Ministry of Road and Transportation
Ministry of Construction and Urban Development
Ulaanbaatar City Government

The Study on Implementation of Ulaanbaatar City Urban Transportation Project in Mongolia （Ulaanbaatar Metro Project）

Final Report

May 2013

Japan International Cooperation Agency (JICA)

Value Planning International, Inc.
Almec Corporation
Oriental Consultants, Co., Ltd.
Marubeni Corporation
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Preface

Ulaanbaatar City, the capital of Mongolia, has been rapidly growing over the last five years. Statistical data shows a population of 1.3 million as of 2011. As the city has expanded with the remarkable economic development and increase in a variety of urban services, the population of the Ulaanbaatar urban area, including surrounding satellite cities, is expected to reach two million by 2030.

The agglomeration of economies maintains a diversity and improves a standard of services, such as business, education, health care, amusement, culture, and tourism. The city grows by absorbing human resources, capital and technology / knowledge for such industries. Such advantages are expected to bring about an increase in competitiveness of the city. However, without the proper responses and measures, this may also directly cause an external diseconomy, such as traffic congestion and environmental degradation.

In order for Ulaanbaatar City to be developed as a world-class capital city, “short-term oriented and cheap patchwork development” must be avoided. A drastic improvement of urban structure and the development of an efficient urban transport system is essential to support long-term and continuous growth. The JICA Study Team firmly believes that the “Ulaanbaatar Metro Project” proposed by this study will take a lead to realize this dream. People who have responsibility for the socio-economic development need a vision which extends far into the future (100-year vision). This dream should encompass the aspirations of the citizens for the steady step towards its realization.

However, it is obvious that this Ulaanbaatar Metro Project needs a large amount of capital. It is important to plan effective capital formation using profits from mineral resources effectively and also with the participation of the growing private sector, in order to build the "World City Ulaanbaatar" with continuous growth potential and attractions. In this sense, this project should be regarded as a national project.

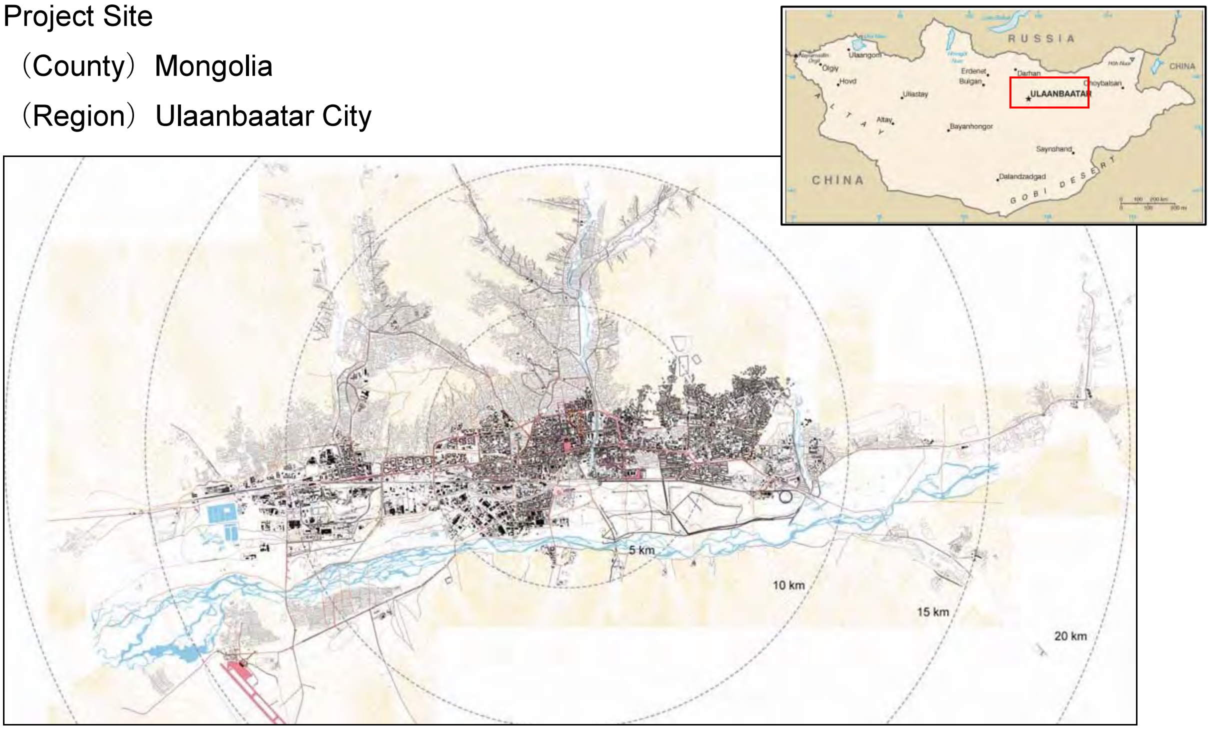
Aiming at the success of this national project, with pride of a professional consultant group, the study team has formulated the "optimal scenario." This final report shows the operational scheme of the metro project and the road to start the operation, including the implementation system, risk analysis, and economic and financial analyses—a study that took over one year to complete after the interim report was formulated in March 2012. We strongly hope that this report will help all concerned to have constructive discussions in order to proceed with the positive step towards the achievement of the final goal of the “Opening of the UB Metro in 2020.”

May 2013
Katsuhide Nagayama
Team Leader, JICA Project Team

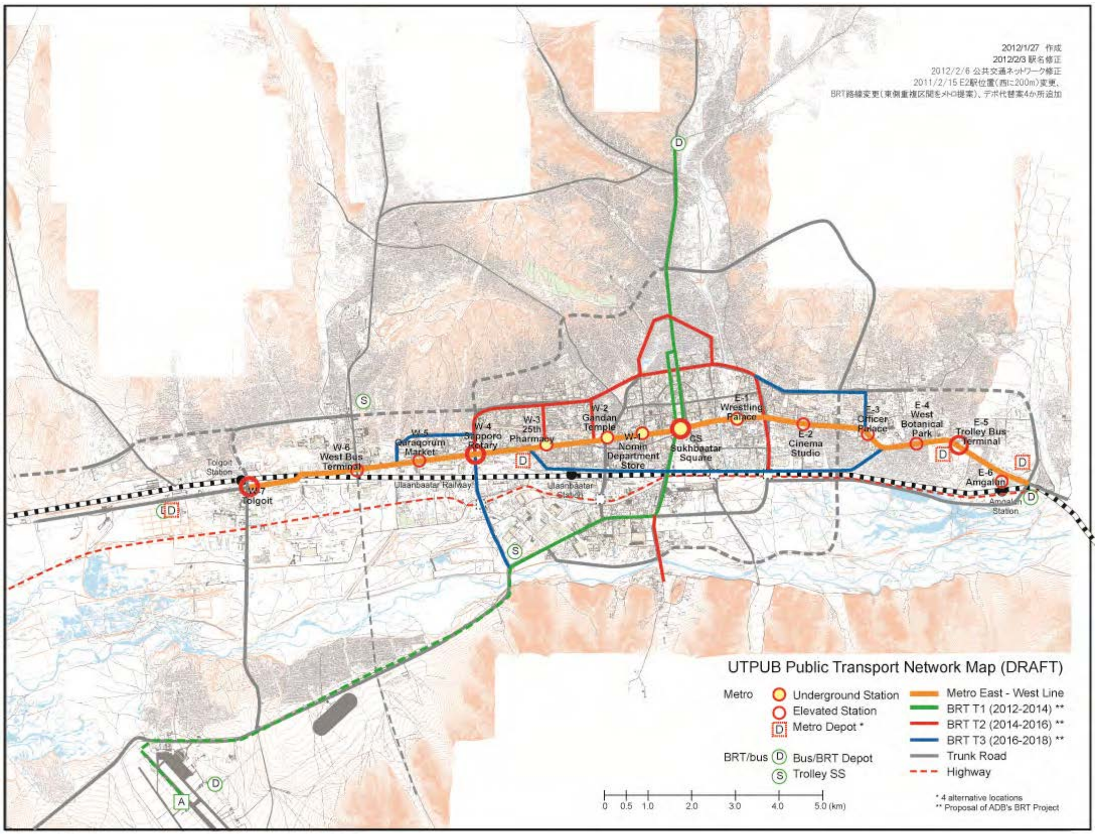
Project Site

（County）Mongolia

（Region）Ulaanbaatar City



Ulaanbaatar City



Proposed Ulaanbaatar UMRT System

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Abbreviations and Acronyms

ACM	Approved Consolidated Methodology
ADB	Asian Development Bank
AGT	Automated Guideway Transit
ATP	Automatic Train Protection
AQDCC	Air Quality Department of Capital City
BAU	Business as Usual
BCR	Base Case Revenue
BLT	Build Lease Transfer
BOCM	Bilateral Offset Credit Mechanism
BOOM	Build Own Operate and Maintenance
BOT	Build Operate Transfer
BRT	Bus Rapid Transit
CBD	Central Business District
CDM	Clean Development Mechanism
CLEM	Central Laboratory of Environment and Metrology
CO_2	Carbon Dioxide
CTC	Centralized Traffic Control
DEIA	Detailed Environment Impact Assessment
E & M	Electrical and Mechanical
EBRD	European Bank for Reconstruction and Development
ECA	Export Credit Agency
ECS	Escalator
EIA	Environment Impact Assessment
EIRR	Economic Internal Rate of Return
EIRR	Equity Internal Rate of Return
EU	European Union
EV	Elevator
FAR	Floor Area Ratio
FIRR	Financial Internal Rate of Return
FS	Feasibility Study
GDP	Gross Domestic Product
GGU	Government Guarantee and Undertaking
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GOM	Government of Mongolia
HSST	High Speed Surface Transport
IC	Investment Certificate
IFIs	International Financial Institutions
IGES	Institute for Global Environmental Strategies
ITF	Intermodal Transfer Facility
JCC	Joint Coordination Committee
JICA	Japan International Cooperation Agency
K&R	Park and Ride
KPI	Key Performance Indicators

LRT	Light Rail Transit
LRTA	Light Railway Transit Authority
MRG	Minimum Revenue Guarantee
MRT	Mass Rail Transit
MRT	Ministry of Roads and Transportation
MRTCUD	Ministry of Road, Transport, Construction and Urban Development
NAMA	Nationally Appropriate Mitigation Actions
NATM	New Austrian Tunneling Method
NOx	Nitrogen Oxide
OCC	Operation Control Center
ODA	Official Development Assistance
OD	Origin-Destination
OEM	Original Equipment Manufacturer
P&R	Park and Ride
PCU	Passenger Car Unit
PIS	Passenger Information Service
PSIF	Private Sector Investment Fund
PPP	Public Private Partnership
PQ	Pre-Qualification
SME	Small and Medium Enterprises
SPC	Special Purpose Company
SCADA	Supervisory Control And Data Acquisition
STRADA	The System for Traffic Demand Analysis
TBM	Tunnel Boring Machines
TIF	Tax Increment Financing
TOD	Transit Oriented Development
TPM	Total Productive Maintenance
TTC	Travel Time Cost
UB	Ulaanbaatar
UBMA	Ulaanbaatar Metro Agency
UBMP2030	City Master Plan of Ulaanbaatar 2030 (Draft)
UBMPS	Study on City Master Plan and Urban Development Program of Ulaanbaatar City in Mongolia
UMRT	Urban Mass Rapid Transit
UNEP	United Nations Environment Programme
USGU	Ulaanbaatar Water and Sewerage Authority
V/C	Volume / Capacity
VGF	Viability Gap Funding
VOC	Vehicle Operating Cost
WHO	World Health Organization

Summary

Final Report
Summary

1. Key Issues on Urbanization and Transportation in Ulaanbaatar

The population of Ulaanbaatar (UB) City was 58,000 in 1990 and doubled to 1.13 million in 2010.

About 27% of the country's population lived in UB City in 1990. The population concentration of UB City reached 41% in 2011. This trend is expected to continue and UB City's share in the population will become larger in the future. Over the last 20 years, the country's population has grown at an average rate of 1.3% per annum, while that of UB City is 3.3%.

Most immigrants to UB City have recently settled in ger areas where infrastructure is inadequately provided. Once these people settle in ger areas of little infrastructure, it would cost much time and money to reorganize the areas into a settlement with a good living environment. In order to avoid such expansion of the ger areas and to lessen the cost for infrastructure provision and adverse environmental impacts in forming a sustainable UB City, it is imperative to construct a compact urban spatial structure with a well-planned public transportation as its spine.

In addition, such population concentration in UB City has increased the demand for various infrastructure and utilities and has had an adverse environmental impact. These resultantly elicited urban problems including inadequate supply of water, electricity and heating, lack of treatment of wastewater and solid waste, and uncontrollable air pollution, water and soil contamination.

Particularly, motorized vehicles are the only current means of urban transportation in Ulaanbaatar. However, the present road network of UB City was planned in a master plan in 1975 when the city's population was 349,000, the number of cars registered was 10,044, and the car ownership ratio was 2.9%. The plan targeted to cope with only 400,000 to 500,000 people. In 2010, the population reached 1.11 million, the number of cars registered was 167,809, and the car ownership ratio became 14.6%. Compared to 1975, the population became 3.2 times greater, the number of cars registered was 16.2 times more, and the car ownership ratio was 5 times higher. For the past 35 years, the trunk road network has had limited improvements, that are inadequate to meet the increasing traffic volume. Consequently, this has led to traffic congestion. Improper traffic management, bad driving manners, and on-street parking have worsened traffic conditions.

Based on the future population by Khoroo, projected according to the future population framework, the number of trips will be double from 2011 to 2030, and the traffic demand (person-km) will be 3.1 times the present level. The main reasons for rapid increase of traffic demand compared to the rate of population increase (1.4 times the present rate) is because of the increase in average trip length in conjunction with expansion of urbanized areas and increase in the number of private cars (see Figure 1).

Traffic volume increase of private cars will be a burden to road transport system. The traffic capacity of main corridors especially Peace Avenue and Chingiss Avenue will be absolutely insufficient. By 2030, the total transport cost will be 14.1 times of the present level, two-thirds of which are shared by Travel Time Cost (TTC). Loss of time value will be serious because of the traffic congestion.

As for the traffic volume of cross section of main corridors in 2030, approximately 700,000 persons (200,000 PCU[1]) will cross Peace Avenue daily. Though it will not be seriously congested inside the city center due to a high density road network, the volume-to-capacity (V/C) ratio of main trunk road access to city center will be 2.6-3.0. In terms of south-north direction, daily trips will be 600,000 persons (170,000 PCU) in Chingiss Avenue, and V/C ratio will be 5.0, which means the road will

[1] PCU stands for passenger car unit and is defined as the number of vehicles equivalent to passenger cars. It is a coefficient used to compare traffic volume consisting of different vehicle types at different spots; for example, a truck is considered equivalent to 2.0-2.5.

already be overloaded.

Lack of road capacities along major corridors will be absolutely serious, so the development of mass transit and effective road transport control will be crucial to expand transport infrastructure and services.

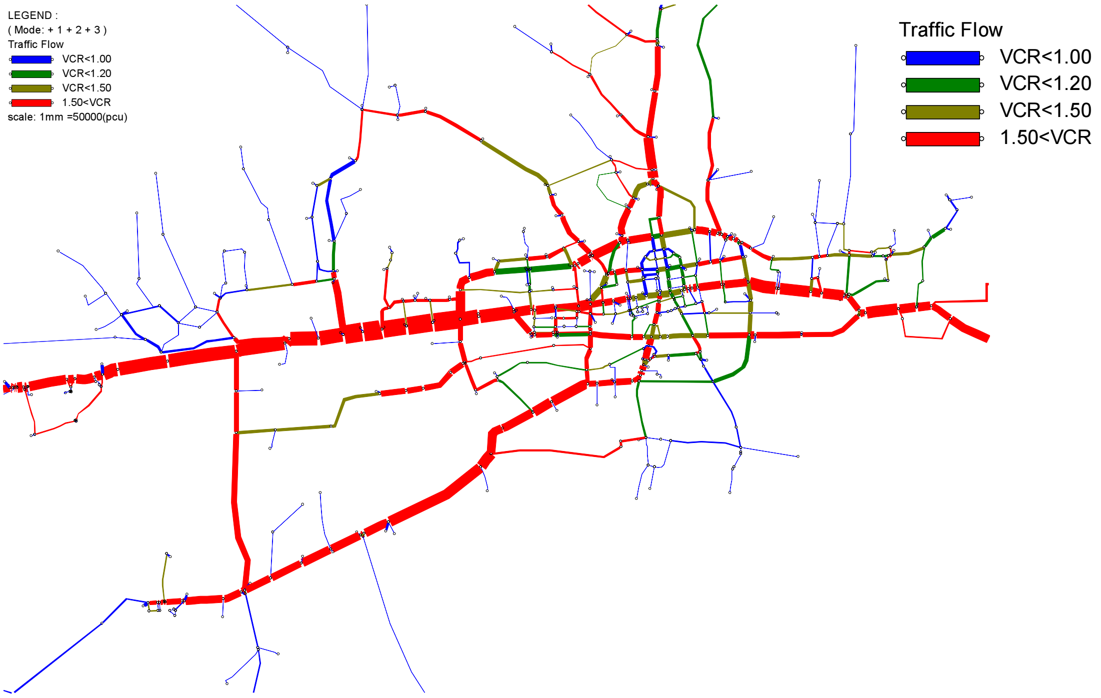


Figure 1: Future Traffic Demand (Baseline Case, 2030)

Source: JICA Study Team

2. Outline of Ulaanbaatar Metro Concept

1) Development of Comprehensive Urban Transport Network

The spatial structure of UB City is a ladder-shaped one, extending from east to west and is surrounded by mountains in the north and south. Peace Avenue is the only trunk road that connects east and west of the city, so most of urban facilities and traffic are gathered along this road. Based on the result of simulation of STRADA, a traffic demand analysis software developed by JICA, about 700,000 trips (approximately 35% of the 2 million trips) are concentrated in Peace Avenue. Among the 58 main bus routes of the city, 21 routes (36%) run along this trunk road.

In this way, Peace Avenue serves as the backbone of urban service, transport and utility service in UB City. There are various strategic development opportunities along this road.

Mass transit development along Peace Avenue has advantages in terms of the transport and urban development. The Ulaanbaatar Metro (UB Metro) project is proposed to develop a mass transit of 17.7 kilometers long between Amgalan Station and Tolgoit Station within the road spaces along Peace Avenue. The UB Metro will be properly connected to Ulaanbaatar Railway at the east and west terminal stations, which are Amgalan and Tolgoit, respectively. The following effects of the UB Metro are expected:

- The UB Metro will be developed within a road space without reducing the traffic capacity of Peace Avenue; traffic capacity can be increased by reducing vehicles.
- The UB Metro will not be an independent line but appropriately integrated with other transport network.
- The UB Metro will be properly connected to Ulaanbaatar Railway when it is possible to be developed as a "commuter railway of a UB city region" after Bogdkhan Railway is developed as a freight line of Ulaanbaatar Railway.

2) Promotion of Integrated Urban Development

An integrated urban development can be promoted by the mass transit development along Peace Avenue where urban activities are accumulated. In particular:

- The UB Metro will be a trigger to strengthen existing urban areas and to develop sub centers.
- The UB Metro will lead appropriate urban growth towards the west side (though urban expansion towards the east is not recommended in terms of water reservoir preservation).
- The UB Metro will be developed without serious social and technical disincentives.

3) Appropriate Railway System

When considering the selection of the mass transit system, some criteria such as i) demand at peak hour, ii) economic consideration, iii) safety, and iv) easy maintenance would be considered in a comprehensive manner.

In addition, with the long-term operation period, a flexible railway system to respond to future urban growth and increase of passengers is expected. Furthermore, selection of facilities and equipment which can adapt to special climate condition of UB City is indispensable. For this, v) flexibility for future expansion (increase in the number of cars and decrease in travel time), vi) resistance to cold climate, and vii) environmental aspect such as gas emission, noise/vibration and daylight interference are important criteria for UB City.

Prospective railway systems are assessed based on conditions of this project such as a route and transport capacity, and it is proposed to select “steel wheel and steel rail system MRT” as an optimum mass transit system for Peace Avenue. This railway system is a double-track urban railway and has the flexibility to respond to future demand increase.

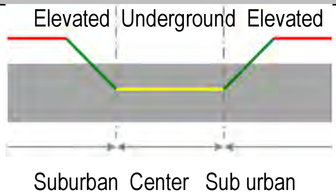
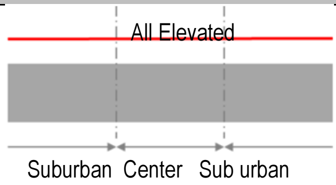
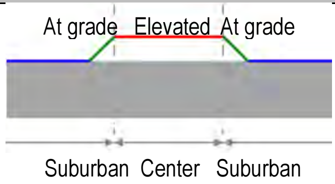
4) Structure

There are three types of Metro structures: elevated, at grade and underground. Based on the criteria listed below, three alternatives of structure are assessed (see Table 1).

a) Socio-economic impact: land acquisition, land use
b) Traffic function: impact on road transport (avoidance of decrease of carriageway, grade crossing with road, impact on intersection)
c) Environmental consideration: landscape, noise and vibration, safety
d) Technical appropriateness: construction method, construction cost

Based on the result of assessment, **alternative A, “underground in city center, elevated in sub urban area,”** is proposed in this project.

Table 1: Alternative Structures of UB Metro

	A: Underground in city center, Elevated in sub urban area	B: All elevated	C: Elevated in city center, at grade in sub urban area
Section Image			
Land Acquisition	○ Not necessary	△ Necessary to secure present width of carriageway and sidewalk in city center	×Necessary to secure present width of carriageway and sidewalk
Road Transport	○ Less impact on road transport	△ Some negative impacts on city center because of pillars	× Serious impacts because of grade crossing with road
Landscape	△No negative impacts in city center but some negative impacts in suburban areas	×Serious Impacts both in city center and suburban areas	×Serious Impacts in both city center and suburban areas. Particularly, significantly affects the city center.
Environment	△No negative impacts in city center but some negative impacts in suburban areas such as noise and vibration	×Serious negative impacts such as noise and vibration because of the elevated structure	×Serious negative impacts, such as creating noise and vibration, and splitting of communities
Cost	×	△	○

Note: Cost of each case includes only the development cost of the train infrastructure. This means that it does not include the cost of loss from the decrease in carriageway width, land acquisition of the reduced carriageway or grade crossing with road.

Source: JICA Study Team

5) Selection of Station Location

Based on some criteria such as potential of urban core, intermodal transfer condition, physical condition (existing medians, soil and underground water) and accessibility, 14 stations are proposed from Tolgoit Station to Amgalan Station, with a total of approximately 17.7 km. Underground section in the city center is 6.6 kilometers long between West Intersection and East Intersection. Other than that, the structure is elevated and completely separate from road traffic (see Figure 2).

A possibility of extension of the line is also assumed towards the west in accordance with the expansion of urbanized area and a new town development in the west of UB City.

6) Transport and Train Operation Plan

The transport plan of UB Metro is outlined in Table 2. Since there are a few sharp curves and the distances between stations are relatively long, the train running time required between two terminal stations can be shortened by setting the maximum speed to 100 km/h. To reduce the construction cost and to ensure effective train operation, the number of cars for a train should be six. Under this assumption, a section with the maximum volume of passengers is between Sappro Rotary station and 25th Pharmacy station. The maximum number of passengers carried to one direction during peak hour in 2030 is about 18,000.

According to the train operation plan, trains operate every eight to nine minutes in 2020 and every five minutes in 2030. The terminal stations through the whole length from east to west (17.7 km) will be connected in 27 minutes by metro.

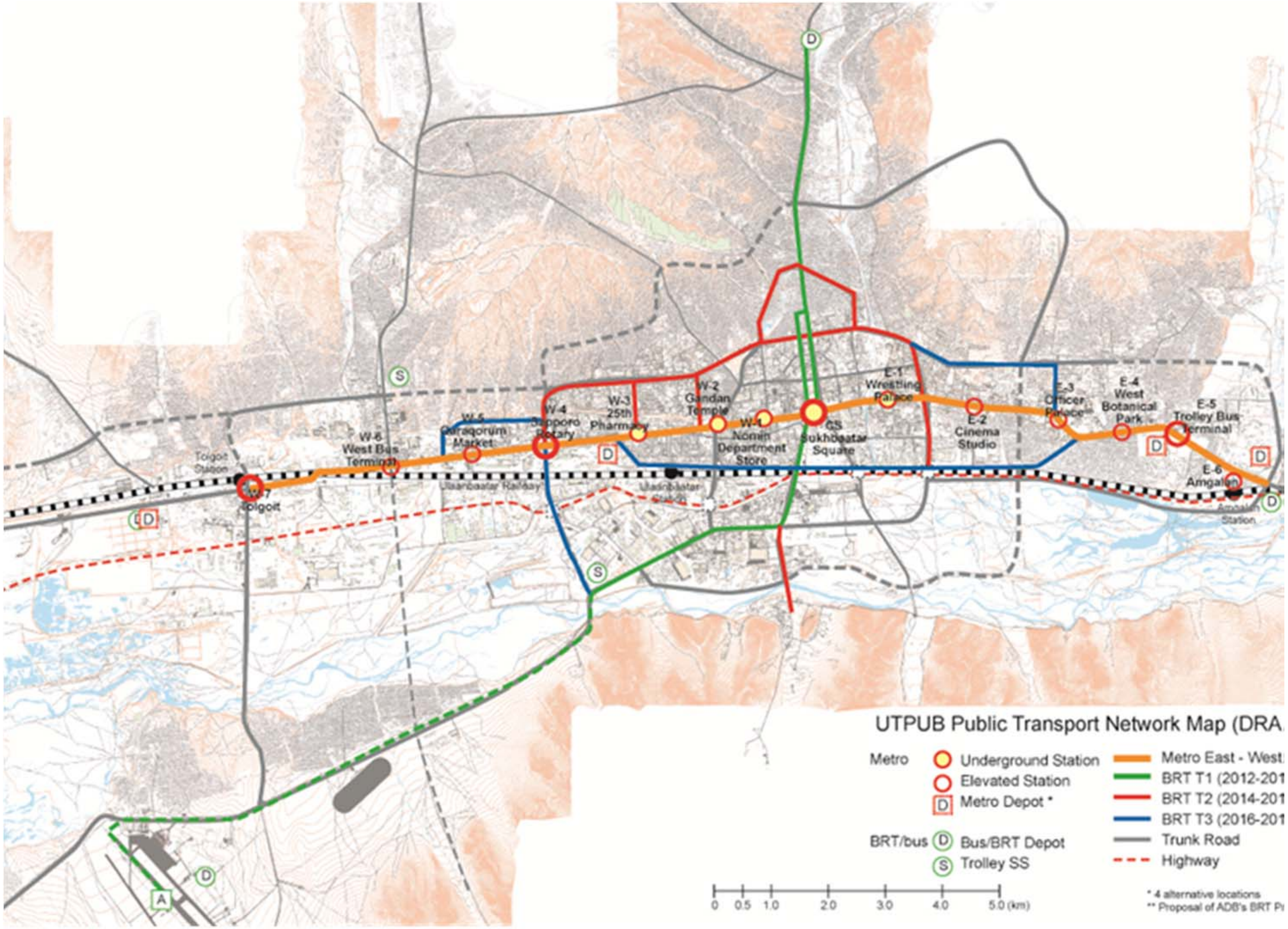


Figure 2: **Location Map of UB Metro (Draft)**

Table2：Transport and Train Operation Plan

Item		Description	
Corridor		Tolgoit Sta. – Amgalan Sta.	
Route length (km)		17.640 km (between starting and terminal stations)	
No. of stations		14 (including five underground stations)	
Service hours		6:00 AM to 11:00 PM	
Demand forecast			
	Corridor	Sapporo Rotary Sta. – 25th Pharmacy Sta.	
	Year	2020	2030
	PHPDT (pax)	10,729	17,767
Car composition for a train		6	
Train capacity (180%)		1,428	1,428
Headway (peak hour) (sec)		515	300
Schedule speed (km/h)		39.2	
Schedule time (minute)		27	
Maximum operation speed (km/h)		100 (80 for underground section)	
Train make-up		2020	2030
	Required No. of trains	8	13
	No. of spare trains for inspection	1	1
	No. of spare trains for extra service	1	1
	Total	10	15

7) Rough Estimate of Project Cost

This is the first urban railway project in Mongolia and large underground and elevated constructions are included in the project. And since it is very cold and construction is restricted in the winter in Mongolia, special specifications of system to be used for cold districts are required for the project.

The project cost has been estimated referring to procurement and winter construction circumstances described and comparing with Korean FS and construction cost of Japan and other foreign countries. Project costs of the following three options have been set up with the difference of procurement.

- Option 1 : the assumption that Japanese firms etc. can enter into the project (base case)
- Option 2 : the assumption that international competitive bidding is conducted (competition case)
- Option 3 : the assumption that Japanese firms can enter into main constructions and procurements (Japan core case)

As for Option 3, it is assumed that Japanese firms would get involved into civil and architecture works for underground section (by shield method), procurements of signal and telecommunication equipment, safety system and rolling stock. In particular, civil works for underground section and rolling stock require advanced techniques and high credibility; and therefore, it is desirable that Japanese companies will get involved in such works and procurements. On the other hand, as for other constructions and procurements, it is preferable to conduct these items with lower cost through international bidding. Accordingly, the Japan core case is proposed in this study. As a result, the total project cost is US$1.5 billion including US$1.3 billion of construction cost for a tunnel, elevated bridge, stations and related facilities and US$200 million of procurement cost for rolling stock and opening expenses (see Table3).

Table 3: Estimated Project Cost

Item		Cost (US$ Million)
Construction Cost	Civil works	913.0
	Track Architect / System Removal of obstacle	65.0 300.0 25.0
	Sub-total	1,303.0
Land acquisition Rolling stock Contingency / Miscellaneous expenses		30.0 122.4 84.0
Total		**1,539.4**
Construction cost per km (US$ Million) Rolling stock cost per car (US$ Million) Project cost per km (US$ Million)		67.51 2.04 79.76

3. Station Area Development

The UB Metro will cover various urban land uses from the Central Business District (CBD) to suburban and rural areas. With appropriate feeder bus service provision, accessibility of ger areas will be improved.

Based on the "Transit-Oriented Development" (TOD) concept,[2] the following are desirable to be implemented.

- Development of intermodal transfer function of station areas and bus feeder service system (Station plaza and intermodal facility development).
- Development of an intensive urban city with a highly dense population where high-level and efficient utilization of land is realized in the central area and intermodal transfer areas (development of sub-centers).
- Restriction of expansion of urban areas and promotion of resettlement of citizens in ger areas by reconstruction of old apartment buildings (promotion of a housing policy).

Currently, the Ministry of Construction and Urban Development is formulating the Urban Redevelopment Law. After the law is passed and enacted, projects will be implemented through the right conversion instead of land expropriation. Accordingly, urban redevelopment projects along Peace Avenue, including old apartment reconstruction projects, are expected to be facilitated. Therefore, it is necessary to formulate an urban redevelopment project implementation plan around stations which are integrated with the UB Metro project.

Furthermore, underground development and utilization of underground space are recommended as a part of the station area development since they are effective on revitalization of economy and improvement of accessibility and safety in the cold winter of Mongolia

Including these urban development projects, multi-faceted spillover effects are expected such as the effects on the citizens' living condition, local economy, safety, environment and local society. Specific effects are shown as follows.

[2] To promote an urban development integrated with public transportation.

Improvement of Accessibility

- Time cost saving by the shortened travel time of citizens (45 minutes of travel time by bus will be reduced to 15 minutes by metro)
- Reduction of traffic congestion in urban areas (16% of reduction of traffic volume, 25% of increase in travel speed)
- Revitalization of business and commercial activities in the central areas and improvement of citizens' living condition by enhancement of accessibility to the city center (increase in the number of employees and shoppers).
- Improvement of safety and reduction of social cost by the decrease in the number of traffic accidents.

Revitalization of Local Economy

- Investment promotion：Establishment of new business facilities in station areas is expected.
- Revitalization of real estate market：1,318 ha of floor demand for commercial and business services is expected in station areas.
- Creation of employment : 155,000 new employment opportunities are created at station areas (within 800 m) by the development of the UB Metro by 2030.
- Increase in tax revenue : Revenue from sale tax, income tax, real estate tax and new tax for redevelopment is expected to increase. The total amount of the increase in 2030 is assumed to reach US$232 million.

Effects on Environment

- CO_2 emitted by cars on main roads is reduced by 34,000 tons per year by 2030
- NOx emitted by cars on main roads is decreased by 1,754 tons per year as of 2030

Technical Transfer to Mongolia

- The UB Metro is the first electric urban railway in Mongolia and new technologies and systems such as civil works for underground (shield tunneling method), communication, train traffic control and power system will be introduced. UBMC will have 580 Mongolian engineers with the operation and maintenance skills to provide safe and comfortable urban railway services
- Know-how on the underground development is introduced in relation to the development of the Metro.

4. Public-Private Partnership (PPP) Implementation Scheme

1) PPP Scheme

With regard to the implementation scheme of the UB Metro, there are basically three types of schemes: the public work scheme, the Public-Private Partnership (PPP), and the hybrid public company scheme. According to the Railway Law of Mongolia, a two-tiered system is a basic structure of the railway business. Accordingly, the government will be the owner of the infrastructure and lease it to concessionaires under a long-term agreement. The concessionaires are supposed to develop, purchase or construct the rolling stock (owned or leased), and related facilities, and own them. After that, they begin to operate the urban public transportation system, which forms a part of this project.

On the assumption of a PPP implementation scheme, the following two schemes are possible:

(1) A special purpose company (SPC) scheme: SPC operates the Metro based on the two-tiered system; and

(2) A public company scheme: A public company by the joint-investment of the public and the private sectors operates the Metro based on the two-tiered system.

With regard to the legal aspect, in case of an SPC scheme, it is expected that the Metro Project will be a concession project under the Law on Concession as long as it is included in the concession list. As for a public company scheme, when the law is applied, the same process as the SPC scheme such as inclusion in the concession list is required. However, the concession law does not clearly stipulate conditions under which the joint investment public company must follow the concession law. Therefore, the procedure of the metro project must be based on the decision of concerned organizations (in this case, the Ministry of Economic Development, which is in charge of the concession law).

As for the implementation scheme, the two-tiered system (the national government is an owner of the infrastructure) is appropriate due to financial reasons as well as the regulation of the Railway Transportation Law of Mongolia.

According to the result of cash flow analysis of this project, Project Internal Rate of Return (PIRR) is around 2% on the assumption that the ODA loan is utilized and average fare is MNT 600. This shows that it is not realistic for one operating company to pay back the investment of the infrastructure with only fare revenue and implement a sustainable operation and management. The infrastructure should be paid back on a long term basis as public goods from the economic point of view. An operation scheme clearly different from the SPC management which provides comfortable metro service on the commercial basis is required.

Regarding the validity of the investment ratio, further discussions between concerned agencies are necessary. The government of Mongolia has clear policies which state that "the government shall provide the public transport services with responsibility" and "the UB Metro is the first urban mass transit system in Mongolia and the know-how from the private sector will be utilized to improve the inefficiency of the public services." Therefore, the study team proposes to choose a "Public Corporation" scheme in which the public does mainly the operation. The private sector will be strategic partners[3] whose roles are to invest in the company and to provide their management know-how (see Figure 3).

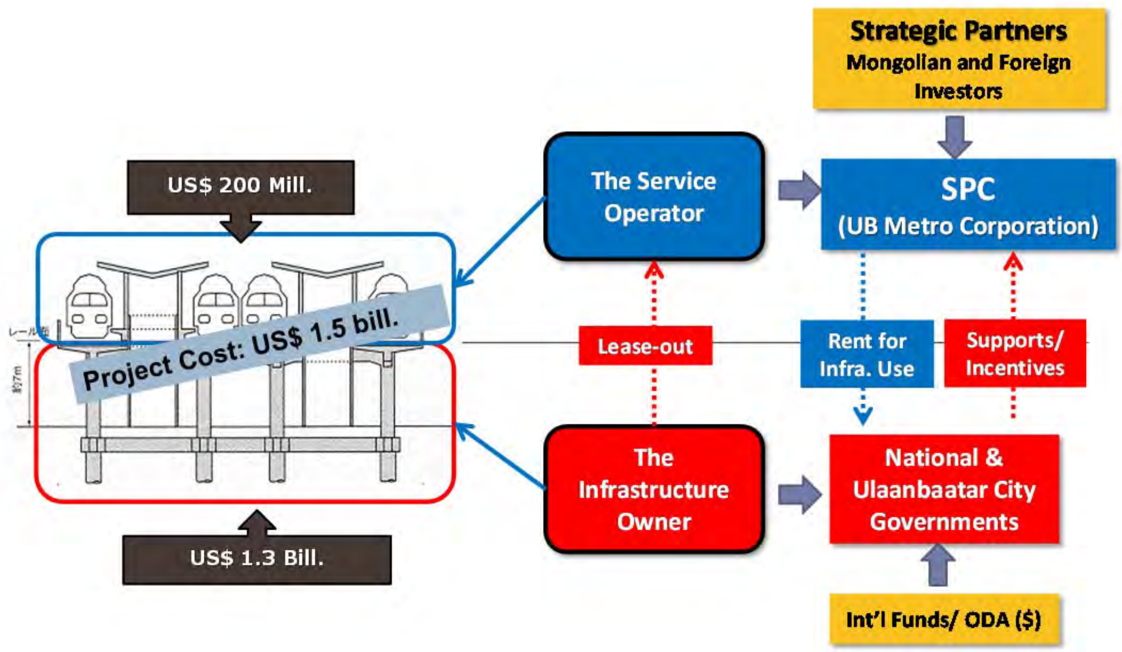


Figure 3: Two-tiered PPP Scheme of UB Metro

[3] There are many projects with strategic partners such as the Light Railway Transit (LRT) Project in France and the Beijing International Airport Project in China.

2) Financing Scheme

On the assumption of the proposed public corporation scheme, a financing plan is prepared on the basis of the following policy. The basic policy is that the government of Mongolia is responsible for the financing because the UB Metro is a public transport service provided by the government. The initial investment is US$1.5 billion (MNT 2 trillion) and this cost is divided into two parts: (i) US$1.3 billion is for the fundamental structures (infrastructure portion) specified in the railway transportation law and (ii) US$200 million is for rolling stock and related systems. The financing scheme is also separately examined for each part.

The starting point is that the UB Metro project must be approved as a national strategic project and granted the highest implementation priority. Regarding the fundamental structures (with US$1.3 billion of investment), as a core fund, Japanese ODA fund, which is a long-term loan with a low interest rate, should be incorporated in the financing scheme, and bilateral technical assistance from Japan will also be provided. This brings about material and immaterial collaboration with partners from Japan. In addition, the budget from the government of Mongolia must be secured as a counterpart fund in order to receive the Japanese ODA fund. Government Special Fund such as Human Development Fund based on revenue from mineral resources and the development bank of Mongolia bonds with government guarantee and Samurai bonds with JBIC guarantee are utilized.

On the other hand, it is assumed that a newly established operator, "Ulaanbaatar Metro Corporation (UBMC)" procures the rolling stock and prepares the opening of the operations. In this case, UBMC needs US$200 million of funding, 30% of which is procured as equity and 70% comes from loans.

A proposed UB Metro Scheme is shown in Figure 4.

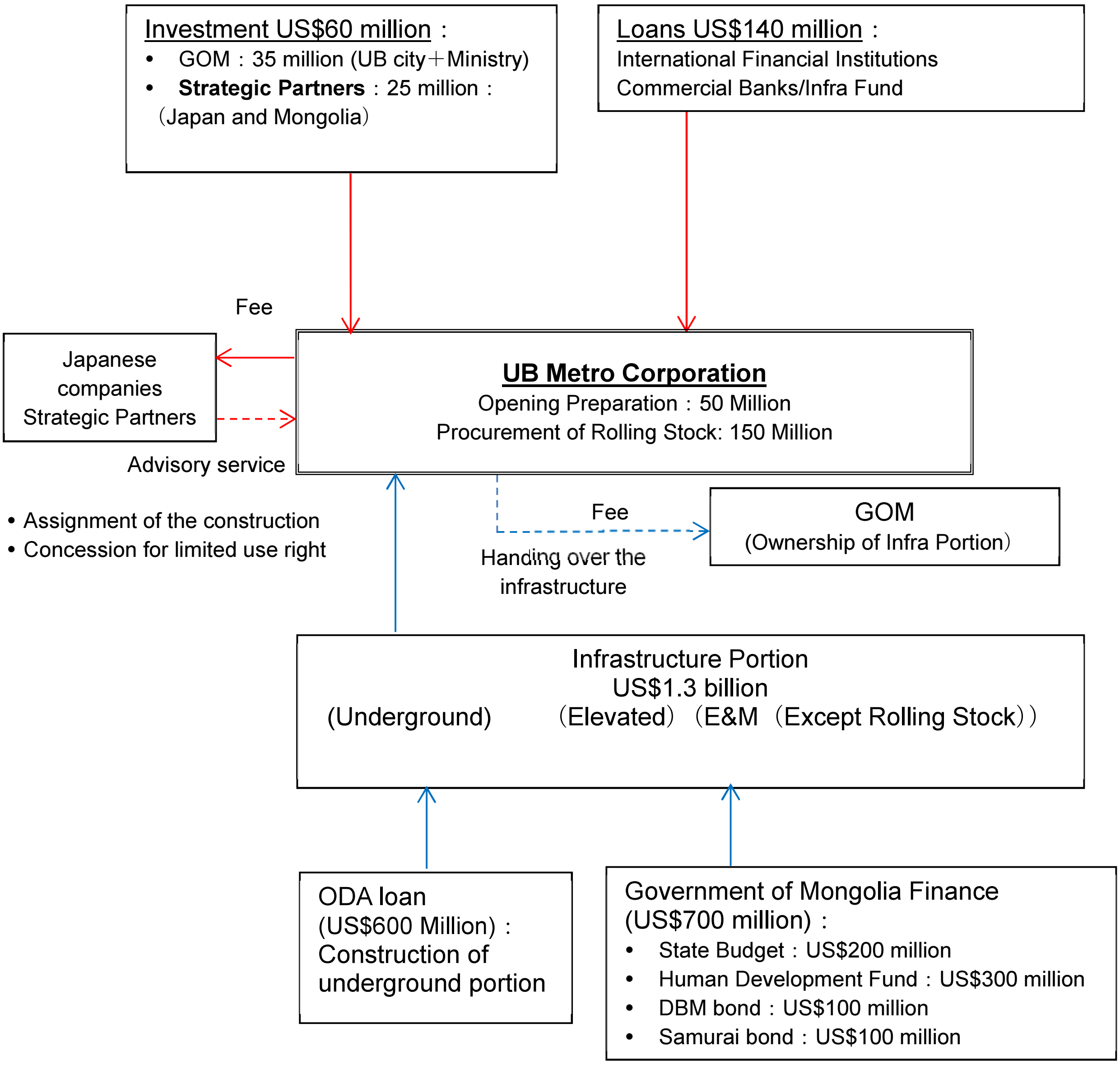


Figure 4: UB Metro Scheme (Draft)

3) Organizational Structure for Operation and Maintenance (O&M)

This study examined the most suitable scheme of the Operation and Maintenance (O&M) based on the legal standpoint of the railway, the Mongolian side's awareness of construction and operations through the concession system and private sector operation, and technological experiences. It is the most appropriate scheme to establish the UBMC, which conducts the O&M with assistance of experienced foreign strategic partners in terms of the techniques and services for urban railways. It is also advised that policies regarding the strategic partner agreement be developed such as strategic partners will transfer their stocks to the Mongolian side when there is already sufficient capacity and a structure for Mongolian personnel to conduct O&M by themselves after a certain period (7~8 years).

Among the personnel necessary for UBMC at the start of business operations, it will be necessary to train particularly the 50 or more drivers required prior to the start of operation. If continuity is taken into consideration, 70 drivers should be employed after that time. Due to the large numbers of required drivers, the hiring of a number of instructors at the stage when on-site training is possible is advised. The driving instructors who develop the system to train drivers on site by themselves must be trained overseas since there is no training facility in Mongolia. It will not be a problem if the training period in other areas is short compared to that of the drivers, but recruitment will need to be done one year before starting operations.

It is expected that in 2030, 580 Mongolian personnel will already be working with various necessary training programs for the UBMC, including 80 head office staff which are not mentioned above.

5. Risk Management of the Project

The following are the risks related to the Metro Project: (1) Viability Gap Risk, (2) Revenue Risk, (3) Country Risk, (4) Foreign Exchange Risk and (5) Regulatory Framework Risk. In implementing the Metro Project, stakeholders need to analyze these risks and manage them by reflecting risk management measures in project contract, procuring various guarantees, and protecting it by insurance, etc.

The following are specific issues for risk management of the proposed UB Metro Corporation (UBMC) based on the two-tiered system. These issues are needed to be considered when private investors negotiate and enter into agreement with the Mongolian government:

1) Project Contract and Formulation of Public Corporation based on the Two-tiered System

A basic assumption of the two-tiered system is to construct the infrastructure portion using the public fund (with huge Viability Gap Funding of which the government is responsible) and to cover operating expenses and additional investment by operating revenues as much as possible to implement the metro operation independently. Therefore, notwithstanding the UBMC, with major shareholding owned by the Mongolian Government, risk management based on the above-mentioned principles of the two-tiered system is necessary to be pursued. Furthermore, a specific project agreement regarding the metro operation and management should be entered into between the government, UB City and the UBMC, in addition to the legal establishment procedure of the company.

2) Agreement of GGU（Government Guarantee and Undertaking）

It is essential to have an agreement with the Government Guarantee and Undertaking (GGU) which requires government support for critical risks of the company management and operations of the UBMC in order to stipulate and secure the support and guarantees from the Mongolian Government about the risks which UBMC is unable to manage and control such as financing risk for the infrastructure portion, demand (ridership) risk, foreign exchange risk, political risk, and force majeure risk.

3) Formulation of Financing Based on the Two-tiered System

Without viability of public funding, no commitment by financiers will be secured for rolling stock, which UBMC is obligated to procure. To this end, prior to the formulation of financing on the UBMC side, it is essential to clarify and verify the necessary degree of commitment of the government for the infrastructure portion in order for the commercial (and/or JICA PSIF) lenders to provide funding for UBMC. This condition should be assumed for the negotiation and contractual arrangement with Mongolian Government for financing obligated by the UBMC.

4) Management of Construction for the Two-tiered System

It is essential for the UBMC to secure a position in charge of management of design and construction as its intention is appropriately incorporated in the design, construction and construction supervision of the infrastructure portion. Regarding the procurement of advisors for the design, construction and construction supervision, besides the one for the infrastructure portion, which is to be constructed using the public fund, an in-house advisor should be procured specifically for the UBMC who could comprehensively manage the design and construction process of the Metro development on the basis of the Strategic Partner agreement.

5) Management of Completion Risk for the Government Portion

Risk of delays in the completion must be managed very stringently. To cover the risk caused by the government, Liquidated Damage Penalty Payment mechanism and compensation payment for the material delay and so on must be stipulated. Furthermore, it is generally practiced in the contractual arrangement that appropriate compensation conditions for the damage of the UBMC caused by the government should be stipulated. These cases must be thoroughly examined and discussed with the government to be included in the project contract.

6) Organizing SPC (UB Metro Corporation: UBMC)

Regarding the establishment of UBMC, it would be preferable in terms of the accumulation of know-how to first establish a specific "UB Metro Preparation Unit" inside the UB City Government. Then the major members of the Unit are to be transferred to the UBMC as its core members. The private sector strategic partner would enter into the strategic partner agreement with this UB Metro Preparation Unit, and support the Unit in all aspects of the Metro preparation. They would then participate in the UB Metro Corporation as major shareholders when the Unit transferred to the UBMC. Eventually, each specific expertise of the Metro project enters into an advisory agreement with the UBMC.

7) Fare Revision Risk

Revision of fare (timing and level) must be stipulated in the project contract entered into between the Mongolian Government and the UBMC because the revision of fare could not sometimes be controlled by the UBMC alone due to politics and other reasons.

8) Application of Minimum Revenue Guarantee Mechanism

It is specifically difficult to control revenue risk during the launching period of the metro business. Therefore, it is required to apply a minimum revenue guarantee mechanism at least during the initial phase of the operation when commercial financing is structured for the procurement of rolling stock by UBMC.

9) Subsidy Mechanism for Additional Investment

It is also necessary to examine and prepare a subsidy provision mechanism at least for the risk of additional investment (addition of rolling stock, renewal of facilities, etc.) which is the most critical risk for the cash flow of the UBMC in the future.

10) Establishment of Bank Account to earmark Infrastructure Use (Lease) Fee

It is preferable to pool the payment of the infrastructure use (Lease) fee which is to be paid by the UBMC to the Mongolian Government, the owner of the Infrastructure. It is also preferred that the payment is managed under the responsibility of the public. The pooled fund should be used for the purpose of the compensation payment for the risk caused by the Government, the subsidy payment for additional investment by the UBMC with certain conditions and so on.

11) Adjustment with Station Plaza Development

It is necessary for the Metro Project to adjust with the station plaza development and other commercial development projects based on master plans created by the public. It is preferable that UB City government initiate the tender for the development of the station plaza area and UBMC participate in the implementation of these master plans and the evaluation committee of such tenders in order to incorporate the proper intentions of the UBMC to the station plaza development along the Metro corridor.

12) Adjustment for the Risks of Initial Phase of Operation

In order to mitigate risks of the initial phase of the operation, it may be worthwhile to examine an adjustment mechanism for such risks in which the risk adjustment (renegotiation of contract conditions including the finance) is to be made after both parties experience the first year of operation. However, in such cases, the procurement of purely commercial financing may be difficult, thus much more involvement of the public and more elaborated financing structure may be necessary.

6. Economic and Financial Evaluation

The economic analysis is to analyze if the return on a project is worth the investment from the viewpoint of the national economy as a standpoint of the government, and the yardstick is the

Economic Internal Rate of Return (EIRR). The rationality of the investment in the project is evaluated based on the EIRR estimate by comparing the economic costs and benefits over the life of the Project, which is normally assumed to be 30 years after opening.

In general, the economic benefit of the transportation development project is defined as the savings in vehicle operation cost (VOC) and travel time cost (TTC) of users attributable to the project. The benefit is comparatively easy to quantify and is estimated through a "with-and without" comparison of traffic demand analysis.

When the proposed mixed fare system (200 Tg within 2 km, 50~70 Tg/km over 2 km) based on the traffic demand analysis is applied, EIRR is 18.6~20.6, which means that the project is economically justified. In this case, the average fare is 426 Tg~452 Tg, but even in the case of the flat fare system with the average fare of 600 Tg, EIRR is 16.0%.

As for financial evaluation, cash flow analysis is conducted to evaluate the project's financial viability. Evaluation indicators are Project Internal Rate of Return (PIRR) and Equity Internal Rate of Return (Equity IRR).[4] This study conducted cash flow analysis of two cases:

(1) An entity is supposed to be responsible for the metro project with all the investments of US$1.5 billion.

(2) The UBMC invests in US$200 million worth of rolling stock and related facilities based on the two-tiered system.

In the first case, the cash flow situation of the entity will be too difficult to manage the project. Given the average fare of MNT 600/passenger, the financial internal rate of return (FIRR) is computed at a low 2.0% p.a. This means that the commercial operation of the project will be practically impossible.

Therefore, a two-tiered system is recommended to make the metro project financially feasible, that is, as the infrastructure owner and as the service provider. As the service provider, or the operation management body, the UBMC shall be established as a public company. The UBMC shall invest a total of US$200 million for procurement of rolling stock and related E&M, and the operation cost and renewal costs of rolling stock and E&M shall be covered by the fare revenue. Moreover, the UBMC shall have a responsibility of paying a certain amount of the concession fee (or the infra-rent) to the infrastructure owner (the state government) out of the fare revenue.

A cash flow analysis of the UBMC was conducted based on the following two fare systems:

- P_0 Case: Average fare of MNT 400
- P_1 Case: Average fare of MNT 600

Under an assumption that the annual infra-rent is equivalent to 2% of the initial infrastructure cost (or US$26 million), the following results are revealed:

In the case of P_0, PIRR is computed at 11.2%, and it drops to 6.0%, given a 10% increase of the cost cum a 10% decrease of the revenue. Thus, the elasticity for risks is low, which concludes that the metro project is not feasible enough.

On the other hand, in the case of P_1, PIRR is 18.7%, which shows that the project is viable. Furthermore, the PIRR can still stay at 13.8%, which is high enough, even if the cost and the revenue changed with +10% and -10%, respectively.

The P_1 Case shows another result that even though the infra-rent fee is raised to 3% (US$39 million/year), the PIRR is 15.9 %, which means that the metro business will still be viable.

[4] Equity IRR is a converted quantity of future return to the capital as an annual rate of interest. It is also defined as a discount rate at which the present value of all future cash flow is equal to the initial investment. To avoid confusion with Economic IRR (EIRR), this section mentions it as Equity IRR.

7. Key Issues towards the Development of the UB Metro

In the development of the UB Metro, the following are the priorities to be addressed.

1) Consistency with the Railway Transportation Law

With a current railway transport law which is not updated with consideration of an urban railway, and because the government issuing a permit for railway operation and arranging supervision is a basic thing, it should be fairly flexible in terms of the law for the two-tiered system. It is also possible to accept international standards and overseas standards as applicable in a special case.

If these are considered, it is possible to proceed with a comprehensive upgrade of the Metro under the current law. However, from the very beginning, the current law is based on the concept of the "Ulaanbaatar Railway," which is a government-owned railway and does not presuppose an independently operated railway like the Metro. And because the administrative agencies of government employees in charge of supervision are not clearly separated from those in charge of operations, there are a lot of unclear portions in terms of which laws actually apply to the Ulaanbaatar Metro. Therefore it will be necessary to proceed with gradual coordination with the related government agencies on how the law will apply to the progression of operations.

2) Establishment of " Ulaanbaatar Metro Corporation (UBMC)"

The UBMC, as the implementing and operating body of the metro project, needs to conduct a survey for a detailed plan and basic design of the UB Metro through discussions with the national government. In addition, it is required to promptly establish the UBMC which is structured collaboratively with the national and city governments and the private entities in line with the Mongolian systems and actual circumstances because recruitment and training of staff need to be conducted prior to the start of the operation.

3) Security of Multiple Financial Sources

The infrastructure is expected to be developed as public works to be executed by the government sector, with support of ODA budget. The state budget and the Development Bank of Mongolia's (DBM's) bonds, as well as Japanese Yen loan, will be utilized. In addition, it is expected that tax revenue will increase in the future and it is also suggested to consider the development of a subsidy mechanism under which a part of increased tax revenue is utilized for the metro project.

4) Formulation of Fare System and Policy

A rational public transport policy with a sustainable fare system, including social support to commuters, students, elderly people, low income people, etc., needs to be established.

8. Next Actions towards the Realization of the UB Metro Project

The following actions are required as preparatory work towards the implementation of the UB Metro Project.

1) Official Approval as a Priority National Project

In order to implement the UB Metro Project with the state budget and ODA loans, it is essential to obtain Cabinet approval and be included in the national project list prepared by the Ministry of Economic Development. Thus, UB City or the preparatory unit needs to proceed with the approval process.

2) Establishment of an Implementation Mechanism（UBMC）

It is required to establish a UBMC preparatory unit and proceed with preparatory work through discussions with stakeholders.

3) Improvement of Legal Framework for Construction and Operation of "Urban Railway System"

The Railway Transportation Law covers the necessary items for railway business and has flexible contents, although the law does not assume urban railways. However, it is necessary to examine the addition and revision of the technical regulations. In addition, the development of a legal system for underground city development and underground space utilization is also necessary.

4) Implementation of Detail Design (D/D)

Once this project is approved as a national priority project and the government makes a decision of the project implementation, the detail design (D/D) of the infrastructure component will be the next step. The D/D is a package of engineering services, including:

(1) Detailed geological surveys;

(2) Detailed design for all infrastructure facilities and stations;

(3) Review of the project costs and the procurement scheme;

(4) Preparation of all tender documents;

(5) Environmental Impact Assessment (EIA);

(6) Review and improvement of related legal framework (the Railway Law and new regulations for "Underground Development"); and

(7) Preparation of ODA loans for the infrastructure construction.

Possible finance sources for the engineering services above are two:

A: Mongolian state budget; or

B: Engineering Service (E/S) loan[5] by JICA.

Needless to say, the first option is the most desirable. However, it is hard for the Mongolian government to conduct the detail design of the infrastructure development by itself because the project is the first urban transport system in Mongolia. Therefore, direct and indirect instructions should be given to them by experienced countries. Thus, the second option is recommended to be chosen on the assumption of Japanese technical support.

Regarding JICA's support, there is another option that the D/D work be granted by JICA, only when the Mongolian government requests a STEP loan[6] for the infrastructure development project in advance. However, this option usually takes a long time for JICA's technical appraisal prior to the official commitment. On the other hand, it may be hard for the Mongolian side to make a decision on the use of JICA-STEP loan before the D/D work is completed. Therefore, the grant option is not necessarily recommendable.

5) Conduct of Environmental Impact Assessment (EIA)

According to the EIA Law of Mongolia and the Guidelines for Environmental and Social Consideration of JICA, sufficient considerations on possible negative effects of the Metro project seem necessary. Possible negative effects are related to topographical and geological features such as land subsidence, groundwater pollution, air pollution, noise/vibration and accidents during construction and noise/vibration after Metro operations begin. Therefore, EIA needs to be conducted during the detail design prior to the start of the Metro Project.

[5] Loan conditions: Annual interest rate: 0.01%; Payback years: 25 years; Grace Period: 7 years; Procurement: Tied.

[6] STEP stands for Special Terms for Economic Partnership. Its loan conditions are as follows: Annual interest rate: 0.1%; Payback years: 40 years; Grace period: 10 years; Procurement: tied; a special condition: more than 30% of the procurement shall be covered by Japan-origin goods.

1 Proposed Study

1 Proposed Study

1.1 Background of the Study

Ulaanbaatar City had a population of 1.13 million in 2010, and it is estimated to increase up to 1.53 million by 2020, and 1.76 million by 2030. In addition, Relative to the entire population of Mongolia, Ulaanbaatar's population is predicted to increase up to 49.5% by 2030, a substantial jump from 37.7% in 2005. This indicates a higher concentration of people in the city. On the other hand, after the switchover to market economy in the 1990s, the economic growth has been in full gear, and the Mongolian economy had grown by an average of 6.5% per year during the decade from 2000 to 2010. In that period, Ulaanbaatar had grown annually by 7%, higher than the national growth average. Further growth is expected with the opening of business operations in Oyu Tolgoioi (copper mine large-scale development project) in 2013, and this mining sector should be the leading force of Mongolian economy in the near future.

However, the existing infrastructure to support the above mentioned population increase and economic activities is not enough. Urban utilities such as water, electricity, and heating are almost in limited supply, and strategic solutions are required for each sector. Moreover, traffic congestions in the central parts of the capital city have caused to limit effective economic and social activities, so a comprehensively balanced urban transportation system is needed.

According to the 2011 survey on the transportation situation in Ulaanbaatar, the number of trips per day is approximately 2.1 million, excluding "Walking", and 3.1 million trips/day including the "Walking". The ratios of each transportation mode are as follows: Private Car, 28.6%; Public Transport, 38.2%; and Walking, 33.2%. Compared with the data of 2007 Study on City Master Plan and Urban Development Program of Ulaanbaatar City in Mongolia (hereinafter referred to as "UBMPS") , the use of "Private Car" and "Walking" have increased, while "Public Transport" has decreased (modal share of "Public Transport" was 42.6% in 2007). With reference to the rate of population growth, the expansion of vehicle ownership is rapid, and within three years from 2007 to 2010, the population growth becomes 1.1 times, while the number of registered vehicles increased to 1.8 times, and the number of vehicle ownership per 1,000 people had become 1.6 times.

The major reasons of the current traffic congestion in Ulaanbaatar are the following: inconsistent compliance of traffic regulations by road users; lack of transportation operations management; and insufficient transportation infrastructure construction/maintenance. In addition, other causes include extension of traffic jam; traffic safety reduction; and deterioration in public transportation services, as well as many other challenges and tasks that need further improvement.

Based on these current situations, seven urban transportation development strategies were proposed in UBMPS in March 2009. These are: 1) construction of public transportation system for appropriate urban development extension; 2) efficient operations of automobile traffic; 3) transportation infrastructure construction/maintenance focused on roads; 4) construction of effective public communication facilities between regions and urban areas; 5) improvement of transportation environment and disaster prevention functions; 6) institution-building for urban transportation maintenance/operations improvement; and 7) sustainable activities of urban transportation tasks.

Considering these strategies, the following transport systems are being planned: urban mass transit (UMRT) for civil mobility improvement based on Ulaanbaatar Metro construction in the city central zone; urban freeway from city east to city west; and new buffer roads around the northern hilly region with disaster prevention functions.

The study team started to conduct surveys to build an appropriate project implementation mechanism for the Ulaanbaatar Metro project by utilizing the JICA Public-Private Partnership (hereinafter referred to as "PPP") infrastructure project scheme. During the surveys, the study team have discussed the possibilities of Ulaanbaatar Metro project implementation and identified key issues for the implementation of the Metro project.

1.2 Needs for the Study

The Country Assistance Program for Mongolia by the Government of Japan was announced officially in April 2012. The primary goal of the program is "Assistance to the self-help efforts for poverty reduction through sustainable economic growth." In order to achieve this goal, the program focuses on the following three issues (medium-term goals):

(1) Sustainable development of mineral resources and strengthening governance

(2) Assistance for extensive socio-economic growth to attain good quality of life for the people

(3) Strengthening urban functions of Ulaanbaatar city

With regard to the third point, "Strengthening urban functions of Ulaanbaatar city," which is closely related to the Metro project, the Japanese government showed its policy that it will continue to provide necessary support on both hard and soft aspects in order to realize "the City Master Plan and Urban Development Program of Ulaanbaatar City 2030" as proposed by the UBMPS study team.

To be more specific, the following are focused on: (1) the development of laws and regulations; (2) the capacity development of governmental organizations in charge of the urban planning, and urban development and management; and (3) the promotion of the infrastructure development by using the knowledge and techniques of Japan. The Metro project is in accordance with this policy and regarded as an important project for Japan.

As other studies such as UBMPS have already revealed the needs for a public transportation system, it is not too much to say that an effective public transportation system and strategic urban planning will support sustainable growth of the city. Moreover, it has already become an accepted truth that an effective public transportation system contains a Metro system and Bus Rapid Transit (BRT). Considering the fact that the population of Ulaanbaatar City continues to increase and a number of socio-economic activities are likely to take place along the mass-transit corridor, it can be concluded that the needs for the projects are growing. Furthermore, its economic efficiency and potential demand were confirmed in UBMPS.

The Technical Assistance for Improvement of Urban Transportation System in Ulaanbaatar, the proposed BRT system by Asian Development Bank (ADB), and the feasibility study by the Public Transport Department of Ulaanbaatar City are also the actions that reflect the need for public transportation.

1.3 Methodology of the Study

1.3.1 Objectives of the Study

Line 1 (east-west line) of Ulaanbaatar UMRT system is the target model of this study. The study aims: 1) to research on the most suitable mass transit system comparing the proposed UMRT to other systems; 2) to suggest a feasible PPP scheme to realize and manage proposed Ulaanbaatar UMRT system; and 3) to reveal critical points to provide Japanese official development assistance (ODA) and private investment.

1.3.2 Target Area of the Study

The target area of the study is Ulaanbaatar City, Mongolia.

1.3.3 Study Items and Framework

This study includes the following three main tasks:

【1】Analysis on socio-economic and project implementation conditions in Mongolia;

【2】Proposal on the implementation plan for a PPP project; and

【3】Proposal on project implementation mechanism and structure.

This study was conducted for 19 months starting from September 2011 until March 2013. All the study items and the timeline for each task are shown in Figure 1.3.1.

In the first phase of the study, the major findings based on operations of Task 1 and Task 2 were introduced in the interim report prepared in March 2012. At that stage, technical considerations for schematic scenarios and proposed systems were done, and the entire picture and framework of the Metro project were clarified.

In the second phase of the study, with all the survey results of Task 3, the project implementation plan was made and issues were addressed in the draft final report, which was prepared in January 2013. In this stage, various aspects of the PPP implementation scheme are studied, including economic and financial analysis, financial management plan, procurement plan, legal system, and project management and organizational structure. About eight months after consultations on the interim report were allocated to complete the draft final report including the coordination with stakeholders. The final report is formulated in May 2013 after careful checking and corrections of the draft final report based on comments and suggestions from concerned departments in the Government at the national and local levels.

After the submission of the interim report, the study team spent enough time to develop a feasible project implementation system and create a schedule of concrete actions to realize the Metro Project through consultation with stakeholders

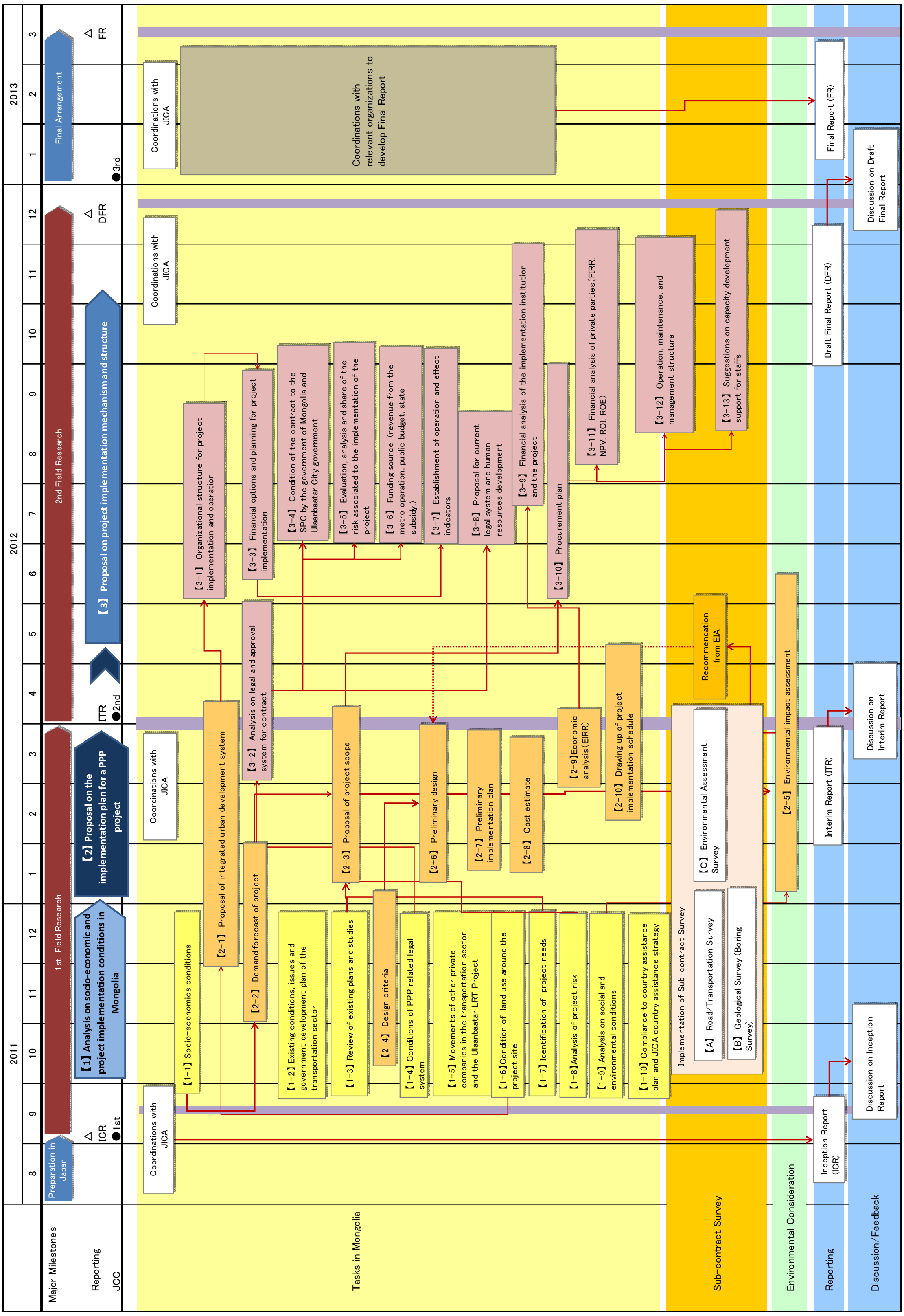


Figure 1.3.1 Study Items and Framework

1.4 Approaches in Conducting the Study

1.4.1 Approaches for Technical Aspect

Survey will be conducted based on the following six points, for the technical aspect:

- Commercialization as PPP project
- Consideration for the appropriateness and relevance of project scale
- Environmental and social considerations
- Review of existing studies
- Survey to update a simulation model for traffic demand analysis
- Planning issues to propose an integrated urban development model

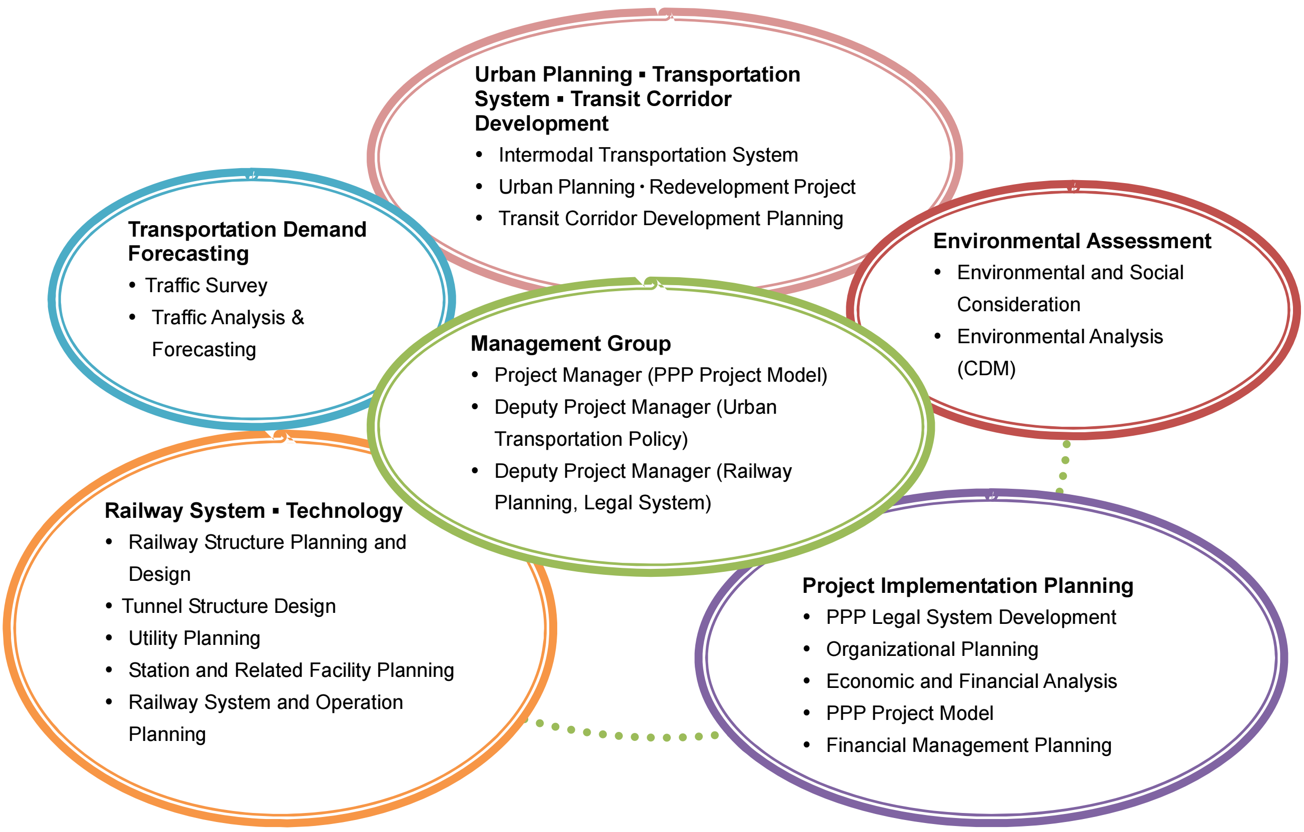
1.4.2 Approaches for Study Implementation Aspect

Survey will be conducted based on the following three points, for the study implementation aspect:

- Information exchange with Mongolian government
- Understanding recent moves of other organizations
- Organization of JCC and its regular meetings

1.5 Structure of the Study Team

In accordance with the tasks to be performed, the team is divided into six groups. Although the study team covers a variety of fields, all groups work closely and cooperatively with one another.



Source: JICA Study Team

Figure 1.5.1 Structure of the Study Team

2 Current Situation and Issues of Development of Ulaanbaatar City Region

2 Current Situation and Issues of Development of Ulaanbaatar Region

2.1 Current Situation, Issues and Related Projects of Development of Ulaanbaatar Region

2.1.1 Urbanization

(1) Population

The population of Ulaanbaatar (UB) City was 590,000 in 1990, 642,000 in 1995, 787,000 in 2000, 965,000 in 2005, and 1.13 million in 2010.

About 27% of the country's population lived in UB City in 1990. The population concentration of UB City, having been spurred by economic growth after the country's shift to a market economy system in early 1990s, reached 41% in 2011. This trend is expected to continue and UB City's share in the population will become larger in the future.

Over the last 20 years, the country's population has grown at an average rate of 1.3% per annum, while that of UB City is 3.3%. Although the population growth rate of UB City was more than 4% per annum for a decade from 1995 to 2005, it slowed down to 3.2% from 2005 to 2010. The population had been increasing by 34,000 people every year for 20 years from 1990 to 2010.

Table 2.1.1 Population of Mongolia and Ulaanbaatar

	Mongolia (thousand)	UB City (thousand)	Share of UB City (%)
1990	2,153.4	586.2	27%
1995	2,243.0	642.0	29%
2000	2,407.5	786.5	33%
2005	2,562.4	965.3	38%
2010	2,780.8	1,131.2	41%

Source: Mongolian Statistics, UB City Statistical Yearbook

(2) Population Distribution of UB City

The total area of UB City is 395,425 has, of which 7% or 27,409 has. is urbanized and further consists of apartment areas (11.8%) and ger areas (88.2%).

The population of the six central districts in UB City was 1,099,775 as of 1 January 2011, with 424,219 or 38.6% in apartment areas and 675,556 or 61.4% in ger areas. The average population density is 183 persons/ha in apartment areas and 26 persons/ha in ger areas based on the Team's Geographic Information Systems (GIS) analysis.

Table 2.1.2 Urbanized Area and Population Distribution in Six Districts of UB City (2011)

Item	Apartment Area	Ger Area	Total
Area (ha)	2,318	25,707	27,409
Population (thousand)	424.2	675.6	1,099.8
Population density (persons/ha)	183	26	40

Source: UB Statistics, and JICA Study Team based on GIS analysis

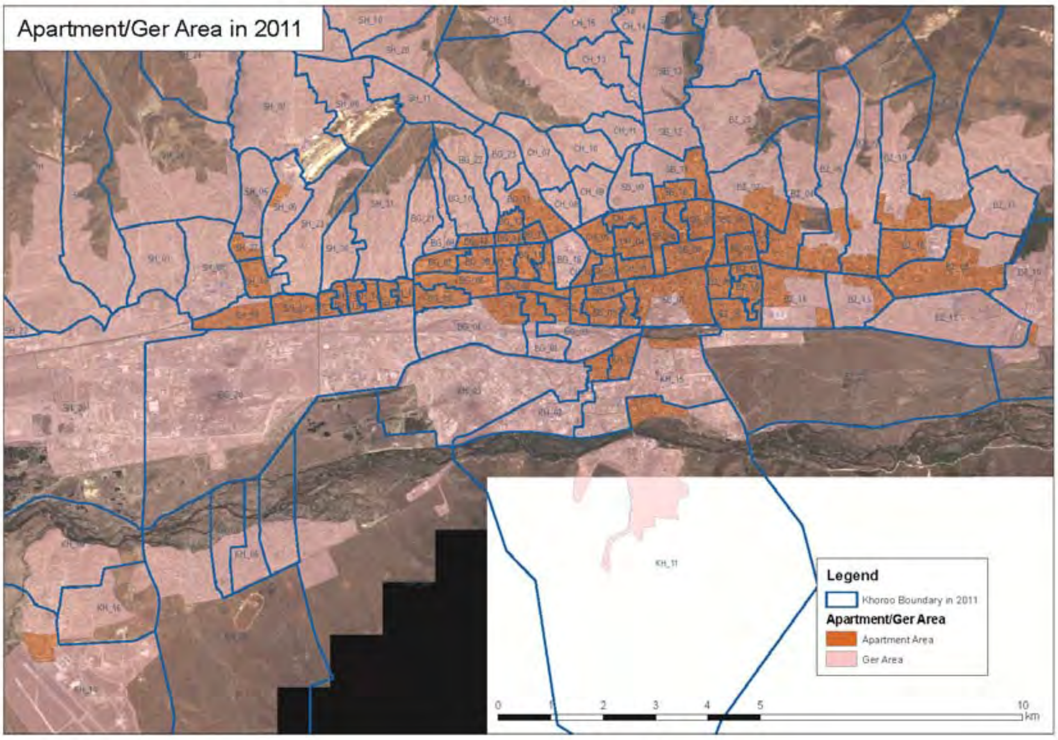
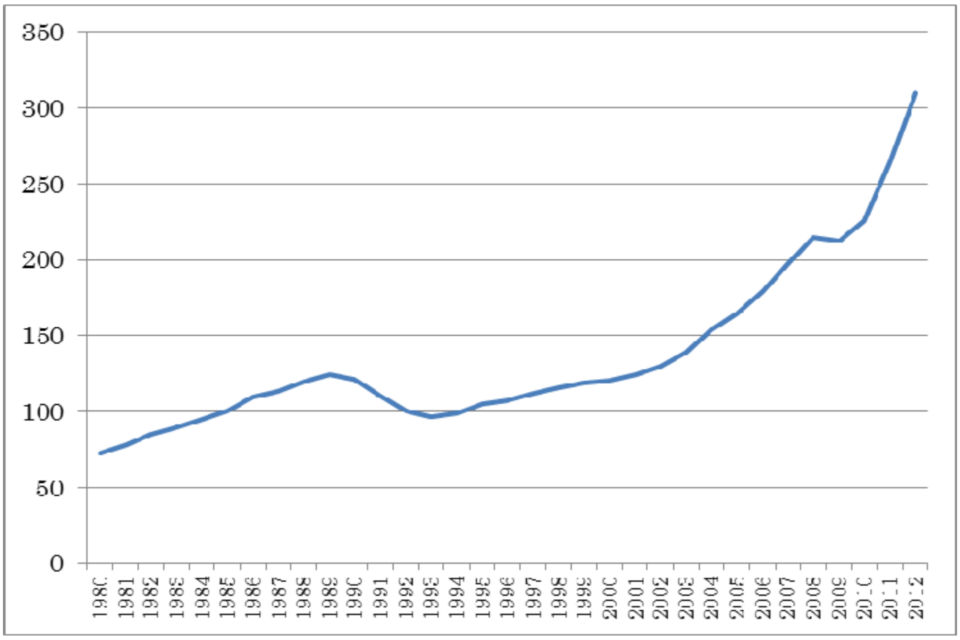


Figure 2.1.1 Apartment Areas and Ger Areas in UB City

(3) Economic Growth of Mongolia

Mongolia's economy has been growing steadily since 1992 when the nation became a market economy. Table 2.1.2 illustrates the trend of GDP with reference to 1992's GDP of 100. After the GDP hit the bottom in 1993, it grew at an average rate of 5.1% until 2010, showing a 6.5% growth from 2000 to 2010. It slumped in 2009 because of the Lehman shock in September 2008. However, it recovered and returned on the rise along with its growth with the emergent support from IMF, financial support from ADB, WB and JICA. In addition, there was an influx of investment recovery in the mining sector along with the recovery of copper price, showing real growth rate of GDP at 6.4% in 2010, 17.3% in 2011, the fastest growth rate in the world. The IMF's Article IV Report (Mongolia – 2012 Article IV Consultation and Third Post-Program Monitoring, Country Report No. 12/320, November 2012) estimates 11.2% in 2012 and 16.8% in 2013. GDP forecast in 2013 was revised downward but it is expected to keep the double digit growth in the mid and long term. This economic growth has accelerated the population concentration and urban development in UB City.

The GDP per capita was USD 2,300 in 2010, and the Ministry of Finance has estimated that it would reach USD 3,800 in 2012, and USD 12,000 to USD 13,000 in 2020.



Source: IMF - World Economic Outlook Databases (April 2012)

Figure 2.1.2 GDP of Mongolia (100 in 1992)

(4) Urbanization Impact

Most immigrants to UB City have recently settled in ger areas where infrastructure is inadequately provided. Once these people settle in ger areas of little infrastructure, it would cost much time and money to reorganize the areas into a settlement with a good living environment. In order to avoid such expansion of the ger areas and to lessen the cost for infrastructure provision and adverse environmental impacts in forming a sustainable UB City, it is imperative to construct a compact urban spatial structure with well-planned public transportation as its spine.

The population concentration in UB City has increased the demand for various infrastructure and utilities and has had an adverse environmental impact. These resultantly elicited urban problems including inadequate supply of water, electricity and heating, lack of treatment of wastewater and solid waste, and uncontrollable air pollution, water and soil contamination.

Relatively, the present road network of UB City was planned in a master plan in 1975 when the city's population was 349,000. The number of cars registered was 10,044 vehicles, and car ownership ratio was 2.9%. The plan targeted to cope with only 400 to 500 thousand people. In 2010, the population reached 1.11 million; the number of cars registered was 167,809 vehicles, and the car ownership ratio became 14.6%. Compared to 1975, the population became 3.2 times greater, the number of cars registered was 16.2 times more, and the car ownership ratio was 5 times higher. For the past 35 years, the trunk road network has had limited improvements, that are inadequate to meet the increasing traffic volume. Consequently, this has lead to traffic congestion. Improper traffic management, bad driving manners, and on-street parking have worsened the traffic conditions.

2.1.2 Urban Development Trend

Urban development, both redevelopment of built-up areas and new development, has been progressing in UB City along with the economic growth and population increase. Urban development patterns found in UB City are shown in Table 2.1.3.

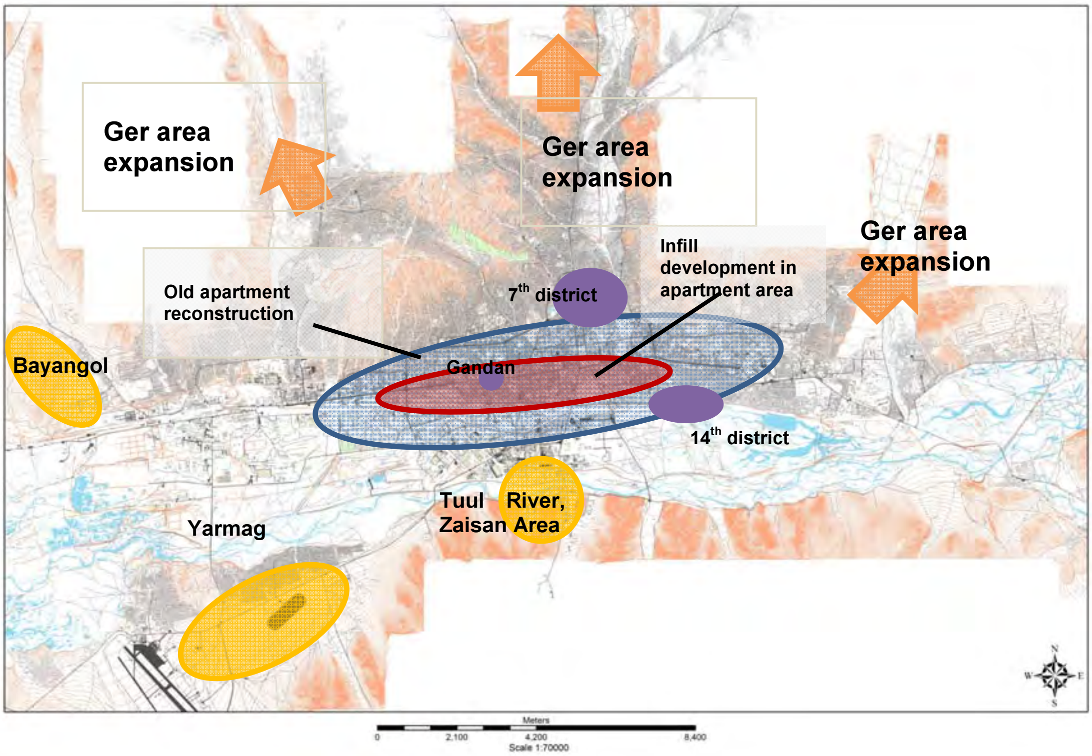
As the UB Metro Project will be developed along Peace Avenue, accompanying urban development projects include: (1) redevelopment of apartment and commercial buildings in the central area along Peace Avenue; (2) redevelopment of the ger area along Peace Avenue; (3) new development in suburbs integrated with UB Metro development, and new development integrated with the UB Metro development in the suburbs near the intermodal railway stations. Furthermore, after the second phase of the UB Metro development, (4) new towns in the suburbs should be integrated.

Table 2.1.3 Development Patterns in UB City

Pattern	Description
(1) Infill development in built-up areas on open space such as courtyards of Russian style apartment buildings	Many high-rise buildings have been constructed on open space such as courtyards of apartment buildings in the central area of UB City although this open space was originally designed for dwellers and neighbors to socialize and for children to play. Urbanization led by such intensive and dense development is done often without proper traffic impact assessment, and this causes degradation in the public service level like the schools and parks.
(2) Reconstruction development of old apartment buildings	As stipulated in the Housing Law, old apartment buildings that are evaluated as “not being seismic resistant” by the State Inspection Agency should not be occupied and must be reconstructed. In UB city, at present, there are 263 old apartment buildings, 27 of which are listed as “old apartments to be reconstructed” by UB City. Difficulty in finding investors to reconstruct these apartment buildings hinders the reconstruction projects. Some cases with investors have reconstruction plans at the rate of 10 or 20 times the current apartment units but without adequate provision of schools, parks, and car parks. This scenario would likely cause the shortage of public facilities.
(3) Redevelopment in Ger Areas	Several large redevelopment projects in ger areas, such as the 7^{th} khoroolol, the 14^{th} khoroolol, and the Gandan Temple area in central UB City are confronting problems on land acquisition and implementation not consistent with the plan. Those have been implemented with the land acquisition not under the urban redevelopment law. These projects are rather stagnant because in many cases the land acquisition cost surpasses the developers’ financial capacity.
(4) New Town Development	There are new development of fashionable, up market high-rise apartment buildings around the Zaisan area and the Tuul River. In the west part of the city, new town development plans have been approved by UB City, including Bayangol and Yarmag. These large development projects are not consistent with the development of public facilities of the transportation network, and schools, and park and likely to cause urban problems..
(5) Expansion of Ger Area	Expansion of the ger areas that are not equipped with adequate

	infrastructure is one of the urban problems UB City is confronting and would like to have strong control over; however, these areas are expanding because of lack of low cost housing to absorb the many immigrants who settle on the fringe of the ger areas. The new administration announced the active development of these areas; however, it is likely unachievable due to the lack of plans and the budget constraints.

Source: JICA Study Team



Source: JICA Study Team

Figure 2.1.3 Diagram of Urbanization Direction of Ulaanbaatar City

2.1.3 Related Projects

Projects strongly related to UB Metro are the BRT development project by ADB and the UB City Feasibility Study (FS) of the UB subway system by a Korean consultant.

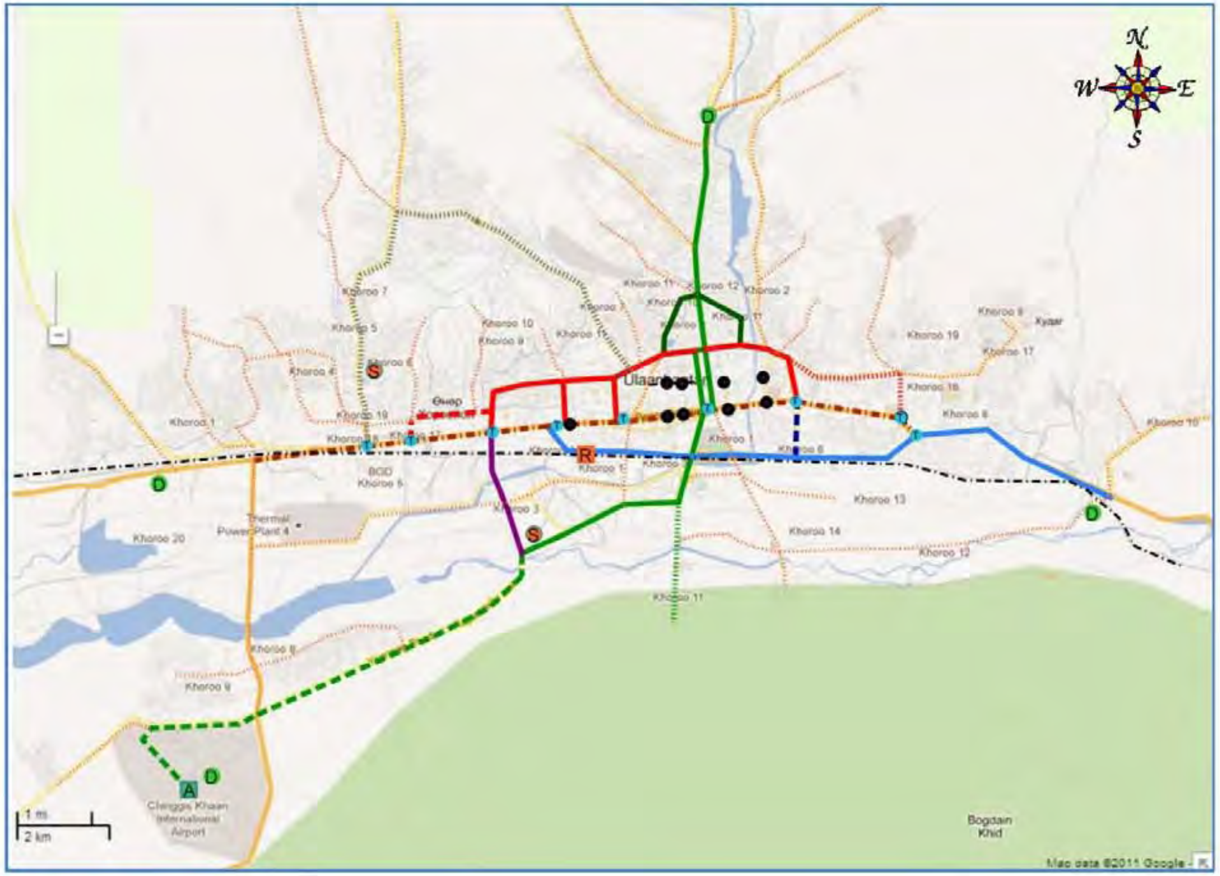
(1) The ADB BRT Project

The ADB BRT project, which has a total length of 64.5 km, contains three tranches as shown in table below. The first tranche has just been started to implement the north-south green line shown in the figure below.

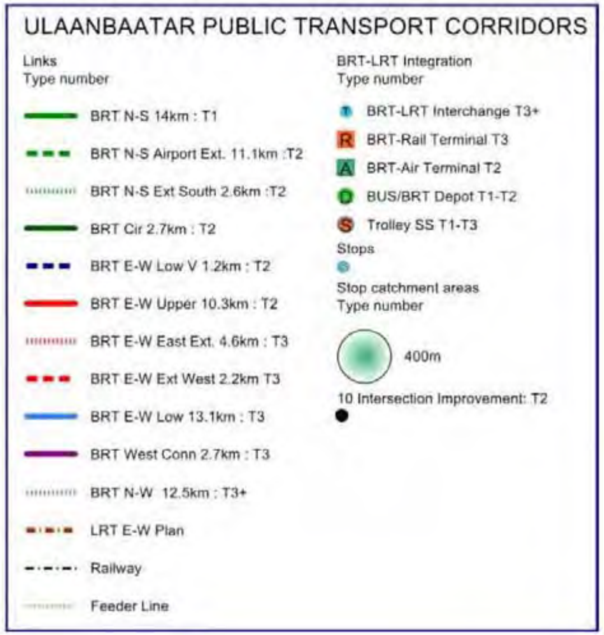
Table 2.1.4 Length of BRT by Tranche

Tranche	Tranche1 (2012～2014)	Tranche 2 (2014~2016)	Tranche 3 (2016~2018)	Total
Length (km)	14.0 km	27.9 km	22.6 km	64.5 km

Source: ADB, Presentaton material, Ulaanbaatar Transport Development Project (MON-MFF: TA 7156-MON), 31 January 2012



KM	T1	T2	T3	Total
BRT	14.00	27.90	22.60	64.50
Road Improvement	7.70	-	4.60	12.30
Trolley Bus Infrastructure Improvement	14.00	11.10	17.20	42.30



Source: ADB, Presentaton material, Ulaanbaatar Transport Development Project (MON-MFF: TA 7156-MON), 31 January 2012

Figure 2.1.4 BRT Plan by ADB (2012-2019)

(2) Feasibility Study of Metro Construction Project in UB City

1) Outline of Metro Project

A feasibility study for Metro construction in UB City was conducted by a Korean company group in 2011. The outline of the Metro Project is shown in Figure 2.1.4 and Table 2.1.5. The east-west line runs along Peace Avenue from Amgalan in the east to Emeelt (new town area) in the west, totaling 28.38 km in length with 21 stations. Of this 28.38 km, 21.12 km is underground in the section running through the central area of UB City, 16.64 km is elevated on both sides of the underground section, and 1.62 km is in the easternmost section at grade.

Open-cut and the New Austrian Tunneling Method (NATM) have been examined as methods for underground work, and the open-cut method has been selected as the more feasible one. The shield method was not examined in the feasibility study.

Source: Final Report, Feasibility Study on Metro Construction Project in Ulaanbaatar City, June 2011, UB City

Figure 2.1.5 Metro Routes Studied in FS

Table 2.1.5 Outline of East-West Route

Item		Description
Length		28.38 km
Structure	At grade	1.62 km
	Bridge (elevated)	14.64 km
	Underground	12.12 km
Station	At grade	1
	Elevated	8
	Underground	12
	Total	21
Underground work method		Open-cut

Source: Final Report, Feasibility Study on Metro Construction Project in Ulaanbaatar City, June 2011, UB City

2) Demand and Operation Plans

The demand and operation plans are shown below.

Table 2.1.6 Operation Plan for East-West Route

Item	Description
Length	28.38 km
Target year	2047
Traffic demand	20,858（trips/hour）
Peak demand	4,135 (p/h/d)
Mode selected	LRT
Average distance between stations	1.32 km
Train formation	18 formations（4 cars/formation） 16 for operation and 2 for reserve Total 72 cars in rolling stock
Congestion rate	120％
Number of passengers per train	469 passengers
Head way (Peak operation interval)	6.67 minutes（9 trains/hour）
Operational (commercial) speed	35 km/h
Operational Frequency	129 trains/day/direction
Operational time	47.5 minutes (one way)

Note: No utility cost is included.
Source: Final Report, Feasibility Study on Metro Construction Project in Ulaanbaatar City, June 2011, UB City

3) Cost Estimate

The cost estimate for the Metro Project is shown in Table 2.1.7. The total cost estimated is MNT 2,787 billion and the annual operation cost is MNT 230 million.

Table 2.1.7 Cost Estimate for East-West Route

Item			Amount（million MNT）
Construction cost	Civil work	Railway	924,729
		Station	370,768
		Subtotal	1,295,489
	Track		122,043
	Architecture		150,959
	System		583,989
	Removal of obstacles		35,632
	Subtotal		2,188,112
Land acquisition			48,978
Rolling stock			153,216
Incidental expenses			177,906
Contingency			218,811
Total			2,787,023
Annual operation cost			23,138

Note:
(1) Utility-related costs are not included.
(2) Removal of obstacles includes that of utility pipes, houses and buildings.
(3) With no explanaition in the source report, incidental expenses are thought to include

design, survey, test, and so on.
(4) Exchange rate is not described in the source report; as of 30 June 2011, US$1 equals MNT 1,258, and MNT 1 equals Yen 0.064, according to the exchange rate converter on the following website: http://www.oanda.com/lang/ja/currency/converter/.

Source: Final Report, Feasibility Study on Metro Construction Project in Ulaanbaatar City, June 2011, UB City

4) Financial Analysis

As shown in Table 2.1.8, a financial analysis has been done for the 30-year period from 2011 to 2047 with the construction period from 2011 to 2017 and start of commercial operation in 2018.

The projected number of passengers in 2018, the starting year of operation, is 133,515 passengers/day, and will gradually increase to reach 172,377 passengers/day by 2030. This will remain at the same level until 2047.

Fare employed for the analysis is MNT 300, the same amount as the bus fare in the city at the time the study was conducted.

As calculated, revenue combined from operation and non-operation will not be able to surpass operation cost, even after the maximum number of passengers is reached in 2030, and will result in a deficit of MNT 200 million every year.

Table 2.1.8 Profit Loss Statement for East-West Route

Year	Passengers (pax/day)	Cost (100 million MNT)			Income (100 million MNT)			Profit (100 million MNT)
		Construction	O+M	Total	Operation	Non-operation	Total	
2011		403		403			0	-403
2012		403		403			0	-403
2013		1,006		1,006			0	-1,006
2014		3,019		3,019			0	-3,019
2015		5,094		5,094			0	-5,094
2016		7,172		7,172			0	-7,172
2017		4,677	116	4,793			0	-4,793
2018	133,515	2,084	231	2,315	164	16	180	-2,135
2019	137,574	2,428	232	2,660	169	17	186	-2,474
2020	141,756	930	232	1,162	174	17	191	-971
2021	144,492		232	232	177	18	195	-37
2022	147,281		233	233	180	18	198	-35
2023	150,123		233	233	184	18	202	-31
2024	153,021		233	233	188	19	207	-26
2025	155,974		233	233	192	19	211	-22
2026	159,125		234	234	195	20	215	-20
2027	162,239		234	234	199	20	219	-15
2028	165,618		234	234	203	20	223	-11
2029	168,964		235	235	207	21	228	-7
2030	172,377		235	235	212	21	233	-2
2031	172,377		235	235	212	21	233	-2
2032	172,377		235	235	212	21	233	-2
2033	172,377		235	235	212	21	233	-2
2034	172,377		235	235	212	21	233	-2
2035	172,377		235	235	212	21	233	-2
2036	172,377		235	235	212	21	233	-2
2037	172,377		235	235	212	21	233	-2
2038	172,377		235	235	212	21	233	-2
2039	172,377		235	235	212	21	233	-2
2040	172,377		235	235	212	21	233	-2
2041	172,377		235	235	212	21	233	-2
2042	172,377		235	235	212	21	233	-2
2043	172,377		235	235	212	21	233	-2
2044	172,377		235	235	212	21	233	-2
2045	172,377		235	235	212	21	233	-2
2046	172,377		235	235	212	21	233	-2
2047	172,377		235	235	212	21	233	-2
		27,216	7,142	34,358	6,048	605	6,653	-27,705

Source: Final Report, Feasibility Study on Metro Construction Project in Ulaanbaatar City, June 2011, UB City
Note: Non-operational income is calculated at 10% of the operational income.

(3) Flyover

UB City has planned seven flyovers as shown in Figure 2.1.5

1) West Intersection
2) East Intersection
3) Sapporo Intersection
4) Bayanburd Intersection
5) Tolgoit
6) Ajilchin
7) Intersection at Olympic Street and Naranii Zam

Of the seven flyovers, intersections 1, 2, 3 and 5 are located in the area for the first phase of this JICA UB Metro Plan; thus, coordination needs to be considered upon the design. Flyovers for the West Intersection and East Intersection have already been designed and approved by the UB City government, and the contractors have been selected. Bidding for Sapporo Intersection Flyover was conducted; however, it will be re-bidden in March or April 2013.

Source：UBMP 2030

Figure 2.1.6 Location of Planned Flyovers

2.2 Urban Development Policy and Related Legal Framework

2.2.1 Urban Development Policy

(1) Urban Development Policy

Presently, the following four policies are addressed as national important policies: (1) Air pollution, (2) Poverty Alleviation, (3) Housing Development, and (4) Small-Medium Enterprises Promotion. Among them, air pollution and housing development are strongly related to the urban development. Smoke from stoves used in the ger areas is the biggest cause of air pollution during winter; therefore, conversion from gers to apartments is one of the critical issues to be addressed to resolve the serious problem on air pollution. In addition, supplying housing with engineered infrastructure at a low cost absorbs many immigrants to UB City, but is still unsuccessful because the number of immigrants settling in UB City outpaces the housing supply.

With these development policy issues and the general elections held on 29 June 2012, both national and UB city have changed their ruling party to the Democratic Party. They are considering the UB Metro as one of the important policy issues.

UB Metro can greatly contribute to the mitigation of air pollution by restructuring UB City to the urban structure with sophisticated public transportation system. In addition, the UB Metro development is expected to bring about a positive economic impact on employment creation, commercial development, and tax revenue.

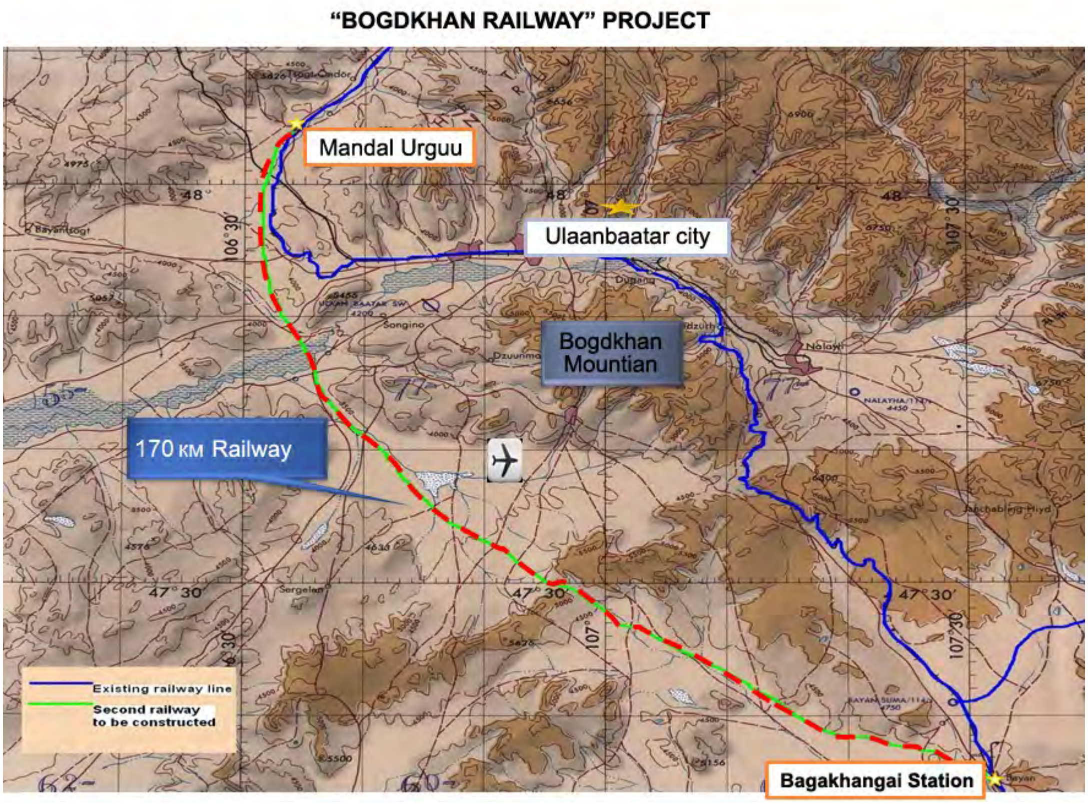
(2) Political Promises of UB City Mayor approved by the City Council

On 15 November 2012, political promises to be implemented during 2012-2016 were approved by the City Council. The promises include 107 projects on the mitigation of air pollution, the development of detached house areas, job creation, security and safety, and the creation of a city without corruption. The Metro is among them to be opened in 2020.

(3) Memorandum between Minister of MRT and UB City Mayor

On 17 October 2012, the Minister of Ministry of Road and Transportation (MRT) and the UB City Mayor concluded a memorandum of their cooperation during 2012 – 2016 for the purpose of implementing programs during 2012 – 2016 creating better living condition for the citizens and safe and reliable transportation systems in UB City. The following items related to urban transportation were described in Section 2.3 (Railway Related) of the memorandum:

1) Construct the basic structure of Bogdkhan Railway (170km) to increase the speed of the railway, shorten the time which trains run through Mongolia, and secure better living and working conditions;
2) Develop a second East-West public transport corridor by developing LRT on the railway track running through Ulaanbaatar (35 km between Khonkhor-Tolgoit) after the bypass construction;
3) Relocate railway depots for locomotives, and passengers and freight trains from within UB city area;
4) Develop overpasses and underpasses at railway crossings at Dunjingara (at 407 km), Tawabn Shar (near Trade Street, at 396 km) for a better traffic flow;
5) Relocate logistics terminals in the city center and develop comprehensive logistics centers for the complex freight transportation;
6) Relocate Passenger Transportation Terminal (Central Railway Station) near Tolgoit;
7) Implement Ulaanbaatar Metro project as a cooperative project between Mongolia and Japan in order to alleviate the traffic congestion and to create the advanced Metro with high capacity;
8) Analyze noise and damage of buildings and houses built in the railway safety area, and consider buildings built within 25 m from locomotives depot in Ulaanbaatar and fuel (6,000t) warehouses and facilities built without permit in the railway premises; and
9) Decide where to build the buildings and facilities of the Railway Transportation Central Control Center.



Source: JICA Study Team

Figure 2.2.1 Bogdkhan Railway Project

Source: JICA Study Team

Figure 2.2.2 Location of Facilities of Ulaanbaatar Railway

(4) Memorandum between Minister of MCUD and UB City Mayor

On 5 October 2012, the Minister of Ministry of Construction and Urban Development (MCUD) and the UB City Mayor concluded a memorandum of their cooperation during 2012-2016 for the purpose of implementing "government programs during 2012 – 2016" and creating better living condition for the citizens in UB City. The memorandum includes the facilitation of approval and implementation of Ulaanbaatar Master Plan, the relationship of land-related projects and urban planning, the reliable urbanization and infrastructure development, and the support for sustainable development from the natural and biological viewpoint. In relation to metro development in Ulaanbaatar City, it aims to "formulate development concept and plan of Underground City (2012-2016)."

2.2.2 Laws Related to Transportation and Urban Development

(1) Transportation Related Laws

1) Railway Transportation Law

The Railway Transportation Law was enacted on 5 July 2007. Article 4 of this law stipulates that the law applies to all railway transportation; however, this was made to target the regional railway transportation of Ulaanbaatar Railway and therefore, it is thought that the law does not assume specifically urban railways, electric cars, and underground metro systems.

This law stipulates the following: Ownership of railway facility (Art. 6), Fare (Art. 7), Authority of State, Government, Governors (Art. 8~11), Government organizations to control railway transportation (Railway Transportation Administration and Train Operation Central Office) (Art. 12), Railway transportation regulations (Art. 15), Special permission regarding railway transportation service (Art. 16), Organizations and Individuals who can participate in railway business (Art 18), Right and duties of owner of infrastructure (Art. 19), Railway facilities (Art. 22~23), Basic conditions for railway transportation safety (Art. 24~28), and others.

Mongolia has two kinds of technical control. One is "regulation" which must be complied with and enforced under the authority of the state and requires the state procedure. The other one is "standard" which simply shows specifications as a standard and does not necessarily require compulsory authority. Sixteen items stipulated in the Railway Transportation Comprehensive Regulations are "regulations" with enforcement authority.

The Central Government Organization administrating railway transportation stipulated in Article 10 is MRT; in Article 12, it was the Railway Authority. . But due to the governmental organizational reform, the two were merged into MRT, while currently, the organization in Article 12 refers to the Department of Railway and Maritime Transportation Policy Implementation and Coordination.

Railway operators, as stipulated in Article 18, may be private but they must be examined by the Railway Authority.

The Railway Transportation Law covers the necessary items for railway business and has flexible contents. As described above, the law does not assume urban railways but it can be applied to them. However, it is necessary to examine the addition and revision of the technical regulations because it is thought that the law was not originally provided for urban railway.

Technical regulations stipulated by the Railway Transportation Law regulate only the Ulaanbaatar Railway and those trains running on the tracks of the UB Railway; and they include detailed items that can be decided in "technical standards." As such, the regulations should be reviewed in order to introduce various urban railway systems in the future.

Technical regulations are divided into three categories: (1) safety requirements, (2) regulations on track specifications, and (3) level of service including “barrier-free” or “universal design.” Of these, safety requirements are determined once items related to safety are specified. The extent and contents of track specifications and service level are to be considered as policy issues.

In general, (1) safety requirements must be determined according to the regulations. As for (2), the most important issue is rail gauge. The Ulaanbaatar Railway uses a specific broad gauge. But for the track sharing between interurban railways and international railways and the extension of urban railway networks, the gauge of urban railways must be determined as a policy issue as early as possible.

Although the Railway Transportation Policy was issued as a government resolution on 4 June 2010 as is stipulated in Article 8.1.1 of the Railway Transportation Law, this describes only regional railway transportation at the national level, not the urban railway systems. A taskforce was established and is planning to amend the Law to cover the urban railway by December 2012. However, as of December 2012, there is no progress regarding this issue.

2) Road Public Transport Related Laws

Public transport such as buses on roads is defined in the Road Transportation Law enacted on 4 June 1999. This law stipulates the authority of governments (Art. 4 ~ 7), the rights and duties of transport operators (Art. 10), the rights and duties of users and passengers (Art. 11), the fare (Art. 12), the license (Art. 15), etc.

Article 43.2.5 of the Education Law also stipulates a special compensated transport fare for public transportation of students. Students enjoy special compensation for use of public transportation except for taxis in Aimag and Ulaanbaatar City. The compensation amount is decided upon approval of the Aimag or UB City Council. This should be applied to the UB Metro and will thus influence fare box revenue.

(2) Urban Development Related Laws

The extent of urban development and underground development around UB Metro stations is yet to be decided for the PPP scheme of the UB Metro Project. This PPP study is supposed to examine and propose models of the urban development as well as the UB Metro Project. Urban development related laws are shown below although there is no law stipulating the underground urban development.

Table 2.2.1 Urban Development Related Laws

Law	Description
Urban Development Law	This law, controlling urban planning and development, was enacted in 2008 and is under amendment.
Urban Redevelopment Law (under enactment)	This law concerns projects of urban redevelopment in ger areas, land readjustment in ger areas, old apartment reconstruction, and improvement of substandard built-up areas. It is being prepared for passage at the Parliament.
Construction Law	This law permits construction.
Land Privatization Law	This law, enacted in 2003, stipulates privatization of land and things related to privatized land. In case of acquisition of private land for the UB Metro Project, the law stipulates acquisition and compensation for private land.
Land Law	This law stipulates possession and use of land. It is under amendment. In case acquisition of possessed or used land is

	required for the UB Metro Project, the law stipulates acquisition and compensation for such lands.
Housing Law	This law was amended in February 2011 and a new article was added about old apartment building reconstruction. The new article stipulates that residents of non-seismic resistant old apartment buildings are not allowed to reside in those buildings, and the old apartment buildings must be reconstructed. Such apartment buildings are found along Peace Avenue and have been incorporated into the urban development plan in an integrated manner with the UB Metro Project.
Land Acquisition and Resettlement Law	This law concerns land acquisition for public purposes, compensation, and resettlement. It is being prepared with technical assistance from ADB. The UB Metro Project possibly needs to acquire land for public purposes such as stations and station squires. Difficulty in land acquisition often hinders implementation of urban redevelopment projects even if they have been approved by the government. Ineffective compensation with non-functional evaluation methods of land and apartments is one of the obstacles in smooth implementation of urban redevelopment projects.
Land Fee Law	This law specifies fees for possession and use of land. Fees are extremely high for land possessed and used for private residences, but apartment dwellers do not pay this fee. Through this law, asset value accrued to commercial development from the UB Metro should be collected and redistributed to the public sector.
Immovable Property Tax Law	Through this law, values accrued to immovable property along the UB Metro Project shall be collected.

Source: JICA Study Team

Regarding underground development, the “Four-Year National Financial Program (2013-2016)” includes a ”survey on the formulation of legal framework and an action plan for the underground development related to the UB Metro project,” which is being planned by MCUD. On the other hand, UB City gave an order that the responsible department shall implement a basic study on the underground development. In this way, administrative actions have just started in Mongolia.

2.3 Future Development Vision and Policy of Ulaanbaatar Region

2.3.1 Ulaanbaatar City Master Plan 2030 (draft)

(1) Outline of Ulaanbaatar City Master Plan 2030 (draft)

UB City formulated the Ulaanbaatar Urban Master Plan targeting year 2030 [UBMP 2030] as a legally authorized master plan, based on the JICA Master Plan Study (March 2009). The UBMP was officially approved by Parliament in February 2013. The following outlines the UBMP 2030.

1) Planning Issues

- Need for development with limited developable land restricted by environmentally sensitive areas such as water source areas and rivers

- Inadequate provision of infrastructure to keep pace with increasing population
- Environmental pollution
- Difficult materialization of housing supply projects as planned.

2) Planning Policy

- Control by urban planning and land use zoning
- Prevention of overconcentration in UB City
- Countermeasures for ger areas
- Planning measures for summer areas
- Provision of urban infrastructure, particularly water supply and measures on urban transportation

3) Future Population Framework

The population of UB City accounted for 41% of the national total population in 2010, and is projected to reach 50.3% by 2030.

Table 2.3.1 Future Population Projection of Mongolia and UB City

	Mongolia (thousand persons)	UB City (thousand persons,%)	Other Area (thousand persons,%)
2010	2,781	1,161 (41.7%)	1,620 (58.3%)
2020	3,162	1,534 (48.5%)	1,628 (51.5%)
2030	3,501	1,763 (50.3%)	1,738 (49.7%)

Source: UB City Statistics, and UBMP 2030

As presented in Table 2.3.2, the future population of UB City is 1.763 million in 2030, of which 85,000 are expected to live in satellite towns.

Table 2.3.2 Future Population Framework of UB City

Area	2010		2020		2030	
	Population (thousand)	Household (thousand)	Population (thousand)	%	Population (thousand)	%
UB City	1068.8	267.5	1,519.0	88.6	1,678.0	79.4
Satellite Cities	9.29	26.9	15.0	11.4	85.0	20.6
Total	1,161.7	294.4	1,534.0	100	1,763.0	100

Source: UB City Statistics and UBMP 2030

Note: UB City includes the remote three districts of Nalaikha, Baganuur, and Bagahangai. Satellite cities are University Town and Airport City.

4) Master Plan of UB City

Figure 2.3.1 illustrates the future land use plan of UB City. The central area is planned to be densified for intense use. The industrial area in the western part of the city will be restructured, and uncontrolled. Sprawling development in ger areas will be controlled by delineating the development promotion area boundary. Water resources and environmental protection areas are designated along rivers such as Tuul River. New towns are planned in the west and around the existing international airport.

Source: UBMP 2030

Figure 2.3.1 UB City Master Plan

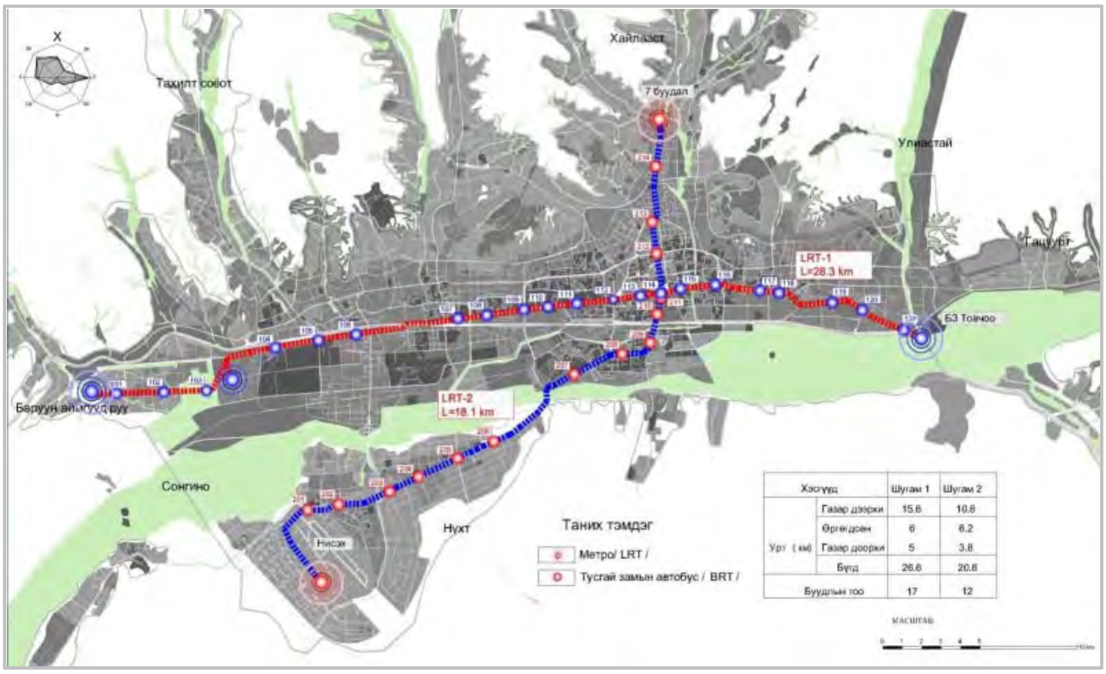
5) Bus Rapid Transit (BRT) and Metro Light Rail Transit (LRT)

The UBMP 2030 has been formulated based on the JICA Study on UB Master Plan (UBMPS), the BRT project of ADB, and the UB City FS of UB Metro Project. BRT and railway systems (LRT) are planned as shown in Table 2.3.3 and Figure 2.3.2. The final plan shall be decided based on the economic and financial analysis, feasibility of implementation, and adverse effects.

Table 2.3.3 Plan of BRT and Metro (LRT)

		Line1 (East-west)	Line2 (North-south)
Length (km)	At grade	15.6	10.60
	Elevated	6	6.2
	Underground	5	3.8
	Total	26.6	20.6
Number of stations		17	12

Source: UBMP 2030



Source: UBMP 2030

Figure 2.3.2 Plan of BRT and Metro (LRT)

(2) Plan of Urban Centers, Sub-centers and Micro Centers

Urban sub-centers are developed for balanced growth within the city, employment creation, and provision of national and social services.

1) Development of Central Business District (CBD)

The CBD of the present UB City is located in the area of Sukhbaatar Square and the National Parliament building, which is the center of political, economic, administrative and social activities. The area is congested and causes negative social impacts. In order to alleviate this situation, national administrative organizations are planned to move to a new location. The new place will form a new center for national administrative activities. The existing center near Sukhbaatar Square will become a new business district after the administrative organizations move to another area.

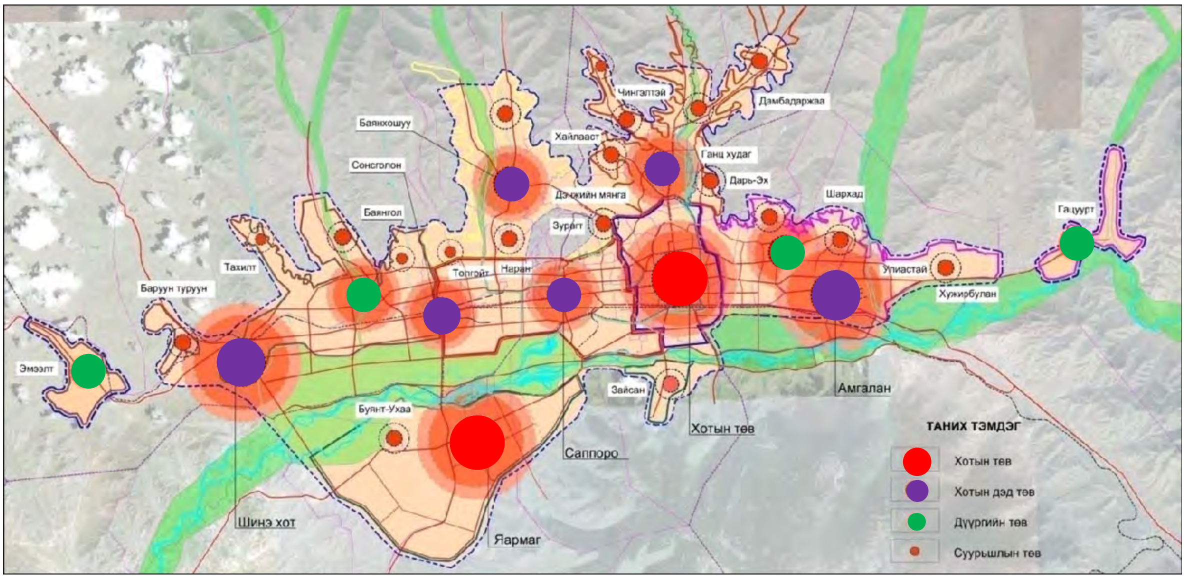
2) Plan of Urban Sub-centers and Micro Centers

Urban Sub-center

An urban sub-center provides services to about 150,000 to 200,000 people. Urban sub-centers are expected to achieve balanced socio-economic growth within the city to bridge the gap among local areas. Sub-centers, with commercial and social infrastructure developments, equally provide citizens with health, education and cultural services. The sub-centers will concentrate on local government offices, commercial facilities, and offices of projects on public interest, cultural centers, hospitals, businesses, etc.

Micro Center

Micro centers are located in the ger areas and serve around 8,000 to 15,000 people. The micro centers house micro offices of local government administration, schools, kindergartens, health centers, commercial facilities, etc.



Source: JICA Study Team based on UBMP 2030

Figure 2.3.3 Location of Urban Centers in UB City

(3) Housing Development Plan

The "New Construction Program" (Parliament resolution No. 36, dated 25 June 2010) is a two-phased housing development plan from 2010 to 2016. The program, which includes the seven development policies below, plans to construct 75,000 housing units (277,500 people) in UB City.

1. New Town: 18,100 units
2. Densification development: 17,350 units
3. Housing development in ger area: 21,040 units
4. Redevelopment of factories and warehouses in built-up area: 6,600 units
5. Reconstruction of non-seismic resistant buildings and old buildings: 6,100 units
6. New apartments for rent: 2,000 units
7. Housing in the remote districts: 3,800 units

In addition, the UBMP 2030 includes a housing development plan of 15,000 units (55,500 persons) or more by 2020, and 74,000 units (259,000 persons) or more from 2020 to 2030.

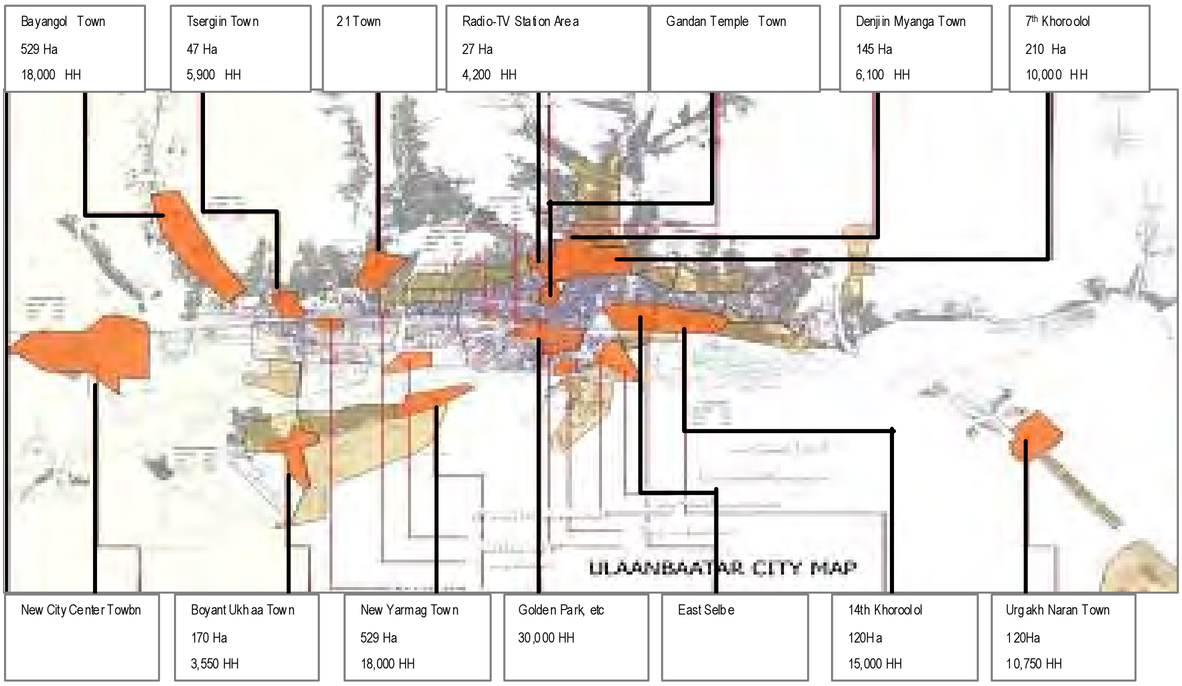
The following table shows concrete projects and Figure 2.3.4 indicates their location.

Table 2.3.4 Housing Development Plan in "New Construction" Program

Project Name	Area (ha)	Household	
		2020	2030
Bayangol Town	529	4,000	18,000
Tserugiin Town	47	-	5,900
21 Town			
Mongol Radio & TV Station Area	27		4,200
Gandan Temple Town			

Denjiin Myanga Town	145	-	6,100
7th Khoroolol	210	6,000	10,000
New City Center			
Buyant Ukhaa Town	170	3,550	12,500
New Yarmag Town	529	4,000	18,000
Golden Park, etc. (Development in built-up area)			30,000
East Selbe			
14th Khoroolol	120	5,000	15,000
Urgakh Naran Town	120	2,500	10,750
Ireedui Town	68	1,500	12,500

Note: No figures for some projects are available in the presentation material of UBMP2030 provided to JICA Study Team.
Source: UBMP2030



Source: UBMP 2030

Figure 2.3.4 Urban Development Projects in UB City (UBMP 2030)

2.3.2 Future Population Framework for the UB Metro Study

(1) Future Population Framework of UBMP 2030

In the UBMP2030, the future population framework of UB City for 2030 is 1.763 million, with 1.4 million in the six central districts and 363,000 in the remote districts and satellite cities.

Table 2.3.5 Future Population Density

	Area (ha)			Population		
	Total Area	Growth boundary	Habitable Area	2010	2020	2030
UB City (6 districts)	32,668	30,193	19,066	1,068,000	1,359,000	1,400,000
Other Area	-	-	-	92,900	175,000	363,000
Total	-	-	-	1,161,700	1,534,000	1,763,000

Source: UBMP2030

Note: Other area includes three remote districts of Nalaikha, Baganuur, and Bagahangai, and satellite cities of University City and Airport City

Of the land area within the growth boundary of 30,193 ha, 19,066 ha is habitable land, land area within the growth boundary minus inhabitable green areas. Population density in the habitable land was 56.0 persons/ha in 2010, and will be 71.3 persons/ha in 2020 and 73.4 persons/ha in 2030. As seen in section 2.1.1 (1), population density in the central districts in 2011 shows a higher population density in apartment areas with 183 persons/ha and a lower one in ger areas with 26 persons/ha. It is forecasted that the future population density will still be higher in the apartment area and lower in the ger area.

Table 2.3.6 Population Density of Habitable Land in Urban Development Promotion Zone in UBMP 2030 (draft)

	2010	2020	2030
Population density (persons/ha)	56.0	71.3	73.4

Source: JICA Study Team based on UBMP2030

UB City needs a higher population density, not an urban sprawl, to become an “Eco-Town” and “Compact City.” The development of the UB Metro is expected to help formulate a compact and eco city since it facilitates densification around the UB Metro stations and along the Metro line.

(2) Future Population Framework used for this Study

Although the above is the future population framework projected by UBMP 2030, with a view of the urbanization over the years, the following are forecasted and adopted by this study as the future population framework for the six central districts:

- Since the decentralization policy does not seemingly work well until 2020, it is highly expected that the population-increasing trend continues. Consequently, the population of the 6 central districts is assumed to reach 1.4 million in 2020. This will be used for the future population in 2020 for this study.
- In 2030, two cases are expected: the formulation of satellite cities proposed in the UBMP 2030 framework, and the population increasing-trend continues, though the speed slows down. In case of the latter, it is prospected that the population of the six central districts will reach 1.76 million in 2030. This will be used for the future population in 2030 for this study.

2.4 Proposed Comprehensive Transport System of Ulaanbaatar City

2.4.1 Present Transport Condition and Issues

(1) Present Traffic Demand

The total trip of UB City is 210 million trips/ day excluding walking, and 310 million trips/ day including walking.

Its modal share is composed of 28.6% of car, 38.2% of public transport, and 33.2% of walking. Compared to the data of 2007 (data of UBMPS), the shares of car and walking are increased while public transport is decreased (42.6% as of 2007).

Compared to the rate of population increase, the number of car ownership has drastically increased. From 2007 to 2010, the number of car ownership was increased by 1.8 times, the number of car ownership per 1000 population was increased by 1.3 times, while population was increased by 1.1 times.

The total transport cost is approximately US$1.87 million.

Table 2.4.1 Present Traffic Demand of UB City (estimated in 2011)

		Private	Public	Total
Traffic Demand (per day)	No. of Trips (000)	889	1,189	2,079
	Person-km (000)	7,474	7,870	13,724
	Person-hour (000)	-	-	1,098
	PCU-km (000)	-	-	5,036
	Average Trip Length (km)	8.4	6.6	7.4
Road Capacity (PCU-km) (000)		-	-	12,296
Transportation Cost (US$000/day)	Vehicle Operating Cost (VOC)	-	-	1,205
	Travel Time Cost (TTC)	-	-	665
	Total	-	-	1,870

Note: PCU stands for passenger car unit and is defined as the number of vehicles equivalent to passenger cars. It is a coefficient used to compare traffic volume consisting of different vehicle types at different spots; for example, a truck is considered equivalent to 2.0-2.5 PCU. Road capacity measured in PCU enables to analyze capacity-demand gap of the road.

Source: JICA Study Team

Table 2.4.2 Number of Registered Vehicle in Ulaanbaatar City

	2005	2006	2007	2008	2009	2010	Growth Rate (%/yr)
Population	965,300	994,300	1,031,200	1,067,500	1,106,719	1,161,785	3.8%
No. of Registered Vehicle	73,740	79,135	92,706	106,848	131,447	167,809	17.9%
No. of Vehicle per 1000 persons	76	80	90	100	119	144	13.6%

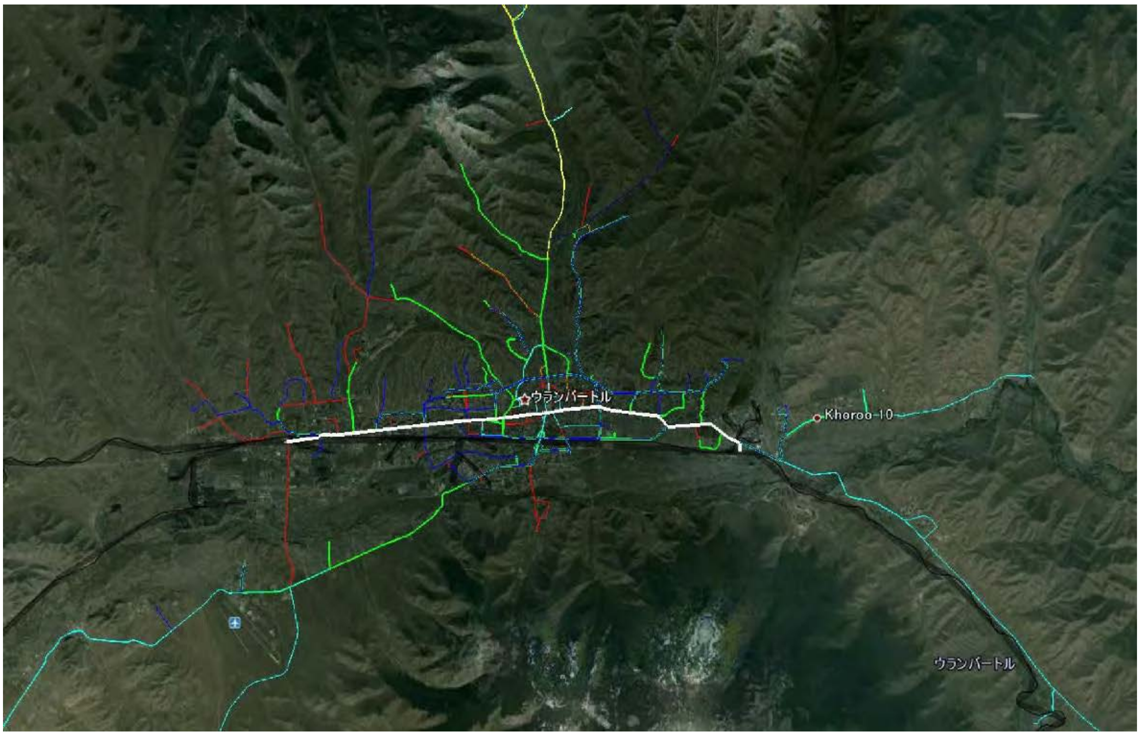
Source: Statistic Data of Ulaanbaatar City

(2) Present Condition of Public Transport (Bus)

Buses operated in UB City are categorized into three: (1) buses on regular routes which run on major trunk roads, (2) trolley buses, and (3) mini buses which serve around ger areas.

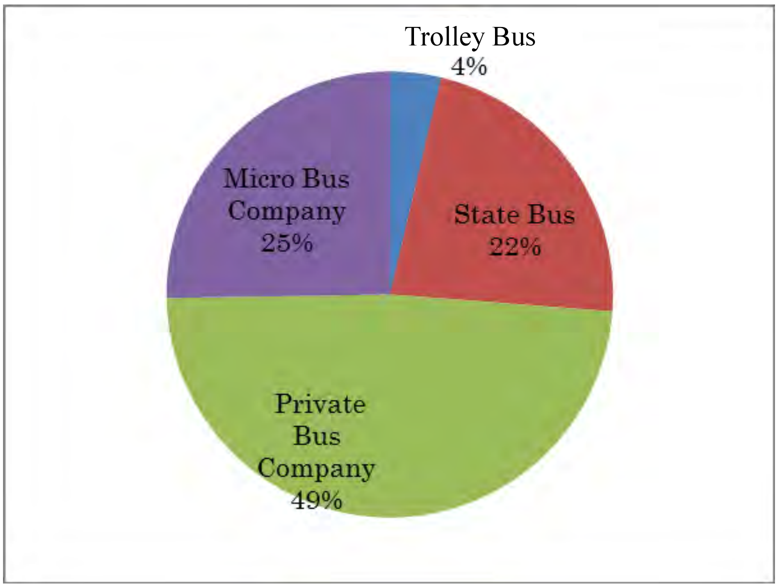
The number of existing bus routes is 113 in total, consisting of 3 routes of trolley buses, 77 routes of buses on regular routes, and 33 routes of mini buses. Among them, 26 routes are operated by public bus companies, 54 routes by private companies of buses on regular routes, and 33 routes by private mini bus companies. The average length of the bus routes is 24-25 km, with the longest routes at 53 km. The traveling speed is 18-20 km/h on average. The operating time interval is less than 15 minutes on average, and 20 minutes interval on longer routes. Figure 2.4.1 shows the current bus route map.

The number of operating trips of buses is around 9,000, with public buses accounting for 26%, followed by private regular buses at 49%, and mini buses at 25%.



Source: JICA Study Team

Figure 2.4.1 Existing Bus Route Map (2012)



Source: JICA Study Team

Figure 2.4.2 Operating Trips of Buses per Day (2012)

Table 2.4.3 Weekday Operation by Bus Type (2012)

Bus Route				Operation plan			Weekday operation performance	
Type of Bus		No. of routes	Length (km)	Round trip time (h:m)	Speed (km/h)	Operating time interval (m)	Operating hours/day (h:m)	No. of trips/day
Public	Trolley bus	3	57.3	1:31	12.7	8.7	494:10	333.0
	Bus	23	640.8	1:28	19.0	15.0	2952:25	2,029.0
	Public bus: sub-total (A)	26	698.1	1:29	18.1	15.0	3446:35	2,362.0
Private	Private bus: sub-total (B)	54	2,178.6	1:51	25.8	22.4	7604:19	4,373.5
Large/middle-sized bus: total (C) (A+B)		80	2,876.7	1.44	20.7	20.0	11050:54	6,735.5
Mini-bus: sub-total (D)		33	942.1	1:20	21.4	16.2	2974:59	2,276.0
Bus: Total (C+D)		113	3,818.8	1:37	20.9	18.9	14025:53	9,011.5

Source: Transportation Department, UB City

(3) Public Transport and Subsidy for bus fares in UB City

As described above, the primary means of public transport currently is bus, including main bus which runs on major trunk roads (400Tg at a flat rate), trolley bus (200Tg at a flat rate), and mini bus which serves around ger areas (fares depend on distance, higher than main bus).

Discount ticket system is popular among students (9,000Tg for 6 months). In addition, the elderly (male: over 60 years old and female: over 55 years old), the pensioners, the disabled, the police officers and the retired officers can ride the bus free of charge. According to the results of the bus user survey conducted by the Transport Department of UB City (Transport Department after December 2012,) in 2010, nearly half of bus users are students, the elderly, the pensioners, the disabled, the police officers and the retired officers who do not have to pay the regular fare.

Such discount (free) ticket system is stipulated by the Education Law, the Social Protection Law, and the Police Law. This system is applied to the buses on regular routes and trolley buses, not to the mini-buses.

Bus fare is decided from the social welfare viewpoint, and this is historically reviewed as shown below:

- In 2003, the state issued an order that would require pensioners who enjoy the benefit of free bus ride to pay bus fare by increasing the amount of the pension annuity so that they would pay the fare by themselves; however, a demonstration that saw protesters march to the Ministry of Finance caused the order to be rescinded.
- Subsidy for the bus fare accounted for 20% of the UB City's budget in 2009 and 50% in 2010, because the bus fare for students, which was half that of adults in 2009, was no longer collected in 2010, allowing students to ride the bus for free.
- In 2011 and 2012, the subsidy for bus fare was allocated to the budgets of responsible ministries such as the Ministry of Education, the Ministry of Police, and the Ministry of Social Welfare and Labor. The Transport Department of UB City is in charge of allocation of the amount of the subsidy to the bus companies based on monthly reports from the bus companies as in the past.

At present, the subsidy amount is calculated based on the route, number of buses, operating times/month, operating (traveling) time, etc. The subsidy is budgeted on the basis of the data of the Statistical Office that 70% of the elderly and 60% of students (96,000 out of 160,000 students) use bus, though precise numbers are not available, and allocated to the bus companies according to their actual operation by the Transport Department.

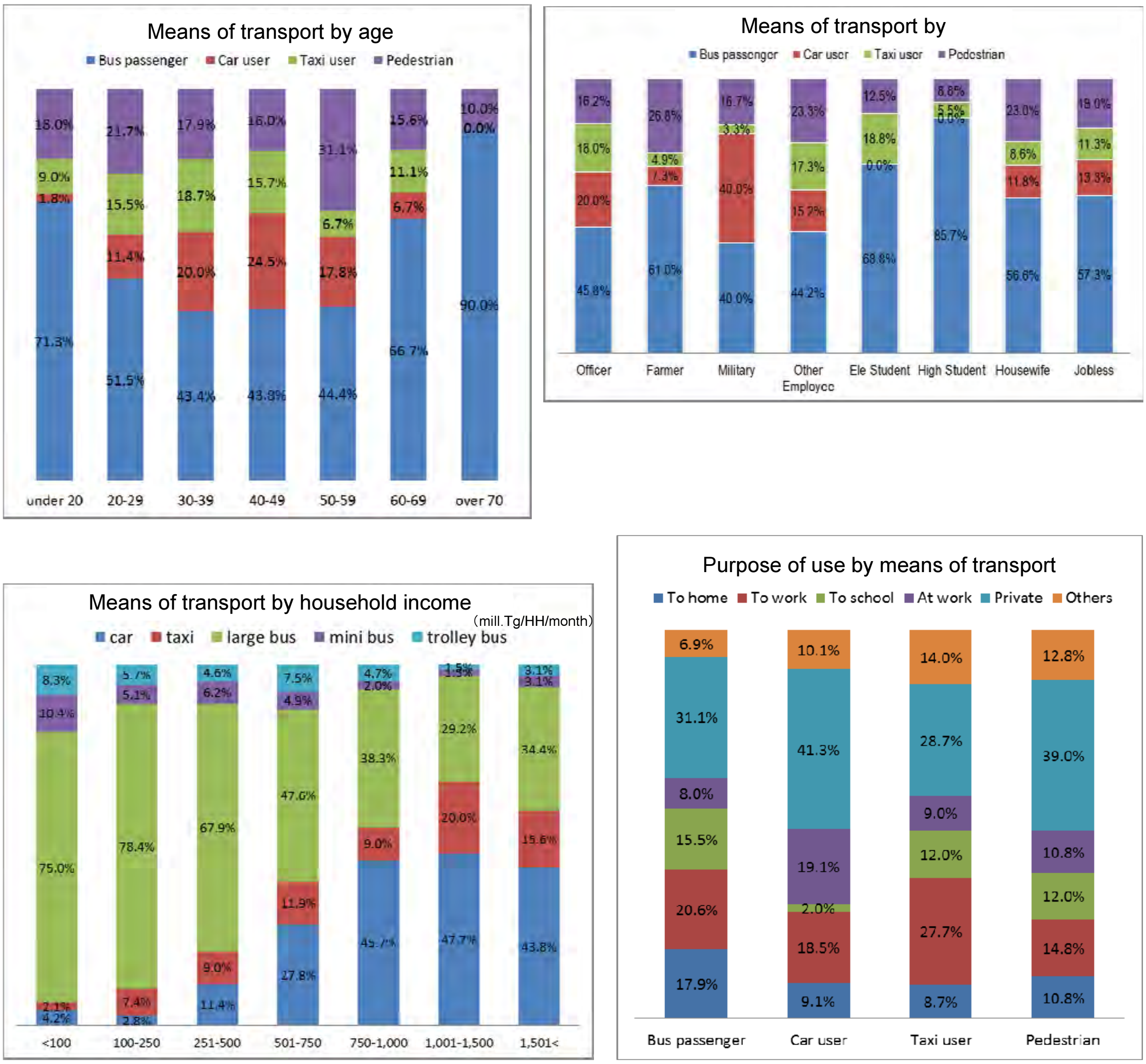
There is a discussion on revising this bus fare subsidy system because it is overgenerous; however, for political reasons, it is not easy to review the bus fare.

(4) Results of Survey of Vehicle Users and Pedestrians

According to the vehicle user survey (with a total of 2,000 samples including 1,000 bus users, 300 car users, 300 taxi users and 400 pedestrians) conducted by the JICA Study Team in November 2011, frequent bus users are young people aged 20 years or under and the elderly aged 60 years or over. As for the bus use by occupation, students, housewives and jobless often use buses.

As for the bus use by household income level, 80% of income groups lower than 500,000 Tg/month/HH frequently use buses. It is said that the average household income in UB City is around 700,000 Tg/HH/month while the poverty line is set at 120,000 Tg/HH/month. It is obvious that low to middle income households frequently use buses and that households over the average income shift to using cars.

The results of the survey show clearly the effect of the flat fare (400 Tg, as of Dec. 2012) scheme to promote the use of public transportation by low and middle income households in accordance with the policy of the Transportation Department of UB City, as well as that of the discount bus fare for students.



Source: Public Transport User Survey, November 2011, JICA Study Team

Figure 2.4.3 General Characteristics (Age, Occupation, Household Income, and Transport Means) of Vehicle Users and Pedestrians

(5) Citizen's Expectation to Metro

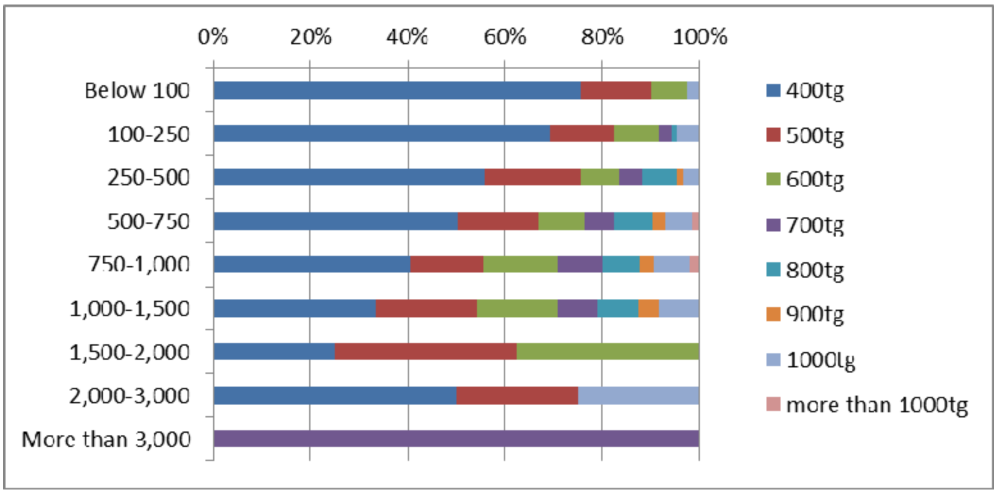
Based on the survey, approximately 95% answered that they "highly expected" or "expected" the Metro project. As to the frequency of use, about 50% said that they "want the Metro daily".

They also expressed their willingness to pay to Metro with 500Tg on the average (1.2 times the bus fare) for low-income group (lower than 750,000Tg/HH), 600Tg on the average (1.5 times the bus fare) for middle-income group (750,000Tg-2,000,000Tg/HH).

In terms of purpose of use, approximately 570Tg (1.4 times the bus fare) is for working, and 500Tg on the average (1.2 times the bus fare) is for going to school. As even students who currently enjoy the discount system show the willingness to pay 500 Tg per metro ride, the willingness to pay is relatively high for both purposes of work and school.

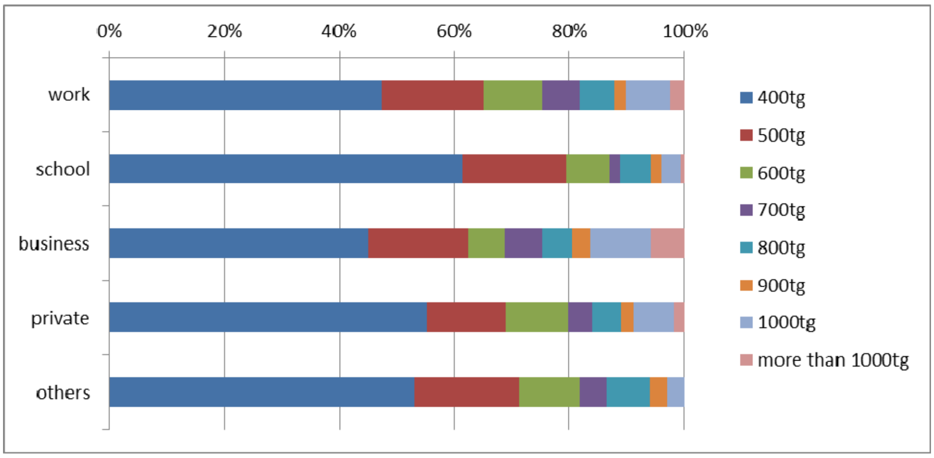
To sum up, the interview survey reveals that though public transport mode is limited to bus at present, expectations for a modern and convenient transport system is very high, and that willingness to pay for the new system is potentially high especially the mid-income groups and commuters.

When introducing the Metro, it is required to examine the arrangement of fares of metro and bus, the necessity of a discount fare scheme for students, elderlies, and others, and measures for lower income groups.



Source: Public Transport User Survey, November 2011, JICA Study Team

Figure 2.4.4 Willingness to Pay to Metro by Household Income Groups (Tg/month/HH)



Source: Public Transport User Survey, November 2011, JICA Study Team

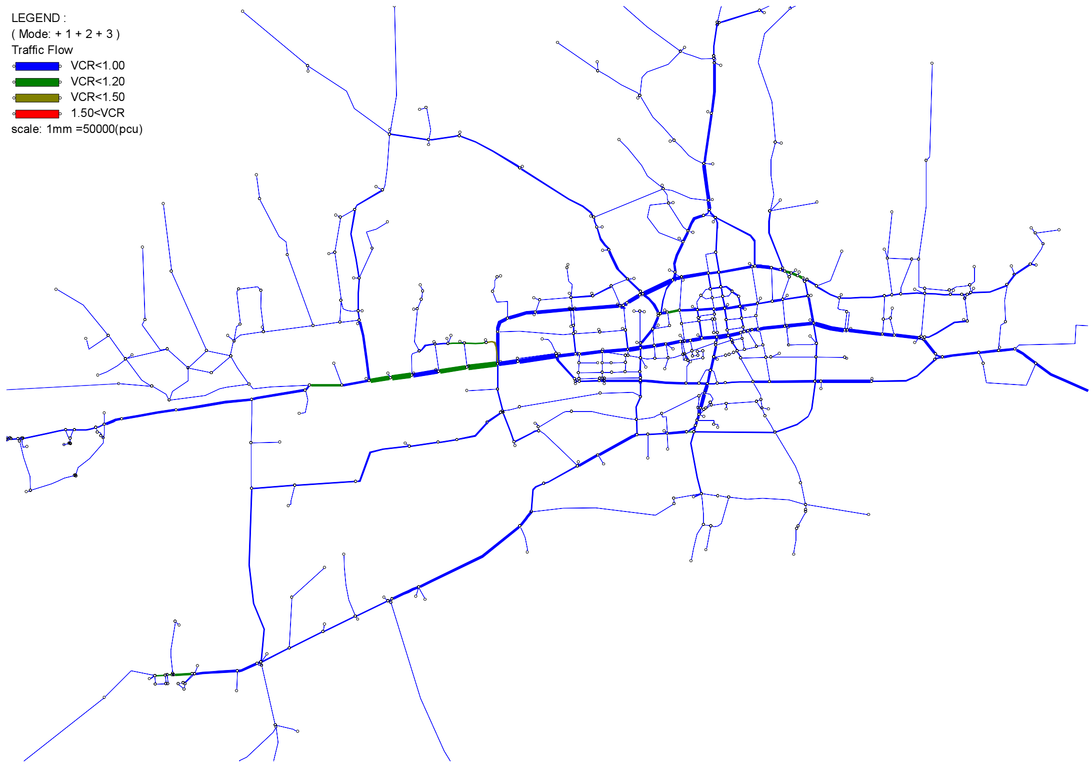
Figure 2.4.5 Willingness to Pay to Metro by Purpose Groups (Tg/month/HH)

(6) Present Road Transport Condition

Based on the result of simulation using the System for Traffic Demand Analysis (STRADA), there are few traffic jams, and V/C (Volume/ Capacity, degree of congestion) is only 0.41. On the contrary, it is obvious that traffic congestion has been serious especially at the city center and trunk roads connecting to the city center.

The main factor that causes traffic congestion is not because of lack of roads, but because of inappropriate usage of road spaces and inefficient traffic management, including bad driving manners, inadequate traffic lights, and on-street parking, so road transport capacity is not fully used. Since 2007, traffic demand, especially from private cars has rapidly increased. But road development has not been preceded, and traffic management has not effectively functioned though there are various measures conducted such as operation of traffic management center, installation of signals, and traffic control by police.

To improve utilization of road spaces and traffic management, it will be possible to increase the traffic volume and to invest on proper road development project.



Source: JICA Study Team

Figure 2.4.6 Present Traffic Condition (2011)

2.4.2 Baseline Scenario Analysis

(1) Future Traffic Demand

The purpose of the baseline scenario analysis is to analyze future traffic condition of the present road network, for which no projects will be implemented (Do Nothing Case). In this case, it is assumed that an existing road network is able to handle as much traffic as its capacity, which means the optimal use of the road network is realized. Thus, it is a necessary condition that the spaces of the roads are properly used and the traffic is managed in the right way.

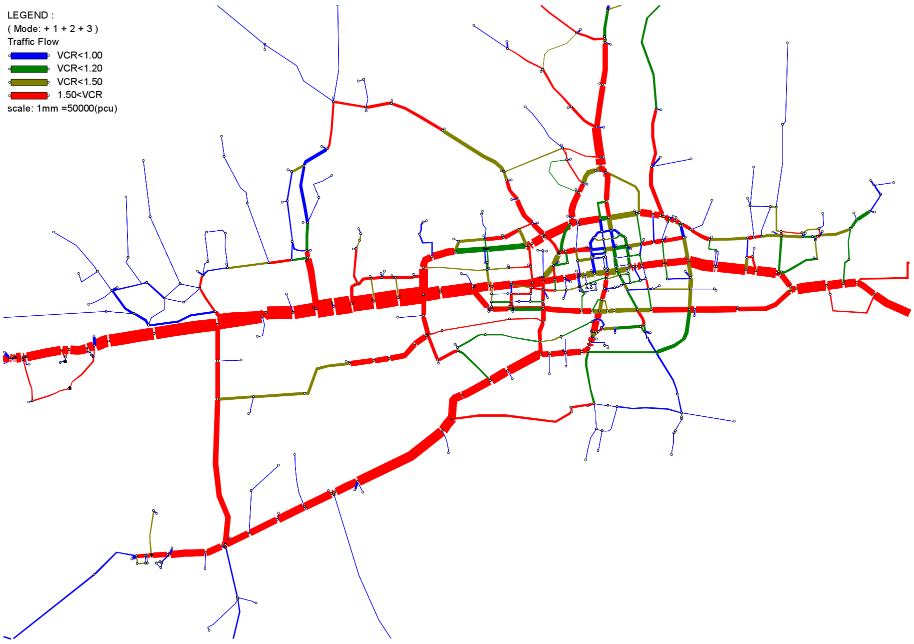
Based on the future population by Khoroo, projected according to the future population framework in Table 2.3.5, the number of trips will be double from 2011 to 2030, and the traffic demand (person-km) will be 3.1 times the present. The main reasons for rapid increase of traffic demand compared to the rate of population increase (1.4 times the present) is because of the increase in average trip length in conjunction with expansion of urbanized areas and increase in the number of private cars.

Traffic volume increase of private cars will be a burden to road transport system. The traffic capacity of main corridors especially Peace Avenue and Chingiss Avenue will be absolutely insufficient.

Table 2.4.4 Future Traffic Demand

	No. of Trips (000)			Growth Rate (%/year)		
	2011 (Estimated)	2020	2030	2007-2011	2011-2020	2020-2030
Private	889	1,684	2,263	-0.6	7.3	3.0
Public	119	1,519	1,996	-4.8	2.8	2.8
Walk	103	1,348	2,087	0.0	3.0	4.5
Total	2,078	4,551	6,346	-2.1	4.3	3.4

Source: JICA Study Team



Source: JICA Study Team

Figure 2.4.7 Future Traffic Demand (Baseline Case, 2030)

(2) Evaluation of Road Network

By 2030, the total transport cost will be 14.1 times the present, two thirds which are shared by Travel Time Cost (TTC). Loss of value of time will be serious because of the traffic congestion.

Table 2.4.5 Traffic Demand and Overall Network Performance (Baseline Case)

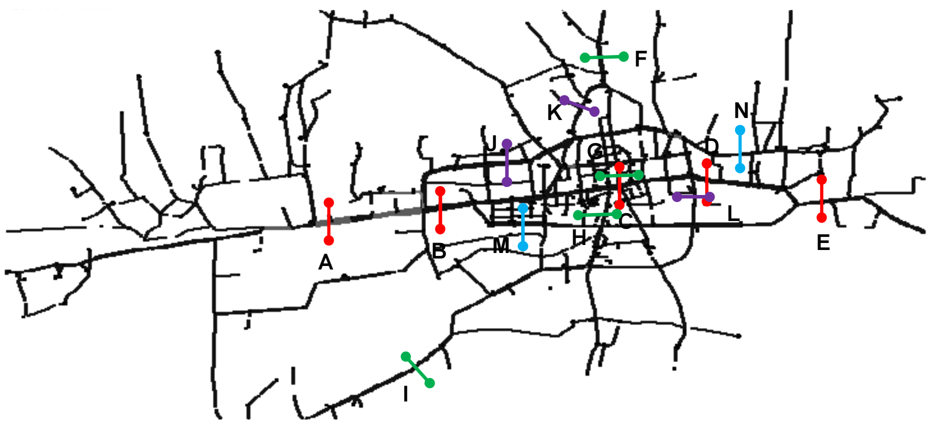
			2010	2020	2030	2030/10
Traffic Demand (per day)	No. of Trips (000)		2,079	3,203	4,259	2.0
	Person-km (000)		13,724	34,120	46,913	3.4
	Person-hours (000)		1,098	7,589	11,203	10.2
	PCU-km (000)		5,036	13,533	18,310	3.6
	Average trip length (km)		7.4	10.9	11.2	1.5
Road Capacity (PCU-km) (000)			12,296	12,296	12,296	0.0%
Traffic Performance	Average Congestion Rate: (V/C)[1)]		0.41	1.10	1.49	3.6
	Average speed (km/h)		12.7	4.5	4.2	0.3
	Congested section: km (%)[1)]	V/C≧1.5	0.0	16.5	28.3	-
		1.2≦V/C<1.5	0.7	10.8	9.9	-
		1.0≦V/C<1.2	0.9	13.9	9.6	-
		V/C<1.0	98.4	58.7	52.1	-
Transport Cost (US$ 000/day)	VOC		1,205	6,078	8,717	7.2
	TTC		665	9,169	17,789	26.8
	Total		1,870	15,247	26,506	14.2
Emission (000 ton/yr)	NOx		5	19	26	5.2
	CO_2		591	2,665	3,822	6.5

Note: 1) V/C (volume/capacity) is a ratio of the traffic volume to the road capacity and is used as a congestion rate: V/C ≧ 1.5 means paralyzed traffic; 1.2≦V/C<1.5 is congested considerably, 1.0≦V/C<1.2 is congested a little, and V/C<1.0 is not congested.

Source: JICA Study Team

As for the traffic volume of cross section of main corridors in 2030, approximately 700,000 persons (200,000 PCU) will cross Peace Avenue daily. Though it will not be seriously congested inside the city center due to high-dense road network, V/C of main trunk road access to city center will be 2.6-3.0. In terms of south-north direction, daily trips will be 600,000 persons (170,000 PCU) in Chingiss Avenue, and V/C will be 5.0 which will be already overloaded.

Lack of road capacities along major corridors will be absolutely serious, so the development of mass transit and effective road transport control will be crucial to expand transport infrastructure and services.



Source: JICA Study Team

Figure 2.4.8Location of Traffic Volume of Cross Section in Main Corridors

Table 2.4.6 Assessment of Traffic Volume of Cross Section in Selected Mass Transit Corridors (Baseline Case, 2030)

Main Corridor		Traffic Volume (persons/day)				Traffic Volume (PCU/day)			Road Capacity (PCU/day)	Performance	
Name	Section	Private	Public: Mass Transit	Public: Bus	Total	Private	Bus	Total		V/C ratio	Average Speed (km/h)
East-West Metro	A	248,032	0	384,034	632,066	248,032	38,146	286,178	72,900	3.9	4.5
	B	207,973	0	349,101	557,074	207,973	31,132	239,105	78,975	3.0	4.5
	C	93,986	0	216,863	310,849	93,986	13,516	107,502	74,250	1.5	4.5
	D	196,753	0	213,292	410,045	196,753	15,425	212,178	82,013	2.6	4.5
	E	139,269	0	214,890	354,159	139,269	20,644	159,913	54,675	2.9	4.0
South-North BRT1	F	139,170	0	204,207	343,377	139,170	19,241	158,411	60,750	2.6	4.0
	G	46,208	0	29,307	75,515	46,208	3,284	49,492	60,750	0.8	12.6
	H	65,678	0	204,252	269,930	65,678	15,353	81,031	42,525	1.9	4.0
	I	144,669	0	235,087	379,756	144,669	28,543	173,212	34,650	5.0	4.0
East-West BRT2	J	88,055	0	122,088	210,143	88,055	10,426	98,481	87,750	1.1	4.5
	K	92,955	0	156,930	249,885	92,955	12,307	105,262	48,600	2.2	4.0
	L	56,520	0	136,260	192,780	56,520	15,575	72,095	54,000	1.3	4.0
East-West BRT3	M	59,275	0	86,091	145,366	59,275	10,252	69,527	60,750	1.1	4.9
	N	40,051	0	94,986	135,037	40,051	11,402	51,453	34,650	1.5	4.0

Source: JICA Study Team

2.4.3 Do Maximum Scenario Analysis

(1) Transport Network integrated with Urban Structure

There are two basic ways to control traffic demand: 1) land use/spatial structure of a polycentric compact urban area, and 2) effective transport network development of road and public transport with traffic management.

The present urban structure is composed of two parts: compact urban center areas and sprawled ger areas with low density/ineffective use of land in urban fringe.

Alternative future urban scenarios are farther expansion scenario (sprawl, unintegrated suburban/satellite city development) and/or compact scenario (densification of existing urban areas, reduction of ger areas).

Accordingly, the UBMP 2030 aims at formulating a polycentric compact urban area with controlled suburban expansion, and with integrated sub centers along main transport corridors.

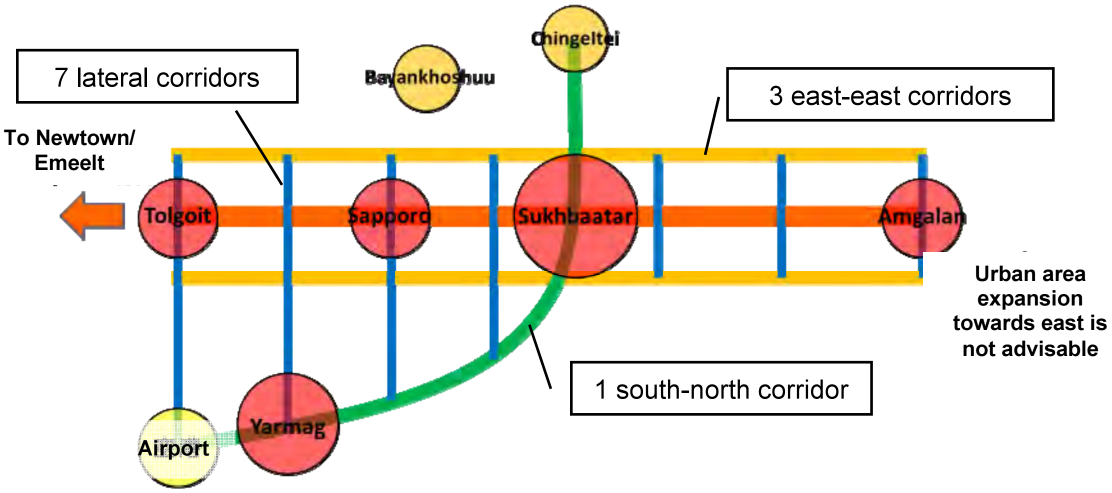
For this, future integrated transport network will be proposed based on the urban development scenario which is proposed in the UBMP 2030.

(2) Basic Structure of Transport Network

To have appropriate transport network integrated with future urban structure, infrastructure development and service improvement plans are proposed.

Infrastructure development includes: 1) three east-west corridors connecting to Sukhbaatar city center and sub centers of Tolgoit, Sapporo, Amgalan; 2) one north-south corridor connecting to Yarmag new city center; and 3) seven lateral corridors connecting to east-west and south-north corridors.

Service improvement means: 1) competitive public transport (mass transit); 2) managed use of private transport; and 3) conductive environment for NMT (non-motorized transport) including pedestrian and bicycles.



Source: JICA StudyTeam

Figure 2.4.9 Proposed Transport Network integrated with Urban Spatial Structure

(3) Future Transport Network in 2030

Do Maximum Scenario assumes the following transport facilities to be developed on the condition that the major road network, the UB Metro, and three routes of BRT are completely developed:

Road Network: Do Maximum Scenario assumes that major roads proposed in the UBMP 2030 are completely developed.

Public Transport: Mass transit network will be promoted in addition to present bus services: 1) east-west Metro along Peace Avenue as a backbone of UB City; 2) south-north and lateral BRT corridors; 3) reformed feeder bus service network (conversion from bus to mass transit along Peace Avenue)

Ulaanbaatar Railway and the Highway are treated as follows:

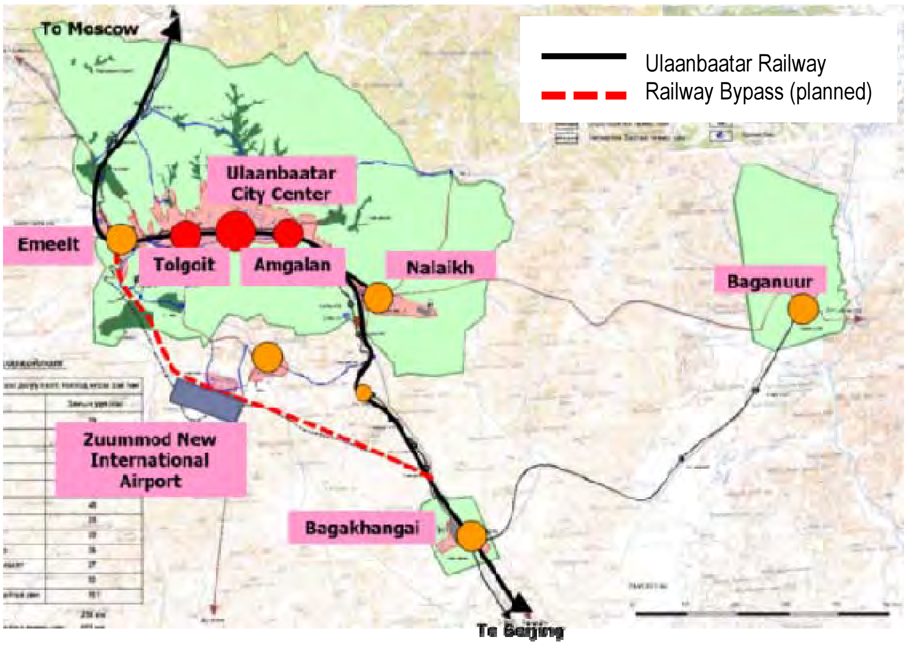
Ulaanbaatar Railway: After the development of railway bypass for freight transport (Bogdkhan Railway), the following functions of UB Railway are proposed: 1) Interface between intercity passenger service and urban service at Tolgoit and Amgalan terminals; 2) operation of suburban passenger services; and 3) intra-urban service is limited. According to future demand forecast in case of development of urban railway on the existing Ulaanbaatar Railway track, the number of passengers is estimated at 188,000 passengers per day in 2020, and 318,000 in 2030, which accounts for only around 60% of the future demand on the urban railway developed on Peace Avenue.

Highway: There are two highway alignment options for the “city south” as follows.

Option (1): The alignment begins at the industrial zones of “city west” and runs along Ulaanbaatar Railway to Amgalan Station (proposed alignment of this project). Being close to and parallel to Peace Avenue, this highway drastically improves the traffic flow of Peace Avenue by distributing the traffic volume of Peace Avenue to the south of the city center. In this case, it is necessary to coordinate with stakeholders to secure lands around the Ulaanbaatar Railway and apartment areas of “city east.”

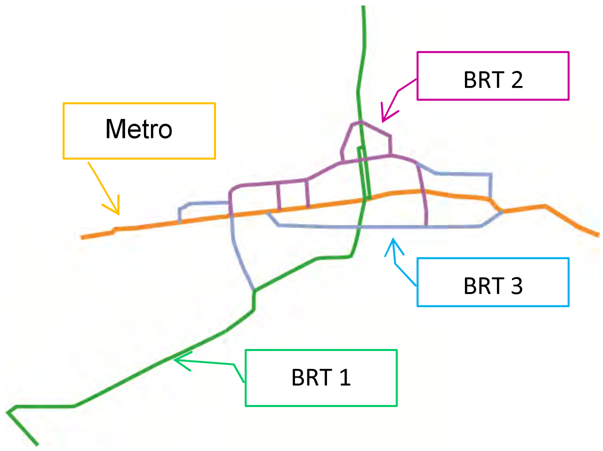
Option (2): This option starts from a river bed of Tuul River to Amgalan Station. In this case, it is expected that the highway will also serve as a dike of Tuul River. Environmental consideration is necessary to preserve water reservoir areas and the surrounding environment.

<u>Option (1) has been evaluated as preferable from the viewpoint of environmental protection and convenience (accessibility to the city center). Therefore, the case of option (1), "Do Maximum Scenario + Highway," has also been studied. In addition, UBMP 2030, approved in February 2013, includes the Highway on the route of option (1).</u>



Source: JICA Study Team

Figure 2.4.10 Proposed Railway Bypass with Urban Transportation Network



Source: JICA Study Team

Figure 2.4.11 Integration of Mass Transit and UB Railway

Figure 2.4.12 Basic Structure of Mass Transit Corridors (Metro, BRT)

(4) Restructuring of bus routes

Buses are expected to function as a feeder transport to connect ger areas with Peace Avenue, not as a major transport, after the metro is developed. It is needed to reorganize bus routes in an integrated and efficient way with the Metro by reducing duplicate bus routes with the Metro and diverting the trolley bus route into the Metro on Peace Avenue.

A route reorganization plan shall be made based on the future demand and actual operational performance of each bus route. In this study, the future Metro demand has been forecasted with the following setting of bus routes:

(1) Fully deleted bus routes because of the full duplication with Metro:

M1, M22, M27, M32, M35, M37, M41, T02, T04, T05, T06, Sub Urban Line to Nalaika, Nairamdal

(2) Partly deleted bus routes which duplicate with Metro:

M4, M5, M6, M13, M17, M23, M24, M26, M39, M42, SR17, SR35, Sub Urban Line to Nalaikh, Hurjirbulan, Gordokh, Terelj.

Figure 2.4.13 Existing Bus Route Network

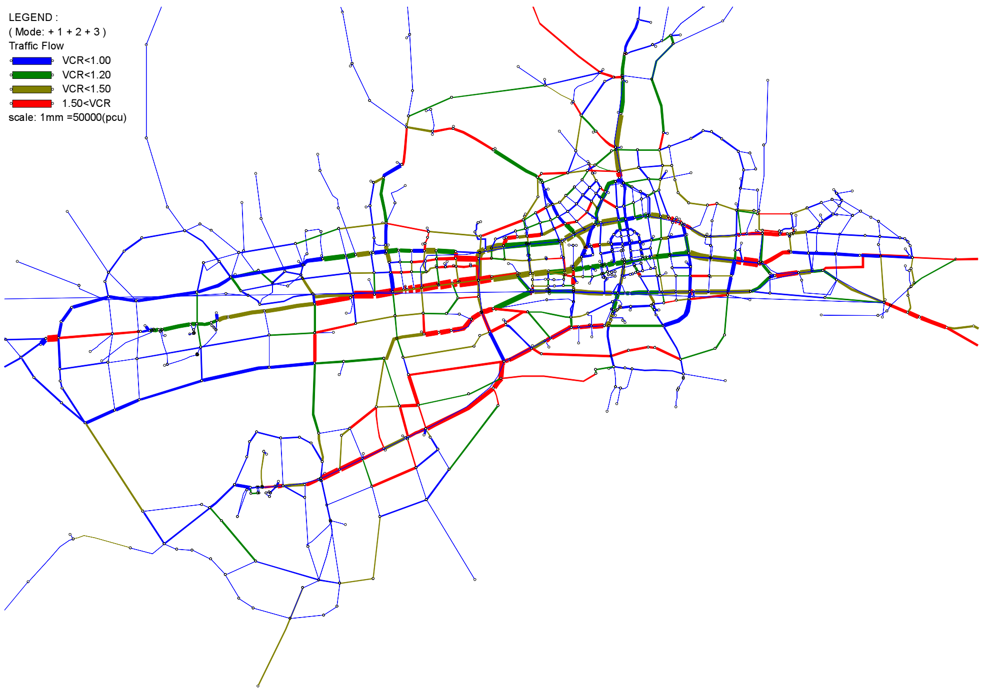
Figure 2.4.14 Proposed Bus Route Network after the Opening of the Metro

(5) Future Traffic Demand and Overall Road Network Performance

In Do Maximum Scenario, future traffic demand analysis aims to clarify future traffic condition in case all proposed projects for future transport network, including the road network proposed by UBMP 2030, the UB Metro, and three BRT lines, are realized.

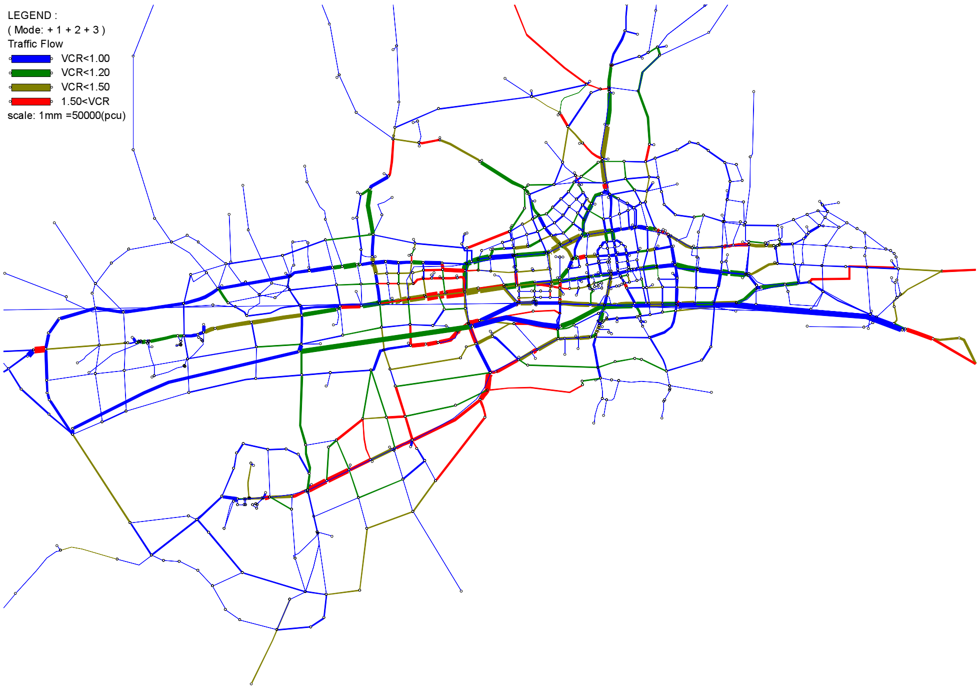
Figure 2.4.15 shows the expected congestion rate (V/C) in trunk roads including roads under planning. Figure 2.4.16 indicates V/C ratios in case that highway is developed. In addition, the condition of overall road network performance in case of Do Maximum Scenario is summarized in Table 2.4.7.

As the table clearly shows, the difference between "with highway" and "without highway" is shown by the difference of V/C ratios: "With Highway" is expected to make a large improvement having a V/C ratio of 0.74, which is better than that of "Without Highway" at 0.8. This improvement contributes to the transport cost savings of the city overall. Specifically, the transport cost in case of "with Highway" is US$20.4 million per day, which means a cost saving by over 10% compared with US$22.8 million per day of transport cost when there is no highway development.



Source: JICA Study Team

Figure 2.4.15 Future Traffic Condition (Do Maximum Scenario, 2030)



Source: JICA Study Team

Figure2.4.16 Future Traffic Condition (Do Maximum Scenario with Highway, 2030)

Table 2.4.7 Traffic Demand and Overall Network Performance (Do Maximum Scenario)

			2010	Do Maximum (without highway)		Do Maximum (with highway)	
				2030	2030/10	2030	2030/10
Traffic Demand (per day)	No. of Trips (000)		2,079	4,259	2.0	4,259	2.0
	Person-km (000)		13,724	47,416	3.5	47,266	3.4
	Person-hours (000)		1,098	9,024	8.2	8,087	7.4
	PCU-km (000)		5,036	18,855	3.7	18,805	3.7
Road Capacity (PCU-km) (000)			12,296	23,108	1.9	25,413	2.1
Traffic Performance	Average Congestion Rate: (V/C)[1)]		0.41	0.82	2.0	0.74	1.8
	Average speed (km/h)		12.7	5.0	0.4	5.8	0.5
	Congested section: km (%)[1)]	V/C≧1.5	0.0	10.3	-	6.6	-
		1.2≦V/C<1.5	0.7	10.2	-	8.4	-
		1.0≦V/C<1.2	0.9	9.8	-	9.5	-
		V/C<1.0	98.4	69.7	-	75.4	-
Transport Cost (US$000/day)	VOC		1,205	7,924	6.6	7,257	6.0
	TTC		665	14,881	22.4	13,106	19.7
	Total		1,870	22,806	12.2	20,363	10.9
Emission (000 ton/yr)	NOx		5	23	4.6	22	11.0
	CO_2		591	3,396	5.7	3,137	5.3

Note: 1) V/C (volume/caacity), which is a ratio of traffic volume to road capacity, is used as congestion rate. V/C ≧ 1.5 means paralyzed traffic; 1.2≦V/C<1.5 is congested considerrably, 1.0≦V/C<1.2 is congested a little, and V/C<1.0 is not congested.

Source: JICA Study Team

(6) Assessment of Selected Mass Transit Corridors

Table 2.4.8 summarizes the future traffic volume and congestion of cross section in main corridors. Due to the increase of mass transit passengers as well as the decrease of private cars and buses of roads of mass transit corridors, PCU will be absolutely decreased, and V/C ratio in Peace Avenue (Sections A-E) will be 1.1- 1.7.

The V/C ratio in the most congested section A will still be 1.7, and thus the congestion will remain to some extent. However, it is fair to say that it will make a large improvement compared with 3.9 of V/C ratio in case of “Do Nothing Scenario” (see Table 2.4.6).

Table 2.4.8 Assessment of Selected Mass Transit Corridors (Do Maximum Scenario with Highway, 2030)

Main Corridor		Traffic Volume (persons/day)				Traffic Volume (PCU/day)			Road Capacity (PCU/day)	Performance	
		Private	Public		Total	Private	Bus	Total		V/C Ratio	Average Speed (km/h)[1]
Name	Section		Mass Transit	Bus							
East-West Metro	A	188,115	262,451	181,114	631,680	102,795	22,164	124,959	72,900	1.7	4.5
	B	203,324	239,417	128,826	571,567	111,106	15,033	126,139	78,975	1.6	4.5
	C	132,677	176,012	93,334	402,023	72,501	7,000	79,501	74,250	1.1	5.5
	D	208,208	169,341	48,858	426,407	113,775	5,404	119,179	82,013	1.5	4.5
	E	119,989	98,620	115,981	334,590	65,568	12,482	78,050	54,675	1.4	4.0
South-North BRT1	F	119,223	70,159	143,531	332,913	65,149	13,656	78,805	60,750	1.3	4.0
	G	56,887	86,081	30,589	173,557	31,086	3,411	34,497	60,750	0.6	21.6
	H	78,642	105,082	141,651	325,375	42,974	10,624	53,598	42,525	1.3	4.0
	I	80,974	192,957	129,209	403,140	44,248	14,815	59,063	34,650	1.7	4.0
East-West BRT2	J	164,720	39,818	81,470	286,008	90,011	7,824	97,835	87,750	1.1	4.5
	K	87,560	31,834	114,828	234,222	47,847	9,228	57,075	48,600	1.2	4.6
	L	51,745	29,927	118,419	200,091	28,276	12,776	41,052	54,000	0.8	21.1
East-West BRT3	M	97,749	15,796	66,967	180,512	53,415	8,814	62,229	60,750	1.0	8.3
	N	56,020	20,877	74,398	151,295	30,612	8,971	39,583	31,188	1.3	4.7

Note: 1) Based on the QV (Quantity – Velocity) Curve, which indicates the relationship between traffic volume (quantity) and velocity, vehicles can run fast when traffic volume is low. However, because distance between vehicles becomes shorter as traffic volume becomes larger, average velocity is constant once the V/C ratio surpasses 1.0.
2) See Figure 2.4.8 for the location of sections A to N.
Source: JICA Study Team

(7) Role of Mass Transit

It is difficult to develop new roads and to expand existing roads in the city center, so, the road development will be insufficient for future traffic demand.

For a compact city development integrated with public transport, it will be effective to develop public transport service in hierarchical manner, including Metro and BRT as mass transit services, and bus services to connect mass transit network, as a feeder service.

Mass transit development will be effective to improve mobility of public transport users, but not enough to decrease traffic congestion of roads. Traffic management measures are indispensable to control cars.

If mass transit network will be developed in road space, it will affect road traffic flow because of the decrease of road capacity and segmentation of the area; hence, appropriate road section plan integrated with BRT and traffic management are important.

By 2030, east-west Metro along Peace Avenue, south-north and lateral BRT lines will become the main transport structures. After 2030, it will be necessary to consider how to manage heavy traffic demand of south-north direction which will be overloaded of BRT. Long-term improvement plan will be necessary.

(8) Role and Impacts of Highway

Impacts of highway on the south of Peace Avenue will be significant. Through-traffic flow between east and west will use the highway, and the traffic volume of Peace Avenue will be distributed to the "city south," and so the congestion will be drastically improved.

The highway is obviously effective. UBMP 2030 designates the highway aligned along the Tuul River; however, it is necessary to further study the alignment of the highway in the Feasibility Study.

2.4.4 Proposal for Future Comprehensive Transport Network

It is obvious that future transport demand is large, much larger than the growth of population. Appropriate transport network will be significant to connect sub centers toward a polycentric compact urban development.

Comprehensive approaches are necessary for urban transport improvement such as 1) effective urban growth management; 2) road network expansion/configuration; 3) increase in capacity and efficiency of public transport; 4) controlled/restricted use of private cars; and 5) much improved traffic management and people awareness.

Public Transport System: Public transport system must be developed in combination with different systems including Metro, BRT, Bus, and others depending on demand characteristics of corridors and areas. Peace Avenue is the most important urban and transport backbone of the city, requiring high quality transport services and integrated urban development.

Road Development: Hierarchical road network including the main corridors of east-east and south-north, the sub corridors to distribute to ger areas, and the highway for through-traffic flow will be necessary.

Traffic Management: Comprehensive traffic management program should also be included particularly the control measures of private vehicles such as road pricing and ticket system of city center, the Park and Ride (P&R) to promote mass transit utilization of sub-urban areas, the common ticket system of mass transit and bus, car parking control; and pedestrian space improvement.

3 Concept Design of Ulaanbaatar Metro

3 Concept Design of Ulaanbaatar Metro

3.1 Present Condition and Development Strategy for Peace Avenue

3.1.1 Station Influence Area

Approximately 70% of citizens live along Peace Avenue and in the Central Business District (CBD) around the Sukhbaatar Square. There are various urban facilities such as public service, commercial and business facilities and apartments. Located in the west of Peace Avenue is the 3rd Power Plant which supplies heating services to apartment areas, through underground pipelines along the Peace Avenue.

The spatial structure of Ulaanbaatar City is a ladder shaped one, extending from east to west, and is surrounded by mountains in the north and south. Peace Avenue is the only trunk road that connects east and west of the city, so most of urban facilities and traffics are gathered along this road. Based on the result of simulation of STRADA, about 700,000 trips (approximately 35% of the 2 million trips) are concentrated in Peace Avenue. Among the 58 main bus routes of the city, 21 routes (36%) run along this trunk road.

In this way, Peace Avenue serves as the backbone of urban service, transport and utility service in Ulaanbaatar City. There are various development opportunities along this road in a strategic way.

In the city center, many of the middle and high-rise apartments are very old, and factories and warehouses are scattered with low density, so it is required to redevelop these areas. In a rapid urbanization process, renovation of central infrastructure facilities and strengthening its provision capacity are urgent issues.

In the near future, it is expected that population along Peace Avenue will be increased because of reconstruction of apartments and resettlement from Ger areas. In addition, employment opportunities will increase as a result of commercial and business development. Furthermore, consolidation of social infrastructure and public service facilities along this road will provide a convenient living environment for citizens.

3.1.2 Development Issues and Strategies

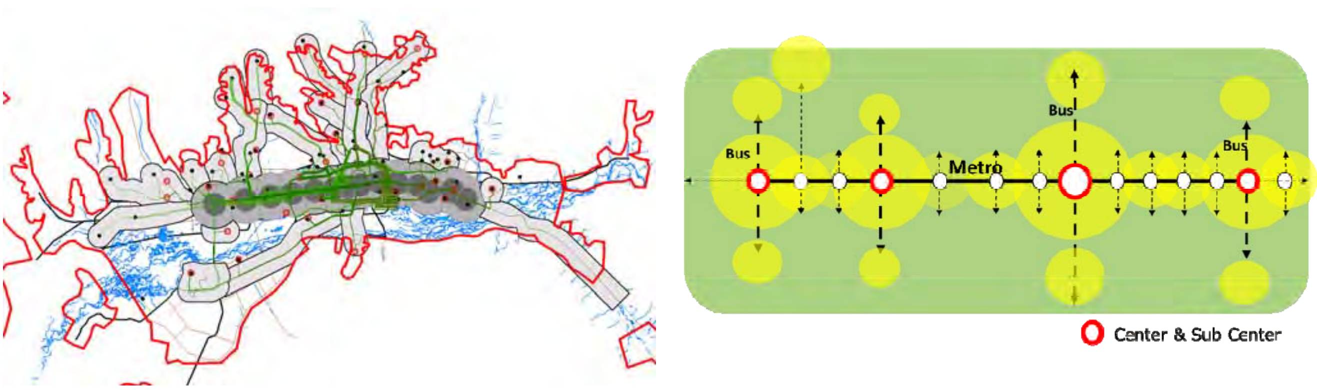
Major development issues along Peace Avenue are summarized in three points, and its development strategies are shown in Table 3.1.1.

1) Restructuring and strengthening urban functions (Promotion of integrated urban development and creation of investment opportunities).
2) Competitive and convenient transport development (Development of Ulaanbaatar (UB) Metro as the core of public transport network).
3) Improvement of urban image (Development of modern and comfortable urban spaces with mass transit corridors as a driving force).

Table 3.1.1 Development Issues, Strategies and Impacts of Metro Development

Issues	Strategies	Impacts of Metro Development
Restructuring urban function	Urban development along Peace Avenue	Promotion of socio-economic activities by urban redevelopment, old apartment reconstruction, commercial and business development
	Creation of job opportunities	Employment promotion by commercial and business facility development
	Improvement of urban service	Consolidation and strengthening of public facilities and infrastructure services
	Living condition improvement	Living condition improvement by urban redevelopment and road development projects
	Creation of investment opportunities	Sub center development, new town development, underground space development integrated with UB Metro development
Competitive and convenient transport development	Reduction of traffic congestion	Reduction of private transport by promotion of mass transit and traffic management
	Promotion of public transport utilization	Provision of integrated public transport services of Metro, BRT and bus
	Improvement of transfer condition	Development of intermodal transfer facilities and restructuring of bus routes
	Improvement of pedestrian spaces	Improvement of safe and comfortable access roads to station
	Traffic management	Comprehensive traffic management including intersection improvement, parking management, road pricing, etc.
Improvement of urban image	Strengthening of local identity	Promotion of modern image of UB Metro
	Urban design	Spatial and facility development based on local characteristics
	Creation of green spaces	Development of environmental spaces around stations
	Reduction of air pollution	Reduction of auto emission by promoting public transport utilization
	Community improvement and public participation	Promotion of local community activities around station

Source: JICA Study Team



Source: JICA Study Team

Figure 3.1.1 Concept of Station Influence Area of Metro and Feeder Bus Service

3.2 Development Orientation of Ulaanbaatar Metro

3.2.1 Railway Alignment Plan

Advantages of mass transit development along Peace Avenue are as follows:

1) Transport development
   - UB Metro will be developed within a road space without reducing the traffic capacity of Peace Avenue; traffic capacity can be increased by reducing vehicles.
   - UB Metro will be appropriately integrated with other transport network.
   - UB Metro will be properly connected to Ulaanbaatar Railway.
2) Urban development
   - UB Metro will be a trigger to strengthen existing urban areas and to develop sub centers.
   - UB Metro will lead appropriate urban growth toward the west side (though urban expansion toward the east is not recommended in terms of water reservoir preservation).
   - UB Metro will be developed without serious social and technical disincentives.

UB Metro project is proposed to develop a mass transit between Tolgoit Station and Amgalan Station within the road spaces along Peace Avenue.

3.2.2 Railway System

(1) Criteria for Selection of Railway System

When considering the selection of the mass transit system, some criteria such as i) demand at peak hour, ii) economic consideration, iii) safety, and iv) easy maintenance would be considered in comprehensive manner.

In addition, with the long-term operation period, flexible railway system to respond future urban growth and increase of passengers is expected. Furthermore, selection of facilities and equipment which can adapt to special climate condition of Ulaanbaatar City is indispensable. For this, v) flexibility for future expansion (increase in the number of cars and decrease in travel time), and vi) resistance to cold climate, are important criteria for Ulaanbaatar City.

(2) Technical Precondition

For the selection of railway system, technical precondition in 2030 are as follows (see Chapter 4 in detail).

- Demand : app. 17,000 PHPDT (Peak Hour Peak Direction Traffic)
- Headway : 5 minutes (12 trains/hour/direction)
- Unit Volume : 17,000 / 12 =1,400 persons/train
- Route : Tolgoit to Amgalan along Peace Avenue (17.640km)
- Station interval : 1.356km on average
- Structure : viaduct (elevated), at grade, underground
- Alignment : excessive gradient and curve are not required
- Climate : large difference in temperature between summer and winter, less than minus 40 degree in winter

(3) Comparison of Urban Railway System

Urban railway system is classified by structure, capacity and system of transmission of power.

Table 3.2.1 Typology of Urban Railway System

Rail- & guideway-based transport system	Steel wheel and rail system	Adhesion driving	Conventional Railway (MRT)
			Light Rail Transit (LRT)
		Non Adhesion driving	Linear motor railway (LIM Train)
	Rubber tire system	Monorail	Straddle type monorail
			Suspended type monorail
		Rubber tire guideway transit	Automated Guideway Transit (AGT)
	Levitation system	Non Adhesion driving	High Speed Surface Transport (HSST)
Non rail- & guideway-based transport system	On-road operation by bus		BRT

Source: Guideline of railway transport planning, Japan

Among these systems above, iron wheel and iron rail system (MRT: Mass Transit Transport and LRT: Light Rail Transit), and rubber tire system (monorail, AGT: Automated Guideway Transit) are the prospects which fulfill criteria. HSST (High Speed Surface Transport) is not popular at present and will not be appropriate as a trunk railway system, so this system is excluded.

Table 3.2.2 Examples of Urban Railway System

System	Steel wheel and steel rail system (ex. MRT)	Steel wheel and steel rail system (ex. LRT)	Monorail (ex. Straddle type)	Rubber tire guideway transit (AGT)
Exterior of Vehicle				
Car length	20.0m	16.0m	15.0m	9.0m
Car width	2.95m	2.4m	3.0m	2.5m
Car height	3.65m	3.4m	5.2m	3.5m
Traction system	Electric motor and steel wheel	Electric motor and steel wheel	Electric motor and rubber tire	Electric motor and rubber tire
Guidance system	Steel rail	Steel rail	Track beam	Concrete slab
Maximum speed	110 km/h	70 km/h	80 km/h	80 km/h
Minimum curve radius	200m (desirable) (120m absolute min.)	150m (desirable) (100m absolute min.)	30m	30m
Maximum Gradient	3.5% (6% for linear Metro)	3.5% (6% for linear Metro)	6%	6%
Capacity per hour/one direction	10,000 – 50,000 persons/hour	5,000 – 35,000 persons/hour	7,000 – 25,000 persons/hour	10,000 – 20,000 persons/hour

Source: JICA Study Team

(4) Selection of Railway System

The optimum system to be adopted for the project should be selected by setting several criteria.

Different railway systems have different features to respond to the curve and the gradient of targeted lines; and therefore, the feature is normally included in the criteria. However, the UB metro line (Peace Avenue) is straightforward, and there is little difference in that point between railway systems. Thus, this is not included in the criteria of this study.

Prospective railway systems are assessed based on various criteria, and it is proposed to select **MRT** as an optimum mass transit system for Peace Avenue.

Table 3.2.3 Assessment of Prospective Railway System

Category	System	MRT	LRT	Monorail	AGT
Technical	Energy saving	**A**	B	C	C
	Expansion potential	**A**	B	C	C
	Compatible with cold climate	B	B	C	C
	High speed transport	B	C	C	C
Environment	Gas emission, noise, vibration	C	C	B	B
	Daylight interferance[1)]	C	C	B	C
	Novelty and innovation	C	C	C	C
Service	Frequency and conformability	**A**	**A**	**A**	**A**
Finance	Maintenance cost	**B**	**B**	C	C
Total Assessment Score[2)]		**9**	6	4	3

Note:1) In the case of monorail, shaded areas are smaller because of the design of the elevated portion.
2) Score is calculated as follows:
A "Preferable"= 2, B "Positive" = 1, C "Satisfactory" = 0, D "Negative" = -1

Source: JICA Study Team

3.2.3 Structure

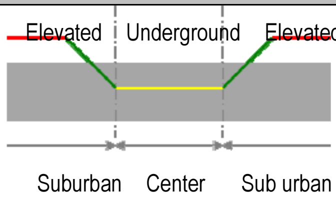
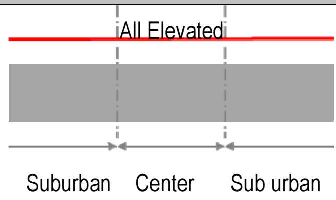
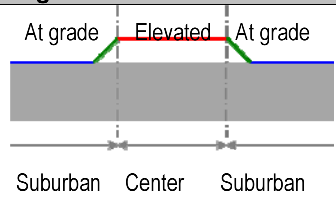
There are three types of Metro structures: elevated, at grade and underground. Based on criteria below, alternatives of structure are assessed.

1) Socio-economic impact: land acquisition, land use
2) Traffic function: impact on road transport (avoidance of decrease of carriage way, grade crossing with road, impact on intersection)
3) Environmental consideration: landscape, noise and vibration, safety
4) Technical appropriateness: construction method, construction cost

There is another alternative structure, all underground, but it was not examined in this study because the construction cost is very high, and no land acquisition is needed in suburban areas even if the structure is elevated or at grade.

Based on the result of assessment, **alternative A "Underground in city center, elevated in sub urban area"** is proposed in this project.

Table 3.2.4 Alternative Metro Structure

	A: Underground in city center, Elevated in sub urban area	B: All elevated	C: Elevated in city center, at grade in sub urban area
Section Image			
Land Acquisition	○ Not necessary	△ Necessary to secure present width of carriage way and sidewalk in city center	×Necessary to secure present width of carriage way and sidewalk
Road Transport	○ Less impact on road transport	△ Some negative impacts on city center because of pillars	× Serious impacts because of grade crossing with road
Landscape	△No negative impacts in city center but some negative impacts in suburban areas	×Serious Impacts both in city center and suburban areas	×Serious Impacts in both city center and suburban areas. Particularly, significantly affects the city center.
Environment	△No negative impacts in city center but some negative impacts in suburban areas such as noise and vibration	×Serious negative impacts, such as noise and vibration because of the elevated structure	×Serious negative impacts, such as creating noise and vibration, and splitting of communities
Cost	×	△	○

Note: Cost of each case includes only the development cost of the train infrastructure. This means that it does not include the cost of loss from the decrease in carriageway width, land acquisition of the reduced carriageway or grade crossing with road.

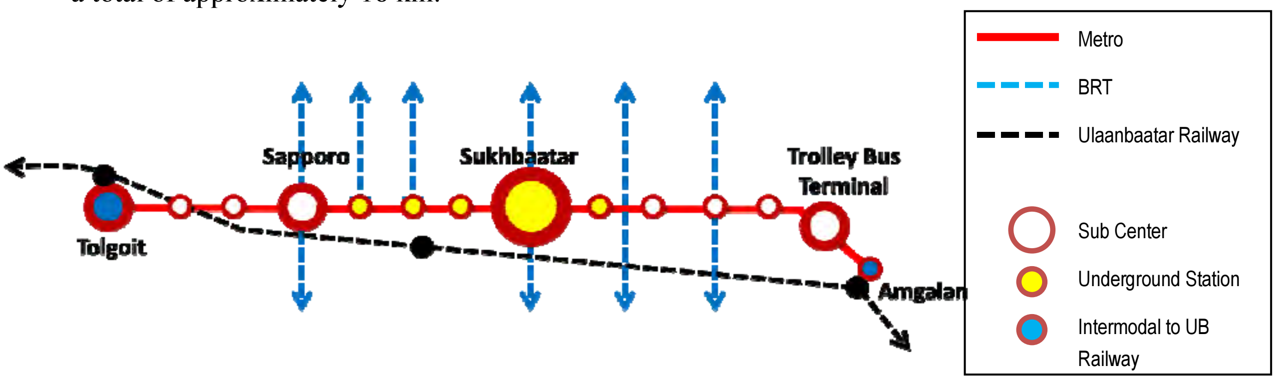
Source: JICA Study Team

3.2.4 Selection of Station Location

Station locations are selected based on the following criteria:

- Potential of urban core: consolidation of urban facilities and socio-economic activities at present and in the future
- Intermodal transfer condition: connectivity to other transport modes (cf. Ulaanbaatar Railway, BRT, bus)
- Physical condition: utilization of existing median and open space to avoid land acquisition at grade, geological condition (cf. soil, water)
- Accessibility: Station distance is within walking distance (app. 500m – 1km), accessible space for bus and pedestrian

Based on criteria above, 14 stations are proposed from Tolgoit Station to Amgalan Station, with a total of approximately 18 km.



Source: JICA Study Team

Figure 3.2.1 Concept of Intermodal System with Mass Transits

Table 3.2.5 Station List of Ulaanbaatar Metro

Name of Station		Structure			Main Function			Other Mode to Transfer		
		Elevated	At Grade	Under-ground	Sub Center	Intermodal	Inter-mediate	UB Rail	BRT	P&R
W7	Tolgoit	○			○	○		○		○
W6	West Bus Terminal	○				○				○
W5	Qarakorum Market	○					○			
W4	Sapporo Rotary	○			○	○			○	
W3	25th Pharmacy			○		○			○	
W2	Gandan Temple			○		○			○	
W1	Nomin Department			○			○			
CS	Sukhbaatar Square			○	○	○			○	
E1	Wrestling Palace			○		○				
E2	Cinema Studio		○				○			
E3	Officer Palace	○				○			○	
E4	West Botanical Park	○					○			
E5	Trolley Bus Terminal	○			○	○				○
E6	Amgalan	○				○		○		○

Source: JICA Study Team

A possibility of extension of the line shall be planned towards the west in accordance with the expansion of urbanized area and a new town development in the west of Ulaanbaatar City. The total length of the Metro will be about 26.6 km to connect with the new town. On the other hand, in the east of Ulaanbaatar City, as there is a water resource area, the development must be restricted. Accordingly, the extension of the Metro to the east is not planned, with the terminal Amlgalan Station in the east. The terminal station is expected to serve as an intermodal transfer facility between the Metro and Ulaanbaatar Railway.

3.3 Demand Analysis of Ulaanbaatar Metro

3.3.1 Approaches for Demand Analysis and Precondition

For demand analysis of Ulaanbaatar Metro, Origin-Destination (OD) table is updated by applying the results of traffic count survey in November 2011 (11 locations of cordon line survey and 10 locations of screen line survey and passenger occupancy survey), based on OD Table of UBMPS, 2007.

Passenger occupancy survey identified average numbers of passengers of each type of vehicle, by counting the number of vehicle and its number of passengers. Based on this, average occupancy and PCU (Passenger Car Unit) was calculated.

Road transport network in 2011 was formulated by distributing OD Table of 2077 to updated network including new or upgraded roads until 2011.

Table 3.3.1 Passenger Occupancy and PCU by Vehicle Type

	Vehicles	Passenger	Occupancy	PCU
Cars	181,855	332,575	1.83	1.0
Micro bus	8,089	66,319	8.20	1.5
Small Bus	605	7,062	11.67	2.0
Large Bus	6,231	245,865	39.46	3.0
Small Truck	17,045	30,776	1.81	2.0
Large Truck	5,088	8,455	1.66	3.0
Motorbike	239	294	1.23	0.7
Others	0		1.00	1.0
Private	204,227	372,100	1.82	1.13
Public	14,925	319,246	21.39	2.15

Source: JICA Study Team

Table 3.3.2 Adjusted Number of Trips by Mode

Mode of Transport	2007		2011	
	Trip	(%)	Trip	(%)
Walking	**1,035.4**	**32.4**	**1,035.4**	**33.2**
Private	**801.7**	**25.1**	**889.8**	**28.6**
Bicycle	2.1	0.1	1.3	0.0
Motorcycle	0.6	0.0	0.8	0.0
Car - driver	480.4	15.0	536.5	17.2
Car - passenger	267.0	8.4	302.4	9.7
Tourist Bus	0.3	0.0	0.4	0.0
Company Bus	10.4	0.3	16.3	0.5
School Bus	1.5	0.0	2.4	0.1
Truck	39.2	1.2	29.4	0.9
Others	0.2	0.0	0.4	0.0
Public	**1,356.6**	**42.5**	**1,189.0**	**38.2**
Minibus (<=25 pax)	664.1	20.8	243.2	7.8
Standard Bus (>25 pax)	377.6	11.8	588.3	18.9
Trolley Bus	7.6	0.2	11.9	0.4
Taxi	307.3	9.6	345.3	11.1
Rail Train	0.0	0.0	0.3	0.0
Air	0.0	0.0	0.0	0.0
Total	**3,193.7**	**100.0**	**3,114.1**	**100.0**

Source: JICA Study Team

3.3.2 Demand Analysis of Ulaanbaatar Metro

(1) Fare System

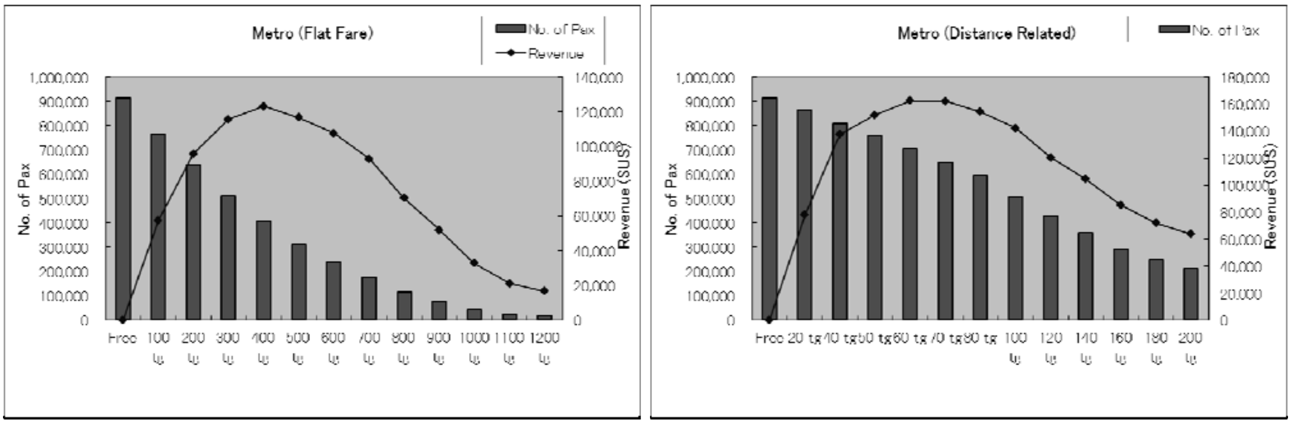
One of the major indicators of traffic demand analysis is fare system. Based on the proposed future transport network (Do Max case) in Chapter 2 of this report, demand of UB Metro is estimated based on various fare system (see Table 3.3.3). According to this, the number of passengers with an average trip length of 6.0 km is maximized, if the fare is free of charge.

Table 3.3.3 Demand Analysis of Various Fare System (2030)

Fare System		No. of Passengers (persons/day)	Revenue ($/day)	Average Fare (Tg/person)	Average Trip Length (km)
Free	0Tg	914,904	0	0	**6.0**
Flat Fare	**400 Tg (same as bus)**	409,521	**123,266**	400	8.1
	500 Tg (bus x1.25)	310,606	116,788	500	8.6
	600 Tg (bus x1.5)	238,600	107,609	600	9.0
	700 Tg (bus x1.75)	176,682	92,935	700	9.6
	800 Tg (bus x2.0)	116,665	70,232	800	10.0

Distance-based Fare	20Tg/km	865,424	77,888	120	5.8
	40Tg/km	808,746	137,487	226	5.6
	60Tg/km	706,864	**162,579**	306	5.1
	80Tg/km	594,090	154,463	346	4.3
	100Tg/km	508,238	142,307	372	3.7

Note: 1US$=1330Tg
Source: JICA Study Team



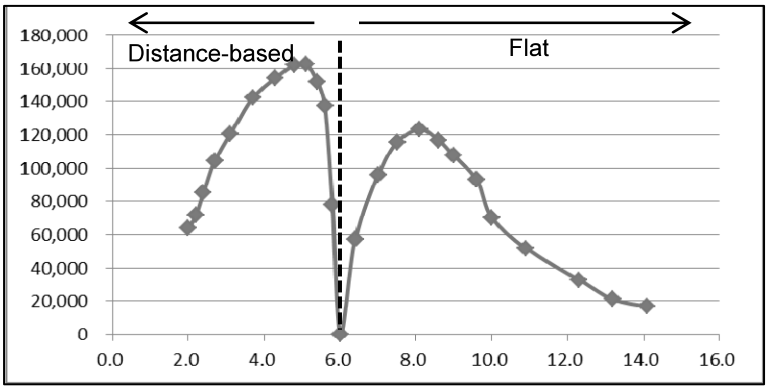
Source: JICA Study Team

Figure 3.3.1 Number of Passengers and Revenue by Fare System (Left: Flat Fare, Right: Distance-based Fare)

The present bus fare is fixed price (400 Tg), but in the case of the metro, which serves long-distance travel, mixed fare including fixed price for short-distance and distance-based fare for mid- to long-distance trips is common. Based on this assumption, a fare system is identified to maximize both passenger demand and fare revenue.

A flat fare of 400 Tg and a distance-based fare of 60 Tg/km both will generate the maximum number of passengers (see Figure 3.3.2). Therefore, both conditions are taken into consideration, and it is proposed that the flat fare be applied up to a certain short distance, and the distance-based fare be applied for a mid- to long-distance travel over the certain short distance.

Fare ＝400/2 + (distance - km) x 60/2 = 200 + (distance - km) x 30



Source: JICA Study Team

Figure 3.3.2 Average Trip Length and Number of Passengers by Mixed Fare System

Based on the result of traffic demand analysis, the fare systems to maximize number of passengers and revenue are identified:

1) Maximum number of passengers: Fare =200+(k-4) x 50 → 570,685 passengers

2) Maximum revenue: Fare =200+(k-2) x 60 → US$158,467/day, and average trip length is approximately 6.0 km.

Table 3.3.4 Demand Analysis of Mixed Fare System (2030)

Fare System		No. of Passengers (persons/day)	Revenue ($/day)	Average Fare (Tg/person)	Average Trip Length (km)
200Tg within 2km + distance-based fare over 2km	200+(k-2) x 50	486,975	155,832	426	6.3
	200+(k-2) x 60	466,080	**158,467**	452	**6.1**
	200+(k-2) x 70	439,565	149,452	452	5.5
200Tg within 4km + distance-based fare over 4km	200+(k-4) x 50	**570,685**	142,671	333	6.4
	200+(k-4) x 60	558,562	150,812	359	6.2
	200+(k-4) x 70	541,685	151,672	372	5.9
300Tg within 2km + distance-based fare over 4km	300+(k-4) x 50	418,070	146,325	466	6.8
	300+(k-4) x 60	404,958	145,785	479	6.6
	300+(k-4) x 70	389,560	144,137	492	6.3
Others	300 + k x 50	287,971	138,139	638	6.8
	600+(k-2)x50	84,554	55,818	878	7.5

Note: 1US$=1330Tg
Source: JICA Study Team

In addition to the result of the demand analysis, other conditions are taken into consideration: a) result of public transport user survey (willingness to pay to Metro fare with approximately 1.2-1.5 times the bus fare); and b) actual distance of UB Metro (approximately 18 km between W7 to E6, approximately 6 km between W4 to E1 of city center). Based on these conditions, it is proposed to apply the mixed fare system below[1]:

Fare = 200Tg + (distance - 2) x 50Tg

In this case, the number of users is 486,975/day; fare revenue is US$155,832 per day; and the fare is 1,000Tg for 18 km between W7 to E6, and 400Tg for 6 km at average trip length. It seems it will be easier for bus passengers to use UB Metro.

(2) Passenger Volume of Cross Section and Each Station

Based on the proposed fare system above, traffic demand of UB Metro is analyzed. The maximum passenger volume of cross section is between W5 Qarakorum Market and W4 Sapporo Rotary. The station with maximum daily passenger volume is W6 West Bus Terminal.

[1] These fare systems are the ones applied in demand forecast described in Chapter 3 and Engineering Plan in Chapter 4 Financial. In Chapter 10, a comparative financial analysis and evaluation is made based on three kinds of average fare (400 Tg, 600 Tg and 800 Tg).

Table 3.3.5 Estimated Maximum Passenger Demand of Ulaanbaatar Metro

	Station	2020	2030
Maximum Volume of Cross Section	W5 Qarakorum Market - W4 Sapporo Rotary	83,750 persons/day (10,050 persons/peak hour)	139,540 persons/day (17,000 persons/peak hour)
Maximum Volume of Station	W6 West Bus Terminal	133,970 persons/day	227,050 persons/day

Source: JICA Study Team

Note: Peak hour ratio is 12% of total daily passengers, based on the result of time distribution of person trip, Household Interview Survey of UBMPS, 2007.

Table 3.3.6 Estimated Passenger Demand of Cross Section and Each Station in 2020

Station		West to East			East to West			Daily passengers (persons/day)
		Board	Alight	Carried	Board	Alight	Carried	
W7	Tolgoit	19,270	0	0	0	15,010	15,010	34,290
W6	West Bus Terminal	66,650	2,650	19,270	3,340	61,320	72,990	133,970
W5	Qarakorum Market	3,520	3,050	83,280	5,580	4,030	71,440	16,200
W4	Sapporo Rotary	18,340	22,320	83,750	16,660	13,800	68,570	71,130
W3	25th Pharmacy	5,180	10,390	79,770	4,370	3,970	68,180	23,910
W2	Gandan Temple	4,810	20,680	74,560	14,990	6,940	60,120	47,430
W1	Nomin Department	4,840	8,010	58,690	4,750	7,680	63,050	25,290
CS	Sukhbaatar Square	16,700	19,980	55,520	25,750	20,160	57,450	82,610
E1	Wrestling Palace	8,260	9,570	52,240	6,620	8,640	59,470	33,100
E2	Cinema Studio	4,740	9,930	50,940	14,360	5,000	50,120	34,050
E3	Officer Palace	5,690	15,840	45,750	15,440	5,740	40,420	42,720
E4	West Botanical Park	130	3,620	35,600	7,620	340	33,140	11,730
E5	Trolley Bus Terminal	760	7,590	32,110	9,340	370	24,170	18,070
E6	Amgalan	0	25,290	25,290	24,170	0	0	49,460
	Total	158,950	158,950	-	153,060	153,060	-	624,030

Source: JICA Study Team

Table 3.3.7 Estimated Passenger Demand of Cross Section and Each Station in 2030

Station		West to East			East to West			Daily passengers (persons/day)
		Board	Alight	Carried	Board	Alight	Carried	
W7	Tolgoit	29,450	0	0	0	19,990	19,990	49,450
W6	West Bus Terminal	113,520	3,340	29,450	3,680	106,500	122,820	227,050
W5	Qarakorum Market	4,150	4,240	139,630	7,580	5,600	120,830	21,580
W4	Sapporo Rotary	31,560	40,380	139,540	37,670	25,530	108,700	135,150
W3	25th Pharmacy	5,880	21,830	130,710	12,480	6,430	102,650	46,640
W2	Gandan Temple	7,000	22,410	114,770	18,230	8,960	93,370	56,610
W1	Nomin Department	4,730	11,670	99,360	6,620	10,600	97,360	33,630

CS	Sukhbaatar Square	23,820	35,120	92,420	35,310	32,840	94,880	127,100
E1	Wrestling Palace	7,960	16,150	81,120	8,440	9,960	96,410	42,520
E2	Cinema Studio	4,420	12,110	72,920	17,710	6,290	84,990	40,550
E3	Officer Palace	8,160	24,630	65,240	29,050	8,280	64,220	70,130
E4	West Botanical Park	1,910	4,040	48,770	14,200	1,950	51,970	22,130
E5	Trolley Bus Terminal	840	12,540	46,640	16,690	510	35,790	30,600
E6	Amgalan	0	34,940	34,940	35,790	0	0	70,740
	Total	243,450	243,450	-	243,510	243,510	-	973,950

Source: JICA Study Team

3.3.3 Overall Concept of the Metro Project

(1) Outline of Ulaanbaatar Metro

The outline of Ulaanbaatar Metro project is summarized in Table 3.3.8.

Table 3.3.8 Outline of Ulaanbaatar Metro

Name	Ulaanbaatar Metro
Route	Tolgoit Station – Amgalan Station (Phase1)
Total length	17.7km
No. of station	14 stations (8 elevated, 1 at grade and 5 underground)
Space	Inside the Peace Avenue
Facilities	Railway, station, entrance, depot

Source: JICA Study Team

(2) Total Image of Metro Project

To make Ulaanbaatar Metro as a centric network of public transport and urban functions, it should be integrated as a main network of public transport system of Ulaanbaatar City.

If the promotion of urban development around UB Metro triggers Metro development, various issues of progress in Ulaanbaatar City such as socio-economic development, investment opportunity creation, employment opportunity creation, and environmental improvement will follow.

To increase synergy effects of UB Metro project, comprehensive and integrated urban and transport development program is indispensable.

Table 3.3.9 Total Image and Comprehensive Project Matrix of UB Metro

	City Center	Peri Urban Area	Sub Urban Area
Total Image	● International competitive development with commerce and business, culture and tourism cores	● Modern sub center development with intermodal cores	● Middle dense living environment improvement with accessibility to city center
Transport Development	● Appropriate traffic management ● Pedestrian network to station with feeder bus service ● Private vehicle control by road pricing and ticket system	● Distribution for road network development ● Intermodal service with BRT and buses to connect to Ger areas	● Development of access road to trunk roads and bus routes ● Improvement of bus feeder service
Urban Development	● Restructuring of urban function by old apartment reconstruction ● Underground development ● Urban design and modern townscape improvement	● Competitive commercial and business districts with convenient urban facilities ● Convenient commuting service ● Public apartment complex development for resettlement of people from Ger areas	● District commercial and business center and public service center ● Living environment improvement of Ger areas

Source: JICA Study Team

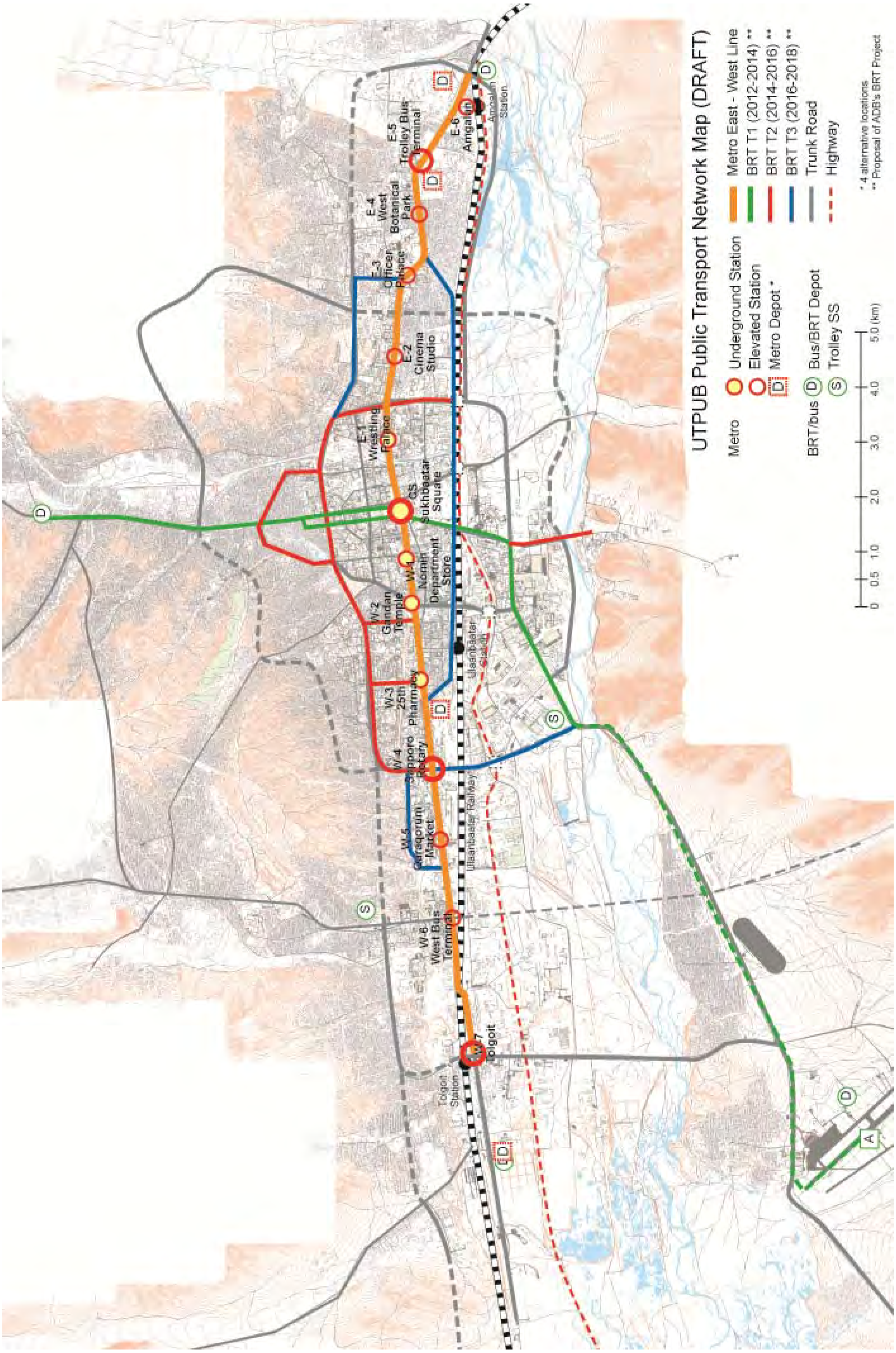


Figure 3.3.3 Location Map of Ulaanbaatar Metro (Draft)

4 Urban Transport System Development Plan

4 Urban Transport System Development Plan

4.1 Route Plan

4.1.1 Selection of the Structure: Elevated, Underground, At-grade

(1) Prerequisites for Selection of the Structure

For the selection of structure (elevated, underground, at-grade), the following prerequisites are set:

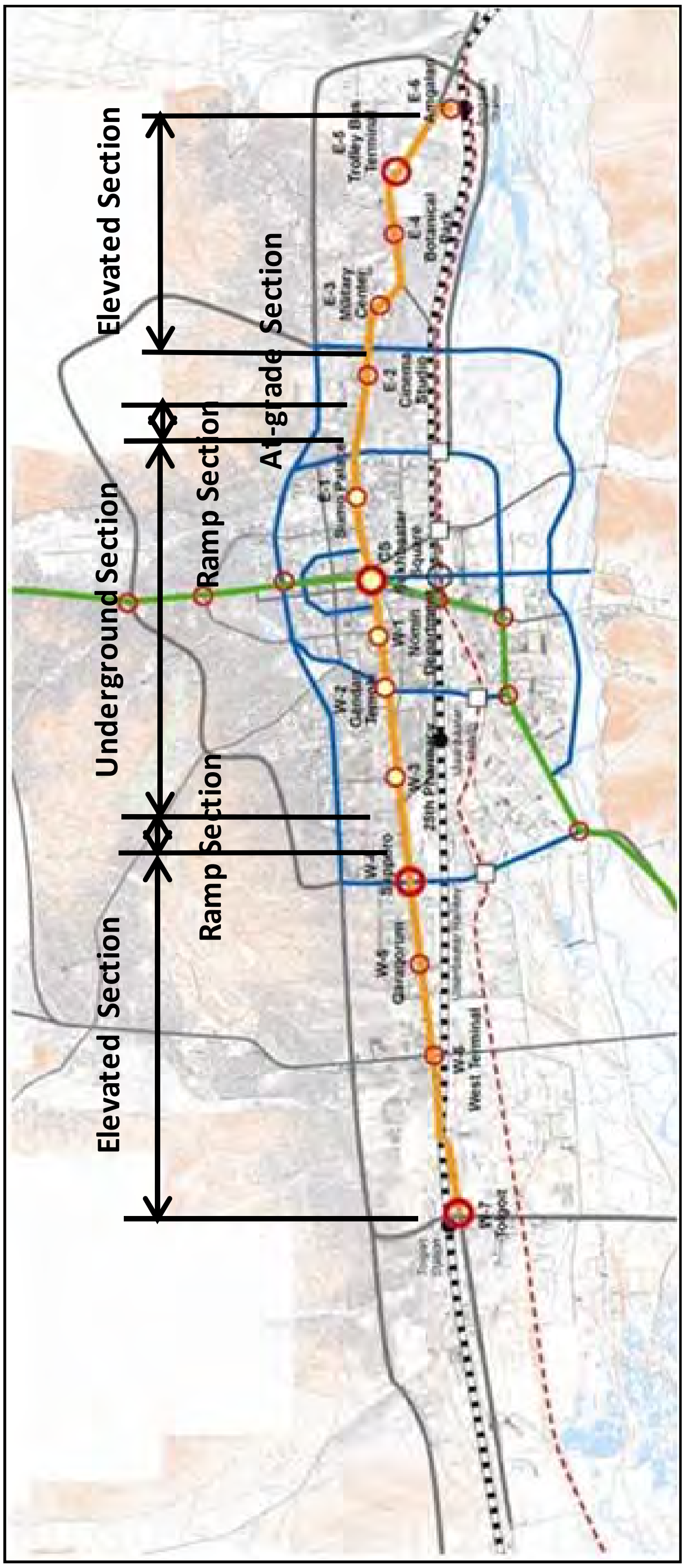
- Avoiding road closure to minimize impact on traffic congestion, i.e., **avoiding reduction in the number of lanes and removal of existing intersections and turn-around points as much as possible.**
- **Avoiding land acquisition as much as possible** to avoid delay or abortion of the project or changing of the plan.
- **No level crossing (railway crossing) provided** between the Metro and road traffic.
- **Considering environmental aspects, such as landscape, noise, vibration, sunlight, etc.,** particularly in the central part.

(2) Selection of the Structure

The type of structure is selected as follows based on the above prerequisites.

- Underground structures will be used in the central part where there is no median strip and there is not much public land on the roadside.
- Ramp sections are to be provided in the roads with a median strip to enable passengers to exit from the underground.
- Elevating the subsequent section extending into the suburbs because this section crosses intersections (roundabouts, ordinary crossroads, ordinary T-junctions), turn-around points, and railway crossing.

The ramp section will have a retaining wall and an embankment of about 9 m in width and about 400 m in length. The ramp section will be provided in the median strip between Sapporo Rotary Station and 25th Pharmacy Station at a point on the east side of East Intersection. Cinema Studio Station is located at a transition point between underground and elevated sections and the section has a median strip. Accordingly, this station will be an at-grade station (over-track station with the track on the ground and the main station building over the track). The details are shown in Figure 4.1.1.



Source: JICA Study Team

Figure 4.1.1 Elevated, Underground, and At-grade Sections

4.1.2 Alignment plan

(1) Prerequisites for Establishment of the Alignment

1) Horizontal alignment

Horizontal alignment is examined on the basis of the following principles:

Underground section: Track center shall be run along the centerline of the road in principle.

Elevated section: Track center shall be run over the median strip for sections with a median strip.

Other sections: Track center shall be run along the wayside public land or the centerline of the road.

Forward/backward of the trolley bus terminal station: Since the trolley bus station is located within the botanical garden, the track center is relocated from the road into the garden.

Note that the radius of the horizontal curve must comply with the conditions stipulated in 4.4.3.

2) Rail level

Elevated station with vehicle traffic down below:
The rail level shall be set at **15 m above the road surface level** taking into account the construction gauge height (5.5 m or more) of the road, girder height, overhead clearance below girder of the concourse floor, and building construction height.

Elevated station without vehicle traffic down below:
The rail level shall be set at **9 m above the road surface level** while including the concourse on the ground floor and the platform on the second floor.

Underground station

The underground station is planned as a two-level structure with the concourse on the first basement level and the platform on the second basement level. The rail level shall be set at **17 m below the road surface level** to secure the space for an underground walkway and underground utilities at a depth of 5 to 6 m below the road surface level.

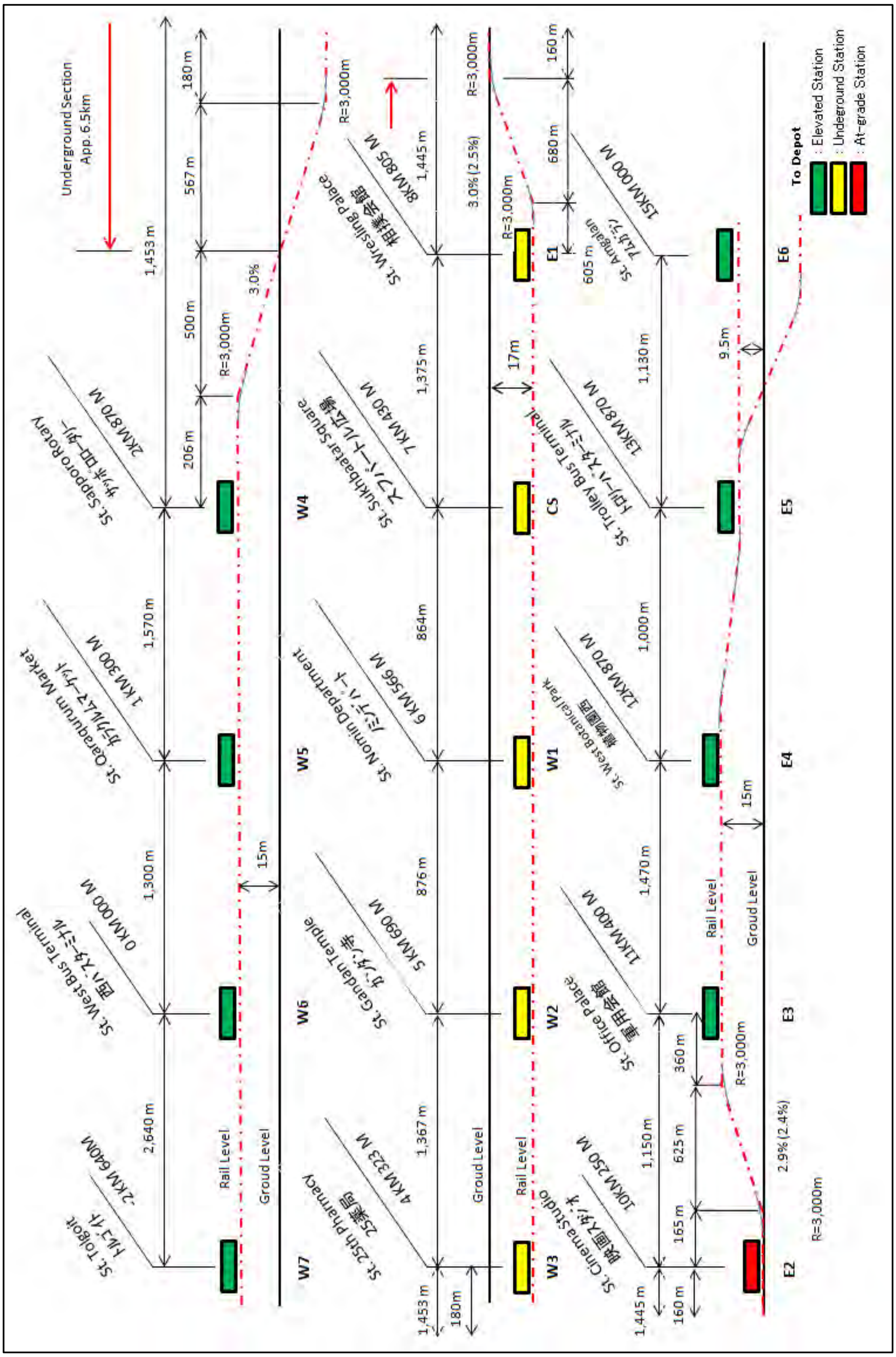
3) Vertical alignment

On the basis of the rail level of each station above, the vertical alignment shall be set on the conditions of the vertical gradient and the radius of the vertical curve stipulated in 4.4.3.

Rail levels shall be kept at 15 m above the road surface level for the sections between elevated stations, to secure overhead clearance below the girder for the Ulaanbaatar Railway, which is expected to have large-span bridges, and at points crossing the Sapporo Rotary, as well as to ensure satisfactory ride quality.

(2) Result of the Study on Horizontal and Vertical Alignments

The schematic vertical alignment diagram planned according to the conditions described above is shown in Figure 4.1.2. The detailed vertical alignment diagram is shown in 4.6 Civil Structure Plan (Underground), and the horizontal alignment diagram is shown in **Appendix**.



Source: JICA Study Team

Figure 4.1.2 Schematic Vertical Alignment Diagram

(3) Coordination with road flyover projects

At present, four road flyover projects (West Intersection, East Intersection, Sapporo Intersection and Tolgoit), which are shown in Figure 4.1.3, are being planned on the proposed metro route. Outlines of these projects, including measures against these projects' impacts, are as follows.

Source: UBMP 2030 (draft)

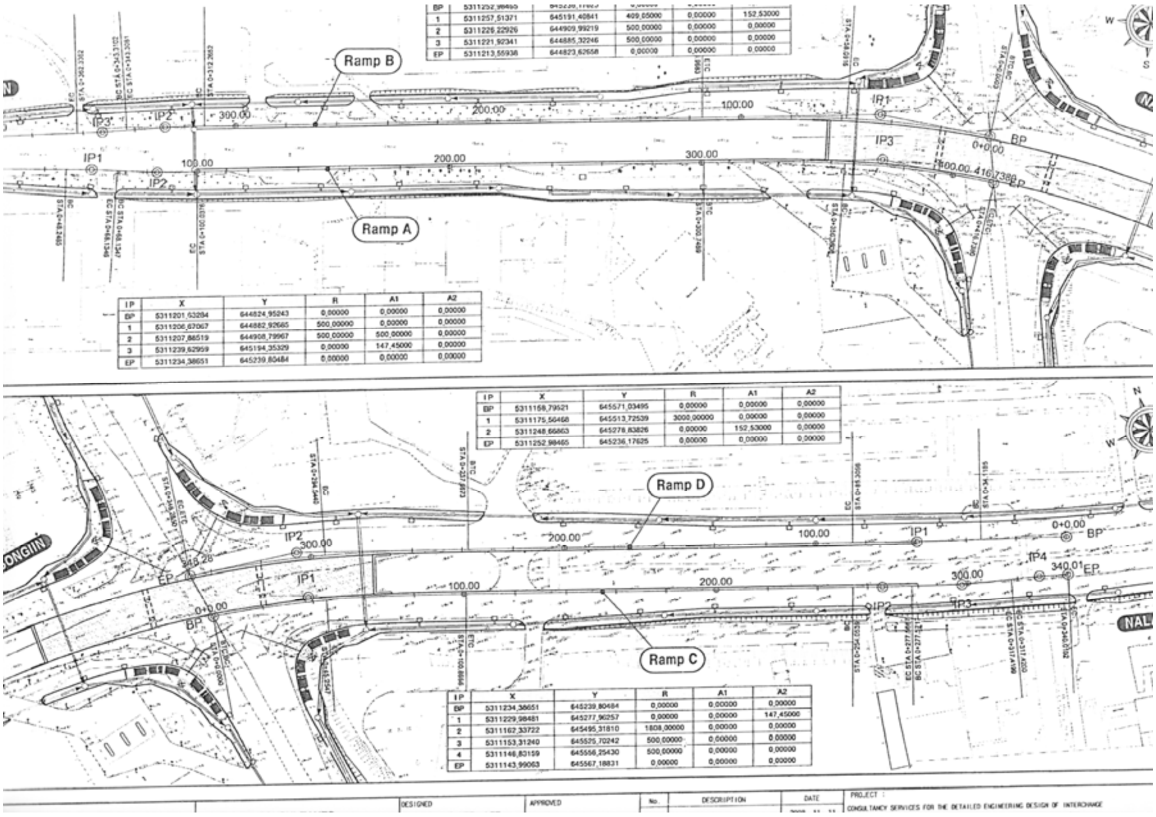
Figure 4.1.3 Road Flyover Projects in Ulaanbaatar

1) East Intersection

Detailed design for this project has been completed by a Korean consultant team and was approved. Utilization of funds from Mongolian Development Bank has been considered, and as soon as it is deiced, a tender for the construction will be held.

This project is to separate a grade crossing between Peace Avenue and North-South Avenue by building overpass in the east-west direction at the East Intersection. Pedestrian underpasses with entrances at four corners are also included in this project. The plan of the flyover project at East Intersection is shown in Figure 4.1.4.

As for measures for the metro project, it will be designed that metro tunnels are constructed by shield method at both sides of the flyover so as to keep some clearance with the pedestrian underpass.



Source: UB City, Road Department

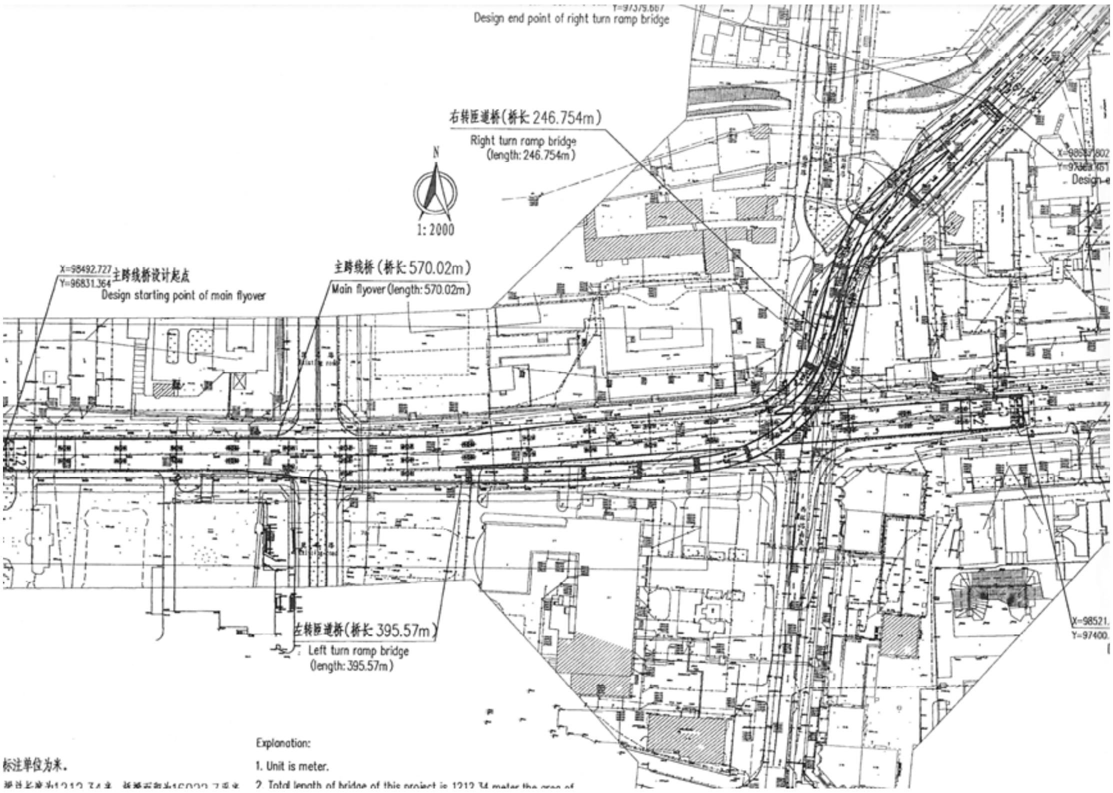
Figure 4.1.4 Flyover Project at East Intersection (Plan)

2) West Intersection

Detailed design for the project has been completed by a Chinese consultant team in 2008, using the Ulaanbaatar City Government budget, and it was then approved. This project is planned to be constructed through Chinese loan. When the evaluation and the approval from MRTCUD and the parliament are completed, the construction will be scheduled to start this year.

This project has two overpasses. One is a continuous overpass to be constructed in the east-west direction over the West Intersection and the next intersection. The other one is the overpass to be constructed in order to connect North and West. The plan of the flyover project at West Intersection is shown in Figure 4.1.5.

Since the flyover which connects North and West will be constructed, a lot of piers of the flyover are designed on the Peace Avenue and the Intersection as if the piers block metro's path. As for measures for the flyover design, there is an idea that the flyover and the metro are constructed at the same time and these are designed as integral-type structure. However, since the actual construction time of the flyover is earlier than the metro construction, it will be requested to change the layout of some piers so that the metro can go through the flyover with the minimum requirement.



Source: UB City, Road Department

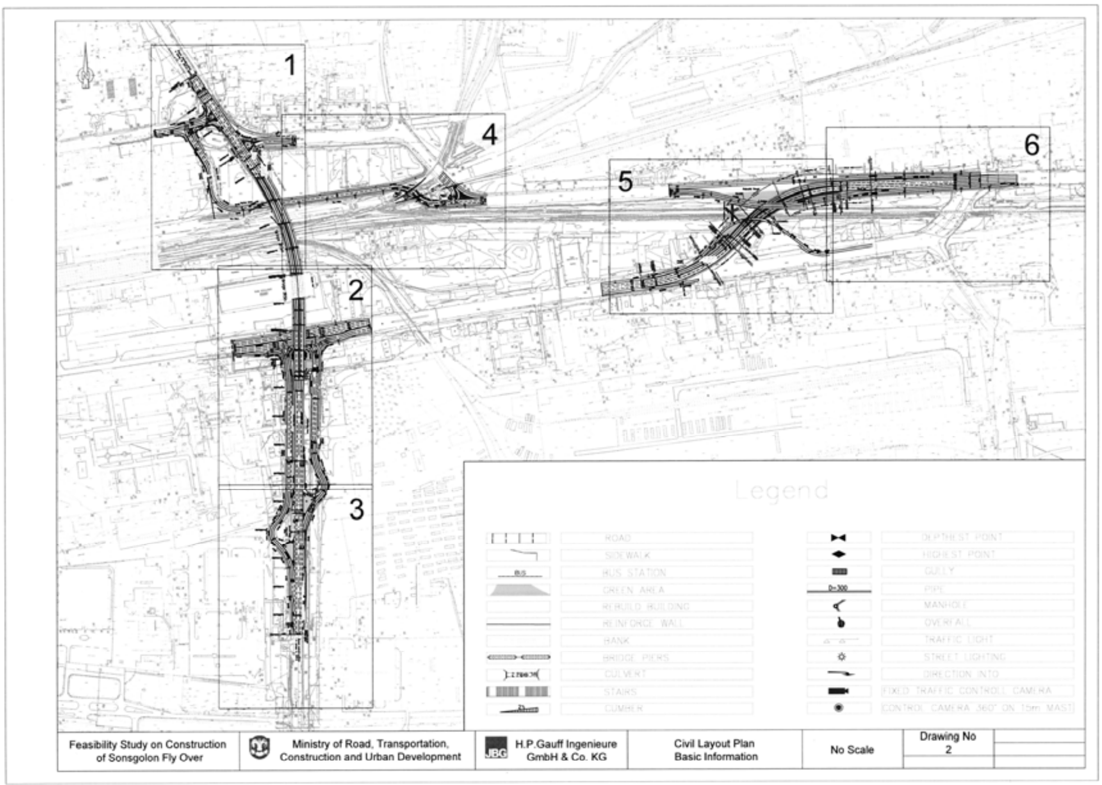
Figure 4.1.5 Flyover Project at West Intersection (Plan)

3) Sapporo Rotary

The designing of a flyover for the Sapporo Rotary has not started yet. An elevated rotary of turbine type was under consideration before, but the concept is not proceeding. On the other hand, a tender for selection of consultant for flyover at Sapporo Rotary was carried out and the Chinese consultant would be selected, but it was declared null and void. Retender for consultant selection will be carried out around March or April, 2014. The concept which the consultant proposed is to make grade separation by building flyover in an east-west direction at the center of Peace Avenue. If the concept was adopted, it was required to change the proposed alignment. As for the design of metro at Sapporo Rotary, it is required to watch future trends in plan of flyover and review our proposed plan holing consultations with Public Transport Department and Road Department of Ulaanbaatar City.

4) Sonsgolon (Tolgoit)

The Sonsgolon project is a grade separation between the Ulaanbaatar Railway and roads. The feasibility study on the project is now in progress with a German consultant team. It is said that the construction of the project will be carried out through Chinese loan, but it has not yet been determined. The project consists of a flyover which passes over Ulaanbaatar Railway and connects North and South and an underpass which passes under Ulaanbaatar Railway at the west side of the existing level crossing. The plan of the Sonsgolon project is shown in Figure 4.1.6. Metro project will be designed so as not to have effect on the Sonsgolon project.



Source: UB City, Road Department

Figure 4.1.6 Flyover Project at Sonsgolon (Plan)

4.2 Transport Plan

4.2.1 Outline of the Transport Plan

The transport plan of Ulaanbaatar Metro is outlined in Table 4.2.1. Since there are a few sharp curves and the distances between stations are relatively long, the train running time required between two terminal stations can be shortened by setting the maximum speed to 100 km/h. To reduce the construction cost and to ensure effective train operation, the number of cars for a train should be six (6).

Table 4.2.1 Outline of the Transport Plan

Item			Description	
Gauge (mm)			1,435	
Traction system			DC1.5 kV 50 Hz overhead line	
Corridor			St. Tolgoit – St. Amgalan	
Route length (km)			17.640 km (between starting and terminal stations)	
Minimum curve radius of main line (m)			200	
Maximum actual gradient of main line (‰)			30.0	
No. of stations			14 (including five underground stations)	
Inter station distance (m)	Maximum		2,640	
	Minimum		864	
	Average		1,356	
Service hours			6:00 AM to 11:00 PM	
Demand forecast				
	Corridor		St. Sapporo Rotary – St. 25th Pharmacy Station	
	Year		2020	2030
	PHPDT (pax)		10,729	17,767
Car composition for a train			6	
Train capacity (180%)			1,428	1,428
Headway (peak hour) (sec)			515	300
Schedule speed (km/h)			39.2	
Schedule time (minute)			27	
Maximum operation speed (km/h)			100 (80 for underground section)	
Average dwell time (sec)			30	
Minimum shuttling time (sec)			300	
Maximum number of trains in operation			7	12
Maximum number of cars in operation			42	72
Train make-up			2020	2030
	Required No. of trains		8	13
	No. of spare trains for inspection		1	1
	No. of spare trains for extra service		1	1
	Total		10	15

Source: JICA Study Team

4.2.2 Train Operation Plan

(1) Traffic Volume at Peak Hours

The traffic volume at peak hours deduced by the demand forecast is shown in Table 4.2.2.

Table 4.2.2 Traffic Volume at Peak Time (PHPDT)

Corridor	YR 2020	YR 2030
St. Sapporo Rotary – St. 25th Pharmacy Stations	10,729	17,767

Source: Study Team

(2) Train Capacity

The train capacity based on the car composition is shown in Table 4.2.3.

Table 4.2.3 Train Capacity According to the Number of Cars

Train Capacity	4-car train	6-car train
Ridership 100%	618 pax	942 pax
Ridership 150%	826 pax	1258 pax
Ridership 180%	940 pax	1428 pax

Note: Calculation made with Tc: control car = 147 pax, M: motor car = 162 pax, T: trailer car = 162 pax, 4-car train: Tc + M + M + Tc = 618; 6-car train: Tc + M + M + T + M + Tc = 942 pax

Source: JICA Study Team

(3) Simulation of Train Operation

The result/data of the train operation simulation is presented in Table 4.2.4.

Table 4.2.4 Simulation of Train Operation

Item		Description
Corridor		St. Tolgoit – St. Amgalan
Corridor length		17.640 km (between starting and terminal stations)
Overhead line voltage		1.5 kV
Maximum speed (km/h)		100 (80 for the underground section)
Train	Car composition	3M3T
	Congestion rate	180%
	Train weight (t)	265
	Departure acceleration (km/h/s)	3.5
	Deceleration (during running) (km/h/s)	2.0
	Deceleration (stop) (km/h/s)	2.5
Operational time (minutes)		21
Dwell time (seconds)		30
Scheduled operation time (minutes)		27
Scheduled speed (km/h)		39.2

Source: JICA Study Team

(4) Calculation of Required Number of Trains

From the information in Table 4.2.2, the number of trains, train operation headway and number of cars required for ridership were presented in Table 4.2.5. Analyzing the data, the 6-car train is more efficient than the 4-car train. The required number of trains is calculated using the following formula:

.

$$\text{Required number of trains} = \frac{(\text{time required to run train one way} + \text{time required to return to terminal}) \times 2}{\text{Train operation headway at peak hour}}$$

Table 4.2.5 Required Number of Trains

Number of Cars per Train (Congestion rate: 180%)	4 cars		6 cars	
	2020	2030	2020	2030
Train operation headway at peak hours (minutes)	5	3	8	5
Time required to return to terminal (minutes)	5	3	5	5
Required number of trains	13	20	8	13
Required number of cars	52	80	48	78

Source: JICA Study Team

(5) Train Operation Plan

Train operation plans for 2020 and 2030 are shown in Table 4.2.6 and Table 4.2.7.

Table 4.2.6 Train Operation Plan for 2020

Year	2020
Section	St.Torgoit - St.Amgalan
The number of cars per train	6
Train operation headway at peak hours (minutes)	7.5
Train operation headway at off-peak hours (minutes)	15
Train operation headway in early morning and late night (minutes)	30

Source: JICA Study Team

Table 4.2.7 Train Operation Plan for 2030

Year	2030
Section	St.Torgoit – St.Amgalan
The number of cars per train	6
Train operation headway at peak hours (minutes)	5
Train operation headway at off-peak hours (minutes)	10
Train operation headway in early morning and late night (minutes)	30

Source:JICA Study Team

(6) Required Number of Trains and Cars

Table 4.2.8 Required Number of Trains and Cars

Year	Trains required for ordinary service	Spare train for inspection	Spare train for extra service	Total number of trains	Total number of cars
2020	8	1	1	10	60
2030	13	1	1	15	90

Source: JICA Study Team

(7) Train-kilometers and Average Daily Train-kilometers

The daily train-kilometers and average daily train-kilometers for 2020 and 2030 are shown in Table 4.2.9.

Table 4.2.9 Train-kilometers and Average Train-kilometers

Year	Train-kilometers/day	Average train-kilometers/day
2020	2,504.88	192.68
2030	3,845.52	295.8

Source: JICA Study Team

4.3 Car Plan

4.3.1 Outline of the Car Plan

It was proposed that the car plan use the advanced Japanese car model as a base. Japanese cars are superior specifically in the reduction of the environmental load while achieving the required four basic elements of RAMS (Reliability, Availability, Maintainability, Safety). The car plan of Ulaanbaatar Metro is outlined in Table 4.3.1.

Cars of the Ulaanbaatar Metro must comply with the following requirements.

- Reliability
- Availability
- Maintenance free
- Safety
- Redundancy and durability during frigid weather
- Universal design and barrier-free
- Crime and disaster prevention
- Energy conservation, low maintenance cost, high recyclability

Table 4.3.1 Outline of the Car Plan of Ulaanbaatar Metro

	TC (Control Car)			M (Motor Car)			T (Trailer)		
Gauge (mm)	1,435								
Electric system	DC 1500 V								
Car body length (m)	20			20			20		
Car width (m)	2.95			2.95			2.95		
Car height (m)	3.655			3.655			3.655		
Car body	Non-coated lightweight stainless steel or aluminum alloy								
Car composition number	6								
Car composition	Tc + M +M +T + M +Tc								
Axle load (t)	14								
Tare weight (t)	25.7			28.2			22.4		
Congestion rate	100 %	150 %	180 %	100 %	150 %	180 %	100 %	150 %	180 %
Seated	48	48	48	54	54	54	54	54	54
Standing	99	149	178	108	162	194	108	162	194
Total	147	197	226	162	216	244	162	216	244
Max. weight of riding (t/car)	20 (average)								
Designed max. speed (km/h) (Operation max. speed)	110								
Max. acceleration (m/s*s)	0.92 (3.3 km/h/s), constant up to the riding mass of 21 t/car								
Normal deceleration (m/s*s)	0.97 (3.5 km/h/s), constant up to the riding mass of 21 t/car								
Emergency deceleration (m/s*s)	1.25 (4.5 km/h/s), constant up to the riding mass of 21 t/car								
Bogies	Bolsterless air spring								
Traction motor	3-phase AC induction motor								
Speed control method	VVVF inverter controlled (IGBT)								
Current collector	Single arm pantograph								
Braking system	Electrical command brake, regenerative brake								
Signal system	Digital ATC								
Gangway	Provided (including the front through door)								
Monitoring system	TIS (Train information system)								
Gradient climbing conditions	For the 35‰ gradient, short-term operation is possible at the passenger mass of 21 t/car by startup with one unit (8 MM) open. Train and driving possible by connecting a train (starting impossible) under similar load conditions.								

T_C: trailer with control M: motor car T: trailer

Source: JICA Study Team

4.4 Civil Engineering Facilities Plan

4.4.1 Ground Condition[1]

The ground condition of this route is characterized by the following:

1) The ground mainly comprises gravel and sand; however, the standard penetration test shows that ground with N= about 20～30 is predominant. This ground condition requires due care when selecting the bearing layer for the pile foundation;
2) The presence of a sandstone layer was confirmed from the underground CS (Sukhbaatar Square) station to East Intersection. Sandstone was also confirmed at GL -2 m at East Intersection;
3) The ground contains abundant groundwater, with the groundwater level ranging from -0.8 m to -8.4 m; and
4) The freezing depth ranges from GL -3 to -4 m.

4.4.2 Underground Utilities and Obstacle Structures

(1) Underground Utilities

There are underground utilities including heating pipes, water supply pipes, sewerage systems, communication cables and electric cables along the new route. The underground utility map has been provided by the Engineering Facilities Division of Ulaanbaatar City.

(2) List of Infrastructures that Obstruct the New Route Plan

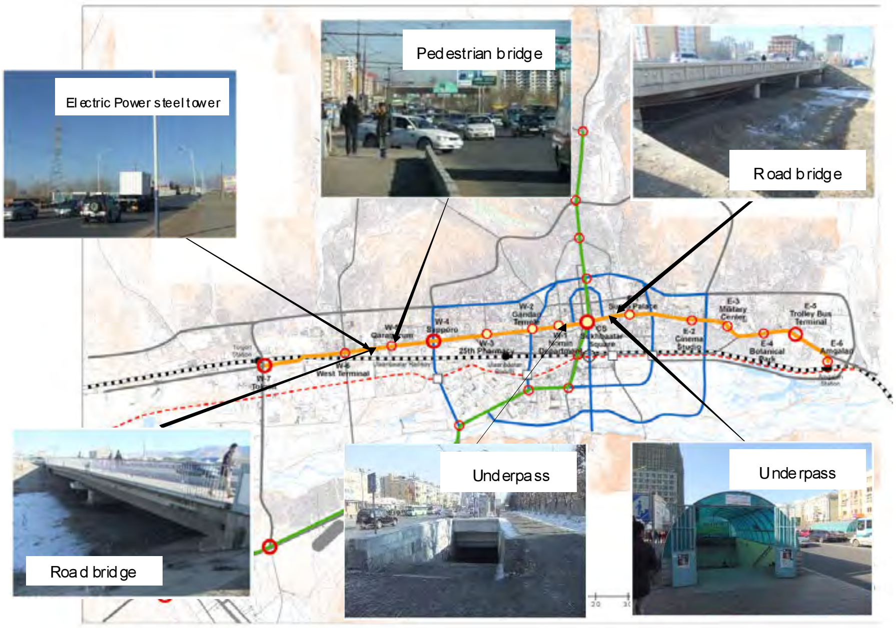
The infrastructures that must be considered when designing the horizontal and vertical alignment plans in the new East-West Line route plan are listed below.

Table 4.4.1 Obstructive Structures

No.	Infrastructure	Location
1	Electric power steel towers	Power steel towers close to or crossing the new route plan
2	Road bridge	Peace Avenue
3	Road bridge	Peace Avenue
4	Underpass	Two underpasses on Peace Avenue
5	Pedestrian bridge	Peace Avenue

Source: JICA Study Team

[1] The geological survey results from the following two surveys were referred to: 1) Feasibility Study on Metro Construction Project in Ulaanbaatar City, June 2011; Public Transport Department of the capital city, Soosung, Seoul Metro; 2) Report on Engineering Geological Investigation for the Basic Study on Urban Transmit Network for the City of Ulaanbaatar: MON-MFF: TA 7156-MON: Ulaanbaatar Urban Transport Development Project, 2012



Source: JICA Study Team

Figure 4.4.1 Obstructive Structure Map for Peace Avenue

4.4.3 Design Condition of Civil Facilities

For the system selected after review in section 3.2, the railway design conditions for railway civil facilities are established as shown in Table 4.4.2 in order to ensure safe operation with considerations given to the local state.

Table 4.4.2 Railway Design Conditions for Civil Facilities

Item	Design Condition
Gauge (distance between rails)	1,435 mm (standard gauge)
Space between rails (Rail center distance)	4,000 mm
Horizontal curve radius (R)	
Main line	300 m or more (200 m or more at minimum)
Along platform	800 m or more
Depot	140 m or more
Maximum gradient	
Main line	35 ‰
Sidetrack and Depot	3.5 ‰
Vertical curve radius (R)	3,000 m or more
Platform length	130 m (6 cars per train)

Source: JICA Study Team

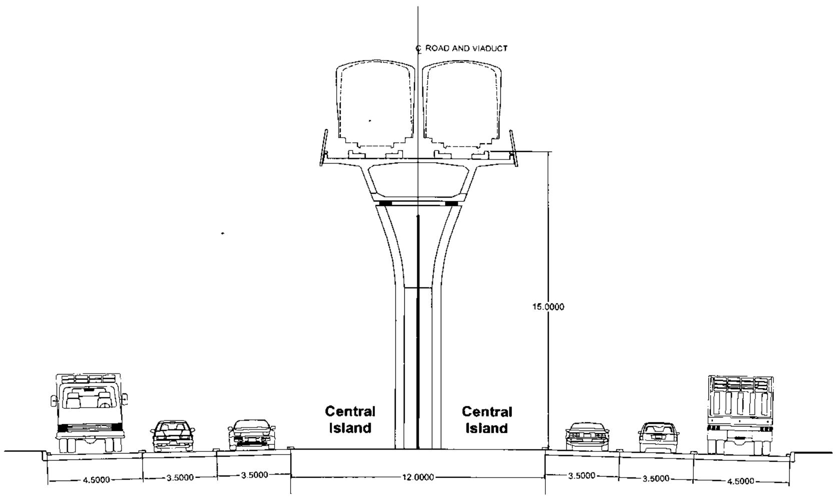
4.5 Civil Structure Plan (Elevated)

4.5.1 General Construction of Elevated Structure

Since this Metro train will run above Peace Avenue, a combination of single-column piers and girders is planned as the base structure type to minimize impact on the road traffic. However, in locations where provision of a single-column pier in the roadway is not desirable, a portal pier will be adopted.

(1) Superstructure

The standard superstructure will be constructed by pre-stressed concrete box girders 25 m in length, which is the most economical bridge in general. The standard cross section is shown in Figure 4.5.1.



Source: JICA Study Team

Figure 4.5.1 Standard Cross Section of Elevated Structure

(2) Substructure

Generally, the gravel layer with an N value of 20 ~ 30 exists at the depth of 10 ~ 40 m from the surface in Ulaanbaatar City, and the rock mass exists below this gravel layer. Although it may be possible to adopt friction piles, it would be better and desirable to drive piles into the rock which is support layer. Detailed study will be carried out at the design stage.

In the case of pile foundations being constructed along the road without a median strip, a large-sized single column foundation might be considered better than a pile group type with footing in the respect that the impact range during work can be minimized. This idea will be examined in the next design stage on which type to select.

4.5.2 Special Construction of the Elevated Structure

The length of the main span of the bridge to be constructed at the road crossing section of Ulaanbaatar Railway will be 70 to 80 m, and pre-stressed concrete continuous box girders are considered most suitable.

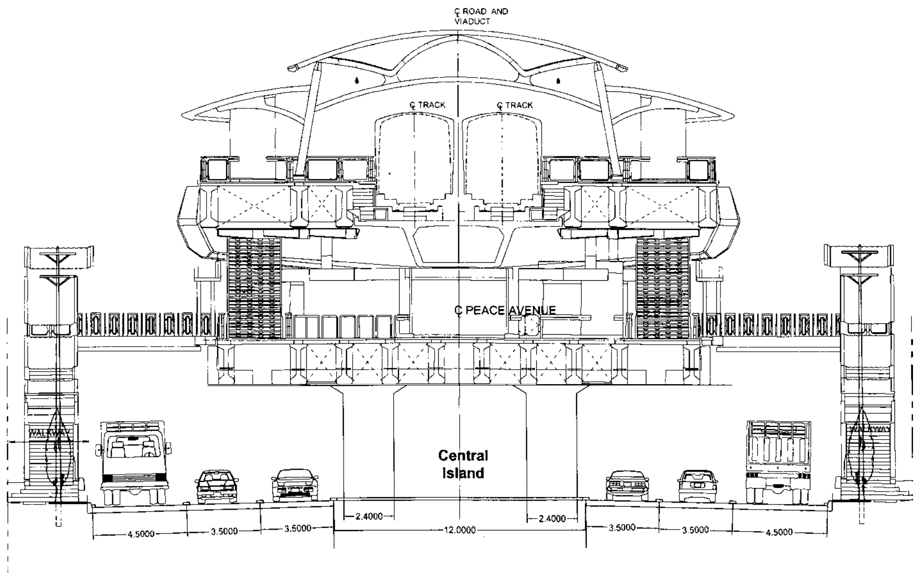
4.5.3 General Construction of the Elevated Station

JICA Study Team proposes the following two (2) types of elevated station.

Elevated station

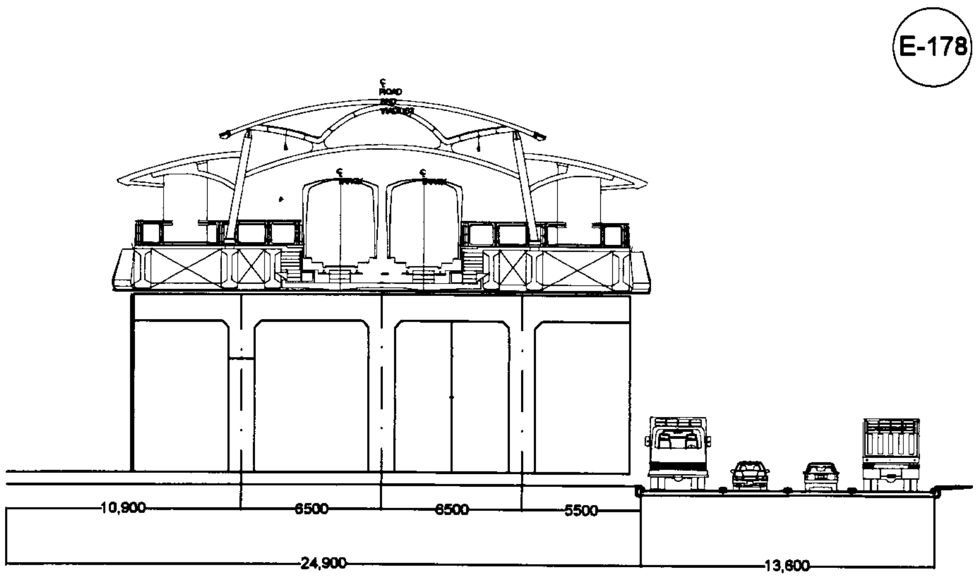
1) Elevated station over roadways: Both track and concourse floors are elevated.
2) Elevated station over locations other than roadways: Only the track floor is elevated.

The standard cross sections are shown respectively in Figures 4.5.1 and 4.5.2.



Source: JICA Study Team

Figure 4.5.2 Standard Cross Section of Elevated Station (Two-layer Structure)

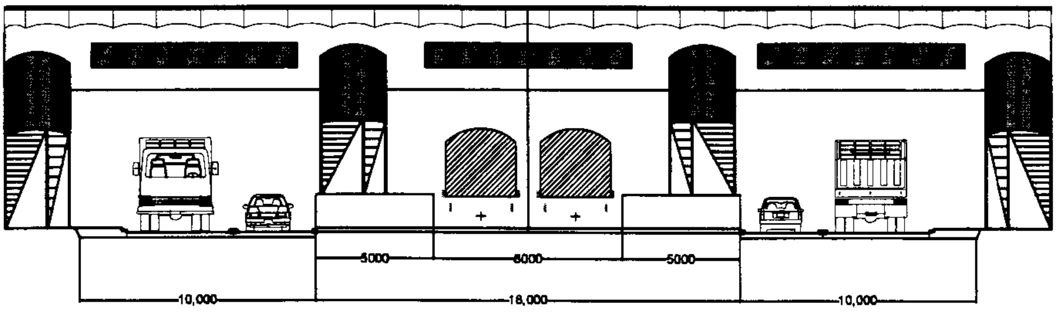


Source: JICA Study Team

Figure 4.5.3 Standard Cross Section of Elevated Station (Single-layer Structure)

4.5.4 General Structure of At-grade Station

Cinema Studio Station is located at the midpoint between the underground section and elevated section. As the medial strip is wide enough to accommodate a station, this station is planned as an at-grade station. The general cross section is shown in Figure 4.5.4.



Source: JICA Study Team

Figure 4.5.4 Cross Section of the At-grade Station (Over-track Station)

4.6 Civil Structure Plan (Underground Structure)

4.6.1 Underground Structure Plan

(1) Underground Station Structure

Cut-and-cover construction for underground stations can be categorized into two types as shown in Table 4.6.1, namely, the top-down method and the bottom-up method. The study team recommends that the bottom-up method be adopted for underground station construction. As most of the underground construction works of UB Metro will be done below the road surface level, road decking should be made to ensure unrestricted road traffic.

Table 4.6.1 Types and Features of Cut-and-Cover Method

Method	Features
Bottom-up method	・ Construction sequence is as follows: 1) Excavation and installation of struts and walers are carried out sequentially 2) After final excavation, the structure work is carried out sequentially from bottom upward. 3) Struts and walers are removed and backfilling is carried out. ・ Direct water-proofing of sidewalls
Top-down method	・ This method integrates the structure and temporary support. The structure to be constructed under the ground is completed sequentially from the top downward through concrete placement in parallel with excavation. An earth-retaining wall is used for structure. This method is used for work close to buildings or the railway for example, to prevent deformation of the backside ground. ・ A diaphragm wall is mostly used for the earth-retaining wall. The ground condition of this new route is mainly sand and gravel. Ground treatment work will be needed to prevent collapse of the pore wall during the construction of diaphragm walls. The cost for such ground treatment work will be relatively high. ・ The pile foundation of Narneezam Bridge currently constructed under Japanese ODA was made by cast-in-place all casing piles. This is the method to cope with the risk of collapse of the pore wall during the top-down method. ・ When the reinforced concrete diaphragm wall is used according to the top-down method, there is the risk of water leakage in the future because waterproofing of sidewalls cannot be done.

Source: JICA Study Team

(2) Impact on Groundwater Vein

In the UB Metro plan, the rail level of the underground section is set at about 17 m underground with underground station dimensions of about 23 m in width, about 210 m in length and about 13 m in height, and twin shield tunnels constructed in parallel between stations. For such structures, the impact on groundwater vein at the underground section in service and construction periods shall be considered. Since there is not so much silt and clay in the geologic strata around here, it can be said that there is no permeable layer. It is understandable because the coefficient of permeability obtained from the permeability test of the existing data is about 10^{-2}, which is relatively high. Therefore, it is unlikely that the groundwater vein is affected by the shield tunnel of about 7 m in diameter located 17 m below ground surface.

As for underground stations, it is required to adopt a groundwater pump-up method to lower groundwater level or a soil improvement method so that the underground construction work can be conducted under conditions of no groundwater. In the case of adoption of the groundwater pump-up method, it is required that a close study be made of the risk of ground settlement and of wells drying up. On the other hand, in the case of adoption of the soil improvement method, the construction cost is higher. With respect to an impact on groundwater vein, it is desirable to adopt the soil improvement method. As for a permanent structure, groundwater vein may be impacted by the station itself and the soil improvement for 210 m long per station. However, measures concerning this impact have been investigated and it is already actualized in Japan. Some measures are proposed and the mechanism of such measures is assisting seepage flow of groundwater held back by the station itself using pipes or pervious materials. As already mentioned, since there is probably no impervious layer up to the rock layer which exists at the bottom, groundwater can flow under the station and diaphragm wall, unless the layer on which the station is constructed is a layer of rock. Therefore, underground stations do not necessarily cut off groundwater vein. It will be analyzed what measure is required for it with detailed data at the next step.

(3) Impact on Hydrometeor

Ground settlement caused by groundwater is classified into consolidation settlement and immediate settlement. Consolidation settlement means that the ground of small grain size such as clay and silt is compressed gradually over a period of time with draining, and immediate settlement means that the ground of large grain size such as sand and gravel is elastically and momentarily compressed regardless of draining. Both of them are phenomena caused by the increase in load at layer object to settlement, and as a phenomenon caused by groundwater, there is the increase in effective stress caused by the drop of groundwater level. As already mentioned above, there is perhaps no need to worry about consolidation settlement, as the ground around here does not contain so much clay or silt. However, attention should be given to the immediate settlement. Since almost all N value of sand and gravel layers around here is over 23 and its elasticity coefficient is relatively high, the amount of immediate settlement is probably not so much. It shall be determined if the groundwater level should be lowered during the construction period at the design stage after detailed investigation of impact on it.

(4) Tunnel between Underground Stations

The tunnel between underground stations can be constructed according to (1) cut-and-cover method, (2) shield tunneling method, and (3) NATM (New Austrian Tunneling Method), as shown in Table 4.6.2. The table also shows the features of each method. Among these methods, the shield tunneling method is proposed in view of the impacts on the traffic and the construction cost.

Table 4.6.2 Types and Features of Tunneling between Underground Stations

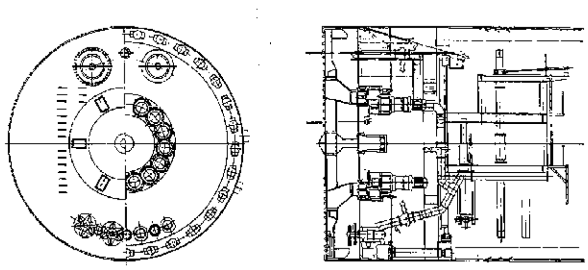
	Cut-and-cover method	Shield tunneling method	NATM (New Austrian Tunneling Method)
Outline of Method	Ground is excavated, and using temporary supporting members such as walls and strust, the underground tunnel is constructed in it. After that the excavation is backfilled. Temporary road panel is generally used to avoid a negative impact on road traffic.	A shield machine is driven from a shield launching pit and the tunnel is constructed, assembling segments made of concrete or steel.	Temporary members are installed after the ground is excavated by using an excavator or other equipment. The tunnel is constructed by using rock bolts and concrete, if required.
Feature	This method has a cost advantage where traffic is not much and the tunnel is not deep. It is possible to dispose of excavated soil by cut and cover tunneling as general surplus soil.	This is a standard method for urban tunnels at present in Japan. It is required to dispose of high water content soil excavated by a shield machine as industrial waste. However, it is possible to dispose of it as general surplus soil if a solidification method is used.	This method can be used for limited soil conditions, and it is not suitable for high water level. It is identified that water level is relatively high at the area of the proposed corridor.
Application to sand and gravel layers	○	○	-
Application to rock	○	○	
Cost	× (Since the proposed tunnel is relatively deep and almost all temporary materials are imported, this construction method is not low cost.)	△ (This construction method is low cost for sand and gravel.)	-
Considerable adverse impact on the road traffic	× (Even though road panel is used, it is impossible to avoid temporary impact on road traffic.)	○ (There is low impact on road traffic as compared with the cut and cover method)	-
Impact to Environment	△ (It is required to consider appropriate measures for excavation work in the case of rock layers)	○ (It is required to reduce noise, vibration, dust particles, etc. and impact on traffic and civilians.)	
Land acquisition/ resettlement	○ Since the construction area is inside public roads, there is no special impact.	○ Since the construction area is inside public roads, there is no special impact.	-

Source: JICA Study Team

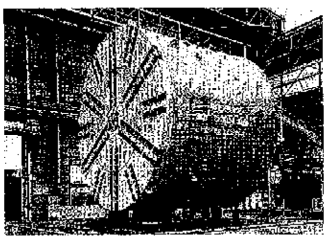
In urban areas and in ground with high groundwater levels, a closed type slurry shield machine or earth pressure shield machine is used. When selecting the shield machine type for stabilizing the face, due attention must be paid to the geological and ground water conditions, ground condition, environment around the shaft, safety and economical efficiency. The following shield machines will be used for the underground section of this UB Metro:

- Shield machine compatible with gravel
- Shield machine compatible with rock mass

The photos of slurry type and earth pressure type shield machines are shown below.



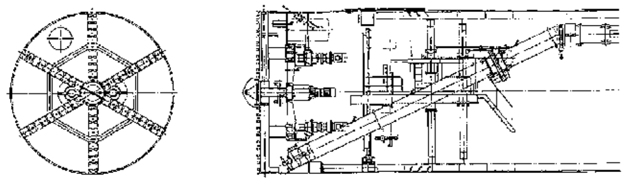
Reference Fig. 21.3 Example of structure of the slurry shield



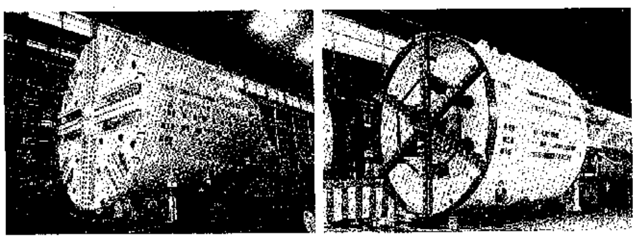
Reference Photo 21.2 Example of slurry shield machine

(Source: Design Standard for Railway Structures, and explanation; Shield tunnel, 2002, Railway Technical Research Institute)

Figure 4.6.1 Slurry Shield Machine



Reference Fig. 21.2 Example of structure of the earth pressure shield



(a) 面板タイプ　　(b) スポークタイプ

Reference Photo 21.2 Example of earth pressure shield machine

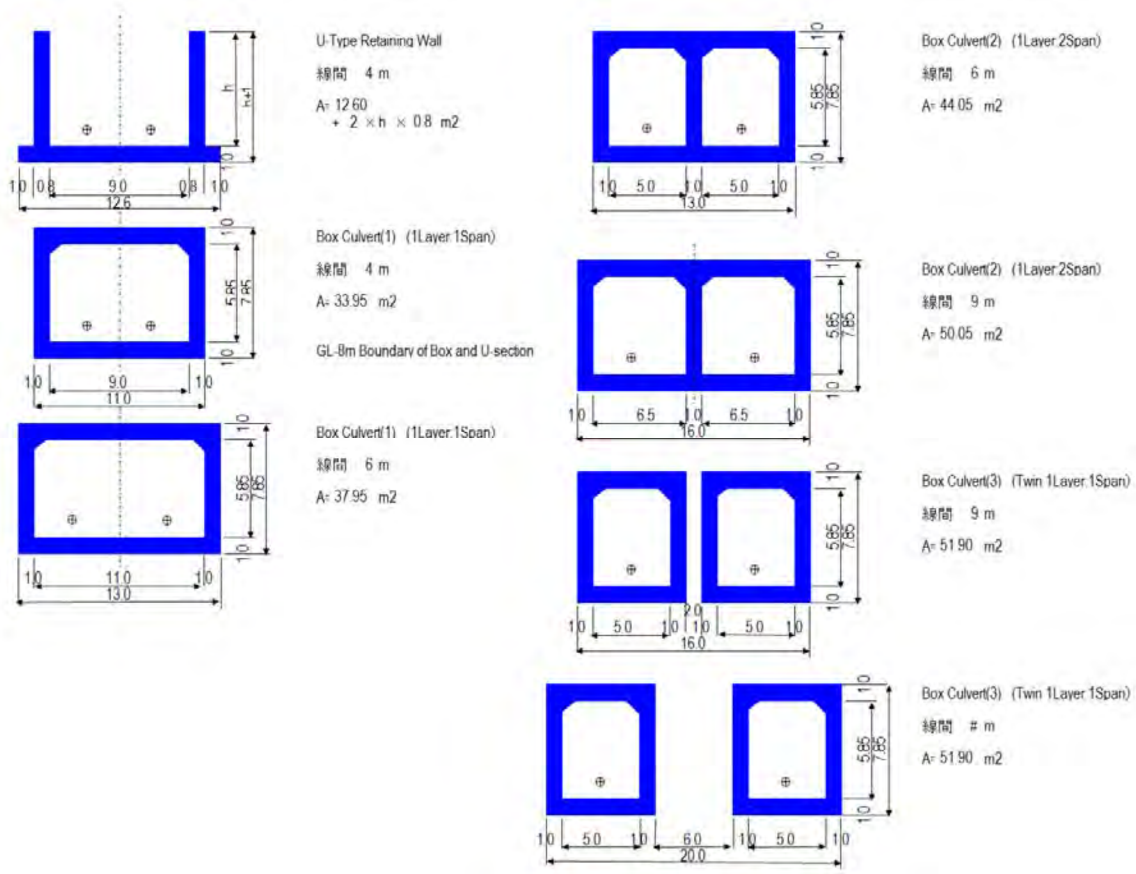
(Source: Design Standard for Railway Structures, and explanation; Shield tunnel, 2002, Railway Technical Research Institute)

Figure 4.6.2 Earth Pressure Shield Machine

(5) From Underground to Above-Ground

It is proposed that cut-and-cover by the bottom-up method should be adopted for the construction of the transition section from underground to ground.

In this section, the track spacing changes from 13 m at the underground section to 4 m at the ground section. The overall structural type is shown in Figure 4.6.3.



Source: JICA Study Team

Figure 4.6.3 The Overall Structural Type for the Transition Section

(6) Construction of Underground Utility Tunnel

A shield tunnel is proposed for the metro project. Although lifelines such as power supply cables, communication cables, water supply pipes, sewage pipes and gas supply pipes are generally not accommodated in railway shield tunnel, it is possible to construct an underground utility tunnel through either a cut-and-cover method or a shield method at a required scale.

4.6.2 Size of Underground Structures

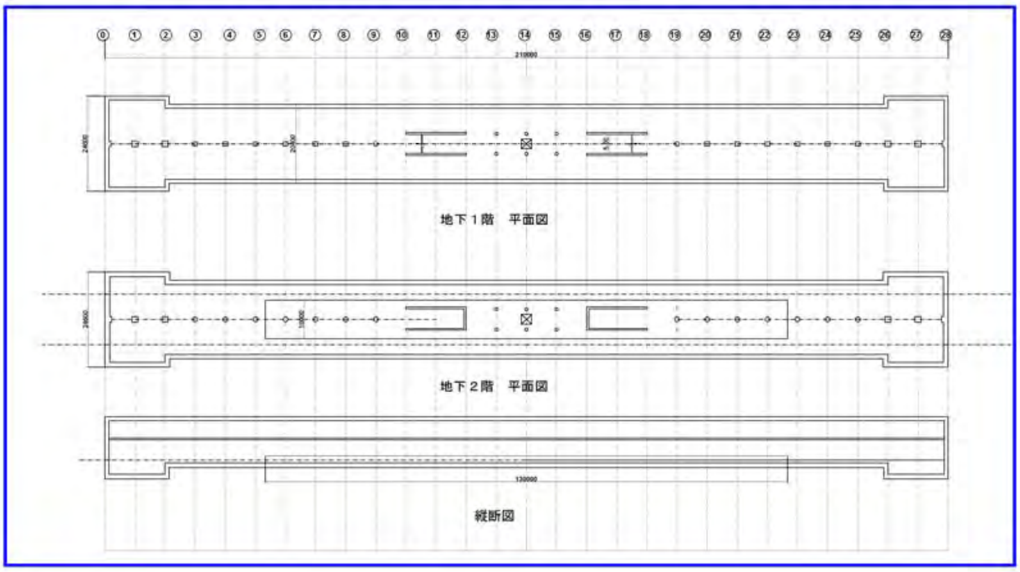
(1) Underground Station

The schematic drawings for an underground station are shown in Figures 4.6.4 and 4.6.5.

Length of underground station: L1=210 m

Length of platform: L2 = 20 m × 6 cars + 2 × 5 m = 130 m

Width of platform : B1 = 10 m

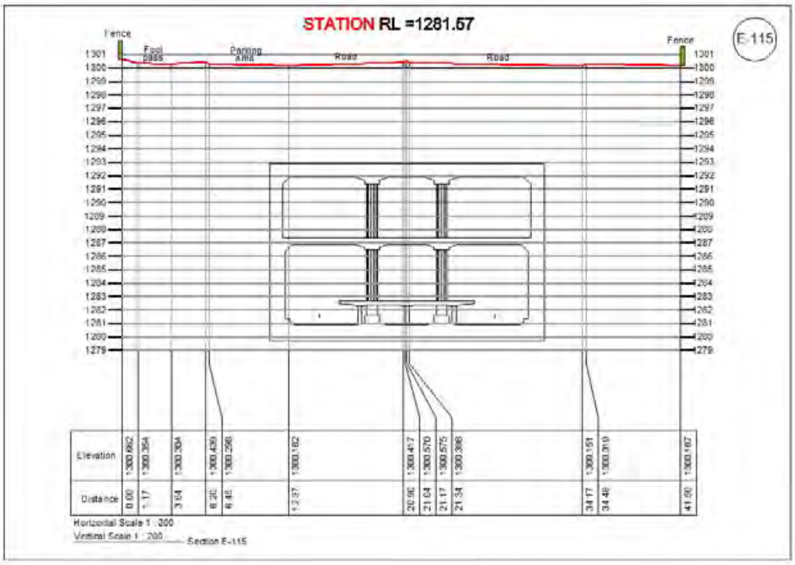


Note: The width and height of the shield machine launching and arrival areas are larger than the ordinary station structure.

Source: JICA Study Team

Figure 4.6.4 Plan View and Profile of Standard Underground Station

In the figure above, shield machine launching and arrival areas are planned at both ends of the station.



Source: JICA Study Team

Figure 4.6.5 Sectional View of Standard Underground Station

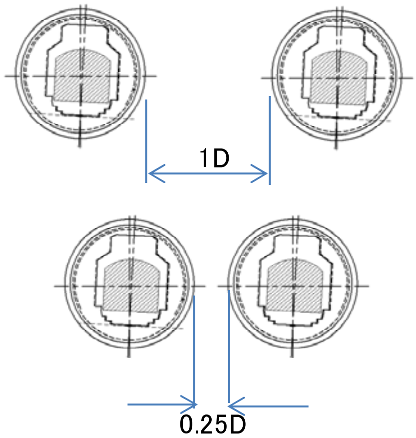
(2) Shield

The shield section will be selected from either double-track shield or single-track paralleling shield.

Since an island type platform is basically considered for the underground station to consider the convenience of passengers, the single track paralleling shield is proposed because of its advantageous alignment.

Generally, spacing of single track paralleling shield is 1D (D: outside shield diameter). As the ground conditions are good for this project, spacing of parallel shields will be around 0.25D for a section on the near side of the shaft in the east to be described later.

The advance shield may develop deformation under the influence of thrust force of the succeeding shield. However, the recent shield design and construction technologies are fully capable of predicting and evaluating such behavior.



Source: JICA Study Team

Figure 4.6.6 Image for Spacing of Parallel Shields

(i) Shield specification: Single track paralleling shield

Shield diameter: about φ6.7 m - φ7.2 m

Distance of shield center:

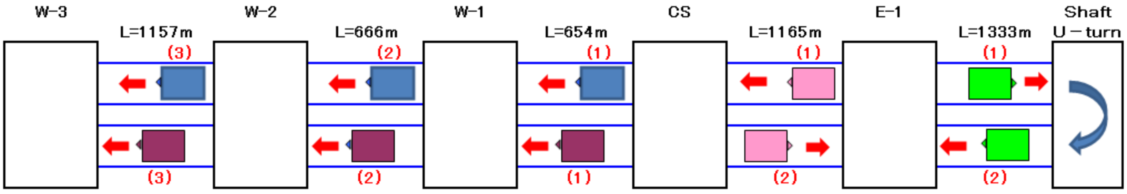
Maximum B1= 13 m, minimum B2=9 m

(ii) Shield excavation progress (as proposed)

Figure 4.6.7 shows the shield excavation progress (as proposed).

For the construction method of the section from the E-1 station up to the ground in the east, the cut-and-cover method may be considered. However, considering the ground features and appearance of sandstones as well as adverse impacts of the cut-and-cover method on the heavy road traffic at East Intersection, the shield method will be proposed.

Accordingly, a shaft for U-turns was planned to the east of East Intersection.



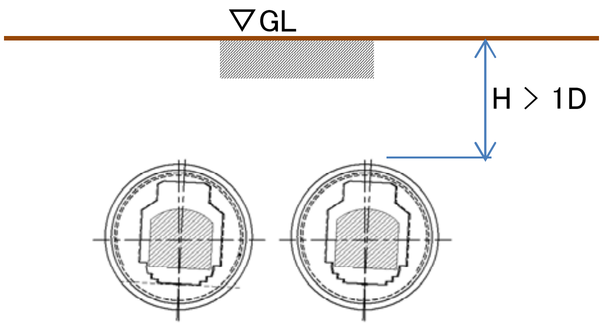
Source: JICA Study Team

Figure 4.6.7 Shield Excavation (as planned)

4.6.3 Vertical alignment plan of the underground section

Conditions for the vertical alignment plan of underground section are enumerated below:

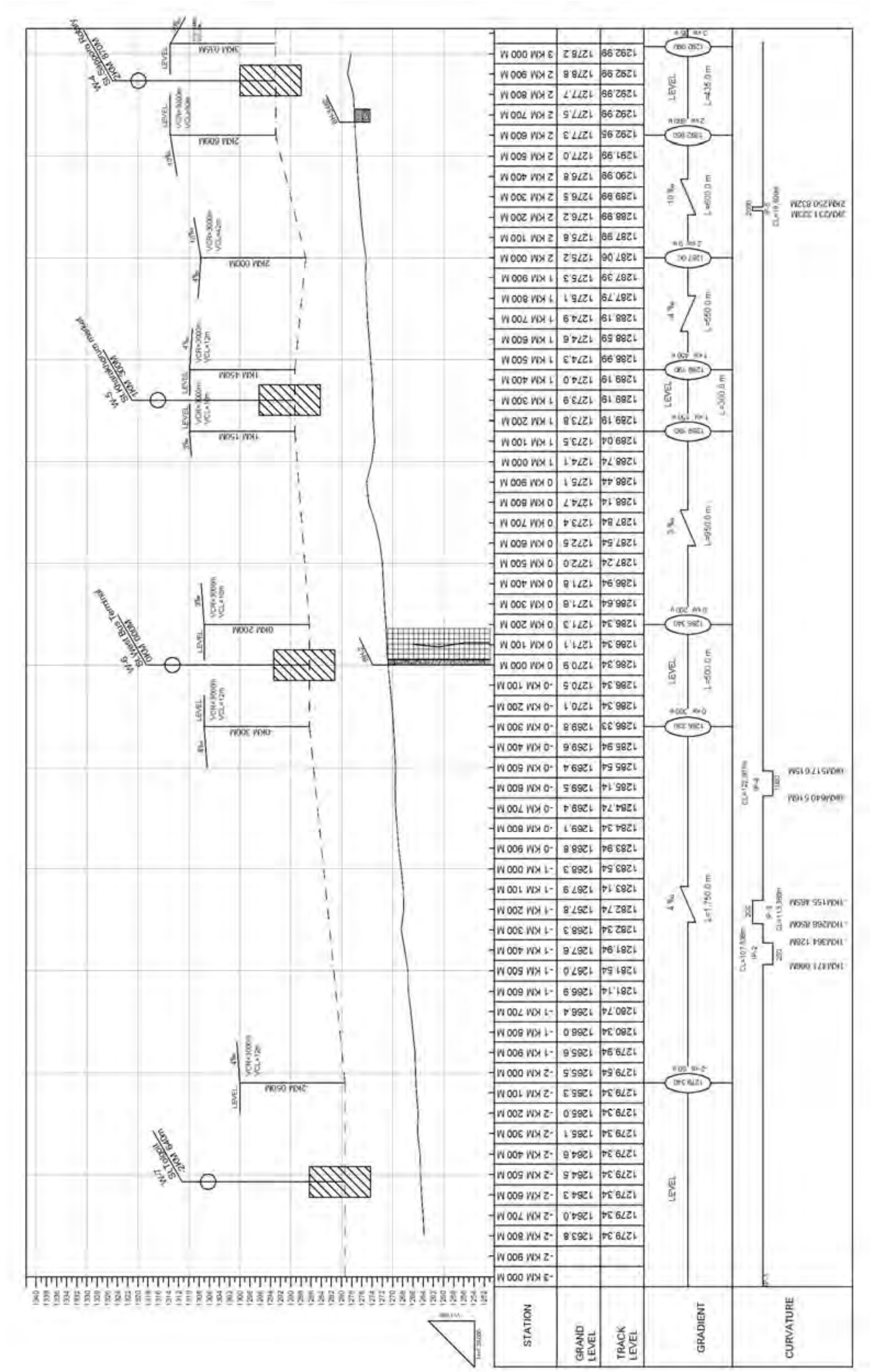
1) Overburden of the station: As underground utilities are located at about 3 m below the ground surface, the overburden of 4 m or more will be secured to accommodate space for underground utilities.
2) The vertical alignment was planned in such a manner that a drainage pump room is not provided between underground stations.
3) The vertical alignment was planned in such a manner that drainage is totally handled by each underground station.
4) The spacing from the ground surface to the top of the shield was set to 1D or more.
5) The spacing from the underground walkway and bridge foundation from the bottom to the top of the shield was set to about 1D.



Source: JICA Study Team

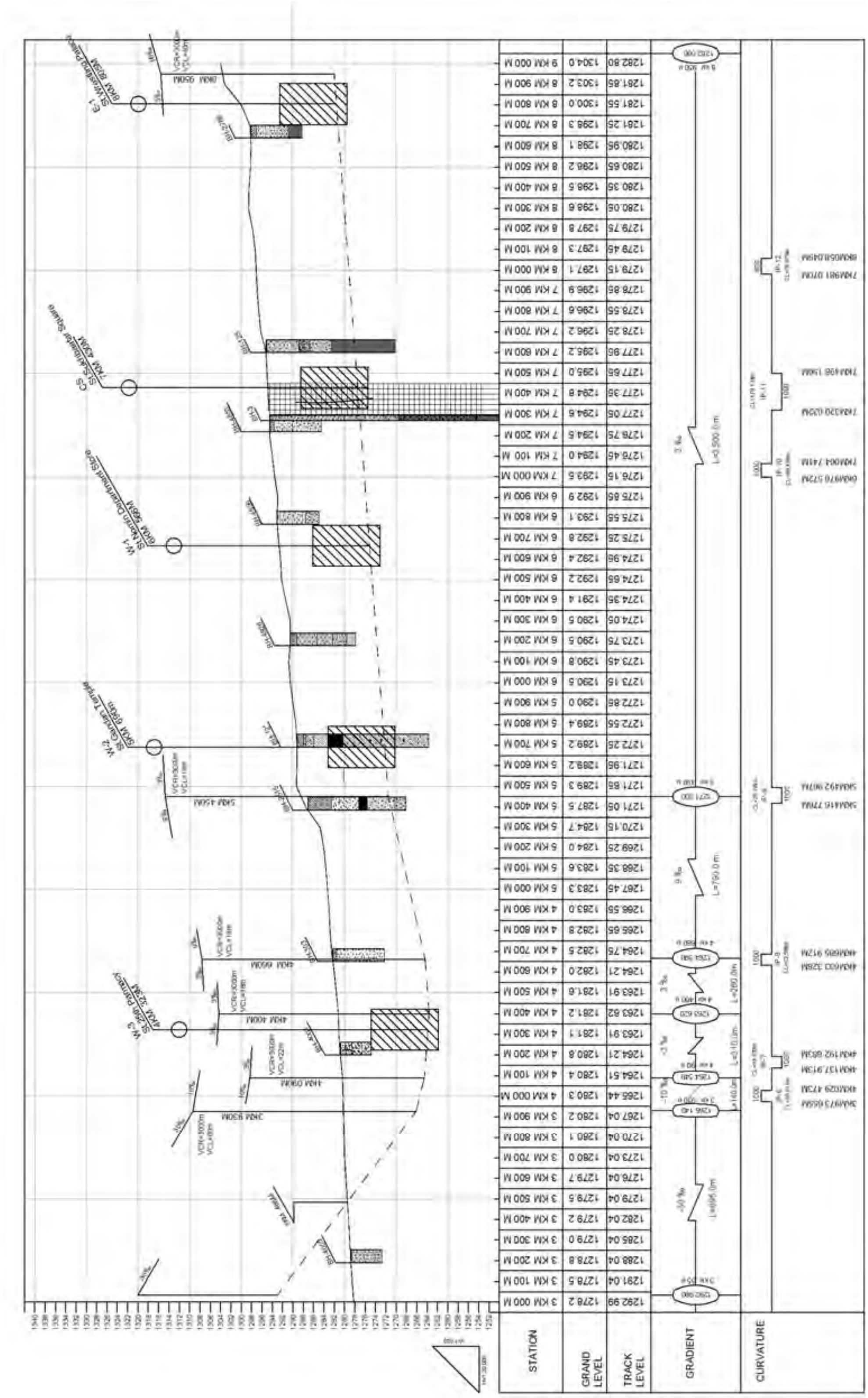
Figure 4.6.8 Image for spacing between shields and ground surface

The vertical diagram is shown in subsequent pages.



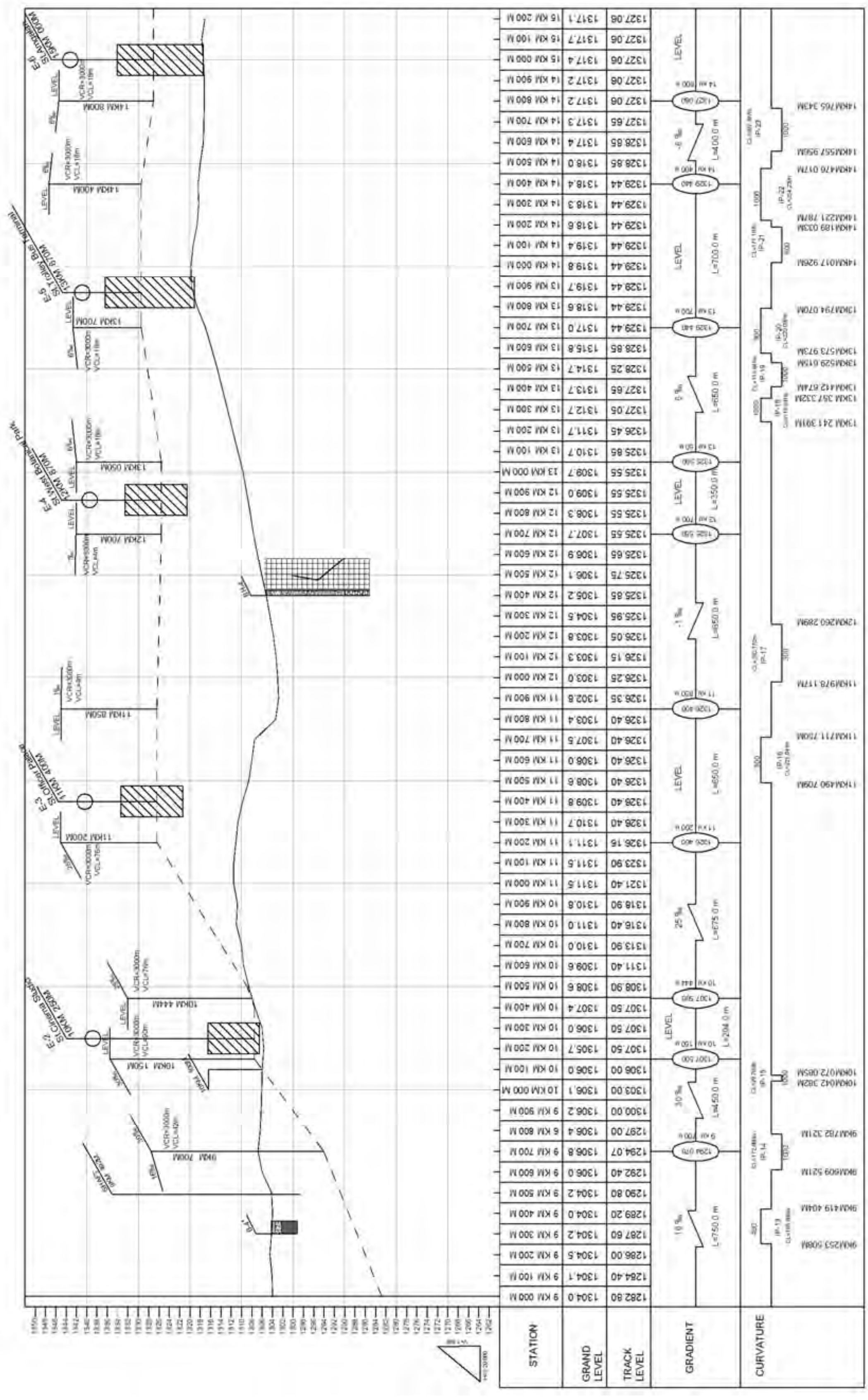
Source: JICA Study Team

Figure 4.6.9 Route Vertical View (1)



Source: JICA Study Team

Figure 4.6.10 Route Vertical View (2)



Source: JICA Study Team

Figure 4.6.11 Route Vertical View (3)

4.7 Car Depot and Inspection/Maintenance Facilities

4.7.1 Outline of the Car Depot

A designated car depot will be provided for the purposes of car inspection/maintenance, servicing, and nighttime storage. This will be a consolidated depot including the facilities for simple inspection and repair and those for disassembly/priority inspection and overhaul. In this depot, duties of the crews will also be determined. The details of duties of the crew in this depot are summarized in Table 4.7.2

Table 4.7.1 Outline of the Car Depot Plan

Rolling Stock		
Year	2020	2030
Corridor	St.Tolgoit – St.Amgalan	
Headway in peak hour (sec)	515	300
Car composition	6	
Rakes required	10	15
Cars required	60	90
Plan for Maintenance Line		
Designed car composition	6 cars: 15 rakes	
No. of lines provided	Car repair line (6 cars)	4
	Special repair line (3 cars)	1
	Wheel turning line (12 cars)	1
	Test line	1
	Reset/composition line (6 cars)	1
Plan for Car Maintenance Equipment Plan		
Washing・cleaning track (6 cars)	3	
Plan for Stabling Line		
Car composition	6 cars	
Year	2020	2030
Required number of storage lines	10	15
No. of storage lines in the depot	10	15

Source: JICA Study Team

Table 4.7.2 Details of Duties at the Car Depot

Duties	Details
Cars	Operation in yard, car maintenance work, car inspection/repair work, car operation plan, technology management
Crew	Crew operation plan, crew operation control, guidance and training
Management and operation	Planning, management (cars, employees), materials

Source: JICA Study Team

The consolidated car depot will have an operation control center and other related facilities, such as the track facilities, machinery, power, signal, communications, maintenance bases, and employee training and learning centers.

4.7.2 Car Depot Location

The functions of a depot are not only for inspection, maintenance and car parking but also for working space of the crew.

It is desirable to place the depot around or near terminals or stations expected to have different levels of passenger demand. It is also desirable to place the depot in the forward direction from stations. Currently, the following nine prospective sites are proposed; these are described in Table 4.7.3 and shown in Figure 4.7.1. Depot location shall not be determined in this study; it will be discussed by the Mongolian Government from this time forward.

The following site conditions are required for the proposed depot.

1) Accessibility to main track
2) Rectangular land
3) Few existing buildings around the site
4) Required area (14 ha, at least)

In addition, the possibility of land use is being investigated by Ulaanbaatar City considering the following two matters:

1) Avoidance of compulsory resettlement
2) No impact on the source of water supply (well)

Since it is not easy to understand the type of land ownership and the existence or absence of land registration in Mongolia, it is required to select a suitable land based on the investigation by Ulaanbaatar City. Moreover, proper attention should be paid to this process to avoid negotiating a large compulsory resettlement; thus, the site proposed shall be withdrawn if compulsory resettlement is expected..

When the location is decided, the following environmental considerations should be taken:

1) Noise/Vibration: It is impossible to perfectly eliminate noise and vibration generated by trains arriving at or leaving the depot, but it is proposed to use ballast track in view of cost and noise reduction measures. The potential site of No. 9 is the best location in terms of minimizing noise and vibration, but it is required to select a location considering its distance from the main track, among other conditions.
2) Water Contamination / Soil Contamination : Sewage generated by washing track shall be isolated into oil and water and neutralized. And then it shall be drained after improvement of the water quality. Since suitable sewage disposal for water generated from depot is carried out, there is no difference for each location of prospective depots.
3) Wastes: Scrap iron waste generated by lathing wheel and consumables for the maintenance of rolling stock shall be disposed of according to applicable criteria.
4) Air Pollution: There is no emission that will pollute air from depots.

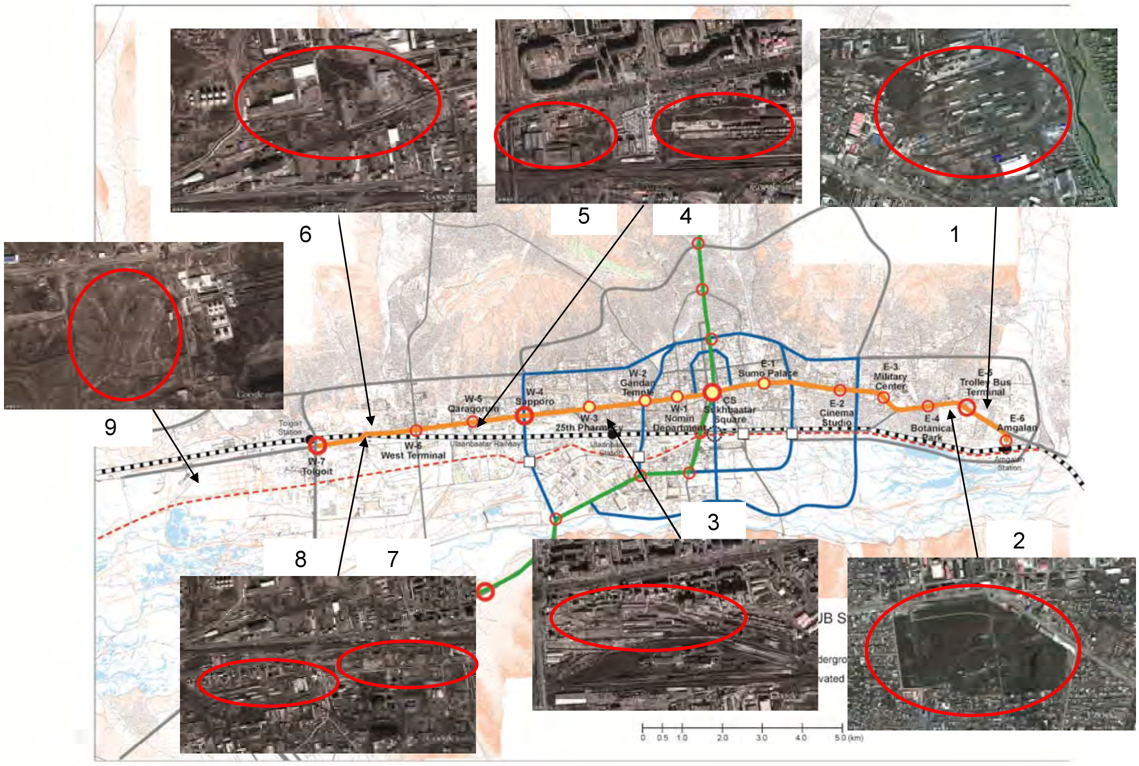
Ulaanbaatar City was investigating a possible site for the depot and concluded that “No. 9: Vacant place about 4.5 km to the west of the planned location of Tolgoit Station” is appropriate among the prospective depot sites. But this is not a final decision, and further discussions with the national government and Ulaanbaatar City are necessary.

Table 4.7.3 Prospective Car Depot Sites

	Location	Function	Current Status	Land Acquisition / Resettlement
1	Railway facility right-of-way to the north Amgalan Station on Ulaanbaatar Railway	Comprehensive Depot	At present, this land is occupied by a private enterprise, but it may be used for the car depot of Metro if the bypass route of Ulaanbaatar Railway is developed.	Landowners are plural private firms and land acquisition is required.
2	Botanical garden near the planned location for the trolley bus terminal	Comprehensive Depot	The land is partly owned by a research institute, The National Science Academy, and the institute has been actively using the land since 1961. The area of the botanical garden is 32 ha and it is used for research/experiments, education and production. The botanical garden is designated as green area by the city urban master plan, which was approved by Parliament in February 2013, and land development may be regulated. Therefore, it may pose some difficulty to use this land for the depot of the project. And since there are only a few green in Ulaanbaatar City, decreasing green makes a negative impact on natural environment.	Landowner is National Science Academy and land acquisition is required.
3	Passenger car depot to the west of Ulaanbaatar Station on Ulaanbaatar Railway	Comprehensive Depot	Passenger car depot. Possibility of use is being confirmed.	Landowners are plural private firms and individuals, and land acquisition is required. Since there are some apartments, resettlement may also be required.
4	Land located at east side of Harhorin market	Storage tracks only	Industrial area. Possibility of use is being confirmed.	Landowners are plural private firms and individuals, and land acquisition is required. Since there are some apartments and houses, resettlement may also be required.
5	Land located at west side of Harhorin market	Storage tracks only	Industrial area. Possibility of use is being confirmed.	Landowners are plural private firms. There are some apartments while other parts of the land are vacant at present. Land acquisition and resettlement may be required.

	Location	Function	Current Status	Land Acquisition / Resettlement
6	Land located at north side of Peace Avenue around Tolgoit	Comprehensive Depot	Industrial area. Possibility of use is being confirmed.	Landowners are plural private firms and individuals, and land acquisition is required.
7	Land located at south side of Peace Avenue around Tolgoit	Comprehensive Depot	Industrial area. Possibility of use is being confirmed.	Landowners are government and plural private firms and individuals, and land acquisition is required. The number of landowners is more than those of other proposed lands.
8	Land located at south side of Peace Avenue around Tolgoit	Comprehensive Depot	Industrial area. Possibility of use is being confirmed.	Landowners are government and plural private firms and individuals, and land acquisition is required. The number of landowners is more than those of other proposed lands. Moreover, there are some apartments and houses and resettlement may be required. There is a hospital and a school as well.
9	Vacant place about 4.5 km to the west of the planned location of Tolgoit Station	Comprehensive Depot	This land is planned for a residential area, but the possibility for use as a car depot remains. The only drawback is the distance.	Landowners are government and plural private firms and individuals, and land acquisition is required.

Source: JICA Study Team



Source: JICA Study Team

Figure 4.7.1 Location Map of the Prospective Car Depots

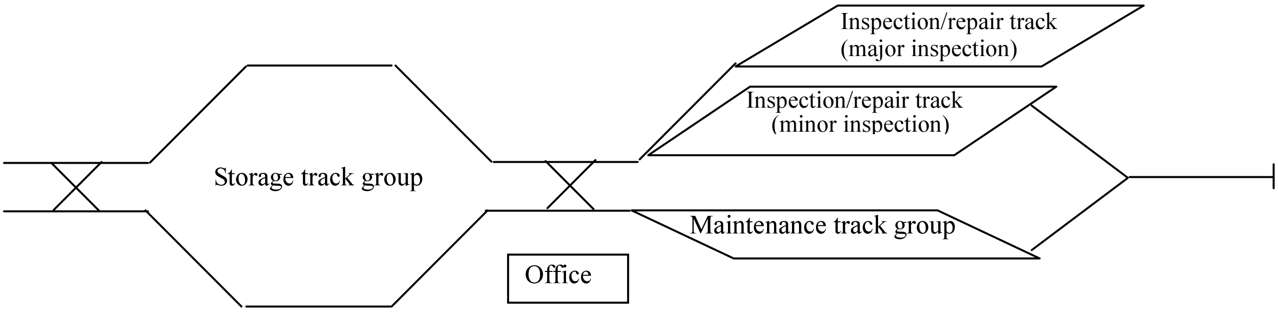
4.7.3 Car Depot Development Plan

(1) Outline of the Car Depot Development Plan

The consolidated car center will perform duties related to the crews in addition to the inspection/repair and maintenance, as well as nighttime storage. For these duties, the following facilities may become necessary:

- Car storage track group
- Car inspection/repair equipment
- Car maintenance track group
- Crew-related facilities
- Consolidated car depot operation-related facilities

To ensure smooth and effective implementation of all works of this car depot, close tie-up of principal facilities/equipment is vital. Facilities/equipment arrangement must be such to achieve this close linkage.



Source: JICA Study Team

Figure 4.7.2 Proposed Layout of the Consolidated Car Depot

4.8 Track Structure

Ballast-less track (slab track, etc.) will be adopted to reduce the maintenance cost and the weight. Ballast track will be adopted to reduce the construction cost in the car depot. For both main line and car depot, rails equivalent to 50N will be used.

4.9 Signal and Communications

4.9.1 Signaling Systems

(1) Signal System

The following signal systems will be adopted:

- Block signal : cab signal
- Train detection : continuous train detection with track circuit
- Signal in car depot: shunting signal

(2) Interlocking Device

The station with the turnout and the car depot will be provided with a device that performs interlocking of the turnout and route. Route setting of the main track and car depot is basically remote controlled at the traffic control system of the operation control center. For individual route setting of each station and car depot, manual operation from the operation panel in each station and car depot must be made possible.

(3) Train Control

Automatic Train Protection (ATP) will be adopted for train control.

4.9.2 Communication System

The communication system will include the following:

- Train radio system
- CCTV monitoring system
- Passenger information service (PIS)
- Telephone system

4.9.3 Train Traffic Control

(1) Outline of the Train Traffic Control

Stations of the UB Metro will have station employees. Fare reception is managed by the station employees by means of automatic fare collection with automatic ticket vender, automatic ticket checking machines, etc. Underground stations will be provided with platform screen doors to ensure passenger safety and efficient operation of air conditioning units. Driver-only train operation will be done. Train traffic control is done by the dispatcher from the OCC (Operation Control Center). Information on train operation in each section is concentrated and displayed in the OCC and the dispatcher performs remote controlling of signal and turnout at each station by means of CTC (Centralized Train Control). Figure 4.9.1 shows the outline of CTC.

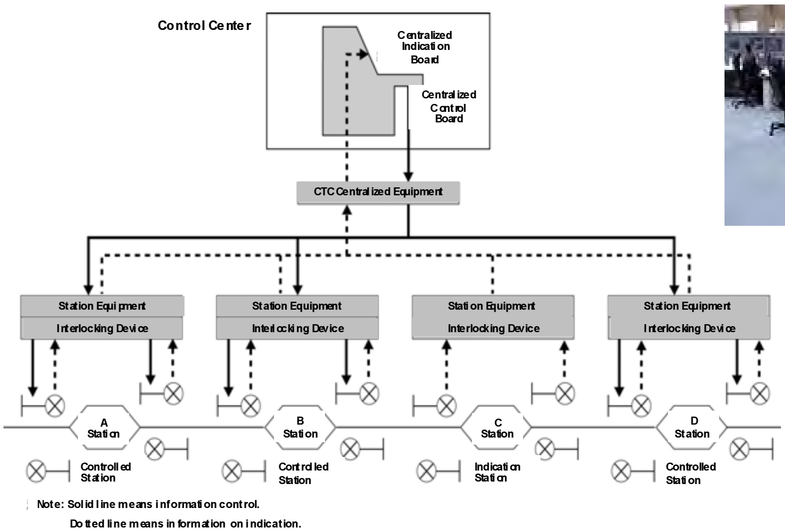


Image of CTC

Source: JICA Study Team

Figure 4.9.1 Outline of CTC

4.10 Power System (Substations and other Equipment/Electric Circuit Equipment)

4.10.1 Outline

The power system will be planned as follows:

Power system for Metro: Including the substations, station electric room, feeder wires, trolley wires, and distribution wires

Substations: Receiving high-voltage power from a substation of the electric power company, stepping down the voltage, and supplying power to the trolley wires and each station electric room

Power for electric car: Supplied from the trolley wires

Power for signal, lighting, and station equipment: Supplied from each station electric room

A stable power supply for the metro operation (15～20 MW) is necessary. Thus, it was determined that construction of the fifth power plant was important to achieve balance in the supply and demand for electricity in Ulaanbaatar City; and when this is done, the Metro can be expected to operate with stable power supply.Power Receiving Plan.

(1) Receiving System

Power will be received via two circuits from the electric power company to ensure higher reliability of response to accidents caused by equipment failure, maintenance, or lightning. Moreover, substations will be connected via linked transmission lines.

(2) Number of Substations to be Installed

Except for the incoming/outgoing line of the car depot, the route length is 18.04 km. The railway substation installation distance is generally 5 to 10 km for the DC electric (DC 1500 V) section in the city where the number of trains is large. Considering this fact and the unconstrained provision of substations in this route, the Metro will have a total of 3 substations at intervals of about 6 km.

(3) Overall Distribution System

Principal distribution system includes the following:

- Feeder high-voltage line (Linked Transmission Lines)
- High-voltage line for signal
- High-voltage line for lighting

A stable power supply for each application point must be ensured. The power supply for the signal and that for lighting will be planned so that each acts as backup for the other. Electric power supplied from the trolley to drive the electric cars will be returned to the substations via the rail.

4.10.2 Substations

The location of Metro substations is planned on the basis of the following factors while taking into account the existing survey and local power state:

- Power distribution grid and supply capacity of the electric power company of the location concerned
- Distance between the substations and that of the electric power company and the possibility of installing the transmission facilities
- Availability of the installation space for substations

Plan details are summarized in the table below.

Table 4.10.1 Outline of the Substation Plan

Items	Description
Voltage received from the electric power company	Receive AC 20 kV, 50 Hz from the power distribution company
Feeder voltage to the trolley wire	Stepped down to DC 1500 V in the substation and supplied to the trolley wire via feeder line
High-voltage line for signal and for lighting	Distributed voltage is stepped down to AC 6000 V in the substation and supplied to the station electric room for signal and lighting
Principal substation equipment	Disconnecting switch, AC breaker, gas insulated transformer, silicon rectifier, DC high-speed breaker, arrester, relay, power regeneration system
Substation area	About 600 m^2

Source: JICA Study Team

4.10.3 Station Electric Room

An electric room will be provided for each station, in which the electric power received from the substation is transformed into the voltage appropriate for the application and supply to facilities. Details of station electric rooms are shown in the table below.

Table 4.10.2 Outline of Station Electric Rooms

Items	Description
Location	Below the elevated structure for the elevated section and in the underground structure for the underground section
Application purpose of power	Lighting system, station equipment (AFC, platform door, escalator, elevator), air-conditioning equipment, ventilation equipment, signal equipment, communication equipment, inspection/repair work shop
Required area	About 100 m^2

Source: JICA Study Team

4.10.4 Transformation Capacity

According to the operation plan, train operation with a headway of 5 minutes in 13 make-ups is planned for the peak hours in 2030. From this operation plan, the approximate transformation capacity of a substation, as a whole on the basis of maximum power per hour for electric cars, will be around 15 to 20 MW. Note that the power for peripheral equipment (air conditioning units, etc.) accounts for 25 kW per car.

4.10.5 Emergency Generator Set

An emergency generator set will be provided for the substations to ensure power supply to the signal equipment, communication equipment, yard lighting, car depot buildings for a certain period in case of a total power failure in the substations.

4.10.6 Electric Car Line

The electric car line will be planned as follows.

Table 4.10.3 Outline of Electric Car Line

Item	Description
Elevated section	For the electric car line of the elevated section, a simple catenary compatible with a speed of 100 km/h, easy in construction, and satisfactory in workability will be employed because the maximum operation speed is set at about 100 km/h. In this case, the trolley wire must have a specification appropriate for cold districts in view of the weather in Ulaanbaatar.
Underground section	The underground portion is a narrow space; therefore, a rigid conductor line (T type rigid conductor) that is short (in line height) and easy to set in the curve will be used -.
Car depot	Since the car traveling speed is low in the car depot, a directly suspended contact wire system simply constructed at a lower cost will be used.
Feeder line	A feeder line is used to feed power from the substation to the trolley while alleviating the adverse effects of voltage drop. For the feeder line, generally, a hard copper stranded wire with low electric resistance will be used.

Source: JICA Study Team

4.10.7 Supervisory Control and Data Acquisition System (SCADA)

This system is used to monitor and control the equipment systems in a remote place. All SCADA equipment is controlled in the control room while the system as a whole is operated from OCC. The principal functions of the SCADA system are as follows:

- Monitoring function: Function for remote monitoring of the operation state from the unmanned equipment state and measured values, which can also be used for decision-making or countermeasures in case of emergency.
- Automatic control function: Function to perform automatic control on the basis of data sent from each component of SCADA, which also includes regular stop/operation control or stop/operation control for regular works.
- Recording function: Function to record the equipment state, measured data, and equipment operation history in the database while preparing the daily and monthly reports.

4.11 Station Plan

4.11.1 Station Function, Type, and Location

(1) Basic Function

In order for stations to be functional, the planning of station buildings and facilities must assure users safety and comfort while making provisions for user convenience with user-friendly facilities. Users of station facilities are not limited to train users, but must include those using the station as a meeting spot. The plan must be designed to make adequate provision for disabled passengers and the station access ways must satisfy emergency egress requirements in the event of a fire or an earthquake.

(2) Structure, Functions, Platform Type, and Location of the Stations

Features of each station are summarized in Table 4.11.1.

Table 4.11.1 Structure, Type, Platform Type, and Location of Stations

ID	Name of Station	Structure	Function	Platform Type	Location
W-7	Tolgoit	Elevated	Sub-center	Side	-2KM640M
W-6	West Bus Terminal	Elevated	Intermodal center	Side	0KM000M
W-5	Qaraqorum Market	Elevated	Intermediate station	Side	1KM300M
W-4	Sapporo Rotary	Elevated	Sub-center	Side	2KM870M
W-3	25th Pharmacy	Underground	Intermodal center	Island	4KM323M
W-2	Gandan Temple	Underground	Intermodal center	Island	5KM690M
W-1	Nomin Department Store	Underground	Intermediate station	Island	6KM566M
CS	Sukhbaatar Square	Underground	Central station	Island	7KM430M
E-1	Wrestling Palace	Underground	Intermodal center	Island	8KM805M
E-2	Cinema Studio	At-Grade	Intermediate station	Side	10KM250M
E-3	Officer Palace	Elevated	Intermodal center	Side	11KM400M
E-4	West Botanical Park	Elevated	Intermediate station	Side	12KM870M
E-5	Trolley Bus Terminal	Elevated	Sub-center	Side	13KM870M
E-6	Amgalan	Elevated	Intermodal center	Side	15KM000M

Source：JICA Study Team

4.11.2 Requirements and sizing of the station facilities

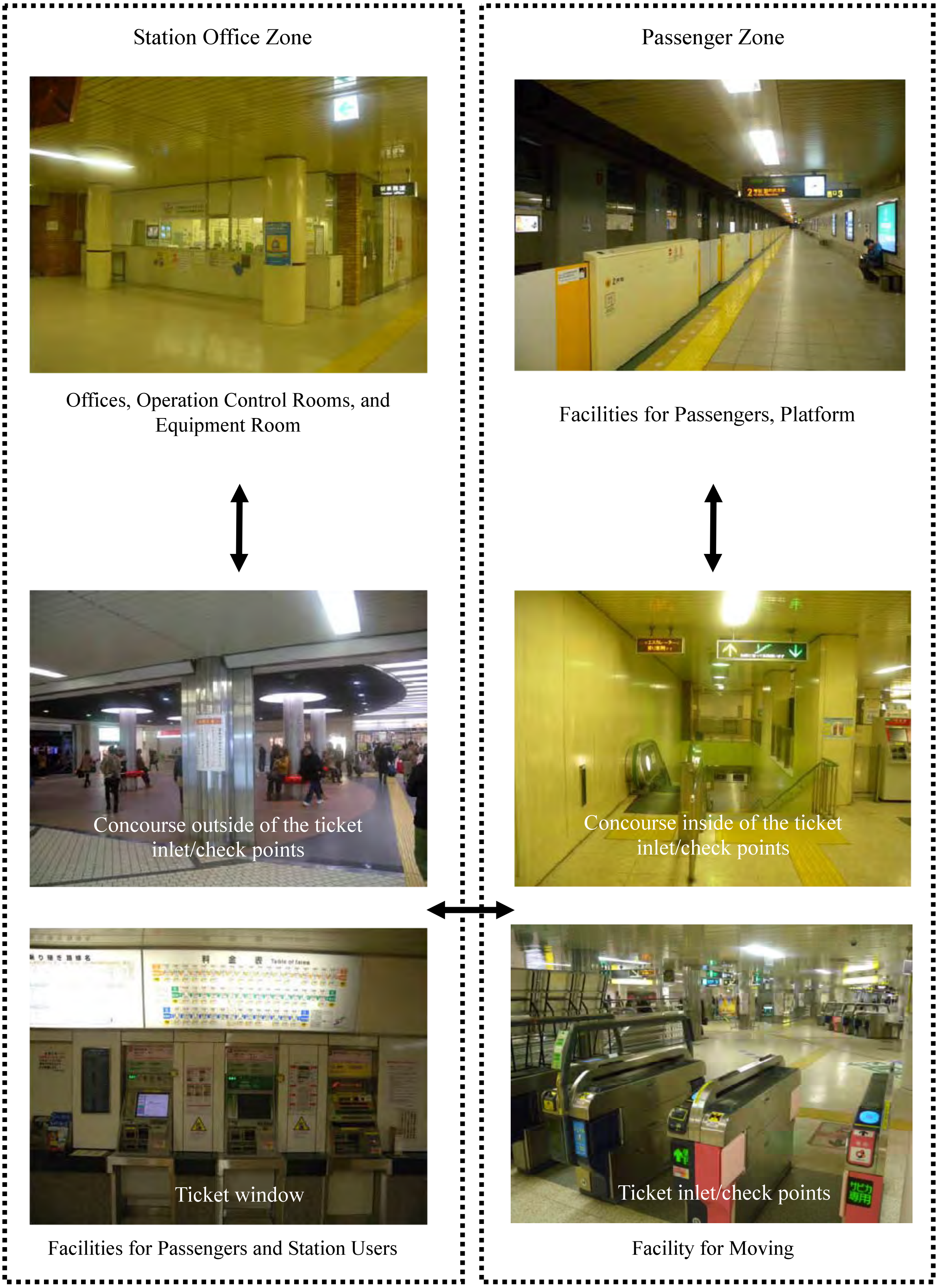
(1) Requirements for Station Facilities

Basic requirement for station facilities are as follows:

1) Two levels are to be provided, a mezzanine concourse level and platforms at the upper or lower level.
2) Transfer between the different levels will be made by using stairs, escalators, and elevators.
3) Emergency stairs shall be provided allowing emergency egress from the platform and concourse level to ground level.
4) The non-paid and paid areas in the station yard should be spacious enough to allow development of commercial activities.
5) Ticket booths should be located centrally and shall house all commands for the station mastering activities such as lighting, access, and operation supervision.
6) Facilities to secure safety and protection against cold weather for station users.
7) Automatic ticket checking machines for smooth passage of users and securing the sufficient space for emergency evacuation shall be available.
8) Public services at the station: Water supply system, Drainage, Sanitary and Sewerage System, Lighting and Electrical Power
9) Fire protection system: Fire Detection and Alarm, Warning system: Fire Protection System and Equipment
10) Signage and graphic system (identification, direction, information and prohibition signs)
11) Engineering and service rooms to be equipped with utilities for fire protection, ventilation and air conditioning facilities; Substations, Electrical distribution boards, Telecommunications equipment, Signal connection boards, and Elevator machine rooms
12) Water tank for fire-fighting, water tank pump and septic tanks should be provided under the station platform (location to be confirmed for each station type).

(2) Policy of Planning the Station Building

The station components can be functionally divided into the Station Office zone and the Passenger zone as shown in the following figure.



Source: JICA Study Team

Figure 4.11.1 Station Components

(3) Consideration for Planning

Planning must be made with due attention paid to the following factors while taking into account the plan considerations and passenger flow:

- The passenger flow facilities are to be positioned close to major streets or towards the center of the station plaza.
- The circulation should be shortened and simplified as much as possible with regard to the passenger flow in areas such as the platform, the over-bridge, the concourse, and the ticketing, etc. These are to be properly placed in strategic locations.
- The passenger flow must be readily identifiable and simplified to connect to the station plaza.
- The ticket inlet and checkpoint must be at the first access point of passenger flow and should be located in the most visible place.
- The station office zone must contain all necessary duties and must be laid out effectively.
- A sufficient passage height and width must be secured for smooth passenger flow.

(4) Planning of the Station Building Size

The station building size will be large enough to meet the minimum requirements based on the demand forecasts of 2020 and 2030. The basic data for calculating the size are shown below:

- The number of boarding and alighting passengers per day
- The peak number of passengers per hour
- Peak ratio
- Total number of station staff and the number of staff simultaneously at work per day
- Station type

4.11.3 Construction Plan

For the construction plan, the following items must be reviewed.

Table 4.11.2 Details of Construction Plan

Plan Items	Description
Station building layout plan	・ The station layout will be planned according to the yard internal wiring, operation plan, passenger flow, and equipment plan.
Station entrance	・ The station entrance will be located based on site conditions, composition of station plaza, location where passengers concentrate, and accessibility from the concourse to the platform.
Concourse	・ Normally, the concourse is divided into the outside and the inside of the ticket inlet/check points. On the outside of the point, passengers acquire information about the Metro and buy tickets. Once inside the point, they access the platform. ・ The concourse layout plan varies depending on the passenger access and site conditions. The basic layout is to ensure thorough monitoring from the ticket window. The ticket window and ticket checkpoint should be side by side, but sufficient space should be secured to allow passenger flow. Similarly, space should also be secured for vertical flow via staircases and escalators.
Service facilities	・ The station service facilities such as offices, operation control rooms, and an equipment room should be planned as paid areas. ・ The layout of various rooms should be determined on the basis of the layout of the station building as a whole and the passenger flow.

Source: JICA Study Team

4.11.4 Other Considerations

In addition, the station building plan shall be prepared with the following considerations:

- Sign plan
- Extension plan
- Emergency response
- Building environment evaluation index
- Barrier free and universal design
- Design considerations for the cold region

Iwamizawa Station

Asahikawa Station

Source: JICA Study Team

Figure 4.11.2 Stations in Cold Regions of Japan（Photo taken by UTPUB Team）

4.12 Procurement Schedule

The outline of specifications of proposed urban railway system have been described up to the previous section. The procurement schedule for the proposed urban railway system is described in this section.

(1) Procurement Tender Packaging

While the proposed urban railway system is roughly divided into civil and architectural works, E&M works, track works and rolling stock, it is appropriate that the number of packages for tender is divided into about 8.

As for civil and architectural works, it is appropriate that elevated sections be divided into western corridor and eastern corridor and that the underground section should be divided into two sections at the Sukhbaatar Square Station. But the tender packages should be reviewed in consultation with clients. The current proposed packaging is shown in Table 4.12.1.

Table 4.12.1 Tender Packages

Item		Package Number	Contents of Procurement	Estimated Cost (US$ million)
Preparatory Works		1	Preparatory works of obstacle relocation, etc.	25.0
Civil and Architectural Works	Elevated and At-grade Structures	2	From W7 (Tolgoit Station) to the ramp between W4 and W3	154.4
		3	From the ramp between E1 and E2 to E6 (Amgalan Station)	138.1
	Underground Structure	4	From the ramp between W4 and W3 to CS (Sukhbaatar Square Station)	359.2
		5	From CS (Sukhbaatar Square Station) to the ramp between E1 and E2	261.3
	Depot and Workshop	6	Stabling Yard, Administration Building, Workshop, OCC Building	29.4
E&M			Maintenance Equipment in Depot and Workshop	
		7	Elevator, Escalator, Platform Screen Door	335.6
			Automatic Fare Collection System	
			Ventilation, Air Conditioning	
			Signaling, Telecommunication	
			Transformer, Distribution, Feeding Wire	
Track Works			Track	
Rolling Stock		8	Rolling Stock	122.4

Source: JICA Study Team

(2) Procurement Source

Materials and equipment to be used for construction of the urban railway in Mongolia must be procured from foreign countries. Although some cement and reinforcement steel are produced in Mongolia, these alone could not cover the materials required for the construction. Besides, almost all materials of E&M works and temporary members such as H-steel and road deck panels as well must be procured from foreign countries. Most of the materials are imported from neighboring countries of Russia, China or South Korea and it is expected that the project will depend on these neighboring countries. However, it is expected that other countries including Japan will get involved in procurements of special machines and equipment. Japan is especially superior in technology of TBMs (Tunnel Boring Machines) required for shield tunneling and there is a possibility that Japanese firms will be interested in TBM procurement.

As for E&M works, it is expected that Western countries, China, Korea and Japan will get involved in each procurement. However, since it is extremely cold in winter season, it is important to procure items reliable and proven for such extreme cold weather. As for rolling stocks, since it is proposed that a leasing company will procure them and UB Metro company will lease them from the leasing company, the leasing company should procure them taking into account the opinion of UB Metro company .

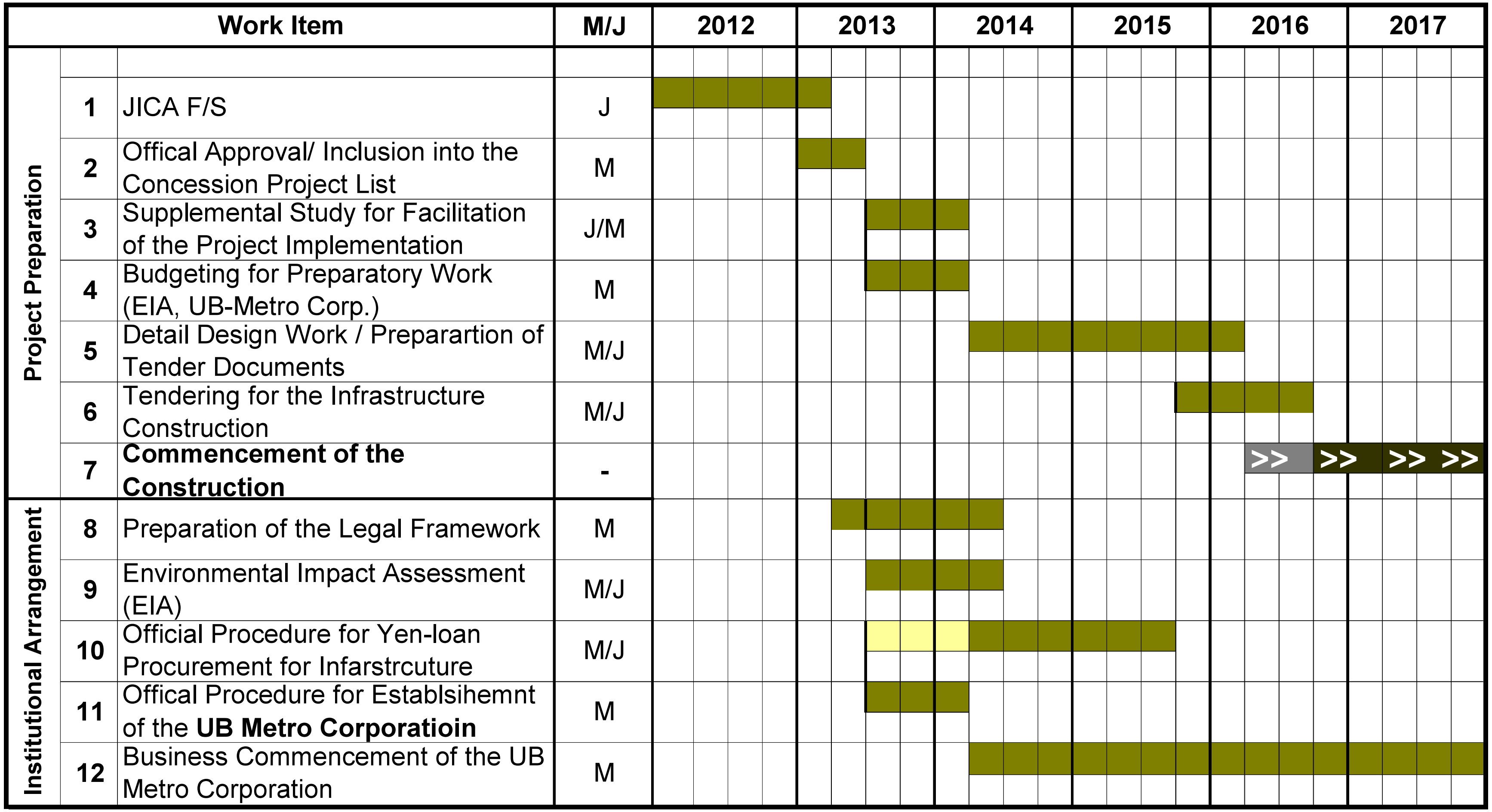
(3) Type of Bidding

It is assumed that the Mongolian Government will use the Mongolian local funds and apply for Japanese Yen Loan for the package number 1 to 7 and it is expected that the type of bid will be international competitive bidding (ICB) with Pre-Qualification (PQ). However, since it is proposed that underground works will be constructed with the Japanese ODA loan, the type of bidding may depend on the conditions of Japanese yen loan. Preparation of tender documents for ICB will be conducted by the consultant which Mongolian Government will outsource, and the consultant will conduct tender assistance to the client.

As for the rolling stock of package number 8, the Ulaanbaatar Metro Corporation (UBMC), which is scheduled to be organized in the near future, is expected to take charge of the procurement.

(4) Procurement Schedule

It is required to conduct a preliminary study for the promotion of the project without any delay, so that detailed design and preparation of tender documents can be commenced in 2014. Supposedly, the construction commencement of permanent structures and the procurement of other systems is scheduled some time in April 2016. Preparatory works and the works from the commencement onward are set up as shown in Figure 4.12.1.



Source: JICA Study Team

Figure 4.12.1 Preparatory Works and Construction Schedule

4.13 Technical Issues on Works and Measures

Underground and elevated sections are proposed for this project. Since the work in the center of Ulaanbaatar city is the first large underground construction, elaborate plan at the design stage and thoroughgoing supervising system are required. It is needless to say that the environmental protection and the safety management are required for the construction of elevated section as well, but issues and measures on underground works which especially require attention are mainly described in this section.

4.13.1 Elevated Works

The elevated sections of the Metro line, which occupy 61 % of the whole line, are approximately 10.8 km long in total. The elevated sections are slightly away from the center of the city, but since the sections are on Peace avenue which has heavy traffic, the impact on the road traffic, the environmental preservation and the safety management should be noted. Main points to note are as follows:

(i) Segment method shall be selected so that impact on road traffic can be reduced and construction period can be shorten.

(ii) Adoption of single pile foundation of large diameter shall be considered as an alternative so that impact on road traffic can be reduced.

(iii) Special considerations should be given for the construction and curing of concrete during wintertime in cold climate areas.

4.13.2 Underground Works

A cut-and-cover method for underground stations and a shield method for the section between underground stations are proposed so that the impact on the road traffic and the construction cost can be reduced. While the shield method is a field-proven and established method, there are several things to be considered when the method is adopted, to wit:.

(1) Environmental Preservation

Essential matters to preserve environmental impacts are: (1) the establishment of a management system by clients and contractors and guidance and education to workers and preservation of documents; (2) forecasts and measures in a preparatory study; (3) discussions with local residents before the start of the construction and even during the construction stage; and (4) monitoring before construction, during construction and after construction. Specific contents on the environmental preservation are as follows:

1) Noise and Vibration

Noise and vibration under construction by shield method are caused by gate type crane at TBM launching pit, earth-and-sand hopper, blower, mud-water treatment equipment, grouting equipment, heavy construction equipment and dump trucks. Preventive measures that could be adopted are as follows:

(i) Adoption of soundproofed machines, to soundproof machines, to install soundproof cover or silencer

(ii) Inspection and maintenance of machines and careful operation

(iii) To invent arrangement of sound source

(iv) Sound insulation equipments (soundproofing panel, soundproofing house)

(v) Consideration of working hours

(vi) Adoption of machines which generate little vibration

(vii) To install rubber and air spring as vibration isolator

(viii) Proper selection of machine layout

2) Ground Subsidence

Subsidence caused by shield tunnel works is described in (2) Ground Deformation and Neighboring Construction in this sub-section.

3) Water Pollution

As for water generated by shield tunnel works, supernatant fluid is generally discharged after suspended solids are removed and pH treatment is conducted. This treatment is conducted by systematized turbid water treatment plant. The supernatant fluid is discharged into sewers or rivers, but discharge destination shall comply with Sewerage Act, River Act, Ulaanbaatar municipal bylaw and so on. And plan for sewage treatment method and equipment shall be set up after grasping environment conditions for the periphery and Acts and Laws concerned prior to the commencement of construction.

4) Excavated Soil

Muddy excavated soil and muddy water caused by excavation are called mud. Out of them the mud regarded as industrial waste disposed as described in waste disposal treatment act etc. is construction sludge. Dump truck of standard specification cannot load with construction sludge and person cannot walk on the construction sludge because of high liquidity. The disposal of the construction sludge shall comply with waste-disposal act, municipal law etc. in Mongolia and it shall be disposed properly.

(2) Ground Deformation

It is possible to curb ground deformation caused by shield tunnel works at a minimum by proper selection of construction method and construction supervision. For that it is required to understand factors and mechanism of ground deformation caused by shield tunnel method and to take some measures against it. Measures against deformation prevention are as follows:

1) Measures against Earth Pressure Imbalance at Cutting Face

As for earth pressure shield method, chamber pressure which is commensurate with earth and water pressures at shield cutting face shall be applied by regulating propulsion speed, the number of revolution of screw, conveyor. Suitable additives shall be infused so as to make liquidization as necessary and void in the chamber shall not be produced.

As for slurry shield method, quality of slurry shall be regulated according to permeability of ground to be excavated and slurry pressure which is commensurate with earth and water pressures at shield cutting face shall be applied.

2) Measures against Disturbance of Ground during Propulsion of TBM

Disturbance to the neighboring ground with TBMs shall be curbed as much as possible. Sufficient attitude control of TBM shall be conducted so that meandering TBM propulsion would be curbed at a minimum.

3) Occurrence of Tail Void and Back-filling

Back-filling materials which are pervious and high in strength for consolidation shall be selected depending on ground conditions. Appropriate impregnating pressure and percentage shall be determined conducting trial construction.

4) Deformation of Primary Lining and Measures against Displacement

Joint bolts shall sufficiently tighten and joint structures with certain rigidity shall be adopted to avoid deformation of segment ring.

5) Measures against Drop in Groundwater Level

Segment shall be elaborately assembled and sealing materials of high imperviousness and endurance shall be used to prevent water leakage from joints of segment and voids in back-filling.

(3) Neighboring Construction

As for neighboring construction, it is required to conduct preparatory survey and analysis of behavior of the ground around the shield machine and its impact to neighboring buildings. If it resulted in the malfunction of neighboring buildings or in physical damage to the buildings , measures against them shall be made depending on the degree. Impact of neighboring buildings caused by shield tunnel construction depends on distance, length, ground deformation and conditions, rigidity type of foundation of neighboring structures. Therefore, it is required to consider these particulars and grasp impact of the neighboring construction.

1) Category of Degree of Neighborhood

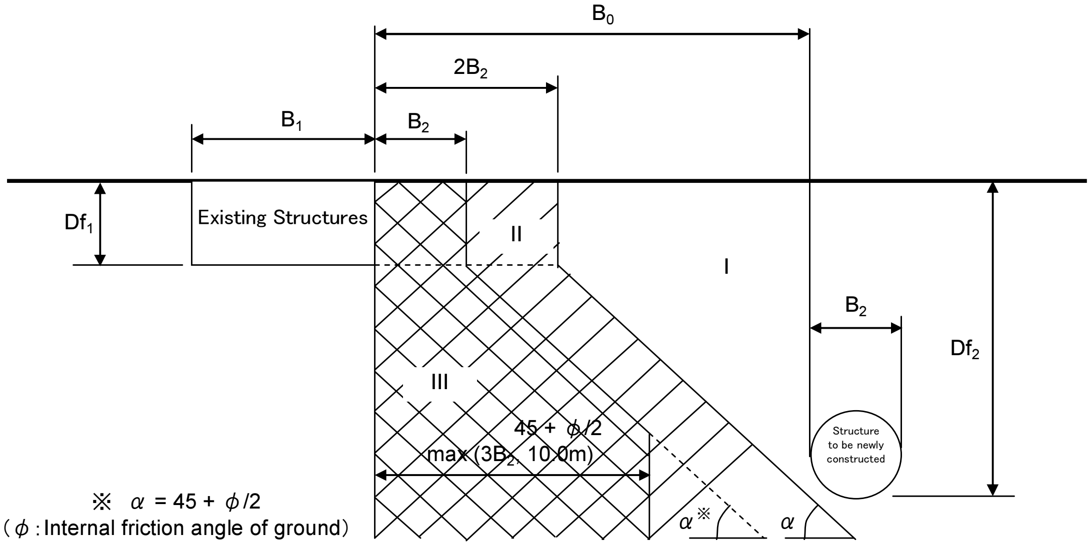
As a first step, it is required to confirm if area along proposed route is regarded as neighboring construction and make an assessment as to range supporting ground for neighboring building by impact of ground deformation caused by shield excavation. The category is divided into three levels: (i) Unconditional Area; (ii) Require Caution Area; and (iii) Restricted Area. Description and measures and measurements supervision for the three levels are shown in Table 4.13.1.

Table 4.13.1 Category of Degree of Neighborhood and Measures

Category of Degree of Neighborhood		Measures and Measurement Supervision
Category	Description	
Unconditional Area (I)	Area which displacement and deformation would not be occurred by structures to be newly built.	Measures are generally not required.
Require Caution Area (II)	Area which displacement and deformation would not occur generally by structures to be newly built, but there is impact on rare occasion.	In principle, it is required to take measures against structure itself to be newly built and conduct analysis on displacement and deformation of existing structures. After that, the result must be compared with allowable displacement and it is required to institute protective measures. Also, it is required to measure movement of existing structures and structures to be newly built including temporary structures and supervise them so that construction can be executed safely.
Restricted Area（Measures required Area）(III)	Area which would have a deleterious effect on existing structures by structures to be newly built.	It is absolutely required to take measures against structure itself to be newly built and conduct analysis on displacement and deformation of existing structures. After that, the result must be compared with allowable displacement and it is required to institute protective measures. Also, it is required to measure movement of existing structures and structures to be newly built including temporary structures and supervise them so that construction can be executed safely.

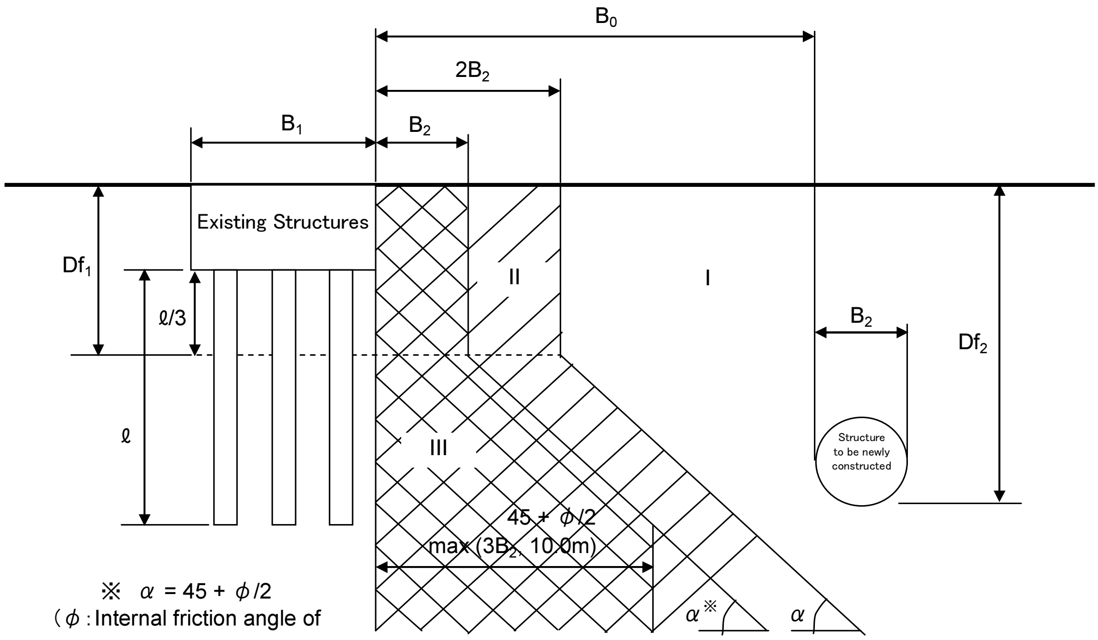
Source: Neighboring Construction Manual

Area categorized for neighboring construction of shield tunnel works against existing buildings with direct foundation and pile foundation which are applicable for the project is shown in Figure 4.13.1 and Figure 4.13.2.



Source: Neighboring Construction Manual

Figure 4.13.1 Neighborhood Area of Shield Tunnel（Direct Foundation）



Source: Neighboring Construction Manual

Figure 4.13.2 Neighborhood Area of Shield Tunnel（Pile Foundation）

Conditions of each category are as follows.

Unconditional area: Area I shown in Figure 4.13.2 (area satisfied by i and ii)

i $B_0 > 2B_2$
ii $B_0 > (Df_2 - Df_1) \tan(90° - \alpha) + 2B_2$

Require Caution Area: Area II shown in Figure 4.13.2
Area other than I and II

Restricted area: Area III shown in Figure 4.13.2 (area satisfied by iii or iv)
iii $B_0 \leqq 2B_2$ and $Df_1 > Df_2$
iv $B_0 \leqq (Df_2 - Df_1) \tan(90° - \varphi) + B_2$ and $B_0 \leqq \max(3B_2, 10.0\text{m})$

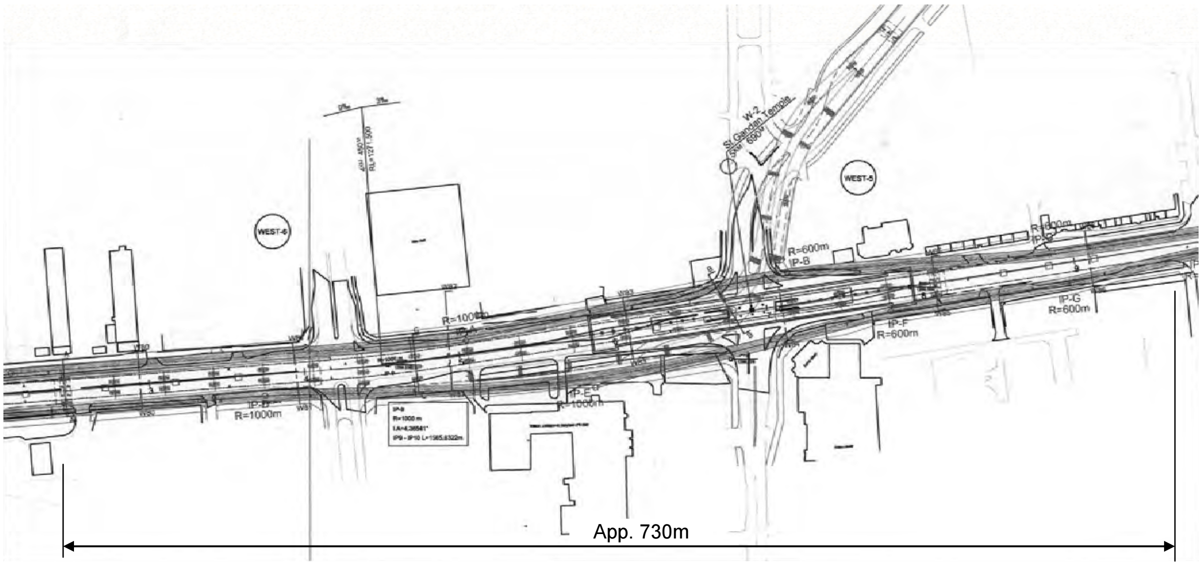
2) Assessment of Degree for Short Distance

Areas applicable to Require Caution Area (II) and Restricted Area (Measures required Area) (III) are shown in Table 4.13.2 and Figure 4.13.3 to 4.13.8. Restricted Area (Measures required Area) (III) is applicable to West Intersection and East Intersection where road flyover will be constructed and Require Caution Area (II) is applicable to some buildings which are located close to carriageway. The assessment of the category shall be studied in more detail in design stage.

Table 4.13.2 Assessment of Degree for Short Distance

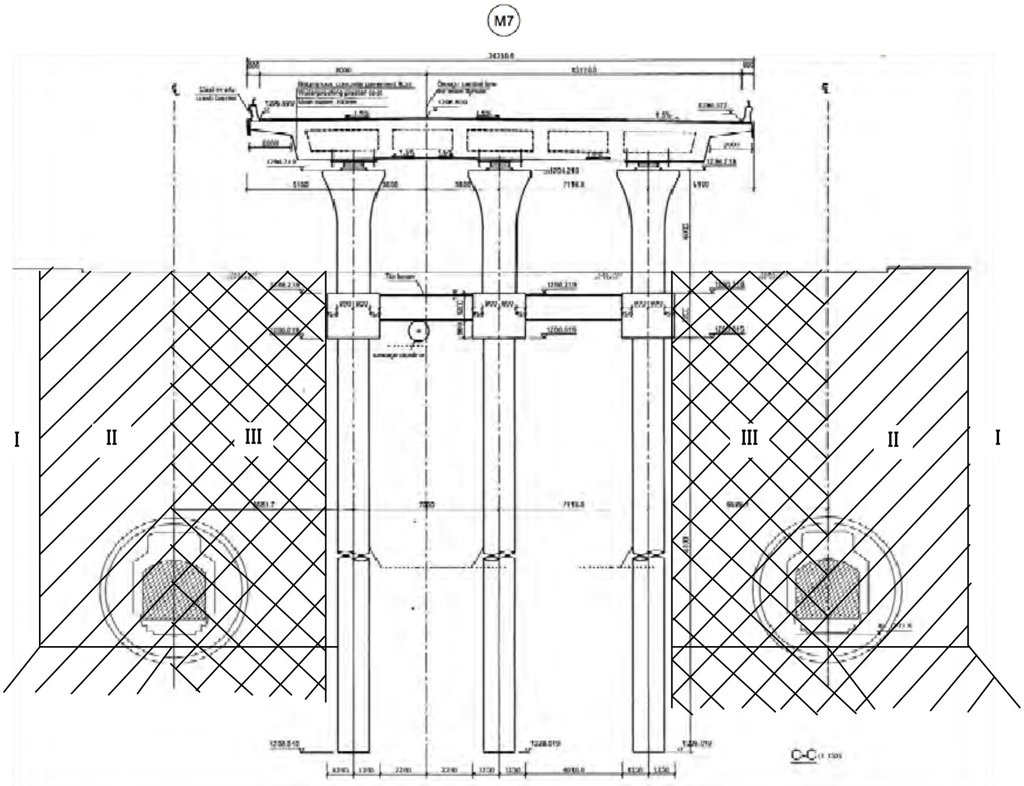
Category	Location	Range（Chainage）	Length	Remarks
Restricted Area （Measures required Area） (III)	West Intersection	5KM250M ～ 5KM980M	App. 730m	Measures against flyover and neighboring buildings are required.
	East Intersection	9KM010M ～ 9KM430M	App. 420m	Measures against flyover and neighboring buildings are required.
Require Caution Area (II)	Sections which buildings are closed to except above locations	4KM430M ～ 9KM010M （Except above restricted range）	-	Measures against front of the central post office etc. are required.

Source: JICA Study Team



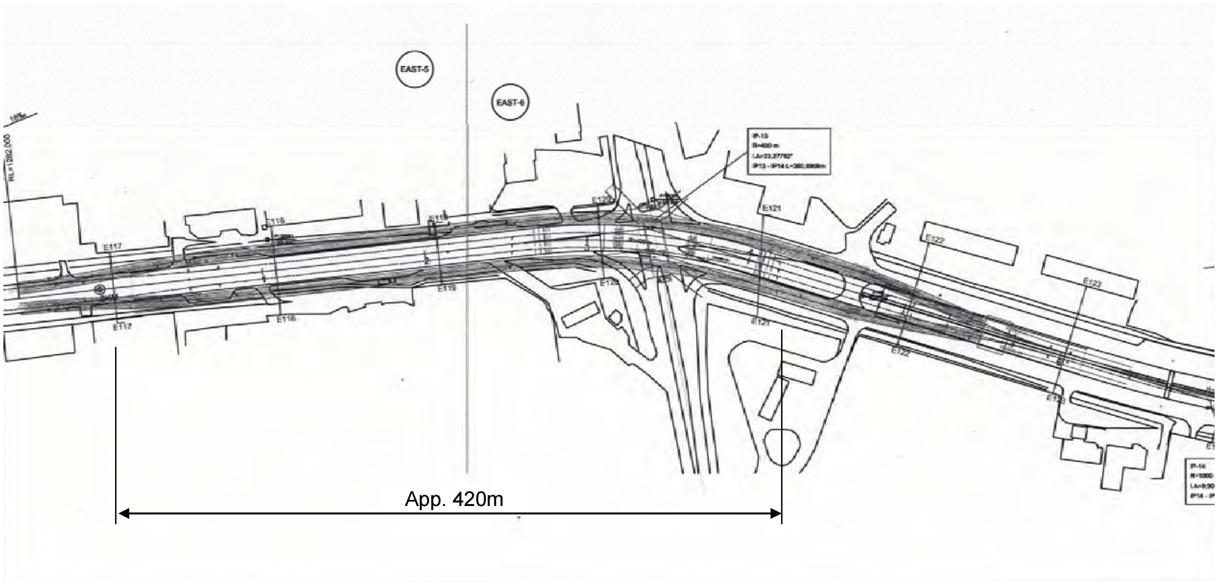
Source: JICA Study Team

Figure 4.13.3 Neighboring Construction against Flyover at West Intersection (Plan)



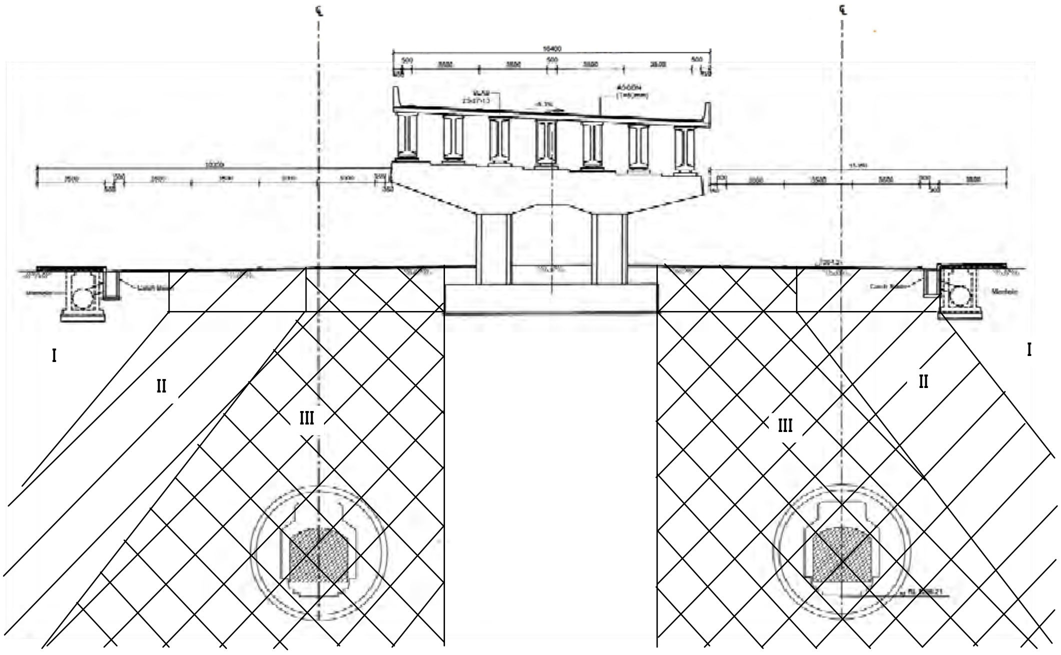
Source: Conceptual Drawing by JICA Study Team

Figure 4.13.4 Neighboring Construction against Flyover at West Intersection (Cross Section)



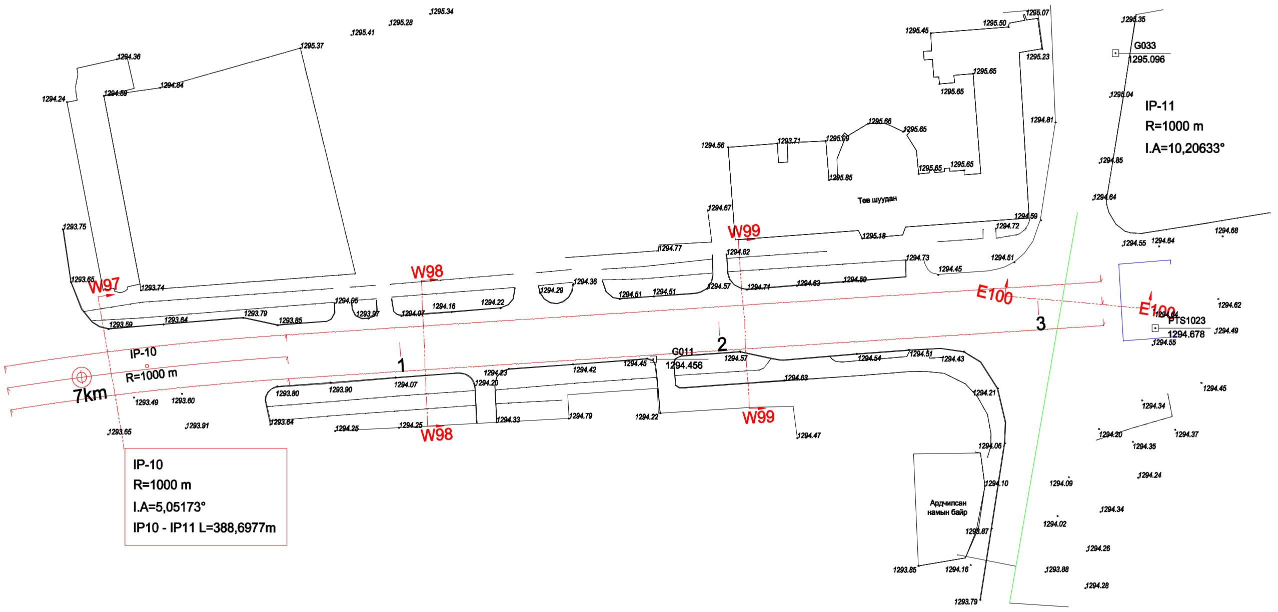
Source: JICA Study Team

Figure 4.13.5 Neighboring Construction against Flyover at East Intersection (Plan)



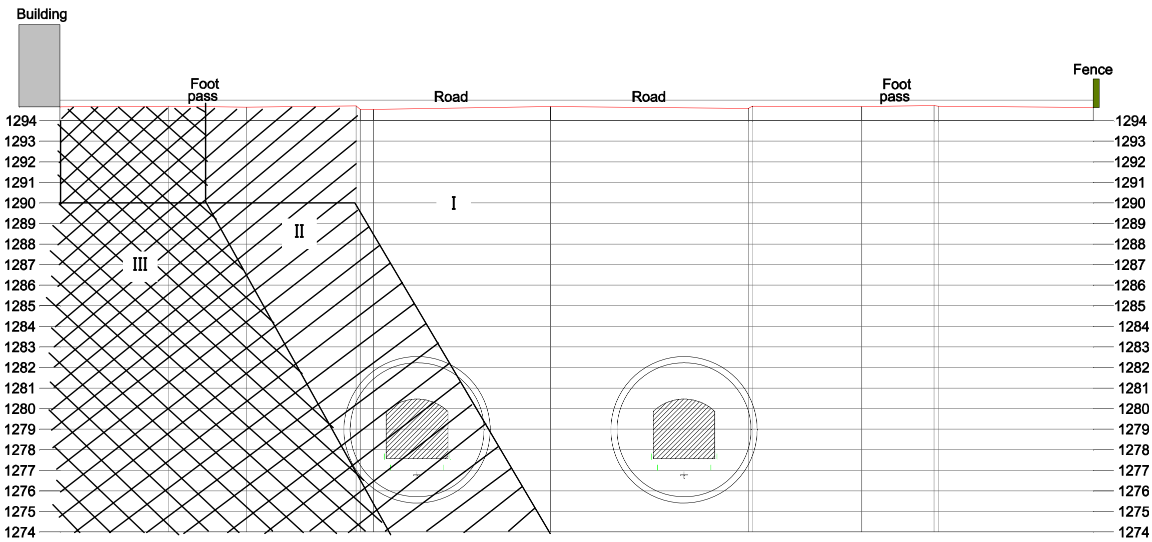
Source: Conceptual Drawing by JICA Study Team

Figure 4.13.6 Neighboring Construction against Flyover at East Intersection (Cross Section)



Source: JICA Study Team

Figure 4.13.7 Require Caution Area in front of the Central Post Office (Plan)



Source: JICA Study Team

Figure 4.13.8 Require Caution Area in front of the Central Post Office (Cross Section)

3) Measures against Neighboring Construction

While it is required to estimate degree of impact by using Finite Element Method of other methods for Require Caution Area (II) and Restricted Area (Measures required Area) (III), quantitative analysis and measures against them will be studied in the next design stage, and some measures proposed at present will be described in this report.

Measures for neighboring construction are roughly divided into measures for newly-constructed structures, measures for existing structures and measures which is conducted for intermediate ground between newly-constructed and existing structures as follows:

(a) Measures for newly-constructed structures

(i) Measures by shield construction

(ii) Reinforcement of grounds around shield machine

(b) Measures for existing structures

(i) Protection wall by sheet pile, continuous column or diaphragm walls, agitation mixing wall, etc.

(ii) Underpinning

(iii) Soil improvement around foundations

(iv) Reinforcement of structures by using members

Generally measures shall be set up in the order of measures for newly-constructed structures and then measures which is conducted for intermediate ground between newly-constructed and existing structures. Measures for existing structures are the final means in most cases and it is the idea that is proposed to be followed and take measures for this project as well.

Especially for areas applicable for Restricted Area (III), the following are proposed as measures of shield construction: (i) use of enclosed shield machine; (ii) use of simultaneous void grouting equipment; (iii) improvement of water resistance at joints of segment etc.; and (iv) use of equipment to keep a real circle. It is also proposed to reinforce ground by agitation mixing method as for reinforcement of ground around shield machine or construct protection wall of continuous column wall between existing structures and shield tunnel. As for measures against the neighboring construction, quantitative analysis of the impact degree shall be conducted considering ground conditions in detailed design stage and suitable measures against the result shall be taken. Quantitative analysis of impact for Require Caution Area (II) as well shall be conducted and suitable measures shall be taken as required.

4) Measurements Management

Measurements for muddy water (soil), shield machine, backfill grouting and segment etc. shall be conducted under construction by shield machine and major measurement items are shown in Table 4.13.3.

Table 4.13.3 Major Measurement Items

Interest	Classification	Measurement Items
Construction	Muddy Water (Soil)	・ Property（Density, Content of clay and sand, volume of additives to be used） ・ Muddy Water（Soil）Pressure ・ Mud Discharge（Soil）Volume
	Shield Machine	・ Driving Speed ・ Cutter Torque during Driving of Shield ・ Status of Use of Jack and Driving Force ・ Attitude of Shield (degree of pitching, yawing, rolling) ・ Volume of Tail Clearance ・ Earth and Water Pressures to Cutter Head ・ Status of Use of Tail Grease
	Backfill Grouting	・ Volume of Infusion ・ Maximum Infusion Pressure ・ Rate of Infusion
	Segment	・ Deformation by Assembly of Segment (degree of real circle) ・ Inner Diameter / Location of Segment after Assemble of Segment
Peripheral Ground	・ Ground surface subsidence ・ Underground Displacement (Settlement Device, Clinometer) ・ Ground water level ・ Temperature	
Existing Structures	・ Displacement (subsidence, tilt etc.) ・ Strain	

Source: Neighboring Construction Manual

4.13.3 Measures against Cold Climate Areas

(1) Considerations for Construction

The temperature of Ulaanbaatar in winter falls to minus 30 to 35 degrees Celsius, and it even registers minus 40 degrees or below depending on the day. Therefore, it is very severe to work outdoors during the three months of December, January and February and thus deliberate measures against construction in the period must be taken. It is required to pay special attention particularly to concrete works.

According to the standard specification for concrete works in Japan, the following matters are laid down. 1) The temperature of concrete during curing shall be kept at 5 degrees or over; 2) AE concrete shall be used; 3) The temperature of concrete during pouring shall be kept at 5 to 20 degrees; 4) Sand and gravel shall be heated; 5) Portland cement and mixed cement B class shall be used. Even if conditions during pouring can be met, it seems to be very difficult to meet conditions required for curing outdoors. It is unrealistic to take measures against curing to keep the required temperature at a huge cost. In addition, according to interviews with some construction companies, they mentioned that they do not pour concrete outdoors in Ulaanbaatar during winter season. Therefore, during winter season, pouring concrete should not be conducted outdoors and it is required to take measures such as making precast concrete indoors. It is probably possible to pour concrete for underground station by the cut and cover method if the conditions of curing concrete are met.

It is desirable that trustworthy companies which have advanced construction techniques for cold climate areas and plenty of experiences will join the project in order to properly implement the civil works during the cold winter.

(2) Considerations for Facilities and System

As measures against cold climate areas, it is required to give special consideration to facilities and systems. Specific items for the measures are as follows: 1) protection against wind at station, 2) freeze-proofing of point, 3) frost-heaving, 4) freeze-proofing of traction power cable, 5) protection against condensation and snow for electric items, 6) rolling stock specified for cold climate areas (anti-slip measure of wheel, souped-up heater, semi-automatic door, protection against low temperatures for windows and strengthening of insulation, etc.).

4.14 Rough Estimate of Construction Cost

This is the first urban railway project in Mongolia and large underground and elevated constructions are included in the project. And since it is very cold and construction is restricted in the winter in Mongolia, special specifications of system to be used for cold districts are required for the project.

Since there is no similar project in Mongolia, it is not easy to estimate project cost for the above conditions. But the project cost has been estimated referring to procurement and winter construction circumstances described in 4.12 (2) and comparing with Korean FS and construction cost of Japan and other foreign countries. Project costs of the following three options have been set up with the difference of procurement.

- Option 1 : the assumption that Japanese firms etc. can enter into the project (base case)
- Option 2 : the assumption that international competitive bidding is conducted (competition case)
- Option 3 : the assumption that Japanese firms can enter into main constructions and procurements (Japan core case)

As for Option 3, it is assumed that Japanese firms would get involved into civil and architecture works for underground section (by shield method), procurements of signal & telecom, safety system and rolling stocks.

Project costs for each option are shown in Table 4.14.1 and project cost-sharing in the case that the owner of the infrastructure and the railway operator are separated is shown in the lower part of the Table.

Table 4.14.1 Cost of Ulaanbaatar Urban Railway Project

Item		Contents	OP-1 (base case)		OP-2 (competition)			OP-3 (Japan core)		
			Cost (Million US$)	Total (Million US$)	Percentage of adjustment	Adjusted cost (Million US$)		Percentage of adjustment	Adjusted cost (Million US$)	
Civil works, Architecture	① ②	Underground section 6.62km Elevated section 12.73km	620.0 418.0	1,038.0	80% 70%	496.0 293.0	789.0	100% 70%	620.0 293.0	913.0
E&M	③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩	Depot Station Air conditioning / ventilation Signaling Power supply Telecommunication SCADA System integration	55.0 102.0 33.0 68.0 53.0 25.0 7.0 14.0	357.0	70% 70% 70% 80% 80% 80% 90% 100%	38.0 72.0 23.0 55.0 42.0 20.0 6.0 14.0	270.0	70% 70% 70% 100% 100% 100% 100% 100%	38.0 72.0 23.0 68.0 53.0 25.0 7.0 14.0	300.0
Track	⑪ ⑫	Main line tracks Tracks in depot	56.0 37.0	93.0	70% 70%	39.0 26.0	65.0	70% 70%	39.0 26.0	65.0
Rolling stock	⑬ ⑭	6 cars x10 train sets 60 cars Ancillary equipment 2 %	120.0 2.4	122.4	70% 70%	84.0 2.0	86.0	100% 100%	120.0 2.0	122.4
Sub-total			1,610.4			1,210.0			1400.4	
Other project costs	⑮ ⑯ ⑰	Design/supervision 6.0 % Land acquisition 30 ha Preparatory works (relocation etc.)	96.6 30.0 25.0	151.6		72.6 30.0 25.0	127.6		84.0 30.0 25.0	139.0
Total			1,762.0			1,337.6			1,539.4	

Infrastructure cost (①+②+③+④+⑤+⑪+⑫+⑮+⑯+⑰) Operation SPC (⑥+⑦+⑧+⑨+⑩+⑬+⑭)	1,472.6 289.4	83.6% 16.4%		1,114.6 223.0	83.3% 16.7%		1,250.0 289.4	81.2% 18.8%
Total	1,762.0	100%		1,337.6	100%		1,539.4	100%

Source: JICA Study Team

Principal specifications of urban railway projects proposed by Korean FS and JICA study are shown in Table 4.14.2. Construction cost per km and project cost per km sorted out based on the specifications are shown in Table 4.14.3. Both costs of Korean FS lie within the range between the value of Option 2 and the value of Option 3 and there is no great difference between them.

Costs for the infrastructure are divided into a foreign portion and a local portion and the costs are allotted every year in percentages shown in Table 4.14.4. The costs allotted every year are shown in Table 4.14.5 to 4.14.13.

Table 4.14.2 Urban Railway Outline Comparison between Korean FS and JICA study

Item		Korean FS	JICA-FS(UTPUB)	Remarks
Total Length		28.38km	19.3km	Total length of whole route
Length	At-grade Section	1.62km	0	
	Elevated Section	14.64km	12.73km	
	Underground Section	12.12km	6.62km	
The Number of Stations	At-grade Section	1	1	
	Elevated Section	8	8	
	Underground Section	12	5	
	Total	21	14	
Method of Tunnel Construction		Cut and Cover Method	Shield Method	
Mode of Urban Railway		LRT	MRT	
The Number of Train Set		18 Trains	10 Trains (2020)	

Source: Final Report, Feasibility Study on Metro Construction Project in Ulaanbaatar City

Table 4.14.3 Cost Comparison between Korean FS and JICA study

Item			Koran FS		JICA – FS (Million US$)		
			Million MNT	Million US$	OP -1	OP - 2	OP - 3
Construction Cost	Civil works	Main track	924,729	739.8			
		Station	370,768	296.6	1,038.0	789.0	913.0
		Sub-total	1,295,489	1,036.4			
	Track		122,043	97.6	93.0	65.0	65.0
	Architect / System		734,948	588.0	357.0	270.0	300.0
	Removal of obstacle		35,632	28.5	25.0	25.0	25.0
	Sub-total		2,188,112	1,750.5	1,513.0	1,149.0	1,303.0
Land acquisition			48,978	39.2	30.0	30.0	30.0
Rolling stock			153,216	122.6	122.4	86.0	122.4
Contingency / Miscellaneous expenses			396,717	1,598	96.6	72.6	84.0
Total			2,787,023	2,229.6	1,762.0	1,337.6	1,539.4
1) Construction cost per KM（Million US$）				61.68	78.41	59.53	67.51
2) Rolling stock cost per car（Million US$）				1.80	2.04	1.43	2.04
3) Project cost per KM（Million US$）				78.56	91.32	69.31	79.76

Source: Final Report, Feasibility Study on Metro Construction Project in Ulaanbaatar City

Table 4.14.4 Annual Allotment of Infrastructure Cost

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Service Operation
Percentage of foreign portion		70%	0%	20%	80%	50%	90%	70%	100%	
1	2012									
2	2013	30%								
3	2014	20%		100%						
4	2015	10%	30%		20%	15%	20%			
5	2016	8%	30%		20%	20%	20%			
6	2017	8%	40%		20%	30%	30%			
7	2018	8%			20%	25%	20%			
8	2019	8%			10%	10%	10%	50%	40%	
9	2020	8%			10%			50%	60%	
10	2021									1

Source: JICA Study Team

【Option 1】

Table 4.14.5 Total Cost（Million US$）（Option 1）

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Total
		96,624	30,000	25,000	620,000	418,000	357,000	93,000	122,400	1,762,024
1	2012	0	0	0	0	0	0	0	0	0
2	2013	28,987	0	0	0	0	0	0	0	28,987
3	2014	19,325	0	25,000	0	0	0	0	0	44,325
4	2015	9,662	9,000	0	124,000	62,700	71,400	0	0	276,762
5	2016	7,730	9,000	0	124,000	83,600	71,400	0	0	295,730
6	2017	7,730	12,000	0	124,000	125,400	107,100	0	0	376,230
7	2018	7,730	0	0	124,000	104,500	71,400	0	0	307,630
8	2019	7,730	0	0	62,000	41,800	35,700	46,500	48,960	242,690
9	2020	7,730	0	0	62,000	0	0	46,500	73,440	189,670

Source: JICA Study Team

Table 4.14.6 Foreign Portion（Million US$）（Option 1）

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Total
		67,637	0	5,000	496,000	209,000	321,300	65,100	122,400	1,286,437
1	2012	0	0	0	0	0	0	0	0	0
2	2013	20,291	0	0	0	0	0	0	0	20,291
3	2014	13,527	0	5,000	0	0	0	0	0	18,527
4	2015	6,764	0	0	99,200	31,350	64,260	0	0	201,574
5	2016	5,411	0	0	99,200	41,800	64,260	0	0	210,671
6	2017	5,411	0	0	99,200	62,700	96,390	0	0	263,701
7	2018	5,411	0	0	99,200	52,250	64,260	0	0	221,121
8	2019	5,411	0	0	49,600	20,900	32,130	32,550	48,960	189,551
9	2020	5,411	0	0	49,600	0	0	32,550	73,440	161,001

Source: JICA Study Team

Table 4.14.7 Local Portion（Million US$）（Option 1）

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Total
		28,987	30,000	20,000	124,000	209,000	35,700	27,900	0	475,587
1	2012	0	0	0	0	0	0	0	0	0
2	2013	8,696	0	0	0	0	0	0	0	8,696
3	2014	5,797	0	20,000	0	0	0	0	0	25,797
4	2015	2,899	9,000	0	24,800	31,350	7,140	0	0	75,189
5	2016	2,319	9,000	0	24,800	41,800	7,140	0	0	85,059
6	2017	2,319	12,000	0	24,800	62,700	10,710	0	0	112,529
7	2018	2,319	0	0	24,800	52,250	7,140	0	0	86,509
8	2019	2,319	0	0	12,400	20,900	3,570	13,950	0	53,139
9	2020	2,319	0	0	12,400	0	0	13,950	0	28,669

Source: JICA Study Team

【Option 2】

Table 4.14.8 Total Cost（Million US$）（Option 2）

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Total
		72,600	30,000	25,000	496,000	293,000	270,000	65,000	86,000	1,337,600
1	2012	0	0	0	0	0	0	0	0	0
2	2013	21,780	0	0	0	0	0	0	0	21,780
3	2014	14,520	0	25,000	0	0	0	0	0	39,520
4	2015	7,260	9,000	0	99,200	43,950	54,000	0	0	213,410
5	2016	5,808	9,000	0	99,200	58,600	54,000	0	0	226,608
6	2017	5,808	12,000	0	99,200	87,900	81,000	0	0	285,908
7	2018	5,808	0	0	99,200	73,250	54,000	0	0	232,258
8	2019	5,808	0	0	49,600	29,300	27,000	32,500	34,400	178,608
9	2020	5,808	0	0	49,600	0	0	32,500	51,600	139,508

Source: JICA Study Team

Table 4.14.9 Foreign Portion（Million US$）（Option 2）

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Total
		53,820	0	5,000	396,800	146,500	243,000	45,500	86,000	973,620
1	2012	0	0	0	0	0	0	0	0	0
2	2013	15,246	0	0	0	0	0	0	0	15,246
3	2014	10,164	0	5,000	0	0	0	0	0	15,164
4	2015	5,082	0	0	79,360	21,975	48,600	0	0	155,017
5	2016	4,066	0	0	79,360	29,300	48,600	0	0	161,326
6	2017	4,066	0	0	79,360	43,950	72,900	0	0	200,276
7	2018	4,066	0	0	79,360	36,625	48,600	0	0	168,651
8	2019	4,066	0	0	39,680	14,650	24,300	22,750	34,400	139,846
9	2020	4,066	0	0	39,680	0	0	22,750	51,600	118,096

Source: JICA Study Team

Table 4.14.10 Local Portion（Million US$）（Option 2）

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Total
		21,780	30,000	20,000	99,200	146,500	27,000	19,500	0	363,980
1	2012	0	0	0	0	0	0	0	0	0
2	2013	6,534	0	0	0	0	0	0	0	6,534
3	2014	4,356	0	20,000	0	0	0	0	0	24,356
4	2015	2,178	9,000	0	19,840	21,975	5,400	0	0	58,393
5	2016	1,742	9,000	0	19,840	29,300	5,400	0	0	65,282
6	2017	1,742	12,000	0	19,840	43,950	8,100	0	0	85,632
7	2018	1,742	0	0	19,840	36,625	5,400	0	0	63,607
8	2019	1,742	0	0	9,920	14,650	2,700	9,750	0	38,762
9	2020	1,742	0	0	9,920	0	0	9,750	0	21,412

Source: JICA Study Team

【Option 3】

Table 4.14.11 Total Cost（US$）（Option 3）

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Total
		84,000	30,000	25,000	620,000	293,000	300,000	65,000	122,400	1,539,400
1	2012	0	0	0	0	0	0	0	0	0
2	2013	25,200	0	0	0	0	0	0	0	25,200
3	2014	16,800	0	25,000	0	0	0	0	0	41,800
4	2015	8,400	9,000	0	124,000	43,950	60,000	0	0	245,350
5	2016	6,720	9,000	0	124,000	58,600	60,000	0	0	258,320
6	2017	6,720	12,000	0	124,000	87,900	90,000	0	0	320,620
7	2018	6,720	0	0	124,000	73,250	60,000	0	0	263,970
8	2019	6,720	0	0	62,000	29,300	30,000	32,500	48,960	209,480
9	2020	6,720	0	0	62,000	0	0	32,500	73,440	174,660

Source: JICA Study Team

Table 4.14.12 Foreign Portion (US$)（Option 3）

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Total
		58,800	0	5,000	496,000	146,500	270,000	45,500	122,000	1,144,200
1	2012	0	0	0	0	0	0	0	0	0
2	2013	17,640	0	0	0	0	0	0	0	17,640
3	2014	11,760	0	5,000	0	0	0	0	0	16,760
4	2015	5,880	0	0	99,200	21,975	54,000	0	0	181,055
5	2016	4,704	0	0	99,200	29,300	54,000	0	0	187,204
6	2017	4,704	0	0	99,200	43,950	81,000	0	0	228,854
7	2018	4,704	0	0	99,200	36,625	54,000	0	0	194,529
8	2019	4,704	0	0	49,600	14,650	27,000	22,750	48,960	167,664
9	2020	4,704	0	0	49,600	0	0	22,750	73,440	150,494

Source: JICA Study Team

Table 4.14.13 Local Portion（US$）（Option 3）

		Design/ Supervision	Land Acquisition	Preparatory Works	Underground Structure	Elevated Structure	E&M	Track	Rolling Stock	Total
		25,200	30,000	20,000	124,000	146,500	30,000	19,500	0	395,200
1	2012	0	0	0	0	0	0	0	0	0
2	2013	7,560	0	0	0	0	0	0	0	7,560
3	2014	5,040	0	20,000	0	0	0	0	0	25,040
4	2015	2,520	9,000	0	24,800	21,975	6,000	0	0	64,295
5	2016	2,016	9,000	0	24,800	29,300	6,000	0	0	71,116
6	2017	2,016	12,000	0	24,800	43,950	9,000	0	0	91,766
7	2018	2,016	0	0	24,800	36,625	6,000	0	0	69,441
8	2019	2,016	0	0	12,400	14,650	3,000	9,750	0	41,816
9	2020	2,016	0	0	12,400	0	0	9,750	0	24,166

Source: JICA Study Team