.5-6.5 m. Therefore, the following measures are planned to prevent intersection with overhead lines:

- Adjusting line height and distance according to standards:
- o 10 kV line → minimum 2.5–3 m distance from tram contact wire
- o 35 kV line → 3.5–4 m distance from tram contact wire
- Studying the possibility of relocating high-voltage lines in different directions
- Increasing the height of power line poles if relocation is not possible
- Calculating the option of replacing with underground cable lines

0.4 kV Power Cable Lines

0.4 kV power transmission lines are typically underground with ducting systems or directly buried. In zones overlapping with tram foundation structures, the following adjustments will be made:

- Placing cable lines in protective troughs or duct systems to protect from mechanical damage
- Studying the technical possibility of redirecting cable lines that pass under the tram route
- Checking and updating power supply reliability in tram foundation structure zones if necessary

The following electrical supply lines and networks were encountered along the route:

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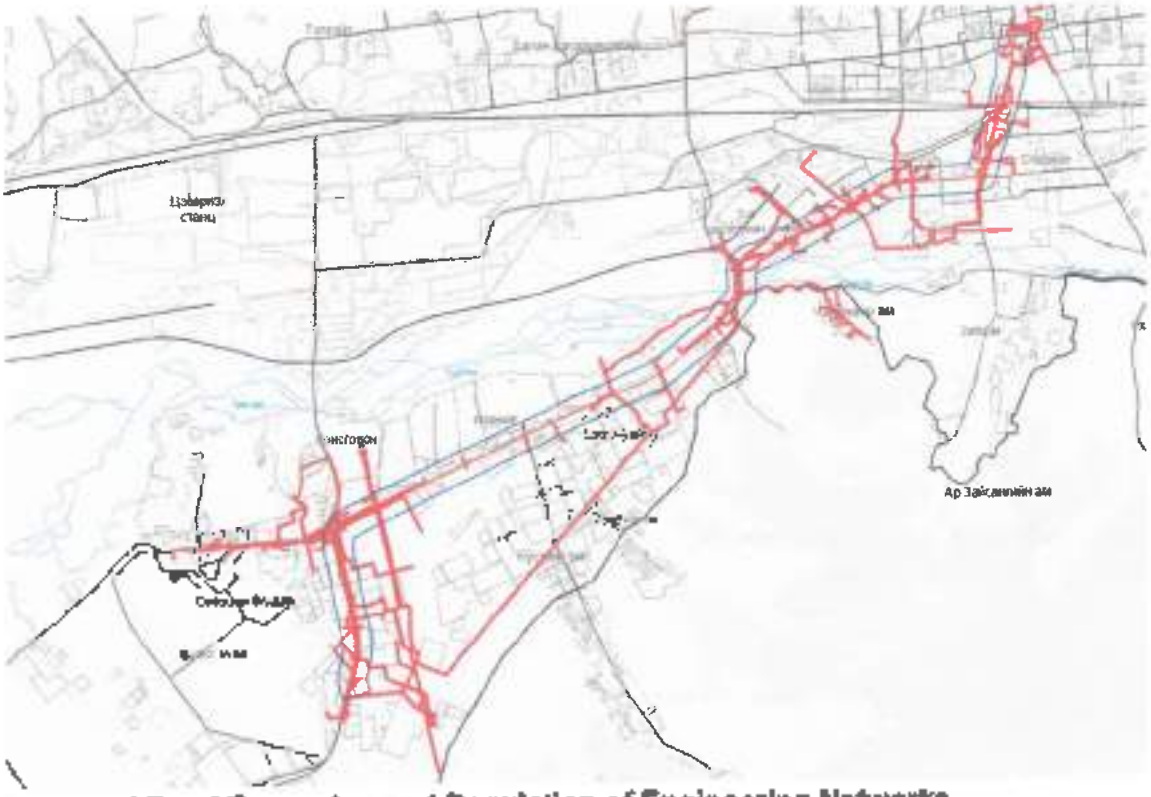

Impact of Road Expansion and Regulation of Engineering Networks

Within the framework of planned road expansion and renovation along the tram route, engineering networks (overhead and cable lines) that intersect with or are located within the route may be affected, requiring relocation of lines and networks or placement in protective troughs.

The table includes only electrical lines and networks that intersect the road or are located within the tram route.

Planning

Since culverts crossing roads are installed at depths less than 1.0m, following recommendations from the National Electricity Distribution Network LLC, cable tensions will be performed using cable detection equipment to lower them to depths of up to 1.2 meters to avoid interference with the tram route, and they will be installed in protective cable ducts.

Table 84. Planning Solution

Line Type	Measuring Unit	Within Road Expansion Route	Planning

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Cable Line		m	17,364	Relocate, transfer, and place in cable ducts under the road
Overhead Line	35kV	Location	2	Relocate, change intersection location along the route
	6 kV	Location	1	Relocate, change intersection location along the route

Along the 15 km tram route from Buyant-Ukhaa Sports Complex through Torgony Zam, 120 thousandth intersection, to Sukhbaatar Square, it is necessary to plan power transmission line surveys, engineering solutions, and protective measures. It is important to conduct detailed studies of power transmission overhead and cable lines along and intersecting the route, making necessary adjustments to ensure project safety and reliable power supply.

Table 85. *Planning Solution*

Line Type		Measuring Unit	Lines Affected by Route	Planning
Cable Line		m	20,325	Relocate, transfer, and place in cable ducts under the road
Overhead Line	35kV	Location	6	Relocate, change intersection location along route
	6 kV	Location	2	Relocate, change intersection location along route
	10 kV	Location	3	Relocate, change intersection location along route

9.4. POWER SUPPLY AND ELECTRICAL PLANNING

The planning of the tram power supply system was developed according to international and Mongolian relevant standards, norms, and regulations, including:

- Russian GOST standards - specifically GOST 23476-79 (Technical requirements for tram and trolleybus contact network fittings), GOST 2584-86 (Technical conditions for contact wires), GOST 12.1.038-82 (Acceptable electrical safety limits), used to detail contact wire type, cross-section, transmission capacity, safety, etc.
- Mongolian MNS and BNbD (Building Norms and Regulations) - MNS 5560:2019, BNbD 3.05.06-90, BD 43-101-03, MNS IEC 60364 applied to power supply systems, substation solutions, grounding, voltage drop, and safety operation.
- SP (SNiP) and technical conditions - SP 52.13330.2011 (Lighting), SP 51.13330.2011 (Noise and protection), etc.

The tram project is planned to run from Buyant-Ukhaa Sports Complex through Torgony Zam, 120,000 intersection, to Sukhbaatar Square, with a total length of 15 km. The contact network line will have a total length of 30 km.

The Buyant-Ukhaa - Sukhbaatar Square tram system will have a total length of 15 km with the total length of the contact network power supply planned at 30 km.

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The tram system belongs to the first category of power supply reliability. Therefore, rectifier substations will be fed from two sources that back each other up.

The power supply for the tram contact network and maintenance depot will be planned according to technical conditions provided by the Ministry of Energy, including:

- Contact line power will be supplied through 10/0.7 kV Rectifier substations.
- Depot power supply will be resolved through a 10/0.4 kV Depot substation (KTP).
- A backup generator will be installed to ensure uninterrupted depot operation during power outages.

The newly planned tram rolling stock will operate on 750V DC power supply, and the power supply calculations and planning have been developed based on this parameter.

The 750V DC system is widely used internationally, is compatible with advanced technology equipment, and represents a reliable, efficient solution for Mongolia's conditions. Within this system, rectifier substations that convert AC to DC will be positioned along the route to power the contact network.

The substations will be interconnected to back each other up, reducing voltage drop and ensuring reliable power supply operation. This increases supply stability and creates conditions for continuous normal system operation.

Power supply equipment requirements:

- The 10/0.7 kV voltage-reducing transformer in the substation shall meet MNS 6520:2015 standard requirements.
- The electricity transmission contact network shall have 750V DC voltage with copper and alloy contact wires.
- The contact network shall be fully connected to the SCADA system.
- Contact network poles will be made of S355 grade material. They will be hot-dip galvanized and protected with epoxy paint.
- Electricity meter: RS 485 interface that meets requirements, with "IEC61107", "IEC62056" connection protocols, certified by the Mongolian Standard SMM, Metrology Department, with 0.2 accuracy class full electronic meter with memory.
- When selecting tram electrical equipment and rolling stock, energy-efficient, environmentally friendly green technology is recommended.
- Current transformer: Transformer with coefficient suitable for consumer load, fully meeting Mongolian standards requirements, relay protection, measuring instruments requirements, with 0.2 accuracy.
- Lightning protection and grounding will be installed for power sources and overhead power transmission lines.

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The total installed power for the 15 km tram line rolling stock will be 8.9 MW, and according to technical conditions provided by the Ministry of Energy, power will be supplied from 110/35/10 kV, 35/10 kV substations at 10 kV level via cable lines, converted to 750V DC through rectifier substations and distributed through the tram contact network.

Power supply system planning

The 15 km long Buyant-Ukhaa – Sukhbaatar Square tram line will be served by 18 train sets. Each tram will consist of a formation with 3 sections, with each section having a traction motor.

According to preliminary calculations, one rolling stock motor will consume a total of 560 kW of electricity. However, motor capacity can be reduced during the project implementation phase, considering capacity, load, and economic efficiency. The total installed capacity of this tram line is 8.9 MW, while the total transformer capacity is 16 MVA.

Tram Installed Capacity

- Total: 560 kW
- 560kW x 16(number of trains) = 8960 kW

Calculated Capacity The planned 15 km tram line will have a normalized substation spacing of 2 km with a total of 8 rectifier substations. At peak load, it is calculated that 3 trains will travel simultaneously within one substation's coverage area. · 3 x 560 kW = 1680 kW · 1680 x 3 = 5040 kW (3 trains within one substation's coverage area)

Source Planning According to clarification No. 01/267 dated 13.02.2025 from Ulaanbaatar Electricity Distribution Network LLC, near the 15 km tram route from Buyant-Ukhaa to Sukhbaatar Square are substations supplied by the Central Energy System: Tashgai 110/35/10, Nukht 110/10, North Yarmag 110/35/10kV, Esgillekh 110/10kV, and Urgoo 110/10kV. These substations will supply the planned tram electricity consumption.

Table 66. Substations

№	Existing Substation Name	Planned Rectifier Substation
1	Tashgai 110/35/10 kV	Rectifier substation-1
2	Nukht 110/10 kV	Rectifier substation-2
3	North Yarmag 110/35/10 kV	Rectifier substation-3
4	North Yarmag 110/10 kV	Rectifier substation-4
5	North Yarmag 110/10 kV	Rectifier substation-5
6	Esgillekh 110/10 kV	Rectifier substation-6
7	Urgoo 110/10 kV	Rectifier substation-7
8	Urgoo 110/10 kV	Rectifier substation-8

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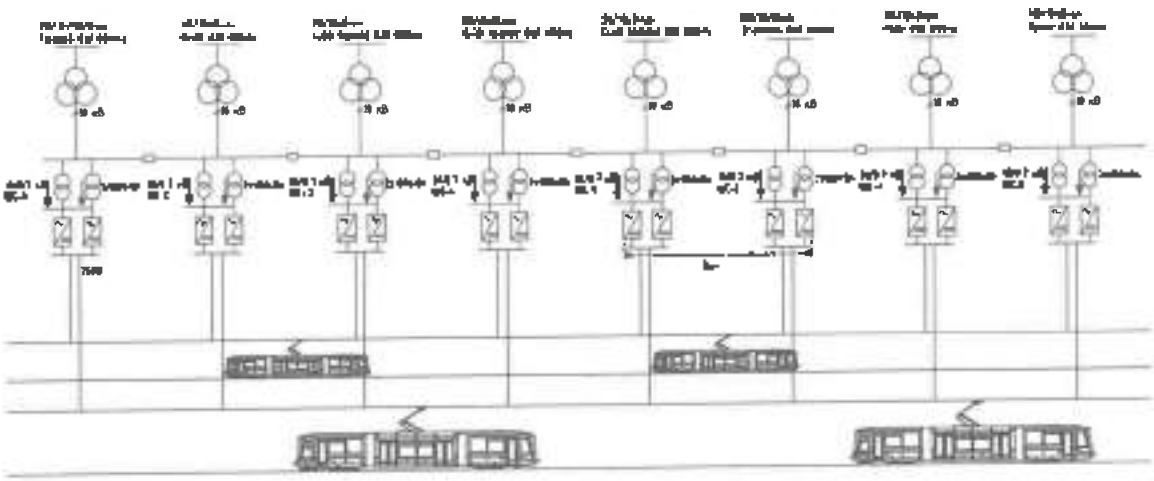

Substation Planning

As the planned tram rolling stock will operate on 750V DC voltage, rectifier substations need to be planned.

When determining the capacity of rectifier stations, it was calculated that 3 trains would operate simultaneously within one station's coverage area during peak load. Accordingly, the capacity of each rectifier station was planned at 1680 kW. Calculations were made for the maximum power when 3 trains operate simultaneously within 2 km of track.

Transformers with 10 kV voltage will be used on the AC side, and the output voltage from the rectifier will be 750V DC.

Basic data: · Capacity of 1 train = 560 kW · Total trains operating on 2 km track = 3 (1-2 in opposite directions) · Rectifier efficiency factor (cosφ): 0.95

Transformer capacity calculation: P=3x560=1680 kW, or 1.7 MW Rectifier input power (S_rectifier): S_rectifier= P

For rectifier input voltage: · Transformer with 10 kV voltage on AC side will be used. · Output voltage from rectifier is 750V DC.

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Required transformer capacity: · Transformer capacity factor: 1.15 (reserve calculated) S_trans = S_rectifier×1.15=1.78 × 1.15 = 2 MVA Transformer selection: 2 × 1000 kVA transformer

Based on the above calculations, considering current and voltage losses in the contact network, 8 rectifier substations with 2 x 1000 kVA capacity each are planned to be located along the route.

Table 87. Planned Substation Capacity

Nr	Substation Location	Power (MW)	Capacity (kVA)	Note
1	RS1 (Start - Buyent-Ukhaa)	1.7 MW	2000 kVA	First supply node
2	RS2 (Near Niseekh roundabout)	1.7 MW	2000 kVA	High-load zone
3	RS3 (Near Yarmag road)	1.7 MW	2000 kVA	High-load zone
4	RS4 (Near Yarmag road)	1.7 MW	2000 kVA	High-load zone
5	RS5 (Near Yarmag road)	1.7 MW	2000 kVA	High-load zone
6	RS6 (Near MSM)	1.7 MW	2000 kVA	Transition zone
7	RS7 (Near 120,000 area)	1.7 MW	2000 kVA	Central section, Intersections
8	RS8 (Near Sukhbaatar Square area)	1.7 MW	2000 kVA	End node
Total:		13.6 MW		

Rectifier Substation Scheme

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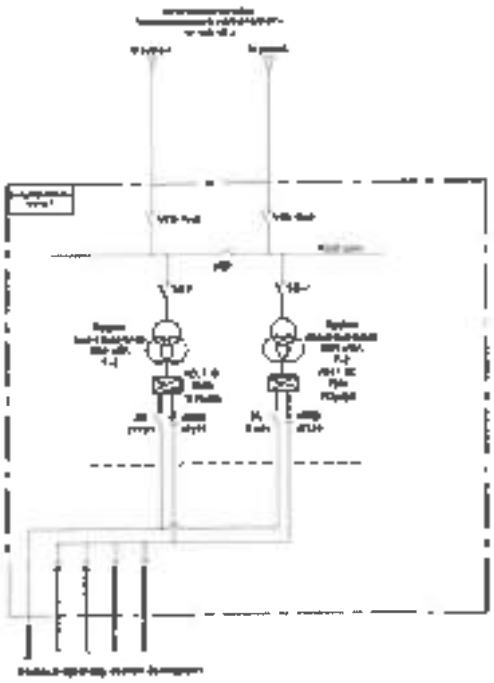

Network Planning

From existing substations, power will be supplied to the planned rectifier substations through newly constructed 10 kV capacity cable lines with a total length of 14.3 km, consisting of 2 pairs.

Table 68. Technical Parameters of Planned Power Cable Lines

No	Station Name	Line Type	Line Length, km
1	Rectifier substation-1	10kV PCCT	1.8
2	Rectifier substation-2	10kV PCCT	1.7
3	Rectifier substation-3	10kV PCCT	1
4	Rectifier substation-4	10kV PCCT	4
5	Rectifier substation-5	10kV PCCT	2.5
6	Rectifier substation-6	10kV PCCT	0.8
7	Rectifier substation-7	10kV PCCT	1.5
8	Rectifier substation-8	10kV PCCT	1
Total line length, km			14.3

The contact line connecting to the rolling stock pantograph must have copper and alloy contact wire. The contact wire height will be 5.5-6 m, and the distance between poles will be 30-45 m.

When planning poles, they will be placed at 45 m intervals in straight track sections (80%). In curve and special structure sections (20%), they will be placed at 30 m intervals. A total of 367 poles are calculated along the planned route.

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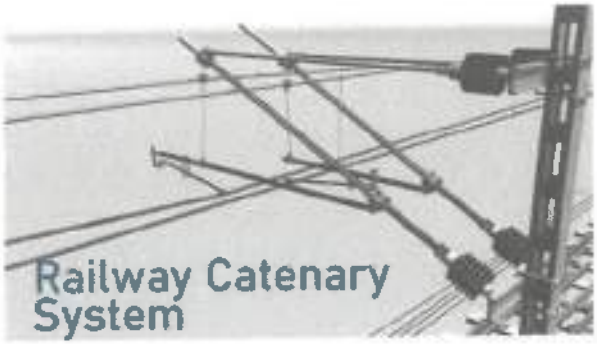
Track Section	Length (km)	Pole Spacing (m)	Number of Poles
Straight track section	12 km	45 m	267 poles
Curve and special structure section	3 km	30 m	100 poles
Total	15 km	-	367 poles

Contact Network Planning at Bridge and Intersection Sections

To ensure reliable operation of the tram contact network and avoid traffic impediments, special solutions should be planned for bridge and intersection sections.

On Bridge Structures:

- Existing lighting poles will be renovated to use dual-purpose special poles.
- A Rigid Catenary System will be used, considering the impact on bridge structure stability, wind load, and vibration effects.
- Tensioned and flexible contact wire installation will be planned along bridges to improve mechanical stability.



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At intersections:

- Flexible contact systems will be used to accommodate multi-directional traffic regulation.
- Contact wire height will be adjusted to ensure traffic safety at intersections.
- Branching and isolating equipment will be installed to ensure uninterrupted electricity transmission.

Implementing these solutions will ensure stable operation of the tram power supply, reduce voltage drop, and increase mechanical stability.

The contact line connecting to the rolling stock pantograph must have copper and alloy contact wire. The contact wire height will be 5.6-6 m, and the distance between poles will be 30-45 m.

When planning poles, they will be placed at 45 m intervals in straight track sections (80%). In curve and special structure sections (20%), they will be placed at 30 m intervals. A total of 367 poles are calculated along the planned route.

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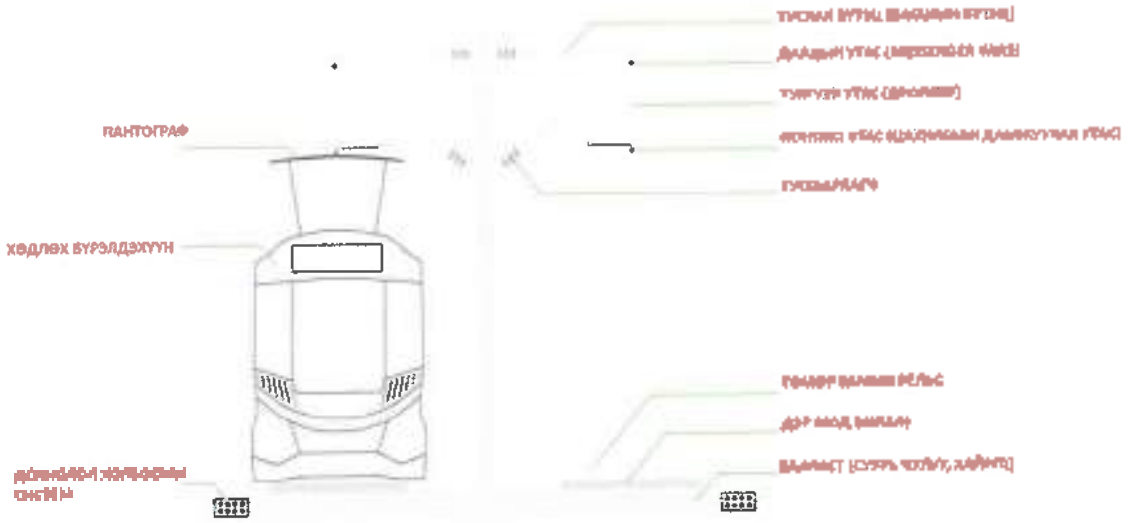
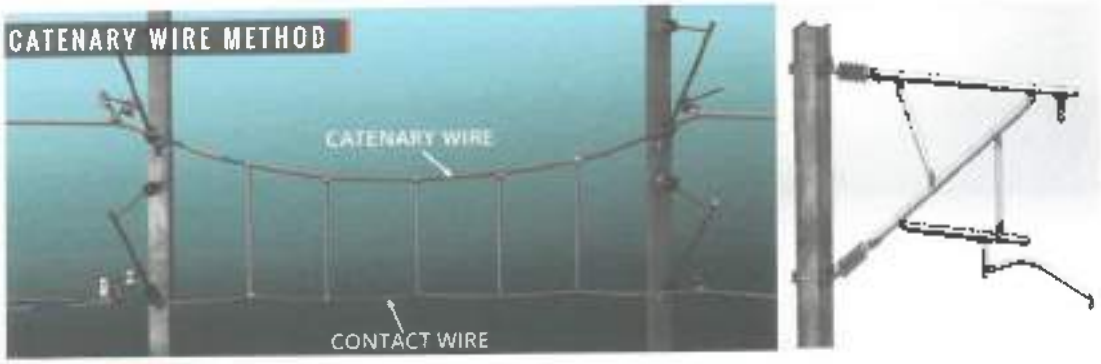
Track Section	Length (km)	Pole Spacing (m)	Number of Poles
Straight track section	12 km	45 m	266 poles
Curve and special structure section	3 km	30 m	101 poles
Total	15 km	-	367 poles

Planned Contact Network Structure



A messenger wire will be positioned at the upper part of the contact line, which will balance mechanical forces and ensure stable line operation.

Planned Messenger Wire and Pole Structure



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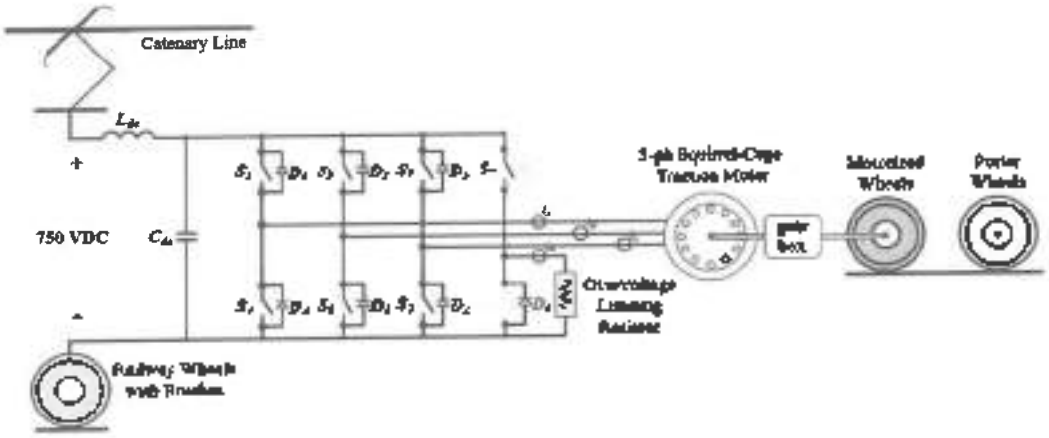
A total of 36 km of contact line is calculated along the planned route.

- 30 km line along the route
- 6 km line inside the depot

Table 89. Planned Cable Planning

№	Cable Type	Usage	Cross-Section (mm^2)	Current Capacity (A)
1	10 KV high-voltage feed cable	Power 6 substations	3x240 mm^2	400-600 A
2	750 V DC feed cable	From substation to contact wire	2x400 mm^2 DC	1000-1200 A
3	750 V DC route distribution cable	Provide additional power to contact wire	2x240 mm^2 DC	600-800 A
4	Grounding cable	Substation, support, protection	1x70 mm^2 Cu	Calculated by zone
5	Contact wire	Power the tram	120 mm^2	800-1000

Tram Electric Motor Principle Diagram



Lighting

A total of 350 outdoor lights are planned along the route.

Table 90. Road Lighting

№	Zone	Lighting Type	Quantity	Lighting Pole Height (m)	Spacing Between Poles (m)
1	Along the road / in dark sections /	LED street lights	150	8-10 m	30-40 m
2	Stop areas	LED pole lights	100	4-6 m	15 m
3	Pedestrian crossings, intersections	LED high pole lights	100	10-12 m	20-25 m

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Depot power supply planning

The tram depot power supply system will be fed by a 10/0.4 kV transformer substation (KTP) with 2×1600 kVA capacity transformers. Since the depot will serve as a center for tram maintenance, storage, and control, an emergency backup power supply is planned to ensure power supply reliability.

Buildings and Facilities

The depot consists of the following main facilities:

- Main repair workshop – Section for performing major and routine technological repair procedures on trams.
- Maintenance building – Section for technical staff to change clothes and shower.
- Daily maintenance section – Section for providing technical maintenance to ensure operational readiness.
- Rolling stock parking section – Section for storing non-operational trams while ensuring their technical integrity and safety.

The depot building complex consists of 6 buildings with a total area of 14,406 m², and the internal electricity consumers are lighting, ventilation, maintenance, and office sections. The total electrical load calculation for these consumers is about 2774 kW.

Economic calculation

Planned Power Supply System

The total investment cost of the tram power supply system includes the following main components:

- Substations – 8 rectifier substations
- Drawing power lines at 10kV level from 110/35 kV or 35/10 kV high voltage distribution facilities
- Rectifier equipment converting 10 kV to 750 V DC
- Energy monitoring, SCADA system
- Power transmission network
- Overhead contact line – Feed system to be drawn along the tram route
- Energy distribution equipment
- Cable line connections, protection, control panels

Tram Signaling Communication System Planning

General Information

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The route of the multimodal public transport project from Buyant-Ukhaa Sports Complex to Torgoni Road Complex, from the 120 thousandth intersection to Sukhbaatar Square is 15 km long in total. The signaling system is an essential component for ensuring transport safety and continuous reliable operation, and must meet the following requirements: Have approved drawings, methodology, and implementation method

- Easy to use and convenient for maintenance
- Reduce the number of field installation equipment, simplify maintenance, and reduce costs by using modern technology

The signaling system consists of equipment capable of monitoring and controlling the control systems of both directions of the tram, ensuring the safety and reliability of tram movement, and responding promptly to emergency situations.

Safety Requirements

The signaling system must fully ensure safe operation and be made and tested according to international standards EN50126, MNS EN50128: 2016-Railway control and protection system software, MNS EN50129:2016-Safety-related signaling electronic systems. For Mongolia, these standards can be confirmed and followed as national standards. Structural and systematic methods will be used to ensure the operational safety of the system and to identify and manage potentially dangerous factors to prevent risks during operation.

1. Safety Integrity Level of the Signaling System

Within the framework of the tram project, the Safety Integrity Level (SIL) plays a crucial role in ensuring system reliability, preventing accidents and injuries, ensuring the safety of drivers and passengers, preventing hazardous conditions, and ensuring continuous operation. Since tram safety directly affects the reliability of the entire system, the SIL level will have the basic indicators to meet these requirements.

Table 91 Comparison of Safety Integrity Levels

Safety Integrity Level	Description	Application Example
SIL0	No safety requirements	Information board
SIL1	Low risk, basic control	Signal control panel
SIL2	Medium risk, with error detection	Urban transport (tram, metro, LRT) signal system, ATP (Automatic protection)
SIL3	High risk, with more protection	ATO (Automatic driving), centralized control, High-speed and freight trains
SIL4	Highest protection	ETCS Level 3, automatic train movement control

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Since this tram route does not intersect with the railway, it is more appropriate to choose the SIL-2 (Safety Integrity Level) signaling system safety level. SIL-2 fully ensures the safety of vehicle movement and is a technology that can be implemented quickly and at low cost.

SIL-2 level has the following functions:

- Automatic braking system
- Maximum speed control
- Route determination
- Object location determination
- Driving safety system
- Smart door opening system
- Transmission of fault signals

2. Automation Level

For the tram project, Automation Level-1 (Grade of Automation-GoA1) has been selected as the operational mode. This mode allows the tram to operate with semi-automatic control by an operator or motorman. The system considers the interconnection between the tram system, rolling stock, mechanical components, power supply, and communication systems. The GoA1 automation level is suitable for connection with the SIL-2 level safety signaling system.

Table 92. Automation Levels

Automation Level (Grade of Automation)	Train Operation Type	Train Movement	Train Stopping	Door Closing
A1	Driver with ATP	Driver	Driver	Driver
A2	Driver with ATP/ATO	Automatic	Automatic	Driver
A3	Without Driver	Automatic	Automatic	Train Technician
A4	Unattended Train Operation (UTO)	Automatic	Automatic	Automatic

The SIL2 + GoA1 selection is an optimal solution for ensuring safety, cost-effectiveness, and technical feasibility for the Ulaanbaatar city tram project. It is technically easy to implement and economically efficient. Therefore, combining SIL2 level system with GoA1 is the most suitable option for the Ulaanbaatar tram project.

3. Selecting the Signaling System

Within the framework of the project, a comparative study of ATP (Automatic Train Protection), CBTC (Communication-Based Train Control), ETCS (European Train Control System), and ATS (Automatic Train Supervision) systems has been conducted, and it is

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appropriate to select the Automatic Train Protection (ATP)-onboard system for the tram project's signaling interlocking prohibition.

Table 93. *System Comparison*

Technology	ATP (Automatic Train Protection)	CBTC (Communication-Based Train Control)	ETCS (European Train Control System)	ATS (Automatic Train Supervision)
Operating Principle	Control speed, stop, ensure track safety	Monitor train location, guide, regulate speed	Ensure railway safety, regulate speed	Monitor and guide trains
Safety Integrity Level (SIL)	SIL2 - SIL4	SIL3 - SIL4	SIL3 - SIL4	SIL2 - SIL3
Advantages	Controls safety, has stop function	High precision, flexible scheduling	Widely used in European market	High automatic scheduling, directional control
	Controls speed, ensures train safety	Fast digital network transmission	Ensures high level of railway and tram safety	More precise transport efficiency and control
	Technologically inexpensive	Highly automated, innovative solution	European standard	Easy to maintain technically
	Easy to establish and configure the system			

The tram signaling system will operate continuously and reliably, monitoring all equipment in real-time mode, and must have fault signal and statistical analysis functions. To ensure the reliable operation of the signaling and communication system, an additional 10% of the total equipment, network capacity, and connection reserves will be planned. This is to ensure the normal operation of the system, and to quickly restore and repair in case of failure or damage. The system capacity and expansion capability will meet the following requirements:

- The system software and hardware will have a standard modular design and can easily expand functionality and capacity
- Additional capacity and future expansion capability will be planned in advance when installing the system.

General Structure of the Signaling System

The general structure of the signaling system consists of the following parts:

- Operation Control Center (OCC)
- Supervisory Control and Data Acquisition (SCADA) system
- Interlocking system
- Wayside equipment
- Automatic Train Protection (ATP) system

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- Trackside signal indicator/transmitter
- On-Board safety system

Equipment	Function
Operation Control Center (OCC)	Monitors and controls all operations of the tram, monitors vehicle movement, determines routes, maintenance, server control, signal, signaling control, and monitors safety.
Depot (SCADA remote monitoring system)	The SCADA (Supervisory Control and Data Acquisition) system is responsible for remote monitoring of electrical supply, signaling, and control equipment, and transmitting information. It should work in coordination with other systems.
Interlocking System	A system responsible for ensuring safety on the tram track and depot. It is used to limit unauthorized access, maintain distance between trams, and regulate movement.
Wayside Equipment	Signaling and communication equipment located along the tram track that works in conjunction with speed control, guidance, protection, and position determination signal systems. The outdoor equipment of the tram signaling system will be protected from dust, moisture, vibration, and use materials and equipment suitable for outdoor installation. (-45°C to +40°C)
Automatic Train Protection (ATP) System	Monitors speed limitation, anti-accident protection, automatic stop system, and ensures safe operation of the vehicle.
Trackside Signals and Signaling	Traffic lights, boards, electronic displays, and other systems responsible for transmitting information to the tram driver and control center.
Station Equipment	Each tram station will have cameras, primary clocks, announcement systems, and integrated communication boards.
On-Board Safety System	Communication equipment, antennas, position locators, camera systems, sensors, cabin control display.

Operation Control Center (OCC)

The operation of the route will be centrally monitored and controlled from the tram Operation Control Center (OCC). The integrated control system will include main and backup systems as specified in the design drawings and estimates, and the control center will be located at the Depot.

The control center will have wall displays (65'+), computers (+ software) dedicated to each control system. The reliable electrical supply operation of signaling and control equipment (OCC and equipment rooms) will be equipped with UPS and other backup supply equipment.

This center will also have a technical room that integrates all control servers, equipment, cable network nodes, meeting special standard requirements. The technical room must be equipped with ventilation, heating systems, environmental control systems, grounding systems, fire alarms, etc.

From the OCC Operation Control Center, the tram movement route will be prepared, and in case of emergency, dispatchers and other authorized operators can manually operate the system and implement necessary measures such as dealing with accidents and damages or working on the route. The central processor (OCC) will be planned to have main and backup systems.

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Since the OCC is related to the safe operation of the tram, the control system components will comply with the SIL-2+ level and follow the safety principles of the tram signaling system. All OCC equipment will be modern, certified, and must be compatible with future route expansion conditions. All workstations for dispatchers and operators will be physically similar. The work environment will be compatible with the working style of dispatchers and operators. This requirement applies to room color, sound-absorbing material, non-reflective simple lighting, etc. The work environment will be designed according to the principles of comfortable work. All materials will be easy to clean and match the overall color scheme. Each workstation will be adjusted to be compatible with the display, computer keyboard, mouse pad or other equipment, and writing surface. Each workstation will have a swivel chair. In addition to the factors below, the signaling operator's environment will follow relevant Mongolian and international standards for workplace hygiene and safety, including:

- Internal lighting, visibility
- Sound requirements
- Color standards
- Environment suitable for computer workstations with displays, etc.

Operation Control Center (OCC)

The Operation Control Center (OCC) will comply with MNS 6869:2020-Requirements for Information and Communication Technology Rooms, MNS 6528:2021-Requirements for Communication and Other Infrastructure of Data Centers, MNS 4244:1994-Labor Protection Standard System, MNS 5146:2002-Electrical Safety, Protective Grounding Expansion, MNS 5596:2020-Safety Requirements for Personnel in Information and Communication Network Facilities, MNS 6669:2017-General Requirements for Rooms

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for Communication Power Supply and Backup Power Equipment, and other additional norms and regulations. The Operation Control Center (OCC) will be able to exchange real-time information with the Traffic Control Center (TCC) and implement measures to optimize traffic management.

/Technical Room/

A dedicated technical room that consolidates all tram signaling and communication equipment aims to ensure reliable operation of the tram system and improve control center centralization. This room will house servers, monitoring system equipment, control panels, system software, communications equipment, security systems, technical maintenance tools, and backup equipment.

1. **Technical Room Organization**
   - Location: The technical room will be located near the Operations Control Center (OCC). This improves operational interconnection and facilitates system monitoring and maintenance.
   - Size: The technical room area should be approximately 30-50m², depending on the quantity and size of equipment to be installed. The room size will be determined considering equipment layout and space for technical maintenance.
2. **Equipment to be Installed:**
   - Communication Equipment:
     - Core Switch (L3 Managed): Layer-3 level switches will be used.
     - Router (Main & Backup): Equipment will be installed as main and backup.
     - IP PBX or VoIP server: For providing internal telephone network.
     - Radio communication base station: Will provide radio connectivity to trams.
   - Servers:
     - SCADA & OCC servers: For operating the tram monitoring and control system.
     - NVR (Network Video Recorder): Video recording equipment for all network-connected cameras.
     - Data storage server: For storing and processing system data.
   - Electrical Equipment:
     - UPS/Power arrestor: Backup power supply equipment.
     - Battery backup (48V DC): To ensure system operation during power outages.
     - Power distribution unit (PDU): For distributing electricity to equipment.
   - Monitoring Equipment:
     - CCTV monitoring system: Monitored via IP camera network.
     - Access control system: With RFID card readers to admit authorized personnel.
     - Fire alarm: Additional fire extinguishing system to be installed for rapid detection and extinguishing of fires.
3. **Safety and Standard Requirements:**

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The technical room equipment and installation must comply with relevant Mongolian standards and regulations, including MNS 6869:2020-Requirements for Information and Communication Technology Rooms, MNS 6528:2021-Requirements for Communication and Other Infrastructure of Data Centers, MNS 5146:2002-Electrical Safety. Protective Grounding, MNS 6669:2017-General Requirements for Telecommunications Power Supply and Backup Power Equipment Rooms.

Wayside Equipment

Wayside equipment is an essential component for monitoring tram movement and ensuring safety, continuous, and reliable operation. This infrastructure must meet the SIL-2 or higher safety standard. Since appropriate planning of wayside equipment directly affects the safe and reliable operation of the tram, it is necessary to plan according to standards and select the most optimal solution. The electronic centralization system, such as signals, axle counters, switches, and other related equipment, will be powered from distribution stations. The distribution station will be reliably powered from primary and backup power sources and provide appropriate power. Lightning protection will be installed at necessary sections of facilities located outside along the route. BD 43-101-03 "Grounding and Electrical Safety Protection Measures" will be followed.

Wayside equipment

Automatic Train Protection System (ATP)

The tram will have automatic braking synchronized operation to prevent overspeeding and entering occupied sections. The train positioning system connects with the control system and other signaling elements to work in accordance with the complete

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blocking principle and provides the most important function of the signaling and control system. Detection systems will be installed at all centralized connection points. The train positioning system will comply with appropriate SIL2, safety principles, and reliability comparable to similar conditions. The architecture of this system will have an open, modular structure fully compatible with future phased implementation of additional subsystems such as automatic train operation (ATO), signaling system expansion, and video monitoring system (CCTV).

The Automatic Train Protection (ATP) system will automatically perform the following basic functions:

- **Speed Control:** If the tram exceeds the permitted speed, the ATP system will automatically activate the braking mechanism.
- **Prevent Violation of Restrictions:** Prevents the tram from entering track sections that are occupied or have other vehicles.
- **Synchronized Brake Operation:** Operates the automatic brake in stages, in accordance with safety requirements, based on positioning system and control system information.

Positioning System

- High-precision Position Information: Will use a combined solution of GNSS (Global Navigation Satellite System), RFID, or Track Circuit technology.
- With SIL2 level (Safety Integrity Level 2) safety certification.
- Based on Complete Blocking Principle: Position information will be processed in conjunction with the signaling system, OCC (Operations Control Center), and traffic control system to ensure only one vehicle exists in a given block section.
- Dual Detection: Secondary detection systems (axle counters) will be used at all traffic recording points for backup protection.
- Direct Connection to Centralized Control System: Position data will be reported to the Operations Control Center (OCC) in real-time, supporting traffic control decisions.

Detection Equipment Location

- Will be installed at all switches, junctions, stations, and intersection points.
- To double-verify vehicle detection, "axle counter" and "track circuit" systems will be used in combination.
- Additional detection sensors (LiDAR, radar, etc.) can be used in high-traffic areas (pedestrians, vehicles).

ATP interlocking system operation

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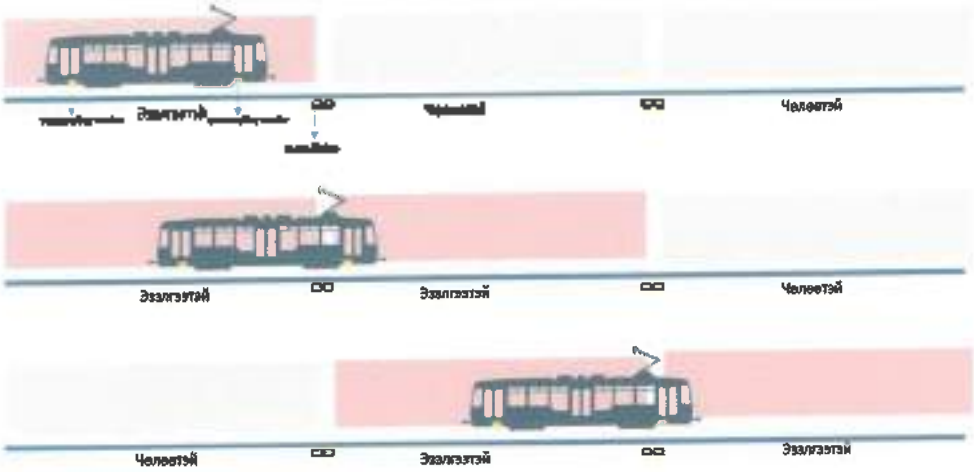
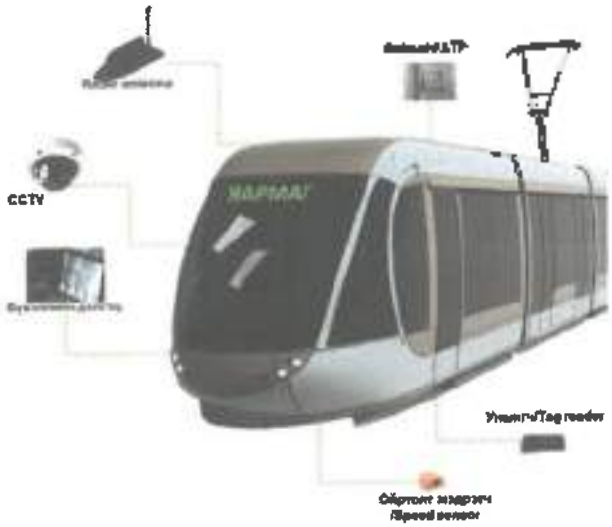


On-Board Equipment/Cabin Safety System

The tram cabin safety system will be equipped with equipment that ensures passenger and vehicle safety, prevents accidents and risks, and transmits real-time information to the integrated control center. These systems will have the following main components:

Additional equipment on the tram (on-board equipment)



The tram ATP (Automatic Train Protection) system must have a backup. The above configuration may change during the production design process.

Light Signals, Signs, and Markings

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Light signals, signs, and markings aim to regulate tram traffic and ensure safety. All points where tram meets road traffic are considered intersections. Tram signals are designed specifically for tram drivers and should not cause confusion for other vehicles or pedestrians. These markings need to be added to existing road and pedestrian crossing traffic light systems and related standards, or new standards need to be developed. The tram signal system must meet visibility requirements according to "Railway Signaling Regulations" and "Train Traffic Control Regulations." Signal lights will be under constant monitoring, and in case of failure, relevant malfunction information will be transmitted to the unified control center (OCC). The road traffic lighting system will connect with the Tram Operations Control Center (OCC), with mutually agreed data exchange protocols and infrastructure. The Order No. A/154 of the Minister of Road and Transport Development dated August 17, 2020, Appendix 2 (Railway Signaling and Communications Regulations) will also be considered.

Table P4. Tram Signal Lights and Markings at Road Intersections

Marking	Explanation	Marking	Explanation
	Stop		Left Turn
	Proceed		Stop Signal Advance Warning
	Right Turn		Start Movement
	Speed Limit		Restriction Cancelled
	Reduced Speed Advance Warning		Reduced Speed
	Reduced Speed Advance Warning Cancelled		Proceed
	Right Turn		Stop
	Left Turn		

Light signals will be installed as follows to prevent tram traffic hazards and ensure traffic safety:

- Tram-specific lights (in line form) provide stop and proceed signals.
- Light signals will be installed on the right side of the tram traffic direction on poles or in vertical form near the intersection stop line or adjacent area, and tram light signals will be installed on separate poles to prevent confusion with general traffic lights.

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- Will be installed to give priority right of way to trams.
- Light signal height may be installed above 3.5m considering visibility and safety.
- Light signals will comply with IP65+ requirements.
- Operating temperature will be from -40°C to +40°C.
- All light signals will have safety level SIL2 and comply with MNS EN 50129 standard requirements.

2. MAIN FUNCTIONS OF THE DEPOT CONTROL SYSTEM

- Monitor and control tram movement in real-time
- Monitor the road signaling and communication system
- Take prompt action in case of accidents, delays, and emergencies
- Optimize passenger flow and traffic regulation
- Monitor the energy system through the SCADA system
- Collaborate with traffic control authorities
- Maintenance & Inspection System
- Vehicle Control
- Track Switching & Signaling Control

3. DEPOT SIGNALING CENTRALIZATION INTERLOCKING SYSTEM:

The receiving, sending tracks, track sections, sorting signals, entry and exit signals will be equipped. A public address system will be planned to ensure normal, safe operation of the depot and improve internal communication. This system is intended for daily announcements, safety notifications, and rapid information dissemination during accidents. The switch will have a microprocessor system connected to unified centralization. The basic components of the switch should be quickly replaceable on-site if damaged. All states of the switch will be monitored at the OCC. The main system for controlling the signaling centralization interlocking facility will be based on computer or microprocessor centralization. The signaling centralization interlocking facility system will ensure safe, reliable, and normal operation of tram movement. The network will be organized to prevent interruptions in case of failures in the main network for transmitting data to the interlocking system. All signaling facilities and equipment will be continuously

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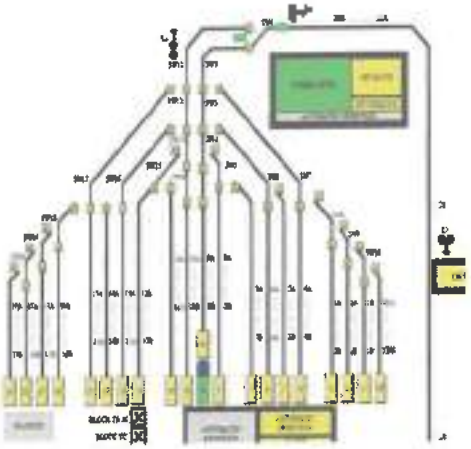
and stably powered from a secondary electrical source if the main power fails. The signaling centralization interlocking system will be controlled by the dispatcher in the depot.

The dispatch center will organize and manage all station and depot movement coordination.

- It will have a centralized control system for tram and light rail switches.
- The depot dispatcher will monitor the status of tram switches, signals, and the electrical supply contact line.
- The depot dispatcher will monitor the operational status of tram switches, signaling equipment, electrical supply contact line, and related infrastructure in real-time and make necessary adjustments and corrections.



Communication System

The communication system has been considered taking into account the weather and environmental conditions of Ulaanbaatar city, economic efficiency, future expansion possibilities, modern technologies, and interconnection with tram, energy, signaling, and other systems. The system will be modern communication systems capable of transmitting various types of information with high speed, high capacity, and broadband transmission.

Communication System Selection

The communication system for the tram in Ulaanbaatar city must comply with international and Mongolian standards.

Components of the Communication System

The system will perform functions such as determining tram location, controlling speed, indicating direction, automatic braking system, ensuring driving safety, and transmitting fault signals. A primary and backup fiber optic network for transmitting information (voice and data) that meets all standard requirements for communication will be planned along the tram route. The radio communication system will be a standardized mobile communication system designed for use in the 1st zone of radio frequency issued by the International Telecommunication Union. The communication system will use the same power source as the signaling system. It will have the following components:

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- Fiber optic network
- Radio communication system
- Public Address System (PAS)
- Passenger Information Display System (PIDS)
- Closed-Circuit Television (CCTV) system
- Master Clock System (MCS)
- Technological communication (PABX)
- Control and data collection system T-SCADA
- Software
- Fire control alarm
- Management Information System (MIS)
- Surveillance camera system
- Public announcement system

Equipment	Function
Fiber optic network	Fiber optic infrastructure with primary and backup networks to provide high-speed data transmission along the tram route and ensure connection between control center, stations, trams, and stops.
Radio communication system	Standardized mobile communication system compliant with international digital radio communication zone 1. A system that ensures uninterrupted communication between drivers, control center, and maintenance teams.
Public Address System (PAS)	Automatic loudspeaker, public announcement equipment for continuous information transmission, alarm system for emergency use
Passenger Information Display System (PIDS)	LED/LCD displays located at the dispatcher control center and in vehicles to provide route information, arrival schedule, and delay information.
Closed-Circuit Television (CCTV) system	Video surveillance system that provides the ability to monitor tram stations, integrated control center, intersections, driver's cabin, and the road. Will have capacity to store information for 180+ days
Master Clock System (MCS)	Clocks located at each station are connected to an integrated clock system via IP network, and the primary clock control is adjusted from the program.
Technological communication (PABX)	The technological communication system is organized as an independent, separate network independent of other types of communication. (Direct phone between dispatcher and depot duty officer, internal organizational communication (PABX), internet loudspeaker communication)
Control and data collection system T-SCADA	Automated monitoring system for monitoring vehicle operation, energy consumption, safety, and transmitting information
Software	Protection of SCADA, PIDS, CCTV, TETRA systems; follow EN50128 standard when developing software (test at each stage of software development)
Management Information System (MIS)	System for collecting and analyzing vehicle movement and operational data, maintenance information system.
Energy supply system (UPS)	Backup energy supply to ensure uninterrupted operation of communication and monitoring systems (operate with battery for 4-6 hours)
Public announcement system	The control equipment of the IP technology public announcement system will be located in the depot and connected to loudspeakers installed at each station via the main fiber optic network. It will be used for public announcements in case of danger and for advertising at other times.

Fiber Optic Network

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The fiber optic transmission network will form the backbone network using physical transmission means such as communication channels and fiber optic cables to provide high-speed, broadband data transmission services to tram subsystems.

To avoid future expansion and replacement of cables with new ones in case of cable breakage or damage, it is necessary to plan sufficient cable fibers (96 core+). Communication infrastructure such as camera surveillance systems, public announcement equipment, signaling systems, base stations, and field facilities located along the route will be planned according to Mongolian standards, urban development norms, regulations, and building technical requirements.

To ensure uninterrupted reliable operation of the signaling and communication network, it is necessary to plan 2 core (+2 backup core) fiber optic cables at each station. The integrated network node will be located in the technical room at the Control Center. Communication methodology and cable technical parameters may change.

For channeling facilities, it is necessary to install protective trays in sections along and across the road. When installing fiber optic cables, consult with "Information Communication Network" LLC and obtain technical conditions. Installation will be carried out according to MNS:6588-General requirements for installing flexible plastic sub-channeling in fixed communication network channeling pipes, MNS 6668:2017 "Technical indicators of communication wells and channeling facilities, installation requirements", MNS 5017:2023-Plastic pipes for communication network channeling, technical requirements, MNS 5276:2013-General requirements for communication cable installation, MNS 5278:2012-Connecting fiber optic cables, MNS 6597:2021-General requirements for installing communication cable lines across roads, railways, and through bridge structures, MNS:5471-Installation of building interior communication, signaling channeling and cables, and other relevant norms and regulations.

General concept of communication and signaling system

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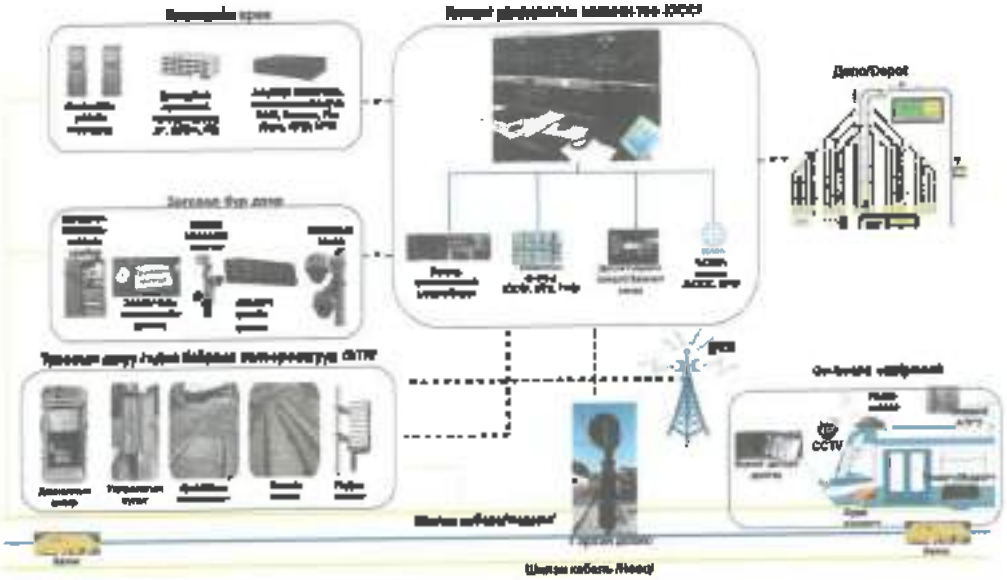

Radio Communication System

1. TETRA

Mongolia belongs to the 1st zone of radio frequency established by the International Telecommunication Union (ITU). The tram communication system will use radio communication that complies with international open digital radio communication standards. Within the signaling and communication system, the safety level SIL2 and the operating frequency band of the automatic blocking protection system (ATP) will be able to integrate with the radio communication system.

The DMR/TETRA radio system must provide reliable radio communication along the 15km route, 23 stops, and storage/maintenance areas. It is designed to provide reliable communication during operations, maintenance, and emergency situations.

The DMR/TETRA radio system will be planned as modular and expandable, requiring additional system modules and software licenses for future network expansion.

The TETRA system was selected because TETRA frequencies are allocated according to ITU Zone 1 regulations. Operating in the 380-400 MHz frequency band, it has good penetration capability in urban environments compared to higher frequency systems. Radio transmission towers will be established where needed. Radio wave propagation will be organized to be completely uninterrupted. It is also necessary to obtain relevant permission from the Communications Regulatory Commission to use this system. The radio communication system for the Yarmag-Sukhbaatar Square tram line will be organized as follows:

- 4 base stations will be positioned along the route, creating overlapping coverage areas.

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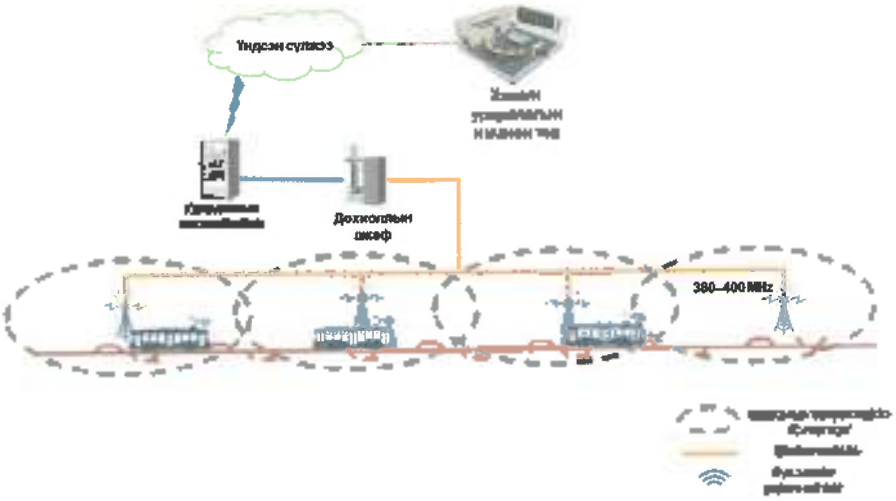
- Antennas will be placed at elevated locations or on top of poles to improve signal quality.
- Base station coverage areas will overlap to prevent "Dead zones."
- Each tram will be equipped with Digital Mobile Radio (DMR)*2 supporting equipment to ensure direct communication in case of network failure.

TETRA radio communication organization



<u>Software</u>

Software for the SCADA or open-source platforms must be used. The following factors should be considered for the software used in the tram control system:

- Management software should be of the same type
- Management software should be complete, reliable, and stable
- "Lifetime" warranty should be obtained from the owner of the management software
- Equipment, other than operational equipment, should be identical or mutually compatible
- Additional changes to the management software should be made by the owner at no cost or at a discounted price for a specific period or at all times.

Integrated software (Yarmag-Sukhbaatar Square)]

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Fire Alarm System

The fire alarm system will be located in all rooms of the control center, inside the depot building, in technical rooms, and at indoor stations. Buildings and facilities will be equipped according to BNbD 21-04-05 norm. Fire detectors will be appropriate for each object. The type of fire signal indicator will be appropriate for the purpose of the room and area (technical room, SADG, control room operated by people, etc.). In case of fire, an appropriate alarm will sound, and the location will appear on the SCADA terminal of the object and on the SCADA terminal screen at the OCC. The fire detection system will automatically record the date and time of the fire. A manual fire extinguisher will be placed at each location. Outside the entrance to the building, a fire alarm box for the manual extinguisher will be installed. The state of the extinguisher will be shown on the SCADA terminal at the location and on the SCADA terminal screen at the OCC. The system must be equipped with a self-checking device and must report detected errors on the screens mentioned above. The fire alarm system should be able to verify that it is working correctly. The fire alarm system will meet the following requirements:

- Alarm Equipment: At least one audio and visual alarm device will be installed to alert staff inside the building during fire alarms.
- Manual Alarm Button: Fire manual alarm buttons will be placed at office exit areas.
- Power Supply: The fire alarm panel will have an independent power supply that operates uninterrupted during power outages.

Surveillance Camera System

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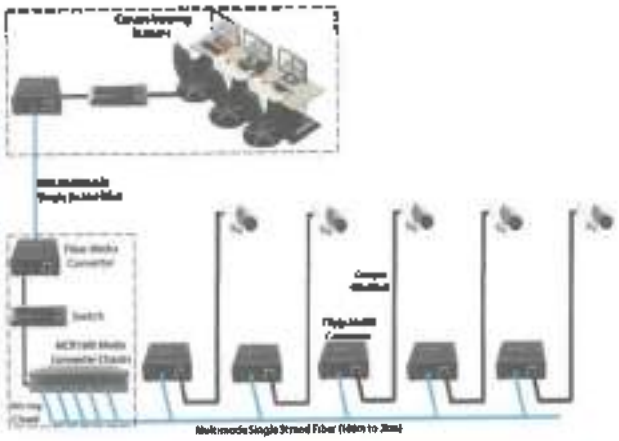
A surveillance camera system will be installed at the 23 stations and 2 terminals of the planned tram line to ensure public safety. The main equipment will be installed at the Unified Control Center, with cameras, public address system speakers, and synchronous clock devices installed on poles at each station, connected via the main fiber optic network. Outdoor surveillance cameras will have the following specifications:

- IP66 standard dust and water protection
- IK10 standard
- Above 30 fps speed
- SD card storage support capability
- IR LED lighting
- H.264/H.265 protocol

The surveillance camera system will comply with Mongolian MNS 6423:2019 standard requirements.



Traffic Signals and Markings

Traffic signals and markings are designed to regulate tram traffic and ensure safety. It is necessary to add these tram signal markings to the existing traffic light system and related standards for regulating road and pedestrian intersections, or to develop new standards. The tram traffic light system must meet the visibility range requirements according to the "Railway Signaling Regulations" and "Train Traffic Control Regulations." Traffic light normal operation will be under constant monitoring, and in case of interruption, relevant fault information will be transmitted to the unified control center (OCC). It is also necessary to consider the second appendix of the Minister of Road and Transport Development's Order No. A/154 dated August 17, 2020 (Railway Signaling and Communication Regulations).

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Tram Traffic Signal Control

Integrating tram and road traffic signal systems plays a crucial role in organizing city traffic optimally, safely, and efficiently. The following principles can be used to ensure this integration:

Technical Solutions

1. Unified Control System (Intelligent Traffic Management System, ITMS)

   Automated Control: Centralizing tram and road signal systems under one central control, changing signal duration and sequence based on real-time traffic information.

2. Tram Detection System (Vehicle Detection)

   - The signal system automatically detects in advance **when a tram approaches**, giving a "green light" in the tram's direction.
   - This **doesn't keep the tram waiting** and has an orderly impact on road **traffic**.

3. Special Signal Lights Trams use **different types of lights (e.g., T-shaped)**. This distinguishes them from road signals, making tram and auto signals separate.

Integration Strategies

A. Time-based Coordination · Coordinating the tram schedule with road signals, adjusting light timing based on how many trams will pass within a specific number of minutes.

B. Transit Signal Priority (TSP) · Signals can be programmed so that trams have **priority** over cars. This increases the ability of trams to travel faster and more consistently within the city.

C. Conflict Area Management · Engineering for clear signal coordination and traffic organization at sections where tram and road intersect.

Safety Requirements Signal coordination is most critical where tram and road traffic intersect. When the tram has a green light, all directions of the road should have a red light. Pedestrian signal coordination must also be considered.

Legal and Standard Requirements Tram and road signal coordination must be resolved in accordance with Mongolian road traffic rules and railway technical operation regulations.

Development Considerations

- Reliable operation of the signal system, resistance to failure

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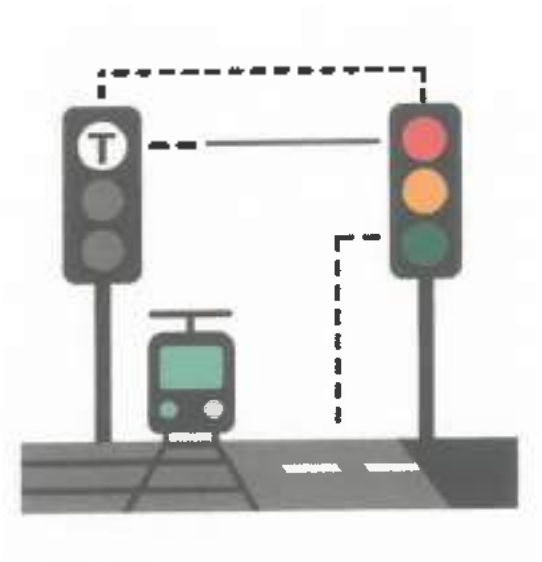
- Flexibility to adjust to changes in traffic load and peak hours
- Installation of understandable, standard-compliant signs and signals for citizens and drivers

Conclusion

Ulaanbaatar City Traffic Control Center performs the function of organizing the movement of vehicles on the capital city's roads. It works to optimally manage city traffic through traffic lights, ensuring the reliable operation of servers, software, and equipment that regulate and monitor road traffic.

Using 52 traffic sensors installed on Ulaanbaatar's main streets and roads, it collects numerical data on the speed, density, and congestion of vehicles traveling on those roads, which is used for traffic organization. Therefore, it would be appropriate to integrate tram signal control into the Traffic Control Center.

To integrate the tram signal system with the road traffic signal system, it is necessary to coordinate tram cycles and timing through a single control center or coordinated software, giving priority to trams, ensuring safety, and developing and enforcing legal and standard requirements.



9.5. ROLLING STOCK

Rolling Stock Depot and Maintenance, Repair Workshop

Depot General Planning

The depot is a facility with the primary purpose of ensuring the quality of passenger rolling stock operations as well as performing technical maintenance of rolling stock. Since high-capacity urban rail transport systems transport a large number of passengers

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at once, it is necessary to fully ensure safety, technical reliability, and continuous passenger transport operations.

Additionally, the main purpose of the depot building and facilities is to ensure technical readiness for passenger transport operations by maintaining the technical completeness, normal operation, and safety of rolling stock. Facilities for technical inspection, routine maintenance (scheduled and unscheduled), major repairs, cleaning, and services are planned in an integrated manner according to technology. The job descriptions, duties, and responsibilities of the depot employees will also be determined.

Depot Location

The depot location should preferably be at the end of the line, and the building and facilities should be planned for maintenance purposes and meet the relevant building and facility standard requirements in terms of spatial arrangement for performing repair technological operations according to safety and normal working standards for engineering and technical staff. In addition to the repair depot building and facilities, the urban tram system operation control center, track facilities, machinery, electrical supply, signaling, communications departments, and training center for employees and other related facilities will be included.

Since the above facilities are special objects consisting of sections with special purpose equipment that ensure the normal and safe operation of rolling stock used in public transport, it is necessary to have a unified security system with isolation by fencing around the perimeter to restrict unauthorized entry. Also, since the depot area will involve rolling stock maneuvering during the dark hours of the day and, if necessary, maintenance and repairs at night, it should be equipped with sufficient lighting to ensure safety and security.

The following requirements will be considered when selecting the location for the depot building and facilities:

1. To be as close as possible to the terminal station and with the possibility of direct connection to the main line
2. Not to overlap with the near and long-term infrastructure and urban planning of Ulaanbaatar city
3. Few neighboring buildings and facilities
4. It is necessary to plan the buildings, facilities, and branch tracks considering the required number of rolling stock park in relation to population growth and future increase in passenger flow, and to calculate the coverage area to be not less than 10 hectares.
5. It is important not to create relocation work and costs, and if inevitable, to choose a location with minimal time and cost.

When selecting the depot location, environmental factors should be considered, including:

- Water and soil pollution: Wastewater generated during maintenance and cleaning of rolling stock and regular washing of the exterior will be discharged into the public

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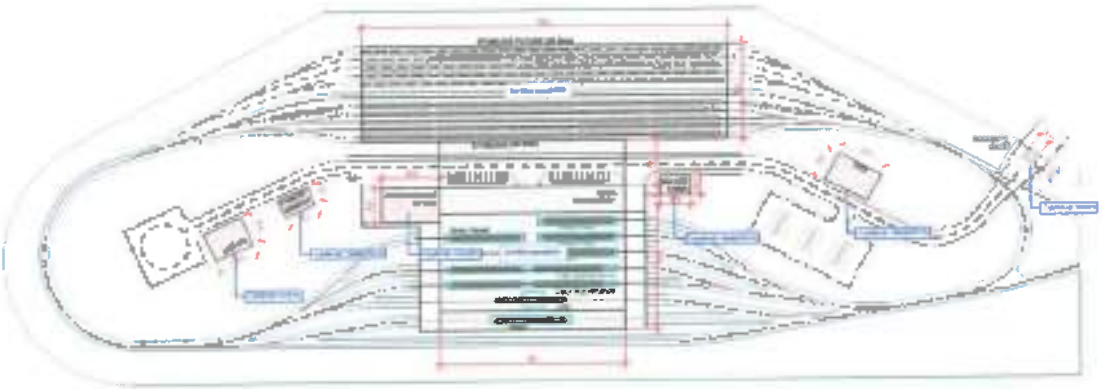
sewage system after meeting the requirements of Mongolian standards and regulations.

- Waste: Lubricating materials, technically decommissioned parts, metal, plastic items generated during rolling stock maintenance must be disposed of in accordance with relevant regulations.
- Air pollution: Since the tram is powered by electrical supply, it does not emit air-polluting gases.

It is open for the project construction contractor to provide an optimal technical solution incorporating the advantages of the latest advanced technology with shorter maintenance cycle times and lower routine maintenance costs.

General Depot Planning



Depot Planning

Stock Repair System

The rolling stock repair system is divided into 3 types:

1. Preventive maintenance
2. Unscheduled repairs
3. Preparation for passenger transport (ensuring technical readiness)

Preventive maintenance is an important repair to ensure reliable and safe technical operation of rolling stock. Failure to perform preventive maintenance will result in an inability to ensure normal reliable technical operation of rolling stock, leading to sudden

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breakdowns and damage. In such cases, it may be necessary to suspend operations for a certain period to ensure passenger safety.

The main functions of the depot are:

- Parking rolling stock (storing and protecting in a special secure environment under guard)
- Conducting inspections, preparing for passenger transport operations
- Repairing technical failures and breakdowns
- Organizing and performing scheduled routine repairs

These main functions are divided into sections of buildings and facilities, each equipped with the necessary equipment for carrying out the operations, with branch tracks for their respective purposes.

To achieve an appropriate level of maintenance design in depot planning, the following conditions must be met:

- Type of rolling stock and number of sections in the composition
- Repair system
- Sequence of each maintenance operation

Repair System Diagram

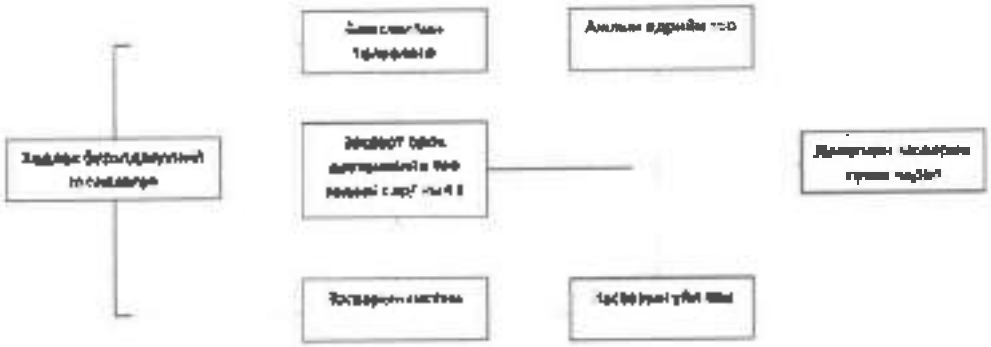

Table 05. Rolling Stock Technological Repair Planning

Category	Main Repair Tasks	Cycle
Readiness Inspection	Check the technical condition of the train and its ability to operate in passenger service.	Before each departure from the depot

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Preventive Maintenance	Minor repairs	Daily inspection	Check consumable materials Check environment and functions Check passenger compartment	Every 10 days
		Monthly inspection	In addition to daily inspection, check environment conditions and operation	Every 3 months
	Major repairs	Medium overhaul	In addition to performing monthly maintenance tasks, repair the primary and essential equipment and devices.	Every 5 years or 450,000 km
		Major overhaul	Perform medium overhaul operations and repair all equipment and device components.	Every 10 years
	Wheel pair reprofiling		Perform wheel pair re-profiling	According to operational plan
Unscheduled Repairs			Check technical condition. Repair damages.	When rolling stock experiences breakdown or damage.
Preparation for Passenger Transport		Daily inspection	Remove waste, perform interior cleaning and clean contamination.	After service operation
		Body cleaning	Wash and clean the exterior body.	Every 3-4 days
		General cleaning	Interior cleaning Wash and clean the body.	Every 30 days

Source: Relevant standards of the PRC urban public transport tram association

Depot Planning Overview

The depot will operate with the primary purposes of organizing operation for rolling stock machinists and providing maintenance, routine repairs, and parking for rolling stock. The following buildings and facilities are required to support these operations:

- Branch tracks for parking rolling stock
- Equipment for technical maintenance and routine repairs
- Facility for machinist operations
- Facility to support daily operations of engineering and technical staff
- Unified operational buildings for the urban tram system
- Branch track equipped with equipment for washing rolling stock (this track must be planned as enclosed to ensure reliable normal operation of electrical and electronic equipment during spring and autumn wind and dust storms and cold winter seasons)

It is necessary to carefully consider the interconnection of main facilities and equipment for optimal and efficient implementation of centralized management organization of unified passenger transport operations, and for this, it is very important to have a correct organizational solution for location and architectural planning.

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Building and facility planning should be done in accordance with the specifics of technological operations, for example: The daily technical service section has a double platform for inspecting the exterior electrical transmission parts.

The maintenance section will be planned as follows:

- Work platforms ensuring safety when accessing the interior, exterior, and upper parts of the rolling stock for technical inspection and maintenance.
- Stationary jack for lifting the vehicle body
- Wheel set removal device (skatopodyemnik)
- Equipped with a bridge crane with a capacity of not less than 20 tons for ongoing repairs and future major repairs.
- The daily technical inspection section will have an inspection pit and platform designed for technical inspection and repair of the running gear, planned to be 60 meters long.
- A track for performing cleaning and washing of rolling stock must also be planned
- One of the ongoing repair tracks will have a fixed wheel turning device installed.
- Workshops for maintenance of auxiliary equipment (such as electrical and electronic equipment repair shop, pantograph repair department, hydraulic system parts repair department, etc.)
- Spare parts warehouse

The length of the technical inspection and ongoing repair track sections in the tram depot building will be calculated by the following methods.

The design of the technical inspection pit shall comply with the following:

Inspection pit depth (height 1.3-1.5m)

- The inspection pit shall have stairs at both ends and an internal drainage system
- The length of the rolling stock inspection pit should be not less than the following calculation

Lj = Inspection pit length (m)

L = Rolling stock length (m)

4 = Additional length (m) Calculating 1m gap for rolling stock stop deviation and a total slope length of 1.5m for stair steps at both ends of the inspection pit

Lj = L + 4 (The total length of the building with inspection pit and the length of the track section for performing technical inspection and ongoing repair work can be calculated to accommodate a certain number of unit formations on a track with one inspection pit, coordinated with the length of the selected rolling stock.)

The length of all types of rolling stock parking tracks can be considered by dividing by the following methods. It should be not less than the length calculated by the following method.

Rolling stock parking track length

Llk = (L+1) × Nt + (Nt-1) × 8 + 9

Llk = Calculated length for rolling stock parking

Nt = Number of rolling stock parking positions per track

8 = Width between rolling stock parking position exits (m)

9 = Total distance of transverse exits at both ends of the rolling stock parking section (m)

The calculated length of the rolling stock inspection section is calculated as follows:

Ljk = Lj × Nj + (Nj-1) × 8 + 9

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Ljk = Rolling stock inspection section
Lj = Inspection pit length
Nj = Number of rolling stock inspection positions per track
8 = Width between rolling stock inspection position exits (mm)
9 = Total width of transverse exits at both ends of the rolling stock inspection section
The calculated length of the planned repair section should not be less than the following calculation:
Ldk = L + Nd × 1 + 16
Ldk = Calculated length of planned repair section (m)
Nd = Number of single (one section) sections of rolling stock
1 = Safety distance for maintenance and repair from auto assembly to auto assembly for a single section (m)
16 = Length planned considering reserve space for the planned repair section (m)
The length of the minor repair section shall not be less than the following calculation.
Lik = L + Lk + 20
Lik = Calculated length of minor (short stopping time) repair section (m)
Lk = Bogie length (m)
20 = Length planned considering reserve space for minor (short stopping time) repair section (m)
Calculating the length of the rolling stock washing section:
Useful length of terminal model rolling stock washing track:
Ljs = 2L + Le + 10
Ljs = Useful length of rolling stock washing track
2L = Length of one rolling stock before and after the washing equipment (m)
Le = Length of washing equipment (m) (including the length of locking device)
10 = Safety distance at the end of track (m)
Useful length of through model rolling stock washing track:
Lts = 2L + Le + 12
Lts = Useful length of through model rolling stock washing track
2L = Length of one rolling stock before and after the washing equipment (m)
Le = Length of washing equipment (m) (including the length of locking device)
12 = Length of signaling equipment (m)

Technical Inspection Section Platform

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The repair depot is equipped with special fixed equipment for re-profiling wheel pairs according to technology during rolling stock operation.

Fixed Equipment for Wheel Pair Re-profiling

Technological Operation for Wheel Pair Re-profiling

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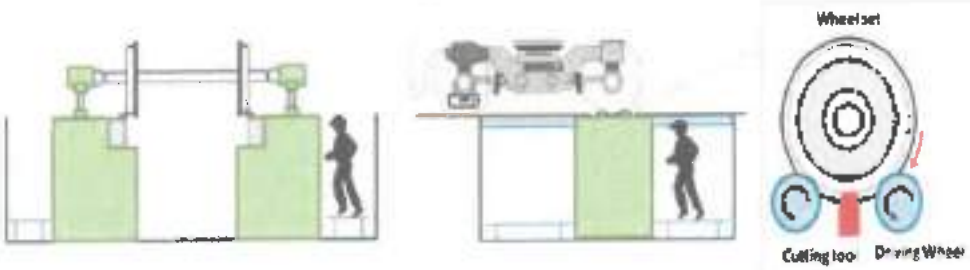
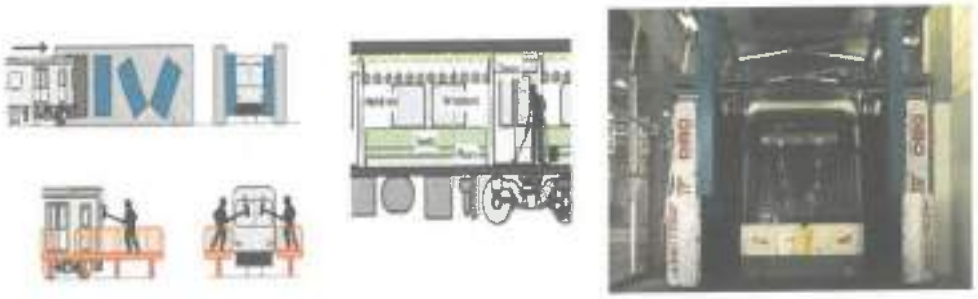


Rolling stock needs to be washed during operation and when entering maintenance, and this section must be included when planning the depot building and facilities.

Rolling Stock Washing and Cleaning Operation



Rolling Stock Basic Indicators and General Requirements

It is necessary to make technical selections that take into account the current and future passenger flow of Ulaanbaatar's public transport, the passenger capacity of each unit, adapt to Mongolia's and Ulaanbaatar's extreme weather conditions, and incorporate the latest advanced energy-efficient technology.

Table 96. Basic Dimensions and Specifications of Rolling Stock

No	Description		70% Low-Floor Tram	100% Low-Floor Tram
1	Height of rolling stock's internal passenger corridor (mm)		High-floor section ≥2000	≥2100
2	Distance between passenger section corridor platform and surface (mm)			
3	Width of passenger door exit (mm)	Double door	1300	
4		Single door	-	800
5	Height of passenger section door exit (mm)		≥1650	
6	Distance between carriage axles (mm)		≤1900	
7	Wheel pair diameter		750	640
8	Auto assembly height		≤680	
9	Pantograph working height (mm)		3900-5900	
10	Axle pressure (tons)		≤11.5	≤12.5
11			Capacity (density 6 people/m²)	≥240

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	Carrying capacity (people)	Capacity (density 8 people/m²)	≥300
12	Maximum speed of tram during operation (km/h)	70	
13	Maximum slope (track incline) (‰)	60	

Source: From PRC standards

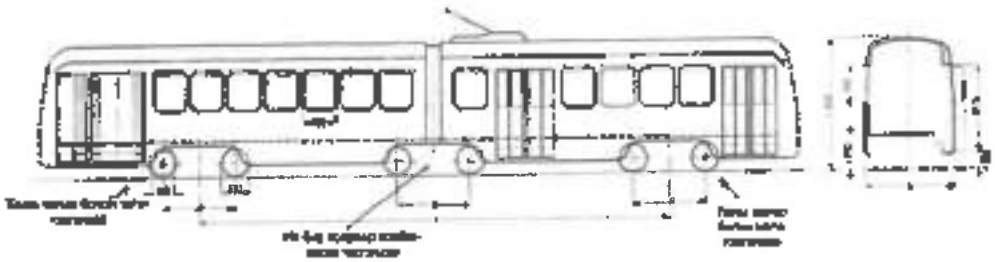
Low-floor tram connected basic composition:= $M_c+T_r+M_c$ =M_c+ one end has a driver's cabin with drive bogie, the other end is connected by an articulated joint with support and also has a corridor section vibration damping device.

Tr - With a driven bogie (no traction motor installed), has a pantograph on the upper exterior part of the body, has articulated joints on both sides, and a corridor section vibration damping device.

= Connection auto assembly

- articulated joint, corridor section vibration damping device

General Diagram of Two-Section Tram



General Requirements for Rolling Stock

Control System

The tram must have a microcomputer control system with electric brake control, hydraulic brake control (or pneumatic brake control), independent brake operation, and the electric brake must work alternating smoothly with the hybrid brake system. The above brake operations must meet the required performance during emergency braking.

Technical Reliability and Safety

It must be able to operate with full technical normal reliability in Mongolia's and Ulaanbaatar's extreme weather conditions (-40°C to +40°C), which are characterized by dryness and dust. The ability to isolate from noise during operation to ensure passenger comfort shall be at the same level as the relevant standard requirements of modern tram manufacturing countries. All parts of the tram, including components, aggregates,

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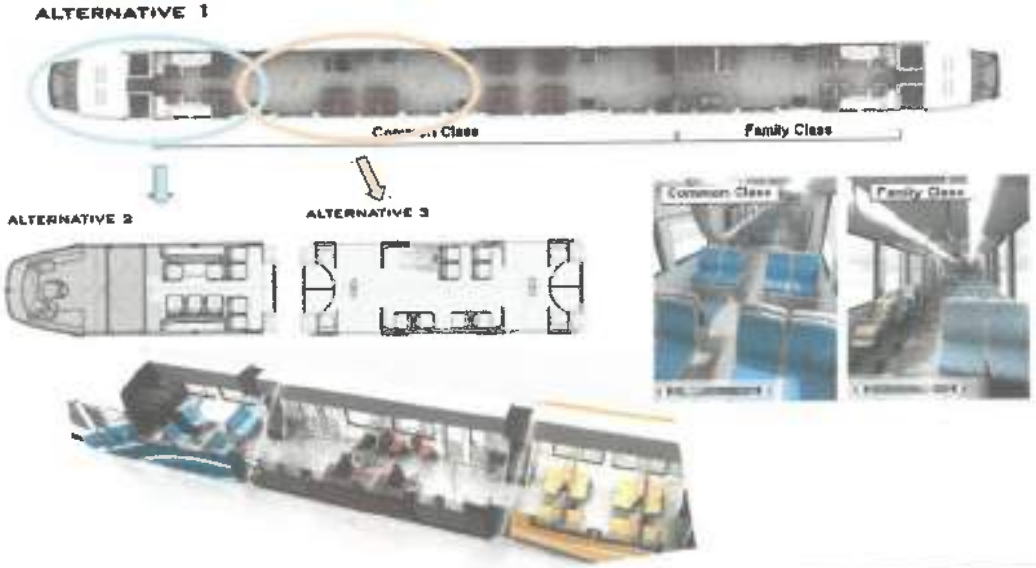
auxiliary and electrical equipment, must comply with international IEC, UIC, JIS, EN, and ISO standards.

General Requirements for Passenger Section

Passenger seats and their equipment must be durable to withstand static and dynamic loads during operation and made of materials resistant to water and moisture for maintenance, service, and cleaning.

- Force applied when passengers board and alight
- Force arising from brake action
- Lateral track force Must be able to withstand these forces.

General Condition of Passenger Compartment



Components should be easy to inspect, repair, and service. All internal and external surfaces must be protected from corrosion. To ensure passenger safety, the following requirements must be met: The interior of the tram and areas around doors must be free of sharp edges. There must be adequate ventilation. It must have emergency exit doors. The tram shall be equipped to display the maximum permitted number of passengers and nominal capacity in the passenger compartment. It shall be equipped with sufficient handrails for standing passengers. Despite having independent brakes, it must be equipped with an automatic stopping system to ensure operational safety. It must also provide full accessibility for elderly and wheelchair passengers, with securing points.

General view of passenger compartment

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Rolling Stock Options

Main tram manufacturers: Siemens Mobility (Germany) - One of the largest players in the global tram manufacturing market. Bombardier (Canada) - Major manufacturer of Flexity trams and light rail transport. Alstom (France) - Stadler Rail (Switzerland) - Considered major manufacturers of trams and light rail. CAF (Spain) - Another major player in the light rail and tram market. Skoda Transportation (Czech Republic) - Also a major manufacturer supplying trams in the European region. CRRC (China) - Represents major manufacturers of railway vehicles including trams. These manufacturers typically produce not only trams but also metro and light rail systems, supplying cities around the world that use tram networks for urban transport. The basic dimensions, axle loads, and other information of rolling stock from the above manufacturers are shown below.

Table 07. Rolling Stock Technical Maintenance Planning

Manufacturer	Number of Sections	Length (mm)	Width (mm)	Height (mm)	Total Traction Motor Power (kW)	Axle Load
CRRC	3	21400	2650	3535	580	≤12.6
Siemens	3	27680	2300	3400	520	≤11
Alstom	3	33000	3620	2650	720	≤8.5
Skoda	3	21150	2460	3600	400	≤12.5
Stadler	3	32250	2650	3600	600	≤12.6

Table 08. Trams from Rolling Stock Manufacturers

Siemens	Stadeler	Alstom

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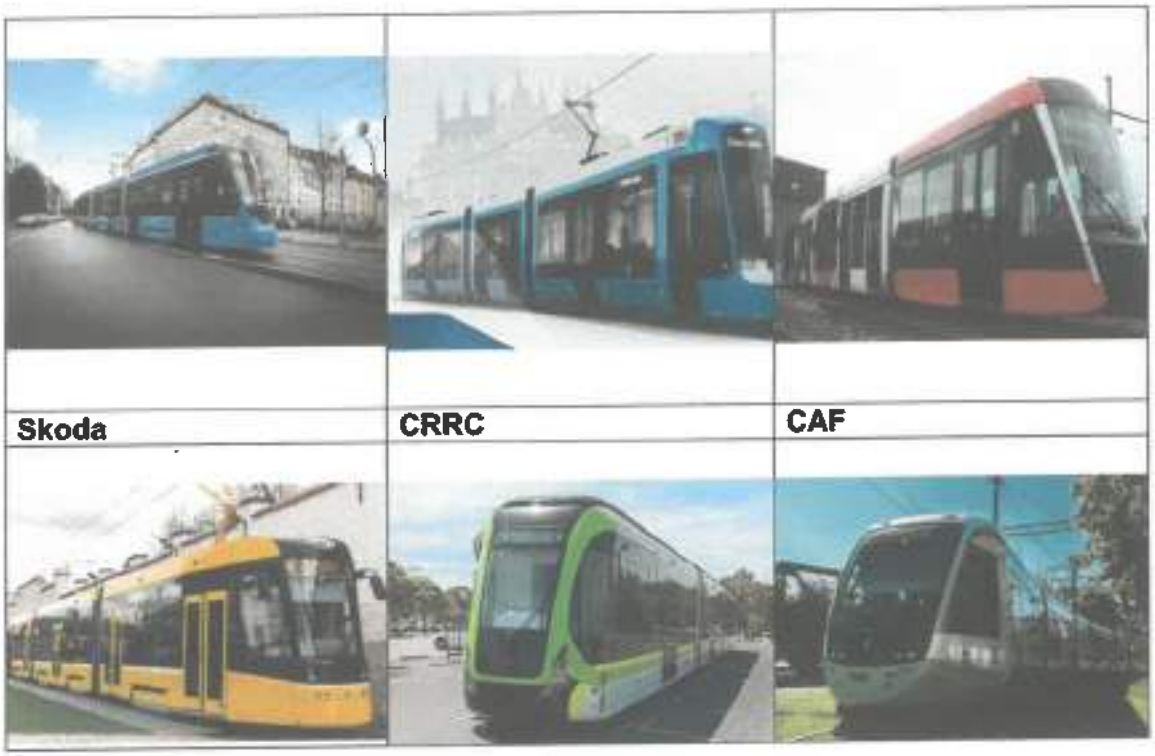
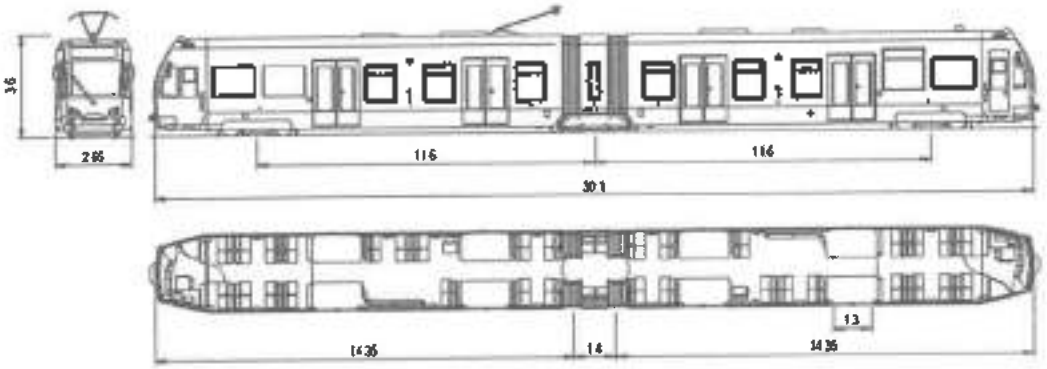


Siemens tram



Skoda tram

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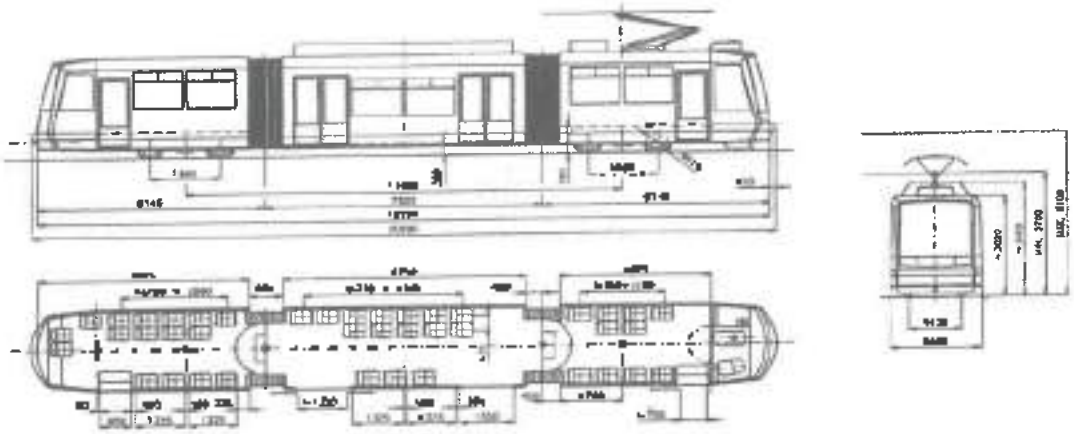
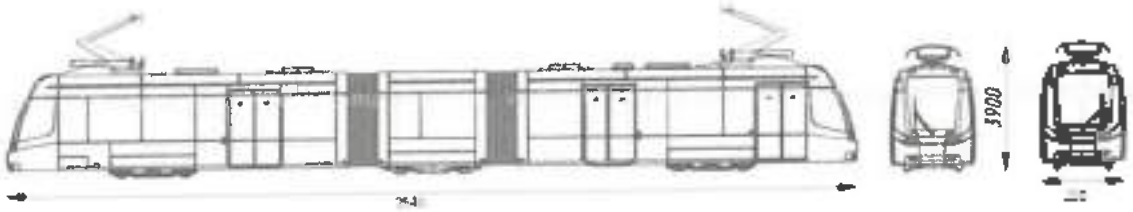
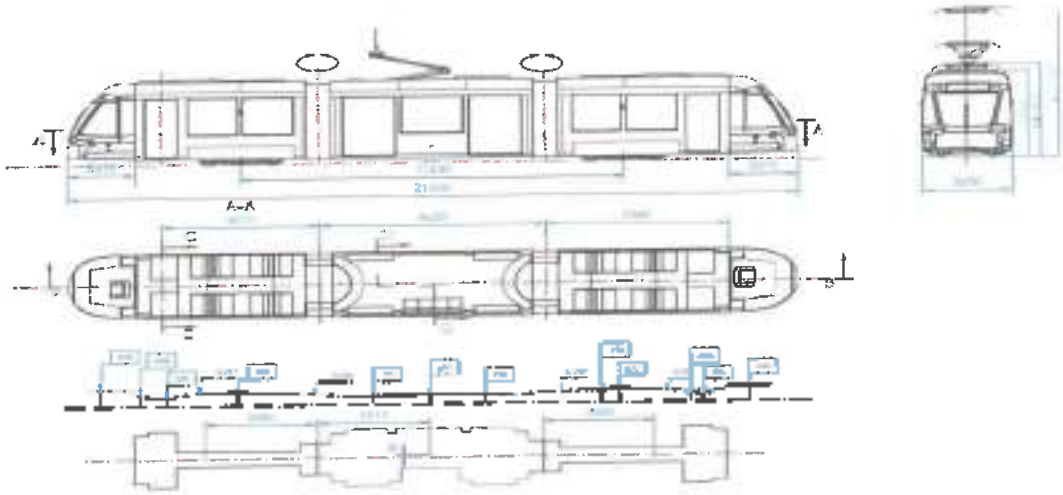


Stadler tram



CRRC tram



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Interval Frequency Calculation

The distance between stops, according to international experience, particularly the Chinese standard, is planned at 500-800m in the city center and 600-1000m in suburban areas. The time for boarding and alighting passengers at a station should not exceed 30 seconds. The headway (time between successive trams) in urban tram transport should be at least 4 minutes, and no more than 6 minutes during peak load times (in prolonged conditions).

The formula for calculating rolling stock in passenger transport is:

$$N = T/t$$

N- Rolling stock (number of trams) [units]
T- Complete travel time for a vehicle on the line (including stopping time at each station and turnaround time at line terminals) [min]
t – Minimum headway time for the next vehicle [min]
The average full-day load established by the operational plan is calculated as follows:

$$C = \frac{Q * l}{L * n * Carrying\ capacity}$$

Q - Full-day passenger flow
l - Average distance
L - Intersection length
n - Number of trams operating in full-day service
The speed limit for trams traveling through curved sections during operation is determined as follows:

$$v = [(h + h0)\frac{R}{11.8} * 0.5$$

R - Curve radius (m)
h + h0 - Track elevation in curved sections (mm)

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CHAPTER 10.PROJECT INVESTMENT, FINANCIAL AND ECONOMIC EFFICIENCY CALCULATION FOR THE TRAM PROJECT

10.1. FINANCING OPTIONS

Determining the financing structure for project implementation is critical, as the project's net present value (NPV) and internal rate of return (IRR) will be determined based on the financing type and associated costs. Accordingly, financial calculations were performed under the following three scenarios, with results presented in the financial analysis section.

	SCENARIO 1 /SOFT LOAN + ECA	SCENARIO 2 /EXIM LOAN FINANCING/	SCENARIO 3 /GOVERNMENT LOAN FINANCING/
	100%	100%	100%
Loan tenor	20 years	15 years	30 years
Interest rate	SOFR + 1%	4.96%	0%
Loan arrangement fee	0.20%	1.00%	0%
Commitment fee	0.15%	0.75%	0%
ECA guarantee fee	21.14%	0%	0%
Loan amount	USD 441.49 million	USD 348.16 million	USD 348.16 million

Economic and Financial Analysis

Table 99. Economic and Financial Analysis Results

No.	Indicator	Unit	Option 1	Option 2	Option 3
1	Total Capital Investment	USD million	348.16		
1.1	Resettlement costs		19.80		
1.2	Track infrastructure construction costs		102.43		
1.3	Signaling and communications costs		14.12		
1.4	Power system costs		38.32		
1.5	Depot and maintenance facility buildings		21.82		
1.6	Rolling stock and maintenance equipment		73.58		
1.7	Client supervision costs		5.40		
1.8	Contractor management costs		20.02		
1.9	Detailed design costs		7.51		
1.10	Contingency costs		13.50		
1.11	VAT		31.85		
2	Total Revenue		882.31		
2.1	Tariff revenue		871.50		
2.2	Other revenue		30.81		
3	Total Operating Costs		413.37		
3.1	Salaries, wages, allowances, bonuses, social insurance costs		165.90		
3.2	Employer social insurance contributions		16.79		
3.3	Facility operational costs		21.13		
3.4	Supply and material costs		72.01		
3.5	Business trip expenses		2.97		
3.6	Third-party services and general work service fees		11.50		
3.7	Operation and service costs		118.85		
3.8	Other costs and contingency costs		4.24		
4	Operating Profit		469.94		
5	Total Interest Costs		283.46	158.30	-

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6	Total Depreciation Costs		568.84		
7	Profit Before Tax		(383.17)	(236.08)	(79.70)
8	Corporate Income Tax		–	–	–
9	Net Profit		(383.17)	(236.08)	(79.70)
10	Operating Cash Flow Total		(268.83)	(16.52)	148.73
11	Ticket Price (₮1500 + 250 per km beyond 5km)*	MNT	₮1500 + ₮50		
12	Economic Net Present Value	USD million	148.2		
13	Economic Internal Rate of Return	%	19.3%		
14	Financial Net Present Value	USD million	(412.26)	(262.76)	(200.36)
15	Financial Internal Rate of Return	%	-2.9%	-6.7%	1.3%

Note: When the ticket price is set at 1500 mnt within 5 km and 50 mnt per additional kilometer beyond 5 km, the financial net present value shows the highest performance compared to other alternatives, and the economic internal rate of return exceeds 12% at 19.3%.

10.2. SUMMARY OF TOTAL INVESTMENT COSTS FOR THE TRAM PROJECT

Table 100. *Investment Summary*

№		Description	Cost Calculation	Percentage
Package-1	1.1	Track Infrastructure Construction Works	102,433,438	38%
	1.1	Substructure works	38,361,086	14%
	1.2	Superstructure works	64,072,344	24%
Package-2	2	Signaling and Communications Works	14,123,200	5%
	2.1	Signaling system installation and setup	14,123,200	5%
Package-3	3	Power System Works	38,321,578	14%
	3.1	Power system supply and installation	38,321,578	14%
Package-4	4	Station and Depot Building Facilities	21,828,497	8%
	4.1	Depot	19,678,062	7%
	4.2	Stations	2,144,435	1%
Total construction work (1+2+3+4)			176,696,715	65%
Package-5	5	Rolling Stock and Maintenance Equipment	73,575,000	27%
	5.1	Rolling stock	63,000,000	23%
	5.2	Maintenance equipment	10,575,000	4%
	6	Resettlement Costs	19,796,605	7%
Subtotal (1+2+3+4+5+6)			270,070,320	100%
	7	Client supervision costs (2%)	5,401,406	
	8	Contractor management costs (8%)	20,021,897	
	9	Detailed design costs (3%)	7,508,211	
	10	Contingency costs (5%)	13,503,516	

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	Subtotal	46,435,031	
	VAT (10%)	31,690,535	
TOTAL INVESTMENT		348,155,886	

Notes: Contractor management costs include: management, quality control, systems engineering, preparatory work, testing and commissioning, alignment, and training expenses.

Detailed cost calculation for tramway track infrastructure construction: Total cost: USD 102.4 million.

Table 101. Upper and Lower Structure Construction Work

№	Equipment Name	Unit	Quantity	Unit Cost (USD)	Total Amount (USD)
1	Railway Construction Work				102,453,439
1.1.1	Lower Structure Work	km	30.00	1,276,703	38,301,090
1.1.1.1	Preparatory Work				6,674,784
1.1.1.1.1	Existing Road Removal	m3	90,000.00	14	1,260,000
1.1.1.1.2	Waste Transportation	m3	2,956.80	5	14,784
1.1.1.1.3	Excavation Work	m3	540,000.00	5	2,700,000
1.1.1.1.4	Waste Soil Transportation	m3	540,000.00	5	2,700,000
1.1.1.2	Construction				1,250,978
1.1.1.2.1	Subgrade Compaction	m2	90,000.00	5	450,000
1.1.1.2.2	Pavement Layer Work	m3	23,173.92	20	463,478
1.1.1.2.3	Drainage Channel, Trough Installation	pc	22,500.00	15	337,500
1.1.1.3	Materials				4,125,000
1.1.1.3.1	Drainage Channel (Trough)	pc	15,000.00	175	2,625,000
1.1.1.3.2	Drainage Channel (Trough Cover)	pc	15,000.00	100	1,500,000
1.1.1.4	Depot				4,310,303
1.1.1.4.1	Embankment Construction from Soil Deposit	1 m3	13,329.21	12	159,915
1.1.1.4.2	Unsuitable Material Excavation and Removal (by Excavator)	1 m3	338,289.39	7	2,401,855
1.1.1.4.3	Concrete Slab Pavement Construction	1 m2	780.00	56	43,680
1.1.1.4.4	Eco Block Installation (Pavement)	1 m2	4,975.11	17	84,577
1.1.1.4.5	Cement-reinforced Crushed Stone Mixture Base Construction (with Spreader) Pavement	1 m3	33,758.40	48	1,620,307
1.1.1.5	Bridge Structure	km	520.00	42,308	22,000,000
1.2	Upper Structure Work	km	36.00	1,779,787	64,072,344
1.1.2	Construction				13,634,668
1.1.2.1	Upper Structure Base Concrete Installation	pc	18,000.00	200	3,600,000
1.1.2.2	Rail Fastening Base Concrete Installation	pc	18,000.00	200	3,600,000
1.1.2.3	Upper Pavement Concrete 1 Installation	pc	18,000.00	50	900,000
1.1.2.4	Upper Pavement Concrete 2 Installation	pc	18,000.00	50	900,000
1.1.2.5	Upper Pavement Concrete 3 Installation	pc	18,000.00	50	900,000
1.1.2.6	Main Track Layer Installation (Rail, Fasteners, Vibration Damping Rubber)	m	36,000.00	70	2,520,000
1.1.2.7	Turnout Installation	set	34	500	17,000
1.1.2.8	Grooved Rail Welding Work	pc	3,000	50	150,000
1.1.2.9	Noise and Vibration Reduction Rubber Installation	m3	128,408	5	642,042
1.1.2.10	Bitumen Pouring	m3	171	5	856
1.1.2.11	Geotextile Installation	m3	85,000	5	425,000
1.1.2.12	Voltage Adjustment Work	m	36,000	5	180,000
1.1.3	Materials		-		50,237,446
1.1.3.1	Upper Structure Base Concrete	pc	18,000	650	11,700,000
1.1.3.2	Rail Fastening Base Concrete	pc	18,000	400	7,200,000
1.1.3.3	Upper Pavement Concrete 1	pc	18,000	125	2,250,000
1.1.3.4	Upper Pavement Concrete 2	pc	18,000	125	2,250,000
1.1.3.5	Upper Pavement Concrete 3	pc	18,000	250	4,500,000
1.1.3.6	Grooved Rail	pc	2,555	1,160	2,963,200
1.1.3.7	Fastener	pc	103,271	50	5,163,529
1.1.3.8	Turnout	set	34	175,000	5,950,000

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1.1.3.9	Turnout Slab	set	34	50,000	1,700,000
1.1.3.10	Vibration Damping Rubber	m3	95,372	50	4,768,581
1.1.3.11	Vibration Dampers	pc	2,459	300	737,647
1.1.3.12	Stanchion	m3	127	600	76,273
1.1.3.13	Geotextile	m3	96,372	10	963,716
1.1.3.14	Equalizing Rail (12.5m)	pc	30	1,150	34,500

Table 102. Signaling and Communication Cost

No.	Equipment Name	Unit	Quantity	Unit Cost	Total Amount (USD)
2.1	**Operation Control Center (OCC)**				
[illegible]	TMS (Laptop/Workstation with TMS Software)	pc	2	7,800	15,600
[illegible]	Real-Time Signaling Server	pair	1	39,000	39,000
[illegible]	Traffic Control (Workstation Computers)	pc	2	4,225	8,450
[illegible]	DEPOT/Local Command Workstation Computer	set	1	3,900	3,900
[illegible]	Power Supply System (UPS)	pc	2	12,675	25,350
	Subtotal				[illegible]
2.2	**TRAM DEPOT CONTROL SYSTEM**				
[illegible]	Depot Management Software & Control Center	pc	1	1,040,000	1,040,000
[illegible]	Automatic Depot Signaling System	pc	1	780,000	780,000
[illegible]	Communication System (TETRA, Wired/Wireless)	pc	1	455,000	455,000
[illegible]	CCTV & Security System	pc	1	325,000	325,000
[illegible]	Power Supply & UPS	pc	1	260,000	260,000
[illegible]	Vehicle Tracking & Automated Diagnostics	pc	1	325,000	325,000
[illegible]	Maintenance & Spare Parts	pc	1	325,000	325,000
	Subtotal				[illegible]
2.3	**Software OCC**				
[illegible]	Supervisory Control & Data Acquisition (SCADA) Software	set	1	325,000	325,000
[illegible]	Traffic Management System (TMS) Software	set	1	260,000	260,000
[illegible]	Interlocking & Signaling Control Software	set	1	195,000	195,000
[illegible]	Passenger Information & Announcement Software	set	1	130,000	130,000
[illegible]	Automatic Vehicle Location System (AVLS) Software	set	1	195,000	195,000
[illegible]	Cybersecurity & Data Protection Software	set	1	65,000	65,000
	Subtotal				1,170,000
2.4	**Signaling Equipment (Non-Interlocking Equipment)**				
[illegible]	Interlocking System (SIL-2 Certified)	set	5	104,000	520,000
[illegible]	Centralized Control System (Basic Control)	set	1	104,000	104,000
[illegible]	Signaling Control Equipment	pc	1	65,000	65,000
[illegible]	Trackside Signal Equipment	set	5	19,500	97,500
[illegible]	Power Supply & UPS for Signaling System	set	1	26,000	26,000
	Subtotal				[illegible]
2.5	**Wayside Equipment**				
[illegible]	Signal Mast with Lights (per mast)	pc	64	43,500	2,912,000
[illegible]	Switching Point Mechanism (per point)	pc	64	16,250	1,040,000
[illegible]	Barrier Traffic (per unit)	pc	45	3,900	175,500
[illegible]	Road Traffic Interface (per intersection)	pc	18	16,250	292,500

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[illegible]	Detection System: Track Circuits/Axle Counters (each station)	pc	25	35,750	893,750
[illegible]	Wayside Signalling Indicators	set	1	260,000	260,000
[illegible]	Automatic Protection System (ATP)	set	1	650,000	650,000
[illegible]	Uninterruptible Power Supply (UPS)	pc	10	4,950	49,500
	Subtotal				**6,289,250**
2.6	**Cabin Safety Equipment**				
[illegible]	Driver's Control Console & Dashboard	pc	16	11,050	176,800
[illegible]	Passenger Information Display System	pc	1	124,800	124,800
[illegible]	CCTV Surveillance System (Interior & Exterior)	pc	16	9,100	145,600
[illegible]	Card Reader (Ticketing & Validation System)	pc	1	93,600	93,600
[illegible]	Onboard ATP (Automatic Train Protection) Interface	pc	1	93,600	93,600
[illegible]	Wi-Fi & Communication System	pc	1	72,800	72,800
[illegible]	Tag Reader (RFID Tracking System)	pc	16	3,250	52,000
[illegible]	Speed Sensor (Axle-Mounted Encoder)	pc	16	3,250	52,000
[illegible]	Detection System (GPS-Based Location Tracking)	pc	16	2,600	41,600
	Subtotal				**852,800**
2.7	**Telecommunication**				
[illegible]	Station Network Equipment	pc	25	4,914	122,850
[illegible]	CCTV Surveillance System	set	60	2,600	156,000
[illegible]	Event Recorder & Data Logger	pc	2	9,750	19,500
[illegible]	Optical Fiber - 96 core	km	32	4,063	130,000
[illegible]	VoIP Communication for OCC & Field Staff	set	1	65,000	65,000
[illegible]	SCADA System	set	1	195,000	195,000
	Subtotal				**[illegible]**
2.8	**Radio Communication System**				
[illegible]	Central Radio Communication Server	pc	1	195,000	195,000
[illegible]	Train Onboard Radio Units	pc	16	11,700	187,200
[illegible]	Radio Base Stations (Repeater Units)	pc	4	39,000	156,000
[illegible]	Handheld Portable Radios (Driver & Maintenance Staff)	pc	20	6,500	130,000
[illegible]	Radio Antenna & Signal Boosters	pc	1	59,800	59,800
	Subtotal				**[illegible]**
	Total Cost				**14,123,200**

Table 103. *Energy Cost*

No.	Cost Category	Unit	Quantity	Unit Cost (USD)	Total Amount (USD)
3.1	**Rectifier Substation**				
3.1.1	Building Structure (20x20x3.5h)	block	9	351,000	3,159,000
3.1.2	1500 KVA Transformer	pc	18	325,000	5,850,000
3.1.3	High Voltage Distribution Equipment (10kV Switch, Panel)	set	9	234,000	2,106,000
3.1.4	Low Voltage or DC Panel (750V Distribution)	set	9	286,000	2,574,000

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3.1.6	Control Panel (SCADA, Protection Equipment)	set	9	260,000	2,340,000
3.1.5	Other Related Equipment	set	9	429,000	3,861,000
Subtotal:					10,000,000
3.2	Contact Line Network (2 circuits, total length 30 km)				
3.2.1	Metal Poles (Square Base, 7-8 m Height)	pc	367	9,750	3,578,250
3.2.2	Contact Wire (2 Circuits, Total Length 30 km)	km	30	54,600	1,638,000
3.2.3	Auxiliary Equipment (Insulators, Cables, Tensioning Set)	set	15	130,000	1,950,000
3.2.4	Other Related Equipment	set	15	71,939	1,079,091
Subtotal:					8,245,341
3.3	Power Cables (750V, from Substations to Overhead Contact Line)				
3.3.1	DC Transmission Cables	m	24,000	32.5	780,000
3.3.2	Cable Protection, Ducting	set	24	6,500	156,000
3.3.3	Other Related Equipment	set	24	6,500	156,000
Subtotal:					1,092,000
3.4	Trackside Lighting				
3.4.1	Lighting Poles (8m, Metal)	pc	350	780	273,000
3.4.2	LED Lights (150W)	pc	350	130	45,500
3.4.3	Cables, Connections	set	23	1,170	26,910
3.4.4	Other Related Equipment	set	23	520	11,960
Subtotal:					357,370
3.5	Depot Contact Line Network				
3.5.1	Metal Poles Square Base, 7-8 m Height	pc	147	9,750	1,433,250
3.5.2	Contact Wire 2 Circuits, Total 12 km	km	12	54,600	655,200
3.5.3	Auxiliary Equipment (Insulators, Cables, Tensioning Set, Protection Devices)	set	5	65,000	390,000
3.5.4	Depot Electrical Equipment (Switches, Panels, etc.)	set	5	64,594	387,566
Subtotal:					2,866,016
3.6	Depot Backup Power Generator				
3.6.1	Diesel Generator (1000kW)	pc	1	65,000	60,000
3.6.2	Distribution Panel, Connections	set	1	13,000	10,000
3.6.3	Other Related Equipment	set	1	10,303	7,925
Subtotal:					67,925
3.7	SCADA System (Monitoring, Control)				
3.7.1	Control Center (Server, Software)	set	1	1,950,000	1,500,000
3.7.2	Monitoring Panel, Sensors	set	1	650,000	500,000
3.7.3	Other Related Equipment	set	1	288,600	222,000
Subtotal:					2,222,000
3.8	Depot Exterior Lighting				
3.8.1	Lighting Poles	set	36	4,550	163,800

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3.8.2	LED Lights (200W)	set	35	2,600	93,600
3.8.3	Cables, Connections	set	35	1,300	46,800
3.8.4	Other Related Equipment	set	35	1,946	68,063
Subtotal:					371,183
3.9	Connection to 10-35kV Power Source				
3.9.1	High Voltage Cables (10-35kV)	set	9	195,000	1,755,000
3.9.2	Transformer Connection, Protection	set	9	65,000	585,000
3.9.3	Other Related Equipment	set	9	96,416	867,742
Subtotal:					3,207,742
Total Equipment Cost:					38,321,578

Table 104. Construction Cost Calculation

No.	Equipment Name	Unit	Quantity	Unit Cost (USD)	Total Amount (USD)
A	STATION BUILDINGS				
4.1	Station 1				$77,830.18
4.1.1	Station Platform	m²	360	$152.06	$54,742.64
4.1.2	Canopy	pc	4	$3,937.12	$15,748.49
4.1.3	Fencing	m	132	$55.60	$7,339.06
4.2	Station 2				$77,830.18
4.2.1	Station Platform	m²	360	$152.06	$54,742.64
4.2.2	Canopy	pc	4	$3,937.12	$15,748.49
4.2.3	Fencing	m	132	$55.60	$7,339.06
4.3	Station 3				$77,830.18
4.3.1	Station Platform	m²	360	$152.06	$54,742.64
4.3.2	Canopy	pc	4	$3,937.12	$15,748.49
4.3.3	Fencing	m	132	$55.60	$7,339.06
4.4	Station 4				$77,830.18
4.4.1	Station Platform	m²	360	$152.06	$54,742.64
4.4.2	Canopy	pc	4	$3,937.12	$15,748.49
4.4.3	Fencing	m	132	$55.60	$7,339.06
4.5	Station 5				$146,686.36
4.5.1	Station Platform	m²	360	$152.06	$54,742.64
4.5.2	Canopy	pc	2	$43,306.34	$86,612.67
4.5.3	Fencing	m	132	$55.60	$7,339.06
4.6	Station 6				$77,830.18
4.6.1	Station Platform	m²	360	$152.06	$54,742.64
4.6.2	Canopy	pc	4	$3,937.12	$15,748.49
4.6.3	Fencing	m	132	$55.60	$7,339.06
4.7	Station 7				$77,830.18
4.7.1	Station Platform	m²	360	$152.06	$54,742.64

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4.7.2	Canopy	pc	4	$3,937.12	$15,748.49
4.7.3	Fencing	m	132	$55.60	$7,339.06
4.8	Station 8				$77,830.18
4.8.1	Station Platform	m²	360	$152.06	$54,742.64
4.8.2	Canopy	pc	4	$3,937.12	$15,748.49
4.8.3	Fencing	m	132	$55.60	$7,339.06
4.9	Station 9				$77,830.18
4.9.1	Station Platform	m²	360	$152.06	$54,742.64
4.9.2	Canopy	pc	4	$3,937.12	$15,748.49
4.9.3	Fencing	m	132	$55.60	$7,339.06
4.10	Station 10				$77,830.18
4.10.1	Station Platform	m²	360	$152.06	$54,742.64
4.10.2	Canopy	pc	4	$3,937.12	$15,748.49
4.10.3	Fencing	m	132	$55.60	$7,339.06
4.11	Station 11				$77,830.18
4.11.1	Station Platform	m²	360	$152.06	$54,742.64
4.11.2	Canopy	pc	4	$3,937.12	$15,748.49
4.11.3	Fencing	m	132	$55.60	$7,339.06
4.12	Station 12				$77,830.18
4.12.1	Station Platform	m²	360	$152.06	$54,742.64
4.12.2	Canopy	pc	4	$3,937.12	$15,748.49
4.12.3	Fencing	m	132	$55.60	$7,339.06
4.13	Station 13				$77,830.18
4.13.1	Station Platform	m²	360	$152.06	$54,742.64
4.13.2	Canopy	pc	4	$3,937.12	$15,748.49
4.13.3	Fencing	m	132	$55.60	$7,339.06
4.14	Station 14				$77,830.18
4.14.1	Station Platform	m²	360	$152.06	$54,742.64
4.14.2	Canopy	pc	4	$3,937.12	$15,748.49
4.14.3	Fencing	m	132	$55.60	$7,339.06
4.15	Station 15				$77,830.18
4.15.1	Station Platform	m²	360	$152.06	$54,742.64
4.15.2	Canopy	pc	4	$3,937.12	$15,748.49
4.15.3	Fencing	m	132	$55.60	$7,339.06
4.16	Station 16				$77,830.18
4.16.1	Station Platform	m²	360	$152.06	$54,742.64
4.16.2	Canopy	pc	4	$3,937.12	$15,748.49
4.16.3	Fencing	m	132	$55.60	$7,339.06
4.17	Station 17				$77,830.18
4.17.1	Station Platform	m²	360	$152.06	$54,742.64
4.17.2	Canopy	pc	4	$3,937.12	$15,748.49
4.17.3	Fencing	m	132	$55.60	$7,339.06
4.18	Station 18				$77,830.18
4.18.1	Station Platform	m²	360	$152.06	$54,742.64

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4.18.2	Canopy	pc	4	$3,937.12	$15,748.49
4.18.3	Fencing	m	132	$55.60	$7,339.06
4.19	Station 19				$77,830.18
4.19.1	Station Platform	m²	360	$152.06	$54,742.64
4.19.2	Canopy	pc	4	$3,937.12	$15,748.49
4.19.3	Fencing	m	132	$55.60	$7,339.06
4.2	Station 20				$148,696.38
4.20.1	Station Platform	m²	360	$152.06	$54,742.64
4.20.2	Canopy	pc	2	$43,306.34	$86,616.67
4.20.3	Fencing	m	132	$55.60	$7,339.06
4.21	Station 21				$148,698.38
4.21.1	Station Platform	m²	360	$152.06	$54,742.64
4.21.2	Canopy	pc	2	$43,306.34	$86,616.67
4.21.3	Fencing	m	132	$55.60	$7,339.06
4.22	Station 22				$148,696.38
4.22.1	Station Platform	m²	360	$152.06	$54,742.64
4.22.2	Canopy	pc	2	$43,306.34	$86,616.67
4.22.3	Fencing	m	132	$55.60	$7,339.06
4.23	Station 23				$148,696.38
4.23.1	Station Platform	m²	360	$152.06	$54,742.64
4.23.2	Canopy	pc	2	$43,306.34	$86,616.67
4.23.3	Fencing	m	132	$55.60	$7,339.06
Subtotal					$2,144,435.01
4.24	Depot				$19,678,062.4
4.24.1	Garage Sandwich Building h=10m, 60x60	m²	3,600	$937.13	$3,373,672.69
4.24.2	Maintenance Center Sandwich Building h=10m, 90.1x96.1	m²	8,659	$573.40	$4,964,809.09
4.24.3	Office Building h=3.3m, 90.1x14, 3-story	m²	3,784	$1,137.04	$4,302,777.45
4.24.4	OCC Reinforced Concrete Building 23.3x15, 5-story	m²	1,748	$1,137.04	$1,988,973.09
4.24.5	Spare Parts Warehouse Sandwich Building, 2-story, 17.6x25	m²	997	$749.71	$747,308.97
4.24.6	Substation Building Reinforced Concrete 15.6x9.4	m²	147	$847.53	$124,946.99
4.24.7	Waste Area (Brick Building) 15x20	m²	300	$1,137.04	$341,111.26
4.24.8	Guard Building 6.1x6.4	m²	37	$1,137.03	$42,309.02
4.24.9	External Electrical 10/0.4 Substation	pc	1	$190,306.86	$190,306.88
4.24.10	External Electrical 10kV Cable Line	m	2,600	$51.06	$132,747.91
4.24.11	External Communication FO-48	m	1,000	$15.15	$15,154.46
4.24.12	External Heating Supply Φ200, Φ125	m	1,700	$1,332.49	$2,265,228.26
4.24.13	Heat and Water Transfer Station	pc	1	$336,383.69	$336,383.69
4.24.14	Clean Water Line Φ100 mm	m	1,700	$106.34	$180,780.41
4.24.15	External Sewerage Φ150	m	1,500	$195.06	$292,588.23
4.24.16	Road	m	1,000	$316.85	$316,848.91
4.24.17	Metal Fence	m²	2,800	$17.19	$48,120.37

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Total	$21,820,497.5

Table 105. Rolling Stock and Equipment

No.	Equipment name	Unit	Quantity	Unit Cost (USD)	Total Amount (USD)
5.1	Rolling Stock, Maintenance Equipment				
5.1.1	Train 3 Sections /20-25m/	set	18	3,500,000	63,000,000
Subtotal					63,000,000
	Vehicles and Equipment				
5.1.1.1	Special Purpose Vehicles /truck, electricity/	set	1	2,500,000	5,000,000
5.1.1.2	Special-purpose self-propelled shunting vehicle	set	1	2,000,000	2,000,000
5.1.1.3	4x4 Vehicles	pc	3	72,000	216,000
5.1.1.4	Snow Clearing Vehicles	pc	2	70,000	140,000
5.1.1.5	Road Maintenance Vehicle	pc	1	70,000	70,000
5.1.1.6	Crane Truck	pc	1	100,000	100,000
5.1.1.7	Service vehicle	set	1	40,000	40,000
Subtotal					5,066,000
Total					68,066,000
5.2	Maintenance Equipment				
5.2.1	Underground Wheel Lathe Machine	pc	1	2,100,000	2,100,000
5.2.2	Wheel Flaw Rock Removal Equipment	pc	1	200,000	200,000
5.2.4	Overhead Crane	pc	1	90,000	90,000
5.2.5	Underground Bogie and Trolley Lifting Mechanism	set	1	100,000	100,000
5.2.6	Bogie Turntable	set	4	67,500	180,000
5.2.7	High Pressure Washing Machine	pc	1	180,000	180,000
5.2.8	Electric Motor Workshop Equipment	pc	3	35,000	105,000
5.2.9	Forklift	pc	1	48,000	48,000
5.2.10	Automatic Rolling Stock Washing Station	pc	1	250,000	250,000
5.2.11	Portable Rolling Stock Washing Equipment	pc	2	15,000	30,000
5.2.12	Drying Room Ventilation System	pc	1	100,000	100,000
5.2.13	Mechanic's Hand Tools	set	4	45,000	180,000
5.2.14	All Types of Measuring Instruments	set	2	20,000	40,000
5.2.15	Air Hose Extension	pc	20	200	4,000
5.2.16	Electrical Power Box	pc	20	200	4,000
5.2.17	Electrical Power Box	pc	10	800	8,000
5.2.18	Lifting Slings Set	set	1	40,000	40,000
5.2.19	Crack Detection Equipment	pc	4	60,000	240,000
5.2.20	Semi-automatic Welding Machine 220V	pc	2	8,000	16,000
5.2.21	Electric Arc Welder 380V	pc	1	7,000	7,000
5.2.22	Plasma Cutter 380V	pc	1	8,000	8,000
5.2.23	Generator Welding Machine 220V	pc	1	8,000	8,000
5.2.24	Welding Machine 220V	pc	2	6,000	12,000
5.2.25	Welding Machine 220V	pc	1	6,000	6,000
5.2.26	Spot Welder 220V	pc	1	7,000	7,000
5.2.27	Portable Welding Fume Extractor	pc	2	9,000	18,000
5.2.28	Air Compressor	pc	1	30,000	30,000
5.2.29	Air Tank	pc	1	11,000	11,000

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S 2.30	Air Dryer	pc	1	30,000	30,000
S 2.31	Self-propelled Depot Stacker	pc	1	350,000	350,000
S 2.32	Repair Work Table	pc	4	1,500	6,000
S 2.33	Repair Work Table	pc	10	1,700	17,000
S 2.34	Spare Parts Shelves	pc	20	2,200	44,000
S 2.35	Mechanic's Work Cabinets	pc	10	2,200	22,000
S 2.36	Wheeled Tool Box	pc	4	2,000	8,000
S 2.37	Electrical Supply Tools and Equipment	set	1	500,000	500,000
S 2.38	Track Maintenance Tools and Equipment	set	1	500,000	500,000
Subtotal					5,500,000
Total (USD)					71,975,000

Note: Spare parts should include high-wear reserve parts and non-reducible stock. When selecting a model, its spare parts should be well-stocked as there is a risk they won't be manufactured again after 10-15 years. Equipment costs may vary depending on the traction unit selection.

Table 106. Relocation and Infrastructure Transfer Costs

No.	Equipment Name	Unit	Quantity	Unit Cost (USD)	Total Amount (USD)
1	Engineering Preparation Measures	m	5,887	20,071.61	5,789,399
2	Heating Supply	m	576	6,638.87	1,914,875
3	Water Supply	m	1,183	5,745.83	1,657,234
4	Sewerage	m	1,420	5,738.31	1,655,123
5	Information Communication	m	3,950	2,241.21	646,441
6	Electrical Supply	m	23,825	16,889.00	4,816,856
TOTAL				57,135	16,479,918

Table 107. Land Acquisition Costs

No.	Equipment Name	Unit	Quantity	Target Price (MNT)	Total Price (USD)
1	Land Acquisition	m²	28,532	11,500	3,316,969

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Tramway investment cost schedule

To initiate the project operations, preparation work is planned to begin from 2025, the project construction phase from 2026, project testing and adjustment phase in 2027, with regular operations stabilizing from 2028.

Table 108 TRAMWAY INVESTMENT COST SCHEDULE

No.	Description	Relocation Transfer	Package 1	Package 2	Package 3	Package 4	Package 5	Client Supervision 2%	Project Management 5%	Detailed working design – 3%	Contingenc
			Track Construction Work	Signaling Communication Work	Energy Work	Station, Depot Buildings	Rolling Stock, Repair Equipment				
1	2025 Preparation Work	19,796,605	20,486,633	2,824,640	11,496,473	6,546,149	29,430,000	1,620,422	6,006,569	7,508,211	13,503,516
2	2026 Project Phase		46,095,049	5,649,280	17,244,710	6,728,199	36,787,500	1,890,492	7,007,664	-	
3	2027 Project Completion Phase /Testing Adjustment/		35,861,704	5,649,280	9,580,394	6,546,149	7,357,500	1,890,492	7,007,664	-	
4	2028 Stabilization		-	-	-	-	-	-	-		
Total		19,796,605	102,433,439	14,123,200	38,321,578	21,820,497	73,575,000	5,401,405	20,021,897	7,508,211	13,503,516
Total amount (excluding VAT)			344,546,381								
Total amount (including VAT)			348,155,896								

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10.3. PROJECT REVENUE CALCULATION

Revenue projections were calculated with passenger numbers and ticket price of 1500 MNT, which equals 0.43 USD at the exchange rate of 3467 MNT as of March 6, 2025. The tram project revenue calculation considered passenger flows, ticket prices, and additional revenue opportunities as follows.

Table 109. Income Projection

No.	Type	Income Projection			
		2020	2030	2035	2040
1	Number of Passengers	51,120	66,464	83,080	99,695.70
2	Ticket Price, USD	0.43	0.37	0.36	0.36
3	Daily Income, USD	22,120	24,922	29,954	35,845
4	Annual Ticket Income, USD	8,073,691	9,096,358	10,933,123	13,199,747
5	Annual Advertising Income, USD	484,569	484,569	484,569	484,569
6	Smart Card Sales	62,302	62,302	62,302	62,302
7	Parking, Public Rental Service	1,298	1,298	1,298	1,298
	Other Annual Income	548,168	548,168	548,168	548,168
	TOTAL ANNUAL INCOME	8,621,859	9,644,526	11,464,291	13,867,914

Table 110. Number of Passengers

Year	2025	2028		2040		2050	
Indicator	Without Project	Without Project	Buyant-Ukhaa – Sukhbaatar Square	Without Project	Buyant-Ukhaa – Sukhbaatar Square	Without Project	Buyant-Ukhaa – Sukhbaatar Square
	-		LRT - 2	-	LRT - 2	-	LRT - 2
Number of daily passengers traveling from Buyant Ukhaa Sports Complex to Sukhbaatar Square route, and passengers shifting to LRT after implementation.	588491.6	683070		1065034.7		1237735.7	
LRT trips - Daily		-	121554	-	188444	-	228695
LRT trips – Peak hour	4392	-	6989	-	10836	-	13161
Average length of a full public transport line cycle	29.232	29.232	29.007	27.670	29.007	29.232	29.007
Total length of public transport lines	2858.128	2858.128	2619.882	2858.128	2619.882	2858.128	2619.882
Average km of public transport passengers	5.872	6.050	6.117	6.043	6.144	6.126	6.081

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Average time of public transport passengers	39м 15s	40м 27s	39м 47s	40м 41s	39м 33s	40м 52s	40м 22s
Average on-route travel time for public transport passengers			22м 12s		22м 17s		22м 42s

Table 111. Revenue Projection

№	Type	2028 revenue projection/USD/	2030	2050
1	Number of passengers	121,554	188,444	228,895
2	Ticket price, USD	0.43	0.48	0.78
3	Daily revenue, USD	52,590	91,314	177,465
4	Annual ticket revenue, USD	19,195,620	33,329,702	64,774,670
5	Annual advertising revenue, USD	484,569	513,642.92	544,461.49
6	Smart card sales	62,302	66,039.80	70,002.19
7	Parking facilities, public rental services	1,298	1,375.69	1,458.38
Other annual revenue		548,168	581,059	615,922
TOTAL ANNUAL REVENUE		19,743,689	19,743,689	33,910,780

Table 112. For the operations start year 2028

№	Indicator	2028 Plan (MNT)	2028 Plan (USD)
1	TOTAL REVENUE	68,451,379	19,744
2	Ticket revenue	66,550,670	19,196
3	Advertising revenue	1,680,000	485
4	Other revenue	220,500	64

Staffing Structure, Organization, and Salary Calculation

The Project Management Consultant (PMC) proposes organizing the Operations and Maintenance Entity (OME) according to the organizational chart below. This organizational structure can be modified and updated in consultation with the Project Implementation Unit (PIU).

Figure 1. Organizational Structure Chart

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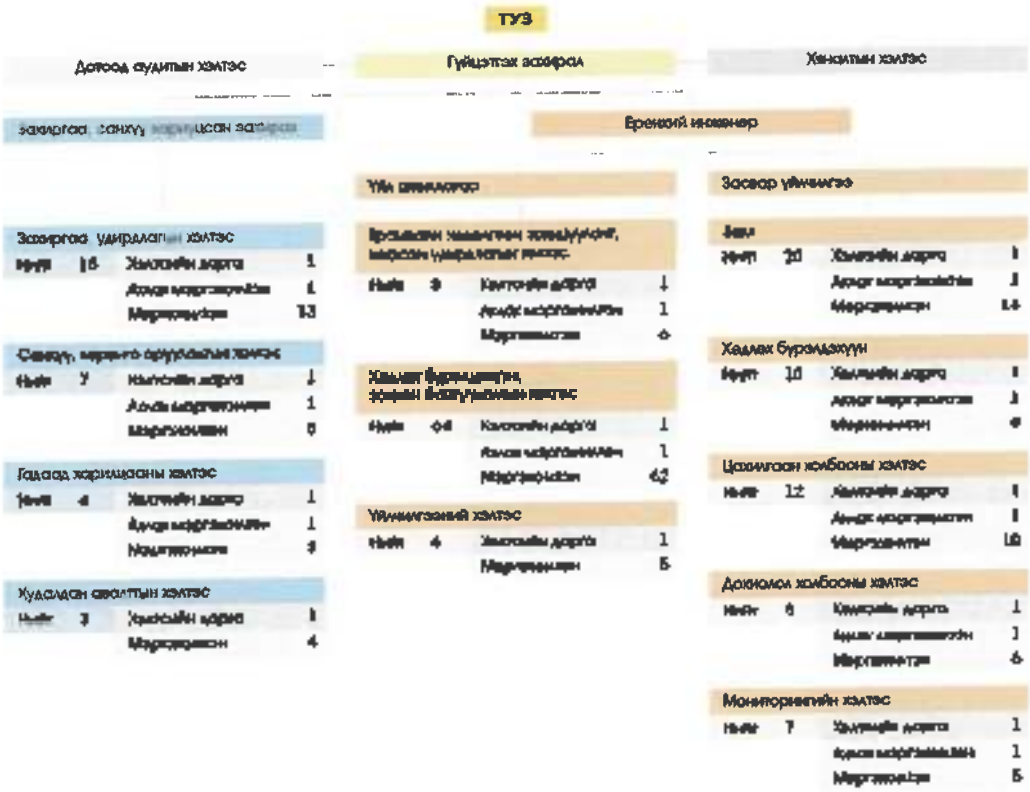

Future calculations follow this structure.

Detailed Calculation of One Year's Operational Expenditure:

The operational budget for the project, starting in 2028, is calculated at 24,48 billion MNT or 7,36 million USD annually.

Table 113. Summary of Operating Costs (thousands MNT)

No.	Item	2028 Plan (thousands MNT)	2028 Plan (USD)	Q1	Q2	Q3	Q4
1	Salaries, wages, allowances, bonuses, social insurance costs	10,234,188	2,952	2,529,297	2,492,297	2,537,297	2,676,297
2	Employer social insurance contributions	1,036,388	299	259,097	259,097	259,097	259,097
3	Facility operational costs	1,304,640	376	520,560	287,280	54,000	442,800
4	Supply and material costs	4,446,881	1,283	1,154,927	876,442	1,224,352	1,091,162
5	Business trip expenses	183,240	53	47,680	52,760	31,760	51,040
6	Third-party services and general work service fees	709,563	205	271,563	157,800	127,800	152,800

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7	Operation and service costs	7,339,586	2,117	1,834,896	1,834,896	1,834,896	1,834,896
8	Other contingency costs	261,822	76	70,209	61,972	62,265	67,377
TOTAL		24,488,519	7,368	6,669,207	6,122,544	6,151,467	6,574,499

The project operating costs were planned using the economic classification of expenditures according to Annex to Order No. 190 of October 29, 2021, of the Minister of Finance of Mongolia.

Depreciation costs are calculated using the straight-line method and are not directly reflected in operating costs but rather in financial statements and profit calculations.

Table 114. Depreciation Cost Calculation

Asset Type	Investment (USD)	Service Life	Annual Depreciation	Annual Depreciation (thousands MNT)
Superstructure and substructure	64,072,344	30	2,135,745	7,404,627.2
Signaling and communications	14,123,200	10	1,412,320	4,896,513.4
Power systems	38,321,579	15	2,554,772	8,857,384.0
Buildings and structures	21,820,497	25	872,820	3,026,066.8
Rolling stock	50,400,000	20	2,520,000	8,736,840.0
Equipment	5,066,000	8	633,250	2,195,477.8
TOTAL	193,803,619	-	10,128,907	35,116,919.0

This classification records recurring current expenses required annually to ensure the normal operation of the organization and implementation of policies and measures in the respective reporting year.

Table 115. Detailed Operating Cost Breakdown (thousands MNT)

No.	Item	Economic Code	2028 (thousands MNT)	2028 (USD)	Percentage %
1	Salaries, wages, allowances, bonuses, social insurance costs	2101	10,234,188	2,953	42%
1.1	Basic salary	210101	5,713,000	1,649	23%
1.2	Academic degree and professional allowances	210102	285,900	82	1%
1.3	Bonuses	210102	1,143,600	330	5%
1.4	Years of service allowance	210102	285,900	82	1%
1.5	Other employer-provided benefits	213102	517,000	149	2%
1.6	Transportation and meal allowances	210103	1,247,400	360	5%
2	Employer social insurance contributions	2102	1,036,388	299	4%
3	Facility operational costs	2103	1,304,640	376	5%
3.1	Electricity and lighting	210301	180,000	52	1%
3.2	Heating	210302	1,088,640	314	4%
3.3	Water and wastewater	210303	36,000	10	0%
4	Supply and material costs	210402	4,446,881	1,283	18%
4.1	Office supplies	210401	45,000	13	0%
4.2	Postal and communication, printing costs	210402	141,765	41	1%
4.3	Occupational safety and health costs	210403	574,960	166	2%
4.4	Administrative costs	210404	137,887	40	1%
4.5	Fuel costs	210402	216,379	62	1%
4.6	Vehicle and tramway maintenance costs	210402	803,430	232	3%
4.7	Vehicle and tramway spare parts costs	210402	1,872,000	540	8%
4.8	Training and information promotion costs	210402	655,480	189	2%
5	Business trip expenses	210703	183,240	53	1%

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5.1	Domestic business trips	210702	20,400	6	0%
5.2	International business trips	210701	120,640	35	0%
5.3	Guest and delegate reception costs	210604	40,000	12	0%
5.4	Gift and souvenir costs	2109	2,000	1	0%
6	Third-party services and general work service fees	210601	709,963	205	3%
6.1	Third-party work and service fees	210601	145,000	42	1%
6.2	Fees, taxes, and insurance costs	210601	564,963	163	2%
7	Operation and service costs	210604	7,339,545	2,117	30%
7.1	Track maintenance costs	210601	619,567	179	3%
7.2	Traction power costs	210602	5,417,280	1,563	22%
7.3	Depot electricity costs	210602	1,302,739	376	5%
8	Other contingency costs		261,822	76	1%
TOTAL		-	24,480,319	7,380	100%

Tramway Staffing Structure and Salary Calculations

The Project Management Consultant (PMC) recommends organizing the Operations, Maintenance, and Engineering (OME) organization structure according to the organizational chart below. This organizational chart can be modified and updated based on consultation with the Project Implementation Unit (PIU).

The total workforce required for tramway operations (number of staff) directly depends on factors such as:

- Tramway line length (km)
- Service level (daily schedule, passenger flow)
- Service frequency (headway)
- Number of rolling stock units
- Technical level of automation and system solutions

According to international standards, 7-12 workers per kilometer are typically calculated.

For our project, the lower limit is calculated as 105 and the upper limit as 180 workers. Within the project framework, depending on service level and automation, we planned for the upper limit with a total of 135 workers.

Table 116. Staffing Structure

Department	Staff Count
Management	4
Internal audit, Track supervision	12
Administration, Finance	14
Operations (tramway drivers, operators, controllers)	44+6+6
Technical, Maintenance	30
Safety, Service	19
TOTAL	135

Table 117. *Tramway Organizational Structure Salary Calculation*

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No.	Position Title	Staff Count	Basic Salary (per unit)	Basic Salary (total)	Monthly Salary
1	Transport management, coordination	4	5,000	20,000	2,500
2	Tramway driver	44	3,800	167,200	25,916
3	Track supervision staff	8	3,500	28,000	4,340
4	Technical maintenance staff	30	3,500	105,000	16,275
5	Electrical signalling engineer	10	3,500	35,000	5,425
6	Ticket sales, control	6	3,300	19,800	3,069
7	Finance, management	14	3,500	49,000	7,595
8	Safety, security	10	3,000	30,000	4,650
9	Cleaning service staff	9	2,500	22,500	3,488
Total		160	135	31,600	476,500

The average salary level for all employees is based on Mongolia's public organization salary standards, public transport bus employee salary standards, and social insurance contribution rates.

When calculating percentage by position, professionals account for 82%.

Table 118. Percentage by Position

Position Category	Staff Count	Percentage %	Division	Personnel	Percentage (%)
Management	4	3%	Management	4	3%
Track supervision	8	6%	Monitoring	8	6%
Audit	4	3%	Audit	4	3%
Administration, Finance	14	10%	Administration & Finance	14	10%
Operations/Maintenance	105	78%	Operation & Maintenance	105	78%
TOTAL	135	100%	TOTAL	135	100%

Other employer-provided benefits and bonuses: Social protection costs provided according to laws, regulations, and other government decisions. Also included are pension, benefits, concessions, compensation, support, and assistance services from the Social Welfare Fund, as well as one-time benefits and support provided through employers according to the Civil Service Law and other relevant legal acts with related compensation, general guarantees, and additional guarantees for civil servants. All 135 project staff are calculated as civil servants.

Table 119. Salary and Bonus Allowances (thousands MNT)

No.	Item	Code	2026 Plan (thousands MNT)	2026 Plan (USD)	Q1	Q2	Q3	Q4
1	Salaries, wages, allowances, bonuses, social insurance costs	2101	10,234,189	2,962	2,529,297	2,492,297	2,537,297	2,675,297
1.1	Basic salary	210101	5,718,000	1,648	1,429,500	1,429,500	1,429,500	1,429,500
1.2	Academic degree, professional allowance	210102	285,900	82	71,475	71,475	71,475	71,475
1.3	Bonuses	210102	1,143,600	330	285,900	285,900	285,900	285,900
1.4	Years of service allowance	210102	285,900	82	71,475	71,475	71,475	71,475
1.5	Other employer-provided benefits	213102	517,000	149	100,000	63,000	108,000	246,000

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1.6	Transportation and meal allowances	210103	1,247,400	300	311,850	311,850	311,850	311,850
2	Employer social insurance contributions	2102	1,036,386	299	259,097	259,097	259,097	259,097

4.2.2 Facility Operational Costs

Regular current costs for buildings and facilities required for the organization's basic operations, calculated under economic expenditure classification code 2103.

Table 120. Facility Operational Costs - 942.2 million MNT

No.	Operational Cost	Quarterly				Total
		1	2	3	4	
1	Electricity costs	45,000	45,000	45,000	45,000	180,000
2	Heating costs	466,560	233,280	-	388,800	1,088,640
3	Water and wastewater costs	9,000	9,000	9,000	9,000	36,000
Total		520,560	287,280	54,000	442,800	1,304,640

Note: Total building volume 111,937.41 m². Heating tariff 16,672 MNT per Resolution No. 639 of 2024. Electricity calculated per Energy Regulatory Committee Resolution No. 632 of 2024.

Supply and Material Costs

Materials and supplies required for normal daily operations under economic classification code 2104. This includes office supplies, fuel and lubricants, postal communications, publications, waste disposal, low-value quickly depreciated household items, etc. Total cost: 3,825 million MNT.

Table 121. Goods, Services Supply, and Current Costs

№	Cost Category		Budget	2028			
				Q1	Q2	Q3	Q4
1	Office supplies		45,000	15,000	7,500	15,000	7,500
2	Postal communications, printing costs		141,765	39,435	34,110	34,110	34,110
3	Occupational safety and health costs		574,960	143,740	143,740	143,740	143,740
4	General expenses	Waste disposal costs	24,000	6,000	6,000	6,000	6,000
5		Goods and materials	30,000	10,000	5,000	5,000	10,000
6		Cleaning service materials	83,967	20,967	20,967	20,967	20,967
	Subtotal		137,967	36,967	31,967	31,967	36,967
TOTAL			899,692	235,142	217,317	224,817	222,317

Table 122. Office Supplies Cost Breakdown

№	Item	Monthly	Quarterly				Total
			1	2	3	4	
1	Office supplies	5,000	15,000	7,500	15,000	7,500	45,000
Total		5,000	15,000	7,500	15,000	7,500	45,000

Table 123. Postal Communications and Printing Costs

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№	Item	Monthly	Quarterly				Total
			1	2	3	4	
1	Publishing orders, books, magazines purchase	1,800	5,400	5,400	5,400	5,400	21,600
2	Printing material costs	936	3,510	3,510	3,510	3,510	14,040
3	Postal communication costs	8,844	30,525	25,200	25,200	25,200	106,125
Total		11,580	39,435	34,110	34,110	34,110	141,765

Table 124. Occupational Safety and Health Costs

№	Goods and Materials	Unit	Quantity	Unit Price	Total
1. Clothing and Protective Equipment					
1.1	Summer work clothes (5 sets)	pcs	135	400.0	54,000.0
1.2	Summer work boots	pcs	135	250.0	33,750.0
1.3	Winter work clothes (4 sets)	pcs	135	450.0	60,750.0
1.4	Winter work boots	pcs	135	300.0	40,500.0
1.5	Red safety helmets for engineers	pcs	135	75.0	10,125.0
1.6	Thin visitor vests	pcs	50	65.0	3,250.0
1.7	Thick vests for engineers	pcs	135	105.0	14,175.0
1.8	Water boots	pcs	135	50.0	6,750.0
1.9	Safety glasses (5 types)	pcs	300	45.0	13,500.0
1.10	Rain coats	pcs	135	60.0	8,100.0
1.11	Laser meters	pcs	30	80.0	2,400.0
1.12	Flashlights	pcs	60	30.0	1,800.0
1.13	Safety harnesses	pcs	50	50.0	2,500.0
1.14	Masks	pcs	135	5.0	675.0
1.15	White gloves	pcs	5000	0.5	2,500.0
1.16	Electrical gloves	pcs	40	50.0	2,000.0
1.17	Cleaning gloves	pcs	100	2.8	280.0
1.18	Canvas gloves	pcs	200	25.0	5,000.0
1.19	Sensitive voltmeter sets	pcs	10	88.0	880.0
1.20	Ear plugs	pcs	500	2.0	1,000.0
1.21	Ear muffs	pcs	30	20.0	600.0
1.22	Headlamps	pcs	50	30.0	1,500.0
1.23	Face shields	pcs	20	65.0	1,300.0
Subtotal					267,335.0
2. Occupational Safety Equipment and Tools					
2.1	Warning tape (black-yellow, red-white)	pcs	46	200.0	9,200.0
2.2	Safety tape with reflectors (black-yellow, red-white)	pcs	46	400.0	18,400.0
2.3	Reflective sheets	pcs	48	400.0	19,200.0
2.4	Traffic cones	pcs	20	70.0	1,400.0
2.5	Safety signs and labels	pcs	300	10.0	3,000.0

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2.6	Emergency equipment boxes	pcs	50	800.0	40,000.0
2.7	Fire extinguisher 80kg (wheeled dry powder)	pcs	24	1,500.0	36,000.0
2.8	Fire extinguisher 5kg	pcs	96	60.0	5,760.0
2.9	Fire extinguisher 2kg	pcs	24	30.0	720.0
2.10	Road signs	pcs	100	160.0	16,000.0
2.11	Professional books, standards, manuals, display boards, reminder posters	pcs	1	30,000.0	30,000.0
2.12	Signal flags (with lights)	pcs	46	20.0	920.0
2.13	Sound and light signals (beacon for cabin installation, yellow light)	pcs	20	200.0	4,000.0
2.14	Work stop and prohibition signs	pcs	100	4.0	400.0
2.15	Sign locking chains and keys	pcs	200	18.0	3,600.0
2.16	Wheel chocks	pcs	16	300.0	4,800.0
2.17	Archive equipment, clothing and tools	pcs	5	1,500.0	7,500.0
Subtotal					208,900.0
3. Occupational Health					
3.1	Medical equipment, medicines and preparations	pcs	12	8,000.0	96,000.0
3.2	Eye wash solution 500ml	pcs	25	125.0	3,125.0
3.3	First aid kit for vehicles	pcs	40	30.0	1,200.0
3.4	First aid kit for units and departments	pcs	40	160.0	6,400.0
Subtotal					106,725.0
TOTAL					574,969.0
Quarterly					143,740.00

Fuel costs are calculated for daily service operations, field work, and official business trips. Vehicle maintenance includes diagnostics, maintenance, oil and lubricants for vehicles and tramways, spare parts costs, etc.

Table 125. Fuel Costs

No.	Vehicle Type	2028	Q1	Q2	Q3	Q4
1	Fuel	216,379	54,094.70	54,094.70	54,094.70	54,094.70
2	Vehicle and tramway maintenance costs	803,430	201,450.00	201,030.00	200,200.00	200,750.00
3	Vehicle and tramway spare parts costs	1,872,000	398,000.00	418,000.00	528,000.00	528,000.00
Total		2,891,809	653,545	673,125	782,296	782,845

Business Trip Expenses

Transportation, accommodation, and meal costs for official business trips domestically and internationally as per authorized decisions and special guidelines, gift preparation, and costs for

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receiving and accommodating foreign guests and delegates. Domestic business trip costs calculated according to Minister of Finance Order No. A/52 of 2024, and international business trip costs according to Minister of Finance Order No. A/188 of 2011.

Table 126. Business Trip and Guest Expenses

№	Official Business Trips	Economic Code	Quarterly				Total
			1	2	3	4	
1	Domestic business trips	210701	1,700	6,800	6,800	5,100	20,400
2	International business trips	210702	36,460	36,460	14,460	36,460	120,840
3	Guest and delegate reception costs	210703	10,000	10,000	10,000	10,000	40,000
4	Gift and souvenir costs	210703	500	500	500	500	2,000
TOTAL		2107	47,660	53,760	31,760	51,060	183,240

Third-Party Services and General Work Service Fees

Costs for purchasing third-party service packages under economic classification code 2108. Total cost calculated at 709.9 million MNT.

Table 127. Third-Party Work and Service Costs

№	Service Fee Work and Service Costs	2026	Quarterly			
			1	2	3	4
1	Third-party work and service fees	145,000	45,000	40,000	20,000	40,000
1.1	Third-party work services, translation	30,000	5,000	10,000	5,000	10,000
1.2	Policy documents	15,000	5,000	5,000		5,000
1.3	Legal consulting	20,000	20,000		-	-
1.4	Financial consulting services	50,000		25,000		25,000
1.5	Asset valuation consulting services	30,000	15,000		15,000	
2	Fees, insurance, tax costs. Other fee costs	564,963	226,563	117,800	107,500	112,500
2.1	Motor vehicle technical inspection tax	15,000	10,000			5,000
2.2	Road tolls	1,200	300	300	300	300
2.3	Insurance (vehicles)	64,763	64,763			
2.4	Insurance (official duty)	8,000	5,500	1,500	1,000	
2.5	Other insurance	60,000	15,000	15,000	15,000	15,000
2.6	Stock exchange fees	5,000		5,000		
2.7	Notary	-				
2.8	International tramway association membership	35,000	35,000			
2.9	Legal entity address change state stamp fees	2,000			500	1,500
2.10	Land fees	280,000	70,000	70,000	70,000	70,000
2.11	Bank fees and other charges	4,000	1,000	1,000	1,000	1,000
2.12	Social responsibility costs	50,000	20,000	20,000	5,000	5,000
2.13	Contingency fee costs	40,000	5,000	5,000	15,000	15,000
Total		709,963	271,563	157,800	127,800	152,800

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Operation and Service Costs

Costs for other goods and services related to the organization's main and non-main activities. This includes power costs for rolling stock electrical consumption, depot electrical consumption, signaling and communication consumption, and current maintenance costs. This cost accounts for 26% of total costs.

Other Goods and Service Costs

№	Operational Costs	Quarterly				Total
		1	2	3	4	
1	Track maintenance costs	164,892	164,892	164,892	164,892	619,567
2	Rolling stock electrical costs	1,354,320	1,354,320	1,354,320	1,354,320	5,417,280
3	Office and depot electrical costs	325,685	325,685	325,685	325,685	1,302,739
Total		1,834,896	1,834,896	1,834,896	1,834,896	7,339,586

Tramway maintenance norms, rules, and standards are based on railway and public transport technical regulations, standards, and operational manuals of respective countries. Since tramways are not currently operated in Mongolia, specific domestic norms have not been established. Therefore, we performed maintenance frequency and calculations based on international standards for basic maintenance categories.

Table 128. International Basic Tramway Maintenance Categories

Maintenance Type	Description	Frequency (Standard)
TO (Technical Service)	Daily inspection, lubrication	Daily / 1-2 days
TR (Seasonal Service)	More detailed inspection, maintenance	1-3 months
KR (Medium Repair)	Component and subsystem replacement, repair	1.5-2 years
KR-2 (Major Repair)	Major repairs, equipment modernization	6-8 years
MR (Modernization)	Engine, system modernization	10-15 years

The maintenance service period is calculated as 4 times per year for seasonal service, medium repair every 2 years, and major repair every 7 years. Maintenance unit costs: Daily service (TO) $0.5-$1.5/km, Planned medium repair (KR) $1-$3/km, Major repair (KR-2) $3-$5/km.

Table 129. Maintenance Cost Calculation

Parameter	Unit	Quantity
Line length	km	16
Number of tramways	units	16
Operating days	days	365
Daily distance per tramway (approximately)	km	128
Annual total distance (14 tramways × 93.5 km × 365)	km/year	744,800
Unit price	USD/km	1.2
Total cost amount	MNT	3,097,833,840
Quarterly cost amount	MNT	774,458,460
Calculated amount with 20% reduction (thousands MNT)		154,891.7

Electrical Power Costs: The tramway electrical consumption calculation uses the average electricity tariff rate of 280 MNT/kWh applied in Mongolia. The tramway rolling stock has regenerative braking control systems that convert kinetic energy generated during braking into

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electrical power and return it to the supply system. This enables efficient use of energy during tramway acceleration and deceleration, reducing total electrical consumption by a certain percentage. Calculations based on 14 rolling stock units, 8 hours of acceleration and constant speed operation, 5 hours of regenerative braking operation.

Table 130. Electrical Consumption Calculation

No.	Phase	Operating Hours	Efficiency %	Capacity kW	Consumption kWday
1	Acceleration and constant speed operation	8	0	600	4,800
2	Regenerative braking operation	5	50	300	1,500

Average power consumption for tramways internationally calculated at 2.5-4.5kW/car-km.

Table 131. Electricity Payment Calculation

Estimated Electrical Consumption kWday	Rolling Stock Units	Track Electrical Consumption kW·day	1 kWh Electricity Price ₮	Daily Consumption (kW·day)	Monthly Consumption (kW·day)	Annual Consumption (kW·day)
3,300	16	52,800	286	15,048,000	451,440,000	5,417,280,000

Complete renewal of substations, supply infrastructure, and line networks planned with multiple substations to ensure reliable electrical supply.

Depot Electrical Costs: These costs are calculated based on electrical consumption for maintenance equipment and buildings/facilities. The tramway electrical consumption calculation uses the average electricity tariff rate of 280 MNT/kWh applied in Mongolia.

Table 132. Depot Electrical Cost Calculation

No.	Type	Total Capacity (kW)	Daily Consumption (kW·h)	Monthly Consumption (kW·h)	Annual Consumption (kW·h)	Annual Payment (₮)
1	Office consumption	864	9,724	291,720	3,500,640	980,179,200
2	Maintenance equipment	1,600	3,200	96,000	1,152,000	322,560,000
Total		2,464	12,924	387,720	4,652,640	1,302,739,200

Annual training costs for government organization employees to improve, specialize, retrain, and conduct practical training domestically and internationally, including training fees, transportation and meal costs, and training material preparation. Training focuses on engineer development, information security and safety, investment and economics, administration and management, occupational safety and health law, and international training based on human resource capacity.

Other Costs and Contingency Costs

A 2% contingency is calculated on facility operational costs, supply and material costs, and operation and service costs.

Table 133. Other Costs Calculation

No.	Item	2028 Plan	2028 Plan (USD)	Q1	Q2	Q3	Q4

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1.3	Facility operational costs	1,304,640	376	520,560	287,280	54,000	442,800
1.4	Supply and material costs	4,446,881	1,283	1,154,927	976,442	1,224,352	1,091,162
1.7	Operation and service costs	7,339,586	2,117	1,834,896	1,834,896	1,834,896	1,834,896
1	Total contingency costs	261,822	76	76,208	61,972	62,265	67,377

Table 134. 2029 Operating Cost Breakdown by Year

No	Item	2028 Plan (thousands MNT)	2029 Plan (USD)	Percentage %	2033	2038	2043	2048	2053	2058
1	TOTAL REVENUE	68,451,370	19,744	100%	25,738	31,661	37,584	43,507	49,430	55,353
1.1	Ticket revenue	66,550,870	19,196	97%	25,023	30,782	36,541	42,299	48,058	53,817
1.2	Advertising revenue	1,680,000	485	2%	632	777	922	1,068	1,213	1,359
1.3	Other revenue	220,500	64	0%	83	102	121	140	159	178
2	Salaries, wages, allowances, bonuses, social insurance costs	10,234,188	2,952	15%	3,848	4,734	5,619	6,505	7,390	8,276
3	Employer social insurance contributions	1,036,388	299	2%	390	479	569	658	748	869
4	Facility operational costs	1,304,640	376	2%	491	603	716	829	942	1,094
5	Supply and material costs	4,446,881	1,283	6%	1,672	2,057	2,442	2,826	3,211	3,730
6	Business trip expenses	183,240	53	0%	69	85	101	118	132	154
7	Third-party services and general work service fees	709,963	205	1%	267	328	390	451	513	596
8	Operation and service costs	7,339,586	2,117	30.0%	2,760	3,395	4,030	4,665	5,300	6,157
9	Other contingency costs	261,822	76	1.1%	98	121	144	166	189	220
	TOTAL EXPENSES	24,480,319	7,360	100.0%	9,594	11,802	14,010	16,218	18,426	21,095
10	Depreciation costs	35,116,919	10,129	58.9%	13,204	16,243	19,281	22,320	25,359	29,457

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10.4. ECONOMIC BENEFIT CALCULATION

Economic Revenue

The Economic Internal Rate of Return (EIRR) considers not only financial benefits but also calculates the project's productivity, social benefits, and environmental impacts. The economic rate of return is a broader concept than budgetary profitability.

$$EIRR = \frac{\text{Эдийн засгийн орлого} - \text{Эдийн засгийн зардал}}{\text{Эдийн засгийн хөрөнгө оруулалт}}$$

Economic Revenue and Cost Calculation
Conclusion:

This project not only creates additional opportunities for urban transport but can also bring broad economic benefits. According to the expected NPV (Net Present Value) and EIRR indicators, implementing the project proves to be economically beneficial.

To improve the project's financial and economic benefits, we need to implement specific changes, increase revenue sources, and organize cost reduction measures more precisely.

10.5. ECONOMIC AND FINANCIAL ANALYSIS

Economic Analysis

Purpose and Methodology of Economic Analysis
The main purpose of economic analysis is to determine the feasibility of implementing social infrastructure projects and programs by measuring their benefits, costs, and impacts on society and the economy. This creates conditions for the government to make optimal tax and budget policy decisions by implementing cost-effective investments.

Since the implementation of the Light Rail Transit (LRT) project will improve traffic conditions, the economic benefits were calculated based on the value of travel time cost (VOT), vehicle operating cost (VOC), Value of Injury Cost savings (VICS), and Value of Pollution Cost savings (VOPCS). The cost savings were calculated by comparing the number and speed of vehicles traveling on the road without the project versus the number and speed of vehicles with the project implemented.

- Benefits for Light Rail Transit (LRT) users: Using LRT will reduce vehicle operating costs (VOC) and save travel time costs (TTC) (shifting from road/public transport to tram).

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- Benefits for road users along the LRT corridor: The current traffic volume along the Light Rail Transit (LRT) corridor will decrease and travel speed will increase, resulting in reduced vehicle operating costs (VOC).
- Benefits from reduced traffic accidents: These were calculated by comparing the "without project" and "with project" scenarios, and determining the difference in accident costs across all road segments between these two scenarios. This was calculated by computing the road traffic accident cost (the product of road accident rate per kilometer, number of vehicles, traffic volume, travel distance, and accident cost) for each scenario and comparing the results.
- Benefits from reduced environmental costs: These were calculated as the difference in environmental costs across all road segments within the "without project" and "with project" scenarios.

Conditions for Economic Analysis

The economic analysis was performed by comparing scenarios with and without the project implemented, based on the current traffic flow information along the Light Rail Transit (LRT) corridor.

The conditions used in the calculations were defined as follows:

- Project timeline: Starting in 2025, operational by 2028
- Operation and maintenance cost calculations were performed by the research team
- Social discount ratio: 12% per annum for the opportunity cost of capital (based on ADB information)
- Project operational period: Until 2057, 30 years after opening
- Tariff system: 1500 MNT + (km-5) × 50 MNT (1500₮ for 5km distance, 50₮/km for distances over 5km)

Methodology for Calculating Economic Benefit Risk Distribution

In this study, financing interest costs and tax expenses were not considered when calculating economic costs.

Total costs were categorized as initial investment and operational costs, calculating the total costs over 30 years from the Light Rail Transit (LRT) commissioning, and the economic benefit analysis was completed.

The following costs were included in the economic costs:

- Track infrastructure construction costs

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- Signaling and communications costs
- Power supply costs
- Station and depot building facilities costs
- Rolling stock and maintenance equipment costs
- Relocation costs
- Other costs

These costs are allocated according to predetermined rates during 2025-2027.

The tramway line will become operational, and from 2028 onwards, O&M costs (operation and maintenance costs) and asset renewal costs are calculated at predetermined rates until 2057.

The table below shows economic costs classified as project costs, operational costs, and residual value:

- **Total capital investment cost** (distributed over 3 years): Option 1: USD 441.49 million, Option 2: USD 348.16 million, Option 3: USD 348.16 million.
- **Total cost** (over 30 years): Option 1: USD 696.83 million, Option 2: USD 569.67 million, Option 3: USD 413.37 million.
- **2057 residual value:** Asset replacement cost USD 1.00 million
- **Total economic cost without discount:** Option 1: (USD 268.03) million, Option 2: (USD 53.67) million, Option 3: USD 91.89 million.
- **Total economic cost at present net value (after discount):** Option 1: (USD 412.28) million, Option 2: (USD 282.76) million, Option 3: (USD 209.36) million.

Table 135. Ulaanbaatar Light Rail Transit (LRT) Cost

(unit: million USD)

Category	Period	Option 1	Option 2	Option 3
Total project cost	3 years	441.49	348.16	
Total cost (30 years)	30 years	696.83	569.67	413.37
Residual value (2057)	1 year	(1.00)		
Before discount		(268.03)	(53.67)	91.89
After discount		(412.28)	(282.76)	(209.36)

Source: Research team

Methodology for Calculating Economic Benefit Risk Distribution

The base year for economic analysis was set as the end of 2024.

VOT: Value of Travel Time savings

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The economic benefits from reduced average travel time after the Light Rail Transit (LRT) becomes operational were calculated using the average wage information of the Mongolian population from the National Statistics Office website, as well as information on the average number of passengers per vehicle and the proportion of each travel purpose, received from the Urban Planning and Research Institute.

As of the end of 2024, the national median monthly salary for business entities and organizations is 2,229 thousand MNT or 643.03 USD, with a daily wage of 3.65 USD. The value of working hours for private car passengers was taken as $3.65/hour, while the value of time for public transport passengers was calculated using the ADB methodology at 60% of private car passengers, or $2.19/hour. For passengers traveling for non-work purposes, the value was calculated at one-third of the working hour valuation, as per the ADB, with private vehicle passengers at $1.22/hour and public transport passengers at $0.73/hour. The Value of Travel Time savings (VOT) are shown in the table below.

Table 135. One Hour Valuation (2024)

	Car		Bus	
Travel purpose	Work	Non-work	Work	Non-work
Vehicle VOT ($/hr)	3.65	1.22	2.19	0.73
Individuals (people/vehicle)	0.46	1.74	6.3	23.7
Used VOT($/hr/person)	1.73		1.04	
Used VOT($/vehicle/person)	3.8		31.1	

Source: 1212.mn, Asian Development Bank, Research team

Travel time costs were calculated for each planned tram stop in both "without project" and "with project" scenarios, and the time savings benefit from the project was calculated as the difference between the cost incurred without the project and the cost with the project. The benefit of Value of Travel Time savings (VOT) is expressed by the following formula:

$$VOT = TCC_{no\ project} - TCC_{with\ project}$$

Where:

$$TCC = \sum_{t} \sum_{k=1}^{6} (T_{kt} \times P_k \times Q_{kt}) \times 365$$

T_{kt} - Travel time for a specific road segment

P_k - Time valuation depending on whether it's a car or bus

Q_{kt} - Number of vehicles participating in traffic on a specific road segment (by type)

k - vehicle type (1: private car, 2: mini-bus, 3: bus, 4~6: truck)

VOC: Vehicle Operating Cost

The benefit from reduced operating costs of traveling vehicles was calculated by subtracting the total operating cost in the "with project" scenario from the total operating cost in the "without project" scenario. The total operating cost was calculated depending on the type of vehicle, speed, and travel distance for each road segment, considering fuel consumption, engine oil consumption, tire wear, operating costs, and depreciation rate.

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Vehicle operating costs include vehicle depreciation costs, fixed costs, and direct user costs such as fuel costs, engine oil costs, tire wear costs, vehicle maintenance, and repair costs which are variable costs.

Information on fuel consumption, engine oil consumption, tire wear, maintenance cost ratio, and depreciation ratio was taken from the 7th Amendment of the Road Infrastructure Investment Assessment Guidelines (September 2022, Ministry of Land Planning, Infrastructure, and Transport). Additionally, the prices of fuel, engine oil, tires, and vehicles were based on research data from the Mongolian market.

Table 137. Fuel and Engine Oil Costs (unit: $/Liter)

	Gasoline	Diesel
Fuel cost	0.7	0.93
Engine oil cost ($/liter)	5.88 – 14.77	

Source: 1212.mn, Research Team

Note: Engine oil prices were set depending on the market price at that time and the size of the vehicle. For passenger and small freight vehicles, 5.88 USD; for small to medium-sized freight vehicles, 10.325 USD; for large buses and heavy-duty vehicles, 14.77 USD.

Table 138. Tire Price and Vehicle Price (unit: $)

	Tire price (calculated for 4 pieces)	Vehicle price
Car	234	3,406
Light-duty bus	264	22,050
Heavy-duty bus	2,068	58,800
Light-duty truck	264	19,100
Medium-sized truck	1,000	33,500
Heavy-duty truck	2,058	56,150

Source: Research Team

Table 139. Fuel Consumption by Vehicle Type (unit: liters/km)

Speed (km/h)	Car	Light-duty bus	Heavy-duty bus	Light-duty truck	Medium-sized truck	Heavy-duty truck
10	0.148393	0.202658	0.492006	0.169566	0.390274	0.696422
20	0.094866	0.127732	0.350863	0.138291	0.264289	0.527038
30	0.073031	0.097853	0.283976	0.113935	0.211348	0.439729
40	0.061753	0.082587	0.247133	0.100882	0.184880	0.389697
50	0.056421	0.074097	0.225888	0.094002	0.172229	0.36068

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60	0.051986	0.069532	0.214713	0.091296	0.168546	0.345332
70	0.050625	0.067722	0.21062	0.092092	0.172820	0.340394
80	0.050788	0.068263	0.213535	0.096583	0.186360	0.346452
90	0.052804	0.071273	0.223392	0.105947	0.214044	0.363031
100	0.057029	0.077457	0.242614	0.123252	0.269959	0.394009

Source: 7th Revised Edition of the Road Traffic Infrastructure Investment Assessment Guidelines issued by the Ministry of Land, Infrastructure and Transport of the Republic of Korea in September 2022 (Road User Savings Metrics, Jan de Weille, 1996)

Note: Experimental indicators calculated by vehicle type, developed by the Korea Transportation Safety Administration's Vehicle Performance Research Institute

Table 140. Engine Oil Consumption by Vehicle Type (unit: liters/km)

Speed (km/h)	Car	Light-duty bus	Heavy-duty bus	Light-duty truck	Medium-sized truck	Heavy-duty truck
10	1.8	2.1	4.8	2.1	3.1	9.4
20	1.5	1.9	4.1	1.9	2.9	8.4
30	1.3	1.7	3.5	1.7	2.5	7.2
40	1.1	1.5	3.2	1.5	2.2	6.4
50	1.1	1.5	2.9	1.5	2.0	5.9
60	1.1	1.4	2.7	1.4	1.8	5.3
70	1.1	1.3	2.6	1.3	1.7	4.7
80	1.0	1.2	2.3	1.2	1.6	3.9
90	0.9	1.1	2.6	1.1	1.7	4.2
100	1.1	1.1	3.1	1.1	1.9	4.7

Source: 7th Revised Edition of the Road Traffic Infrastructure Investment Assessment Guidelines issued by the Ministry of Land, Infrastructure and Transport of the Republic of Korea in September 2022 (Road User Savings Metrics, Jan de Weille, 1996)

Table 141. Tire Wear by Vehicle Type (unit: km/h, %/1,000km)

Speed (km/h)	Car	Light-duty bus	Heavy-duty bus	Light-duty truck	Medium-sized truck	Heavy-duty truck
10	0.7	0.6	1.6	0.6	1.2	1.9
20	1.3	1.1	2.6	1.1	1.9	3.3
30	2.0	1.8	3.5	1.6	2.7	5.0
40	2.9	2.5	5.3	2.5	3.7	7.1
50	3.7	3.2	7.1	3.1	4.9	9.3
60	4.7	4.0	9.2	4.0	6.1	12.3

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70	5.8	5.0	11.6	5.0	7.4	16.4
80	7.0	6.1	14.8	6.1	9.2	19.6
90	8.5	7.4	18.6	7.4	11.0	24.7
100	10.1	8.8	22.9	8.8	13.2	30.3

Source: 7th Revised Edition of the Road Traffic Infrastructure Investment Assessment Guidelines issued by the Ministry of Land, Infrastructure and Transport of the Republic of Korea in September 2022 (Road User Savings Metrics, Jan de Weille, 1996)

Table 142. Maintenance Cost Ratio (unit: km/h, Vehicle price percentage (%)/1,000km)

Speed (km/h)	Car	Light-duty bus	Heavy-duty bus	Light-duty truck	Medium-sized truck	Heavy-duty truck
10	0.055	0.078	0.068	0.078	0.163	0.038
20	0.065	0.088	0.078	0.088	0.195	0.048
30	0.077	0.097	0.087	0.097	0.207	0.057
40	0.080	0.100	0.090	0.100	0.220	0.060
50	0.090	0.110	0.103	0.110	0.243	0.063
60	0.095	0.115	0.115	0.115	0.260	0.070
70	0.100	0.120	0.120	0.120	0.282	0.070
80	0.110	0.130	0.140	0.013	0.320	0.080
90	0.113	0.143	0.153	0.143	0.356	0.093
100	0.120	0.154	0.163	0.154	0.380	0.103

Source: 7th Revised Edition of the Road Traffic Infrastructure Investment Assessment Guidelines issued by the Ministry of Land, Infrastructure and Transport of the Republic of Korea in September 2022 (Road User Savings Metrics, Jan de Weille, 1996)

Table 143. Depreciation Percentage (unit: km/h, Vehicle price percentage (%)/1,000km)

Speed (km/h)	Car	Light-duty bus	Heavy-duty bus	Light-duty truck	Medium-sized truck	Heavy-duty truck
10	0.880	1.150	0.310	1.150	0.780	0.28
20	0.750	0.950	0.270	0.950	0.660	0.23
30	0.640	0.750	0.220	0.780	0.580	0.19
40	0.540	0.650	0.180	0.650	0.490	0.16
50	0.460	0.560	0.153	0.560	0.430	0.133
60	0.415	0.495	0.135	0.495	0.385	0.116
70	0.380	0.445	0.123	0.445	0.350	0.103
80	0.340	0.400	0.110	0.400	0.320	0.09

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90	0.315	0.367	0.097	0.367	0.293	0.088
100	0.293	0.340	0.087	0.340	0.279	0.079

Source: 7th Revised Edition of the Road Traffic Infrastructure Investment Assessment Guidelines issued by the Ministry of Land, Infrastructure and Transport of the Republic of Korea in September 2022 (Road User Savings Metrics, Jan de Weille, 1996)

Operating costs were calculated by vehicle type and speed as follows and used as input data for calculating vehicle operating costs (Traffic volume × Travel distance × Operating cost by vehicle type and speed)

Table 144. Operating Cost by Vehicle Type and Speed (Unit: USD/km)

Speed (km/h)	Car	Light-duty bus	Heavy-duty bus	Light-duty truck	Medium-sized truck	Heavy-duty truck
10	0.149	0.481	0.781	0.424	0.730	1.032
20	0.106	0.370	0.643	0.340	0.582	0.863
30	0.088	0.300	0.573	0.268	0.514	0.779
40	0.078	0.264	0.544	0.252	0.471	0.747
50	0.073	0.240	0.548	0.232	0.456	0.742
60	0.071	0.224	0.575	0.220	0.453	0.773
70	0.072	0.214	0.614	0.214	0.468	0.815
80	0.073	0.208	0.683	0.191	0.486	0.894
90	0.077	0.209	0.773	0.221	0.545	1.028
100	0.084	0.215	0.888	0.238	0.622	1.176

Source: Research team

A cubic equation was derived to establish a formula for calculating operating costs based on speed-based vehicle operating cost calculations.

Table 145. Formula for Calculating Operating Costs (X: Speed, km/h)

	X3	X2	X1	Constant
Car	-0.0000003	0.0000720	-0.0052454	0.1905003
Light-duty bus	-0.0000007	0.0001790	-0.0144923	0.6028826
Heavy-duty bus	-0.0000007	0.0002541	-0.0188884	0.9366364
Light-duty truck	-0.0000003	0.0000997	-0.0068892	0.5073684
Medium-sized truck	-0.0000006	0.0002151	-0.0177515	0.8750575

Source: Research team

Formula for Calculating Operating Costs (X: Speed, km/h)

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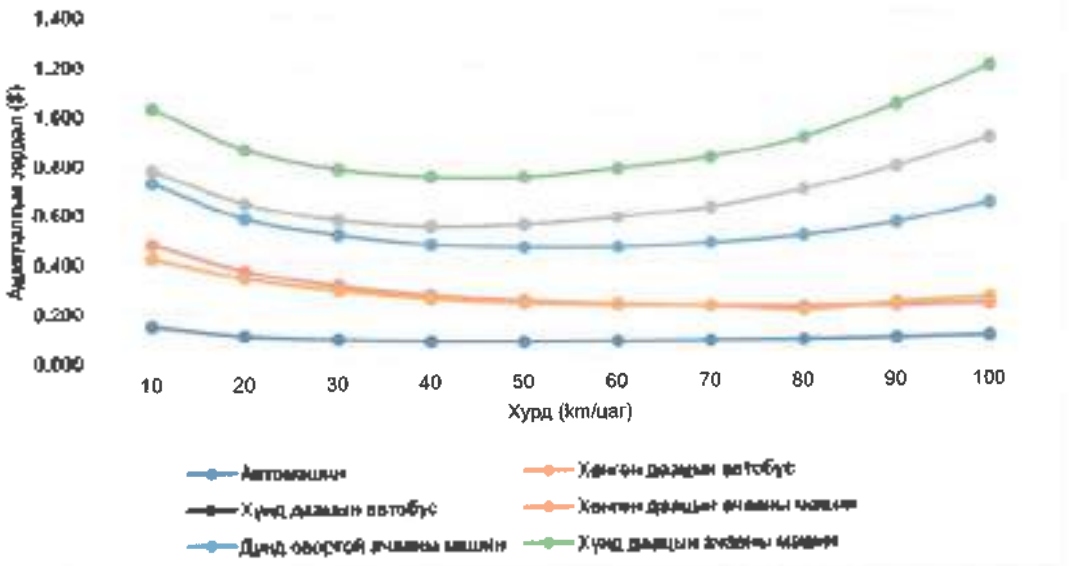

The operating costs were calculated for all links in the "without project" and "with project" scenarios, and the difference in total costs was calculated as the benefit of reduced operating costs. The vehicle operating cost savings (VOCS) is expressed by the following formula:

$$VOCS = VOC_{without\ project} - VOC_{with\ project}$$

Where:

$$VOC = \sum_{l} \sum_{k=1}^{6} (D_{kl} \times VT_k) \times 365$$

D_{kl} - Distance traveled by vehicles on a specific route (vehicle km)
VT_k - Vehicle operating cost measured by vehicle type and average
k - vehicle type (1: private car, 2: mini-bus, 3: bus, 4–6: truck)

Value of Injury Cost:

The economic benefit from reduced road traffic accidents was calculated by subtracting the number of injuries and fatalities in the "with project" scenario from the number of injuries and fatalities in the "without project" scenario at each travel point, multiplied by the actual damage cost.

Road traffic accidents are directly related to the number of vehicles, so as traffic volume increases and travel distance extends, the number of accidents tends to increase. Therefore, this project will reduce traffic volume, leading to a decrease in road traffic accidents and generating benefits from accident reduction.

In calculating the monetary value of road traffic accident damage, not only the damage to individuals but also damage to the surrounding environment and society as a whole was included. The rate of road traffic accidents is calculated as the number of injury-related accidents (fatal, injured) per 100 million vehicle-kilometers, where "100 million vehicle-

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kilometers" represents how frequently vehicles are concentrated in environments where road traffic accidents occur more often.

The road traffic accident rate was calculated using information from the National Statistics Office. In 2023, there were 57 traffic-related fatalities and 525 injuries in Ulaanbaatar. Based on this information and the traffic volume (km × number of vehicles) along the tram construction route, the unit costs for road traffic accident fatalities and injuries were calculated. The calculation results are as follows:

Table 146. Road Traffic Accident Rate Per Unit (fatalities, injuries)

	Fatalities	Injuries
Number of road traffic accidents recorded annually (2023)	57	525
Number of accidents recorded per 100 million kilometers of road traffic annually × number of vehicles	2,000.3	18,423.7

Source: 1212.mn

Table 147. Calculated Result of Lifetime Income Per Person (unit: $)

2024	Car	Bus
Time value VOT ($)	3.65	2.18
Average VOT ($/hour)	2.92	
Average VOT ($/month)	514.43 (22 day, 8 hour)	
Average VOT ($/year)	6,173.1	
Average VOT ($/20 years)	123,463	

Note: Working years are calculated as an average of 20 years, based on the assumption that people can work for 40 years (ages 20-60).

Road traffic accident costs were categorized as fatal and injury-related, with accident costs calculated as $155,192 for human life loss (considering 25% damage to the environment and society) and $6,297 for injuries. For fatalities, the calculation was based on annual average salary ($6,173/year) and average years worked (20 years, considering ages 20-60 as economically active period). Injury costs were calculated as 5.1% of fatality costs.

Table 148. Road Traffic Accident Cost Calculation (unit: $)

	Ratio compared to fatality cost		Road traffic accident cost	
	Without social cost	Including social cost	Without social cost	Including social cost
Fatality	100.0%	125.7%	123,462.59	155,192.48
Injury	1.2%	5.1%	1,481.55	6,296.59

The benefit of road traffic accident reduction is expressed by how transportation-related projects affect road traffic accidents. The formula for calculating the benefit of reduced road traffic accident costs is as follows:

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$$VICS = VIC_{without\ project} - VIC_{with\ project}$$

Where:

$$VOC = \sum_{s=1}^{2} (A_s \times P_s \times VL_s)$$

A_s - Number of road traffic accidents per 100 million vehicle-kilometers by accident type

P_s - Accident cost by accident type

VL - Annual operating distance (100 million km·vehicle)

s – accident types

VOPCs: Value of Pollution Cost savings:

The economic benefit of reduced air pollution resulting from the Light Rail Transit (LRT) project becoming operational was calculated by subtracting the amount of air pollution emissions in the "with project" scenario from the amount of air pollution emissions in the "without project" scenario, multiplied by the corresponding pollution valuation.

Among environmental pollution types, this project is expected to have a high impact on reducing air pollution and greenhouse gases. The benefits of reduced air pollution costs and greenhouse gas reduction were calculated through the following:

Vehicle speed-dependent pollution and greenhouse gas emissions,

Calculation of the cost of environmental damage caused by pollutants and greenhouse gases,

Calculation of the change in pollutant and greenhouse gas emissions between the "with project" and "without project" scenarios.

In calculating air pollution costs, damage costs from carbon monoxide (CO), hydrocarbons (HC/VOC), nitrogen oxides (NOx), particulate matter (PM), and carbon dioxide (CO2) are taken into account. These costs are determined by multiplying the emission factor of each pollutant by the unit social cost. The air pollutant emission factors were derived using the formula specified in the 7th Revised Edition of the Road Traffic Infrastructure Investment Assessment Guidelines issued by the Ministry of Land, Infrastructure and Transport of the Republic of Korea in 2022.

Table 149. Environmental Pollutant Emissions by Vehicle Type and Speed (unit: km/h, g/km)

	Speed (km/h)	CO	NOx	HC(VOC)	PM2.5	CO2
Car	10	1.51	0.59	0.15	0.02	380.85
	20	0.8	0.38	0.06	0.01	261.48
	30	0.57	0.3	0.04	0.01	197.3
	40	0.45	0.25	0.03	0.01	160.1
	50	0.38	0.22	0.02	0.01	146.34
	60	0.33	0.2	0.02	0.01	130.33
	70	0.29	0.18	0.01	0.01	118.85
	80	0.27	0.17	0.01	0.01	109.73
	90	0.25	0.15	0.01	0.01	102.27

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	100	0.23	0.15	0.01	0.01	96.03
Light-duty bus	10	1.58	1.67	0.41	0.04	831.41
	20	1.28	1.47	0.35	0.03	578.14
	30	1.16	1.29	0.33	0.03	464.99
	40	1.08	1.18	0.32	0.02	399.43
	50	1.03	1.11	0.31	0.02	355.09
	60	0.99	1.05	0.3	0.02	322.46
	70	0.96	1.01	0.3	0.02	297.27
	80	0.94	0.97	0.29	0.02	277.05
	90	0.92	0.94	0.29	0.02	260.36
	100	0.9	0.92	0.28	0.02	246.29
Heavy-duty bus	10	2.26	5.92	0.71	0.04	1492.95
	20	1.87	4.16	0.61	0.03	1052.31
	30	1.72	3.42	0.57	0.02	858.31
	40	1.63	3	0.56	0.02	743.04
	50	1.57	2.72	0.53	0.02	664.54
	60	1.53	2.52	0.52	0.01	606.68
	70	1.5	2.36	0.52	0.01	561.78
	80	1.48	2.24	0.51	0.01	525.59
	90	1.46	2.14	0.51	0.01	495.65
	100	1.44	2.05	0.5	0.01	470.34

	Speed (km/h)	CO	NOx	HC(VOC)	PM2.5	CO2
Light-duty truck	10	0.8	0.98	0.11	0.08	454.17
	20	0.53	0.62	0.07	0.06	337.16
	30	0.41	0.48	0.06	0.05	283.48
	40	0.35	0.39	0.05	0.04	250.78
	50	0.31	0.34	0.04	0.04	228.03
	60	0.28	0.3	0.04	0.03	211.02
	70	0.25	0.27	0.03	0.03	197.65
	80	0.23	0.25	0.03	0.03	186.77
	90	0.22	0.23	0.03	0.03	177.67
	100	0.2	0.22	0.03	0.02	169.92
Medium-sized truck	10	3.82	5.39	0.92	0.2	740.4
	20	2.47	3.93	0.61	0.14	579.59
	30	1.91	3.26	0.48	0.12	502.26
	40	1.6	2.86	0.4	0.1	453.74
	50	1.4	2.59	0.35	0.09	419.35
	60	1.26	2.38	0.32	0.08	393.22
	70	1.14	2.22	0.29	0.08	372.39
	80	1.06	2.09	0.27	0.07	355.24
	90	0.98	1.98	0.25	0.07	340.78
	100	0.92	1.89	0.23	0.07	328.33
Heavy-duty truck	10	7.03	25.21	1.64	0.79	1490.65
	20	4.29	17.85	1.11	0.57	1140.67

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	30	3.24	14.77	0.89	0.47	975.58
	40	2.67	12.66	0.75	0.41	873.04
	50	2.3	11.56	0.66	0.37	800.99
	60	2.04	10.6	0.6	0.34	746.56
	70	1.85	9.84	0.55	0.31	703.43
	80	1.69	9.24	0.51	0.3	668.09
	90	1.57	8.74	0.47	0.28	638.4
	100	1.47	8.31	0.45	0.27	612.96

Source: 7th Revised Edition of the Road Traffic Infrastructure Investment Assessment Guidelines issued by the Ministry of Land, Infrastructure and Transport of the Republic of Korea in 2022

In calculating environmental costs, traffic volume, speed dependent on traffic distribution, and air pollution costs (cubic equation and unit values) were used. The formula for calculating environmental pollutant emissions by vehicle type and speed is expressed as follows:

Table 150. Formula for Calculating Environmental Pollutant Emissions (X: Speed, km/h)

		X3	X2	X1	Constant
CO	Car	-0.0000058	0.0012131	-0.0825594	2.1413333
	Light-duty bus	-0.0000023	0.0004853	-0.0357393	1.8640000
	Heavy-duty bus	-0.0000031	0.0006527	-0.0466065	2.6276667
	Light-duty truck	-0.0000022	0.0004580	-0.0329918	1.0613333
	Medium-sized truck	-0.0000106	0.0022694	-0.1631509	5.1090000
	Heavy-duty truck	-0.0000219	0.0046284	-0.3266946	9.5833333
NOx	Car	-0.0000016	0.0003441	-0.0247618	0.7840000
	Light-duty bus	-0.0000030	0.0006450	-0.0483895	2.2576667
	Heavy-duty bus	-0.0000137	0.0028379	-0.2129141	7.6060000
	Light-duty truck	-0.0000028	0.0005829	-0.0428702	1.3180000
	Medium-sized truck	-0.0000110	0.0023767	-0.1781832	6.8223333
	Heavy-duty truck	-0.0000547	0.0115263	-0.8782490	32.2393335
HC (VOC)	Car	-0.0000007	0.0001417	-0.0095000	0.2193333
	Light-duty bus	-0.0000005	0.0000984	-0.0066767	0.4630000
	Heavy-duty bus	-0.0000008	0.0001751	-0.0123326	0.8080000
	Light-duty truck	-0.0000002	0.0000510	-0.0040287	0.1406667

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	Medium-sized truck	-0.0000025	0.0005291	-0.0380965	1.2236667
	Heavy-duty truck	-0.0000041	0.0006813	-0.0643671	2.1520000
PM2.5	Car	-0.0000001	0.0000167	-0.0009284	0.0260000
	Light-duty bus	-0.0000001	0.0000161	-0.0012409	0.0606667
	Heavy-duty bus	0.0000000	0.0000117	-0.0011820	0.0496667
	Light-duty truck	-0.0000002	0.0000390	-0.0028483	0.1043333
	Medium-sized truck	-0.0000004	0.0000876	-0.0067667	0.2536667
	Heavy-duty truck	-0.0000016	0.0003550	-0.0266664	1.0043333
CO2	Car	-0.0010030	0.2149046	-15.614	504.556
	Light-duty bus	-0.0018461	0.4194762	-30.937	1078.285
	Heavy-duty bus	-0.0033406	0.7213614	-63.453	1920.290
	Light-duty truck	-0.0006684	0.1886424	-14.246	568.886
	Medium-sized truck	-0.0011621	0.2548632	-19.859	889.999
	Heavy-duty truck	-0.0026570	0.5589596	-42.728	1836.614

Source: Research team

Air pollution costs were calculated for each environmental pollutant, using the air pollution cost values specified in the 7th Revised Edition of the Road Traffic Infrastructure Investment Assessment Guidelines (September 2022, Ministry of Land, Infrastructure and Transport). Since these costs were calculated at 2015 prices, they were adjusted to 2024 prices using the Consumer Price Index (CPI, 2015/2024 = 114.4/96.05 = 119%).

Table 181. Environmental Pollutant Cost (unit: USD/kg)

	CO	NOx	HC(VOC)	PM2.5	CO2
2015	0.04	0.13	1.95	337.2	0.04
2024	0.04	0.16	2.33	401.6	0.04

Source: 7th Revised Edition of the Road Traffic Infrastructure Investment Assessment Guidelines issued by the Ministry of Land, Infrastructure and Transport of the Republic of Korea in 2022

Environmental costs were calculated for all links in the "without project" and "with project" scenarios, and the difference in their total sums was considered as the benefit of reduced environmental costs. The benefit of reduced environmental costs (VOPCS) is expressed by the following formula:

$$VOPCS = VOPC_{without\ project} - VOPC_{with\ project}$$

Where:

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$$VOPC = \sum_{t} \sum_{k=1}^{6} (D_{kt} \times VT_{ka}) \times 365$$

D_{kt} - Distance traveled by vehicles on a specific route (vehicle km)
VT_k - Air pollution cost measured by vehicle type and average speed on that route
k - vehicle type (1: private car, 2: mini-bus, 3: bus, 4~6: truck)

Economic Benefit Calculation

By inputting the above unit costs into the traffic demand result data and calculating the total sum of VOT, VOC, VIC, and VOPC, the total transportation cost was calculated. The economic benefit is the difference in total costs between the "with project" and "without project" scenarios. The following tables show the economic benefits for the opening years 2030 and 2040 for each tariff option.

Table 162. Light Rail Transit (LRT) Line 2 Benefit Calculation(unit: million USD)

Base Price	Price per km	2030					2040				
		VOT	VOC	VIC	VOPC	Total	VOT	VOC	VIC	VOPC	Total
500	50	103.02	24.85	0.59	8.86	137.32	103.02	24.85	0.59	8.86	137.32
	100	98.89	24.24	0.58	8.51	132.22	98.89	24.24	0.58	8.51	132.22
	150	94.83	23.62	0.57	8.15	126.97	94.83	23.62	0.57	8.15	126.97
750	50	97.45	23.31	0.57	7.96	124.29	97.45	23.31	0.57	7.96	124.29
	100	87.98	22.69	0.56	7.58	118.82	87.98	22.69	0.56	7.58	118.82
	150	83.37	22.07	0.55	7.20	113.19	83.37	22.07	0.55	7.20	113.19
1000	50	81.01	21.75	0.55	7.00	110.30	81.01	21.75	0.55	7.00	110.30
	100	76.16	21.12	0.54	6.59	104.41	76.16	21.12	0.54	6.59	104.41
	150	71.15	20.49	0.53	6.17	98.34	71.15	20.49	0.53	6.17	98.34
1250	50	68.58	20.17	0.52	5.96	95.23	68.58	20.17	0.52	5.96	95.23
	100	63.31	19.53	0.52	5.52	89.87	63.31	19.53	0.52	5.52	89.87
	150	57.85	18.88	0.51	5.06	82.30	57.85	18.88	0.51	5.06	82.30
1500	50	55.04	18.55	0.50	4.83	78.93	55.04	18.55	0.50	4.83	78.93
	100	49.28	17.90	0.49	4.36	72.03	49.28	17.90	0.49	4.36	72.03
	150	43.30	17.24	0.48	3.88	64.90	43.30	17.24	0.48	3.88	64.90
1750	50	40.23	16.91	0.48	3.61	61.24	40.23	16.91	0.48	3.61	61.24
	100	33.91	16.26	0.47	3.10	53.72	33.91	16.26	0.47	3.10	53.72
	150	27.34	15.58	0.46	2.58	45.94	27.34	15.58	0.46	2.58	45.94
2000	50	23.95	15.25	0.46	2.29	41.94	23.95	15.25	0.46	2.29	41.94
	100	16.98	14.57	0.45	1.72	33.72	16.98	14.57	0.45	1.72	33.72
	150	9.73	13.89	0.44	1.14	25.19	9.73	13.89	0.44	1.14	25.19

Source: Research team

Base Price	Price per km	ENPV	EIRR	BCR
500	50	474.95	34.9%	2.52
	100	445.70	33.8%	2.43
	150	413.63	32.3%	2.33

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750	50	400.27	31.6%	2.26
	100	365.89	30.1%	2.18
	150	336.59	28.7%	2.06
1000	50	320.07	27.9%	2.02
	100	286.30	26.3%	1.92
	150	251.47	24.7%	1.81
1250	50	233.66	23.8%	1.76
	100	197.17	22.1%	1.63
	150	159.50	20.2%	1.51
1500	50	140.20	19.3%	1.45
	100	100.64	17.3%	1.32
	150	59.72	15.2%	1.19
1750	50	38.74	14.1%	1.12
	100	-4.34	11.8%	0.99
	150	-48.97	9.2%	0.84
2000	50	-71.89	7.7%	0.77
	100	-119.01	4.4%	0.62
	150	-167.92	-0.1%	0.48

Economic Sensitivity Analysis

This section includes the benefit indicators VOT, VOC, VIC, and VOPC calculated in the previous section for economic analysis, while the cost indicators include the project costs and operational costs calculated in Chapters 4 and 8 of this feasibility study. Within the scope of this analysis, economic analysis and sensitivity analysis were conducted for the optimal tariff option of 1500 MNT (for distances under 5 km) + 50 MNT/km (for distances over 5 km). Basic assumptions for economic analysis:

- Social discount rate: 12%, analysis period: 30 years
- Economic benefits increase by 2% annually, in line with population growth
- The EIRR is 15.1%, which is higher than the social discount rate of 12%. Therefore, this project is economically viable.

Table 153. Results of Economic/Sensitivity Analysis (LRT Line 2)

	Sensitivity Percentage	B/C	ENPV (million USD)	EIRR
Cost (C)	-20%	1.84	202.67	24.8%
	-10%	1.64	171.44	21.8%
	0%	1.45	140.20	19.3%
	10%	1.32	108.96	17.2%
	20%	1.21	77.73	15.5%
Benefit (B)	-20%	1.16	49.69	14.7%
	-10%	1.30	94.94	17.0%
	0%	1.45	140.20	19.3%

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	10%	1.59	185.46	21.5%
	20%	1.74	230.71	23.7%
Social Discount Rate	10%	1.63	216.43	19.3%
	11%	1.54	175.12	19.3%
	12%	1.45	140.20	19.3%
	13%	1.37	110.64	19.3%
	14%	1.30	85.26	19.3%

10.6. FINANCIAL ANALYSIS

Purpose and Assumptions of Financial Analysis

Purpose and Methodology: In this chapter, a cash flow analysis was performed to assess the financial viability of the project. The evaluation indicators are Project Internal Rate of Return (PIRR) and Project Net Present Value (PNPV).

Assumptions: The analysis was based on the following assumptions:

- Analysis Period The project preparation phase is planned to continue until 2025, and the construction phase will take place from 2025-2027. The operational period is calculated as 30 years, continuing from 2028-2057.
- Investment Cost Investment costs are based on the project costs calculated in Chapter 4 and the operations and opening costs included in Chapter 8. Investment costs are calculated as general project costs.

Table 154. Investment (LRT Line 2)

(Constant price, million USD)

	2025	2026	2027	Total	Percentage
Total	121.24	146.69	80.22	348.16	
Relocation costs	21.78	-	-	21.78	6.3%
Track infrastructure construction costs	22.54	50.78	39.44	112.80	32.4%
Signaling and communications costs	3.11	6.21	6.21	15.54	4.5%
Power supply costs	12.65	18.07	10.54	42.15	12.1%
Station and depot building facilities	7.20	9.60	7.20	24.00	6.9%
Rolling stock and maintenance equipment	32.37	40.47	8.09	80.93	23.2%
Client supervision costs	1.78	2.08	2.08	5.94	1.7%
Project management costs	6.64	7.71	7.71	22.02	6.3%
Contingency costs	8.28	-	-	8.28	2.4%

Source: Urban Planning and Research Institute

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Operational Costs

Operational costs were also calculated as follows. Operational costs are calculated as general operational costs.

Table 165. Annual Operational Costs

	2028		2040	
	Million MNT	Million USD	Million MNT	Million USD
Total	25,516.71	7.36	43,960.60	12.69
Salaries, wages, bonuses, allowances and social insurance expenses	10,234.19	2.95	17,639.65	5.09
Social insurance premiums paid by employer	1,036.39	0.30	1,786.32	0.52
Facility usage expenses	1,304.64	0.38	2,248.68	0.65
Supplies and materials expenses	4,446.88	1.28	7,664.84	2.21
Business trip expenses	183.24	0.05	315.83	0.09
Other outsourced work, general services, fees and charges	709.96	0.20	1,223.89	0.35
Operations and maintenance expenses	7,339.59	2.12	12,650.31	3.65
Other expenses and contingency expenses	251.82	0.06	451.28	0.13

Source: Urban Planning and Research Institute

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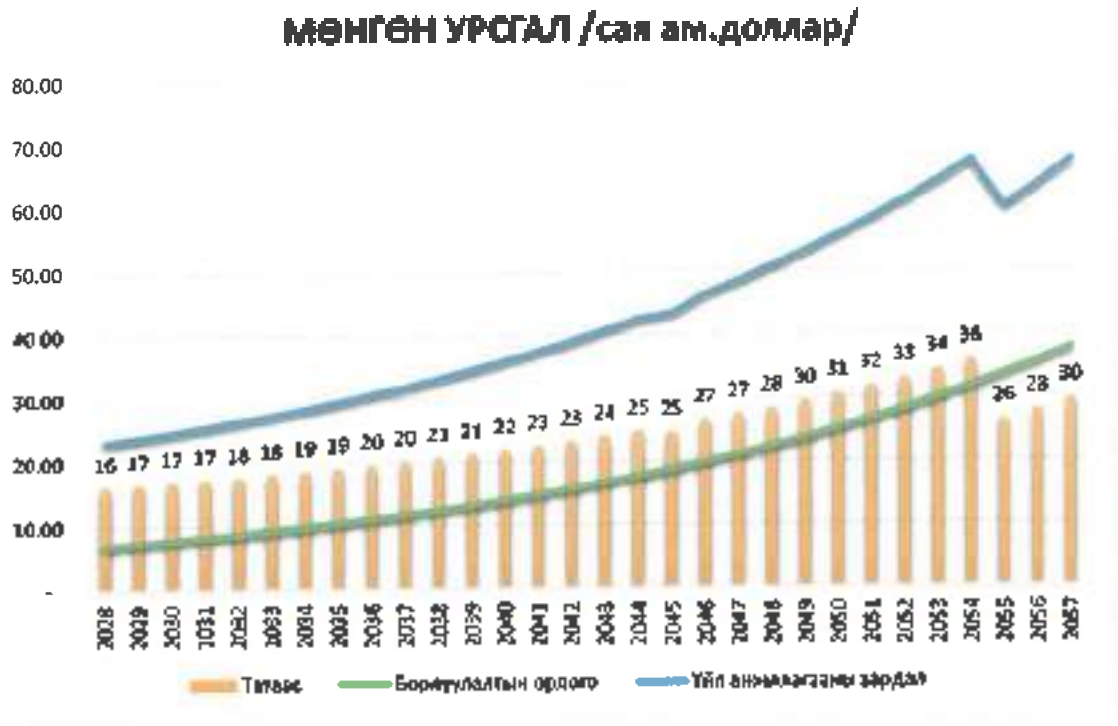

1. **Useful Life of Depreciable Assets** This study was developed according to international standards, and since LRT is Mongolia's first urban railway project, the useful life of civil construction was defined as 40 years, railway track as 30 years, E&M and rolling stock as 15 and 20 years respectively.
2. **Tariff Revenue** Tariffs were set based on the options in the demand analysis results. See Section 10.2.2 for the tariff system.
3. **Other Revenue** Other revenue is defined in Section 8.5.3 Summary of Non-Tariff Revenue.

Table 158. Other Revenue

Other Revenue	Million MNT	Million USD
Advertising revenue	1,680.00	0.48
Other revenue	220.50	0.06
Total	1,900.50	0.55

1. **Tax** Tax cost calculations were performed considering the current applicable corporate income tax, VAT, and customs duties.
2. **Subsidies** This project will be implemented with public financing and will be funded by the government. Therefore, this study did not consider government subsidies such as Viability Gap Funding (VGF) and minimum revenue guarantees.**Exchange Rate:** The exchange rate as of March 6, 2025, was used.

- USD=MNT 3,467.00

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3. **Inflation Rate** The inflation rate was calculated based on World Bank data, with an inflation rate of approximately 7.485% expected until 2025. Therefore, 6.00% was calculated until 2025, 6% inflation during the construction phase from 2025-2030, and 5% inflation during the operational phase starting from 2031.
4. **Discount Rate** The financial discount rate represents the required return for the project implementing organization. For government-funded projects, the government does not have a specific required return as it is not an ordinary business organization. Therefore, this financial analysis used the 12% discount rate used in the economic analysis.

Table 157. Financial Analysis Assumptions

Assumption		Description
Project start:	2025	
Opening year:	2028	
Analysis period:	Construction period: 2025-2028, Operational period: 2028-2057 (30 years)	
Investment cost	348.16 million USD	
Operational cost	7.36 million USD/year	
Useful life:	Civil construction: 40 years, Railway track: 30 years, E&M: 15 years, Rolling stock: 20 years	
Tariff system:	Increases annually at the same rate as inflation. Considering only total passengers switching from public transport to LRT: 46.9% are regular passengers paying full ticket price, 11.5% are children paying 50% of ticket price, 41.6% are elderly and disabled citizens who travel free on public transport.	
Exchange rate:	USD=MNT 3,467.0	
Inflation rate:	– 2025 : 7% 2026–2030: 6% 2031– : 5% Mongolian labor costs are calculated to increase by 70% of the inflation rate.	World Bank statistics
Discount rate	12.0%	

Tariff System

The following three cases were analyzed within the tariff system framework:
The proposed tariff system (5a) is the primary case.

Table 158. Demand and Tariff System

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2028	Basic (within 5km)	Distance (per km over 5km)	Daily demand	Daily revenue (million MNT)	Average tariff (MNT/person)	Average travel length (km)	PHPDT (passengers)	Highest (tariff)
1-a	500	50	210,849	82.22	483.43	5.00	6747	1000
1-b	500	100	201,979	78.91	483.57	5.00	6463	1500
1-c	500	150	193,110	75.60	483.71	5.00	6180	2000
2-a	750	50	188,875	110.91	725.59	5.00	6038	1250

2028	Basic (within 5km)	Distance (per km over 5km)	Daily demand	Daily revenue (million MNT)	Average tariff (MNT/person)	Average travel length (km)	PHPDT (passengers)	Highest (tariff)
2-b	750	100	179,805	105.94	725.94	5.00	5754	1750
2-c	750	150	170,935	100.97	726.22	5.00	5470	2250
3-a	1000	50	166,500	131.32	988.49	5.00	5328	1500
3-b	1000	100	157,630	124.69	988.92	5.00	5044	2000
3-c	1000	150	148,760	118.07	989.40	5.00	4760	2500
4-a	1250	50	144,325	143.45	1,212.08	5.00	4618	1750
4-b	1250	100	135,455	135.17	1,212.79	5.00	4335	2250
4-c	1250	150	126,585	126.89	1,213.50	5.00	4051	2750
5-a	1500	50	122,150	147.29	1,456.84	5.00	3909	2000
5-b	1500	100	113,280	137.36	1,459.03	5.00	3626	2500
5-c	1500	150	104,410	127.42	1,459.40	5.00	3341	3000
6-a	1750	50	99,975	142.86	1,703.53	5.00	3199	2250
6-b	1750	100	91,108	131.27	1,705.50	5.00	2915	2750
6-c	1750	150	83,773	122.37	1,708.90	5.00	2681	3250
7-a	2000	50	80,875	138.30	1,856.65	5.00	2588	2500
7-b	2000	100	75,079	129.20	1,861.38	5.00	2403	3000
7-c	2000	150	69,283	122.10	1,867.77	5.00	2217	3500

2040	Basic (within 5km)	Distance (per km over 5km)	Daily demand	Daily revenue (million MNT)	Average tariff (MNT/person)	Average travel length (km)	PHPDT (passengers)	Highest (tariff)
1-a	500	50	267,408	104.27	517.74	5.00	8557	1000
1-b	500	100	255,159	100.07	481.90	5.00	8167	1500
1-c	500	150	244,910	96.87	482.09	5.00	7837	2000
2-a	750	50	239,285	140.96	724.40	5.00	7657	1250
2-b	750	100	228,036	134.36	723.24	5.00	7297	1750
2-c	750	150	216,787	128.06	723.38	5.00	6937	2250
3-a	1000	50	211,162	166.54	986.55	5.00	6757	1500
3-b	1000	100	199,913	158.14	984.83	5.00	6397	2000
3-c	1000	150	188,664	149.74	985.08	5.00	6037	2500
4-a	1250	50	183,039	181.92	1,209.29	5.00	5857	1750
4-b	1250	100	171,790	171.42	1,206.88	5.00	5497	2250

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4-c	1250	150	160,541	160.92	1,207.29	5.00	5137	2750
5-a	1500	50	154,918	168.01	1,453.93	5.00	4957	2000
5-b	1500	100	143,667	174.20	1,449.63	5.00	4597	2500
5-c	1500	150	132,416	181.40	1,450.94	5.00	4237	3000
6-a	1750	50	126,793	181.18	1,696.00	5.00	4057	2250
6-b	1750	100	116,544	168.46	1,693.84	5.00	3697	2750
6-c	1750	150	106,244	155.19	1,695.96	5.00	3400	3250
7-a	2000	50	107,569	172.88	1,948.03	5.00	3262	2500
7-b	2000	100	95,218	163.85	1,945.26	5.00	3047	3000
7-c	2000	150	87,867	154.85	1,950.82	5.00	2812	3500

Cash Flow Analysis of Light Rail Transit (LRT) Project

Sensitivity analysis on tariffs and passenger numbers shows that overall profitability generally improves as tariffs increase.

Although passenger numbers decrease as tariffs increase, the analysis shows that tariff increases have a more significant impact.

Financing option №1 assumes project financing through international financial institution project loans with international export agency guarantees, with financial analysis results shown in Table 159. Under the condition of setting tariffs at ₮1500 + 50, the net present value resulted in the lowest loss of -USD 412.28 million, with a project internal rate of return of -2.9%, indicating that the investment will not be recovered over the 30-year period.

Table 159. Financial Analysis for Financing Option 1

	FIRR*	FNPV	Payback Period*	Total Sales 2040 (million USD)	Total Sales 2050 (million USD)	Net Cash Flow 2040 (million USD)	Net Cash Flow 2050 (million USD)	Average Tariff (MNT)
1-a	-10.9%	(473.72)	–	163.09	352.11	(515.48)	(858.36)	483.43
1-b	-11.9%	(476.88)	–	158.91	338.77	(521.68)	(884.22)	483.57
1-c	-13.2%	(480.05)	–	150.74	325.43	(527.83)	(882.11)	483.71
2-a	-6.0%	(446.47)	–	216.81	467.65	(461.96)	(546.10)	725.69
2-b	-6.8%	(451.17)	–	207.34	447.44	(471.23)	(563.86)	725.94
2-c	-7.3%	(455.88)	–	198.08	427.64	(480.49)	(564.69)	726.22
3-a	-4.1%	(427.24)	–	264.89	549.86	(424.21)	(468.64)	968.49
3-b	-4.6%	(433.46)	–	242.33	523.17	(436.38)	(493.70)	968.92
3-c	-5.0%	(439.70)	–	229.97	496.49	(448.62)	(518.83)	969.40
4-a	-3.1%	(415.66)	–	277.31	598.70	(402.89)	(422.93)	1,212.06
4-b	-3.8%	(423.53)	–	251.86	565.35	(417.11)	(464.11)	1,212.70

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4-c	-4.4%	(431.40)	–	246.42	532.00	(432.33)	(485.39)	1,213.59
5-a	-2.8%	(412.28)	–	284.49	614.29	(386.12)	(406.46)	1,468.84
5-b	-3.6%	(421.57)	–	265.95	574.18	(413.16)	(445.83)	1,459.04
5-c	-4.4%	(430.68)	–	247.42	534.16	(431.34)	(483.35)	1,458.40
6-a	-3.2%	(416.42)	–	276.22	596.35	(403.15)	(425.12)	1,703.53
6-b	-4.1%	(427.28)	–	254.80	549.66	(424.50)	(466.82)	1,705.56
6-c	-4.9%	(435.65)	–	237.99	513.80	(440.68)	(502.52)	1,706.90
7-a	-3.7%	(422.57)	–	263.98	569.91	(418.10)	(449.84)	1,965.66
7-b	-4.2%	(429.29)	–	250.73	541.31	(429.09)	(474.64)	1,991.98
7-c	-4.9%	(435.81)	–	237.48	512.72	(441.78)	(503.65)	1,967.77

*not calculable

Financing option №2 assumes project financing through concessional funding from international organizations, with financial analysis results shown in Table 116. Under the condition of setting tariffs at ₮1500 + 50, the net present value resulted in the lowest loss of -USD 282.76 million, with a project internal rate of return of -0.7%, indicating that the investment will not be recovered over the 30-year period.

Table 160. Financial Analysis for Financing Option 2

	PIRR*	PNPV	Payback Period*	Total Sales 2040 (million USD)	Total Sales 2050 (million USD)	Net Cash Flow 2040 (million USD)	Net Cash Flow 2050 (million USD)	Average Tariff (MNT)
1-a	-8.6%	(343.22)	–	163.69	352.11	(455.68)	(437.54)	483.43
1-b	-9.5%	(348.34)	–	166.91	338.77	(461.60)	(450.10)	483.57
1-c	-10.6%	(349.46)	–	150.74	325.43	(467.92)	(462.66)	483.71
2-a	-3.9%	(316.37)	–	216.61	487.65	(403.49)	(329.52)	725.89
2-b	-4.6%	(321.00)	–	207.34	447.64	(412.42)	(348.11)	725.94
2-c	-5.1%	(325.64)	–	198.08	427.64	(421.42)	(366.70)	726.22
3-a	-1.8%	(297.46)	–	258.88	549.55	(367.06)	(253.36)	968.49
3-b	-2.5%	(303.58)	–	242.33	523.17	(378.83)	(270.04)	968.92
3-c	-3.1%	(309.71)	–	229.87	496.49	(390.63)	(302.73)	969.40
4-a	-1.0%	(288.29)	–	277.31	598.70	(345.63)	(208.34)	1,212.08
4-b	-1.6%	(293.91)	–	261.88	565.35	(360.25)	(239.06)	1,212.79
4-c	-2.3%	(301.56)	–	246.42	532.00	(374.93)	(269.27)	1,213.59
5-a	-0.7%	(282.76)	–	284.49	614.29	(388.87)	(184.10)	1,468.84
5-b	-1.4%	(291.89)	–	265.96	574.18	(356.38)	(230.94)	1,458.03
5-c	-2.3%	(301.06)	–	247.42	534.16	(373.97)	(267.87)	1,458.40
6-a	-1.0%	(288.82)	–	276.22	596.35	(346.68)	(218.61)	1,703.53
6-b	-1.9%	(297.50)	–	254.80	549.66	(367.13)	(253.54)	1,705.56
6-c	-2.7%	(305.74)	–	237.99	513.80	(382.97)	(286.71)	1,706.90

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7-a	-1.5%	(292.87)	–	283.98	569.91	(366.28)	(234.08)	1,955.85
7-b	-2.1%	(299.41)	–	250.73	541.31	(370.81)	(261.28)	1,961.36
7-c	-2.7%	(305.99)	–	237.48	512.72	(383.48)	(287.71)	1,967.77

*not calculable

Financing option №3 assumes project financing through interest-free government funding, with financial analysis results shown in Table 117. Under the condition of setting tariffs at ₮1500 + 50, the net present value resulted in the lowest loss of -USD 209.36 million, with a project internal rate of return of 1.3% and investment payback period of 28 years.

Table 161. Financial Analysis for Financing Option 3

	PIRR*	PNPV	Payback Period*	Total Sales 2040 (million USD)	Total Sales 2050 (million USD)	Net Cash Flow 2040 (million USD)	Net Cash Flow 2050 (million USD)	Average Tariff (MNT)
1-a	-8.3%	(266.40)	*	163.09	352.11	29.60	83.92	463.43
1-b	-7.2%	(269.30)	*	156.91	338.77	24.00	81.86	463.57
1-c	-8.3%	(272.21)	*	150.74	325.43	18.40	39.84	463.71
2-a	-1.8%	(241.25)	*	216.81	467.65	78.06	158.21	726.69
2-b	-2.4%	(245.61)	*	207.34	447.64	69.67	150.15	726.94
2-c	-3.0%	(249.96)	*	198.08	427.64	61.28	132.09	726.22
3-a	0.1%	(223.38)	32 years	254.69	549.85	112.55	242.40	969.49
3-b	-0.5%	(229.17)	*	242.33	523.17	101.95	216.32	969.92
3-c	-1.1%	(234.96)	*	229.97	496.49	90.16	194.24	969.40
4-a	1.1%	(212.79)	29 years	277.31	598.70	133.94	268.49	1,212.08
4-b	0.4%	(219.98)	31 years	261.66	565.35	119.85	258.39	1,212.79
4-c	-0.3%	(227.25)	*	246.42	532.00	105.66	226.29	1,213.89
5-a	1.3%	(209.39)	28 years	294.49	614.20	138.64	300.49	1,456.84
5-b	0.6%	(218.07)	30 years	285.95	574.18	122.75	264.36	1,458.03
5-c	-0.2%	(226.78)	*	247.42	534.16	105.96	228.24	1,459.40
6-a	1.0%	(213.24)	29 years	276.22	598.35	132.08	284.37	1,703.59
6-b	0.1%	(223.40)	32 years	264.60	548.94	112.47	242.23	1,705.56
6-c	-0.7%	(231.21)	*	237.99	513.60	87.42	209.87	1,706.90
7-a	0.5%	(219.00)	31 years	253.98	569.91	120.96	260.61	1,955.85
7-b	-0.1%	(225.22)	*	250.73	541.31	106.96	254.70	1,961.36
7-c	-0.7%	(231.44)	*	237.48	512.72	96.97	208.89	1,967.77

*not calculable

Financial and Economic Analysis Conclusion

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When calculating financial profitability under three types of financing options, interest-free government financing for 30 years resulted in the highest financial profitability. With a discount rate of 12% and ticket prices set at ₮1500+50, the net present value resulted in a loss of USD 209.39 million, but the project internal rate of return was 1.3% with an initial investment payback period of 28 years.

From the economic and financial analysis, setting ticket prices at 1500 MNT within 5 km and 50 MNT per km beyond 5 km is the most appropriate choice. Under this option, not only is the project's financial net present value loss minimized, but the economic internal rate of return is higher than 12% at 19.3%, making it the most optimal pricing option.

As mentioned above, the Light Rail Transit LRT project is economically viable, while the negative PNPV indicates that the project is financially unviable. Since it is economically viable but financially unviable, it is concluded that this project is more suitable for public financing.

Sensitivity Analysis

Sensitivity analysis generally examines the sensitivity of project costs and revenues. Therefore, we conducted sensitivity analysis on three types: revenue, costs, and exchange rates.

Project sales revenue sensitivity analysis was conducted from 0% to 30%, and cost sensitivity analysis from -20% to +20% to determine how capital investment fluctuations affect project returns. The analysis was based on the most appropriate ticket system option 5a.

Table 162. Revenue Sensitivity Analysis for Financing Option 1 (Unit: USD million)

	Investment	PIRR*	PNPV	Payback Period*	Total Sales 2040	Total Sales 2050	Net Cash Flow 2040	Net Cash Flow 2050
Base Case	**348.16**	**-2.9%**	**(412.28)**	-	**131.56**	**327.43**	**(395.12)**	**(408.46)**
10%	348.16	-1.4%	(395.19)	-	144.72	360.17	(365.63)	(330.62)
20%	348.16	-0.5%	(380.33)	-	157.87	392.92	(337.18)	(269.20)
30%	348.16	0.3%	(365.48)	32 years	171.03	425.66	(308.73)	(207.78)

Table 163. Revenue Sensitivity Analysis for Financing Option 2 (Unit: USD million)

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	Investment	PIRR*	PNPV	Payback Period*	Total Sales 2040	Total Sales 2050	Net Cash Flow 2040	Net Cash Flow 2050
Base Case	348.16	-0.7%	(282.76)	-	131.56	327.43	(338.87)	(194.10)
10%	348.16	0.9%	(264.46)	30 years	144.72	360.17	(263.11)	(203.46)
20%	348.16	1.8%	(249.60)	27 years	157.87	392.92	(234.64)	(142.04)
30%	348.16	2.6%	(234.75)	25 years	171.03	425.66	(206.21)	(80.62)

Table 164. Revenue Sensitivity Analysis for Financing Option 3 (Unit: USD million)

	Investment	PIRR*	PNPV	Payback Period*	Total Sales 2040	Total Sales 2050	Net Cash Flow 2040	Net Cash Flow 2050
Base Case	348.16	1.3%	(209.30)	-	131.56	327.43	(9.92)	(22.43)
10%	348.16	3.0%	(186.46)	30 years	144.72	360.17	(107.20)	(47.16)
20%	348.16	4.0%	(171.60)	27 years	157.87	392.92	(78.75)	14.26
30%	348.16	4.9%	(156.75)	25 years	171.03	425.66	(50.30)	75.68

Table 165. Cost Sensitivity Analysis for Financing Option 1 (Unit: USD million)

	Investment	PIRR*	PNPV	Payback Period*	Total Sales 2040	Total Sales 2050	Net Cash Flow 2040	Net Cash Flow 2050
-20%	278.52	-1.9%	(379.15)	-	284.49	614.20	(434.17)	(296.75)
-10%	313.34	-2.3%	(355.69)	-	131.56	327.43	(478.32)	(339.90)
Base Case	348.16	-2.9%	(412.28)	-	131.56	327.43	(388.12)	(488.46)
10%	382.97	-3.0%	(426.71)	-	131.56	327.43	(566.61)	(428.20)
20%	417.79	-3.3%	(465.23)	-	131.56	327.43	(610.76)	(472.35)

Table 166. Cost Sensitivity Analysis for Financing Option 2 (Unit: USD million)

	Investment	PIRR*	PNPV	Payback Period*	Total Sales 2040	Total Sales 2050	Net Cash Flow 2040	Net Cash Flow 2050
-20%	278.52	0.2%	(226.40)	-	284.49	614.20	(285.07)	(124.47)
-10%	313.34	-0.3%	(254.58)	-	131.56	327.43	(319.68)	(159.29)
Base Case	348.16	-0.7%	(282.76)	-	131.56	327.43	(338.87)	(194.10)
10%	382.97	-1.1%	(310.94)	-	131.56	327.43	(389.51)	(228.92)
20%	417.79	-1.4%	(339.12)	-	131.56	327.43	(434.33)	(263.73)

Table 167. Cost Sensitivity Analysis for Financing Option 3 (Unit: USD million)

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	Investment	PIRR*	PNPV	Payback Period*	Total Sales 2040	Total Sales 2050	Net Cash Flow 2040	Net Cash Flow 2050
-20%	278.52	2.7%	(162.38)	24 years	264.48	614.20	(138.99)	21.96
-10%	313.34	2.0%	(189.56)	26 years	131.56	327.43	(173.80)	(12.29)
Base Case	348.16	1.3%	(209.36)	28 years	131.56	327.43	(9.82)	(22.43)
10%	382.97	0.8%	(236.92)	30 years	131.56	327.43	(243.43)	(32.48)
20%	417.79	0.3%	(265.08)	31 years	131.56	327.43	(278.28)	(117.30)

Exchange rate sensitivity analysis was conducted in the range of 2,500 MNT/USD to 6,000 MNT/USD.

Table 168. Exchange Rate Sensitivity Analysis for Financing Option 1 (Unit: USD million)

	Investment	PIRR*	PNPV	Payback Period*	Total Sales 2040	Total Sales 2050	Net Cash Flow 2040	Net Cash Flow 2050
2,500	251.06	-1.7%	(302.18)	-	94.87	236.10	(284.91)	(294.53)
3,000	301.26	-2.3%	(358.10)	-	113.84	283.33	(341.90)	(353.44)
3,467	348.16	-2.9%	(412.28)	-	131.56	327.43	(396.12)	(408.46)
4,000	401.68	-3.4%	(472.98)	-	151.79	377.77	(455.86)	(471.26)
4,500	451.89	-3.8%	(529.92)	-	170.76	424.99	(512.84)	(530.16)
5,000	502.10	-4.2%	(586.86)	-	189.73	472.21	(569.83)	(589.07)
6,000	602.52	-4.9%	(700.73)	-	227.68	566.65	(683.79)	(706.88)

Table 169. Exchange Rate Sensitivity Analysis for Financing Option 2 (Unit: USD million)

	Investment	PIRR*	PNPV	Payback Period*	Total Sales 2040	Total Sales 2050	Net Cash Flow 2040	Net Cash Flow 2050
2,500	251.06	0.7%	(189.37)	30 years	94.87	236.10	(244.36)	(139.96)
3,000	301.26	-0.1%	(242.49)	-	113.84	283.33	(293.23)	(167.96)
3,467	348.16	-0.7%	(292.76)	-	131.56	327.43	(338.87)	(194.18)
4,000	401.68	-1.3%	(328.72)	-	151.79	377.77	(390.97)	(223.94)
4,500	451.89	-1.8%	(371.84)	-	170.76	424.99	(439.84)	(251.94)
5,000	502.10	-2.3%	(414.96)	-	189.73	472.21	(488.71)	(279.93)
6,000	602.52	-3.0%	(501.19)	-	227.68	566.65	(586.45)	(335.91)

Table 170. Exchange Rate Sensitivity Analysis for Financing Option 3 (Unit: USD million)

	Investment	PIRR*	PNPV	Payback Period*	Total Sales 2040	Total Sales 2050	Net Cash Flow 2040	Net Cash Flow 2050
2,500	251.06	3.3%	(132.32)	23 years	94.87	236.10	(7.15)	(16.18)
3,000	301.26	2.2%	(172.15)	26 years	113.84	283.33	(8.58)	(19.41)
3,467	348.16	1.3%	(209.36)	28 years	131.56	327.43	(9.82)	(22.43)

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4,000	401.88	0.5%	(251.82)	31 years	151.79	377.77	(11.44)	(25.88)
4,500	451.69	-0.1%	(291.66)	-	170.76	424.99	(12.87)	(29.12)
5,000	502.10	-0.7%	(331.49)	-	189.73	472.21	(14.30)	(32.35)
6,000	602.52	-1.6%	(411.16)	-	227.68	566.65	(17.16)	(38.82)

Annual Cash Flow

Table 171. Annual Projected Cash Flow for Financing Option 1

	Passenger	Tariff Revenue	Other Revenue	Investment	Operational Cost	Interest Expense	Net Cash Flow	Principal Repayment	Total Net Cash Flow
	person	million USD	million USD	million USD	million USD	million USD	million USD	million USD	million USD
2025	-	-	-	121.24	-	-	-	-	-
2026	-	-	-	140.69	-	6.45	(6.45)	-	(6.45)
2027	-	-	-	86.22	-	17.96	(17.96)	-	(17.96)
2028	122,150	13.36	0.56	-	7.36	22.21	(15.52)	-	(15.52)
2029	124,593	14.15	0.58	-	7.80	24.28	(15.06)	-	(15.06)
2030	127,085	15.01	0.62	-	8.27	24.28	(14.51)	(13.80)	(28.31)
2031	129,627	15.81	0.65	-	8.71	23.14	(12.95)	(27.59)	(40.44)
2032	132,219	16.61	0.68	-	9.16	21.69	(10.87)	(27.59)	(38.46)
2033	134,864	17.41	0.71	-	9.59	20.11	(8.77)	(27.59)	(36.36)
2034	137,561	18.22	0.75	-	10.04	18.59	(6.73)	(27.59)	(34.32)
2035	140,312	19.02	0.78	-	10.48	17.07	(4.69)	(27.59)	(32.28)
2036	143,116	19.82	0.81	-	10.92	15.60	(2.70)	(27.59)	(30.29)
2037	145,981	20.62	0.85	-	11.36	14.03	(0.81)	(27.59)	(28.21)
2038	148,900	21.42	0.88	-	11.80	12.52	1.43	(27.59)	(26.17)
2039	151,878	22.22	0.91	-	12.24	11.00	3.47	(27.59)	(24.13)
2040	154,916	23.02	0.94	-	12.69	9.51	5.48	(27.59)	(22.11)
2041	158,014	23.83	0.98	-	13.13	7.98	7.54	(27.59)	(20.05)
2042	161,175	24.63	1.01	-	13.57	6.48	9.59	(27.59)	(18.01)
2043	164,399	25.43	1.04	-	14.01	4.99	11.62	(27.59)	(15.97)
2044	167,688	26.23	1.08	-	14.45	3.42	13.65	(27.59)	(13.94)
2045	171,049	27.03	1.11	-	14.89	1.89	15.97	(27.59)	(11.63)
2046	174,481	27.83	1.14	-	15.34	0.36	17.74	(13.90)	3.84
2047	177,950	28.63	1.18	-	15.78	-	18.64	-	18.64
2048	181,509	29.44	1.21	-	16.22	-	19.16	-	19.16
2049	186,138	30.24	1.24	-	16.68	-	19.68	-	19.68
2050	189,842	31.04	1.27	-	17.10	-	20.20	-	20.20
2051	192,619	31.84	1.31	-	17.54	-	20.73	-	20.73
2052	196,471	32.64	1.34	-	17.98	-	21.25	-	21.25
2053	200,400	33.44	1.37	-	18.43	-	18.69	-	18.69

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2054	204,408	34.25	1.41	-	18.87	-	16,14	-	16,14
2055	208,497	35.05	1.44	-	19.31	-	20.11	-	20,11
2056	212,667	35.86	1.47	-	19.75	-	17.13	-	17.13
2057	216,920	36.65	1.50	-	20.19	-	14.83	-	14,83

Table 172. *Annual Projected Cash Flow for Financing Option 2*

	Passengers	Tariff Revenue	Other Revenue	Investment	Operational Cost	Interest Expense	Net Cash Flow	Principal Repayment	Total Net Cash Flow
	person	million USD	million USD	million USD	million USD	million USD	million USD	million USD	million USD
2025	-	-	-	121.24	-	-	-	-	-
2026	-	-	-	140.69	-	3.50	(3.50)	-	(3.50)
2027	-	-	-	86.22	-	11.62	(11.62)	-	(11.62)
2028	122,150	13.36	0.56	-	7.38	16.45	(6.76)	-	(6.76)
2029	124,593	14.18	0.59	-	7.80	17.34	(8.12)	-	(8.12)
2030	127,085	15.01	0.62	-	8.27	17.34	(7.57)	(15.83)	(23.39)
2031	129,627	15.91	0.65	-	8.71	16.16	(5.88)	(31.65)	(37.51)
2032	132,219	16.81	0.69	-	9.15	14.52	(3.80)	(31.65)	(35.45)
2033	134,864	17.41	0.71	-	9.59	13.09	(1.87)	(31.65)	(33.52)
2034	137,561	18.22	0.75	-	10.04	11.42	0.43	(31.65)	(31.22)
2035	140,312	19.02	0.78	-	10.46	9.55	2.53	(31.65)	(29.12)
2036	143,118	19.82	0.81	-	10.92	8.30	4.60	(31.65)	(27.05)
2037	145,981	20.62	0.85	-	11.36	6.70	6.73	(31.65)	(24.92)
2038	148,900	21.42	0.88	-	11.80	5.12	8.82	(31.65)	(22.83)
2039	151,878	22.22	0.91	-	12.24	3.54	10.92	(31.65)	(20.73)
2040	154,916	23.02	0.94	-	12.69	1.97	13.01	(31.65)	(18.64)
2041	158,014	23.83	0.98	-	13.13	0.38	15.12	(15.83)	(0.71)
2042	161,175	24.63	1.01	-	13.57	-	16.03	-	16.03
2043	164,398	25.43	1.04	-	14.01	-	16.55	-	16.55
2044	167,686	26.23	1.08	-	14.45	-	17.07	-	17.07
2045	171,040	27.03	1.11	-	14.63	-	17.66	-	17.66
2046	174,461	27.83	1.14	-	15.34	-	18.12	-	18.12
2047	177,950	28.63	1.18	-	15.78	-	18.64	-	18.64
2048	181,508	29.44	1.21	-	16.22	-	19.16	-	19.16
2049	185,139	30.24	1.24	-	16.66	-	19.66	-	19.66
2050	188,842	31.04	1.27	-	17.10	-	20.20	-	20.20
2051	192,618	31.84	1.31	-	17.54	-	20.73	-	20.73
2052	196,471	32.64	1.34	-	17.98	-	21.25	-	21.25
2053	200,400	33.44	1.37	-	18.43	-	21.77	-	21.77
2054	204,408	34.25	1.41	-	18.87	-	22.29	-	22.29
2055	208,497	35.05	1.44	-	19.31	-	22.81	-	22.81

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2066	212,667	35.85	1.47	-	19.75	-	23.33	-	23.33
2067	216,920	36.65	1.50	-	20.19	-	23.86	-	23.86

Table 173. Annual Projected Cash Flow for Financing Option 3

	Passengers	Tariff Revenue	Other Revenue	Investment	Operational Cost	Interest Expense	Net Cash Flow	Principal Repayment	Total Net Cash Flow
	person	million USD	million USD	million USD	million USD	million USD	million USD	million USD	million USD
2025	-	-	-	121.24	-	-	-	-	-
2026	-	-	-	140.69	-	-	-	-	-
2027	-	-	-	36.22	-	-	-	-	-
2028	122,164	13.36	0.56	-	7.38	-	8.70	8.43	0.26
2029	124,593	14.15	0.58	-	7.80	-	9.22	8.94	0.28
2030	127,085	15.01	0.62	-	8.27	-	9.77	9.48	0.29
2031	129,627	15.81	0.65	-	8.71	-	10.28	9.98	0.31
2032	132,219	16.61	0.68	-	9.15	-	10.81	10.49	0.32
2033	134,884	17.41	0.71	-	9.59	-	11.34	11.00	0.34
2034	137,641	18.22	0.75	-	10.04	-	11.88	11.50	0.36
2035	140,312	19.02	0.78	-	10.49	-	12.38	12.01	0.37
2036	143,118	19.82	0.81	-	10.92	-	12.90	12.51	0.39
2037	146,081	20.62	0.85	-	11.36	-	13.42	13.02	0.40
2038	149,900	21.42	0.88	-	11.80	-	13.94	13.53	0.42
2039	151,878	22.22	0.91	-	12.24	-	14.47	14.03	0.43
2040	154,916	23.02	0.94	-	12.69	-	14.99	14.54	0.45
2041	158,014	23.83	0.98	-	13.13	-	15.51	15.04	0.47
2042	161,176	24.63	1.01	-	13.57	-	16.03	15.55	0.48
2043	164,399	25.43	1.04	-	14.01	-	16.55	16.05	0.50
2044	167,686	26.23	1.08	-	14.45	-	17.07	16.56	0.51
2045	171,040	27.03	1.11	-	14.89	-	17.59	17.07	0.54
2046	174,461	27.83	1.14	-	15.34	-	18.12	17.57	0.54
2047	177,950	28.63	1.18	-	15.78	-	18.64	18.08	0.56
2048	181,509	29.44	1.21	-	16.22	-	19.16	18.59	0.57
2049	185,139	30.24	1.24	-	16.66	-	19.68	19.09	0.59
2050	188,842	31.04	1.27	-	17.10	-	20.20	19.60	0.61
2051	192,619	31.84	1.31	-	17.54	-	20.73	20.10	0.62
2052	196,471	32.64	1.34	-	17.98	-	21.25	5.13	16.12
2053	200,409	33.44	1.37	-	18.43	-	21.77	-	21.77
2054	204,408	34.25	1.41	-	18.87	-	22.29	-	22.29
2055	208,497	35.05	1.44	-	19.31	-	22.81	-	22.81
2056	212,667	35.85	1.47	-	19.75	-	23.33		23.33
2057	216,920	36.65	1.50	-	20.19	-	23.86	-	23.86

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10.7. INTEGRATED SOCIO-ECONOMIC IMPACT SWOT ANALYSIS OF LIGHT RAIL TRANSIT (LRT)

Table 174. *SWOT Analysis*

Internal Factors	
Strengths	Weaknesses
Reducing Traffic Congestion – LRT will reduce traffic congestion in Ulaanbaatar and improve traffic flow throughout the city. Environmentally Friendly – Contributes to improving air quality by reducing vehicle emissions and harmful gases. Reliable Public Transportation – Improves the current bus system and reduces private vehicle usage. Economic Growth – Improved transport accessibility can lead to business development, increased property values, and new job creation. Government and Public Support – Government and international organization investments increase the likelihood of successful project implementation.	High Investment Costs – The project's initial investment is high, creating a burden on the state budget. Construction Challenges – Road closures, land acquisitions, etc. may cause difficulties for residents and businesses. Weather Impact – The extreme climate will increase LRT operation and maintenance costs. Financial Sustainability – The project's long-term profit and revenue may be overly dependent on governmental support. Limited Coverage – The first phase of construction risks not covering all parts of the city Financially Unprofitable – The project will operate at a financial loss if ticket prices remain at the same level as current public transport services.
External Factors	
Opportunities	Threats
Foreign Investment and Public-Private Partnership (PPP) – International organization financing and private sector participation can reduce budget pressure. Integration with Other Public Transport – Integration with bus networks, taxi services, and bicycle paths can make the system more accessible. Urban Planning and Infrastructure Development – Developing areas around LRT stations to establish residential and commercial zones. Technological Advancements – Implementation of smart ticketing systems, AI-based scheduling, and energy-efficient solutions. Improving Tourism and Accessibility – Developing urban infrastructure to support tourism and improve residents' quality of life.	Financing and Cost Increases – Project implementation may be delayed if budgets are exceeded or investor support is interrupted. Public Opposition – Some residents may oppose the project due to construction difficulties and changes in public transportation. Land Issues – Land acquisition difficulties may affect the project timeline. Economic and Political Risks – Mongolia's economic conditions, currency fluctuations, and political changes may negatively impact the project.

Leveraging Strengths to Utilize Opportunities

1. **Reducing Congestion and Improving Urban Planning**
   - Plan LRT stations in strategic locations to develop commercial, service, and residential projects
   - Implement zoning development policies to benefit from increased land valuation.
2. **Using Environmental Advantages to Attract Financing**
   - Seek support from international financial institutions by positioning the project as reducing emissions and meeting sustainable development goals.
   - Participate in green loan financing and carbon offset programs.
3. **Developing a Reliable Transport System Integrated with Other Modes**
   - Align bus routes with the LRT and implement smart payment systems.

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- Improve taxi services, bicycle paths, and pedestrian crossings.

4. **Accelerating Economic Growth**
   - Attract international financing and private sector investment.
   - Create jobs during construction and operational phases.

Seeking Opportunities to Overcome Weaknesses

1. **Reducing High Cost Risks**
   - Utilize long-term, low-interest financing.
   - Monitor project expenditures against the approved budget.
2. **Minimizing Construction Challenges**
   - Implement a zoned, phased construction plan.
   - Conduct land acquisition activities legally and provide compensation to residents.
3. **Reducing Weather Impacts**
   - Use technologies suitable for winter operation (heated tracks, enclosed stations, de-icing systems).
   - Automate regular maintenance.
4. **Ensuring Financial Sustainability**
   - Create multiple revenue streams (advertising, rentals, government support).
   - Set strategic ticket pricing and develop a sustainable financing model.
5. **Expanding Coverage**
   - Plan additional stations in urban areas.
   - Install payment systems compatible with buses and other public transport.

Strengths to Mitigate Risks and Challenges

To successfully implement the Ulaanbaatar LRT project, it is necessary to leverage the project's strengths to reduce potential risks and challenges. By utilizing public support, environmental friendliness, and economic benefits, potential difficulties can be effectively addressed.

1. **Using Traffic Reduction Benefits to Decrease Public Opposition and Negative Attitudes from Current Transport Operators**
   - Promote that LRT will improve overall traffic flow and benefit all road users.
   - Work with bus and taxi service operators to ensure route integration, fostering cooperation rather than competition.
2. **Using Environmental Friendliness to Attract Green Financing and Reduce Operating Costs**
   - Emphasize LRT's importance in reducing emissions and improving urban air quality to attract financing from Green Financing Programs (Green Climate Fund, ADB, etc.).

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- Use energy-efficient trains and renewable energy to reduce long-term operational costs.

3. **Using Government and Public Support to Reduce Policy and Financing Risks**
   - Align the project with Mongolia's long-term development policies to ensure political stability.
   - Maintain regular communication with the public, ensure transparency, and increase citizen participation.
4. **Using Economic Growth and Job Creation Benefits to Reduce Financing Risks**
   - Create numerous jobs during construction and operation, positively impacting economic growth.
   - Develop areas around LRT stations, creating commercial and service centers to generate additional funding sources for the project.
5. **Developing Reliable Infrastructure to Reduce Weather-Related Risks**
   - Implement solutions suitable for winter operation (e.g., heated tracks, enclosed stations, de-icing systems).
   - Use artificial intelligence and automated maintenance systems to ensure reliable train operation.
6. **Addressing Limited Coverage Issues through Integration with Other Transport Modes**
   - Integrate LRT stations with bus networks, taxis, and bicycle paths to make them more accessible to passengers.
   - Implement smart payment systems to facilitate transitions between different types of public transport.

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CHAPTER 11. PROJECT RISK ANALYSIS AND SAFETY

11.1. RISK ANALYSIS METHODOLOGY

Risk Analysis Steps

The risk analysis for the Light Rail Transit (LRT) project connecting the resort area to the city center, implemented according to the EPC-based budget financing model, will follow these comprehensive steps:

1. **Identify All Potential Risks** Develop a comprehensive list of all potential project risks, including:
   - Construction risks: Delays caused by weather conditions, land acquisition issues, supply chain disruptions.
   - Operational risks: Uncertainty in initial passenger demand and operational and management costs higher than anticipated.
   - Financial risks: Budget overruns, cost increases due to inflation, exchange rate fluctuations.
   - Legal and regulatory risks: Delays or complications arising from uncertainty in transport policy or the legal framework.
   - Focus on risks where the government has direct oversight and bears financial responsibility.
2. **Risk Assessment and Classification** Categorize risks by probability of occurrence and impact as high, medium, or low:
   - High risk: Construction delays affecting project deadlines, financial instability, regulatory challenges.
   - Medium risk: Inefficiencies in operations and management or initial operational capacity issues.
   - Low risk: Minor material delays or small-scale contractor performance issues.

   To improve clarity, risks will be categorized as:

   - Internal risks: Risks arising within the project scope, such as construction delays, regulatory issues.
   - External risks: Influence of external factors, such as geopolitical challenges or global economic fluctuations.
3. **Determine Risk Probability and Magnitude of Damage** Use quantitative techniques to estimate potential financial losses and probabilities:
   - Example: Severe winter conditions delaying construction could increase costs by 8-12%.
   - Highlight risks with significant financial implications for the government.
4. **Calculate Risk Value Using Scenario Analysis and Financial Modeling** Evaluate different risk outcomes using scenario analysis, for example:
   - Scenario A: Passenger numbers below expectations in the first five years.
   - Scenario B: High inflation increasing operational costs by 20%.

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- Develop financial simulations to evaluate the impact of risks and develop risk mitigation strategies.

Risk Allocation Methodology

In publicly funded projects, risk allocation operates on the principle that the government bears full responsibility for major risks. Key stakeholder roles include:

1. Performance Risks: Primarily the responsibility of the EPC contractor, with the Project Management Consultant (PMC) having an oversight role. Contracts should include penalty clauses for delays or quality issues. Operations and Maintenance (O&M) risks: Allocate operations and maintenance to the government and institution. The Project Management Consultant (PMC) to monitor operational performance in the initial phase and take corrective measures.
2. Financial Risks: Fully the responsibility of the government. Prepare risk budgets and funding guarantees to mitigate cost overruns and currency fluctuations.
3. Legal and Regulatory Risks: The government should establish a clear regulatory framework and ensure policy coherence.

Risk Management Measures for Major Project Risks

Key Risks in Implementing the Light Rail Transit (LRT) Project

The main risks that may affect the project and their consequences include:

1. Viability Gap Risk: Financial sustainability challenges associated with high initial investment costs.
2. Revenue Volatility Risk: Fluctuations in tariff revenue due to demand variability or economic conditions.
3. Financial and Political Risk: Financial and political risks associated with Mongolia's credit rating.
4. Exchange Rate Risk: Risk of increased costs for equipment and materials purchased in foreign currency.
5. Legal and Regulatory Risk: Delays due to weak institutional and legal framework.

Viability Gap Risk

Viability gap risk arises when the initial investment cost of infrastructure projects such as trams is high and cannot be recovered solely through operational revenues, such as passenger fares. While the investment required for such infrastructure is enormous, the long-term economic benefits can contribute to stimulating regional economic growth and improving quality of life.

Challenges

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Financial burden of major public infrastructure projects:

- In public financing models, the financial burden often falls on the government, necessitating innovative financial strategies and sustainable economic development to compensate.

Project delays and cost escalation:

- Delays in decision-making and project implementation may increase costs and cause project timelines to slip. Active management is crucial to mitigate this risk.

Public perception and social resistance:

- Limited public understanding and support for the LRT project may cause delays and resistance. Transparent communication and public participation are essential to build trust and secure support.

Economic disparities:

- Regions with limited tax base or weak economic activity face increased risk of financial deficiency, requiring targeted planning to ensure financial sustainability.

Risk Mitigation Strategies

A multifaceted approach combining budgetary measures, urban planning strategies, and government-supported policies is essential to address viability gap risk:

Enhance Revenue through Tax and Development Policies:

- Increase Economic Efficiency: Increase revenue through property taxes, corporate taxes, and VAT resulting from economic activity along the tram route.
- Designate specific areas as development zones to increase investment and economic returns.
- Special Development Zones: Declare land around stations as special development zones to attract investment in commercial, residential, and mixed-use projects.

<u>Economic Development Initiatives:</u>

- Stimulate Business Growth: Increase business activity by improving connectivity and reducing travel time.
- Indirect Economic Benefits: Implement policies to capture benefits such as increased employment, consumer spending, and regional GDP growth.
- Urban Renewal Programs: Implement renewal projects along the tram corridor, focusing on improving living environments and creating sustainable revenue sources.

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Time Risk and Project Performance Management:

- Conduct detailed analysis of project schedules and develop management mechanisms to monitor critical phases.
- Improve stakeholder coordination and optimize decision-making from the early stages of the project.

Public Participation and Social Risk Management:

- Transparently communicate project benefits and encourage public participation to support resident feedback.

Government Policy Support and Incentives:

- Active Tax Policy: Develop tax policies that invest in tram-related economic activities. For example, implement property tax increments in areas experiencing rapid price increases.
- Public Incentives: Offer tax breaks to businesses and property investors located in the tram zone to stimulate investment and promote economic development.
- Monitoring and Regulation: Regularly monitor tax policies and revenue streams to adapt to economic changes.

Financial Risk Mitigation Measures:

- Expand the tax base and create long-term sustainable revenue sources.
- Attract private sector and international investment through policy reforms and flexible mechanisms.

Key Considerations:

The project's financial sustainability ultimately depends on the government's ability to effectively integrate these strategies and manage associated risks. Long-term planning, policy coordination, and stakeholder involvement are critical to enhancing the economic potential of the tram system while reducing viability gaps.

Revenue Volatility

Revenue volatility risk refers to the risk associated with uncertainty in revenue generated from the project, particularly transport fee revenue. This stems from passenger numbers, operational challenges, and external economic factors. In publicly funded projects, revenue risk may be less critical than in PPP models, but it remains important for ensuring long-term financial sustainability and operational efficiency.

Challenges

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1. Overoptimistic Demand Projections: Passenger numbers may be below expected levels when the tram begins operation. Demand fluctuations can result from economic downturns, competition from other transport modes, or obstacles to integrating the tram into the existing public transport network.
2. Insufficient Transit Network Integration: If the tram lacks connecting bus routes to other stations and connections to other public transport, passenger satisfaction may decrease, likely reducing passenger numbers.
3. Long-term Financial Sustainability Risks: Initial years will see lower usage and tend to have reduced revenue, requiring appropriate measures to ensure long-term financial sustainability.
4. Public Trust and Tariff Policy Issues: High fares may not attract passengers, while excessively cheap prices lead to operational losses. Additionally, lack of transparency in tariff policy can negatively impact public trust.

Risk Mitigation Measures

To effectively manage revenue volatility risk, we recommend implementing a combination of fare policy, public transport network integration, and government financial support:

1. Develop Tariff Policy
   - Affordability and Revenue Needs: Initial tariffs should be in proportion to income to ensure public accessibility.
   - Dynamic Tariff Adjustments: The policy framework should allow for timely tariff adjustments considering inflation, additional operational costs, and economic changes. These changes should be communicated transparently to maintain public trust and acceptance.
2. Transit Network Integration
   - Integrated Connections: Improve passenger comfort and increase passenger numbers by connecting tram stations with other transport systems through connecting buses.
   - Develop Intermodal Centers: Establish intermodal centers at tram stations to facilitate transfers and ensure sustainable demand.
3. Government Financial Support
   - Emergency Subsidies: If passenger numbers are below planned levels in initial years, the government should provide funding to cover operational losses.
   - Long-term Financial Planning: Develop a sustainable financial plan covering operations and maintenance (O&M) costs for the first 5-10 years.
4. Develop Demand Forecast Scenarios
   - Scenario Planning: Develop various demand scenarios based on factors such as economic growth, demographic changes, and inflation trends.
   - Accurate Projections: Avoid overly optimistic passenger flow projections and anticipate potential deficits with realistic projections.
5. Revenue Guarantee Mechanisms
   - Government Guarantees: The government should provide guarantees to ensure stable operations in case of revenue shortfalls.

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- Performance-Based Incentives: Link subsidies or financial support to operational performance to encourage efficient operations.

Key Considerations

Addressing revenue volatility risk requires an integrated approach combining financial, operational, and policy measures. Transparent communication with stakeholders, public trust in pricing policy, and robust transit network planning are crucial to mitigating revenue volatility risk and ensuring the system's financial sustainability.

Financial and Political Risk

Mongolia's credit rating, economic stability, and external borrowing capacity-related financial and political risks may significantly affect the project's financial structure and conditions for foreign investment and loans.

Table 173. Mongolia's Foreign Currency Credit Rating

Country	Country Rating (Moody's 2024)	GDP per capita (2024 USD)
Republic of China	A1	13,720
Russian Federation	Ba1	11,630
Kazakhstan	Baa2	10,340
India	Baa3	2,980
Mongolia	B2	5,580
Ukraine	Caa3	3,870
Vietnam	Ba2	4620

Note: Aaa>Aa>A>Baa>Speculative>Ba>B>Caa>Ca>C (1>2>3)

Source: Moody's Investors Service, Worldbank, IMF(2024)

CHALLENGES:

1. Poor credit rating: Mongolia has a Moody's B2 rating, which is classified as high investment risk, and this rating makes it difficult to obtain foreign loans compared to neighboring countries like China (A1) and Russia (Ba1).
2. High dependence on foreign financing: Due to limited domestic financial resources, Mongolia relies heavily on foreign loans and investments to implement infrastructure projects. However, this dependency increases the risk of exposure to political and financial risks associated with international lenders.
3. Economic vulnerability: Mongolia's economy is heavily dependent on mining exports, making it susceptible to fluctuations in global market commodity prices. This economic instability risks deterring foreign investors and lenders.
4. Political and institutional instability: Legal and regulatory instability, political changes, and bureaucratic obstacles can delay the project approval process and negatively impact infrastructure project implementation timeframes and financial efficiency.

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5. Geopolitical and International Factors: Changes in the international political and economic environment and policy changes in neighboring countries may adversely affect Mongolia's access to international financing.

RISK MITIGATION MEASURES:

To effectively address the country risk challenges, the following risk mitigation measures are proposed:

Debt Management:

- International Financial Institutions (IFIs) and Export Credit Agencies (ECAs) provide guarantees for long-term foreign currency financing through concessional loans and guarantees. These institutions can provide favorable terms with low interest rates and favorable repayment conditions as mentioned in Table 75.
- Develop a debt management system to optimize payment schedules and reduce Mongolia's dependence on high-risk financing.

Table 176. IFI and ECA Programs for Infrastructure Development Projects

Institution Name	Support Type	Focus Sectors
World Bank (IBRD, IDA)	Concessional loans	Infrastructure, social development, climate adaptation
Asian Development Bank (ADB)	Technical assistance	Urban development, transportation, energy
International Finance Corporation (IFC)	Project financing	Private sector participation (Limited)
European Investment Bank (EIB)	Long-term loans	loansEnergy, Water supply infrastructure
Export Credit Agencies (ECAs)	Guarantees	Political risk protection, infrastructure

Source: World Bank ADB, IMF, EIB(2024)

2. **Increase Domestic Financial Sources:**
   - Increase domestic revenue through innovative financing mechanisms such as tax reforms, land value capture, and public-private partnerships (PPP).
   - Establish wealth funds to stabilize state budget revenues and build reserves to protect against economic shocks.
3. **Diversify Economic Base:**
   - Expand the economic base by developing non-mining sectors such as tourism, agriculture, and renewable energy to reduce vulnerability to global market commodity price fluctuations.
4. **Strengthen Institutional Capacity:**
   - Implement institutional reforms to strengthen governance, including creating transparent decision-making processes and simplifying regulations.
   - Provide training programs for civil servants to improve decision-making and cooperation with international organizations.

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5. **Political Risk Mitigation Measures:**
    - Conduct regular political and economic impact assessments involving neighboring countries and international organizations.
    - Develop contingency plans to address risks associated with geopolitical tensions and financing delays.
6. **Time Management:**
    - Define realistic project implementation schedules and include critical phases to ensure financial and operational stability.
    - Regularly monitor project progress to avoid delays and cost overruns.

KEY CONSIDERATIONS:

Managing financial and political risks requires not only implementing financial strategies but also political and institutional improvements. The main proposed measures are:

- **Improve legal and policy framework:** Develop specific regulations and policies for major infrastructure projects.
- **Strengthen international cooperation:** Develop partnerships with institutions such as the World Bank and ADB to align with global best practices.
- **Increase transparency:** Implement internationally recognized project management reporting and standards to build investor confidence.

By addressing these challenges comprehensively, dependence on high-risk financing will decrease, the economy will stabilize, and a favorable environment for infrastructure development will be created.

Currency Exchange Rate Risk

Currency exchange rate risk arises when conducting transactions in foreign currencies for project expenses, particularly for equipment purchases and acquisition of rolling stock. Although funding for the Light Rail Transit (LRT) project connecting the resort area to the city center can primarily utilize domestic currency, which helps reduce this risk, key components need to be sourced from foreign suppliers, making the project vulnerable to currency exchange rate fluctuations.

Challenges:

1. Dependence on foreign manufacturer purchases: • Many tram components such as rolling stock and specialized equipment cannot be purchased domestically and must be imported. • Currency exchange rate instability leads to cost overruns during procurement or especially during contract payments.

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2. Insufficient domestic production capacity: • Limited domestic production capabilities increase dependence on foreign suppliers, increasing exposure to currency risks.
3. Global currency market fluctuations: • Sudden and significant changes in global exchange rates due to geopolitical disputes or economic instability may unexpectedly increase procurement costs.
4. Geopolitical risks: • Geopolitical tensions or regional instability may exacerbate currency market fluctuations and potentially disrupt supply chains.

Risk Mitigation Measures:

To address currency risks, a combination of procurement strategies, financial planning, and currency risk management methods will be implemented:

1. Prioritize domestic sourcing: • Give priority to domestic manufacturers where possible to reduce dependence on foreign suppliers and strengthen domestic supply chains. • Develop domestic production capacity to meet the long-term needs of Light Rail Transit (LRT) project components.
2. Secure favorable foreign aid conditions: • Engage with international financial institutions (e.g., ADB, World Bank) or bilateral agreements to obtain concessional loans and grants with favorable currency conditions. • Establish long-term contracts with fixed exchange rate terms to reduce cost fluctuations.
3. Utilize hedging strategies: • Use financial instruments such as currency insurance or forward contracts to maintain exchange rates and reduce the impact of fluctuations. • Collaborate with international agencies to use risk protection instruments tailored to infrastructure projects.
4. Develop contingency budget: • Reserve a specific portion in the project's financial plan to address unexpected expenses resulting from currency exchange rate fluctuations. • Monitor currency market movements and make appropriate budget adjustments to avoid sudden financial risks.
5. Strengthen currency risk monitoring and management systems: • Implement systems to monitor currency fluctuations and geopolitical impacts on procurement costs. • Improve collaboration between financial institutions and government agencies to enhance response mechanisms.
6. Key considerations: An active, multi-faceted approach is required to reduce foreign exchange risk. Domestic financing reduces the likelihood of exposure to currency risk, but establishing strategic partnerships with international financial institutions and improving currency risk management policies play a crucial role in ensuring project cost stability. Strengthening domestic production capacity, diversifying supply chains, and using financial hedging instruments can protect against foreign exchange rate fluctuations and ensure budget stability.

Table 177. Risk Mitigation Measures

Strategy	Description

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Domestic resources	Emphasize domestic purchases of materials and equipment to reduce currency risk.
Favorable foreign aid	Collaborate with institutions that provide fixed-rate concessional loans.
Currency hedging	Use instruments such as forward contracts and currency insurance to manage risk.
Reserve fund planning	Create financial reserves to compensate for cost increases due to currency fluctuations.
Improve risk monitoring	Implement systems to monitor exchange rates and geopolitical impacts, improving response measures.

11.2. LEGAL FRAMEWORK RISK

It is essential to establish appropriate legal, institutional, and infrastructure systems during this publicly funded implementation phase. If these systems are not sufficiently developed, there is a high risk of extended permit issuance periods, inefficiencies, or financial constraints, which could hinder project progress and successful implementation.

Risks:

1. Limited Legal and Policy Framework: Mongolia lacks comprehensive regulations and policies suitable for large-scale tram systems, increasing the likelihood of delays in approval and compliance processes. It is important to emphasize that the absence of a legal and regulatory framework is a key gap affecting project implementation.

2.Institutional Capacity Deficit: Government agencies and relevant parties lack experience in "managing urban rail transport projects," slowing decision-making and regulation. Effective capacity-building programs are needed to overcome this challenge.

3.Inadequate Infrastructure Readiness: Critical infrastructure such as integrated traffic systems, urban roads, and safety standards are underdeveloped, causing difficulties in effectively supporting tram operations.

4.Specialized Knowledge Requirements: Developing legislation and technical standards tailored to the project's specifics requires specialized knowledge. The technical supervision and collaboration of the Project Management Consultant (PMC) will play a crucial role in effectively implementing the project on time.

Risk Mitigation Measures:

A phased approach involving legislation development, institutional capacity strengthening, and close collaboration with the Project Management Consultant (PMC) is required to address legal regulatory risk:

Risk Classification: Recognizing that the lack of legal and regulatory framework is the main challenge improves risk classification accuracy. For example, in the "Legal and Policy Framework Limitations" section, it is important to emphasize that this framework is not limited but completely missing or incomplete. This allows for a clearer understanding of institutional and infrastructure gaps.

Risk Mitigation Measures:

Comprehensive Legal Study: Conduct a detailed study of Mongolia's legal environment with respect to urban public transport specifics.

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Develop Preliminary Regulations: Create essential rules and policies necessary for tram operations, such as safety standards and land acquisition guidelines.

Leverage International Experience: Study regulatory approaches successfully implemented in similar countries and implement these experiences in Mongolia's policy program.

Stakeholder Cooperation and Capacity Building:

Strengthen civil servant preparation through seminars, training programs, and capacity-building activities.

Facilitate decision-making processes by organizing regular coordination meetings between the project management consultancy (PMC), government agencies, and other stakeholders.

Standardized Processes and Manuals:

Standardize procurement, contracting, and project management processes to reduce uncertainty and delays.

Develop internationally recognized systems and models to ensure consistency.

Focus on Domestic Policy Integration:

Align tram-related regulations with Mongolia's broader urban transport and infrastructure policies to ensure coherence.

Create the legal and institutional foundation for implementing long-term tram operation and expansion plans.

Key Considerations:

Addressing legal framework risk is essential for project progress and successful implementation. Implementing the proposed measures will create a solid legal and regulatory foundation to reduce delays, optimize efficiency, and ensure sustainable development of urban transport infrastructure for the Light Rail Transit (LRT) project connecting the resort area to the city center.

11.3. KEY RISK ANALYSIS AND MANAGEMENT MEASURES

Common Risks

The first step in this process is to create a risk matrix as identified in the following table. These tables summarize common project-related risks by type and detail corresponding management measures. In a budget-funded model, most risks such as political, social environmental, and force majeure are regulated by the government, which is responsible for ensuring project efficiency.

Table 173. Common Risks

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Planning Phase Risks

The preliminary planning phase focuses on detailed design, preliminary studies, and aligning stakeholder expectations. Delays or errors in this phase can cause significant disruptions in the construction and operational phases.

Table 179. Detailed Risks and Mitigation Measures in the Planning Phase

Risks of the Planning Phase

Risk Type	Detailed Information	Risk Description	Risk Mitigation Measure
Political Risk	Legal, regulatory risk	Changes in law, regulatory requirements public transport policy	Create legal regulatory environment, coordinate regulations
	Political risk	Change in governance, delay in approval process	Political risk insurance, resolve disputes in advance
	Permit/Approval risk	Changes or delays in permit conditions	Follow regulations
	Risk of legal changes	Updated tax legislation or changes in tax rates	Consult and discuss policy with stakeholders
Economic Risk	Price risk	Project cost changes due to inflation/deflation	Price indexation mechanisms, tariff change policies
	Interest rate risk	Financial pressure arising from loan interest rate fluctuations	Protect from interest rate risk, long-term fixed interest loans
	Currency exchange risk	Increased procurement costs due to currency fluctuations	Protect from currency risk, use national currency
Natural disaster risk	Resident opposition risk	Land acquisition or project plan opposition by local people	Work early with the public, maintain transparent relations
	Environmental risk	Potential environmental pollution during construction	Follow environmental standards, monitoring plan
	Response protocol, force majeure provisions	Delay in construction work and operations due to earthquake or severe weather conditions	Emergency response protocol, force majeure provisions

The preliminary planning phase focuses on developing detailed designs, conducting preliminary studies, and aligning stakeholder expectations. Delays or errors occurring during this phase can lead to significant disruptions during both the construction and operational phases.

Table 180. Detailed Risks in the Planning Phase and Mitigation Measures

Risk Type	Risk Description	Risk Mitigation Method
Survey/assessment risk	Engineering-geological survey and land assessment data	Implement comprehensive survey procedures, apply appropriate survey technology

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Design risk	Design errors and non-compliance with standards	Implement thorough design verification, apply expert evaluation
Management/Control risk	Environmental assessment, control mechanism implementation	Implement effective control procedures, apply comprehensive monitoring methods

Construction Phase Risks

The construction phase transitions the plan to actual construction, increasing the likelihood of exposure to physical risks such as weather-related delays, resource shortages, and quality control issues. Mongolia's climate and land acquisition challenges further amplify these risks.

Table 181. Detailed Construction Phase Risks and Mitigation Measures

Risk Type	Detailed Information	Risk Mitigation Measure
Weather-Related Delays	Harsh winter conditions reduce possible working time	Account for winter season downtimes, adjust schedules, and invest in cold-weather technologies
Land Acquisition Risk	Delayed land permission issues along stations	Secure land rights during planning phase; provide fair compensation
Resource Shortage Risk	Supply disruption of critical materials such as rebar and concrete	Contract with multiple suppliers, increase reserves, develop domestic supply strategy
Cost Overrun Risk	Unforeseen costs due to time overruns or inflation	Establish EPC (Engineering, Procurement, and Construction) contracts with fixed costs including specific penalty clauses for delays
Quality Control Risk	Risk of substandard performance due to rushing construction ahead of schedule	Implement strict quality control measures and regular third-party inspections
Utility Network Damage Risk	Risk of damaging underground utility networks and infrastructure not included in mapping	Conduct detailed underground surveys (e.g., Ground Penetrating Radar - GPR) and include identified networks in designs
Unforeseen Utility Network Damage	Risk of delays due to unforeseen underground infrastructure damage	Form a dedicated team responsible for utility-related issues during construction to resolve quickly
Technical and Geological Risk	Sudden soil issues, seismic risks, water penetration complications	Conduct geotechnical studies, implement site-specific engineering solutions, and develop risk contingency plans
Transport and Logistics Risk	Construction material transport delays, supply chain failures	Develop logistics management plans, prepare alternative transport routes, improve material reserves
Road Closure Related Risk	Traffic congestion from road closures, impact on passenger safety, service flow disruption, negative impact on businesses in the domestic impact zone, additional costs	Develop detailed traffic management plans to reduce road closure impacts, provide advance notice to stakeholders, increase route options, perform construction work during low traffic hours

Operational Phase Risk

After the tram becomes operational, it will face real-world conditions including passenger flow fluctuations, cost increases, and integration issues with other transport

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modes. The operational phase is crucial for creating long-term financial sustainability and public satisfaction.

Risk Type	Detailed Information	Risk Mitigation Measure
Market Risk	Passenger numbers not reaching expected levels, insufficient demand, declining passenger numbers	Implement promotional programs; improve connectivity with other public transport networks such as BRT (Bus Rapid Transit)
Tariff Risk	Passenger resistance to tariff changes, negatively impacting revenue streams	Implement tariff increases gradually; distribute transparent information about tariff policy
Operation and Maintenance Cost Risk	Operational inefficiencies, increased costs due to external economic factors	Implement performance-based Operation and Maintenance contracts; regularly audit operational costs
Maintenance Risk	Equipment failure or poor maintenance	Establish maintenance schedules ensuring operational reliability, invest in technology to improve maintenance
Technology Risk	Cybersecurity risks and system failures due to outdated technology	Conduct regular cybersecurity audits, invest in system upgrades, develop emergency response plans for technical failures

11.4. SAFEGUARDS PACKAGE

For projects funded from the state budget, such as the "Project to introduce multimodal public transport (tram) from Buyant-Ukhaa Sports Complex to Torgonii Road Complex, from 120 thousandth Intersection to Sukhbaatar Square," traditional safety packages used in PPP projects cannot be utilized since private sector financing is not involved. Instead, implementing the project requires specialized measures focused on stability and efficient financial management.

Key Challenges:

Protecting Public Investment:

1. Ensure effective use of public funds by preventing budget overruns, delays, and improper resource management.
2. Prevent financial instability risks arising from unforeseen circumstances such as inflation or sudden policy changes during project implementation.

Financial Accountability:

1. Ensure transparency in government funding allocation and utilization to build public trust.
2. Establish reliable financial control mechanisms to prevent potential financial violations and inefficient expenditures.
3. If financing comes from international financial institutions (e.g., World Bank or ADB), additional guarantees and management controls must be established to meet their requirements and ensure smooth disbursement of funds.

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Components of the Safeguards Package:

To successfully implement the project and protect public investment, we recommend the following measures for the safeguards package:

Risk Analysis

Identify all potential risks associated with the project, including environmental, political, and financial risks. Example risks:

- Environmental risks: Causing environmental pollution during construction.
- Political risks: Delays in legislative approval or changes in government policy.

Develop mitigation measures, such as:

- Ensuring early stakeholder involvement.
- Continuous monitoring and compliance checks.

Contracts and Guarantees

Contracts: Develop clear, legally enforceable contracts with contractors, suppliers, and other parties involved in the project, clearly defining responsibilities and liabilities for violations.

- Include fixed costs in "EPC" (Engineering, Procurement, and Construction) contracts to reduce cost overruns.

Guarantees:

- Create government-backed financial guarantees to ensure timely payments and prevent construction delays.
- When participating in international financing, comply with foreign guarantee requirements to maintain international lender confidence.

Financial Stability and Control

1. Develop a financial management plan that ensures transparency and sustainability.
    - Implement multi-stage calculations accounting for price increases and cost additions.
    - Establish a reserve fund to finance unexpected expenses.
2. Conduct regular inspections and reporting to ensure accountability.
3. Minimize foreign debt to reduce dependence on foreign currency loans and avoid exchange rate risks.

Integrating International Financial Institution Oversight

1. For projects partially financed by international financial institution loans:
    - Work with these institutions to ensure compliance with financing agreements.
    - Implement independent audit mechanisms to monitor financial expenditures.

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2. Example: Collaborate with institutions such as ADB, World Bank to adhere to strict financial standards when providing concessional loans.

Monitoring and Evaluation Framework

1. Establish a monitoring system to track project progress and financial performance.
   - Key Performance Indicators (KPIs) may include construction progress, financial efficiency, and effectiveness of risk mitigation activities.
2. Conduct regular evaluations to identify areas for improvement and implement strategies.

In infrastructure projects funded from the state budget, the safeguards package serves as an essential tool for effectively spending and protecting budgetary resources. By integrating risk management strategies, detailed contracts, and financial control mechanisms, the government can reduce risks, increase transparency, and ensure successful project implementation. Such a system not only guarantees efficient financial management but also strengthens public confidence in the government's capacity to sustainably implement major infrastructure projects.

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CHAPTER 12.PROJECT IMPLEMENTATION PLAN AND WORK SCHEDULE

Chapter Sub-contents:

- Project management methodology and plan
- Project work schedule
- General organization of construction work

General Provisions

Implementing the tram complex construction project will contribute to improving the public transport system within Ulaanbaatar, reducing traffic congestion, decreasing air pollution, protecting the environment, and increasing economic efficiency by improving citizens' quality of life.

When implementing the project, it is important to develop a project management plan following international project management standards, paying attention to risk management, technological and quality control, environmental impact mitigation, human resource management, budget and time control, and communication management. By properly organizing and implementing these elements, the project's objectives can be successfully realized, enabling the successful implementation of a high-quality, safe, modern tram system.

12.1. PROJECT MANAGEMENT METHODOLOGY

A Hybrid project management methodology is most appropriate for implementing the tram construction project, combining both Waterfall (traditional) and Agile (adaptive) methodologies. This hybrid approach allows for efficient organization and execution of work while enabling adaptation and response to uncertainties, emerging challenges, and changes when necessary.

Traditional (Waterfall) Methodology:

- All project processes are performed sequentially in a specific manner, within fixed timeframes, and all requirements are developed in a clear, planned manner.
- Time and budget are precisely established and followed from the initial phase of the project.

Adaptive (Agile) Methodology:

- This methodology will be used during project execution, especially during the construction and system testing phases, allowing quick responses when new challenges or changes arise in the project.

This hybrid approach provides the ability to effectively monitor project progress while allowing adaptability to circumstances.

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Project Planning and Documentation

The project will follow international standards and best practices during implementation. The following documents will be developed and followed to monitor and organize the project progress:

Project Management Plan

The project management plan is the primary document defining all types of project management, organization, objectives, and processes. This document will contain the following content:

- Scope Management: Defines the project's scope of work, deliverables, outcomes, phases, and limitations.
- Time Management: Defines a comprehensive schedule detailing the phases of each project activity and deadlines for each major activity.
- Budget Management: Defines the budget plan covering all life cycle costs including project design, construction, procurement, and operational costs.
- Quality Management: Defines how quality standards will be maintained throughout the project life cycle, ensuring that all construction and operational processes comply with specified standards and requirements.

Procurement Plan

Defines the process for purchasing all materials, services, and equipment required for project implementation. This plan will define the processes for selecting suppliers, managing the tender process, and contracting.

Risk Management Plan

A risk management plan will be developed to identify, assess, and mitigate all project risks. This plan will:

- Identify Risks: Detect technical, financial, environmental, and safety-related risks.
- Conduct Risk Assessment: Analyze and evaluate the impact and probability of identified risks.
- Mitigate Risks: Develop strategies to reduce or eliminate risk impacts.

HSE and Environmental Plan

An HSE (Health, Safety, and Environment) plan will be developed to provide a safe working environment for all workers involved in the project. This plan will include safety measures, emergency plans, and environmental protection standards to reduce impacts around the construction work.

Quality Management Plan

The quality management plan defines quality control and verification procedures for the project, including:

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- Inspection and Testing: Verifying that materials and work comply with quality standards
- Audits and Evaluation: Conducting regular quality audits and inspections throughout the project life cycle.

Project Key Documentation and Reports

For successful project implementation, the following documents and reports need to be developed and monitored:

- Project Charter: A document defining the project's purpose, objectives, and stakeholders.
- Project Progress Report: Regular reports that monitor project status, including achievements, challenges, potential delays, and issues.
- Change Request: Documents for making and approving any changes to the project scope, schedule, or budget.
- Final Report: A report reflecting all work results, achievements, and lessons learned after the successful completion of the project.

International Standards and Requirements

All project activities must comply with international standards. For example:

- ISO 9001: Quality Management System.
- ISO 14001: Environmental Management System.
- ISO 45001: Occupational Health and Safety Management System.
- PMI PMBOK® Guide: International standard for project management.
- FIDIC Contracts: Internationally recognized guidelines for construction contracts.

Project Execution and Control

The project will be implemented in phases, and a regular system for monitoring project timeline, budget, quality, and risks must be continuously implemented.

- Progress Monitoring: Regularly evaluate project activities and take measures for any delays, budget overruns, errors, non-conformities, and record and resolve other necessary issues.
- Cost Control: Continuously monitor project costs, control payments, complaints, and cost changes resulting from scope modifications.
- Schedule Control: Regularly monitor phase and final deadlines to ensure project completion on time.

Stakeholder Engagement and Communication

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For successful project implementation, it is important to properly identify stakeholders, determine their interests, influence, and responsibilities, and implement effective communication management to ensure their productive involvement. Hold regular meetings with project stakeholders, provide reports, and update their records as needed. Key project stakeholders include:

- Government authorities,
- Project financiers, investors,
- Local citizens, residents,
- Tenderers and suppliers, etc.

Project Handover and Closure

After project completion, all systems and equipment will be inspected, adjusted, and a comprehensive verification process will be conducted until commissioning. All project results will be consolidated and handed over along with documentation.

Project Work Schedule

The project work schedule plays a crucial role in monitoring project implementation and efficiency, ensuring compliance with planned objectives and criteria. When developing the construction schedule, both long-term and short-term planning must be thoroughly incorporated. When organizing the project schedule, it is necessary to closely examine the construction control processes, the connections between preceding and subsequent processes, taking into account construction work, technical requirements, geographic location, geological conditions, weather conditions, environmental conditions, project complexity, and other factors.

12.2. OVERALL PROJECT DURATION:

The total project duration is 25 months. The project work sequence consists of multiple activities including construction preparation work, land acquisition, tram track, stations, buildings, power supply, automation systems, transport management systems, rolling stock delivery, transport equipment installation, and testing and adjustment. The schedule is defined as follows:

Table 162. Construction Work Plan Overview

WORK SECTION	ACTIVITY NAME	DURATION
1. Construction Preparation Work	Engineering surveys, road line relocation, utility line relocation along the route, temporary bridge construction, site clearance.	3 months
2. Tram Track Construction	Railway installation, concrete foundation installation, installation of rails and crossovers.	15 months
3. Power Supply Work	Substation, overhead contact line and underground cable installation, high voltage line installation, tunnel construction.	15 months
4. Signaling and Communication System Installation	Transport control system, traffic lights, camera system, automatic blocking system, and fiber optic cable installation.	8 months

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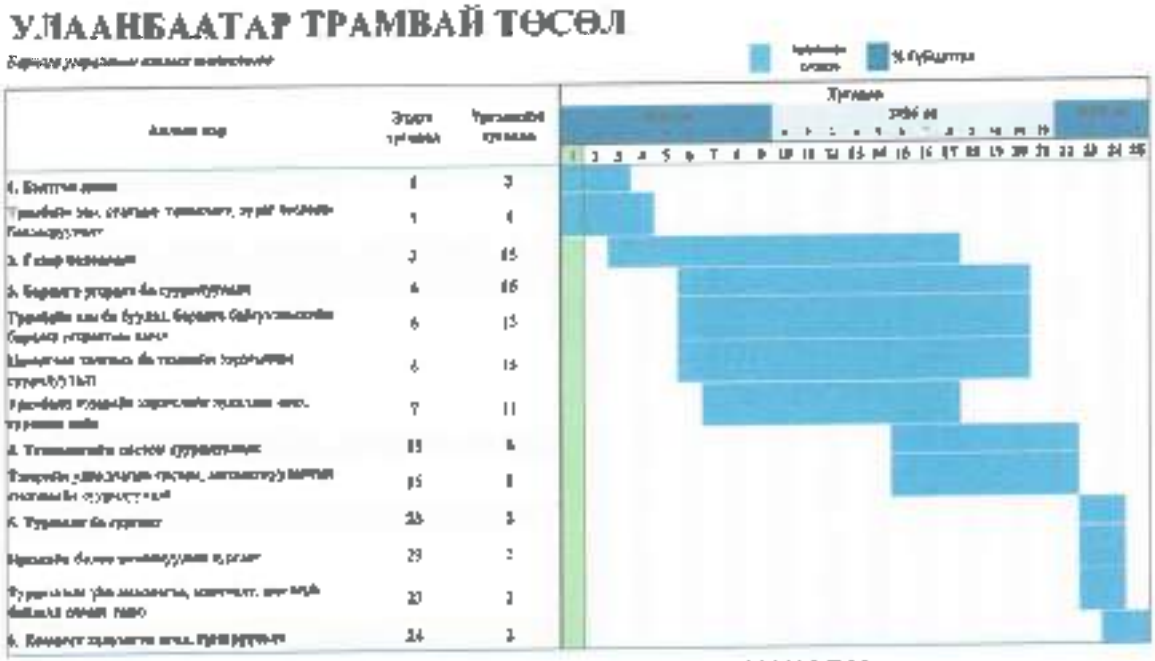
5. Building Construction	Management building, maintenance building, tram stations, office, security building, outdoor area, parking lot.	15 months
6. Rolling Stock and Maintenance Equipment	Delivery of trams, maintenance vehicles, and maintenance equipment.	11 months
7. Material Supply	Purchase, transport, and delivery of construction materials and equipment to the construction site.	Throughout the project

Construction Work Plan Schematic



12.3. GENERAL ORGANIZATION OF CONSTRUCTION WORK

Tram Track Construction

Track construction preparatory work includes engineering surveys, road removal, relocation of utilities along the route, temporary bridge construction, and site clearance. This will be followed by tram track installation, concrete foundation installation, and adjustment of rails and crossovers. This work will take 15 months to complete.

Tram track construction requires very detailed organization and multi-stage operations. It begins with preparatory work, engineering surveys, utility relocation along the route, temporary bridge construction, and site clearance, followed by track installation, concrete foundation installation, and installation of rails and crossovers. This entire process must be completed within 15 months and can be broken down in detail as follows:

1. Engineering Survey Work

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- Technical studies: Conduct detailed engineering studies to examine geological, hydrogeological, and weather conditions at the project site before earthwork and track installation.
- Ground analysis: Study soil conditions, drainage requirements, and cross-sectional and longitudinal alignment plans on the land where the tram track will be installed to meet engineering standards.

2. Road Removal and Utility Relocation
   - Road removal: Temporarily close existing roads, remove pavement and asphalt, and relocate obstacles interfering with road construction.
   - Utility relocation: Relocate high and low voltage power lines, communication cables, water supply lines, internet and TV lines in the area where the tram track will be installed, and construct temporary bridges if necessary.
3. Temporary Bridge Construction
   - Bridge construction plan: Develop a temporary bridge construction plan where required in the tram track environment. This is necessary to maintain continuous vehicular and public transport operations.
   - Bridge assembly: Install bridge support columns, structural components, and manage associated line flow.
4. Site Clearance
   - Cleaning work: Prepare the construction site by removing waste, vegetation, stones, and other obstacles.
   - Detailed analysis: Site cleaning work focuses on the track area and includes checks of the earthwork environment to prevent any risks.
5. Tram Track Installation
   - Railway foundation and installation: The installation foundation must be prepared before installing the tram tracks. Track installation includes creating concrete foundations, preparing bridges, tunnels, and drainage facilities of appropriate dimensions, and monitoring the track structure.
   - Concrete foundation laying: Create the main foundation of the track and position the concrete base. This is essential for track stability and long-term operation.
6. Installation of Rails and Crossovers
   - Rail installation: Install rails on the concrete foundation. The rails must be perfectly sized to ensure safe tram movement. Rails will need to be welded and connected.
   - Crossover installation: Install and adjust crossovers. Crossovers play an important role in allowing both large and small trams to move continuously.
7. Drainage Channel Installation
   - Drainage system: Install drainage channels and pump systems along the tram track. The purpose is to prevent water accumulation around the track and ensure successful maintenance operations.
8. Welding Work
   - Rail connection: Welding work is required during rail connection and installation. Welding work is important to prevent track damage and defects.
9. Adjustment and Testing
   - Track adjustment: Check and adjust the size, angle, height, and configuration of the track area as needed.

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- Testing: Test the complete tram track after rail installation. Safety requirements must be met for tram movement.

This tram track construction work can be successfully completed within 15 months, and attention must be paid to timely completion of numerous activities including earthwork, track foundation, railway installation, utility relocation, drainage systems, welding work, and track adjustment. Proper organization, detailed planning, professional workers, and quality control are of the utmost importance for completing the project with quality and on time.

Power Supply Work

Power line, substation, overhead contact line and underground cable installation, high voltage line, and tunnel construction work will be completed within 15 months.

Power supply work is a fundamental component of the tram system and is essential for the continuous, safe operation of trams. Power supply work involves implementing various engineering solutions and is carried out in multiple stages to fully execute not only the configuration of the tram track but also its power supply. The following breakdown details specific areas of focus:

1. Power Line Installation
   - Line installation preparation: Organize earthwork, foundation preparation, and line installation direction for power lines. Specifically check the area for high voltage line installation, speed limits, and safety requirements.
   - High voltage line installation: Successfully install high voltage lines used for tram transport. The type and capacity of the line must meet the power consumption of tram movement. Also, install high voltage lines consistently and safely to ensure power performance.
2. Substation Installation
   - Determine substation location: Plan substation locations and all necessary equipment to meet the power requirements of the tram network.
   - Substation installation: Install substations for voltage reduction, distribution, and safe tram movement. Install substation equipment and connect associated engineering lines and supplies.
   - Voltage distribution system: Install control and protection systems for power distribution, transmission, temporary stoppage, and reserve.
3. Overhead Contact Line System (OCLS) and Power Transmission Control System (PTCS) Installation
   - OCLS installation: Install an automated power transmission system to automate power distribution and tram movement. This system is responsible for controlling, detecting, stopping, and correcting faults in tram power supply.
   - PTCS installation: Install a power transmission control system designed to manage control of the power transmission system, maintain power levels,

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and monitor power loss and safety. The system monitors power consumption and makes automatic adjustments.

4. High Voltage Line Installation
   - High voltage line construction: High voltage lines are responsible for concentrating power supply for tram transportation and maintaining normal operations. High voltage lines affect the consistency of power and quality of service over a wide range.
   - Line operational safety: Position high voltage lines and regularly check all connections and isolation devices. Also install protective coverings to prevent external environmental influences.
5. Tunnel Construction Work
   - Tunnel construction: Tunnel construction may be necessary to protect tram tracks and power transmission lines. Tunnels serve to ensure safe operation of lines and protection from environmental factors.
   - Tunnel protection: After the installation of lines and other equipment in the tunnel, the tunnel must be fully equipped with walls, doors, and control systems to protect power equipment.
6. Installation Technologies
   - Technological recommendations and testing: Follow technological recommendations for installing all power transmission equipment including power lines, substations, OCLS, and PTCS, and conduct necessary testing. Test to ensure user safety and generate the required capacity.
7. Power System Monitoring
   - System monitoring: Monitoring of all power supply operations is the basis for successful, safe operation. The monitoring system is responsible for keeping power levels within permissible ranges and adjusting voltage fluctuations and consumption levels.
   - Automation of monitoring: Ensure full operation of systems to automate, monitor, detect, and resolve errors in the power supply process.

Power supply work requires a wide range of engineering solutions necessary for the normal operation of the tram system. This work covers installation preparation, power transmission lines, substations, tunnels, OCLS and PTCS installation, and must be performed at a high professional level over a 15-month period. During this time, safety, quality, and constant monitoring are important.

Signaling and Communication Facility Work

Transport control system, traffic lights, camera system, automatic blocking system, and fiber optic cable installation will be done within 8 months.

Signaling and communication work plays a crucial role in ensuring the safe operation of the tram system, regulating traffic flow, and ensuring the safety of operating trams and vehicles. This section requires the installation of various high-tech systems, which are important for the successful implementation and safety of the project.

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1. Transport Control System
   - System installation: The transport control system is responsible for regulating tram movement, monitoring safety, and optimally adjusting tram loads. This system helps ensure safe, responsible transportation and improves connectivity between new tram lines and other vehicles.
   - Technical installation: Connect the control system with related components and link all system communications. Pay attention to technical connection and integration.
   - Monitoring system: The transport control system is responsible for sending information to drivers and the tram control center, determining the direction of tram movement, and improving safety monitoring.
2. Traffic Lights
   - Traffic light installation: Install traffic lights and traffic signals along the tram route, in the middle of roads, and in common areas. This plays an important role in ensuring coordination between tram movement and traffic lights.
   - Light system monitoring: Monitor the traffic light system and manage traffic light updates and congestion prevention activities.
   - Energy consumption: Optimally regulate and efficiently use the energy consumption of the traffic light system.
3. Camera System
   - Camera installation: Position camera systems along the tram route, at bus stops, parking areas, and along main roads. The camera system is responsible for monitoring tram safety, issuing violation alerts, and checking camera recordings.
   - System integration: Directly transmit camera recordings and information to the control center and monitor the effectiveness of the camera system.
   - Audio response system: The camera system is responsible for transmitting not only video information but also real information about activities and conditions at a given location.
4. Automatic Blocking System
   - Automatic blocking system installation: Install an automatic blocking system to monitor the movement of trams and other vehicles on the tram track and ensure safety.
   - Protection system configuration: If a dangerous condition occurs, the system automatically stops or sends some kind of warning. This plays an important role in increasing system safety.
   - System test and trials: Thoroughly check the operation of the automatic blocking system and make necessary adjustments.
5. Fiber Optic Cable Installation
   - Fiber optic cable installation: Install fiber optic cable designed to support all communication and information transmission of the tram system. Fiber optic cable offers high speed, reliability, and broadband capacity, enabling fast, lossless transmission of information for all tram control systems.
   - Fiber optic cable connection: Fiber optic cable is responsible for transmitting information between all tram centers and their local connections. High requirements are placed on cable connection installation.

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- Fiber optic cable testing and configuration: After fiber optic cable and connection combination work is completed, check that all connections are working correctly.

6. System Monitoring and Testing
   - Testing operations: After installing signaling and communication systems, check the operation of all systems and conduct appropriate tests. The testing phase is important for ensuring system safety and configuring safe operation and normal operational settings.
   - System monitoring: All signaling, camera systems, and communication information are monitored through the control center and monitoring system.

Signaling and communication systems play an important role in ensuring tram safety, traffic regulation, and increasing the stability of transport operations. Within 8 months, all system installation, monitoring, and configuration will be fully completed, establishing reliable system operation.

Building Construction Work

The project's building construction work includes construction of management buildings, maintenance buildings, tram stations, offices, security buildings, outdoor areas, and parking lots. This work will be completed within 15 months.

Building construction work for the project is interconnected with other parts of the tram system and is important for ensuring transport, service, maintenance structure, operational safety, and comfort. Building construction work as a whole is a key part of improving citizens' quality of life and supporting tram system services and operations. The following activities will be carried out when performing this work:

1. Management Building
   - Organization, design: The management building should serve as the main center for project management, monitoring, establishing communication, and conducting management activities, as well as storing all service and necessary equipment.
   - Building structure: The basic structure of the management building consists of the following parts:
     - Management room, conference hall: Designed for organizing project management, management team, and communication activities. Public and internal meetings will be organized in this hall.
     - Employee workplaces: Workplaces designed for performing structural cost, calculation, performance monitoring, and other tasks.
   - Building materials: Materials used in the management building structure must be selected to be durable, ensure safety, and be energy efficient.
2. Maintenance Building

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- Maintenance center: The maintenance building will be a center for repairing and adjusting all components, rolling stock, and equipment of the tram system, and the following activities will be carried out:
  - Maintenance hall: A hall for technical service of trams and maintenance vehicles.
  - Equipment storage: Storage facility for tools, equipment, and spare parts needed for repairs.
- Building structure: The maintenance building must have a structure suitable for ensuring safety and repairing tram components. This building must be fully equipped with ventilation, heating, electrical supply, water supply, etc.

3. Tram Stations
   - Tram station construction: Tram stations are areas dedicated to passenger service, supporting tram arrival and departure activities, and consisting of the following parts:
     - Station building: Passenger rest, information section, ticket purchase section.
     - Outdoor area: The tram station will have an outdoor area that makes it easy and safe for passengers to board and alight from trams, as well as offering economic efficiency.
     - Lighting: Safe lighting for passengers, maintaining a suitable environment.
4. Office Building
   - Office space: The office building offers daily workplace for project employees and creates space for activities related to project documentation and requirements.
   - Working environment: The office building must provide public use and private work spaces, computer rooms, and archives.
   - Equipment, power supply: The office building must be equipped with electricity, ventilation, internet, and all other necessary conditions.
5. Security Building
   - Security building: The security building is designed to ensure project safety, monitor and regulate all parts of the tram system.
   - Structure, building: This building must essentially have personal space for security workers, surveillance cameras, guard posts, call centers, and all equipment necessary to ensure security.
6. Outdoor Area
   - Safe passenger movement: The outdoor area encompasses many activities to ensure safe passenger travel, pedestrian crossings, road signs, lighting, and green infrastructure.
   - Parking lot: The organization of parking lots and parking areas around tram stations and buildings will help alleviate waiting times for passengers.
7. Parking Lot
   - Parking area: Organize parking space for vehicles of passengers using the tram, which must be safe and suitable.
   - Building materials: The parking lot structure must be made of concrete and metal structures to ensure safety and stability, and must be resistant to maintenance and other influences.

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8. Outdoor Equipment
    - Outdoor improvement: Work on outdoor improvement of buildings includes creating agriculture, green infrastructure, and green areas. This will have a positive impact on the environment of the tram system and improve the quality of the living environment.

Building construction work is an important process for ensuring proper organization, safety, and comfortable operation of the tram system. Within this work, various types of buildings must be planned and safety ensured. Detailed organization, quality, and efficient operation of these buildings play an important role in the successful implementation of the project.

Rolling Stock and Maintenance Equipment

The delivery time for trams, maintenance vehicles, and equipment will be 11 months.

The process of delivering, installing trams, maintenance vehicles, and equipment is a critical part of the tram system and directly affects the efficiency, safety of transport operations, and quality of maintenance. Let's examine the activities to be implemented in this section in detail:

1. Tram Rolling Stock:
    - Tram delivery: The rolling stock of trams will play a crucial role in the successful implementation of the project. Tram vehicles must meet high technology, safety, and economic efficiency requirements. This includes:
        - Determining tram types: Select tram types that are suitable for the project's needs, capacity, and road conditions. These should include not only transport vehicles but also advanced technological solutions.
        - Rolling stock orders: Select and obtain rolling stock from the relevant manufacturer. Supplier selection will be made considering quality, price ratio, and after-sales supply.
        - On-site testing: Conduct initial testing and adjustment of tram vehicles. Check that tram components fully comply with all control systems, mechanical and electrical systems.
    - Rolling stock operation and maintenance:
        - Technical service program: Develop a regular repair and service program once the tram rolling stock is operational. This includes preventive maintenance, sensor device checks, and mechanical component inspections.
        - Establish a repair center: Establish a tram repair service center, supply the center with the necessary equipment, and train operation and maintenance staff.
2. Maintenance Vehicles and Equipment:

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- Maintenance vehicle delivery: Deliver vehicles designed to ensure normal tram operation, prevent breakdowns, and perform maintenance. Maintenance vehicle types should be capable of performing all types of tram maintenance.
    - Tram adjustment and repair equipment: Supply equipment necessary during repair work. This includes engines, electrical components, reinforcements, lubrication systems, wheel repair equipment, etc.
    - Maintenance vehicle installation: Position maintenance vehicle components at the transport vehicle maintenance center, connect equipment, and check proper operation.
- Delivery of other equipment for technical service:
    - Technical equipment: Deliver special equipment required for tram and repair work. This includes automatic control systems, sensor equipment for checking the durability of tram components, and essential tools for maintenance.
    - Measurement and testing: Check the safe operation of technical equipment, test adjustments made during installation.

3. Maintenance Equipment Service:
    - Maintenance instructions: When using maintenance machines and equipment, provide not only standard settings but also maintenance instructions and technical economic information.
    - Full operational control: Continuously monitor maintenance machines and equipment and perform necessary maintenance.
    - On-site practical control: Check maintenance machines and equipment in practical conditions, make necessary adjustments, and prevent damage.
4. Delivery Configuration and Testing:
    - Delivery and acceptance: After delivery of trams and maintenance equipment, receive components, perform installation and adjustment operations. This must be carried out with operational testing and monitoring.
    - Performance verification: Conduct performance testing and trials of all systems of delivered trams and maintenance vehicles. This inspection will focus on verifying the operation and safety of all technical components with the network.
5. Required Conditions for Rolling Stock and Maintenance Vehicle Service:
    - Tool and service material supply: Supply essential tools for trams and maintenance vehicles, provide service materials in a timely manner.
    - Service tool installation: Maintenance workers should be able to use essential tools on rolling stock and maintenance vehicles.

The activity of delivering trams, maintenance vehicles, and equipment will take place over 11 months and will include delivery, installation, configuration, testing, and all necessary maintenance activities. High-quality configuration and careful monitoring are needed to ensure the required efficiency and reliability of the rolling stock and maintenance equipment.

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Material Supply

The work of purchasing construction materials and equipment from manufacturers, transporting them to the construction site, and storing them will be organized. Materials must meet size and quality requirements suitable for construction needs.

The activities of supplying, transporting, and storing construction materials and equipment play an important role in the successful implementation of the project. The quality and result of construction work depend not only on project planning and management organization but are also directly related to the quality, quantity of materials, and how they are properly organized, transported, and stored.

Let's examine the activities to be implemented in this section in detail:

1. Material Equipment Selection, Ordering:
    - Selection of construction materials and equipment: Select materials that meet project needs, project quality requirements, and technical requirements. This includes:
        - Material types: All types of construction materials such as rails, concrete, metal components, infrastructure, electrical equipment, power connections, maintenance tools, etc.
        - Technical requirements: Materials must comply with project technical requirements and standards. Quality, durability, economic efficiency, and environmental friendliness are also important.
        - Supplier selection: Select suppliers considering product quality, price, delivery time, and basic contract terms.
    - Placing orders: Place orders with suppliers according to project requirements, technical specifications, and quality requirements. The order should cover all types of materials and equipment.
2. Transportation Processing:
    - Transportation activities: Organize the transportation of materials and equipment from the factory to the construction site. This serves several important functions:
        - Transport routes, vehicles: Carefully define transport routes, check the safety of transport vehicles, identify potential obstacles when loading and unloading.
        - Transport phases: Transportation includes several phases which are carried out as follows:
            - Start transporting materials from the factory;
            - Transport delivered materials to temporary storage locations;
            - Safely transport to the construction site with precise organization.
    - Transportation control: Address all issues that need to be monitored during transportation. This includes:
        - Material quantity and quality checks: Check materials being transported. Record cargo integrity, quantity, quality, and all items during transportation.

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        - Transportation schedule: Resolve obstacles that may arise during transportation, optimally organize transportation times.
3. Material Storage at Construction Site:
    - Material storage environment: Proper organization for storing materials and equipment at the construction site is important. Materials arriving at the construction site should have:
        - Safe storage: Store materials in special environments to protect them from external influences. They should be protected from natural factors such as water, wind, soil, etc.
        - Clean, organized storage: Materials should be stored without interference from many elements, in required quantities. This includes organization of storage areas, classification of materials, and storage according to brands.
        - Safety: Take storage measures to ensure no danger to human life and health, and ensure material safety.
4. Material Management and Registration:
    - Material registration: Include all construction materials and equipment in a registry with required information (quantity, brand, supplier name, delivery time). This helps conduct effective material control.
    - Material distribution: Distribute materials arriving at the construction site to appropriate sections, based on the activity start plan.
    - Material disclosure: Quickly and efficiently disclose and distribute materials needed for use.
5. Proper Material Use and Control:
    - Material usage control: Monitor the usage of materials at the construction site. These materials should be correctly calculated and fully utilized.
    - Usage report: Generate records and reports on material usage, storage, and transportation.
6. Material Inspection and Issue Response:
    - Conduct inspections: Check the quality, quantity, and type of materials being transported and arriving at the construction site.
    - Response: Resolve any issues with materials after inspection, submit service requests.
7. Issues That May Affect the Project:
    - Transportation delays: There may be delays during transportation, slow cargo delivery, violation of transportation times. This can directly affect construction work and risk delaying timelines.
    - Excessive material storage: Storing too many materials at the construction site can cause problems with site safety, reduced turnover, and obstruction of worker movement.
    - Material quality degradation: Materials may deteriorate if not regularly checked, especially when stored in natural conditions.

Material supply is a process with many stages including transportation, storage, and quality control, requiring detailed organization. If this activity is not carried out in a timely, safe, and organized manner, it can negatively affect the project timeline and quality.

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Regular material registration, transportation, storage, and usage control are important for successful project implementation.

Key Considerations for Completing Project Work on Time

The schedule, which contains several important activities including project construction, material supply, power supply, and transport system installation, is highly important for the successful implementation of the project. However, the following difficulties may arise during project implementation, so it is important to plan strategies in advance to account for risks for successful project implementation.

1. Weather Conditions Weather conditions may pose significant challenges during project implementation. Soil freezing, heavy rain, wind, snow, and other weather risks can cause difficulties for construction work and delays in installation and assembly times. It may also be necessary to stop work for certain periods to ensure the safety of buildings and structures in connection with this. Impact time: This should be anticipated and the construction calendar plan should be updated to reflect conditions.
2. Geological Conditions and Land Acquisition Land acquisition, local geological conditions, aquifer velocity, and earthquakes may be unstable in project implementation. This may affect the engineering foundation of the route and utility installation as well as the construction budget and timeline. Impact time: Additional studies and tests may be required to adapt to geological conditions, which could cause timeline obstacles.
3. Technical Issues and Material Shortages During the construction phase, suppliers' inability to supply needed materials at an adequate level and quality can extend the project timeline and create budget issues. There may also be a need for special equipment, vehicle repairs, spare parts, and adjustments. Impact time: It may be necessary to contact manufacturers and suppliers to establish timely delivery contracts. To prevent delays in the event of supply disruptions, it is necessary to confirm orders in advance.
4. Worker Labor Issues During the project, factors such as worker capacity, non-permanent workforce, training, and inexperienced workers can create difficulties in completing work on time. Pandemics and constant worker movement can also be anticipated to hinder timely work. Impact time: It is necessary to create worker organization, contracts, and organized plans, which will quickly generate implementation times if difficulties arise.
5. Legal Issues Government regulation, obtaining special permits, tax, and legal issues may delay the project. Changed legislation, ecological requirements, new environmental control regulations, and tax conditions may directly affect the project stage. Impact time: Before starting the project, it is necessary to thoroughly study legal conditions and regulations and obtain necessary permits in advance.

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Implementation Timeframes and Comparisons of Projects implemented internationally

1. Tram Project in Europe (Belgium): It took a total of 24 months to implement a 12 km long tram system project in Brussels, Belgium, which included all network activities such as land acquisition, construction performance, electrical line installation, safety, and installation of automated systems compliant with international standards.
2. Tram Project in China (Shanghai): A new tram line construction project in the central part of Shanghai was 30 km long and took a total of 36 months. The technology used in China was highly productive and aimed at fast operation, so there was little construction delay and good performance control. However, the tram system built in Belgium had to comply with environmental conditions and international labor rules, so the timeline was longer.

Comparison: Our project length is similar to the timeframe of the Brussels project in Belgium and could potentially be faster. Although there is potential to increase technological advancement, organizational efficiency, and shorten work time, factors such as land acquisition and weather conditions may slow down the project.

To successfully implement the project without extending the timeline, it is important to identify delay causes in a timely manner and develop solutions. Detailed planning, proper organization, and multi-faceted monitoring are necessary to ensure investment efficiency and complete the project on schedule.

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CHAPTER 13. CONCLUSION

Chapter sub-contents:

Summary of research results

13.1. SUMMARY OF RESEARCH RESULTS

(1) Population Growth and Transportation Issues in Ulaanbaatar City

1) Rapid population growth:

- The population of Ulaanbaatar city is expected to grow from 1.49 million in 2023 to 1.68 million by 2040.
- Satellite cities are rapidly expanding and developing, with their share of the total regional population increasing from 9% to 19%.

2) Public transportation:

- Daily traffic demand: 3.388 million trips (65.2% by private vehicles) significantly contributes to congestion.
- The daily transportation cost of major streets is 5.51 million USD.
- By 2040, traffic demand is expected to increase by 1.33 times, with Naadamchdin Road and Chinggis Avenue predicted to be heavily overloaded.

(2) Overview of Ulaanbaatar Tramway Project Planning

1) The Ulaanbaatar Tram (UB Tram) is proposed as a public transport system that meets the future needs of Ulaanbaatar city. The tramway line is planned to extend 16 kilometers along Naadamchdin Road and Chinggis Avenue, connecting the southwest part to the central area of the city. The entire route will be in the form of an above-ground railway.
2) The Ulaanbaatar tramway is planned as a modern, comfortable, fully electric double-track railway system with an integrated signaling system with road traffic to meet future demands.
3) The total estimated budget cost of the Ulaanbaatar tramway project is 325.699 million USD, with the majority (176.6 million USD) allocated for construction work. This includes: Costs required for track infrastructure construction of superstructure and substructure (102.4 million USD), signaling and communications (14.1 million USD), power supply (38.3 million USD), buildings and structures (21.8 million

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USD), rolling stock and technical equipment (60.9 million USD), calculated as 5 work packages.

4) In addition, costs for utility network relocation and reinforcement (16.4 million USD), land acquisition (3.3 million USD), other related Owner's supervision costs (5.1 million USD), Contractor's management (20.5 million USD), and Contingency work (12.8 million USD) have been calculated respectively (excluding VAT).

(3) Ulaanbaatar Tramway and Integrated Urban Development Plan

Ulaanbaatar city will be gradually transitioned from the current monocentric city to a polycentric urban system at the 2040 level, decentralizing concentration. Within the framework of the newly established legal status, Ulaanbaatar will be developed into 14 financially and economically independent cities with local status, each with its own centers. When implemented, the tramway project will be able to connect 5 cities.

Key features:
Transit-Oriented Development (TOD):

- Support multi-modal transport hub centers connected to station areas and transit facilities.
- Develop high-density urban spaces that promote efficient land use in centralized areas and multi-modal transport hub centers.
- Limit urban expansion and promote residential migration by redesigning old residential areas and ger districts.

(6) Business Sustainability Management
Ensuring sustainability:

A balanced approach combining public-private partnership financing will create a framework for sustainable project operations and ensure long-term sustainability.
Export Credit Agency (ECA) guarantees will enhance financial stability and support the project's financial viability.

(7) Issues to Consider in Project Implementation

1) The Ulaanbaatar tramway should be planned according to relevant railway standards.
2) Multiple financial sources such as the Mongolian state budget, Official Development Assistance (ODA) fund, and private financing need to be established.

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3) To maintain sustainable and reliable tramway operations, it is necessary to create an optimal public transport policy with a stable fare system that includes social support for citizens such as students, elderly, and low-income individuals.

1.1.1. Strategic Recommendations

(1) Policy and Institutional Framework

- Establish policy and regulatory mechanisms to ensure political and financial stability throughout all phases of project implementation, creating opportunities for key stakeholders (Government, international donors, private sector, domestic citizens) to collaborate.
- Establish a joint regulatory committee to oversee planning, financing, and implementation, streamlining the management decision-making process.

(2) Infrastructure Development

- Focus attention on the planning of stations and depots that comply with international safety standards and increase accessibility. This planning aims to improve public transport accessibility and reduce congestion.

(3) Financial Sustainability

- Diversify funding sources by utilizing Government of Mongolia bonds, international development assistance, and private investment. Use Tax Increment Financing (TIF) for urban development projects along the tramway corridor.
- Design station layouts optimally to allocate space for retail, advertising, and other commercial activities to ensure continuous non-tariff revenue.

(4) Operational Efficiency

- Develop a capacity building, capacity enhancement, and efficient workforce management plan.
- Implement modern automation technology (GOA Level 1) to optimize operations and ensure reliability and safety.

(5) Public Understanding and Participation

- Build public confidence by emphasizing the long-term benefits of the project, particularly reducing traffic congestion, promoting sustainability, and improving quality of life. Work with citizens affected by construction work to address pressing issues and reduce the impact of obstacles.

(6) Collaboration with International Partners

- Collaborate with international organizations and donors such as ADB to obtain technical and financial support.
- Collaborate with experienced leading private sector companies to transfer knowledge and implement experience in tramway operations and management.

(7) Risk Management and Project Monitoring

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- Create a strong risk management system to identify and mitigate risks at each project phase.
- Implement special monitoring mechanisms to closely monitor work progress to complete the project on schedule and within budget.

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