APPENDIX 4 PRE-FEASIBILITY STUDY

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ABBREVIATIONS and ACRONYMS

AGT	Automated Guideway Transit
ATO	Automatic Train Operation System
ATP	Automatic Train Protection System
ATS	Automatic Train Supervision System
BTN	Backbone Transmission Network
BTS	Bangkok Mass Transit System
CBTC	Communication-Based Train Control
CCR	Central Control Room
CCTV	Closed Circuit Television
CO	Carbon Monoxide
CO2	Carbon Dioxide
DBFM	Design, Build, Finance and Maintain
DD	Detailed Design
Dr	Diversion rate
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
FC	Foreign Cost
FIRR	Financial Internal Rate of Return
FS	Feasibility Study
GHG	Greenhouse Gas
HIV/AIDS	Human Immunodeficiency Virus / Acquired Immunodeficiency Syndrome
IL	Interlocking system

JICA	Japan International Cooperation Agency
LC	Local Cost
LCC	Life Cycle Cost
LEPNRM	Law on Environmental Protection and Natural Resources Management
LRT	Light Rail Transit
LRTA	Light Rail Transit Authority
MEF	Ministry of Economic and Finance
MOE	Ministry of Environment
MRT	Mass Rail Transit
MRTA	Mass Rail Transit Authority
NO2	Nitrogen Dioxide
NPV	Net Present Value
NR	National Road
OD	Origin-Destination
ODA	Official Development Assistance
PAPs	Project-Affected Persons
PAS	Public Address System
PCU	Passenger Car Unit
PIDS	Passenger Information Display System
PIS	Passenger Information System
PM	Particulate Matter
PPHPD	Passengers at Peak Hour Per Direction
PPP	Public-Private Partnership
PPUTMP	Project for Comprehensive Urban Transport Plan in Phnom Penh Capital City
PT	Person Trip
RAMS	Reliability, Availability, Maintainability and Safety
ROW	Right-of-Way
SCADA	Supervisory Control and Data Acquisition
SCF	Standard Conversion Factor
SCR	Station Control Room
SIL4	Safety Integrity Level 4
SO2	Sulphur Dioxide
St.	Street
Sta.	Station
TD	Train Detection System
TTC	Travel Time Cost
UG	Underground
UTO	Unattended Train Operation
VAT	Value Added Tax
VOC	Vehicle Operation Cost
WHO	World Health Organization

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1. Introduction

A pre-feasibility study was conducted for the rail transit system, which will be the main public transport system in Phnom Penh, the capital city of Cambodia. Basically, the entire process of the pre-feasibility study was completed along the east-west public transport corridor in Phnom Penh (Russian Corridor), which obtained the highest score among alternatives at the first stage of the study.

However, from the discussions among stakeholders, it was found that Russian Blvd. is the VIP road in Phnom Penh. Therefore, development of the elevated public transport system is not allowed along this corridor. Thus, the stakeholders suggested that the project team include the analysis of the alternative rail transit route in the Appendix for reference.

A more detailed feasibility study is to be conducted after the completion of the urban transport master plan. This pre-feasibility study report contains the following chapters, with Chapters 1 and 2 in the main text and the rest as appendices:

1. Introduction
2. Analysis and Screening of Target Public Transport Corridor
3. Passenger Demand Forecast
4. Proposed Rail Transit System
5. Preliminary Route Alignment Study
6. System Operation Plan
7. Preliminary Facility Plan
8. Economic and Financial Analysis
9. Environmental and Social Consideration Study
10. Project Implementation

2. Passenger Demand Forecast

2.1 General

The demand forecast for the preliminary feasibility study was conducted according to the following framework. The target years for the demand forecast are 2035 (long term) and 2020 (medium term), which correspond to the target years designated in the master plan.

- Input sources are collected from the demand forecast database which was elaborated in the demand forecast task in the master plan (i.e., future person trip data by transport mode and travel impedance data on road traffic between zones).

- For the output of the demand forecast, the following data are required:
  - Data to formulate the train operation plan such as peak load volume estimation (PPHPD: passengers per hour per direction);
  - Data to estimate operating revenue such as daily ridership estimation; and
  - Data for design parameters like number of boarding and alighting passengers by stations (trip interchange matrix between stations).

- Rail transit passenger trips are divided into the following categories:

  (i) Passengers along the Rail Transit Corridor

  This trip category means ordinary daily trips consisting of urban trip demand such as trips by trip purpose and trips by transport mode. This kind of data can be provided as a trip projection data, i.e., trip distribution. Accordingly, based on the 2035 OD table prepared in the master plan study, rail transit passengers are estimated by applying a simple modal choice model in which car trip diversion rate is calculated by the travel time comparison with/without transit route between zones.

  (ii) Airport Passengers

  The proposed transit system serves not only ordinary urban transport needs like commuter trips and students' trips but also airport access/egress trips generated at the Phnom Penh Airport. Based on this, the number of rail transit passengers to/from Phnom Penh Airport is estimated. The future number of airport passengers was estimated based on the projection of the latest trend of airport passenger volumes. As for the modal choice rate for rail transit, the existing modal choice rate for public transport access was applied.

  (iii) Intercity Bus Passengers

  Intercity bus passengers transferring to rail transit at the Cham Chau multimodal transport terminal, mainly to/from NR4, are also considered.

2.2 Passengers along the Rail Transit Corridor

(1) Trips Database

The initial trip data source for future rail transit passenger demand was adopted from the future projection results for person trip interchange matrix in 2035, which was estimated as trip distribution in the study area through demand forecast in the master plan study. Table 2.2-1 shows the results of the future trip projection prepared by existing transport mode.

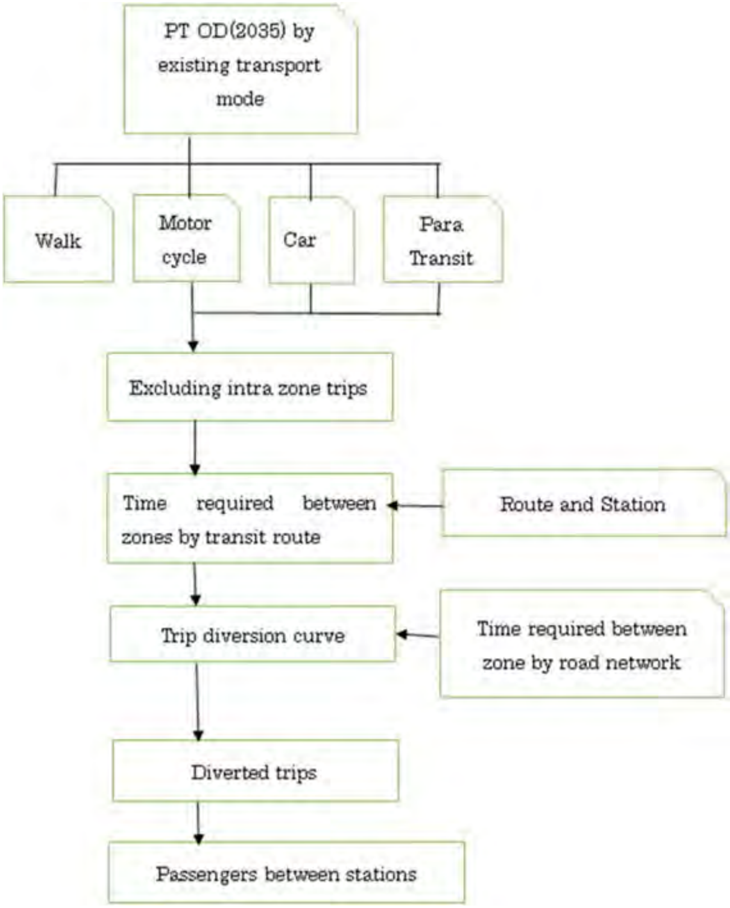
Table 2.2-1 Projected Trips by Mode in 2035

	Total	Walk	Motorcycle	Car	Para-transit
Trips	6,963,369	1,138,200	3,833,961	1,198,570	792,638
Modal share	-	16.3	55.1	17.2	11.4

Source: PPUTMP Project Team

(2) Work Flow of Passenger Demand Estimation

The outline of the demand estimation process is shown in Figure 2.2-1.



Source: PPUTMP Project Team

Figure 2.2-1 Flow Chart of Estimating Corridor-Based Passengers

(3) Analysis of Trip Diversion Algorithm to Rail Transit from Existing Transport Mode

1) Modal Choice Factor

Since no public transport system exists in Phnom Penh, there is no clue as to estimate the modal choice behavior of people when a new rail transit will be introduced in Phnom Penh. In general, there are several influential factors affecting trip modal choice, as follows:

- Distance: Travel distance is considered to be the initial criterion for choosing the transport mode of travel because travel length limits trips by walk because of the resulting physical burden and, thus, promotes the use of transportation. However, under the urban transport category, no clear boundary exists between transport means other than walk trips.

- Time: Travel time is considered to be the predominant factor by which travelers decide their mode choice if there are several transport modes available for a trip. Obviously, a transport mode requiring travel time less than other modes would be highly desirable. However, it does not necessarily mean that a transport mode requiring shorter time can obtain the largest share in mode competition because transport modal choice also depends on other mode characteristics, for example, travel cost, transport quality, etc.

- Travel cost: Travel cost is also considered to be a predominant factor for travel mode choice behavior of people. There is, however, a problem on how to measure actual travel cost by mode. In the case of private transport use, it is difficult to know how much users can perceive their virtual travel cost, including indirect expense such as vehicle maintenance cost and insurance payment. In the case of public transport, there is no regulation and no market price because there is no official public transport system in Phnom Penh at present.

- Mode specific factor: Each transport mode has its specific features in transport services, for example, riding comfort, punctual operation, etc. These characteristics will provide intangible benefits to users and, consequently, attract more users.

From the viewpoint of model building regarding modal choice, application of the above factors is assessed as follows (see Table 2.2-2):

Table 2.2-2 General Characteristics of Modal Choice-Related Factors

Factor	Tangible Nature	Significance in Modal Choice	Measurable	Remarks
Distance	○	△	○	Indistinctive in applied transport category
Time	○	○	○	
Cost	○	○	△	Unable to measure some hidden costs
Others	△	○	△	Operation punctuality, riding comfort, etc.

Source: PPUTMP Project Team
Note: ○ - Yes △ - No

2) Model Formula Approximation

Based on the above, the trip diversion model was formulated as a mode choice model in which time factor is used as an evaluation variable. The diversion model should be applied by origin-destination. Regarding how trip diversion will take place, the following assumptions were made:

(i) Calculating required time between two zones with/without rail transit system based on road network condition and transit route alignment, taking into account the access/egress link and lost time for waiting and transfer using rail transit;

(ii) Assessing time difference between with/without transit cases by certain evaluation formula to get the diversion rate;

(iii) Complete diversion (100% diverted) will take place when the time difference is over the threshold value. The threshold value was assumed to be 30 minutes, based on the existing average trip time in Phnom Penh (see Table 2.2-3).

Table 2.2-3 Average Travel Time in Existing Trips

Mode	Average Trip Length (km)	Average Travel Time (min.)	Average Travel Speed (km/h)
Motorbike	5.4	23.7	13.6
Car	6.4	29.5	13.0
Para-transit	4.6	21.5	12.9
Total	**5.2**	**23.6**	**13.1**

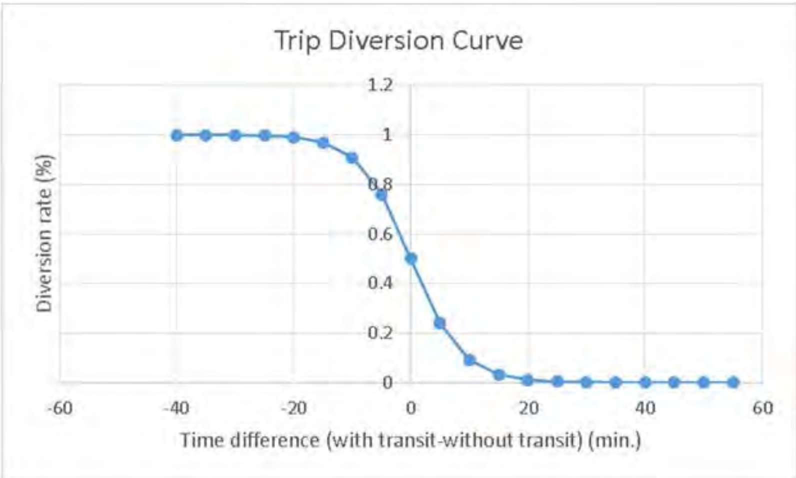
Source: PPUTMP Project Team

(iv) If the time difference is equal to 0, then the modal share for rail transit and that of the existing mode are both 50%.

To satisfy both conditions (iii) and (iv), the following logit type function was used (see Figure 2.2-2):

$$Dr = \frac{1}{1 + e^{0.2302(t_n - t_m)}}$$

Where Dr : diversion rate
t_n ,t_m: : time in with transit case, time in without transit case



Source: PPUTMP Project Team
Note: Model parameters are estimated through the approximation to threshold value.

Figure 2.2-2 Trip Diversion Curve Applied for Passengers Estimation

3) Some Definitions and Preconditions in Travel Time Calculation

To calculate travel time in with transit case, the following definitions are applied:

- Travel time in with transit case is defined in the following order: [In vehicle time], [access and egress (A&E) time to/from station], [mode interchange extra time];
- In vehicle time is calculated, assuming the commercial speed of transit is 30km/h;
- Access and egress time are calculated by dividing A&E link length with average speed (18km/h); and

- As mode interchange extra time, waiting time for train, and transfer time between transit station and connecting spot at corridor level are assumed to be 3 minutes and 5 minutes, respectively.

2.3 Airport Passengers

(1) Estimation of Total Passengers

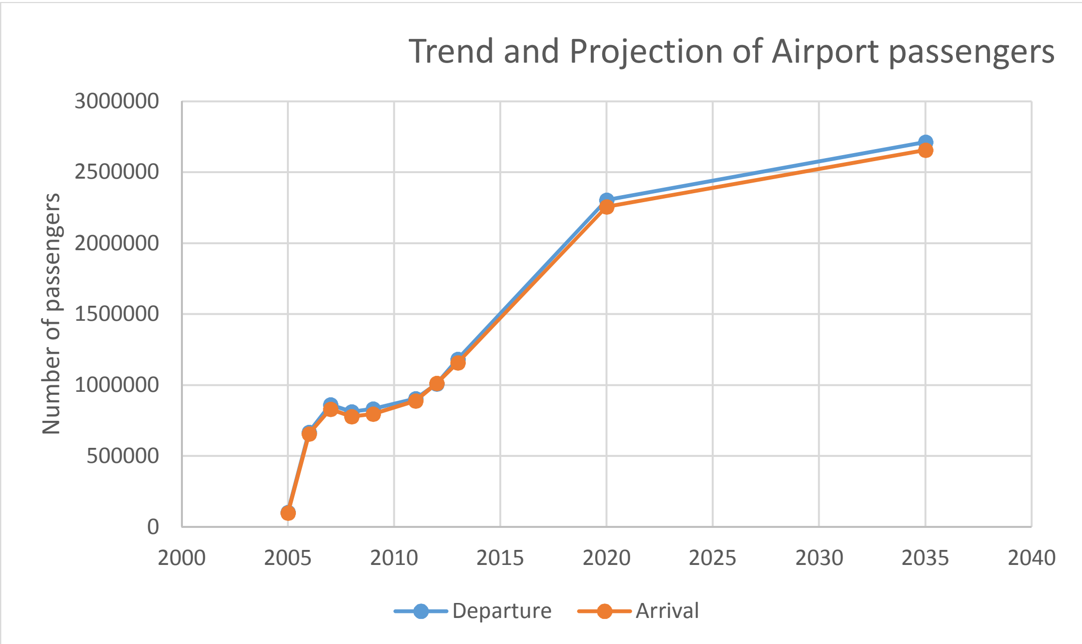
The number of airport passengers in 2035 is estimated based on trend data during the latest decade. Table 2.3-1 shows the volume of passengers departing/arriving in Phnom Penh Airport from 2005 to 2013. From this table, the average annual growth rate is estimated at around 10% per year for both departure and arrival.

Table 2.3-1 Latest Trend in Passenger Volume in Phnom Penh Airport

	2005	2006	2007	2008	2009	2011	2012	2013
Int.-departure	95,439	591,190	781,149	747,792	774,689	847,587	944,222	1,099,768
Dom.-Departure	7,251	75,842	80,052	63,529	57,375	57,062	64,416	82,873
Total Departure	102,690	667,032	861,201	811,321	832,064	904,649	1,008,638	1,182,641
Int.-arrival	90,567	575,641	754,060	718,148	743,416	833,550	951,312	1,081,508
Dom.-arrival	7,383	79,594	76,609	58,517	52,286	54,351	60,636	76,266
Total Arrival	97,950	655,235	830,669	776,665	795,702	887,901	1,011,948	1,157,774
Transit Passengers	5,492	0	0	0	45,655	47,342	56,696	53,265
Total		1,322,267	1,691,870	1,587,986	1,673,421	1,839,892	2,077,282	2,393,680
Annual growth rate(departure)			1.29	0.94	1.03	1.09	1.11	1.17
Annual growth rate(arrival)			1.27	0.93	1.02	1.12	1.14	1.14

Source :Phnom Penh Airport Website

Applying the 10% annual growth rate up to 2023 (assuming the growth rate will become zero after 2023), the future passenger volume is projected as shown in Figure 2.3-1.



Source: Phnom Penh Airport Website

Figure 2.3-1 Projected Volume of Passengers in Phnom Penh Airport

(2) Estimation of Transit Users

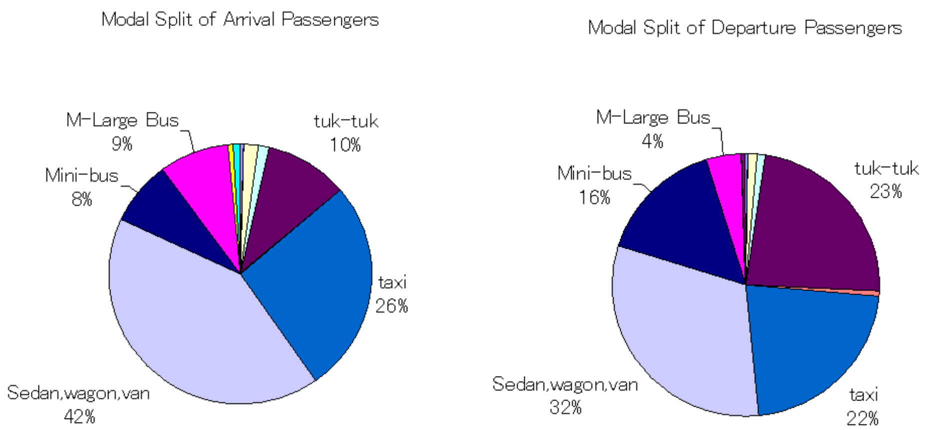
The following steps are carried out to estimate the passengers using rail transit: (i) conversion from annual volume to daily volume, and (ii) modal split of airport passengers.

In the conversion of passengers to daily base demand, the following points are taken into account:

- To consider seasonal demand peak of passengers, a conversion factor from annual base to daily base is set to 280 based on the monthly variation of passengers;
- In addition to air transport passengers, accompanied passengers such as well-wishers are included. For this estimation, 0.33 person for 1 international air traveler and 2 persons for every domestic air traveler are assumed; and
- The modal split rate for rail transit is assumed to be 68% for departing travelers and 58% for arriving travelers, based on the airport passengers interview survey results shown in Figure 2.2-4.

The final estimation results are as follows:

- Airport access transit passengers = 9,554 trips /day
- Airport egress transit passengers = 7,977 trips /day

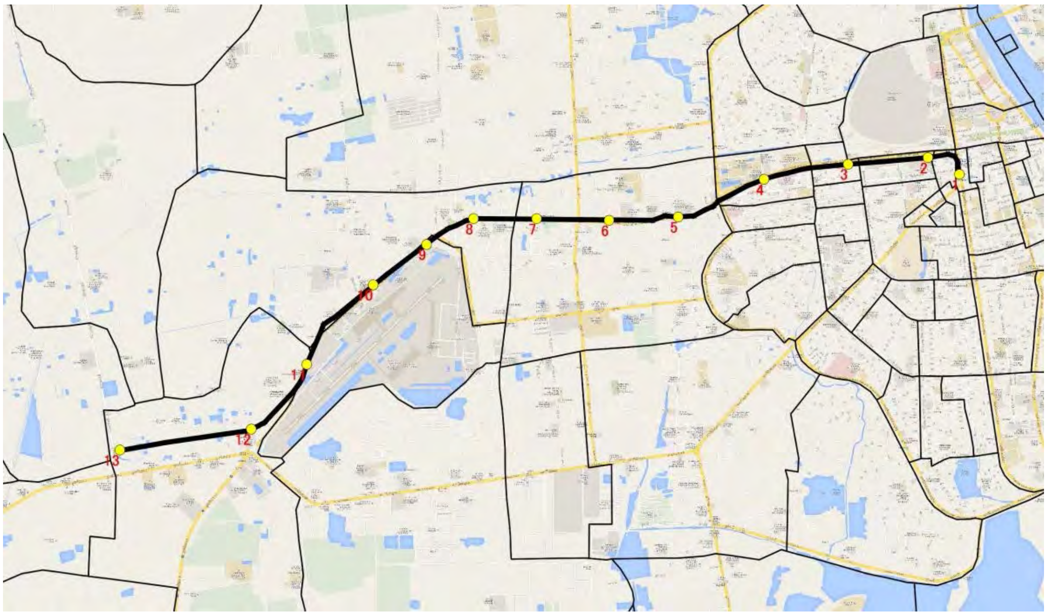


Source: PPUTMP Project Team

Figure 2.3-2 Modal Split Results of Current Airport Access Passengers

2.4 Passengers of Long-Distance Bus

Due to the relocation of the long-distance bus terminal, dispatching of long-distance bus services for NR4 will be expected to take place at the Cham Chau transport node near the transit station 12 (see Figure 2.4-1). Based on this, the demand for long-distance bus for NR4 is added to the boarding and alighting passengers at station 12. Boarding and alighting passengers were estimated to make 1,600 trips/day.



Source: PPUTMP Project Team

Figure 2.4-1 Location of Stations

2.5 Estimation of Rail Transit Ridership

(1) Total Passenger Volume Between Stations

According to the methodology described above, ridership estimation was conducted for year 2035. The resulting passenger trip table between stations is presented in Table 2.5-1.

The total rail transit passengers in 2035 is estimated at around 82,000 passengers/day. The number of passengers in 2020 is estimated at around 68,000/day and peak hour section volume in 2020 is estimated at around 5,000 PPHPD (see Table 2.5-2).

Table 2.5-3 presents a summary of the passenger demand indicators. There will be an average of 23,600 passengers/km/day traveling an average of 3.8 km.

Table 2.5-1 Matrix of Transit Passengers Between Stations

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
1	0	10,012	3,163	544	552	1,551	175	4	9	5,648	22	452	97	22,228
2	6,333	0	4,911	299	311	814	154	4	16	5,026	7	418	24	18,317
3	3,407	4,886	0	2,199	321	1,012	108	3	2	183	12	395	12	12,540
4	887	448	1,027	0	264	379	15	0	0	23	1	7	1	3,052
5	659	266	428	281	0	276	8	0	0	18	0	0	1	1,937
6	1,671	709	1,206	504	293	0	358	3	1	454	2	16	5	5,221
7	55	41	23	15	0	8	0	413	410	1	0	0	0	967
8	122	83	103	33	7	242	414	0	414	246	6	16	1	1,688
9	10	8	14	1	0	1	410	414	0	13	1	1	0	874
10	5,008	4,207	318	62	6	468	0	241	16	0	415	447	30	11,218
11	31	9	15	3	0	2	0	2	0	404	8	430	36	940
12	343	255	293	18	0	14	0	16	1	442	453	0	275	2,110
13	114	21	23	3	0	6	0	1	0	32	0	335	0	534
Total	18,639	20,945	11,524	3,961	1,755	4,774	1,641	1,101	871	12,489	927	2,519	481	81,626

Source: PPUTMP Project Team

Table 2.5-2 Section Passengers Volume (per day, per hour)

Sta (i)-Sta (j)		1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13
Daily volume	→	22,228	24,200	20,373	18,021	16,877	13,683	13,690	13,948	13,110	2,392	2,391	481
	←	18,639	23,239	18,396	16,954	15,627	11,985	12,667	12,337	11,496	2,049	2,035	534
Peak load (PPHPD)	→	5,557	6,050	5,093	4,505	4,219	3,421	3,423	3,487	3,277	598	598	120
	←	4,660	5,810	4,599	4,238	3,907	2,996	3,167	3,084	2,874	512	509	133

Source: PPUTMP Project Team

Note: Peak hour concentration rate is assumed to be 25% based on the current hourly variation of traffic in Phnom Penh.

Table 2.5-3 Summary of Passenger Demand Indicators

Indicator	Value
Passengers/route length (passengers/km)	6,200
Passengers*kilometers (‘000 pax*kilometers)	312,100
Average traffic density (passengers/km/day)	23,600
Average travel length (km)	3.8

Source: PPUTMP Project Team

2.6 Review of Transit Passengers Estimation Results

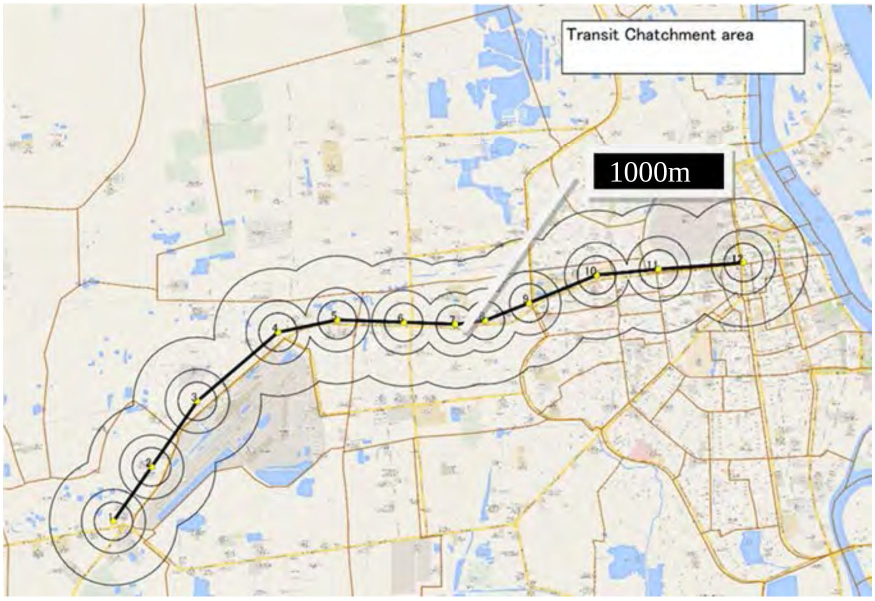
Validation of the results of the passenger estimation was conducted using another methodology. For this purpose, the passengers' catchment area analysis was applied. Passengers' catchment area is defined as a circular area within a certain radius from the station (see Figure 2.6-1). The population in the catchment area within the radius of the stations was estimated (see Table 2.6-1).

Table 2.6-1 Estimated Population in Transit Catchment Area

Year	Distance from Station			
	300 m	400 m	500 m	1,000 m
2012	42,193	74,497	112,825	307,773
2035	54,686	95,492	143,503	373,226
Average Annual Growth rate (%)	1.30	1.28	1.27	1.21

Source: PPUTMP Project Team

If the radius of the catchment area is assumed as 1,000 m, then the target population size is estimated at around 308,000 persons in 2012 and 373,000 in 2035. If the average trips/day is 2.5, the rate for inter-zone trips is 40%, and the mode choice rate of 20% is applied, the ridership in the catchment area base is estimated at around 74,600. This value exceeds the corridor base passenger estimation of 55,000 and, thus, the ridership estimation is considered to be appropriate.



Source: PPUTMP Project Team

Figure 2.6-1 Concept of Transit Catchment Area

3. Proposed Rail Transit System

3.1 How to Select the Optimum Rail Transit System

Based on the passenger demand and urban characteristics in Phnom Penh, rail transit system alternatives were selected from the medium capacity rail transit systems found in many parts of the world. These are (i) Linear Metro, (ii) Monorail, (iii) Automated Guideway Transit (AGT), (iv) Light Rail Transit (LRT), and (v) Tramway.

A comparison of the main specifications of these five rail transit system alternatives is shown in Table 3.1-1.

3.2 Evaluation Criteria and Their Description

It is possible to introduce any rail transit system in Phnom Penh. However, in proposing the most suitable rail transit system for the city, three things are to be considered, namely: (i) comparison of the specifications of the rail transit system alternatives (as outlined in Table 3.1-1), (ii) Cambodia’s economic development trends, and (iii) Phnom Penh’s urban and transport characteristics.

The following are the items considered in the evaluation criteria, and the results of the evaluation are summarized in Table 3.2-1. A transit system that satisfies a criterion is marked with ○; and a system that does not satisfy a criterion is marked with △. The system with the largest number of ○ marks is deemed the most suitable system to be introduced in Phnom Penh.

(1) Passenger Capacity

A comparison is made between maximum peak hour passengers by direction (7,000 passengers/ hour/ direction) and the system’s passenger capacity considering the passenger capacity/coach and minimum operational interval.

(2) Contribution to Urban Development

Any system has a possibility to be a tool of urban vitalization. It could become famous, something new in Phnom Penh.

(3) Contribution to Urban Scenery

An elevated infrastructure gives a negative impact on the urban scenery in Phnom Penh because of its narrow road space and low skyline. However, it is possible to minimize this negative impact by improving the design of the coaches and infrastructure. Moreover, it is possible to create new urban scenery by introducing a well-designed rail transit system.

(4) Future Expansion of the System

It is possible to cope with future passenger demand by increasing the number of coaches of the candidate rail transit systems, except the Tramway. In the case of the Tramway, it is necessary to increase its frequency, though such an increase will directly affect vehicular traffic.

(5) Impact on Road Traffic

Tramway operation uses the same space as vehicular traffic. Therefore, Tramway operation will have a negative impact on vehicular traffic.

(6) Flexibility of Geometric Design (minimum curvature, maximum longitudinal slope and tunnel cross-section)

It is possible to minimize the curvature in the case of the AGT and the Tramway. On the other hand, it is possible to use a bigger longitudinal slope for the Linear Metro, Monorail and AGT. These systems have more advantages when constructed in dense urban areas. Moreover, it is possible to reduce the size of the tunnel cross-section for the AGT as compared to the other systems. This can bring down construction cost.

(7) Operational Reliability (Maintaining a Stable Operation Speed)

A transit system, excluding the Tramway, has exclusive operational space such as elevated and underground. Therefore, it is possible to maintain a stable operation.

(8) Countermeasures for Heavy Rain and Emergency

The operation of a Tramway system may be affected during heavy rain because its structure is at-grade. The Monorail, on the other hand, has a negative impact on passenger safety in case of fire because its rail structure would not be able to provide an evacuation route.

(9) Passenger Comfort (Transfer)

The Tramway system has an advantage in passenger transfer because it is at-grade and many coaches are now of the low floor type.

(10) Consideration for the Urban Environment (Noise, Vibration and Air Pollution)

The Linear Metro, LRT and Tramway, which run on steel rails, have disadvantages of noise and vibration.

(11) Preliminary Cost Including Infrastructure

Based on actual cost data, the LRT and Tramway systems, which cost less than USD50 million/km, may be economically advantageous for Cambodia.

(12) Operational Cost (Maintenance and Reduced Labor Cost)

The Linear Metro has a disadvantage in maintenance because of its sensitive reaction plate and high electricity consumption rate. The AGT has an advantage in terms of reduced labor cost because of the automated system operation.

(13) Ease of Procurement

There are many examples of LRT and Tramway systems around the world.

(14) Advantage of the Japanese Technology

Japanese technology has advantages of sensitive and detailed measures to produce rail transit systems and good maintenance systems. There are many examples of the Linear Metro, Monorail and AGT systems in Japan.

(15) Potential of System Development

It is believed that any company involved in the production of rail transit systems is always looking for ways to produce the best systems as possible.

3.3 Conclusion

From the foregoing evaluation, it is found that the AGT is the optimum rail transit system for the East-West transport corridor. Several reasons may be given for the choice of the AGT, as shown in Table 3.2-1 and discussed above. These may be summarized as follows:

Among the alternative rail transit systems, the AGT is the most flexible system in terms of geometric design, is environment-friendly, and has advantages of Japanese innovative technologies.

Table 3.1-1 Outline and Specifications of Candidate Public Transport Systems

System			Linear Metro	Monorail	AGT	LRT	Tramway
Route Name			Green Line/Yokohama	Yui-Rail/Okinawa	Sengkang/Punggol LineSingapore	Line 1/Manila	Hiroshima Electric Railway
Vehicle Type			1000 Series	1000 Series	Crystal Mover	3rd Generation	5100 Series (Green Mover Max)
Train Overview							
Tire/Wheel			Steel Wheel (Linear Motor)	Rubber Tire	Rubber Tire	Steel Wheel	Steel Wheel
Bogie Structure			2 Bogies(4 Axles)	2 Bogies(4 Axles)	2 Axles(no Bogie)	3 Bogies(6 Axles)	3 Bogies(6 Axles)
Car Body Structure			1 Body/1 Car	1 Body/1 Car	1 Body/1 Car	2 Bodies/1 Car (1-Articulated)	5 Bodies/1 Car (4-Articulated)
Dimension	Length		15,500	14,700	11,200	26,500	30,000
(mm)	Width		2,490	2,980	2,690	2,590	2,450
	Height		3,105	5,100	3,615	3,910	3,645
Alignment	Minimum Curve Radius (m)		160 (100)	100 (50)	100 (30)	160 (100)	11
Criteria *1	Maximum Gradient (‰)		60	60 (100)	60 (100)	35	40
Electric Sysytem			DC 1500V	DC 1500V	DC 750V	DC 750V	DC 600V
Power	per One Motor		135	100	80	105	100
(kW)	Total Fleet Power		1,080	600	160	630	400
Vehicle	Max. Operation Speed	(km/h)	80	65	70	60	70
Performance	Acceleration	(km/h/s)	3.2	3.5	3.6	4.0	3.5
	Normal Deceleration	(km/h/s)	3.5	4.0	3.6	4.7	4.8
Car Capacity	Normal Ride	(3.3 persons/m2)	95	82	72	199	149
(persons/car)	Peak Hour Ride	(6 persons/m2)	144	122	115	305	225
Train	Configuration	(cars/train)	4	2	1	4	1
Capacity	Frequency	(trains/hour/1direction)	16	11	17	20	13
(Actual Result)	Capacity	(PHPDT)	9,216	2,684	1,955	24,400	2,925
Max.	Configuration	(cars/train)	6	6	6	4	1
Train	Frequency	(trains/hour/1direction)	30	30	30	30	30
Capacity	Capacity	(PHPDT)	25,920	21,960	20,700	36,600	6,750
Weight	Tare Weight of Motor Car		26.0	26.3	14.9	36.5	33.9
(t)	Passenger	Normal	5.7	4.9	4.3	11.9	8.9
	Weight	Pear Hour	8.6	7.3	6.9	18.3	13.5
	Total	Normal	31.7	31.2	19.2	48.4	42.8
	(Tare+Passenger)	Peak Hour	34.6	33.6	21.8	54.8	47.4
Axle Load (t)	with Maximum Passengers		9.8	9.3	12.9	10.7	7.5
Car Weight per Passenger (Nomal)		(t/person)	0.33	0.38	0.27	0.24	0.29
Line Length		(km)	13.1	12.9	20.2	20.0	21.5
Unit Cost of Construction	Total	(Million USD/km)	184	86	(N.A)	約 50	(N.A)
	Rolling Stock	(Million USD/car)	1.3	2.5		約 2	3.2
	Precondition		Actual result of Yokohama Major part is underground (Underground 10.7 km, Surface 2.4 km)	Actual result of Okinawa Monorail	Actual result in Japan About USD55～140 Million/km	Assumed value of Manila Line1	Actual result of Hirosima Electric Railway

Note: Figures of each system include assumed value by calculation. Therefore, some values may be different from those stated by the manufacturers.
*1: According to Japanese railway criteria / ( ) unavoidable case

Source: PPUTMP Project Team

Table 3.2-1 Evaluation of the Rail Transit System Alternatives

	Item	**Linear Metro**	**Monorail**	**AGT**	**LRT**	**Tramway**
						
1	**Passenger capacity**	Applicable	Applicable	Applicable	Applicable	Partially applicable
2	**Contribution to urban development**	Possible	Possible	Possible	Possible	Possible
3	**Contribution to urban environment (urban scenery)**	Possible	Possible	Possible	Possible	Possible
4	**Applicability to the staging (flexibility for future expansion)**	Possible	Possible	Possible	Possible	A little difficult
5	**Impact to vehicular traffic**	None	None	None	None	Yes
6	**Flexibility to geometric design**	Difficult for small radius of curvature but possible for steep gradient	Possible for small radius of curvature and steep gradient	Possible for small radius of curvature and steep gradient	Difficult for small radius of curvature and steep gradient	Difficult for small radius of curvature and steep gradient
7	**Operational reliability (operational speed and travel time)**	High reliability because of exclusive right of way	High reliability because of exclusive right of way	High reliability because of exclusive right of way	High reliability because of exclusive right of way	Mixed with vehicular traffic
8	**Countermeasures for heavy rain and emergency**	Possible	Difficult to secure	Possible	Possible	Affected by flood
9	**Passenger comfort (transfer)**	Different levels during transfer between other modes	Different levels during transfer between other modes	Different levels during transfer between other modes	Different levels during transfer between other modes	Same level during transfer
10	**Urban environment (noise, vibration and air pollution)**	Steel wheel	Quiet because of rubber tire	Quiet because of rubber tire	Steel wheel	Steel wheel
11	**System cost**	USD160 mil./km - USD310 mil./km	USD90 mil./km - USD150 mil./km	USD50 mil./km - USD130 mil./km	Manila LRT No. 1 USD50 mil. /km	Systra Study USD20 mil./km
12	**Running cost (maintenance and work savings)**	Relatively high	Relatively high	Relatively high	Relatively high	Relatively low
13	**Ease of procurement**	Limited development	Limited development	Limited development	Globally popular	Globally popular
14	**Advantages of Japanese technology**	Has technical advantages because it is much developed and widely used in Japan	Has technical advantages because it is much developed and widely used in Japan	Has technical advantages because it is much developed and widely used in Japan	Few development examples in Japan	Few development examples in Japan
	Overall Evaluation	**Applicable in Phnom Penh but more effort needed to develop as the elevated system**	**Applicable in Phnom Penh**	**Highly applicable in Phnom Penh**	**Applicable in Phnom Penh**	**Some corridors can be used**

Source: PPUTMP Project Team

4. Preliminary Route Alignment Study

4.1 Criteria for Route Alignment Plan

(1) Design Standards

The design standards for the AGT system is shown in Table 4.1-1, which are the basis of the most suitable railway system route planning and selection of depot location.

Table 4.1-1 Design Standards for AGT Planning

Item	Standard	Remarks
Gauge	1,850 mm	
Distance between center of tracks	4,000 mm	
Minimum curve radius, for both main line and depot	100 m	Unavoidable case: 30 m
Maximum gradient	60/1000	
Minimum vertical curve radius	1,000 m	
Turnout dimension	See attached figures	
Maximum operating speed	70 km/h	
Operation system	• Unattended Train Operation (UTO) can be applied. • Operation system is decided by responsible proprietor.	
Location for centralized traffic control	Operation Control Center (OCC)	
Electric power system	Direct current 750V	
Electric current collection system	Third rail	

Source: PPUTMP Project Team

(2) Planning Policy to Select the Most Suitable Railway System

The basic concept for planning the most suitable railway system should meet the following objectives:

(i) To select the location of each station, the intervals between stations should be well-balanced and convenient for passengers;
(ii) To decrease the negative impact on smooth vehicular traffic;
(iii) To decrease the purchase of private lands by making use of public land such as roads;
(iv) To decrease construction cost and future maintenance and management costs;
(v) To shorten as much as possible the length of tunnel section, the cost of which is comparatively larger than viaduct section;
(vi) To maintain good ride quality and to decrease maintenance cost, too small curvature is to be avoided except in unavoidable cases; and

(vii) To decrease the effect on the environment.

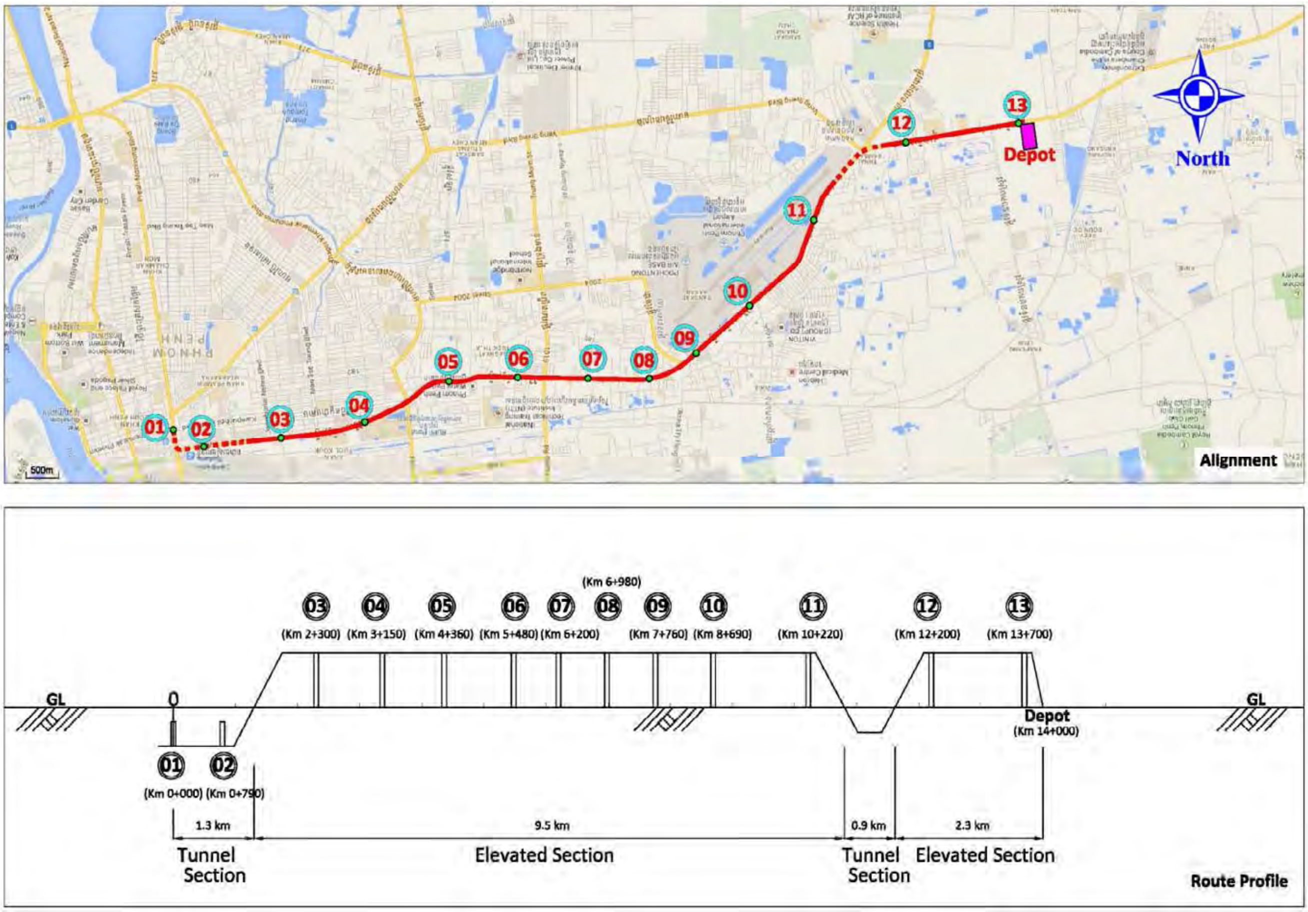
(3) Selection of Depot Location

Following are the basic principles for selecting a suitable depot location:

(i) The depot area should be more than 7 or 8 ha for the stabling of rolling stock, maintenance facilities, etc. for the present planning and future expansion;
(ii) The depot location should be selected near the operational line and it should be easy for trains enter into and depart from the depot; and
(iii) To make land acquisition as smooth as possible, the depot area should be selected in a place where it is not being used for some definite purpose and where structures such as buildings and houses are few.

4.2 Railway System Route Planning of Each Section

The outline of the planned line alignment and longitudinal cross-section is shown in Figure 4.2-1. They are described in more detail by railway section in the following section (Note: "Reference drawing No.:" refers to the Drawings Volume in the Appendix).



Source: PPUTMP Project Team

Figure 4.2-1 Outline of Planned Line Alignment

(1) Sta. No. 1 at the Starting Point of the Line (0k 000m) (SHEET No. 1)

The center of Sta. No.1, as the central station of the city, is planned at the starting point of the line where Monivong Blvd. and Kampuchea Krom Blvd. cross each other. Monivong Blvd. is located at the central area from north to south, and Kampuchea Krom Blvd. from east to west starting at the Central Market.

Sta. No.1 is planned to be the underground station so as not to disturb the road traffic. It will be valuable to examine the renovation of the neighboring area of Sta. No.1 to become a more potential, convenient and comfortable area in future.

The underground station of Sta. No.1 is planned to be box type. The surface of the station from the ground is planned to be about 5 m deep to leave space for utilities such as water and sewage, gas supply, and electric power. The railway level from the ground is planned to be 16 m deep to reserve station concourse floor space, and platform and railway floor space. The width of the underground station is planned to be 19 m. The width of the island platform will be 9 m and the distance between centers of tracks will be 12 m.

(2) Section from Sta. No. 1 (0k 000m) to Sta. No. 3(2k 300m) (SHEET Nos. 1～3)

After Sta. No. 1, the route is located on the curve of 90 m radius and enter into Russian Blvd. The curve of 90 m radius is being settled to avoid the necessity of getting private land. Next to this curve, the route is located below the center of a long park in front of the Municipality Council of Ministries, etc. along Russian Blvd. on a straight line with 4 m of distance between centers of tracks.

The route goes up by a gradient of 20/1000 from 0k 500m to 0k 600m. After having risen approximately 2 m in height, Underground Sta. No. 2 (0k 790m) is planned at the flat section. After this section, a changing point of gradient at 0k 900m is being planned and the route of the tunnel goes up by a gradient of 40/1000. The route of the tunnel goes through the point of Czechoslovakia Blvd. having reserved 3 m of depth from ground level to the top of the box tunnel. After this point, the tunnel section ends and the railway makes appears at a U-shaped retaining wall section within the park in front of the National Defense Ministry. The elevated section begins, and the viaduct goes over Jawaharlal Nehru Blvd., having reserved more than 5.2 m overhead clearance from the road surface.

To decrease the effect on the park environment, a tunnel is being planned under the center of the park. Following the tunnel section at the western part of the park, the route goes up by a gradient of 40/1000 to be able to cross under or over the existing roads.

At the crossing point with Jawaharlal Nehru Blvd., the route transfers to Russian Blvd. from the center of the park. To transfer the route and to reduce the acquisition of private land, the reverse curve of 730 m radius is being planned.

After having passed the reverse curve at the point of 1k 650m, a change point of gradient from 40/1000 upward to 8/1000 downward is being planned. A flat and straight section continues, next to the 8/1000 downward section of 100 m in length.

(3) Section from Sta. No. 3 (2k 300m) to Sta. No. 4 (3k 150m) (SHEET Nos. 3～4)

This is the flat and viaduct section. This section is the environmentally superior school zone where the Institute of Technology of Cambodia, Royal University of Phnom Penh, etc. are located. Station 3 and Station 4 are being planned in front of each university.

(4) Section from Sta. No. 4 (3k 150m) to Sta. No. 5 (4k 360m) (SHEET Nos. 4～5)

Around the point of 3k 500m, there is a road viaduct along Russian Blvd. to cross over the road. The route is being planned at the side of the road viaduct so as not to make contact with it. Near the road viaduct, there are service stations, etc. The route is planned to reduce the purchase of private lands. The route is planned to settle the reverse curve of 800 m and 600 m before and after Sta. No. 4. At the point of 3k 700m, the curve of 1,200 m is planned as well.

(5) Section from Sta. No. 5 (4k 360m) to Sta. No. 9 (7k 760m) (SHEET Nos. 5～8)

The section consists of an existing commercial zone along the street. To select the suitable point of each station, the expected number of passengers, convenience of passengers, and suitable intervals between each station are being taken into consideration.

(6) Section Close to Phnom Penh International Airport

The vicinity of this section is developing as a new commercial zone along the street. Sta.No.10 is planned to be the junction with Phnom Penh International Airport.

It was recognized that in case a viaduct might be planned for the section between Sta. No. 11 and Sta. No. 12, it would violate the aerial restriction area. To avoid this violation, the section is being planned as a tunnel section of 40/1000 downward after having passed Sta. No. 11, a flat section from 10k 942m to 11k 478m, and 40/1000 upward. The transfer of bus transit passengers from National Roads No. 3 and No. 4 is expected to increase the demand for the AGT system.

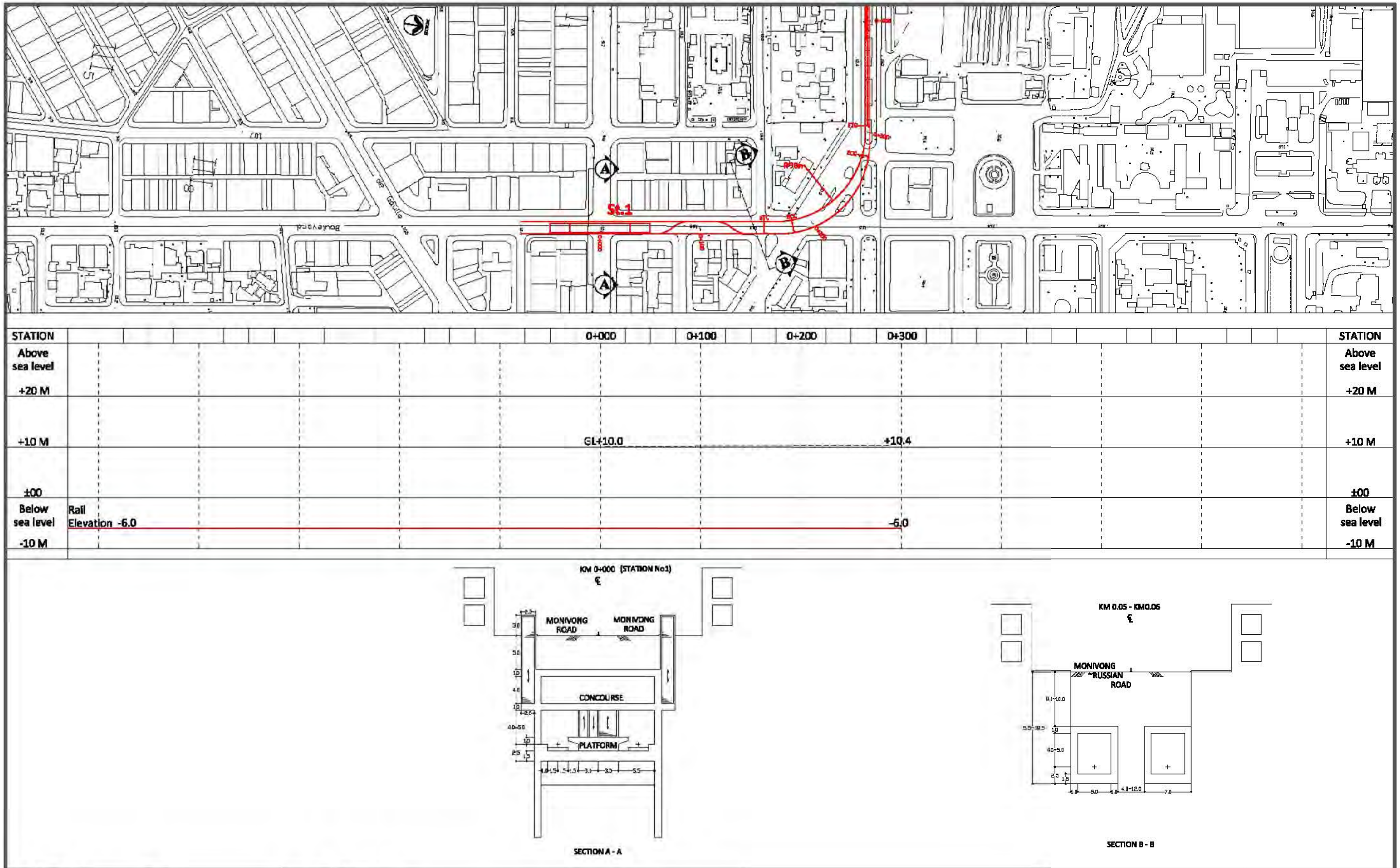
(7) Section from Sta. No. 12 (12k 200) to Sta. No. 13 (13k 700m) (SHEET Nos. 12～13)

A viaduct is planned for this flat section. After having passed Sta. No. 13, the route is connected with the depot planned at the neighboring wide area.

(8) Depot Location

The location of the depot is shown on SHEET No. 14. The depot is located at the vicinity of National Road No. 4. The planned area is 18 ha wide and seems not to be used sufficiently. The location where to connect Sta. No. 13 and the depot is also shown on SHEET No.14.

By planning the long-distance bus terminal for buses, the convenience of passengers will be increased. The transfer of bus transit passengers from National Roads No. 3 and No. 4 is also expected to increase the demand for the AGT system.



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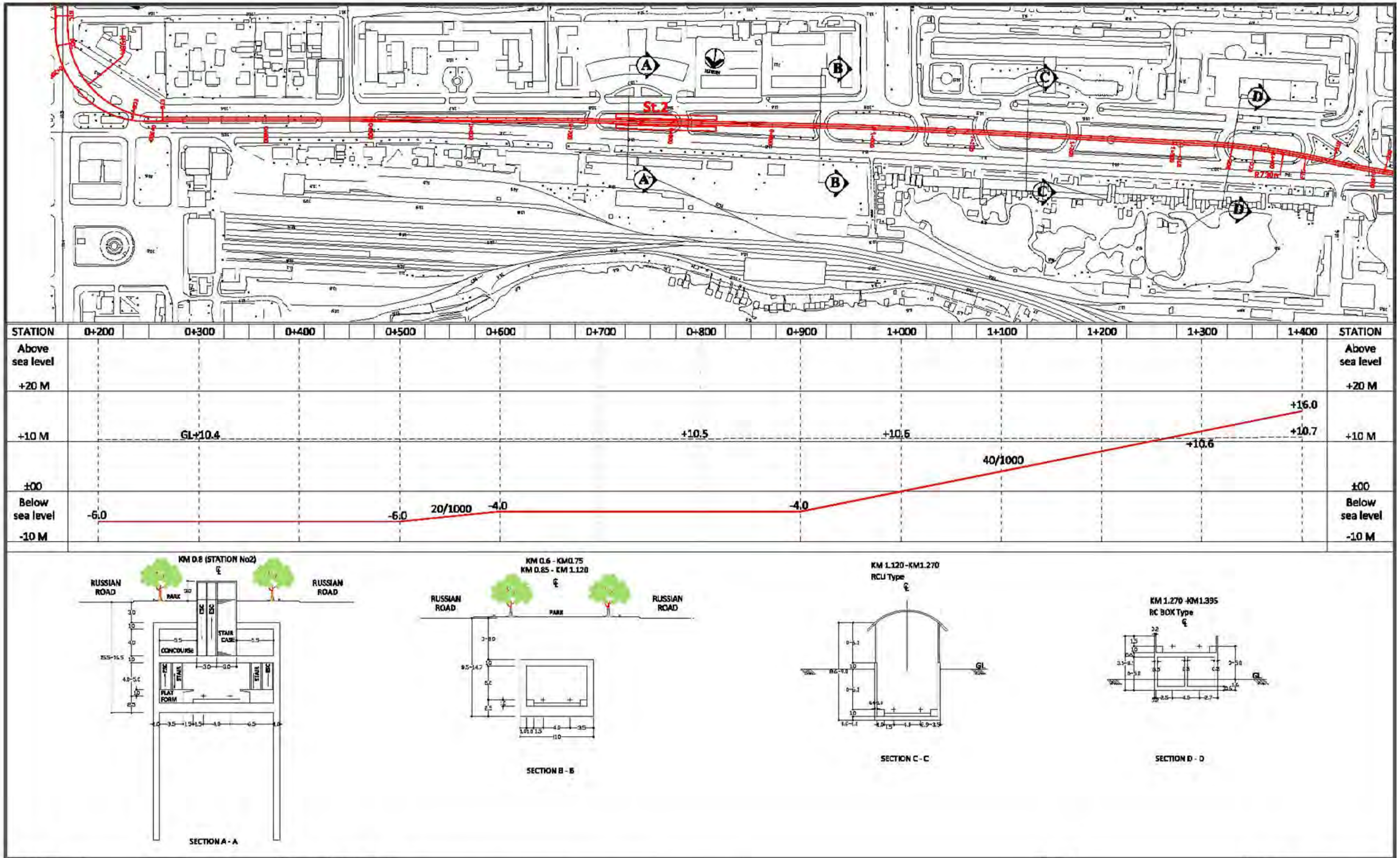

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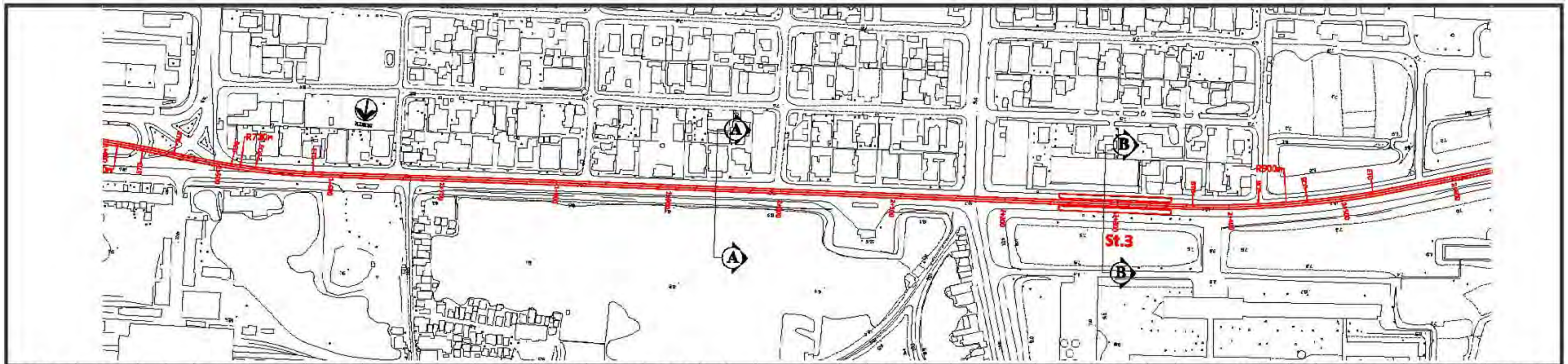

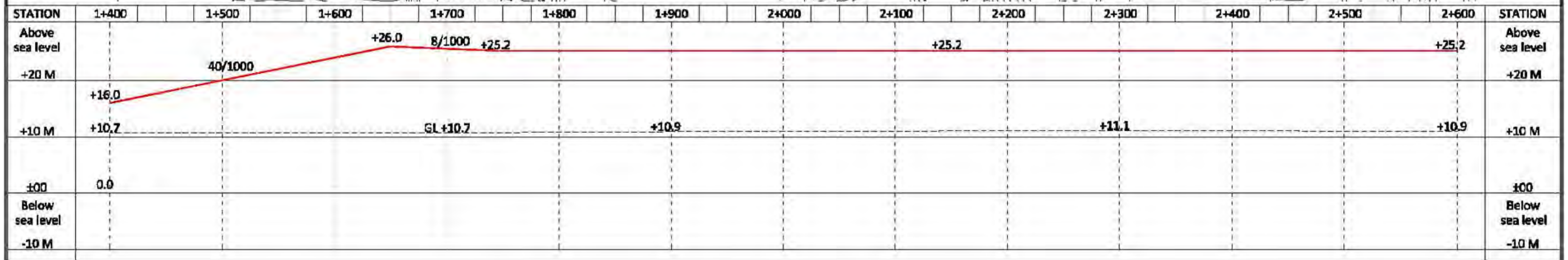

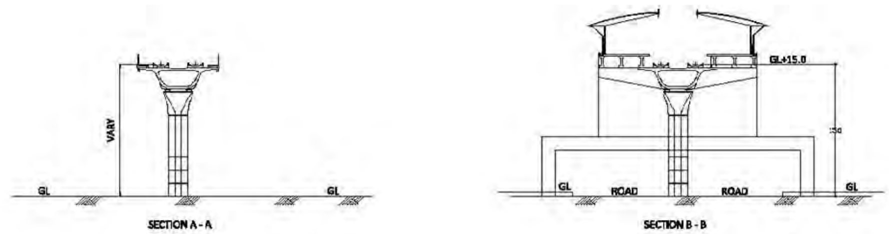

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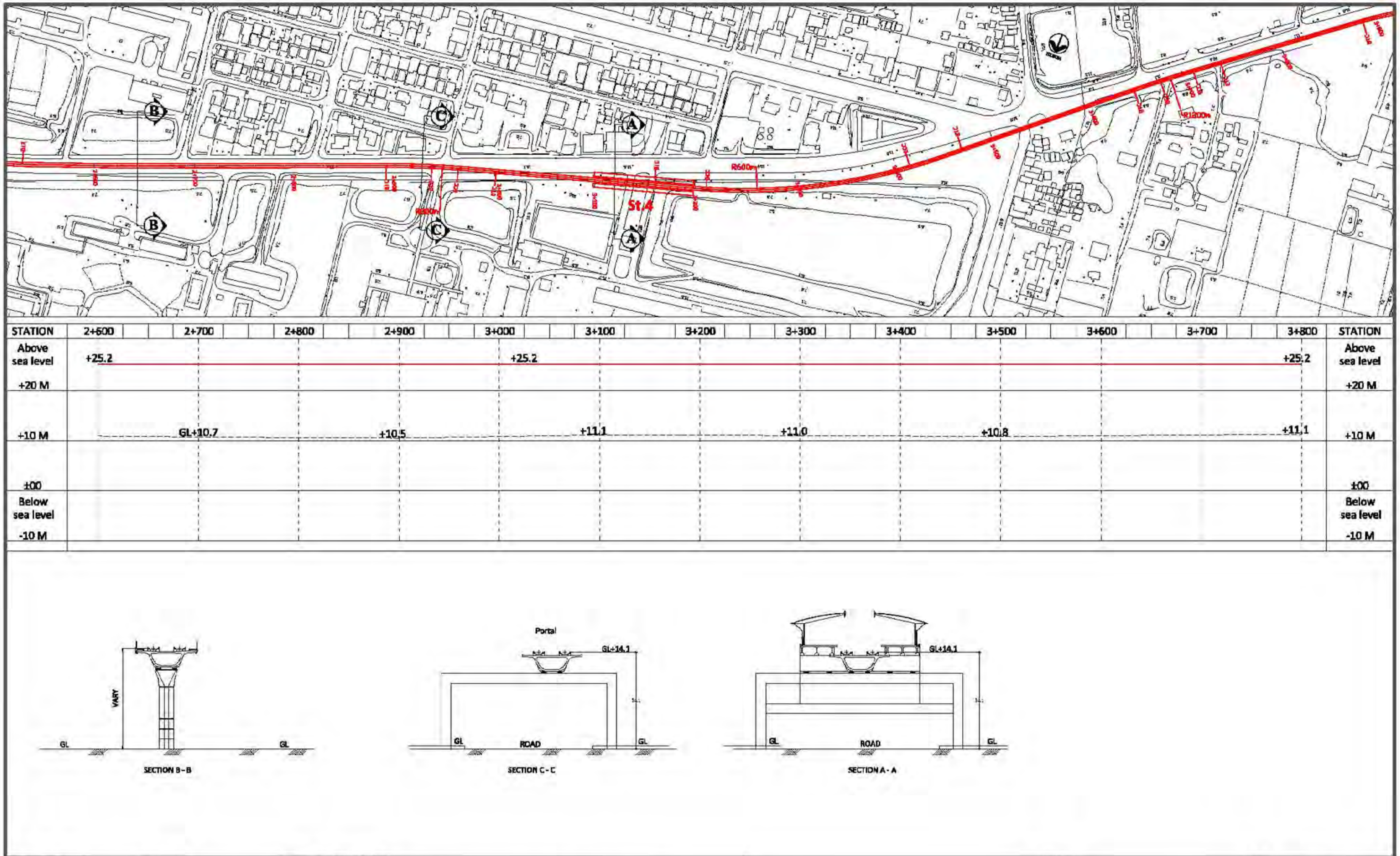

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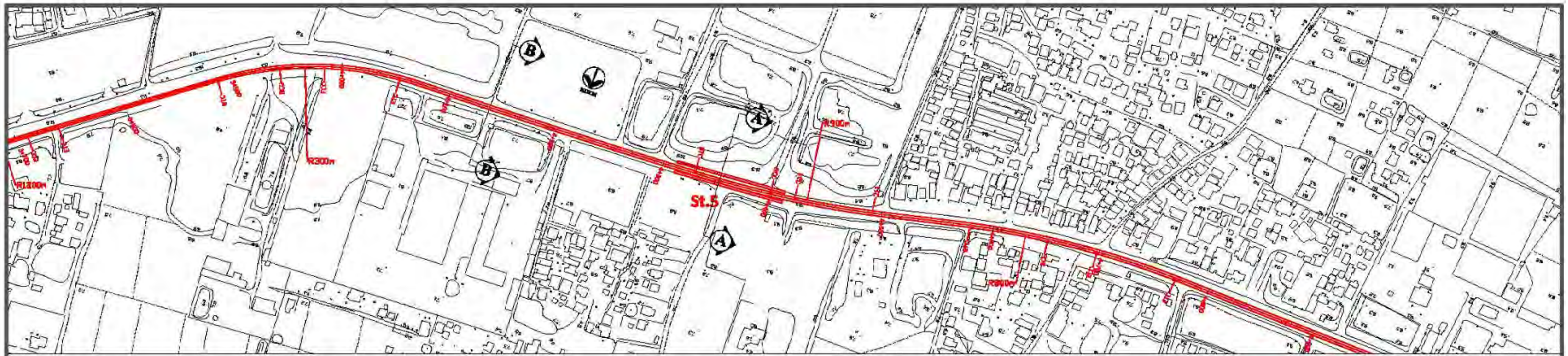

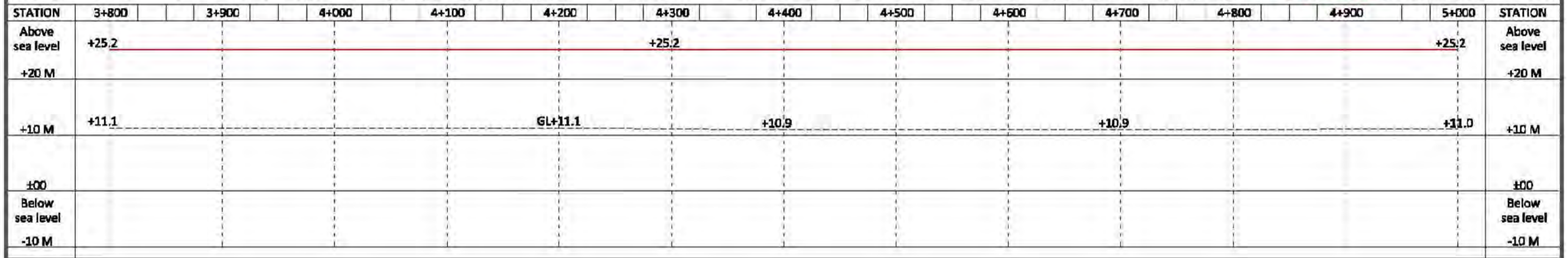

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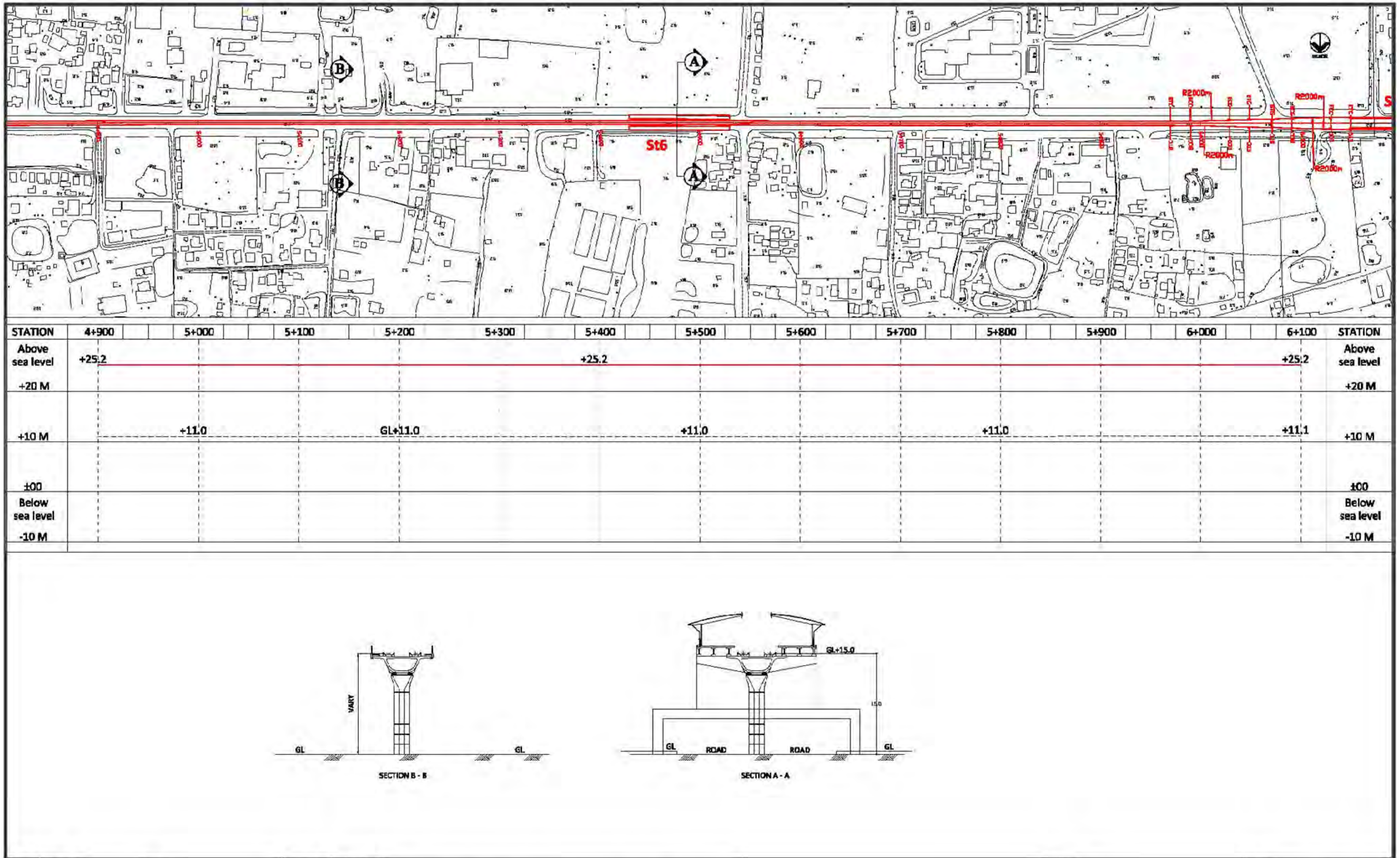

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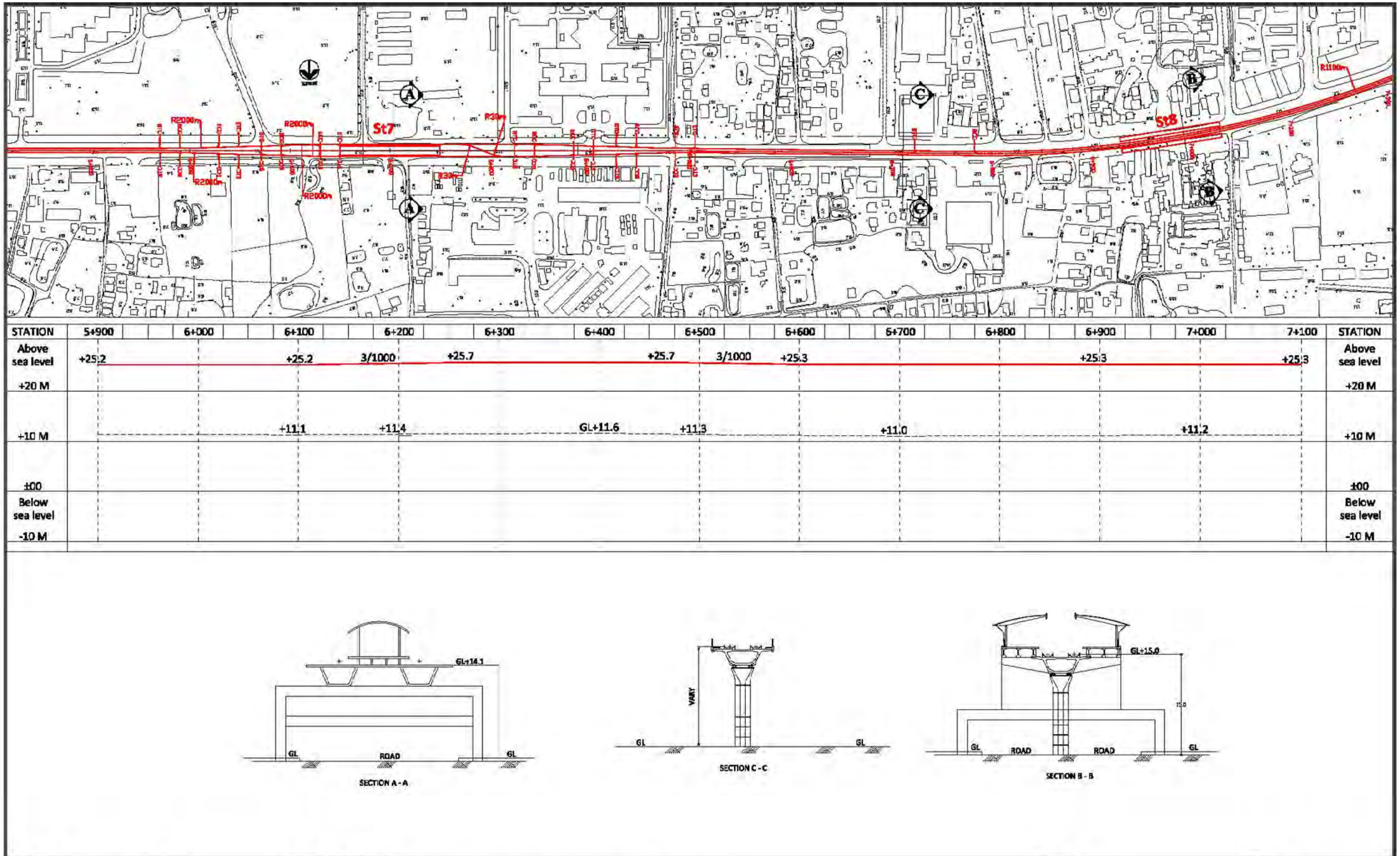

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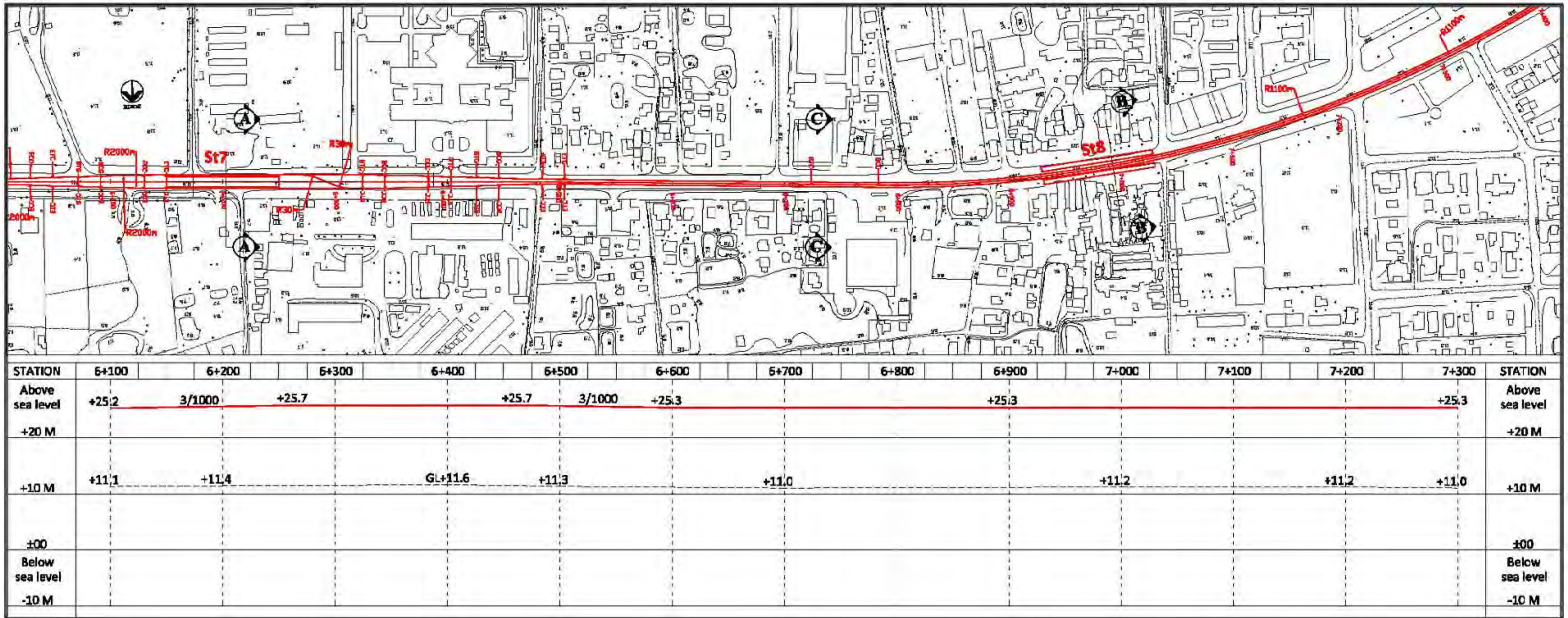

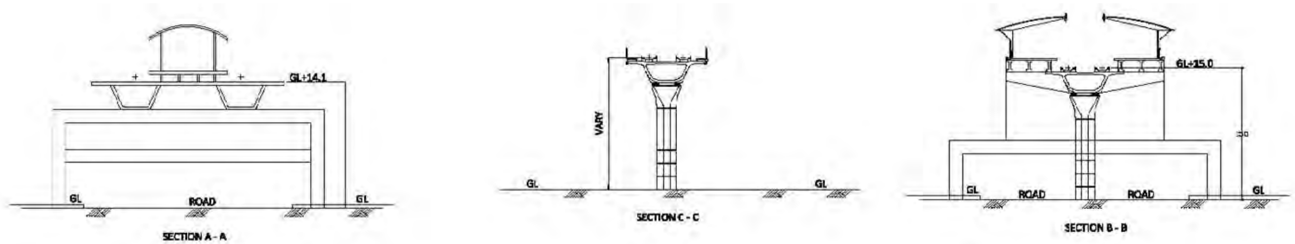

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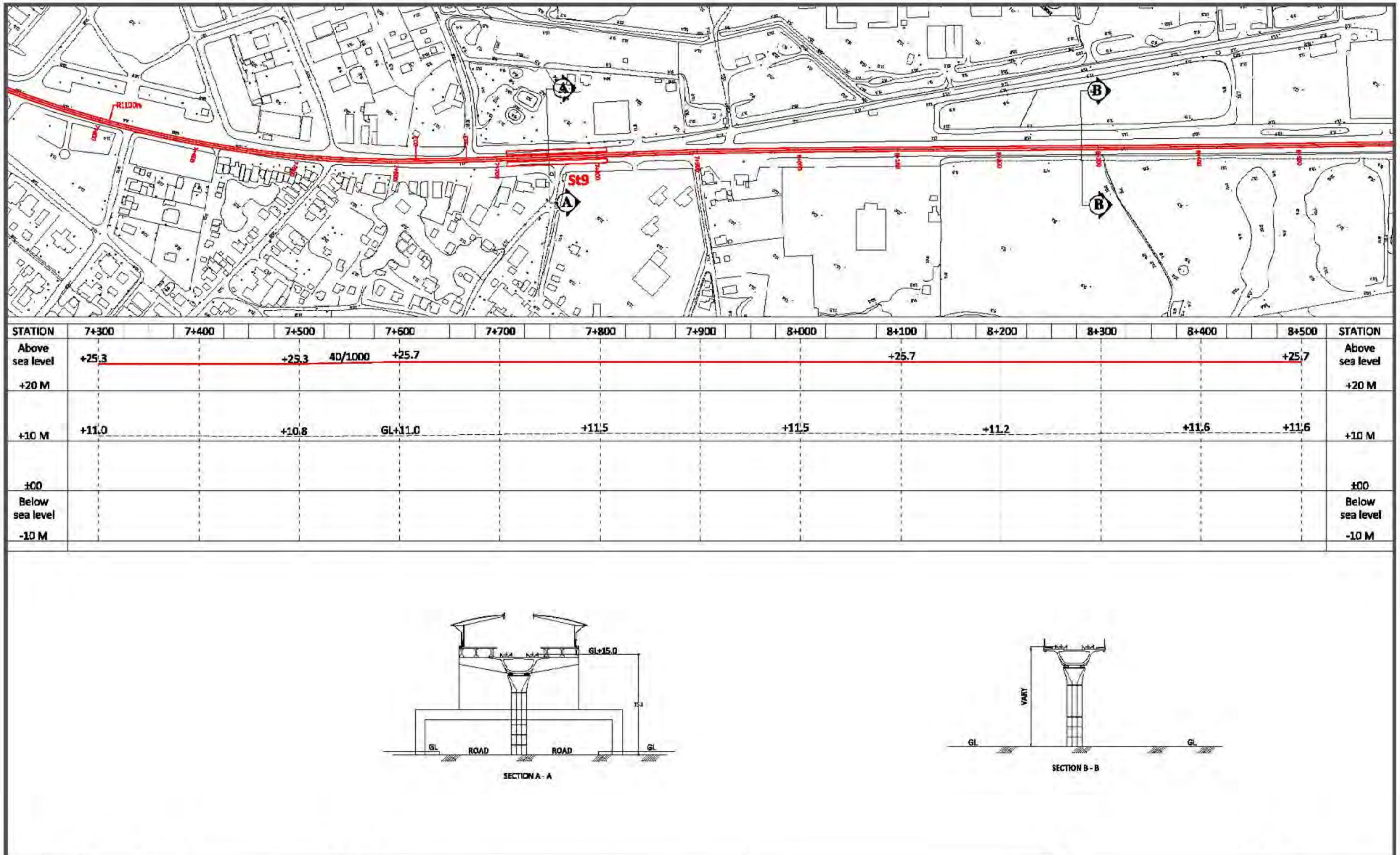

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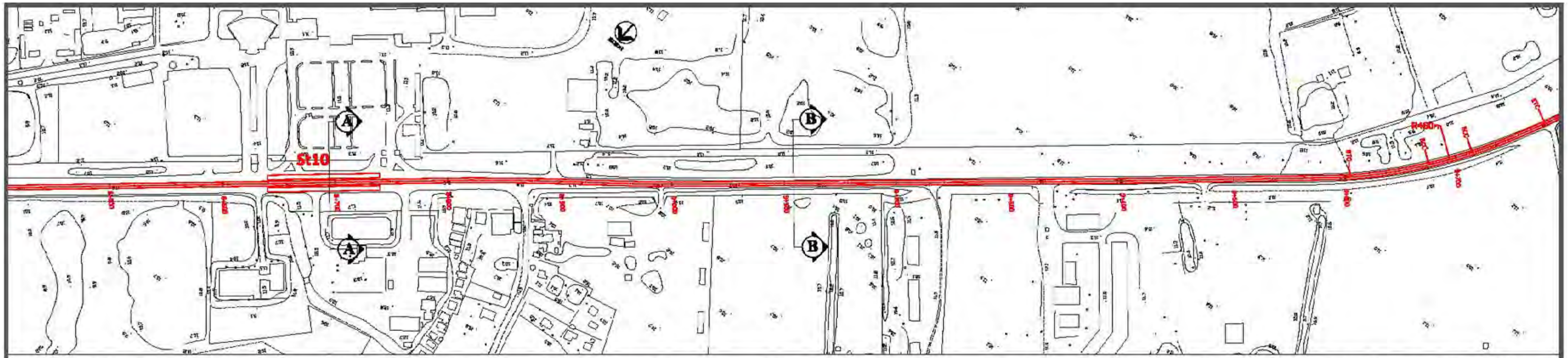

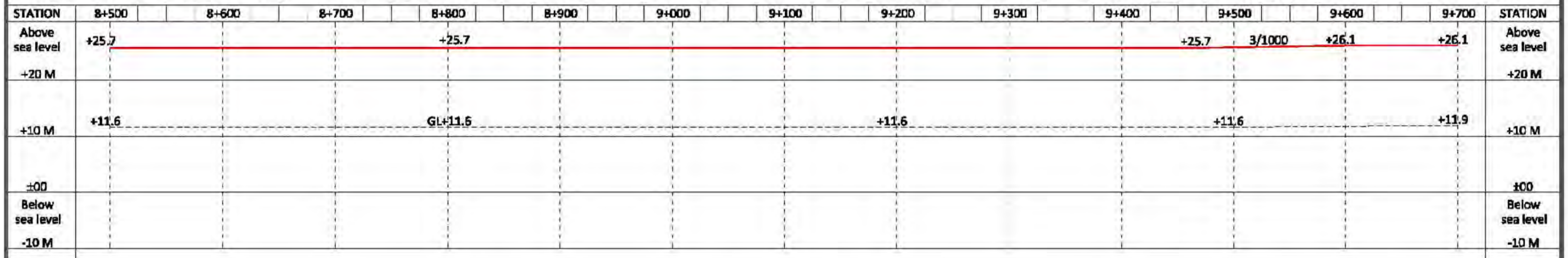

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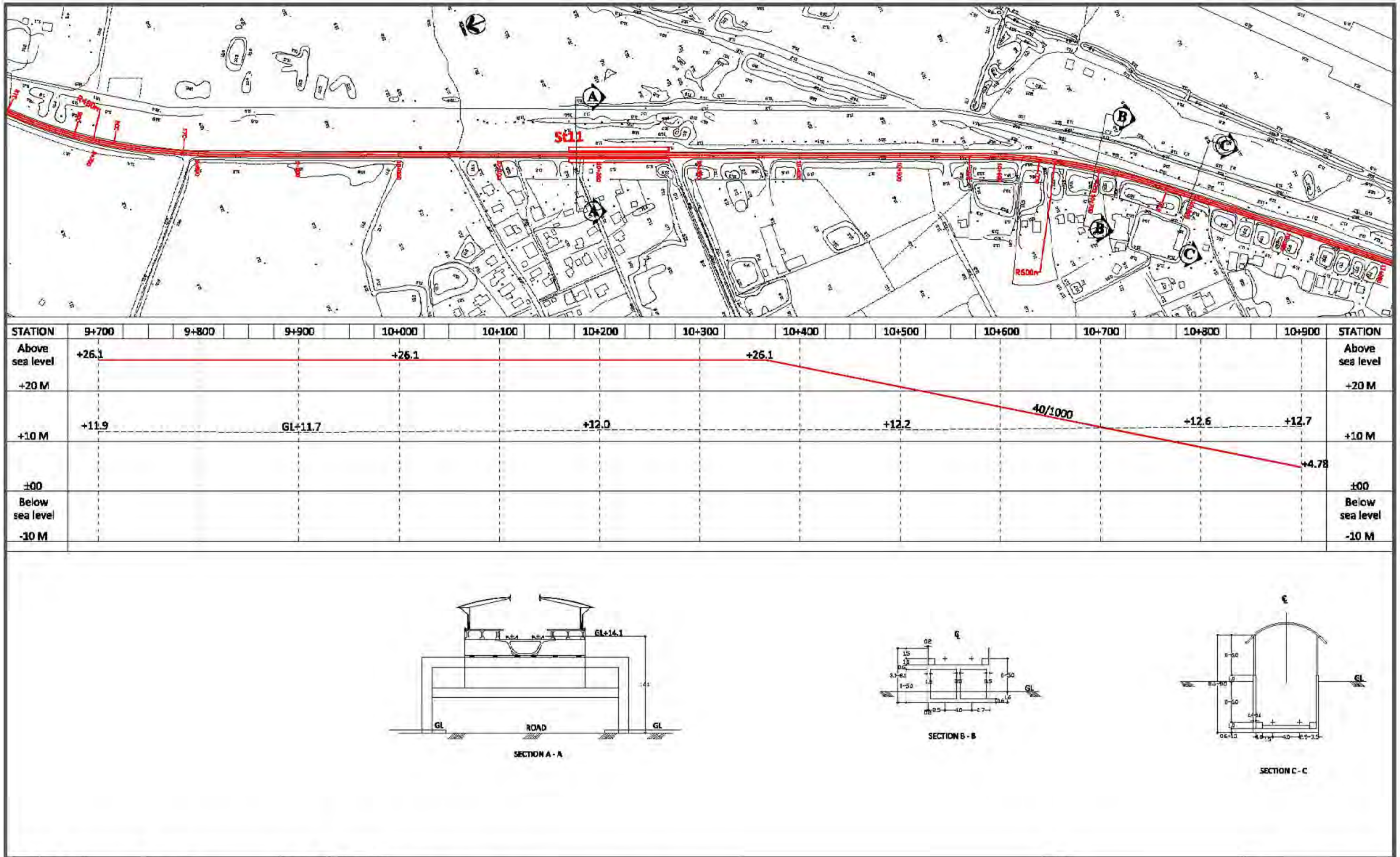

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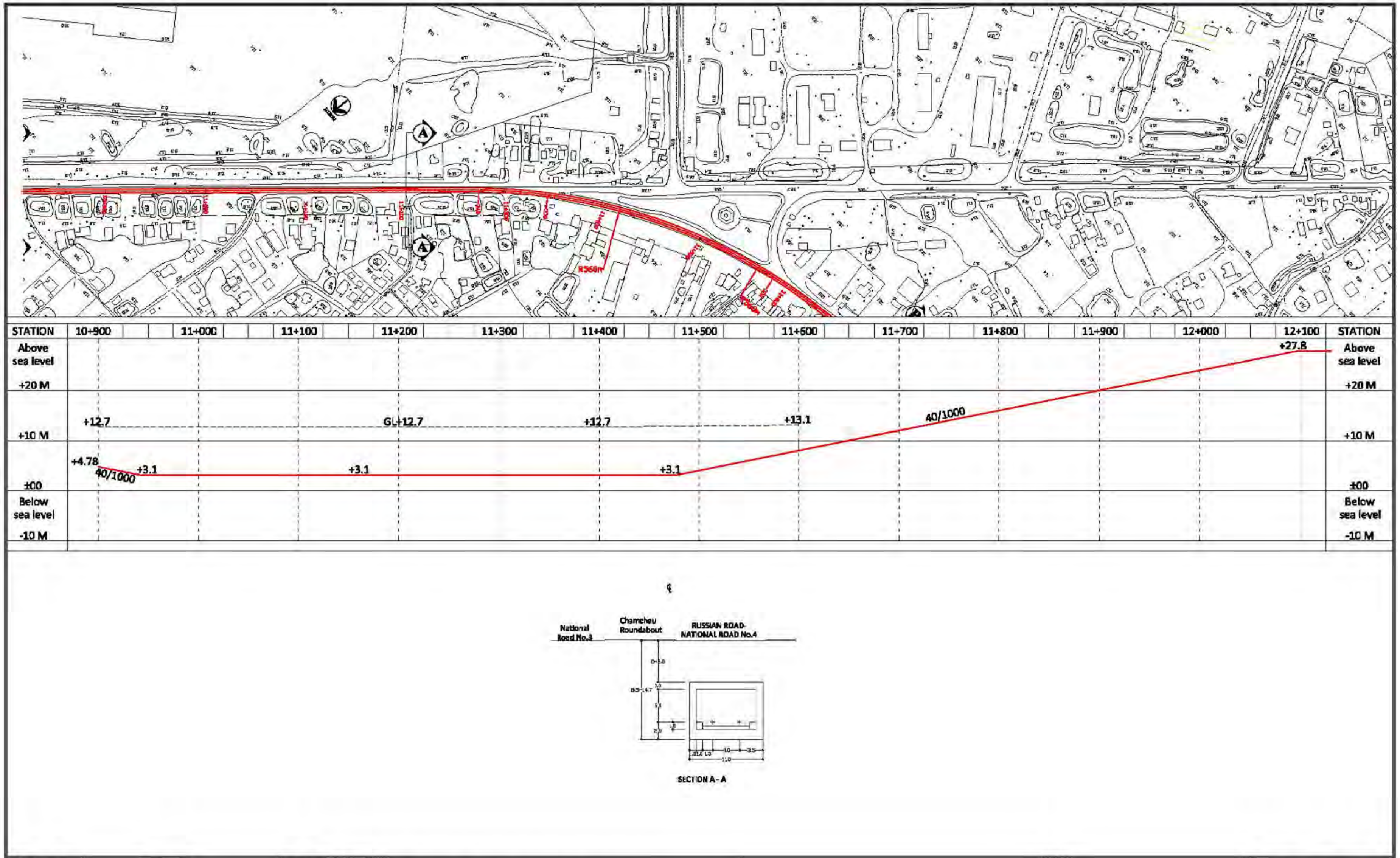

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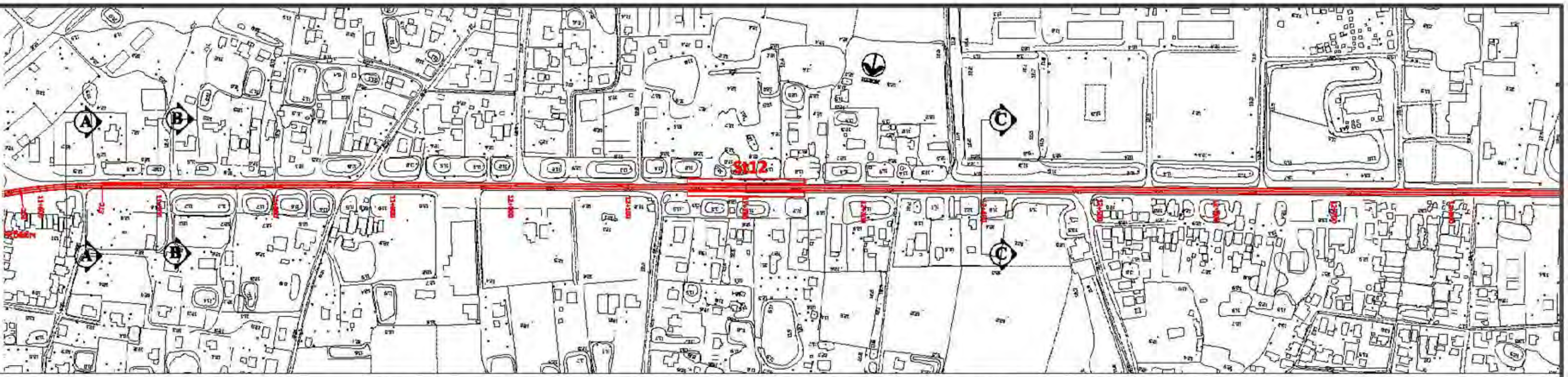

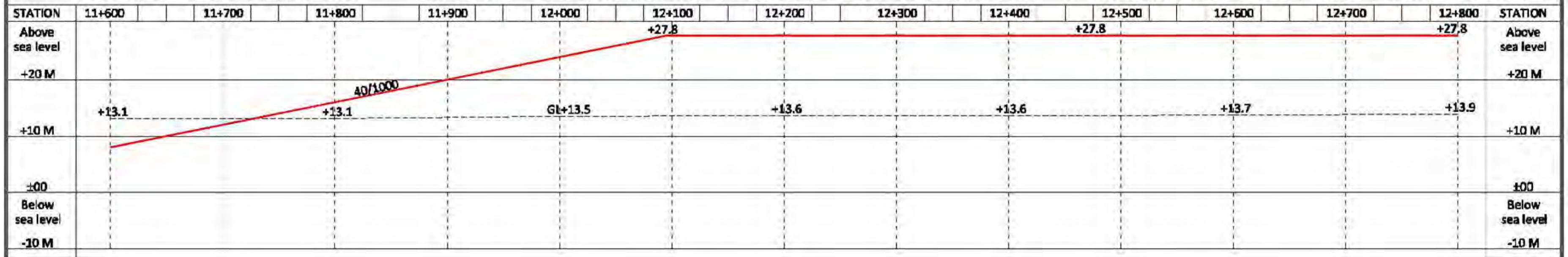

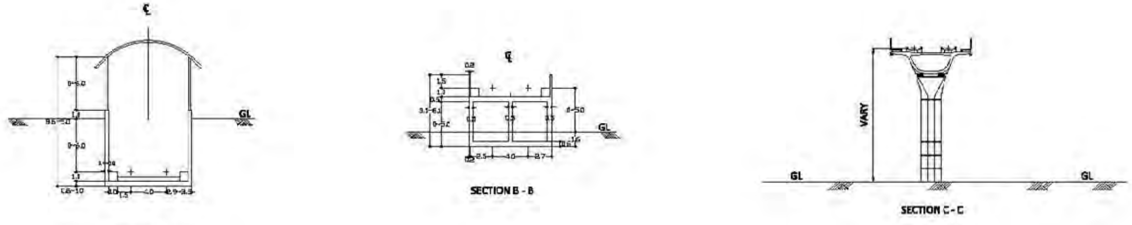

SECTION A - A

SECTION B - B

SECTION C - C

REV.NO.	DATE	DESCRIPTION	APPROVED	PROJECT NAME :		DRAWN:	DATE: 20 March 2014
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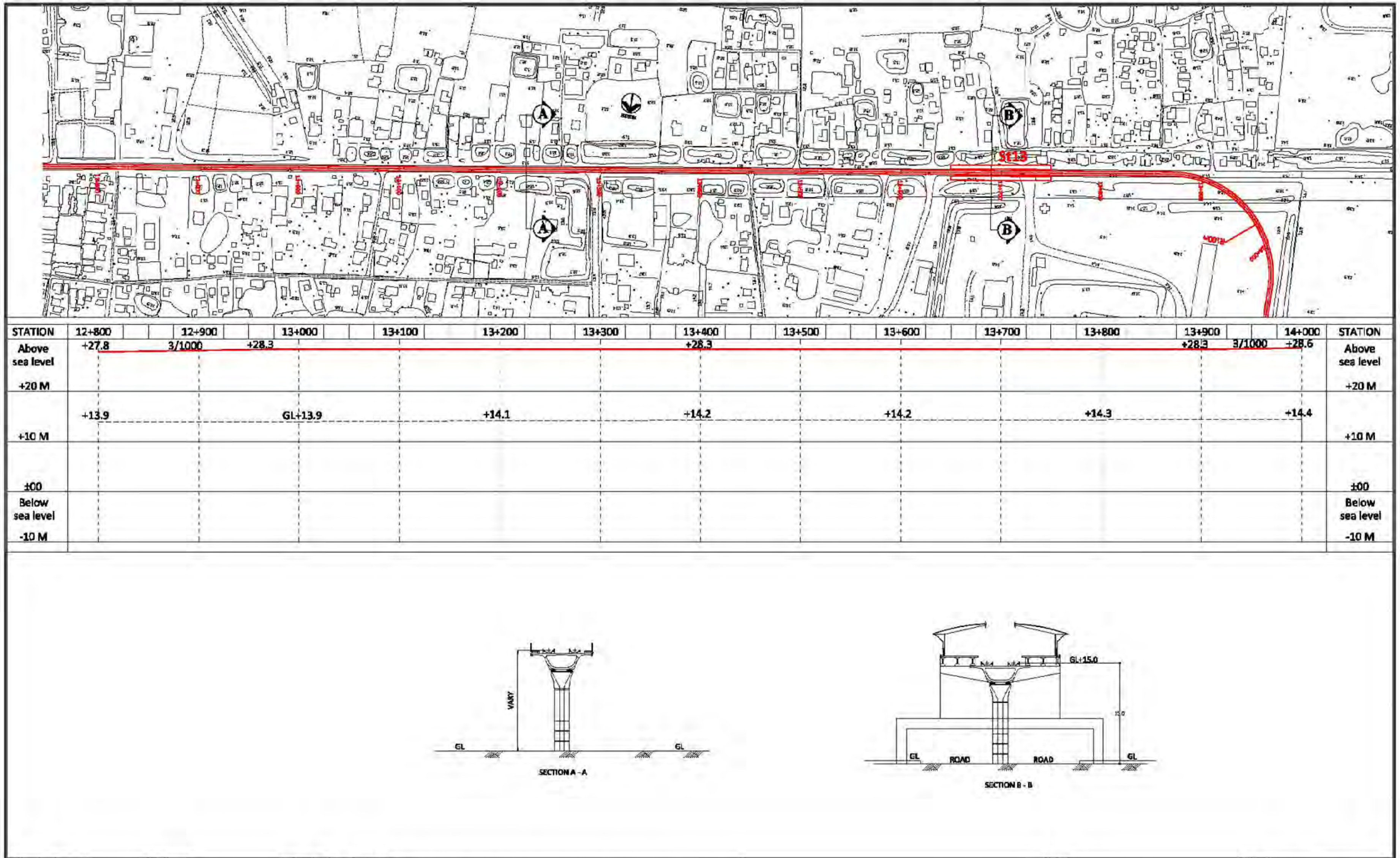

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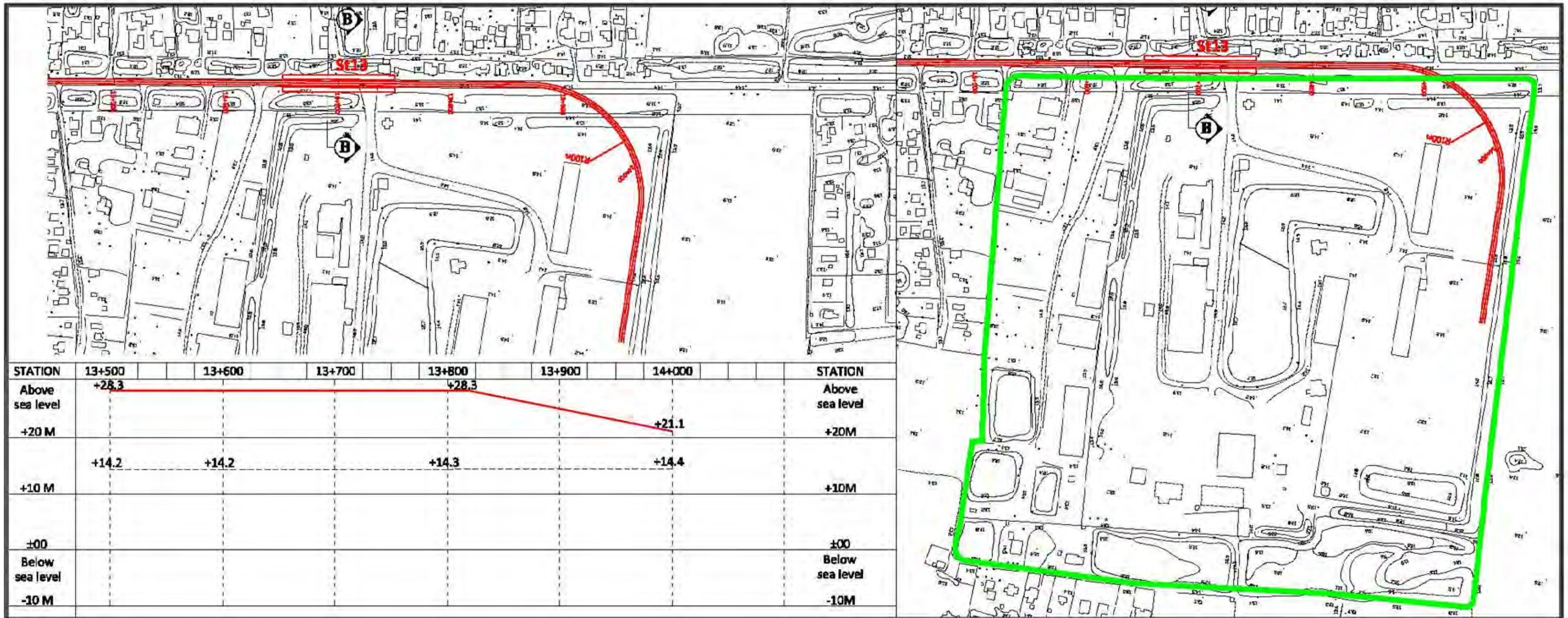

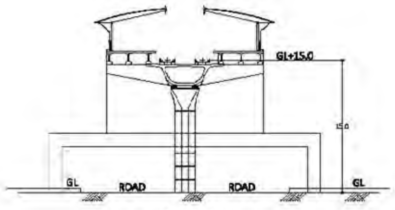

SECTION B - B

REV.NO.	DATE	DESCRIPTION	APPROVED	PROJECT NAME :		DRAWN:	DATE: 20 March 2014
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				PLAN AND PROFILE		DATE:	DWN No. / SHEET No. 14

5. System Operation Plan

5.1 Rolling Stock Plan

5.1.1 Target Passenger Demand

According to the demand forecast, the passenger demand on this railway transit in 2020 and target year 2035 are shown in Table 5.1-1. The demand in 2035 is approximately 82,000 passengers for a whole day, with approximately 6,200 passengers at peak hour per direction (PPHPD). The rolling stock plan is examined as well as the train operation plan to transport this passenger demand and meet further expansion in the future.

Table 5.1-1 Results of Passenger Demand Forecast

	2020	2035 (Target Year)
Whole Day Demand (persons/ day・2 directions	68,000	82,000
Max. Demand at Peak Time (persons/ hour・1 direction)	5,000	6,200

Source: PPUTMP Project Team

5.1.2 Rolling Stock Plan

(1) Transport Plan

The transport capacity of a railway transit system at peak hour is calculated by multiplying the train capacity by the train operation frequency of a peak one hour. Although one train capacity is computed by multiplying one vehicle capacity by the number of vehicles per train, and one vehicle capacity is mostly decided by the size of vehicles, transport capacity is also decided by a combination of the number of vehicles per train and the train operation frequency of a peak one hour.

The railway transit system of this route is assumed to be the AGT system, a medium-sized type introduced in Singapore and Macau. The capacity of one AGT vehicle is about 80 persons as a normal ride (3.3 persons/m^2) and about 110 persons as a peak hour ride (5 persons/m^2, equivalent to 140% load factor). In addition, one vehicle capacity of this route is set considering that this is the first time to introduce a railway transit in Cambodia and its passenger demand is smaller than that of Japan, although one vehicle capacity at a peak hour is 6 persons/m^2 in Japan, equivalent to 150% load factor.

The results of examination of the transport capacity at a peak hour by the combination of the number of vehicles per train and the train operation frequency are shown in Table 5.1-2. To meet the target demand of 6,200 persons/hour・direction and the future increase or expansion with enough margin, it is appropriate to plan for a 3-car train and 20 trains/hour・direction (equivalent to 3 minutes headway).

The maximum capacity of this AGT system is possibly more than 13,000 persons/hour・direction. In the future, plans should prepare for 4-car train stations or the depot.

Table 5.1-2 Results of Examination of Transport Plan

1 Train Capacity

	Normal Ride Capacity (3.3 persons/m2)				Peak Hour Ride Capacity (5 persons/m2)			
	Seating	Standee	Total	Seating/Total	Seating	Standee	Total	Seating/Total
2car-train	36	120	156	23%	36	182	218	17%
3car-train	54	182	236	23%	54	277	331	16%
4car-train	72	244	316	23%	72	372	444	16%

Transport Capacity in Case of 5 persons/m2 (PPHPD)

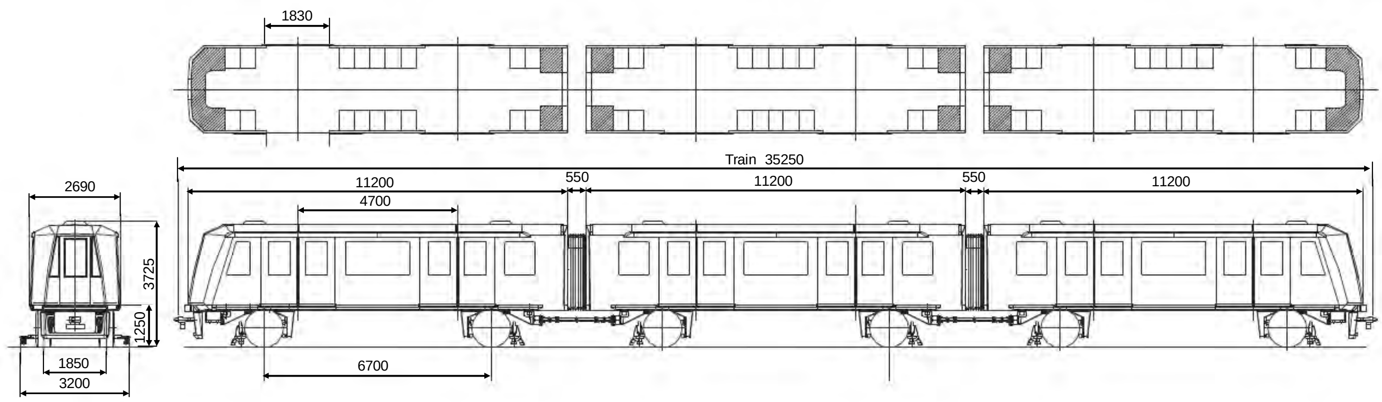
Headway	10 min	6 min	5 min	4 min	3.3 min	3 min	2.5 min	2 min
Frequency	6	10	12	15	18	20	24	30
2car-train	1,308	2,180	2,616	3,270	3,924	4,360	5,232	6,540
3car-train	1,986	3,310	3,972	4,965	5,958	6,620	7,944	9,930
4car-train	2,664	4,440	5,328	6,660	7,992	8,880	10,656	13,320

LEGEND
6,000 -- 7,000
7,000 -- 8,000
8,000 --

Source: PPUTMP Project Team

(2) Image of Vehicle

A sample image of an AGT train configuration is shown in Figure 5.1-1. The dimensions of one vehicle are 11.2 m long (11.8 m including coupler), 2.7 m wide, and 3.7 m high. The total train length of 3 cars is 35.3 m.



Source: PPUTMP Project Team based on the example of Singapore

Figure 5.1-1 Image of AGT Vehicle

(3) Main Specifications of AGT System

The main specifications of the AGT system are shown in Table 5.1-3.

Table 5.1-3 Main Specifications of AGT System

Item		Unit	Content / Value
Type of System			AGT (Automated Guideway Transit) with Rubber Tires
Bogie Structure			2 Axles/car (no Bogie)
Vehicle Dimension *1	Length	(mm)	11,200
	Width	(mm)	2,690
	Height	(mm)	3,615
Tare Weight of 1 Vehicle		(t)	Approximately 18
Alignment Criteria *2	Minimum Curve Radius	(m)	100 (30)
	Maximum Gradient	(‰)	60 (100)
Electric Sysytem			DC 750V
Power Collection Method			Third Rail Sysytem
Power Control Method			VVVF Inverter
Train Configuration			3 cars/train (4 cars/train possible in Future)
Power	per One Motor	(kW)	80
	Total Train Power	(kW)	480 (3 cars/train)
Vehicle Performance	Max. Operation Speed	(km/h)	70
	Acceleration	(km/h/s)	3.6
	Normal Deceleration	(km/h/s)	3.6
Vehicle Capacity	Normal Ride (3.3persons/m2)	(persons/car)	End Car 78 (18 Seated) Middle Car 80 (18 Seated)
	Peak Hour Ride (5persons/m2)	(persons/car)	End Car 109 (18 Seated) Middle Car 113 (18 Seated)
Train Capacity	Peak Hour Ride (5persons/m2)	(persons/train)	331 (3 cars/train)

(Note) *1 : Value of Singapore Type Vehicle
*2 : Accourding to Japanese railway criteria / ( ) unavoidable case
Source: PPUTMP Project Team

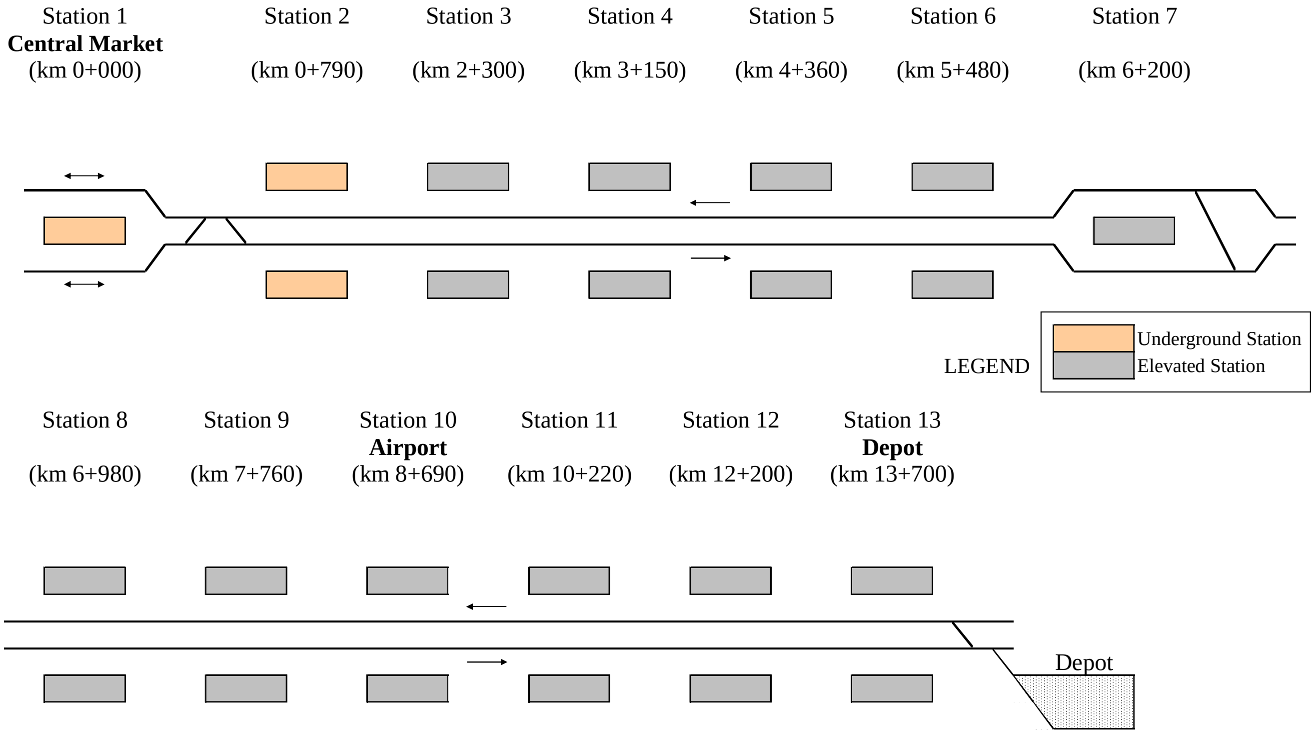
5.2 Train Operation Plan

5.2.1 Track Layout Plan at Stations

The schematic track layout for this line is shown in Figure 5.2-1. The operation length of this line is 13.7 km and the construction length is 14.1 km from the starting point in front of Central Market to the depot. The separate platform type is basically adopted because it provides a good alignment in the station area. However, at Sta. No. 1 (Central Market), the island type platform wherein the total width of the station area is narrower, is adopted because this station is constructed underground below Monivong Blvd.

Among the 13 stations, Sta. Nos. 1 and 2 which are both in the city center are underground while the other 11 stations are elevated.

In addition, a crossover or a turn-back track is installed at the start and the end stations to allow for turn-back operation. Moreover, an emergency crossover is installed at an intermediate Sta. No. 7, which platform is also an island type, to secure service operation in case of emergency.



Source: PPUTMP Project Team

Figure 5.2-1 Track Layout Plan at Stations

5.2.2 Required Train Operation Time and Commercial Speed

The key data concerning the operation of this line are shown in Table 5.2-1 and the average distance between stations and the commercial speed of the AGT in Japan are also shown in Table 5.2-2. The average distance between stations of the AGT in Japan is 0.8 km to 1.0 km (or an average of 0.9 km) and its commercial speed is 25 km/h to 30 km/h (or an average of 27 km/h).

From this table, the characteristics of the proposed AGT line for Phnom Penh indicate that the average distance between stations is 1.1 km, which is 0.2 km longer than the Japanese examples, and the maximum operation speed is 70 km/h, which is comparatively higher than that of the Japanese examples (60km/h to 65km/h). In addition, the route alignment of the proposed line is good so that the train can run with a maximum speed 70 km/h in almost all sections.

From this analysis, the commercial speed of this line can be estimated at 35km/h, which is a little faster than those of the Japanese examples. The required train running time for the whole line with the commercial speed of 35km/h is approximately 24 minutes.

Table 5.2-1 Key Data Concerning Train Operation

Item		Content/Value
Operation Length		13.7 km
Number of Stations		13 Stations
Distance Between Stations	Average	1.14 km
	Maximum	1.98 km (Sta. 11 and Sta. 12)
	Minimum	0.72 k m (Sta. 6 and Sta. 7)
Train Configuration		3-car Train of all Motor Car (Mc-M-Mc)
Maximum Operation Speed		70 km/h
Acceleration		3.6 km/h/s
Normal Deceleration		3.6 km/h/s
Estimated Commercial Speed		35 km/h
Required Operation Time per One Way (Including Dwell Time at Stations)		Approximately 24 minutes

Source: PPUTMP Project Team

Table 5.2-2 Average Distance Between Stations and Commercial Speed of AGTs in Japan

System	Route Name	City	Operatin Section	Operation Length (km)	No. of Stations	Average Distance between Stations (km)	Operation Time (min)	Commercial Speed (km/h)
AGT	Yurikamome	Tokyo	Shimbashi to Toyosu	14.7	16	0.98	30	29.4
	Nippori-Toneri Liner	Tokyo	Nippori to Minumadai Shinsui-Koen	9.7	13	0.81	23	25.3
	Seaside Line	Yokohama	Shin-Sugita to Kanazawa Hakkei	10.6	14	0.82	25	25.4
	South Port Line	Osaka	Cosmo Square to Suminoe-Koen	7.9	10	0.88	18	26.3
	Port Island Line	Kobe	Sannomiya to Kobe Airport	8.2	9	1.03	17	28.9
	Rokko Island Line	Kobe	Sumiyoshi to Marine Park	4.5	6	0.90	10	27.0
	Astram Line	Hiroshima	Hon-Dori to Koiki-Koen Mae	18.4	21	0.92	37	29.8
	Average			**10.6**		**0.89**		**27.4**

Source: PPUTMP Project Team

5.2.3 Examination of Train Operation Plan

(1) Train Operation Plan at Peak Hour

The required train operation trips at peak one hour are calculated by dividing the maximum passenger load at peak one hour (for two cases of 5,000 passengers in 2020 and 6,200 passengers in 2035) by one train capacity (331 persons for 3-car train). As shown in Table 5.2-3, the calculated train operation trips at peak one hour is 16 trains in 2020 (3.8 minutes headway) and 19 trains in 2035 (3.2 minutes headway).

(2) Calculation of Required Number of Train-sets/Vehicles

The required number of train-sets/vehicles is calculated from the round-trip time at peak hour. First, the round-trip time is calculated by doubling the time including one way operation time

(24 minutes) and turn-back time (set at 5 minutes). The required number of train-sets is computed as the required number of train-sets for operation plus the number of spare train-sets (spare rate is set at 10%). Based on this, the required number of train-sets/vehicles is 18 train-sets/54 cars in 2020 and 21 train-sets/63 cars in 2035 (see Table 5.2-3).

In addition, the length of station platforms and the scale of the depot are planned for a 4-car train to meet the increased demand by future development along the line or a network expansion.

Table 5.2-3 Train Operation Plan at Peak Hours and Calculation of Required Number of Train-sets/Vehicles

Item		Unit	Formula	2020	2035	Remarks
Train Operation Plan	Peak Demand per Hour	persons/hour･direction	a	5,000	6,200	between St2 to St3
	Train Capacity	persons/train	b	331	331	5persons/m2
	Required Train Operation Trips	trains/hour･direction	c=a/b	16	19	
	Operation Headway	min	d=60/c	3.75	3.16	
Calculation of Required Number of Train-sets /Vehicles	Operation Time	min	f	24	24	Commercial Speed 35km/h
	Turn Back Time	min	g	5	5	
	Roundtrip Time	min	h=(f+g)*2	58	58	
	Required No. of Train-sets for Operation	train-sets	j=h/d	16	19	
	No. of Train-sets for Spare	train-sets	k=j*10%	2	2	Spare Rate 10%
	Total No. of Train-sets	train-sets	m=j+k	18	21	
	Train Configuration	cars/train-set	n	3	3	
	Total No. of Vehicles	cars	p=m*n	54	63	

Source: PPUTMP Project Team

(3) Calculation of Train Running Distance

The calculation results of the train operation plan and the train running distance in a whole day are shown in Table 5.2-4. The operation hours are planned as 19 hours from 5:00 to 24:00. The train operation trips per hour at peak hours are previously shown in Table 5.2-3, and the trips at off-peak hours are planned as 60% of trips at peak hours on average.

Table 5.2-4 Train Operation Plan and Train Running Distance in a Whole Day

		Year 2020	Year 2035
Operation Hours		5:00 to 24:00 (19 Hours)	
Train Operation Frequency per Hour per One Direction	Peak Hours	16	19
		Total 4 Hours (2 Hours Each in the Morning and Evening)	
	Off-Peak Hours	50% of Peak Hours on Average	
		(15 Hours Except for Peak Hours)	
Train Operation Trips per Day per Two Direction		368	437
Train-km per Day (km)		5,042	5,987
Car-km per Day (km)		15,125	17,961

Source: PPUTMP Project Team

5.2.4 Rough Estimation of the Number of Personnel

An actual record of the number of personnel of AGT systems in Japan is shown in Table 5.2-5. The average number of personnel per line-km is 10.0 persons, though there is more than twice the difference between the minimum (6.3 persons) and the maximum (13.2 persons) numbers. This is because of the differences in the line scale, operation method (whether with a driver or driverless), and the rate of outsourcing. In the Japanese AGT, the operation is mainly executed by the O&M organization itself and the maintenance is mainly outsourced.

The operation and maintenance of the proposed AGT line for Phnom Penh is recommended to be handled by an O&M organization, with technical assistance from advanced countries such as Japan, because (i) this is the first time to introduce an urban railway system in Cambodia, and (ii) it is considered that there is no company/organization which can be outsourced to execute the O&M of AGT in Cambodia.

Although the organization and the number of personnel should be considered in detail from now on, this pre-feasibility study sets the number of personnel at about 280 persons or twice the average number of personnel per line-km of AGTs in Japan, which is computed as follows:

$$20.0 \text{ persons/km} \times 13.7 \text{ km} = 274 \text{ persons or about 280 persons}$$

Table 5.2-5 Number of Personnel of AGTs in Japan

Route Name	City	Total No.of Personnel (persons)	Line Length (km)	No.of Personnel per Line Length (persons/km)	Remarks
New Shuttle	Saitama	130	12.7	10.2	Partially Single Track
Yamaman Eucaulyptus Line	Sakura	26	4.1	6.3	Loop Single Track
Yurikamome	Tokyo	194	14.7	13.2	
Seaside Line	Yokohama	106	10.6	10.0	
Port Island/Rokko Island Line	Kobe	168	15.3	11.0	Partially Loop Single Track
Astram Line	Hiroshima	172	18.4	9.3	
Average				**10.0**	

Source: Railway Statistics Annual Report 2010

6. Preliminary Facility Plan

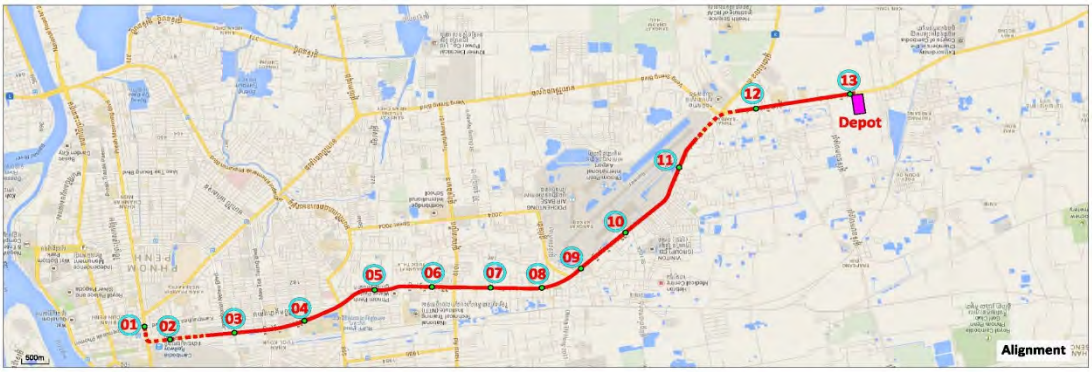
6.1 Civil Work Facility Plan

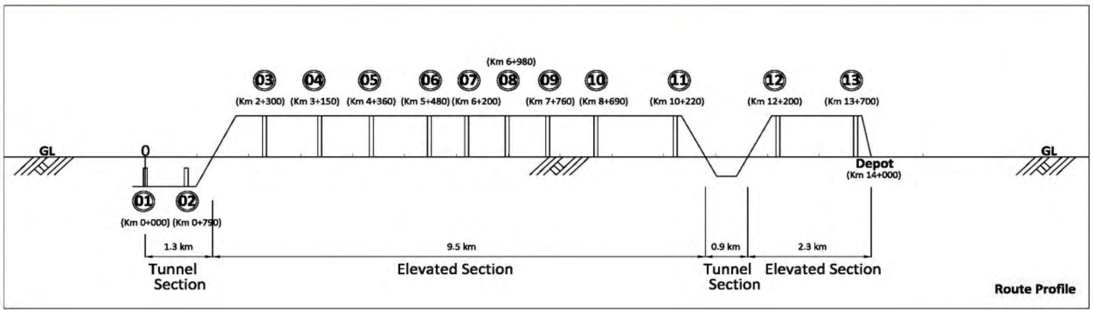
(1) Outline of Railway Alignment

The planned railway system route is about 14.0 km long, from the intersection of Monivong Blvd. and Kampuchea Krom Blvd as a starting point (starting railway station), down to the west running through Russian Blvd. and National Road No. 4, and ending 1.3 km to the east from the crossing point of National Railway South Line as ending point (terminal railway station). The starting railway station is located 200 m west of Central Market, the center of Phnom Penh City, and the terminal station is located in the place near the railway depot and workshop proposed in the Project. The proposed railway line runs on the corridor where there is high traffic volume at present and expected in the near future, running through the center of the main commercial area, university area, existing commercial area developed along the road, airport (crossing point of large-scale transportation), commercial area newly developed along the road, and the Cham Chau roundabout where there is a long-distance bus terminal for the western area.

Elevated railway structures which substructures narrow the traffic road width and limit road traffic are not recommendable to be constructed on Monivong Blvd. where there is a starting station and a large traffic volume in the narrow road with just 2-2.5 lanes per one way. Therefore, an underground railway structure which does not limit the road traffic capacity is proposed. The central park (median strip), with about 25 m width in front of the Defense Ministry and in the center of Russian Blvd., is proposed to be utilized for the gradient section from the underground to the elevated track. There are continuous elevated bridge (viaduct) structures constructed on Russian Blvd. in the section from the park to the airport. The underground structure is proposed in the railway line passing after the airport station as the railway line access to the center of the airplane runway about 145 m in minimum which is in a restricted zone of flight route The elevated track structure is proposed after the airport restricted zone to the terminal station where there is a depot and workshop.

The railway line with about 11.4 km of route length consists of about 2.2 km of tunnel section, 11.8 km of elevated track section, 2 underground stations, and 11 elevated stations. Figure 6.1-1 shows the route's conceptual plan and profile.





Source: PPUTMP Project Team

Figure 6.1-1 Conceptual Plan and Profile

(2) Track Structure

The introduction of a metropolitan railway system is being planned for the first time in Phnom Penh City. Considering the medium-scale AGT and LRT systems used in metropolitan transportation, the following track structural specifications are proposed for the track plan and design:

- Gauge: 1435 mm (LRT), 1850 mm (AGT);
- Distance between railway lines: 4000 mm;
- Minimum curve radius (main line): 160 m (LRT), 100 m (AGT); 100 m (LRT), 30 m (AGT) in special cases;
- Minimum curve radius (siding line/depot): 100 m (LRT), 30 m (AGT);
- Maximum gradient: 40/1000 (LRT), 60/1000 (AGT);
- Minimum vertical curve radius: 2000 m (LRT), 1000 m (AGT);
- Turnout: Sta. No. 10 (LRT main line), Sta. No. 8 (LRT depot), Sta. No. 3-4 (AGT);
- Rail (LRT): UIC 60 kg/m or equivalent (main line), UIC 54 kg/m or equivalent (depot); in case of AGT with rubber tire wheel, the concrete track and guide rail are used;
- Track bed: Concrete bed for both main line and depot;
- Maximum train speed: 60-80 km/hr (LRT), 70 km/hr (AGT);

- Train composition and train length: 1-2 cars/train and 26-52 m/train (LRT), 3-4 cars/train and 34-45 m/train (AGT);

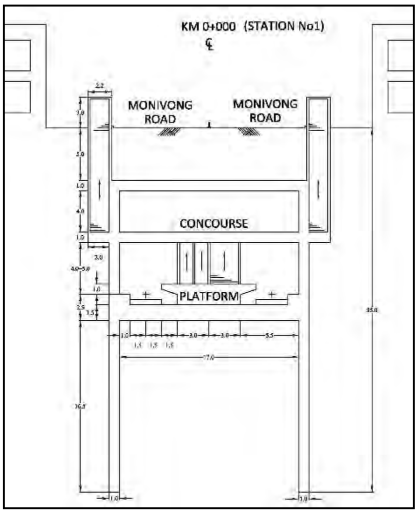
- Platform: Length: 50 m (AGT), 60 m (LRT), Width: 9 m for island platform of starting underground station, 5 m for side platform of underground station No.2, 9 m for island platform of elevated station No. 7, 6 m for side platform of other middle elevated stations;

- Station length: 80 m (AGT) and 90 m (LRT) for starting underground station with shuttle operation, 50 m (AGT) and 60 m (LRT) for middle stations; and

- Construction clearance: 4-5 m height (LRT) and 4 m height (AGT), 3.4-3.8 m width (LRT), 3.4 m width (AGT).

(3) Underground Station Structure

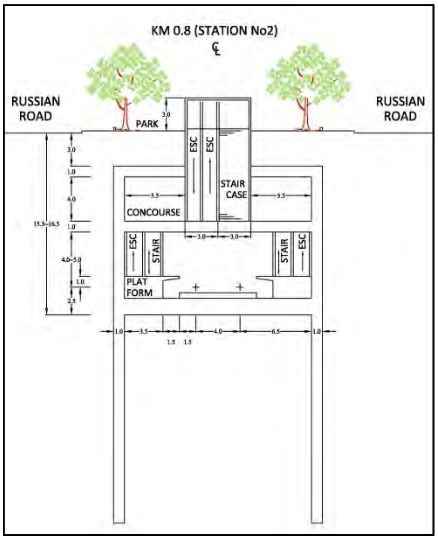
There are two underground (UG) stations, which are the starting station (km 0.0) and the second station (km 0.8). The starting station (Sta. No. 1) is under Monivong Blvd. as a terminal station located in the city center and expected to be used by many railway passengers. The island platform type is proposed in this station considering its convenience for railway passenger movement. The 9 m width of the platform is planned considering the up/down escalators and 3 m staircase. The rail level of Sta. No. 1 is planned as 16 m (LRT) or 15 m～16 m (AGT) below the ground level (GL) considering the 5 m space for utilities under the road used for embedded pipes, UG car parking and shopping area, 4 m space for concourse, and 5 m (LRT) or 4 m (AGT) space for rail car construction clearance (see Figure 6.1-2). The inside width of UG Sta. No. 1 is 17 m considering the rail inspection/maintenance space, car width, and platform width. The siding wall is planned as a continuous element wall structure considering the open-cut excavation method in the narrow space.



Source: PPUTMP Project Team

Figure 6.1-2 Starting Station (Km 0.0) Cross-Section

The second station is planned under the park in the center of Russian Blvd. This is a middle station with the siding platform type for passengers getting on and off the train. The elevator, escalator and staircase are planned for the passengers to move from/to the concourse and upper ground park. The rail level is planned at 13 m-14 m below the ground surface considering the utility space of about 3 m deep under the ground such as embedded pipes (see Figure 6.1-3).

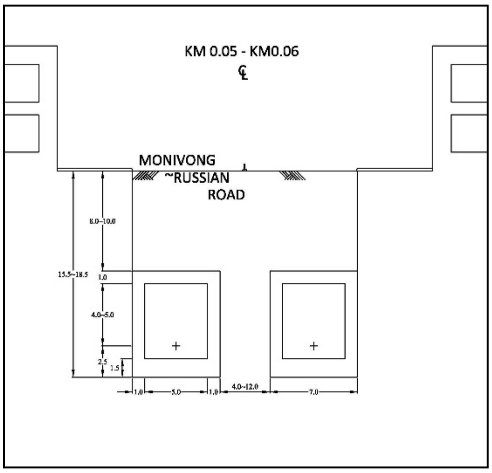


Source: PPUTMP Project Team

Figure 6.1-3 Station No. 2 (Km 0.8) Cross-Section

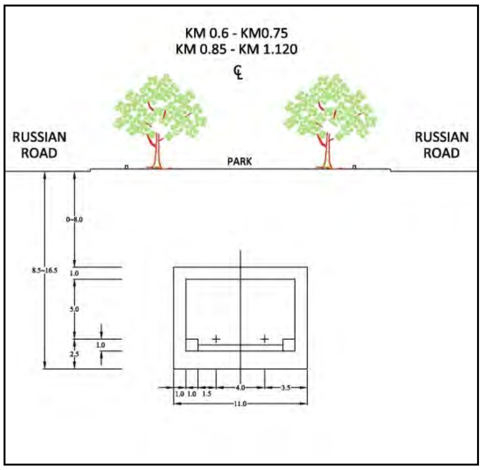
(4) Tunnel Structure

The tunnel will be constructed by open-cut excavation method from the viewpoint of economy, as the tunnel length is short, and the box-culvert type structure is planned for the tunnel section. The section access to the starting station is planned as two tunnels, as the station has an island platform and the distance between railway lines is wide at about 12 m. On the other hand, the section access to the second station is planned as a single tunnel as this has a siding platform and the distance between railway lines is narrow at about 4 m. The tunnel between Sta. No. 11 and Sta. No. 12 is planned as a single tunnel as well (see Figures 6.1-4 and 6.1-5).



Source: PPUTMP Project Team

Figure 6.1-4 Two-Box Tunnel



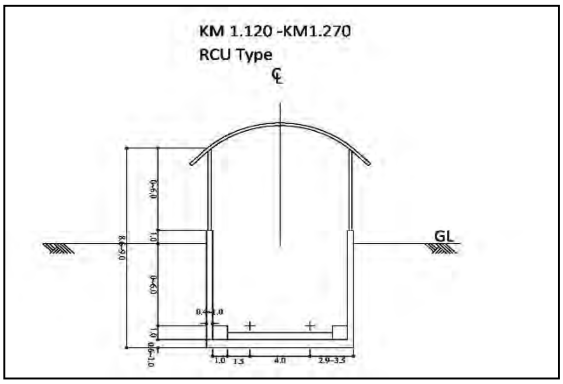
Source: PPUTMP Project Team

Figure 6.1-5 One-Box Tunnel

(5) Approach Structure

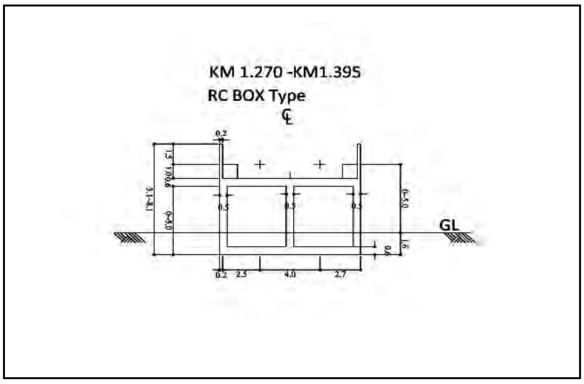
As the approach structure connected from/to the tunnel to/from the elevated bridge intercepts the road traffic, the structure of the section between the second and third stations is planned to be constructed in the place which minimizes such interception of the road traffic (i.e., Central Park in Russian Blvd.). The structures between the 11th and 12th stations are planned in the place at the airport side of Russian Blvd. which does not intercept the road traffic and in the median strip of National Road No. 4.

The structure of the access section to the underground is planned as a U-type structure and the access section to the elevated track is planned as a box culvert-type foundation, as shown in Figures 6.1-6 and 6.1-7.



Source: PPUTMP Project Team

Figure 6.1-6 U-Type Structure



Source: PPUTMP Project Team

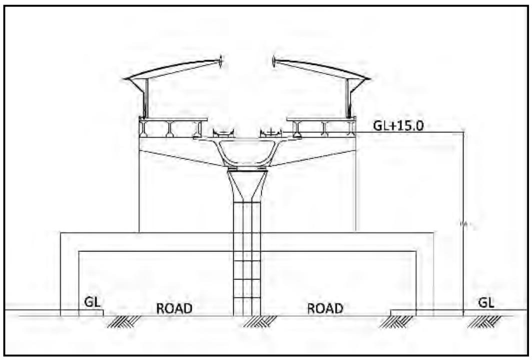
Figure 6.1-7 Box Culvert-Type Structure

(6) Elevated Station Structure

There are 11 elevated stations, starting from the third station (Km 2.3) to the 11th station (Km 10.2) and the 12th station (Km 12.2) to the 13th station (Km 13.7). The location of the elevated stations are selected from the viewpoint of where there are better conditions for construction and alignment of train operation. The distance between stations in the city area are planned to be short (0.7 km-1.5 km) and those outside the city area are planned to be comparatively long (1.5 km-2.0 km).

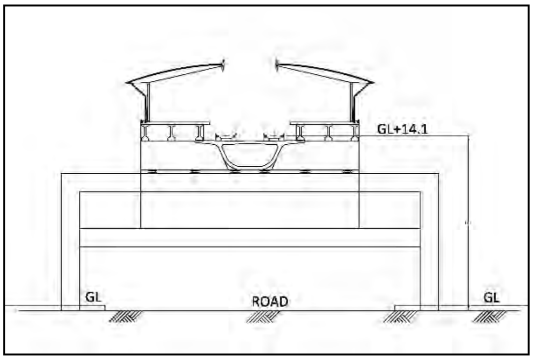
The type of structure for the elevated stations are selected based on whether there is space for construction of the pier and foundation of the substructure in the road median strip, or only available for the space in both sides of the walkway (portal-type pier). The rail level is planned as 14 m-15 m from the ground level considering the 5.0 m-5.5 m road clearance, 3 m height of the concourse, and 3 m height of the super structure (PC box girder). The elevated station consists of structures that allow the railway passengers to go up to the upper concourse from the walkway on the ground through the escalator and or stairs, then go up to the platform through the ticketing gate on the concourse level.

The platform of the elevated station is planned as siding type from the viewpoint of economy, and will be 6 m wide including the 4 m width of the escalator and stairs. The total width of the elevated station on the platform level is 19 m including 4 m distance between rails and 2 platforms width (see Figures 6.1-8 and 6.1-9).



Source: PPUTMP Project Team

Figure 6.1-8 Elevated Station (Pier in Road Median Strip)

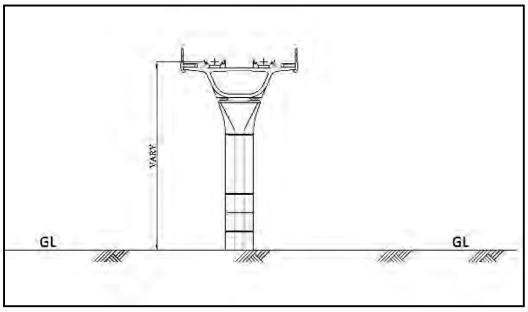


Source: PPUTMP Project Team

Figure 6.1-9 Elevated Station (Foundations in Roadside Walkways)

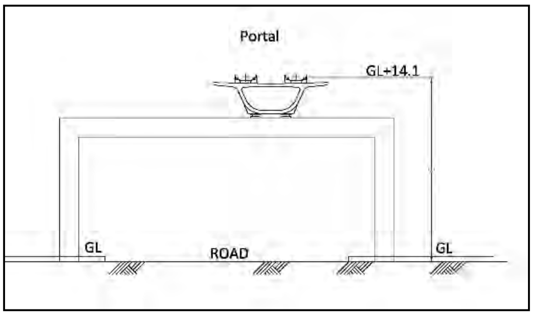
(7) Elevated Structure

The elevated structure between stations consists of a super-structure (PC girder) and a substructure (pier). The type of super-structure is planned as PC (prestressed concrete) box girder considering the economy and construction-ability. Similar with the station structure, the type of substructure is selected on the basis of whether there is space for construction of the pier and foundation of the substructure in the road median strip, or only available for the space in both sides of the walkway (portal-type pier). The rail level of the structure is planned as 14 m-15 m from the ground level, same as the elevation of the station considering the train operation on a flat track level without up/down operation and construction-ability of the roadway flyover on the existing road in the future. The width of the elevated structure is planned as 9.5 m including the 4 m distance between rails and 1 m rail inspection and maintenance way (see Figures 6.1-10 and 6.1-11).



Source: PPUTMP Project Team

Figure 6.1-10 Elevated Structure (Pier in Road Median Strip)



Source: PPUTMP Project Team

Figure 6.1-11 Elevated Structure (Portal Type) (Pier in Road Siding Walkway

(8) Station Facility and Equipment Plan

(i) Elevated Station

The following facilities and equipment are installed in the elevated station:

- Escalators and stairs for passenger movement;
- Elevators for handicapped people movement;
- Electric power and lighting equipment;

- Air conditioning equipment and machines;
- Signaling, telecommunications, safety and security equipment;
- Ticketing and vending equipment;
- Administration office; and
- Platform screen doors.

(ii) Underground Station Equipment

In the underground station, large-capacity drainage and ventilation machines and equipment will be installed, in addition to the facilities and equipment of the elevated station.

(9) Depot and Workshop

The railway depot and workshop will have the train operation control center, equipment/facilities necessary for train operation, train stabling yard, periodic inspection and repair equipment and machines, and storage areas for various kinds of inspection/repairing machines and equipment, as enumerated below:

(i) Civil and Building Facilities

- Administration Office;
- Operation Control Center (OCC);
- Workshop;
- Substation;
- Storage; and
- Water treatment plant and equipment.

(ii) Track Facilities

- Stabling lines and test track and necessary railway (rail and fastenings);
- Track bed, concrete slab supported by piling;
- Turnouts No. 8; and
- Track in workshop.

(iii) Manufacturing and Fabrication of Repair Equipment and Machinery

- Cleaning area, train wash, pressure washer, etc.;
- Heavy maintenance/overhaul area;
- Under floor wheel lathe;
- Wheel and axle shop;
- Bogie repair shop;
- Storage area;
- Handling equipment;
- Compressed air equipment;
- Battery, electrical, mechanical, welding shop;
- Break/Coupler shop;
- Pantograph shop;
- Miscellaneous equipment main workshop;
- Civil/Signal/Telecommunication inspection/maintenance area; and
- Fueling system.

(10) Construction Planning

1) Pre-Construction Schedule

It is estimated to take about four years from the government approval of the Railway System Plan (Project) until the commencement of construction after the process of the Feasibility Study, Detailed Design, and Tender, as shown below:

- Feasibility Study (FS): 12 months
- Detailed Design (DD): 18 months
- Tender: 12 months

2) Construction Period

(i) Conditions of Construction

The construction of the project's civil works will be carried out under and above the main road connecting the city center and suburban areas where there is much road traffic. Therefore, construction is expected to take more time than in regular suburban new line construction due to the requirement of special and temporary road relocation, special construction method, limitation of working time, many preparatory works before construction, etc.

(ii) Elevated Civil Works

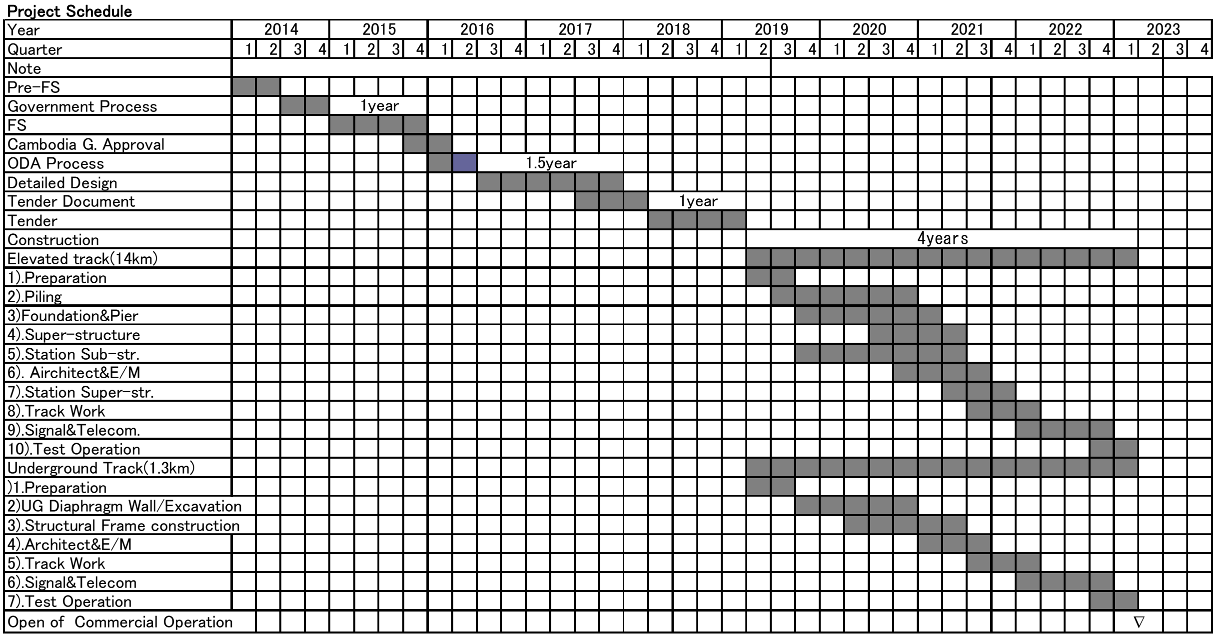
There are about 450 foundations (piers) requiring about 2,900 piles of large-sized diameter necessary for reducing the environmental impact such as construction noise and vibration. It would take about 1.5 years to complete the piling work if the work would be carried out by 10 working groups with machines. It is supposed to take a total of about 3.5 years for the other works of pier and PC girder construction, track works, station building works, electrical and mechanical (E&M) works, and signal and communications. Civil works are carried out in sequence. This will take a minimum of four years until opening of the commercial operation including the train operation test period.

(iii) Underground Civil Works

The shield tunnel method is not an economical option because of the short tunnel length and the complicated track alignment (two separate tunnels to one tunnel between the stations). As the construction is carried out under the road in the city center, it is proposed to construct the tunnel by open-cut method using the continuous element wall. This can reduce the noise and vibration during construction and is useful for both the temporary and main walls of the tunnel structure. It is supposed to take about 15 months for completion of excavation work of the 1.3 km tunnel section. It is possible to complete the underground civil works in about four years including the construction works of the main structure, architecture, track, signal and communications, and test operation.

(iv) Project Implementation Schedule

The project implementation schedule is shown in Figure 6.1-12.



Source: PPUTMP Project Team

Figure 6.1-12 Project Implementation Schedule

(11) Cost Estimation of Civil Works

1) Cost Estimation Method

(i) Use of Actual Cost

As there is no experience of underground and continuous elevated track construction in Cambodia, the actual costs of a similar project implemented in a neighboring country, Thailand, are used. The cost estimation of the civil works for the Project uses the costs of the underground railway in Thailand (Blue Line Extension, 2006), the viaduct elevated railway (Red Line, 2006), and the airport railway link (ARL, 2006). A price escalation of 4% per year is considered for the period from 2006 to 2014 to arrive at the current estimate of the project cost.

(ii) Conditions of Cost Estimation

In addition to the cost of main works, the preparatory works (3-10% of main works), detailed design cost (5%), construction supervision service cost (5%), provisional sum (5%), physical contingency (5-10%), and value added tax (VAT, 10%) have been considered for estimation.

(iii) Items of Civil Works

The civil works are classified as follows:

- Land Acquisition;
- Elevated Civil Works;
- Underground Civil Works;
- Track Works;
- Elevated Station Civil Works;
- Underground Station Civil Works; and
- Depot and Workshop.

2) Cost of Civil Works

Based on the above conditions, the costs of civil works are calculated and subdivided into local/ foreign portion. The final estimates are summarized and shown in the tables under Section 7.

6.2 Electric Power System Plan

6.2.1 General

AGT traction uses electric motors and major equipment such as signaling system, facilities in stations and depot are powered by electricity. Therefore, a power shortage or power interruption will directly result in disruption of train service. As a solution, the power system with redundancy is necessary. The power system will be designed to supply sufficient power for train operation service in consideration of system redundancy.

6.2.2 Power Supply System

The power supply system will be Bulk AC Substation Type, in which bulk AC substations receive electric power from the Electric Power Company via electrical transmission lines with high performance, and feed power to traction substations and station service substations along the line.

(1) Bulk AC Substation

The bulk AC substation will be basically installed in the depot, which will receive AC 50Hz/115kV or 66kV power from a power grid. The received power will be supplied to traction substations and service substations after being transformed to 24kV in the bulk substation by two transmission lines for redundancy purposes.

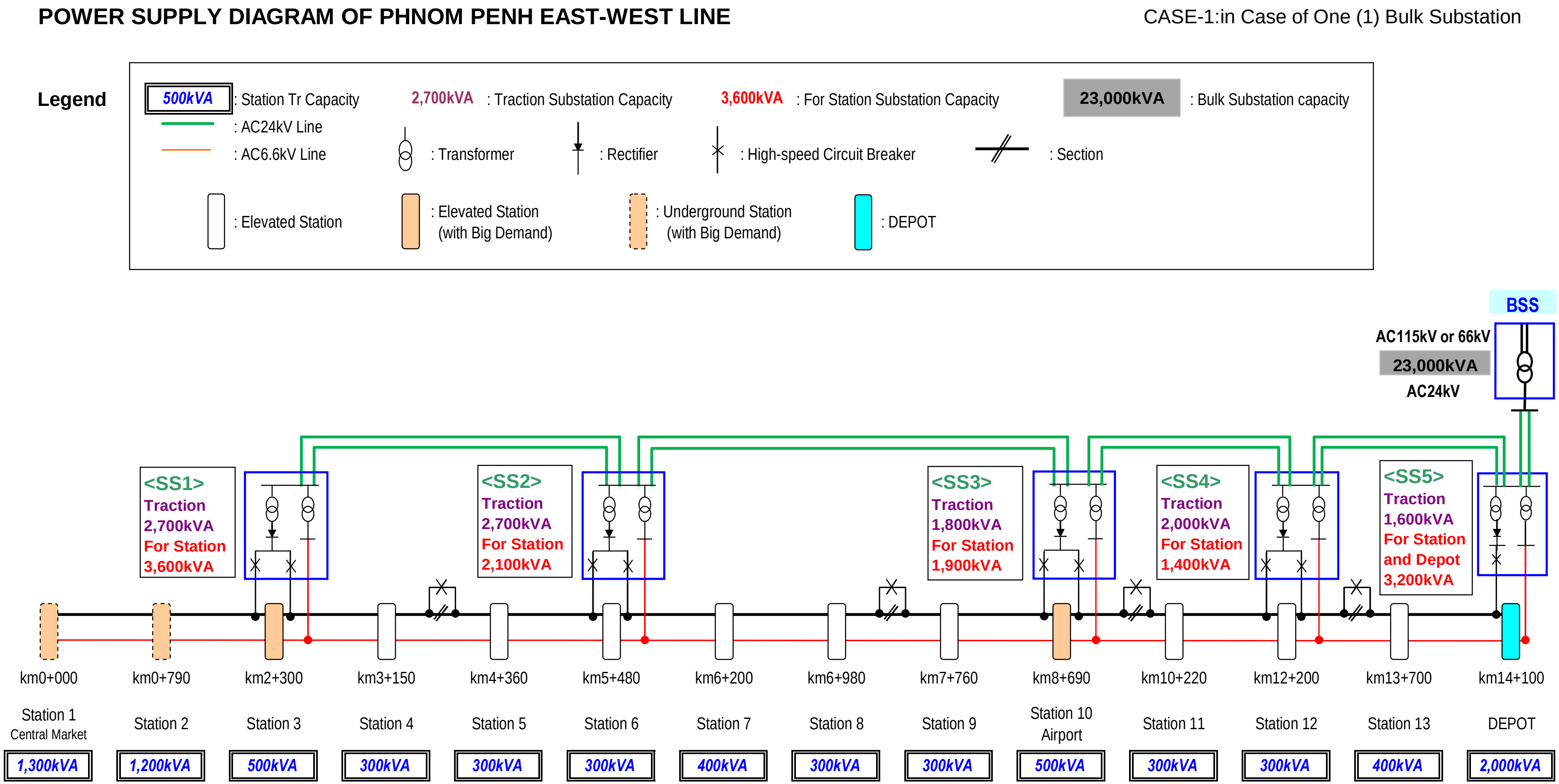
The total electric power consumption of this line is estimated at a maximum of 23,000kWh at peak one hour in case of a 4-car train in the future. This power consumption is so big that it may be impossible to receive it at one bulk substation given the power supply situation of Phnom Penh. Therefore, one more bulk substation will be added at some other place (near Sta. No. 6 may be suitable). Moreover, from the comment of the Cambodian Electric Public Company, it will be possible to supply sufficient power in the year 2023 when the railway operation service will commence because the expansion plan of the transmission network is progressing and targeted in 2020.

(2) Traction and Station Service Substation

The capacity and the interval of substations should be designed to secure normal operation even if a certain substation stops operating due to power failure or maintenance work. In such a case, the necessary power will be supplied from the adjacent substations. The interval between those substations should be less than 4 km so that when a substation is disabled, each of the two adjacent substations are capable of supplying power for half of the feeding section of the disabled substation.

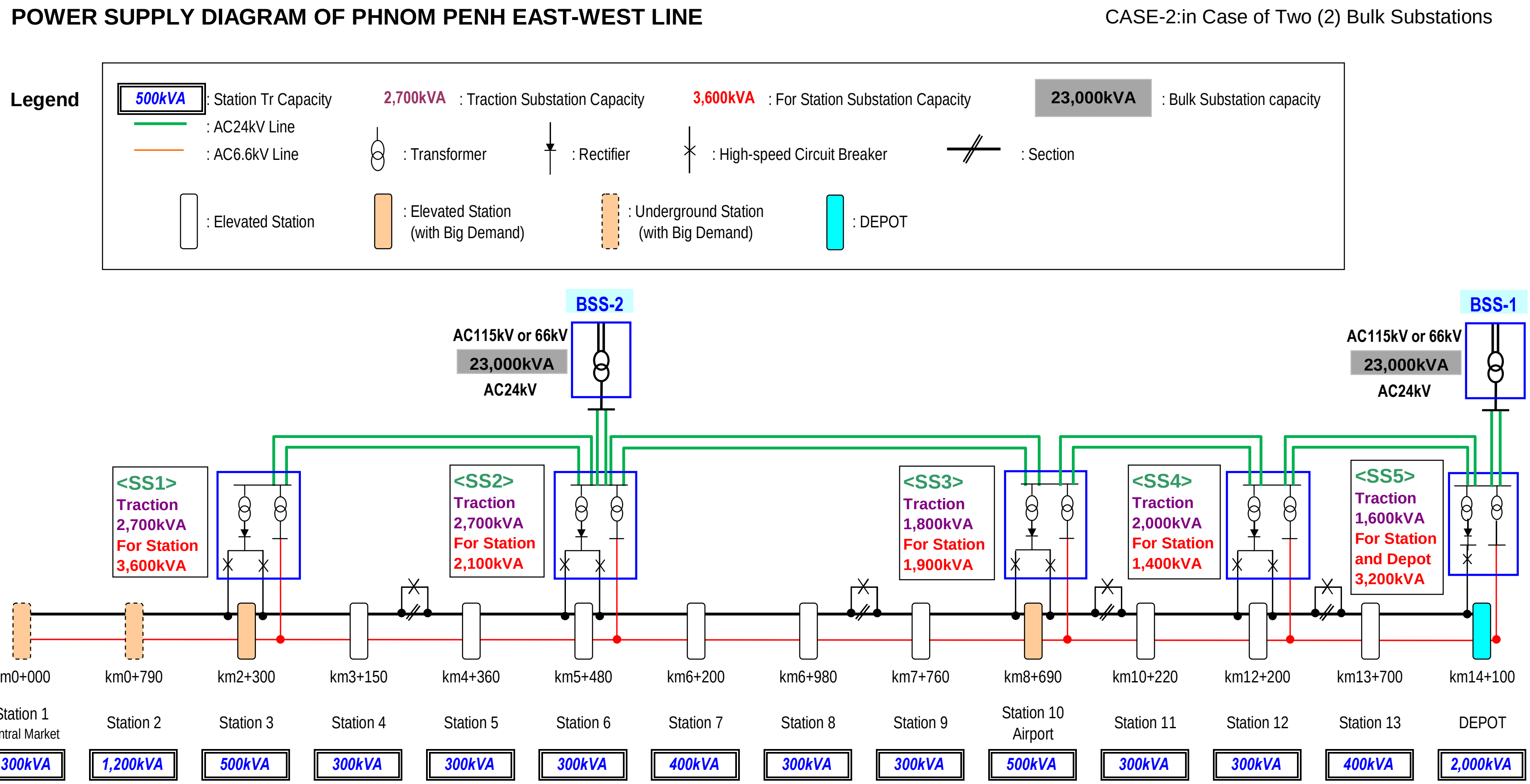
Traction power for the AGT is supplied by traction substations, which convert electricity from AC 24kV/50Hz to DC 1,500V. Power for stations, depot, signaling system and turnouts is distributed to transformers at each station and depot, and then supplied to each equipment at an appropriate voltage. These station service substations transform electric power from AC 24kV to AC 6.6kV.

The planned power supply diagrams of this line are shown in Figures 6.2-1 and 6.2-2.



Source: PPUTMP Project Team

Figure 6.2-1 Power Supply Diagram (in the Case of 1 Bulk Substation)



Source: PPUTMP Project Team

Figure 6.2-2 Power Supply Diagram (in the Case of 2 Bulk Substations)

(3) Contact Line

The traction voltage of the proposed AGT is DC 750V. The contact lines named "Third Rail" are arranged along one side of the elevated/ underground tracks. There is a positive electrode and a negative electrode. Third rails are fixed to walls by insulators (see Figure 6.2-3).

Source: Mitsubishi Heavy Industries

Figure 6.2-3 Image of Contact Line of AGT

6.3 Signal and Telecommunications Plan

6.3.1 Signaling System

(1) General

For this rail line, the CBTC (Communication-Based Train Control) system is proposed as an ATP (Automatic Train Protection). CBTC is not a conventional fixed block system that depends on the track circuit. It can detect the train position onboard and transmit it to the ground system and the following train by radio system. It is a signaling system to realize a moving block system. CBTC can minimize the safety distance between trains. In addition, it can respond to the increase in future traffic without upgrading the signaling system.

The reasons for adopting the CBTC system are as follows:

- By using the radio system, CBTC can be lightly equipped and can realize a system with high cost performance;
- The global standard has been established by IEEE 1474, which achieve high safety;
- Recently, CBTC has been adopted in many urban transport systems;
- CBTC can achieve a high-density traffic operation by the moving system; and
- Future railway expansion is relatively easy by using the radio system.

(2) Premise of East-West Line

- Target line: Sta. No. 1 to Sta. No. 13 and Depot (13 stations and Depot);
- Target train density: (1st stage in 2020): approximately 3 min. headway; (future capability): approximately 2 min. headway, which depends on future traffic demand;
- Installation environment: Elevated area and underground;
- Train operation: One driver operation, Driverless operation or Unattended Train Operation (UTO) (The selection of train operation depends on the Operator's policy);

- OCC location: in Depot area (tentative);
- CCR (Central Control Room) location: in Depot area; and
- SCR (Station Control Room) location: Station.

(3) Basic Concept

Standards:

- IEC 62278: Railway Applications–The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS);
- IEEE 1474.1, 2, 3: Standards for Communication-Based Train Control (CBTC); and
- Other standards.

(4) Safety Design Concept

The signaling system consists of the following main components:

- Automatic Train Protection System – ATP*1*3
- Train Detection System– TD*1
- Interlocking System - IL*1
- Automatic Train Operation System – ATO*2*3
- Automatic Traffic Supervision System – ATS*2
- RAMS standard will be applied to satisfy the safety design concept.
    - Note *1: Vital (Critical) component; SIL4 (Safety Integrity Level 4) will be applied;
    - Note *2: Non-vital (critical) component; and
    - Note *3: Common unit between ATP and ATO is vital component.

(5) Concept of Main Subsystems

The functions and the concepts of the proposed major subsystems are summarized in Table 6.3-1.

Table 6.3-1 Functions and Concepts of Proposed Signaling Subsystems

No	Subsystem	Functions	Concept of the Proposal
1	ATP (Automatic Train Protection System)	Safety protection function to protect from train collision and to minimize distance between trains. 1) Fixed block system: Conventional way by track circuit. 2) Moving block system: The system for high density traffic operation. CBTC (Communication-Based Train Control) is one of the moving block system, which detects the train position and transmits it to the ground system and the following train by radio, and can shorten the distance between trains flexibly. It is effective for high density traffic operation.	CBTC is proposed for the following reasons: 1) By radio system, CBTC can realize a light system; 2) Global standard (IEEE 1474) has been established; 3) Recently, many systems adopted CBTC; 4) CBTC can achieve the high-density traffic operation; and 5) The future extension is easy by radio.
2	TD (Train Detection System)	TD is a function of train detection. There are 3 systems in TD, as follows: a) Track circuit system; b) Loop coil system; and c) Radio system.	As CBTC is adopted, the radio system should be adopted. Train position is detected by the CBTC onboard and transmitted to ground system and the following train; Distance calculation by Tachometer; Original position and correction; Transponder (Balise).

No	Subsystem	Functions	Concept of the Proposal
3	IL (Interlocking System)	Control function of route setting in station and depot according to interlocking rule. Individual control type, which is installed at each station to have turnout route. Collective control type, which control stations collectively and remotely.	Electronic interlocking system using computer is adopted. Individual type or collective type will be decided at the later design stage.
4	ATO (Automatic Train Operation System)	Automatic train operation function. There are some grades, which are one driver operation, driver-less operation, and UTO (Unattended Train Operation), in automatic train operation.	UTO is the best, but the system selection of ATO depends on the policy of the Operator (railway company). In any case, whatever little difference, ATO functions are required to realize automatic train operation.
5	ATS (Automatic Traffic Supervision System)	ATS has an integrated train operation management and monitoring function. a) Train diagram management; b) Train route control; c) Train diagram recovery when diagram is disturbed; and d) Man-machine communication between dispatchers and system.	The general traffic control system is adopted as ATS. It also includes a backup manual control function from the dispatching room if the ATS fails.
6	Signalling system in Depot	There are the stabling yard and the maintenance yard (including workshop and carwash shop) in the Depot.	1) Stabling yard: (a) UTO (by CBTC) or (b) Manual operation, in which the way side signals are controlled from the Depot. SCR manually. Driver operates manually without ATO and CBTC. 2) Maintenance yard: (a) UTO until maintenance yard entrance or (b) manual operation. 2) Maintenance yard; a) UTO until maintenance yard entrance. Or b) manual operation.

Source: PPUTMP Project Team

The general configuration of the ATP system is shown in Figure 6.3-1. A schematic diagram of the signaling system is shown in Figure 6.3-2.

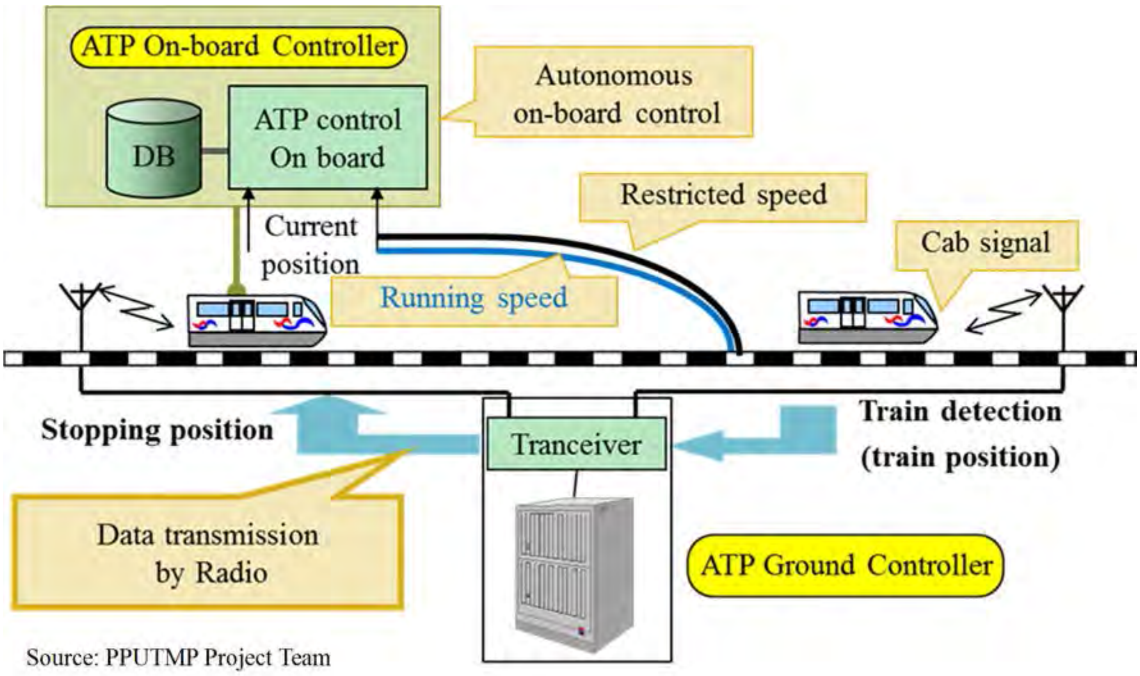
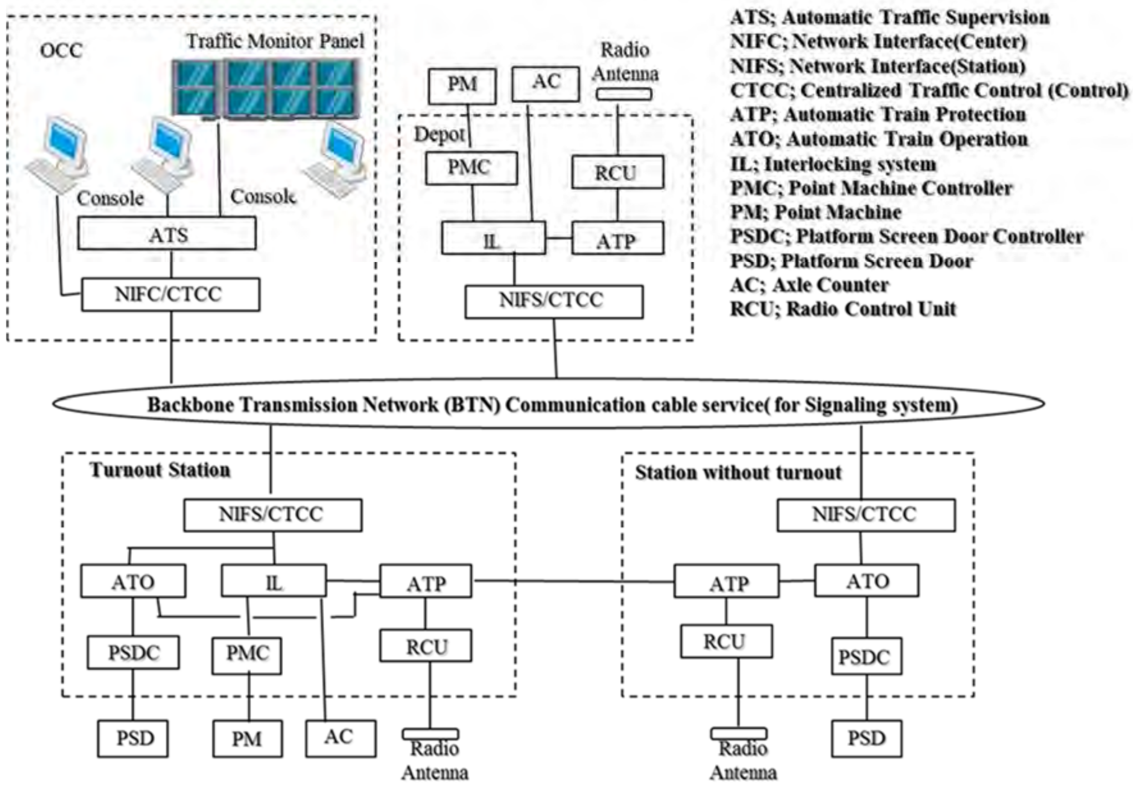


Figure 6.3-1 General Configuration of Automatic Train Protection (ATP) System



Source: PPUTMP Project Team

Figure 6.3-2 Schematic Diagram of Signaling System

6.3.2 Telecommunications System

(1) General

The purpose of the telecommunication system and required telecommunication service is to support the business environment and train operation safely and efficiently. To achieve this, the system and the following functions are generally required (see Table 6.3-2).

Table 6.3-2 Outline of Telecommunication System Specifications

Required Service	Required Functions	System
Telecommunication service for safety	1) Dispatching control 2) Emergency protection	1) Radio communication system 2) Closed Circuit Television (CCTV) system
Telecommunication service for passenger service	1) Monitoring of passengers 2) Information dissemination to the passengers	1) Closed Circuit Television (CCTV) system 2) Passenger Information System (PIS) a) Public Address System (PAS) b) Passenger Information Display System (PIDS) 3) Clock System
Administrative and common telecommunication service	1) Communication among related parties	1) Telephone system 2) Backbone Transmission Network (BTN)

Required Service	Required Functions	System
	2) Common network service	

Source: PPUTMP Project Team

(2) Premise of East-West Line

- Target line: Sta. No. 1 to Sta. No. 13 and Depot (13 stations and Depot);
- Installation environment: Elevated area and underground;
- Train operation: One driver operation, Driverless operation, or UTO (The selection of train operation depends on Operator's policy);
- OCC location: in Depot area (tentative);
- CCR location: in Depot area; and
- SCR location: Station.

(3) Concept of Main Subsystems

Radio communication system:

- Radio communication system: TETRA
- Frequency: 400 MHz or 800 MHz
- Antenna:
  (a) Open area: Standard antenna installed approximately every 2 km (on the top of stations or buildings); and
  (b) Underground area: LCX antenna.
- Functions:
  (a) Dispatching telephone: between OCC (Dispatcher) and Train;
  (b) Emergency communication: from train to OCC;
  (c) Train status data: from train to OCC; and
  (d) Control data: from OCC to train.

(4) Telephone System

The telephone system consists of:

- Administrative and general telephone with PABX (Private Automatic Branch Exchange);
- Dispatching telephone; and
- Operation and maintenance telephone.

Functions:

- Individual calls;
- Group calls; and
- Broadcast calls.

(5) Closed Circuit Television (CCTV) System

- CCTV installed points:
  (a) Platform
  (b) Concourse
  (c) Ticket office
  (d) Landing area of escalator
  (e) Depot area
  (f) OCC area

- Monitoring places (video terminal installed areas):
  (a) OCC
  (b) Station staff room

- On board monitoring by driver:
  (a) Driver monitors passengers' movements at boarding and disembarking train by on board display.
  (b) The image data is transmitted from ground to the cabin display through wireless LAN (5GHz).

(6) Passenger Information System (PIS)

- Public Address System (PAS):
  (a) OCC PA system: PAS equipment are provided for OCC controllers to broadcast messages to the stations and Depot.
  (b) Station PA system: PAS equipment are provided for station controllers to broadcast messages to the station itself (platform, concourse, each elevator, paid/unpaid area).
  (c) Depot PA system: PAS equipment are provided for station controllers to broadcast messages to the Depot itself (maintenance workshop, stabling yard, carwash shop).

- Passenger Information Display System (PIDS):
  (a) PIDS control system: OCC server, station server
  (b) Display (LCD) units: platform, concourse

(7) Master Clock System

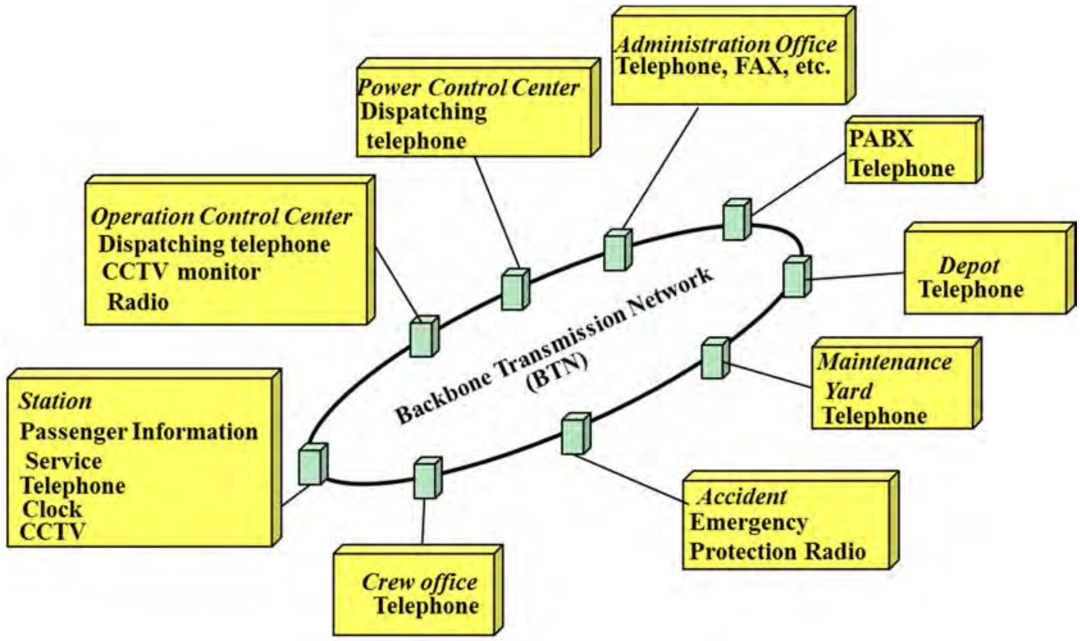
- Master clock system:
  (a) Master clock system: Clock accuracy is within +/-1 second
  (b) Clock system includes the following:
    - Antenna unit;
    - Central master clock unit;
    - Station/Depot master clock unit;
    - Fan out unit (for distribution);
    - Slave clock unit;
    - Slave clock location:
      - Administration building: CCR, entrance area
      - Depot: workshop, stabling area
      - Stations: SCR, platform area, concourse area

(8) Backbone Transmission Network (BTN) System

- Network configuration: Ring network
  (a) Widely applied to railway system
  (b) Ring network has been standardized by ITU-TG.841
  (c) Leveling network traffic: Network traffic is not concentrated in the center.

- Network service by BTN:
  (a) Total communication network service (using SDH): CCTV, PA, PIDS, Telephone
  (b) Communication cable service (using optical fiber directly)
  (c) Signaling, SCADA, AFC (each system configures own network).

Figure 6.3-3 illustrates the general configuration of the telecommunications system, showing its above-described various components.



Source: PPUTMP Project Team

Figure 6.3-3 General Configuration of Telecommunications System

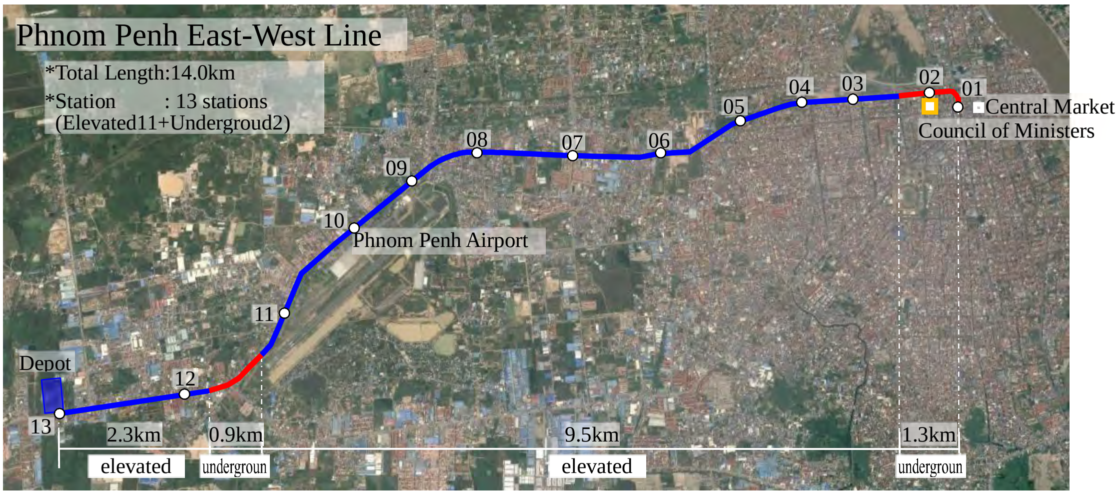
7. Economic and Financial Analyses

7.1 Basic Assumptions

(1) Route and Schedule

1) Route

The economic and financial analyses are carried out based on Alternative 1 "Russian Blvd. Route." The route is shown in Figure 7.1-1 below.



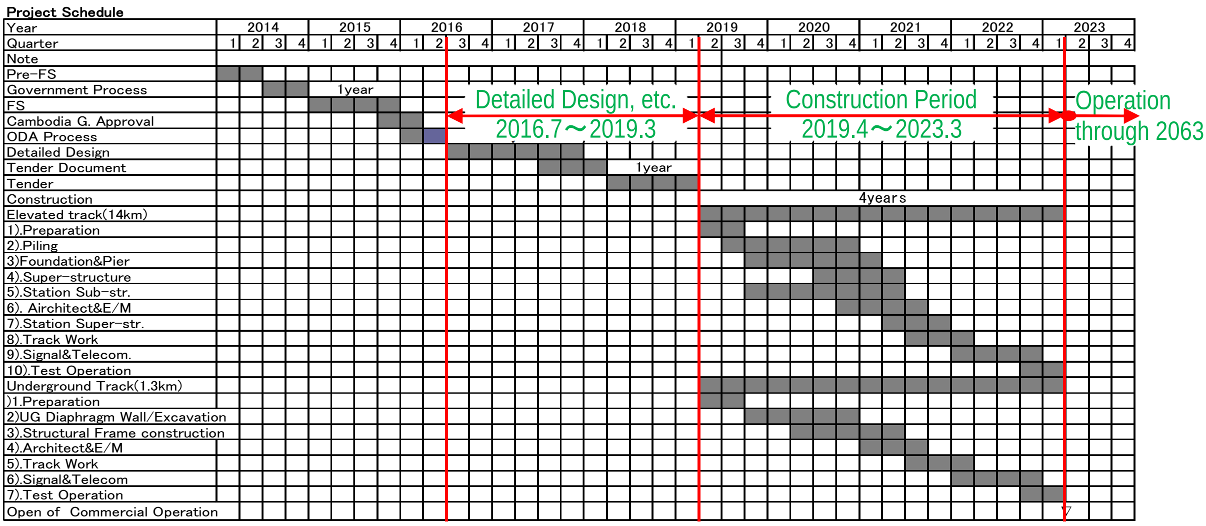
Source: PPUTMP Project Team

Figure 7.1-1 Assumed Route in the Economic and Financial Analyses

2) Schedule

(a) Construction and Operation Period

The project implementation schedule (see Figure 7.1-2) assumes that the construction works and procurement processes will be completed in March 2023. Then, operation of the Phnom Penh East-West Line will commence from April 2023. Project life is 40 years after the start of operations.



Source: PPUTMP Project Team

Figure 7.1-2 Project Implementation Schedule

(b) Replacement Time

The future replacement time (asset lives) of civil works, electricity, rolling stock and signaling facilities are shown in Table 7.1-1.

Table 7.1-1 Replacement Time (Asset Lives)

Item		Asset Lives (Yrs.)	Remarks
Civil Works, etc.	Civil Works Track, Station, Depot	40	No need to replace in project life
Electricity, etc.	Transforming Equipment	20	
	SCADA	20	
Rolling Stock, etc.	Conduct Line System	30	
	Passenger Cars	30	Large-scale repair in 15 years
	Maintenance Cars	15	
Signaling, etc.	Signaling & Telecommunication	15	

Source: PPUTMP Project Team

(2) Other Assumptions

Other assumptions on With Project and Without Project, project life, price and exchange rate are shown in Table 7.1-2.

Table 7.1-2 With Project and Without Project, Project Life, Price and Exchange Rate

Item	Assumptions
With Project	East-West Line will be installed along Russian Blvd. (Alternative 1 route)
Without Project	Do-nothing Scenario
Project Life	40 years after the start of operating services of Phnom Penh East-West Line (i.e., from year 2023 to 2062)
Price	2014 price
Exchange Rate	USD1.00 = KHR4,000 = JPY100

Source: PPUTMP Project Team

7.2 Economic Internal Rate of Return (EIRR)

(1) Overview

The objective of economic analysis is to assess the economic impact of the Phnom Penh East-West Line Project on the national economy, and to clarify the economic feasibility of the project. The Discounted Cash Flow method is adopted in this analysis and the Economic Internal Rate of Return (EIRR) is used as an evaluation indicator.

(2) Economic Benefits of the Project

1) Economic Benefits

The following benefits are anticipated from the implementation of the project:

- Saving of vehicle operation cost (VOC);
- Saving of travel time cost (TTC);
- Reduction in traffic congestion;
- GHG reduction; and
- Decrease in traffic accidents, etc.

In principle, among the abovementioned anticipated benefits, the savings of travel time cost (TTC) and vehicle operating cost (VOC) are treated as quantitative benefits in conventional economic analysis of railway. Also in this study, the JICA Study Team treats other benefits as qualitative benefits of the project.

2) Calculation of Unit Value for Benefit Estimate

The unit values of VOC and TTC are based on the “Cambodia Neak Loeung Bridge Construction Plan Preparatory Survey" (JICA, 2009), hereinafter referred to as the "Neak Loeung Survey." These are converted to 2014 prices using the consumer price index, economic growth rate, and so on. The resulting updated unit prices are shown in Table 7.2-1 below.

Table 7.2-1 Unit Price of VOC and TTC (2014 Price)

Mode	VOC (USD/1000km)		TTC
	20 km/h	30 km/h	(USD/hour)
Motorcycle	43	39	0.48
Sedan	243	221	3.65
Paratransit	43	39	0.71
Bus	299	272	1.95
Truck	391	356	0.30

Source: PPUTMP Project Team

3) Economic Benefits

The economic benefits, equivalent to the total savings of VOC and TTC, are computed and shown in Tables 7.2-2 and 7.2-3.

In 2035, implementation of the East-West Line is expected to yield VOC and TTC savings of USD55 million and USD182 million, respectively.

Table 7.2-2 Result of Vehicle Operating Cost (VOC) Saving in 2035

■ VOC in 2035 Without East-West Line (average speed=about 20km/hour)

	Result of Demand Forecast		Vehicle*000km	Unit of VOC ($/1000km)	Total VOC ($million)
	PCU*000km A	PCU/vehicle B	C=A/B	D	E=C*D
Motorcycle	730,524	0.30	2,435,080	43	104
Car	627,302	1.00	627,302	243	152
Paratransit	210,820	0.60	351,366	43	15
Bus	115,694	2.08	55,622	299	17
Truck	391,330	2.20	177,877	391	70
				Total	358

■ VOC in 2035 With East-West Line (average speed=about 30km/hour)

	Result of Demand Forecast		Vehicle*000km	VOC ($/1000km)	Total VOC ($ millon)
	PCU*000km A	PCU/vehicle B	C=A/B	D	E=C*D
Motorcycle	273,242	0.30	910,805	39	36
Car	595,945	1.00	595,945	221	132
Paratransit	83,469	0.60	139,115	39	5
Bus	530,307	2.08	254,955	272	69
Truck	373,384	2.20	169,720	356	61
				Total	303

Economic Benefit from VOC in 2035 is ***55 million USD*** (=358-303)

Source: PPUTMP Project Team

Table 7.2-3 Result of Travel Time Cost (TTC) Saving in 2035

■ Travel Time Cost (TTC) in 2035 Without East-West Line

	Result of Demand Forecast		Vehicle*000hour	Time Value ($/hour)	Total TTC ($million)
	PCU*000hour A	PCU/vehicle B	C=A/B	D	E=C*D
Motorcycle	39,167	0.30	130,558	0.85	112
Car	36,311	1.00	36,311	6.55	238
Paratransit	11,157	0.60	18,595	1.26	24
Bus	3,901	2.08	1,875	3.50	7
Truck	14,086	2.20	6,403	0.53	3
				Total	383

■ Travel Time Cost (TTC) in 2035 With East-West Line

	Result of Demand Forecast		Vehicle*000hour	Time Value ($/hour)	Total TTC ($million)
	PCU*000hour A	PCU/vehicle B	C=A/B	D	E=C*D
Motorcycle	8,268	0.30	27,561	0.85	24
Car	21,603	1.00	21,603	6.55	141
Paratransit	2,522	0.60	4,203	1.26	5
Bus	17,079	2.08	8,211	3.50	29
Truck	8,211	2.20	3,732	0.53	2
				Total	201

Economic Benefit from TTC in 2035 is ***USD182 million*** (=383-201)

Source: PPUTMP Project Team

(3) Economic Cost of the Project

1) Construction Cost

In economic analysis, the financial construction cost is converted to the economic construction cost by excluding the tax portion and the contingency portion and by applying the SCF (Standard Conversion Factor) to the non-trade portion in the financial price. The total economic construction cost of the East-West Line project is USD685 million, 67% of which will be spent for civil works (see Table 7.2-4).

Table 7.2-4 Estimated Economic Construction Cost (2014 Price)

	Item	FC (JPY mil)	LC (KHR mil)	Total (JPY mil)	Total (USD mil)
Land	Land Acquisition	0	96,181	2,405	24
	Sub-total	*0*	*96,181*	*2,405*	*24*
Civil Works, etc.	Civil (Elevated)	4,513	361,198	13,543	135
	Civil (Underground)	1,985	176,678	6,402	64
	Track	1,380	22,063	1,932	19
	Station (Elevated)	4,962	217,959	10,411	104
	Station (Underground)	3,564	257,909	10,012	100
	Depot	2,658	29,487	3,395	34
	Sub-total	*19,062*	*1,065,294*	*45,694*	*457*
Electricity, etc.	Transforming Equipment	1,036	25,681	1,678	17
	SCADA	461	0	461	5
	Sub-total	*1,497*	*25,681*	*2,139*	*21*
Rolling Stock, etc.	Conduct Line System	2	0	2	0
	Passenger Car (57 cars)*	10,773	0	10,773	108
	Maintenance Car	210	0	210	2
	Sub-total	*10,985*	*0*	*10,985*	*110*
Signaling, etc.	Signaling & Telecommunication	4,397	116,257	7,303	73
	Sub-total	*4,397*	*116,257*	*7,303*	*73*
Total		35,941	1,303,413	68,526	685

*Note: 3 passenger cars will be introduced additionally in 2030 and 2035 (Total= 6 cars).
Source: PPUTMP Project Team

An item such as the import tariff generates price differences between domestic and foreign markets. The SCF converts domestic prices to international prices by adjusting distortion of domestic prices (see Table 7.2-5).

Table 7.2-5 Standard Conversion Factors

Unit: USD mil

		2008	2009	2010	Average
Import	I	5,077	4,490	5,466	5,011
Import Tax	Di	262	228	248	246
Export	E	3,492	2,996	3,884	3,457
Export Tax	De	28	28	28	28
SCF	$\frac{(I+E)}{((I+Di)+(E-De))}$	97.3%	97.4%	97.7%	97.5%

Source: Cambodian Statistical Yearbook 2011

2) Operation & Maintenance (O&M) Cost

Tables 7.2-6 and 7.2-7 show the O&M Cost (staff cost and material and other cost) for the project, which are computed as follows:

- Staff cost is estimated by multiplying staff numbers by the salary per staff. Staff numbers are estimated based on the examples of Japanese AGT operators.
- Material and other cost is estimated by multiplying the railway length by the unit price based on the examples of Japanese AGT operators.

Table 7.2-6 Staff Cost (2014 Price)

Item			Value	Remarks
Number of Employees	Railway Length (km)	A	14	Study Team
	Employee number/ km	B	20	Case study
	Necessary employee number	C=A*B	280	
Salary per Staff (USD/Month)		D	300	Case study
Total Salary (USD mil/Year)		F=C*D*12month/1000000	1.0	

Source: PPUTMP Project Team

Table 7.2-7 Material and Other Cost (2014 Price)

Item			Value	Remarks
Railway Length	km	A	14	Study Team
Unit Price of O&M Cost	USD mil/km (year)	B	0.37	Case study
Material and Other Cost	USD mil/Year	D＝A*B	5.2	-

Source: PPUTMP Project Team

(4) Economic Analysis of the East-West Line

1) Calculation of EIRR

The results of the cost-benefit analysis of the project are shown in Table 7.2-8. The EIRR of the Phnom Penh East-West Line over its 40-year life is 21%. This indicates that the project is economically feasible.

Table 7.2-8 Cash Flow of Cost-Benefit Analysis (Unit: USD million)

Year		CostTotal			BenefitTotal			Balance
			ConstructionCost	OM Cost		VOC Saving	TTC Saving	
-4	2019	111	111	0				-111
-3	2020	116	116	0				-116
-2	2021	148	148	0				-148
-1	2022	234	234	0				-234
1	2023	82	76	7	156	45	111	73
2	2024	7	0	7	163	46	117	156
3	2025	7	0	7	169	47	123	163
4	2026	7	0	7	176	47	129	169
5	2027	7	0	7	183	48	135	176
6	2028	7	0	7	189	49	140	183
7	2029	7	0	7	196	50	146	189
8	2030	13	6	7	203	51	152	190
9	2031	7	0	7	210	52	158	203
10	2032	7	0	7	216	52	164	210
11	2033	7	0	7	223	53	170	216
12	2034	7	0	7	230	54	176	223
13	2035	14	7	7	237	55	182	223
14	2036	20	13	7	237	55	182	217
15	2037	101	94	7	237	55	182	135
16	2038	42	35	7	237	55	182	194
17	2039	9	2	7	237	55	182	228
18	2040	9	2	7	237	55	182	228
19	2041	22	15	7	237	55	182	215
20	2042	14	7	7	237	55	182	222
21	2043	7	0	7	237	55	182	230
22	2044	7	0	7	237	55	182	230
23	2045	11	4	7	237	55	182	226
24	2046	7	0	7	237	55	182	230
25	2047	7	0	7	237	55	182	230
26	2048	7	0	7	237	55	182	230
27	2049	7	0	7	237	55	182	230
28	2050	11	4	7	237	55	182	225
29	2051	40	33	7	237	55	182	197
30	2052	152	145	7	237	55	182	85
31	2053	73	66	7	237	55	182	164
32	2054	7	0	7	237	55	182	230
33	2055	7	0	7	237	55	182	230
34	2056	7	0	7	237	55	182	230
35	2057	7	0	7	237	55	182	230
36	2058	7	0	7	237	55	182	230
37	2059	9	2	7	237	55	182	227
38	2060	19	12	7	237	55	182	217
39	2061	26	19	7	237	55	182	211
40	2062	16	9	7	237	55	182	220

EIRR	21%
Discount rate	12%
B-NPV	1,625
C-NPV	551
NPV	1,459
B/C	2.9

Source: PPUTMP Project Team

7.3 Financial Analysis

(1) Overview

In this section, the financial feasibility of the East-West Line is analyzed. In assessing financial feasibility, the discounted cash flow method was adopted and the Financial Internal Rate of Return (FIRR) was utilized as evaluation indicator.

(2) Revenue (Fare-box and Other Revenues)

1) Fare-box Revenue

a) Setting of Fare-box Revenue

The major revenue from the project comes from the rail service fare. The minimum fare is set at KHR2,000 and the maximum is set at KHR5,000 (see Table 7.3-1), which are determined based on the fares of the bus, taxi, tuk-tuk, and motodop in Phnom Penh (see Table 7.3-2). The fare is proportioned to distance and increases in unit of KHR1,000.

Table 7.3-3 shows the fares of some railway services in neighboring countries, for comparison.

Table 7.3-1 Fare of East-West Line (Unit: KHR)

		Destination												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Origin	1	—	2,000	3,000	3,000	3,000	3,000	4,000	4,000	4,000	4,000	4,000	5,000	5,000
	2	2,000	—	2,000	3,000	3,000	3,000	3,000	3,000	4,000	4,000	4,000	5,000	5,000
	3	3,000	2,000	—	2,000	3,000	3,000	3,000	3,000	3,000	4,000	4,000	4,000	5,000
	4	3,000	3,000	2,000	—	2,000	3,000	3,000	3,000	3,000	3,000	4,000	4,000	4,000
	5	3,000	3,000	3,000	2,000	—	2,000	3,000	3,000	3,000	3,000	3,000	4,000	4,000
	6	3,000	3,000	3,000	3,000	2,000	—	2,000	3,000	3,000	3,000	3,000	4,000	4,000
	7	4,000	3,000	3,000	3,000	3,000	2,000	—	2,000	3,000	3,000	3,000	4,000	4,000
	8	4,000	3,000	3,000	3,000	3,000	3,000	2,000	—	2,000	3,000	3,000	3,000	4,000
	9	4,000	4,000	3,000	3,000	3,000	3,000	3,000	2,000	—	2,000	3,000	3,000	4,000
	10	4,000	4,000	4,000	3,000	3,000	3,000	3,000	3,000	2,000	—	2,000	3,000	3,000
	11	4,000	4,000	4,000	4,000	3,000	3,000	3,000	3,000	3,000	2,000	—	2,000	3,000
	12	5,000	5,000	4,000	4,000	4,000	4,000	4,000	3,000	3,000	3,000	2,000	—	2,000
	13	5,000	5,000	5,000	4,000	4,000	4,000	4,000	4,000	4,000	3,000	3,000	2,000	—

Source: PPUTMP Project Team

Table 7.3-2 Fares of City Bus, Taxi, Tuk-Tuk and Motodop in Phnom Penh

Item		Fare (KHR)	Fare (USD)	Exchange Rate	Remarks
Phnom Penh	City Bus	KHR1,500	USD0.38	USD0.00025/KHR	—
	Taxi	USD9	USD9	—	Airport-City Center
	Tuk-Tuk	USD7	USD7	—	Airport-City Center
	Motodop	KHR8,000～10,000	USD2-2.5	USD0.00025/KHR	Airport-City Center

Source: Fares are based on the field survey. Exchange rate is based on OANDA (as of 2014.3.26).

Table 7.3-3 Fares of City Railway in Neighboring Countries

Country	Railway	Fare (Local Currency)	Exchange Rate	Fare (USD)
Malaysia	KLIA Ekspres KLIA Transit 	MYR3-35	0.30272 USD/MYR	0.91 - 10.60
	AMPANG Line KELANA JAYA Line MONORAIL Line 	MYR0.7-5.1	0.30272 USD/MYR	0.21 - 1.54
Thailand	MRTA 	THB16-40	0.03068 USD/THB	0.49 - 1.23
	BTS 	THB10-52	0.03068 USD/THB	0.31 - 1.60
	Airport Rail Link 	THB15-45	0.03068 USD/THB	0.46 - 1.38
Philippines	LRTA 	PHP12-20	0.02222 USD/PHP	0.27 - 0.44
	MRT 	PHP10-15	0.02222 USD/PHP	0.22 - 0.33
India	Delhi Metro 	INR8-30	0.01651 USD/INR	0.13 - 0.50

Source: Websites of Railway Companies. Exchange rate is based on OANDA (as of 2014.3.26).

b) Number of Passengers

Table 7.3-4 shows the result of the passenger demand forecast. The number of passengers in 2035 will be 81,626 a day.

Table 7.3-4 Passenger Demand Forecast of East-West Line in 2035

(Unit: persons/day)

		Destination													
		1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Origin	1	0	10,012	3,163	544	552	1,551	175	4	9	5,648	22	452	97	22,228
	2	6,333	0	4,911	299	311	814	154	4	16	5,026	7	418	24	18,317
	3	3,407	4,886	0	2,199	321	1,012	108	3	2	183	12	395	12	12,540
	4	887	448	1,027	0	246	379	15	0	0	23	1	7	1	3,052
	5	659	266	428	281	0	276	8	0	0	18	0	0	1	1,937
	6	1,671	709	1,206	504	293	0	358	3	1	454	2	16	5	5,221
	7	55	41	23	15	0	8	0	413	410	1	0	0	0	967
	8	122	83	103	33	7	242	414	0	414	246	6	16	1	1,688
	9	10	8	14	1	0	1	410	414	0	13	1	1	0	874
	10	5,008	4,207	318	62	6	468	0	241	16	0	415	447	30	11,218
	11	31	9	15	3	0	2	0	2	0	404	0	430	36	940
	12	343	255	293	18	0	14	0	16	1	442	453	0	275	2,110
	13	114	21	23	3	0	6	0	1	0	32	0	335	0	534
	Total	18,639	20,945	11,524	3,961	1,755	4,774	1,641	1,101	871	12,489	927	2,519	481	81,626

Source: PPUTMP Project Team

c) Fare-box Revenue

Table 7.3-5 shows the projected fare-box revenue of the railway line. In 2035, the line will be generating an annual revenue of USD19.4 million from ticket sales.

Table 7.3-5 Daily Fare-box Revenue of East-West Line in 2035 (Unit: KHR1,000)

		Destination												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Origin	1	0	20,024	9,488	1,632	1,657	4,652	699	15	36	22,590	89	2,261	483
	2	12,666	0	9,822	1,541	1,577	3,087	461	11	66	20,102	30	2,092	120
	3	10,220	9,772	0	3,968	963	3,036	324	8	7	732	47	1,581	59
	4	2,660	1,344	2,054	0	98	1,136	44	1	1	68	4	29	6
	5	1,977	799	1,283	562	0	123	24	0	0	54	1	2	2
	6	5,013	2,127	2,974	867	155	0	716	1,238	1,232	1,362	6	63	20
	7	219	122	70	45	1	16	0	7	1,230	2	0	1	0
	8	489	248	310	99	22	725	828	0	9	739	18	48	3
	9	42	34	41	3	0	2	0	8	0	25	1,189	1,189	0
	10	20,030	16,827	1,272	186	18	1,405	0	724	32	0	39	1,342	90
	11	123	37	58	10	0	7	0	7	1	809	0	69	108
	12	1,716	1,273	1,172	71	1	57	0	48	4	140	116	0	549
	13	571	103	115	10	0	24	0	4	0	96	0	669	0

Total (KHR000)	231,689
Total (USD mil)	0.058
Annual Revenue (USD mil)	19.4

Note: Annualized factor from daily revenue to yearly revenue is assumed to be 335 days.
Source: PPUTMP Project Team

2) Other Revenue

Other revenue is from off-rail business. Examples of such revenue are from advertisement at stations and inside the train cars, concession or tenant fees for kiosk service, and so on. The revenue is set as 10% of fare-box revenue in each year, reflecting examples in other railway projects in Asian countries (see Table 7.3-6).

Table 7.3-6 Income Balance Between Fare-box and Other Revenues in Neighboring Countries

■ Balance

Country	Railway	Fare-box		Other Revenue		Total	
		Amount	%	Amount	%	Amount	%
Thailand	MRTA (THB mil) *1	2,106	83.0%	431	17.0%	2,537	100.0%
	BTS (THB mil) *2	4,897	81.4%	1,119	18.6%	6,016	100.0%
India	Delhi Metro (INR mil)*3	15,237	95.0%	801	5.0%	16,038	100.0%
Japan	Tokyo Metro (JPY mil)*4	298,651	89.7%	34,157	10.3%	332,809	100.0%

Notes: *1: MRTA is consolidated accounts.
*2: BTS is the data of mass transit segment.
*3: Delhi Metro is total amount of "Traffic Operation + Real Estate + Consultancy" in Revenue from Operation. External Project is excluded.
*4: Tokyo Metro is separated account.

■ Contents of Other Business

Country	Railway	Contents
Thailand	MRTA	Advertising media services, telecommunications services, and retail space leases
	BTS	Operating and maintenance for the core network
India	Delhi Metro	Lease income, consultancy income
Japan	Tokyo Metro	Advertisement fee, tenant fee, etc.

Source: MRTA - Bangkok Metro 2013 Annual Report; BTS - BTS Annual Report 2012-13; Delhi Metro - Delhi Metro 2012-13 Annual Report

(3) Cost of the East-West Line

1) Initial Construction Cost

Table 7.3-7 indicates the construction cost of the project, which includes physical contingency and VAT (FC portion is assumed to be exempted). The total initial construction cost is estimated to be USD759 million.

Table 7.3-7 Initial Construction Cost of East-West Line (2014 Price)

	Item	FC (YPY mil)	LC (KHR mil)	Total (JPY mil)	Total (USD mil)
Land	Land Acquisition	0	108,522	2,713	27
	Sub-total	*0*	*108,522*	*2,713*	*27*
Civil Works, etc.	Civil (Elevated)	4,739	426,069	15,390	154
	Civil (Underground)	2,184	217,470	7,620	76
	Track	1,449	26,025	2,100	21
	Station (Elevated)	5,210	257,104	11,638	116

	Item	FC (YPY mil)	LC (KHR mil)	Total (JPY mil)	Total (USD mil)
	Station (Underground)	3,920	317,457	11,857	119
	Depot	2,791	34,783	3,660	37
	Sub-total	*20,292*	*1,278,909*	*52,265*	*523*
Electricity, etc.	Transforming Equipment	1,036	28,976	1,761	18
	SCADA	461	0	461	5
	Sub-total	*1,497*	*28,976*	*2,221*	*22*
Rolling Stock, etc.	Conduct Line System	2	0	2	0
	Passenger Cars (57cars)	10,773	0	10,773	108
	Maintenance Cars	210	0	210	2
	Sub-total	*10,985*	*0*	*10,985*	*110*
Signaling, etc.	Signaling & Telecommunication	4,397	131,175	7,676	77
	Sub-total	*4,397*	*131,175*	*7,676*	*77*
Total		37,171	1,547,581	75,861	759

Source: PPUTMP Project Team

2) Operation & Maintenance Cost

As previously discussed in Section 7.2, the O&M cost of the project includes staff cost and material and other cost which are referenced from examples of Japanese AGT operators. These are shown in Tables 7.3-8 and 7.3-9.

Table 7.3-8 Staff Cost (2014 Price)

Item			Value	Remarks
Number of Employees	Railway Length (km)	A	14	Study Team
	Employee number/ km	B	20	Case study
	Necessary employee number	C=A*B	280	
Salary per Staff (USD/Month)		D	300	Case study
Total Salary (USD mil/Year)		F=C*D*12month/1000000	1.0	

Source: PPUTMP Project Team

Table 7.3-9 Material and Other Cost (2014 Price)

Item			Value	Remarks
Railway Length	km	A	14	Study Team
Unit Price of O&M Cost	USD mil/km (year)	B	0.37	Case study
Material and Other Cost	USD mil/Year	D＝A*B	5.2	

Source: PPUTMP Project Team

(4) Financial Analysis of the East-West Line

1) Calculation of FIRR

The result of financial analysis is shown in Table 7.3-10 and Figure 7.3-1. The FIRR for the project is -0.3%.

Table 7.3-10 Financial Analysis of East-West Line

Year		Cost				Revaneue			Balance
		Investment Cost	Replacement Cost	OM Cost	Total	Fare-box	Other	Total	
-4	2019	143		0	143				-143
-3	2020	148		0	148				-148
-2	2021	183		0	183				-183
-1	2022	281		0	281				-281
1	2023	89		8	97	16	2	18	-79
2	2024		0	8	8	23	2	25	17
3	2025		0	9	9	24	2	26	18
4	2026		0	9	9	25	3	28	19
5	2027		0	9	9	26	3	29	20
6	2028		0	9	9	27	3	30	21
7	2029		0	10	10	28	3	31	22
8	2030		7	10	17	30	3	33	16
9	2031		0	10	10	31	3	34	24
10	2032		0	11	11	32	3	36	25
11	2033		0	11	11	34	3	37	26
12	2034		0	11	11	35	4	39	28
13	2035		8	11	19	37	4	40	21
14	2036		15	12	27	38	4	42	15
15	2037		142	12	154	39	4	43	-111
16	2038		50	12	62	40	4	44	-18
17	2039		3	13	16	41	4	45	30
18	2040		3	13	16	42	4	47	30
19	2041		21	14	35	44	4	48	13
20	2042		11	14	25	45	5	50	24
21	2043		0	14	14	46	5	51	37
22	2044		0	15	15	48	5	53	38
23	2045		4	15	20	49	5	54	34
24	2046		0	16	16	51	5	56	40
25	2047		0	16	16	52	5	57	41
26	2048		0	17	17	54	5	59	43
27	2049		0	17	17	55	6	61	44
28	2050		5	18	22	57	6	63	40
29	2051		37	18	56	59	6	65	9
30	2052		240	19	259	61	6	67	-192
31	2053		95	19	114	62	6	69	-46
32	2054		0	20	20	64	6	71	51
33	2055		0	20	20	66	7	73	52
34	2056		0	21	21	68	7	75	54
35	2057		0	22	22	70	7	77	56
36	2058		0	22	22	72	7	80	57
37	2059		5	23	28	74	7	82	54
38	2060		16	23	40	77	8	84	45
39	2061		32	24	57	79	8	87	30
40	2062		17	25	42	81	8	90	47

NPV	-81
FIRR	-0.3%

Source: PPUTMP Project Team

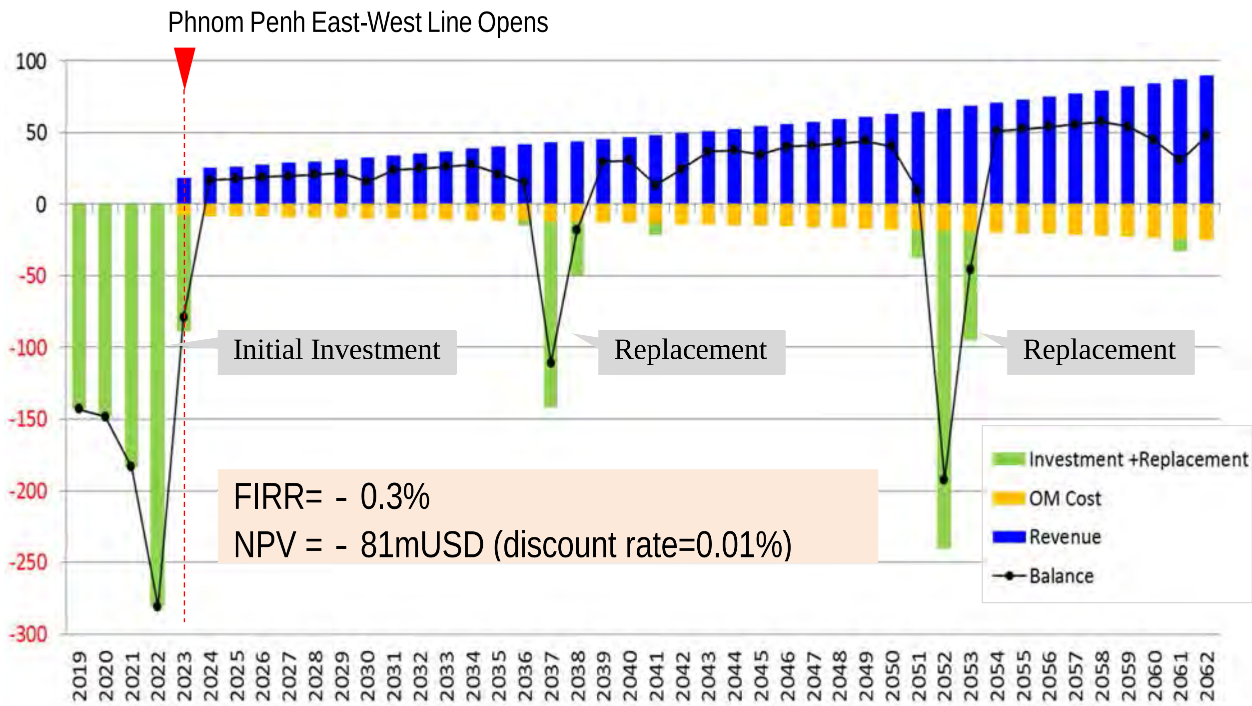
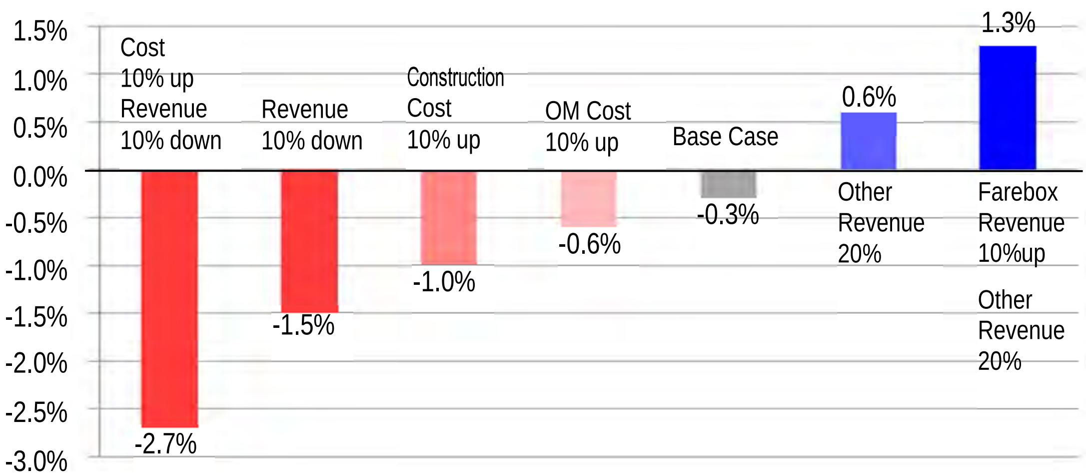


Figure 7.3-1 Result of Financial Analysis of Phnom Penh East-West Line

2) Sensitivity Analysis

Table 7.3-11 and Figure 7.3-2 show the results of the sensitivity analysis. The FIRR of the base case is almost zero. If other revenue increases by 2 times (=20%), the FIRR turns positive. This 20% level is the same as the MRTA and BTS in Thailand. In addition, if fare-box revenue increases by 10%, the FIRR becomes 1.3%.



Source: PPUTMP Project Team

Figure 7.3-2 Result of Sensitivity Analysis of Phnom Penh East-West Line

Table 7.3-11 Result of Sensitivity Analysis

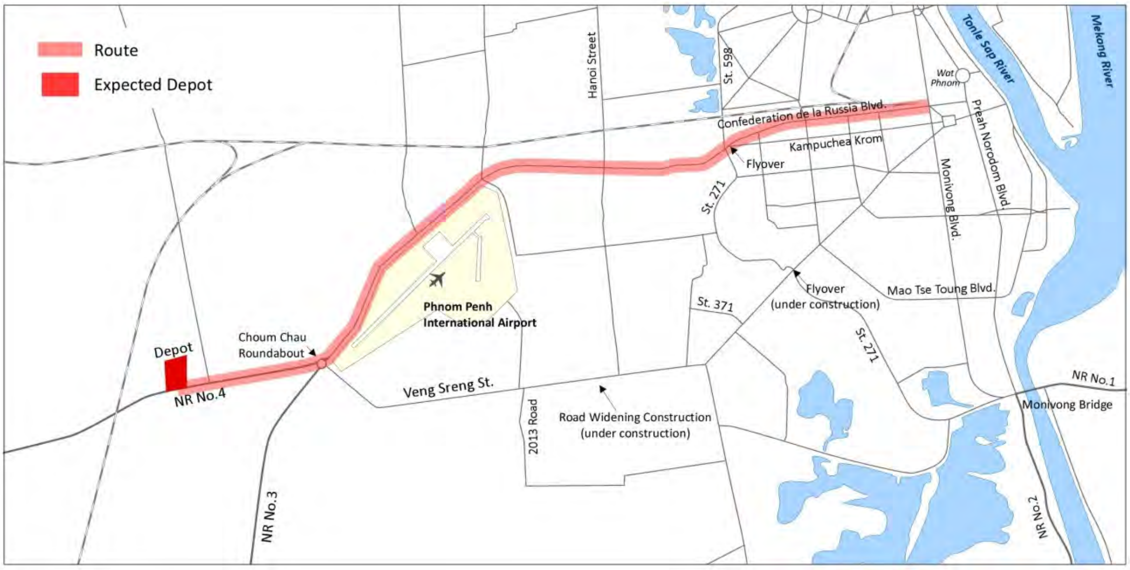
Case	NPV (USD mil)	FIRR
1) Increase of Revenue (10% up)	289	1.3%
2) Increase of Other Revenue (10% to 20%)	104	0.6%
3) Base Case	-81	-0.3%
4) Increase of O&M Cost (10% up)	-139	-0.6%
5) Increase of Construction Cost (10% up)	-234	-1.0%
6) Decrease of Revenue (10% down)	-284	-1.5%
7) Increase of Total Cost (10% up) and Decrease of Revenue (10% down)	-496	-2.7%

Source: PPUTMP Project Team

8. Environmental and Social Considerations

8.1 Outline of the Project

The Phnom Penh East-West Line runs from Russian Blvd. at the intersection with Monivong Blvd. to the expected depot on National Road No.4 through the international airport and the Choum Chao Roundabout (see Figure 8.1-1). The total route length is expected to be 14.0 km including an elevated section of 11.8 km and an underground section of 2.2 km. Most of the route consists of elevated structure and runs in the middle of the ROW. The underground section consists of two parts; one is in the central area from the Central Market to the Ministry of Defense, and the other is from the airport to the Choum Chao Roundabout.



Source: PPUTMP Project Team

Figure 8.1-1 Route of the Project

8.2 Natural and Social Environment of the Project Site

(1) Natural Environment of the Project Site

(i) Geographic Features

Phnom Penh is located in the Mekong River Delta and faces the meeting point of two large-sized rivers, the Tonle Sap River and Mekong River. The land is relatively flat, which attitude generally ranges from 2-4 m above sea level. The project site is located in the middle of Phnom Penh Capital and its features are the same as in other areas in Phnom Penh.

(ii) Geological Features

According to the survey report[1] by Japan's Ministry of Economic and Finance (MEF), and Trade and Industry (METI) in 2009, the soil consists of firm sand and clay stratum covering with topsoil of medium-soft sandy clay. In the western part of Phnom Penh City, surrounding the international airport, the soil feature changes into firmer clay consistency than at the city

[1] Study on Phnom Penh City Skyrail Airport Line Project in Kingdom of Cambodia, MEF/METI, 2009.

center. The soil ground investigation in the feasibility study project[2] for National Road No.1 (JICA, 2003) reported that no serious soft soil problems could be found in Phnom Penh.

(iii) Climate

Phnom Penh enjoys a tropical monsoonal climate and has two major seasons, rainy and dry seasons. The monthly average rainfall ranges from 0 to 300 mm. The average temperature is around 29 degree Celsius and the weather is rather warm and humid. The project site has the same climate feature as the rest of Phnom Penh.

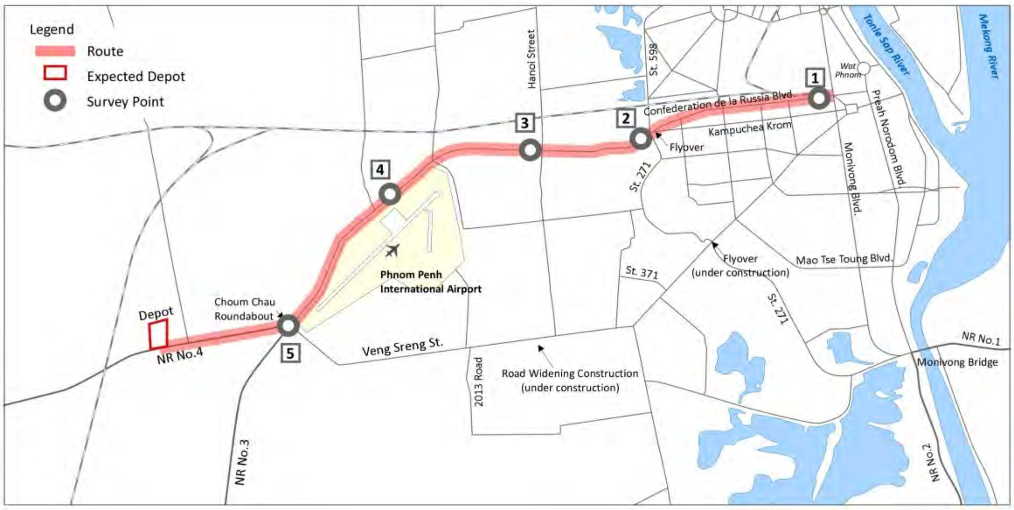
(iv) Conservation Area

Along the project route, no conservation and protection area can be found. Furthermore, there are no religious facilities such as pagoda and temple for local communities.

(v) Air Pollution

Air pollution monitoring has been conducted by MOE every month since 2008. However, the survey point and type of pollution are not enough to compare with the Cambodian standard. Therefore in the study, a roadside air pollution survey was carried out along the route. The monitoring points and survey results are summarized in Table 8.2-1 and Figure 8.2-1.

The results indicate that carbon monoxide (CO), nitrogen dioxide (NO2) and sulphur dioxide (SO2) levels were below the standards defined in Sub-Decree #42. However, particulate matter of both PM2.5 and PM10 sizes indicated very high values compared to the standards of the World Health Organization (WHO).



Source: PPUTMP Project Team

Figure 8.2-1 Air Pollution Survey Monitoring Points

[2] The Feasibility Study on the Improvement of National Road No.1 (Phnom Penh – Neak Loueng Section) in Kingdom of Cambodia, JICA, 2003.

Table 8.2-1 Air Quality along the Project Route

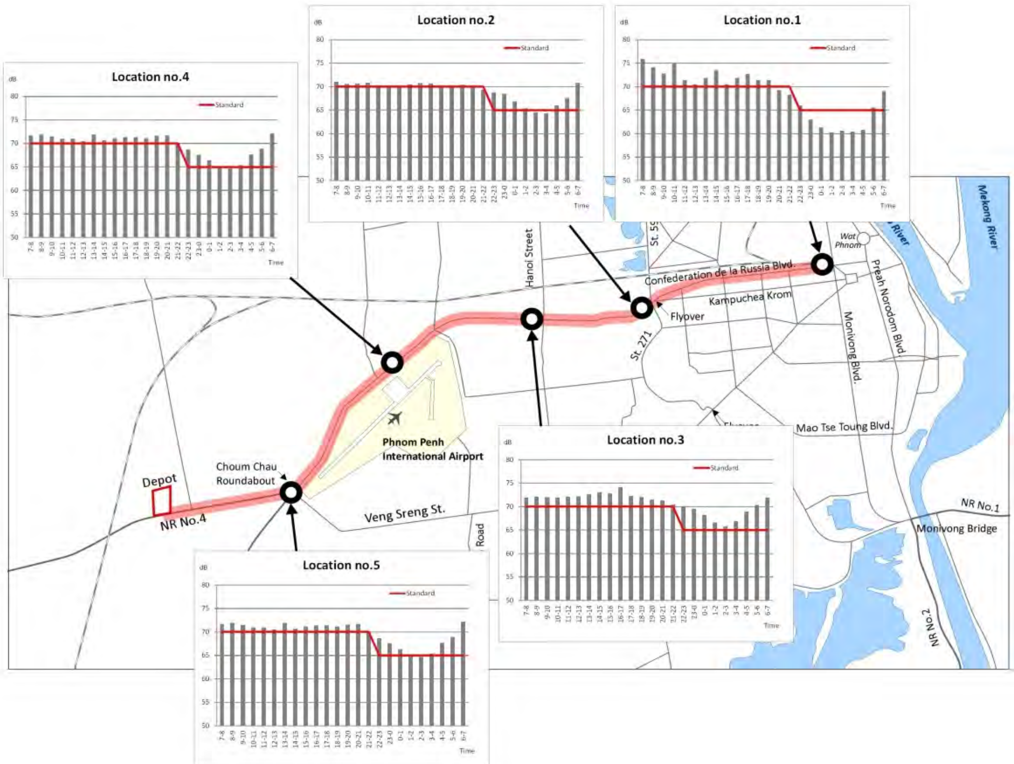
Type	Unit	Point 1	Point 2	Point 3	Point 4	Point 5	Cambodia Standard*1	WHO Standard*2
CO	mg/m3	2.86	1.79	2.86	3.58	3.58	20	
NO2	mg/m3	0.057	0.029	0.045	0.056	0.058	0.1	
SO2	mg/m3	0.033	0.027	0.027	0.025	0.033	0.3	
PM2.5	µg/m3	128	107	284	186	248	n.a.	25
PM10	µg/m3	93	68	150	71	169	n.a.	50

Notes: The results are average of 24 hours continuous survey.
*1: Sub-Decree #42 on the Control of Air Pollution and Noise Disturbance, MOE Cambodia.
*2: WHO Air Quality Guidelines for particulate matter, ozone, nitrogen, dioxide and sulfur dioxide, Global update 2005.
Source: PPUTMP Project Team

(vi) Noise and Vibration

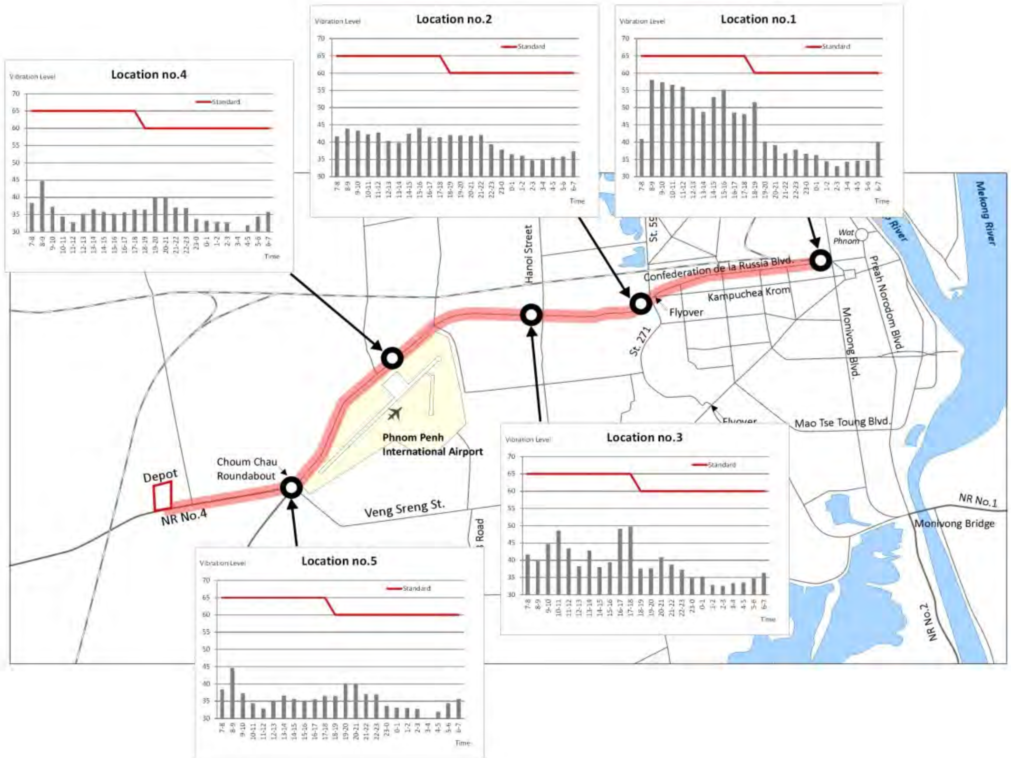
Same as with air pollution, since noise and vibration have never been monitored regularly and there are no available appropriate secondary data, a survey was also conducted along the route. Results show that noise levels along the project route was generally above the Cambodian standard (see Figure 8.2-2).

Meanwhile, the vibration level seems to be not serious. Compared to the vibration standards in Japan (since Cambodia does not have its own standards), the results were all below the said standards (see Figure 8.2-3).



Source: PPUTMP Project Team

Figure 8.2-2 Noise Level along the Project Route



Source: PPUTMP Project Team

Figure 8.2-3 Vibration Level along the Project Route

(2) Social Environment of the Project Site

(i) Population

The project route, along Russia Blvd., connects between the heart of Phnom Penh and the newly developed area in the western part including the international airport. This route can be said as one of the backbone routes for connecting the east and west parts of the study area, and brings many passengers, commuters and visitors every day.

The route runs through a densely populated area. In particular, along the route from the east terminal side intersecting with Monivong Blvd. to the airport, many buildings face the road such as shop houses, government offices, commercial buildings, schools and public facilities. The population and population density along the route are shown in Table 8.2-2 and Figure 8.2-4.

Table 8.2-2 Population and Density in the Project Site

District Name	Commune Name	Population	Density
Doun Penh	Phsar Thmei Ti Pir	7,400	692
	Srah Chak	39,500	125
	Voat Phnum	9,300	144
Prampir Meakkara	Monourom	11,200	810
	Mittakpheap	10,300	266
Toul Kouk	Phsar Depou Ti Muoy	10,700	329

District Name	Commune Name	Population	Density
	Tuek L'ak Ti Muoy	13,500	149
	Tuek L'ak Ti Pir	13,100	309
	Boeng Kak Ti Pir	29,200	174
Sen Sok	Tuek Thla	61,600	92
Posen Chey	Chaom Chau	34,500	13
	Kakab	35,100	28
	Kantaok	12,500	9

Source: General Population Census of Cambodia 2008

Source: PPUTMP Project Team based on General Population Census of Cambodia 2008

Figure 8.2-4 Population Density along the Project Route

(ii) Land Use

The land use along the route is mostly covered built-up area (see Figure 8.2-5). From the intersection with Monivong Blvd. to St. 215, the south side of the route is occupied by government offices such as The Council of Minister and Ministry of National Defense. Also, this route has a large median used as an urban park. From St. 215 to Choum Chao Roundabout, the roadside is occupied by houses, factories, shops, educational facilities including the University of Phnom Penh, and public facilities including hospitals and clinics. After St. 271, there is a huge vacant land which is already starting to be developed for residential area. A large local market, the Pochentong Market, is located along the road and beside the airport. On the opposite side of the market is the Pochentong Children's Park. The surrounding area of these facilities are relatively busy in the morning and night time. The section from Choum Chao Roundabout to the candidate depot is mainly occupied by factories, shops and houses. Some vacant lands are still observed. Throughout the entire route, there are no religious facilities such as pagoda and shrines that have been observed.

Source: PPUTMP Project Team based on Google Earth Pro

Figure 8.2-5 Land Use along the Project Route

8.3 Legal Framework for Environmental and Social Consideration

In order to implement the East-West Line project, relevant environmental laws and regulations should be considered. These include the following:

- Law on Environmental Protection and Natural Resources Management (LEPNRM)
  - Sub-Decree #27 on Water Pollution Control;
  - Sub-Decree #36 on Solid Waste Management;
  - Sub-Decree #42 on the Control of Air Pollution and Noise Disturbance;
  - Sub- Decree #72 ANRK.BK on Environment Impact Assessment Process; and
  - Prakas (Declaration) on General Guideline for Conducting Initial and Full Environmental Impact Assessment Report.

- Law on Expropriation

In the planning stage, the project needs to comply with the regulations related to environmental impact assessment (EIA). According to Sub- Decree #72, this project can be categorized as a “railway project” that needs to prepare an initial EIA (IEIA) and/or EIA regardless of its size. The project owner, therefore, should get the approval from MOE before submission of the project proposal for the Royal Government's decision. Preparation and submission of the IEIA is a necessary step to go forward.

In the implementation stage, the project needs to comply with the guidelines with respect to water pollution, solid waste management, and air pollution and noise, particularly during the construction phase. While resettlement is not necessary in this project, land acquisition for the depot development is vital. Thus, the Law on Expropriation should be considered.

8.4 Environmental Scoping

With consideration to the checklist for preparing IEIA and EIA under the Cambodian Declaration[3] and JICA Guidelines[4], the items with anticipated negative environmental impacts were listed and evaluated. Each impact was evaluated according to three phases, namely preparation, construction and operation. The results are shown in the matrix in Table 8.4-1.

Table 8.4-1 Environmental Scoping Matrix for the Project by Phase

Impact		Preparation Phase	Construction Phase	Operation Phase
Social Environment	Involuntary resettlement			
	Land acquisition	✓		
	Local economies			✓
	Land use and utilization of local resources			✓
	Social institutions			
	Existing social infrastructures and services		✓	
	Poor, indigenous, or ethnic people			
	Misdistribution of benefits and damages			
	Local conflicts of interest			
	Limitation of accessibility to information, meetings, etc. of a specific person or group			
	Gender			
	Children’s rights			
	Cultural heritage			
	Infectious diseases such as HIV/AIDS		✓	
	Health and sanitation		✓	
	Water right and usage			
	Accidents		✓	
	Access to sunlight		✓	✓
Natural Environment	Topography and geology		✓	✓
	Soil erosion			
	Groundwater		✓	✓
	Flow of hydrological features		✓	✓
	Biota and ecosystems			
	Meteorology			
	Landscape		✓	✓
	Global warming			
Pollution	Air pollution		✓	
	Water pollution			
	Soil pollution		✓	
	Waste		✓	
	Noise and vibration		✓	✓
	Ground subsidence			
	Offensive odour			
	Bottom sediment			

Source: PPUTMP Project Team

The results of the evaluation and their reasons/justifications are shown in Table 8.4-2. The evaluation was categorized into four levels from “A” to “D” depending on the expected

[3] Prakas on General Guideline for Conducting Initial and Full Environmental Impact Assessment Report, MOE, September 2009.

[4] Guidelines for Environmental and Social Considerations, JICA, April 2010.

magnitude of adverse impact, where A means significant, B does some, C does small, and D does nothing.

Table 8.4-2 Evaluation of Negative Impact

Impact		Level	Reason
Social Environment	Involuntary resettlement	D	Since the alignment takes the middle of the ROW, involuntary resettlement is not necessary. Furthermore, the candidate depot is planned in a vacant land.
	Land acquisition	C	<u>Preparation phase:</u> Since the project needs land with size of approximately 10 ha for construction of the depot, land acquisition is necessary. The location of the candidate depot is on private land without any houses or buildings. The project owner needs to purchase the land with respect to the Law of Expropriation.
	Local economies	C	<u>Operation phase:</u> The East-West Line project will provide the transportation service for airport users and visitors. Thus, tuk-tuk drivers might be affected by a decrease in their job opportunities. However, with the development of the transport terminal at Choum Chao Roundabout proposed by the PPUTMP, such tuk-tuk drivers could shift from the airport to the terminal to provide feeder services.
	Land use and utilization of local resources	C	<u>Operation phase:</u> Only the land for the depot will be changed from the existing land use, vacant, into public facility. This land use change does not give negative impacts on local resources.
	Social institutions	D	Since public consultation is required in preparing the EIA report before implementation of the project, information disclosure and public participation will be conducted. This kind of activity can avoid giving negative impacts on social institutions.
	Existing social infrastructures and services	C	<u>Construction phase:</u> Since during the construction some road lanes will be closed, traffic congestion may occur. However, the route is wide, equivalent to 4-lanes in most parts. The impact is expected to be small.
	Poor, indigenous, or ethnic people	D	Small positive impacts to the transport poor by providing public transportation is expected.
	Misdistribution of benefits and damages	D	Since the alignment will not cross any agglomeration in terms of community and land, this impact is not expected.
	Local conflicts of interest	D	No influence on local conflicts is expected.
	Limitation of accessibility to information, meetings, etc. of a specific person or group	D	Since public consultation is required in preparing the EIA report before implementation of the project, information disclosure and public participation will be conducted without any discrimination.
	Gender	D	No influence on gender is expected.
	Children's rights	D	No influence on children's rights is expected.
	Cultural heritage	D	No cultural heritage facility exists along the project route.
	Infectious diseases such as HIV/AIDS	C	<u>Construction phase:</u> During the construction many seasonal workers will be hired. Since they tend to be young and sexually active in general, spread of infectious diseases is anticipated. This may create a negative impact on local communities.
	Health and sanitation	C	<u>Construction phase:</u> Concrete construction of viaduct and underground railway

Impact		Level	Reason
			construction with the open-cut method are anticipated to cause dust-fall. Vehicles for delivering materials also might contribute to it. Passage of construction vehicles such as dump trucks, bulldozers and cement mixer trucks are expected to emit exhaust gas. Such pollution may create negative impacts on residents living near the project site as well as construction workers.
	Water right and usage	D	No influence on water right or usage is expected.
	Accidents	C	Construction phase: During construction, some road lanes will be closed. Some traffic accidents may occur.
	Access to sunlight	C	Construction phase and Operational phase: The route in some parts of the city center and airport areas will be underground with the total length of 2.6 km. However, the remaining part with a total length of 12.6 km will be built as viaduct with approximately 14 m high. Accordingly, this concrete structure may cut the sunlight in the surrounding area. However, Cambodia has a tropical climate and the access to sunlight of the buildings is not important like in Japan. Correspondingly, no regulation or policy for the access to sunlight exists. Furthermore, from past project experience, arguments on the access to sunlight have not been addressed so far. Therefore, the impact may not be significant because the shadow will be made in a small area and will seasonally appear since the alignment runs from east to west.
Natural Environment	Topography and geology	D	Construction phase and Operational phase: Some parts of the route will be constructed underground, with a total length of 2.6 km. Small negative impacts are expected since each section is supposed to be 1.3 km long and the radius of the tunnel is planned to be rather small compared to other railway systems.
	Soil erosion	D	No influence on soil erosion is expected.
	Groundwater	D	Construction phase and Operational phase: Small influence on groundwater is expected due to construction of the underground section. However, each section is supposed to be 1.3 km long in the central area. The tunnel may not cut the groundwater vein. This urban area has water supply service and does not use wells. Furthermore, PPWSA is taking the water from Tonle Sap and Mekong rivers. Therefore, the level of impact is evaluated to be small.
	Flow of hydrological features	D	No influence on hydrological features is expected because the alignment does not cross any river.
	Biota and ecosystems	D	Since the alignment will not cross any natural area or park, this impact is not expected.
	Meteorology	D	No influence on meteorology is expected due to the size of the project.
	Landscape	C	Construction phase and Operational phase: The viaduct structure will change the landscape in the project site. However, in the city center which is the famous area of Phnom Penh, it will be stored underground. The impact is expected to be limited. In contrast, the viaduct of the modern railway system may contribute to an increased modernized image.
	Global warming	D	Some positive impacts on the global warming is expected due to the shift from private vehicles to public transportation. Furthermore, the AGT is driven by electrical power and does not emit CO_2.
Pollution	Air pollution	C	Construction phase: Emission of particulates is expected due to the construction activities and related heavy vehicle movement. This, however, may be caused in

Impact		Level	Reason
			a short time.
	Water pollution	D	No influence on water pollution because the alignment is located a certain distance from the rivers.
	Soil pollution	C	<u>Construction phase and Operational phase:</u> Small influence on groundwater is expected due to construction of the underground section. However, each section is supposed to be 1.3 km long in the central area. Furthermore, well water is not used in this area.
	Waste	C	<u>Construction phase:</u> Hazardous waste will not be generated during the construction, but some solid waste will be created by viaduct construction, underground construction, and land development for the depot. In addition, domestic waste will be generated by construction workers during the construction period. The level of these impacts is evaluated as small.
	Noise and vibration	C	<u>Construction phase:</u> Certain noise and vibration will arise due to a series of construction activities such as drilling, filling, paving, piling, and building construction. Additionally, passage of construction vehicles, particularly heavy vehicles, near the site may contribute to an increase in bothersome noise and vibration from dump trucks, cranes, wheeled front loaders, and earth excavation vehicles. However, such impacts only arise during the construction phase. <u>Operation phase:</u> Some noise and vibration will arise from the train operations. However, since the AGT system employs rubber tires instead of iron wheels, the noise might rather be small than other systems. In contrast, positive impacts on the noise and vibration are expected due to decreased number of private vehicles due to the shift to public transportation.
	Ground subsidence	D	Although the project includes construction underground, the size will be limited. Since the geological feature in Phnom Penh seems to be firm, ground subsidence is not expected from the project.
	Offensive odour	D	No influence on offensive odor is expected.
	Bottom sediment	D	No influence on bottom sediment is expected.

Note: The level of impact is categorized into four types: A means significant, B does some, C does small, and D does nothing.
Source: PPUTMP Project Team

8.5 Overall Results of the Environmental Scoping

The overall size of the environmental impacts caused by implementation of the Project can be considered small. Most of the impacts occur only during the construction phase, while some impacts expected in the operation phase are evaluated to be relatively small. These expected negative impacts could be made even smaller by undertaking appropriate mitigation measures.

8.6 Mitigation Measures

In order to reduce the project's negative impacts, mitigation measures must be taken during project implementation. These measures are summarized in Table 8.6-1.

Table 8.6-1 Mitigation Measures

Item	Effect	Mitigation Measures
Land acquisition	C	The location of the candidate depot is on private land without any houses or buildings. The project owner needs to purchase the land from the landowner in accordance with the Law of Expropriation.
Local economies	C	Project implementation can have a negative impact on the livelihood of the tuk-tuk drivers who provide the transport service from/to the airport. In order to mitigate such impact, alternative service routes or job opportunities can be prepared for them. Since development of the transport terminal at Choum Chao Roundabout is proposed by the PPUTMP, the tuk-tuk drivers can obtain alternative job opportunities at the terminal by providing transport feeder services.
Land use and utilization of local resources	C	Land use of the expected depot is supposed to change. The land can be used not only for the depot itself but also for complex facilities such as offices or commercial facilities. The project owner can utilize the land and create job opportunities for local people to work in the depot and such facilities.
Existing social infrastructures and services	C	In the construction period, some roads will be closed. This can create some inconvenience for the road users and local people. Prior to construction, public consultations should be conducted to share information and to promote understanding about the project and construction schedule among the local people and road users.
Infectious diseases such as HIV/AIDS	C	A risk of spreading infectious diseases by seasonal workers is anticipated in the construction period. To minimize such risk, educational training on HIV/AIDS and other infectious diseases should be conducted for the construction workers. In addition, information dissemination by means of posters and brochures about the diseases in the project area can help prevent them.
Health and sanitation	C	During construction, dust-fall caused by construction equipment and vehicles is anticipated. To reduce dust, sprinkling of water in the project site and access roads needs to be carried out regularly especially in the dry season. Covering the truck bed for carrying soil, sand, etc. is another mitigation measure for reducing dust.
Accidents	C	In the construction period, traffic accidents are anticipated due to changes in the traffic flow or closing of roads. Traffic control personnel need to be hired for facilitating smooth traffic. Prior dissemination of information on construction schedule, and temporary road system and traffic flow should be undertaken to call the attention of road users, especially vehicle drivers.
Access to sunlight	C	Seasonal or intermittent blocking of sunlight may be caused by the construction of the viaduct railway facility. Before project implementation, public consultations need to be conducted among the affected households and to obtain consensus from them.
Landscape	C	The viaduct structure will change the landscape, though the modern railway system may contribute to enhancing the image of Phnom Penh City. Wall plants on the concrete structures and coloring the train cars can contribute to a preferable landscape.
Air pollution	C	During construction, air pollution by dust-fall is anticipated. The same mitigation measures for “Health and sanitation” will apply to preventing air pollution.
Soil pollution	C	Construction of the underground railway can cause some soil pollution if arsenic or other chemical compounds are present in the soil. Before project implementation, a detailed soil survey is required to understand the site's current condition. In case arsenic or other chemical compounds are found, dust distribution needs to be prevented by sprinkling water and covering contaminated soil with waterproof sheets. The soil waste shall be disposed appropriately in accordance with regulations.
Waste	C	In the construction period, solid waste caused by construction activities and domestic waste of workers need to be disposed in accordance with Sub-Decree

Item	Effect	Mitigation Measures
		#36 on Solid Waste Management. At the same time, contractors and workers will be educated about proper disposal.
Noise and vibration	C	In the construction period, some noise and vibration will be caused by construction activities and passage of heavy vehicles. Prior information dissemination of the construction schedule and relevant activities should be undertaken to promote understanding among the local people.

Source: PPUTMP Project Team

8.7 Way Forward to Project Implementation

To implement the project, the next steps in terms of environmental and social considerations are as follows:

(i) Requirements for Environmental Approval

Before obtaining the project approval, the project owner needs to submit the feasibility study report and IEIA, which includes the contents of this section, to MOE. After examination by MOE, it will be decided to carry out the EIA.

According to the "Prakas on General Guideline for Conducting Initial and Full Environmental Impact Assessment Report" and the interview with the MOE officer, the Phnom Penh East-West Line Project might be required to conduct a full-scale EIA.

(ii) Required Surveys

In order to prepare the full-scale EIA report, the following detailed surveys and monitoring are expected to be carried out:

- Geological Survey;
- Groundwater Survey;
- Soil Survey; and
- Indirect PAPs Survey.

Before construction, the geological, groundwater and soil surveys are necessary particularly for the underground section. In addition, public consultations must be conducted in order to share the project information and discuss with the local people and relevant parties and organizations. Furthermore, since the tuk-tuk drivers who provide the transportation service from/to airport can be categorized as "indirect project-affected persons (PAPs)," the current condition survey of tuk-tuk drivers also needs to be considered. Depending on the results, an appropriate plan for route relocation might be necessary.

Regarding air quality and noise, current conditions are above the standards. In the feasibility study, air quality and noise levels need to be estimated based on the future traffic volume along the project route and on the detailed construction design. Based on the estimation results, the appropriate countermeasures (e.g., use of noise absorbing materials) will be taken account in the design.

9. Project Implementation

As described in previous sections, there are many issues in carrying out project implementation. First, the huge initial cost of the project presents difficulty on how to secure the financial requirements and becomes the first hurdle to whoever will implement the project. Second, it is pointed out that commercial operation will be difficult to maintain if operation cost is compensated only by fare-box revenue at current tariff levels. In addition, looking at the fiscal status of PPM, the budgetary limitations of the public sector could become the largest obstacle to project implementation.

Given these circumstances, promoting private sector participation in the rail project could make it possible to find a practical solution to this difficult situation.

9.1 General Considerations on Private Sector Involvement in Rail Project Implementation

Since the railway project is carried out through complex steps by many parties with precious resources, it is quite important to choose the relevant entity that is responsible for specifying the process and clarifying the role sharing among the parties. Although railway projects have traditionally been a public sector endeavor, they have recently become more like commercial ventures where private sector involvement is gaining popularity. Initial discussions should be conducted on how the private sector can be involved in the railway project, and what are its advantages as compared with the traditional public sector-led modality.

Table 9.1-1 shows the technical characteristics and requirements for each step of project implementation and their suitability for public and/or private sector involvement.

Table 9.1-1 General Notes on Adaptability for Implementation by Entity Attribute

Steps in Project Implementation		Required Capacity / Standpoint	Adaptability	
			Public	Private
Preparation	Route definition	• Necessary route from public interests • Feasible route based on professional judgment	◎	○
	Plan formulation	• Identification of project purpose • Insight for future prospect	◎	△
	Project institutional arrangement	• Appropriate knowledge on legal aspect	◎	△
Construction	Financial arrangement	• Fund raising ability • Asset management and financial transaction knowledge	○	◎
	Land acquisition	• Authorization by public law	◎	△
	Design	• Technical knowledge, skills and experience	△	◎
	Infrastructure	• Construction skills and experience • Construction management know-how	△	◎
	E & M	• Procurement know-how	○	○
Operation	Operation	• Operation know-how and experience • Management capacity	△	◎
	Maintenance	• Management capacity • Moral and tight discipline	○	○
	Exploitation	• Marketing capacity • Accounting capacity	△	◎

Note: Meaning of symbols: ◎=Suitable ○=Possible △=Not suitable
Source: PPUTMP Project Team

Following are some considerations regarding the selection of project entity by project implementation stage:

- Which sector is better than another is not concluded by stage;
- The public sector seems to be preferable at the project preparation stage;
- On the other hand, the private sector seems to be preferable at both the construction and operation stages; and
- Depending on the stage, joint implementation by both public and private sectors will be applicable.

9.2 Role Sharing Model

As for the model of project implementation, there are several models in which the public and private sectors share roles according to the project stage. Typical examples and their evaluation are shown in Table 9.2-1.

Table 9.2-1 Comparison of Various Project Implementation Schemes

Typical examples / Comparison			1	2	3	4
					PPP type	
			traditional public enterprise type	Management contract	concession through track access charge	BOT
Asset ownership		Infrastructure				
		Rolling stocks				
Role sharing by project stage	Planning/preparation	Principal				
		Agent	–	–		
	Land acquisition	Principal				
		Agent	–	–	–	–
	Construction	Principal				
		Agent	–	–	–	–
	Operation	Principal				
		Agent				
Main fund source			Public money including ODA	Public money including ODA	Public fund+Commercial finance	Commercial finance
Project risk analysis	Financial burden to public sector		High	High	fair	Low
	Operation efficiency		Low	Relatively High	Relatively High	High
	Commercial risk burden for private sector		–	Low	Relatively High	High
	Project default risk		fair	Low	fair	High
Note	Public sector	Private sector				

Source: PPUTMP Project Team

Following are some considerations regarding the above role sharing models:

- If the public sector is assumed to take the financial burden, Scenario 2, the management contract method is recommended.
- If low financial burden for the public sector should be an absolute condition, Scenario 3,

concession type is recommended, though it might involve some default risk.

- As a conclusion, it becomes a choice of the public sector whether the public sector accepts the financial burden without project default, or assumes project default risk to some extent although with low financial burden.

9.3 Possibility and Limitation of Private Sector Participation Scheme Application

Table 9.3-1 presents an overview of the key characteristics of selected public-private partnership (PPP) railway projects in Europe based on United Nations (UN) data.

Table 9.3-1 Overview of Selected PPP Rail Projects in Europe

Project	Time from Design to Completion	Contract Duration (Yrs.)	Route Length (Km)	Capital Expenditure	Public Co-funding (Grants)	Type
Stockholm-Arlanda Airport	1993-1999	41	39	SEK4.1 bil	SEK22.4 bil	BOT
HS1 Channel Tunnel Rail Link	1996-2003 (20079	90	109	GBP5.8 bil	GBP2.1 bil	DBFM
Oresund Road-Rail Link	1991-2000	25-30	38	EUR2.0 bil	N.A.	DBFM
HSL-Zuid	2000-2007	25	100	EUR6.0 bil	EUR0.11 bil/year	DBFM
Perpignan-Figueras HS	2005-2009	50	45	EUR1.1 bil	EUR0.6 bil	BOT
Diabolo Rail Link Brussels	2007-2012	35	3	EUR0.54 bil	EUR0.25 bil	DBF
Liekenshoek Rail Link Antwerp	2008-2013	38	16	EUR0.84 bil	EUR0.05 bil/year	DBFM
Tours-Bordeaux HS	2011-2016	50	340	EUR7.8 bil	EUR4.0 bil	BOT
GSM-R France	2010-2015	15	14000	EUR1.5 bil	EUR0.16 bil	DBFM
Lisbon-Madrid HS	2009-2013	40	165	EUR7.8 bil	N.A.	DBFM
Nimes-Montpellier HS	2012-2017	25	80	EUR1.8 bil	N.A.	DBFM
Montpellier Odysseum Station	2012-2017	30	-	EUR100/120 mil	50%	DBFM
Bretagne-Pays de la Loire HS	2011-2017	25	214	EUR3.4 bil	EUR1.85 bil	DBFM

Source: United Nations, 2012

The above table provides an overview of PPP application in rail projects in Europe during the last two decades. They include 5 French projects, 2 projects each in Sweden and Belgium, and others.

It seems that DBFM is the more frequently applied PPP scheme, with 9 of the projects involving such scheme and the other 3 projects involving BOT.

Project capital costs vary from EUR100 million to EUR7.8 billion, but most projects are considered to be relatively large. Regarding public money expenditure, it is shown that there are no such cases of withdrawing public fund spending even if the BOT scheme is applied. On average, around 50% of total project cost was paid by the public sector. Regarding the cost expenditure itself, private sector involvement might not bring a reduction in initial investment cost, as compared with a purely public project, because private finance depends on the capital market.

What is improved by private sector involvement in project implementation is the quality aspect of project. For instance, there is a possibility of project cost reduction in the long term by applying the maintenance know-how of the private sector, so-called Life Cycle Cost (LCC). In addition, project implementation time will be shortened by participation of the private sector at an early stage.

APPENDIX 5 Verification of Target Public Transport Modal Share in 2035 based on the SP Survey

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ABBREVIATIONS

BAU	Bureau of Urban Affairs
DPWT	Department of Public Works and Transport
JICA	Japan International Cooperation Agency
PE	Public Experiment
PPCC	Phnom Penh Capital City
PPCH	Phnom Penh City Hall
PPUTMP	Project for Comprehensive Urban Transport Plan in Phnom Penh Capital City

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1 Introduction

1.1 Background

One of the planning targets of PPUTMP is the shift from private transport to public transport of Phnom Penh citizens, and the introduction of public transport in Phnom Penh Capital City is inevitable as it is the only capital city without public transport excluding para-transit in the Southeast Asian region. PPUTMP has set the target public transport modal share in 2035 at 30% based on the traffic congestion rate in the city centre and the examples of other cities with public transport.

Phnom Penh citizens realize that the merits and demerits of a public transport system through the experience of the public experiment of city bus operation. After the public experiment, the number of bus routes has been increased from 1 to 3 routes plying not only the north and south but also the west and east covering major transport corridors in PPCC. Forty-three (43) second-hand buses from Korea were operated and 6,930 (average of 1 - 15 December 2014) daily passengers are served.

It was not expected that the city bus system would become the ordinary mode of transport for citizens in the city when PPUTMP started.

Considering above conditions, it was proposed that the verification of the target public transport modal share (30%) which was set during the master plan formulation be made through the conduct of a survey called Stated Preference (SP) survey.

1.2 What is SP Survey?

SP survey is aimed at verification of target public transport modal share based on finding out which transport service plan will Phnom Penh citizens choose from by comparing between a rail transit system that is being planned for the western part of the city with several alternative service plans (variations of time and fares), and current transport modes and bus in operation in the city.

As stated above, the SP Survey focuses on putting forth several rail transit service plans that can be compared to the current transport modes in operation in the city. The selected survey interviewees are then asked to select their preferred transport service plan. For this purpose, there are two methods or approaches in questioning the interviewees in such a survey: (1) in the case where a rail transit service is provided which is capable of meeting the conditions of their current travel demand requirements; and (2) in the case where nothing is suggested to the current transport situation and interviewees are asked to imagine the future transport scenario. The selection of approach to use for the survey depends largely on the considerations of ease of answering the questions for interviewees. In the end, the first was used for the survey.

2 Overall Work Procedure

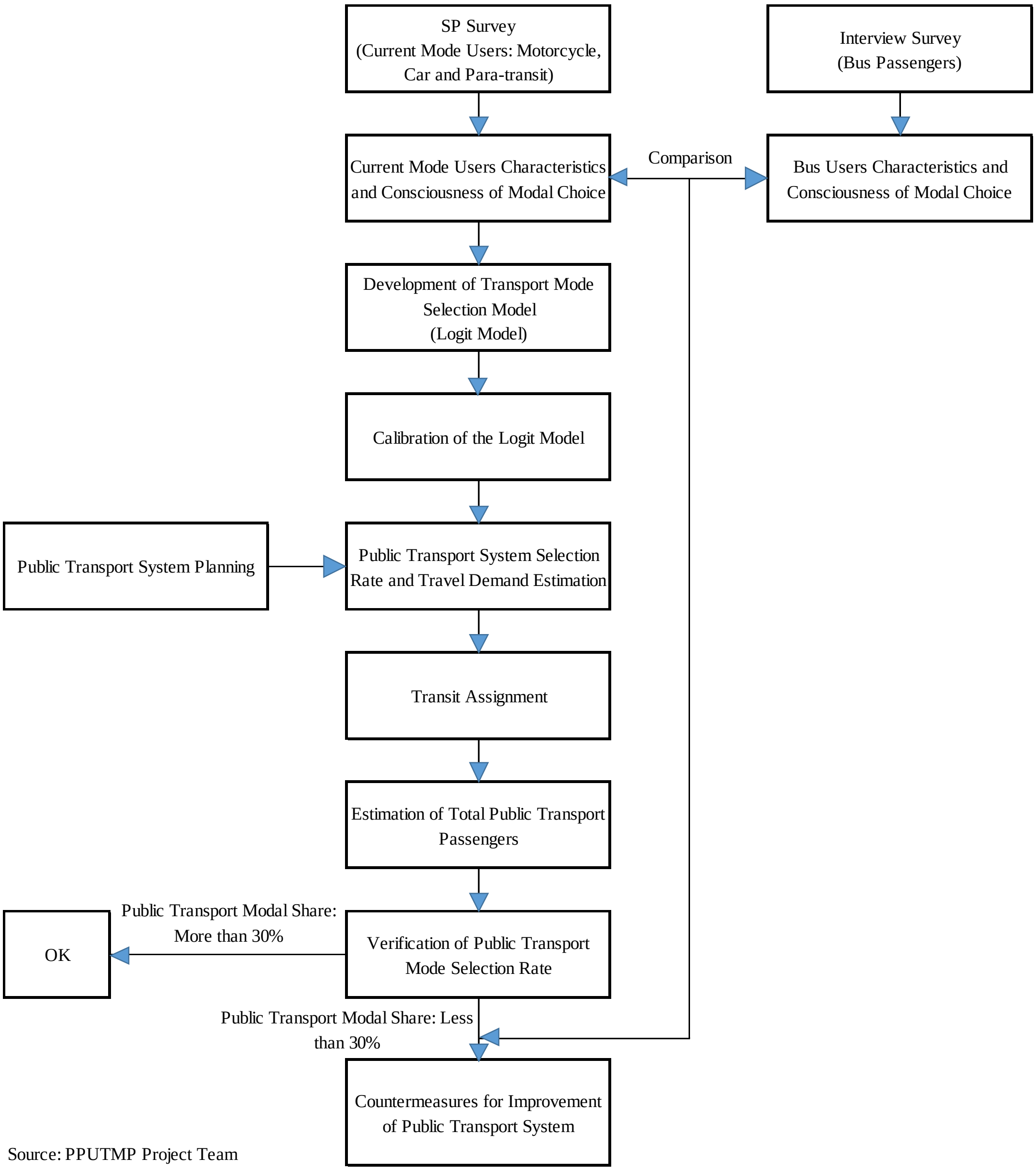
The data collected from the SP survey will be used to develop a Logit model in predicting the travel modes of interviewees based on the rates of selection between their present transport modes and the proposed rail transit transport mode. The present transport modes to be targeted in the survey are the passenger car, motorcycle and para-transit. In principle, the transport conditions or requirements shall include the origin-destination (OD), travel time, travel cost and other special features that are reflective of these trips.

In addition, a bus passenger interview survey will also be conducted and to know the user's characteristics and the consciousness of the modal choice.

In this manner, the Logit model can be calibrated in predicting more accurately the choice of transport modes among the residents.

Subsequently, the calibrated model is used to predict the future travel demand by mode (car, motorcycle

and para-transit) based on growth trend. At the same time, the model is also used to predict the share of demand transferred from these travel modes to a future rail transit and bus service modes when it is introduced. Finally, the travel demand transferred to the new rail transit or bus mode predicted by the model is essential in planning the transit routes as well as the number of passengers.
Then, public transport selection rate will be checked as to whether it is over or under 30%.
In the case of “less than 30%”, countermeasures for the improvement of public transport system such as development of convenient mode interchange areas will be proposed.
The above survey planning concept is illustrated in the following flowchart.



Source: PPUTMP Project Team

Figure 2.1-1 Overall Work Flow

3 Survey Method (SP Survey for Current Mode Users and Bus Passenger Interview Survey)

The SP survey shall be conducted at the earlier stated four locations of mall/markets and on the three bus routes as shown in Figure 3.1-1. Passenger cars, motorcycles and para-transit users traveling in the city shall be asked regarding their preference of transport service.

Before conducting the SP Survey, information that explains clearly the features of the rail transit system must be prepared including a video clip. During the interview survey, such information shall be explained to interviewees first before seeking their answers to the questions in the survey form.

The SP Survey must be conducted by direct interviews with the motorcycle, car, para-transit (motodop and tuk-tuk) and bus users. At the same time, the survey should clearly indicate their trip purposes such as 'to work', 'to school' or other purposes.

A total target of 400 samples is to be collected for the SP survey for the current mode users. The samples are to be distributed evenly among the transport modes, that is, 100 samples per mode (car, motorbike and 2 para-transit modes).
For the interview survey for the bus passengers, it is basically an interview survey to be conducted with the bus passengers in the bus.
A total target of 800 samples is to be collected in the survey for the bus passenger. This shall be distributed by the passengers' previous modes of travel. Hence 100 samples each must be collected from those whose previous travel mode is car (driver and passenger), motorbike (driver and passenger) or para-transit (motodop and tuk-tuk). Supplementally, bicycle and cycle users are also to be collected 100 samples per mode.

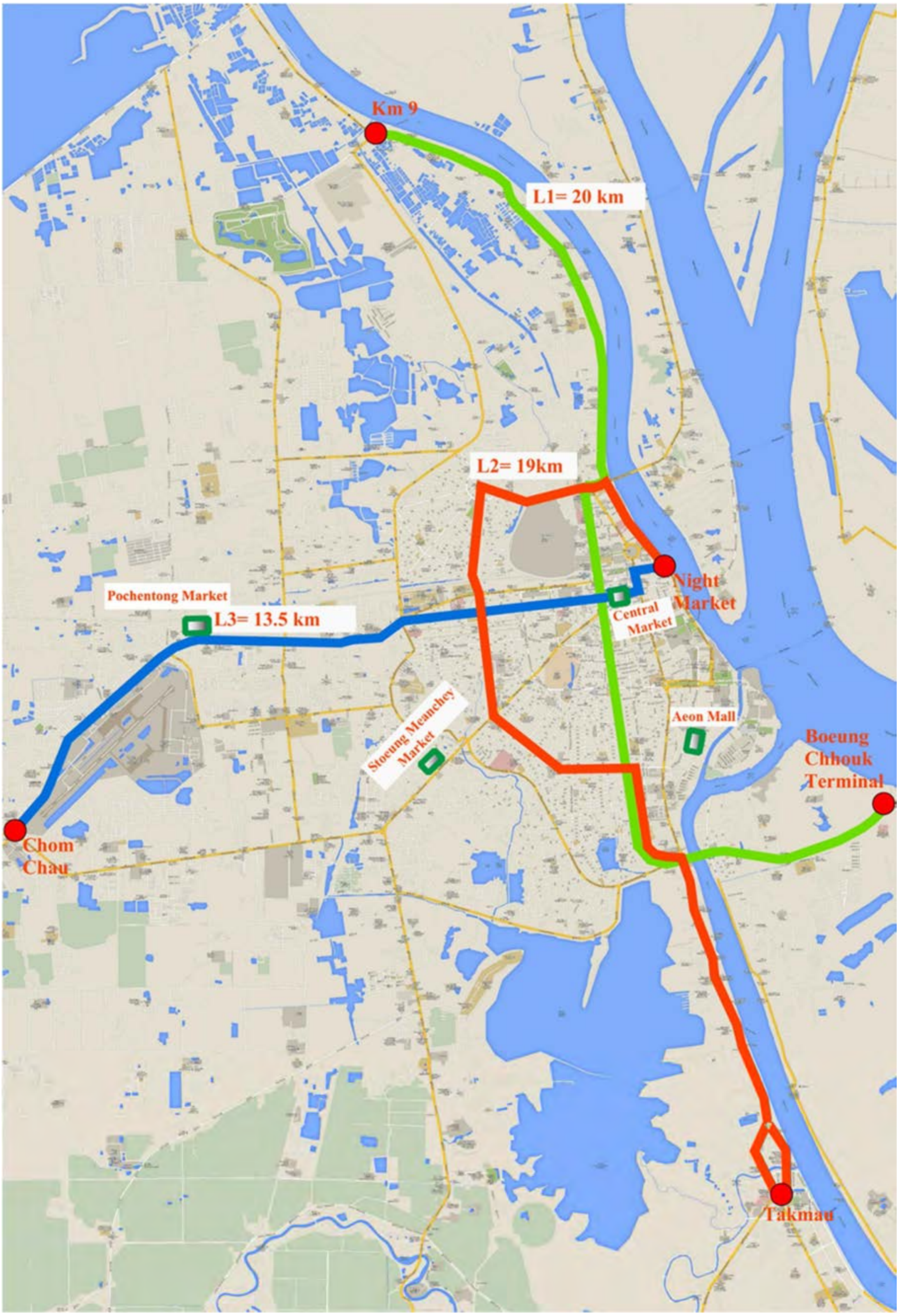
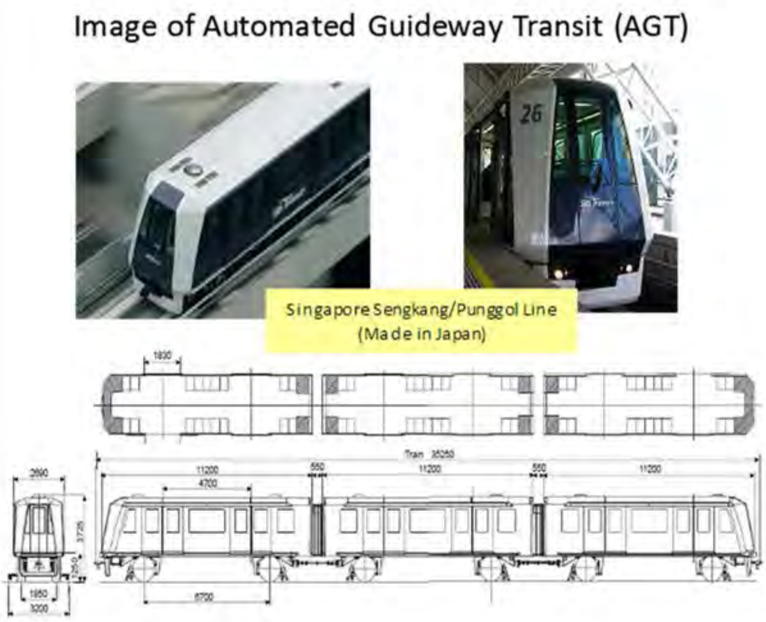


Figure 3.1-1 Survey Locations (3 Bus Routes and 4 Mall/Markets)

Table 3.1-1 Image of Rail Transit (Automated Guideway Transit (AGT))

The following table shows the characteristics of the Automated Guideway Transit (AGT) which will be introduced into Phnom Penh Capital City as a new public transport in the future.

Items	AGT
Photo	
Train Capacity	331 passengers/train (3 cars)
Track Structure	Elevated and partially underground
Advantages	It is not noisy because it uses rubber tires.
	It is possible to travel comfortably with the fully air-conditioned trains, and avoid the heat of the sun or rain.
	Unlike the motodop, it is a safe mode of transport as it is completely separate from road traffic.
	On time every time unlike cars and motorcucles on road. Travel time of cars and motorcycles depends on road traffic conditions.
	It has a high passenger carrying capacity and lesser discharge of CO2 than a car.
Disadvantages	A few minutes of walking or riding a mode of transport is needed to reach the station and some waiting time spent for the AGT to arrive.
	It is necessary to use a stairway to reach the elevated platform.

SP Survey Form 1-1 (Current Mode User)

Cooperation for the Public Transport Survey

JICA Study Team

1. Purpose of the Survey

Currently, the JICA Project Team is formulating the Urban Transport Master Plan for Phnom Penh Capital City. The introduction of public transport system in the city is being studied to ease traffic congestion and prevent the present traffic condition from worsening. As a public experiment, a one-route city bus operation was carried out, which is part of the master plan activities. This experiment has resulted in the ongoing city bus operation with expanded routes under the management of Phnom Penh Capital City (PPCC) and the Department of Public Works and Transport (DPWT).

This survey has a two-fold purpose: (1) to gauge citizen awareness of the public transport including rail transit system whose introduction the city is also considering; and (2) to forecast future public transport demand in Phnom Penh.

1.2 Survey Contents

・Current trip characteristics
・User's trip purpose in using public transport
・Consciousness for modal choice
・Individual characteristics

Rest assured that your responses will be used only for the purpose stated above.

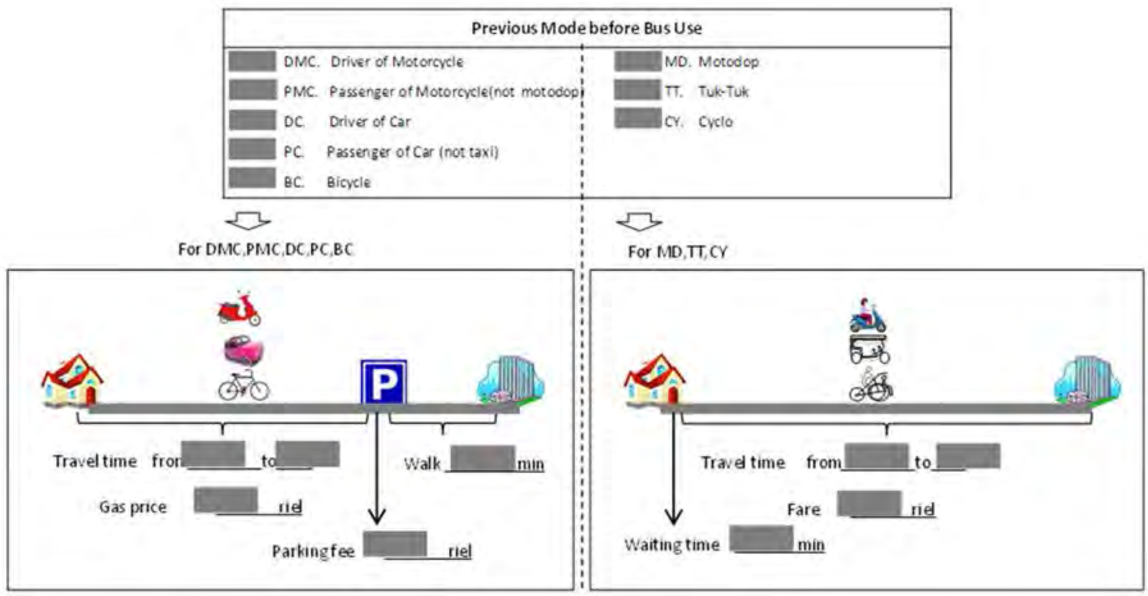
1.3 Interview Time

Approximately 30 minutes

Thank You for Your Cooperation!

2. Current Mode and Trips

Please select the mode of transport (Car, M/C, Motodop or Tuk-tuk, etc.) which you used now. Then fill in the figures required indicated by in the illustration.



SP Survey Form 1-2 (Current Mode User)

3. SP Survey Form (Rail Transit)

Form Code	RESP#	STN	Day	Type	No.

Survey Station: A | B | C | D

Surveyor Name		Field Supvr. Name	
QC Name		Encoder Name	
DP Supvr. Name			

	MM	DD	YR
Date	09		14

	HR	MIN	PER
Time			

Address

Origin	TZ	Destination	TZ

Respondent's Trip Data

Time	(A)		minutes
Cost	(B)		Riels

Time	Cost	Preference	
		Mode Used	UMRT
(A) 0 minutes	1,500 Riels		
(A) + 15 minutes			
(A) + 10 minutes			
(A) + 5 minutes			
(A) - 5 minutes			
(A) - 10 minutes			
(A) - 15 minutes			
(A) 0 minutes	3,000 Riels		
(A) + 15 minutes			
(A) + 10 minutes			
(A) + 5 minutes			
(A) - 5 minutes			
(A) - 10 minutes			
(A) - 15 minutes			
(A) 0 minutes	5,000 Riels		
(A) + 5 minutes			
(A) - 5 minutes			
(A) - 10 minutes			
(A) - 15 minutes			
(A) 0 minutes	10,000 Riels		
(A) - 5 minutes			
(A) - 10 minutes			
(A) - 15 minutes			
(A) 0 minutes	15,000 Riels		
(A) - 5 minutes			
(A) - 10 minutes			
(A) - 15 minutes			

SP Survey Form 1-3 (Current Mode User)

4. Awareness Survey of ModalChoice

Please check degree of awareness per item according to the five choices given:

Awareness survey for the choice of transport mode	not aware	Not aware	Fair	Aware	Absolutely aware
(1) Short waiting time	-2	-1	0	1	2
(2) Fast travel speed	-2	-1	0	1	2
(3) Assurance of punctuality	-2	-1	0	1	2
(4) Cheap fare	-2	-1	0	1	2
(5) Low rate of traffic accident	-2	-1	0	1	2
(6) Low rate of snatching	-2	-1	0	1	2
(7) Avoidance rain and sunshine	-2	-1	0	1	2
(8) Avoidance exhaust gas and dust	-2	-1	0	1	2
(9) Environmental consideration	-2	-1	0	1	2
(10) No long walking	-2	-1	0	1	2
(11) Affected by modal choice of other people	-2	-1	0	1	2
(12) Status symbol	-2	-1	0	1	2
(13) Want to try the mode of transport in foreign countries	-2	-1	0	1	2
(14) Want to try the new mode of transport	-2	-1	0	1	2
(15) Current mode is most satisfactory	-2	-1	0	1	2

5. Correspondent Characteristics

Please fill in the shaded space ( ), put a check mark in the ( ) if applicable, and encircle the number

Items	
Age	years old
Sex	1. male 2. female
How many family members are living in your house?	members
How many Motorcycles do you have at the house?	Number of Motorcycle ___, Own one License
How many Cars do you have at the house?	Number of Car ___, Own one License

Occupation	1. Student 2. Companystaff 3. Governmentstaff 4. Shopowner 5. Housewife 6. Jobless 7. Other
Monthly income	1. Under 50 USD 2. 50 - 99USD 3. 100-249USD 4. 250-499USD 5. 500-749USD 6. 750-999USD 7. Over 1,000USD

Thank you for your cooperation!!

Interview Survey Form 2-1 (Bus passenger)

Cooperation for the Public Transport Survey

JICA Study Team

1. Purpose of the Survey

Currently, the JICA Project Team is formulating the Urban Transport Master Plan for Phnom Penh Capital City. The introduction of public transport system in the city is being studied to ease traffic congestion and prevent the present traffic condition from worsening. As a public experiment, a one-route city bus operation was carried out, which is part of the master plan activities. This experiment has resulted in the ongoing city bus operation with expanded routes under the management of Phnom Penh Capital City (PPCC) and the Department of Public Works and Transport (DPWT).

This survey has a two-fold purpose: (1) to gauge citizen awareness of the public transport including rail transit system whose introduction the city is also considering; and (2) to forecast future public transport demand in Phnom Penh

1.2 Survey Contents

・Current and previous trip characteristics
・User's trip purpose in using public transport
・Consciousness for modal choice
・Individual characteristics

Rest assured that your responses will be used only for the purpose stated above.

1.3 Interview Time

Approximately 30 minutes

Thank You for Your Cooperation!

Interview Survey Form 2-2 (Bus Passenger)

1. Revealed Preference Survey

I ask about the trip you are making now.
Please fill in with numeric value or sign to ____. If you don't pay for, please fill in 0

Why do you make this trip ? Please choose from Trip purpose (____)

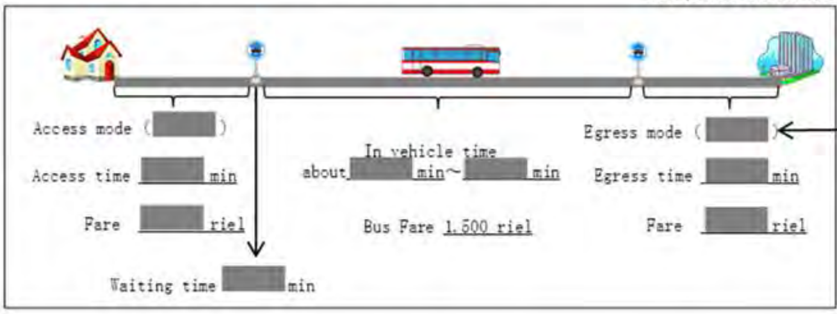
Trip purpose			
H.	To Home	B.	Business
W.	To Work	P.	Social and shopping
S.	To School	O.	Other

Using bus stop No. Get on ____, Get off ____,

Trip Origin place: address ____
Symbol Building(place) ____

Trip Destination place: address ____.
Symbol Building(place) ____

Frequency of using bus ____ times／a week or less than once a week → ____ times／a month
※if you use bus for round trip, please count 2times



mode	
W.	Walk
MD.	Motodop
TT.	Tuk-Tuk
MC(p).	Passenger of Motorcycle (not motodop)
Car(p).	Passenger of Car (not taxi)
CY.	Cyclo

2. Previous mode trip survey

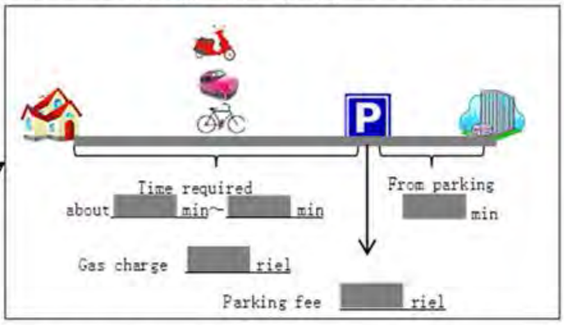
I ask about the trip you ware doing, before this bus service started.
①Please choose your previous mode and check like this ✔
②Please fill in with numeric value to ____.

①

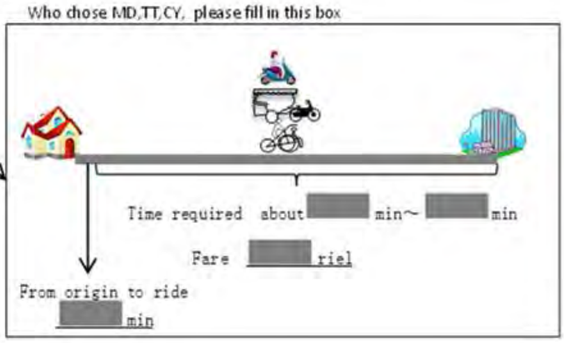
Previous mode		
MC(d).	Driver of Motorcycle	
MC(p).	Passenger of Motorcycle(not motodop)	
Car(d).	Driver of Car	
Car(p).	Passenger of Car (not taxi)	
BC.	Bicycle	
MD.	Motodop	
TT.	Tuk-Tuk	
CY.	Cyclo	

Who chose MC(d),MC(p),Car(d),Car(p),BC, please fill in this box

②



Who chose MD,TT,CY, please fill in this box



Interview Survey Form 2-3 (Bus Passenger)

4. Transportation attitude survey

I ask about the attitude when you chose a transportation mode.
Please answer the below questions, from(1)to(15)
Please check a number which best represents your consciousness when you chose a transportation mode.

	Not at all conscious	←		→	Very conscious
(1) I choose the mode with shorter waiting time	-2	-1	0	1	2
(2) I choose the mode with faster speed	-2	-1	0	1	2
(3) I choose the mode with high reliability of the time required	-2	-1	0	1	2
(4) I choose the mode with cheaper cost	-2	-1	0	1	2
(5) I choose the mode lower rate of traffic accident encounters	-2	-1	0	1	2
(6) I want to avoid snatching	-2	-1	0	1	2
(7) I want to avoid rain and sun shine	-2	-1	0	1	2
(8) I want to avoid exhaust emission and dust	-2	-1	0	1	2
(9) I consider global environment to chose mode	-2	-1	0	1	2
(10) I don't walk as much as possible	-2	-1	0	1	2
(11) I choose mode which other people around are using	-2	-1	0	1	2
(12) I want to use the mode which is the symbol of rich or cool	-2	-1	0	1	2
(13) I want to use a transportation mode from foreign country	-2	-1	0	1	2
(14) I want to use a new transportation mode	-2	-1	0	1	2
(15) If I have my own vehicle (motorcycle, car, bicycle), I want to use it	-2	-1	0	1	2

Please evaluate on the overall bus service quality. (This is not related to the upper question)

	Very bad	←		→	Very good
(16) The overall evaluation on bus service quality	-2	-1	0	1	2

5. Respondent's profile

Please fill in with a number to ▢, and check ▢, which apply you.

項目	選択肢
Sex	1. male 2. female
Age	▢ years old
Family members in your house	▢ members
How many Motorcycles do you have in the house?	Number of Motorcycle ▢ ▢ Own one ▢ License
How many Cars do you have in the house?	Number of Car ▢ ▢ Own one ▢ License

Occupation	1. Student 2. Company staff 3. Government staff 4. Shop owner 5. House wife 6. Jobless 7. Other
Monthly income	1. Under 50 USD 2. 50-99USD 3. 100-250USD 4. 250-499USD 5. 500-749USD 6. 750-999USD 7. Over 1,000USD

Thank you very much for your kindly answer

4 Conduct of SP Survey

4.1 Overview

This survey is divided into two: The first is the SP survey to current mode users conducted at 4 locations (mall/markets) as follows: (1) Cham Chao to Pochentong Market, (2) Steung Meanchey Market, (3) Central Market and (4) Aeon Mall. Respondents' travel modes are categorized into: (i) Car (privately owned), (ii) Motorcycle (privately owned) and (iii) Para-transit. Para-transit vehicles are divided into 2 types which are Tuk-tuk and Motodop. Total number of samples is 400, distributed as follows: 130 each of car users and motorcycle users, and 70 each of tuk-tuk and motodop users.

The second is an on-board bus interview covering three bus lines, namely, Bus Line No. 1 (A), Bus line No. 2 (B), and Bus Line No. 3 (C). Respondents' previous travel modes are targeted for 8 classifications, which are as (1) Car passengers (privately owned), (2) Car drivers (privately owned), (3) Motorcycle passengers (privately owned), (4) Motorcycle drivers (privately owned), (5) Bicycle, (6) Motodop (only passengers), (7) Tuk-tuk (only passengers) and (8) Cyclo (only passengers). The number of samples targeted for each mode is 100 for a total of 800.

4.2 Schedule and Activities

The survey schedule is shown below.

Table 4.2-1 Survey Schedule

Activity	Oct.			November						December					
	20	25	31	5	10	15	20	25	30	5	10	15	20	25	31
1. Planning															
2. Fieldwork															
3. Quality Control															
4. Data Process and Report															
5. Submission															●

4.3 Survey Plan

With the arrival of the official survey forms, planning started on November 15, 2014 until November 24, 2014 and it included the process flow, hiring of project staff, advanced ocular survey of the two main areas, metadata of important figures such as data codes of khan, sangkat and village, collection of materials, printing, mobilization, training, questionnaire codification and survey dry run.

Three-Day Training of Survey Personnel held November 20-22, 2014

4.4 Field Work

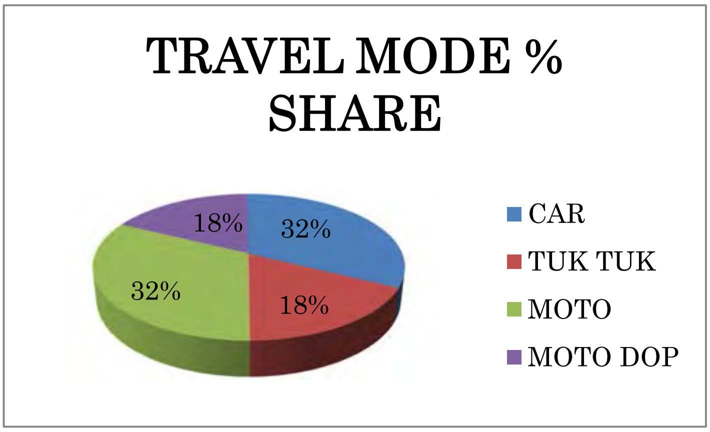
The city bus survey was conducted from November 24, 2014 to December 3, 2014. For the SP survey for current mode users (mall/markets) and bus passenger interview survey, these were conducted from November 29, 2014 until December 4, 2014.

Poster and Banner of the Survey for the Bus and Mall/Markets

(1) SP Survey for Current Mode Users at Mall/Markets

1) Travel Mode

The target sample for this survey is 400, with 130 samples each for car and motorcycle and 140 for para-transit, which is divided equally between motodop and tuk-tuk passengers. The actual number of respondents interviewed was 401, and all travel modes were completed.



Team II	Total
Mode	
CAR	130
TUK TUK	70
MOTO	130
MOTO DOP	71
Total	401
Sub Total	401


Actual SP Survey at one Market location

(2) Interview Survey for Bus Passengers

The number of bus passengers interviewed by previous mode of travel is shown in Table 4.4-1. The table also gives a comparison of bus interview survey in the public experiment of city bus operation and bus passenger interview survey. The share of previous mode between the two interview surveys seems similar. With regards to motorcycle users, their share is lower in this survey (50.9%) than the public experiment's (54.8%) while motodop users' share in the interview survey is higher (29.7%) than the public experiment's (22.4%).

Table 4.4-1 Number of Bus Passengers Interviewed by Previous Mode of Travel (Public Experiment and Bus Passenger Interview Survey)

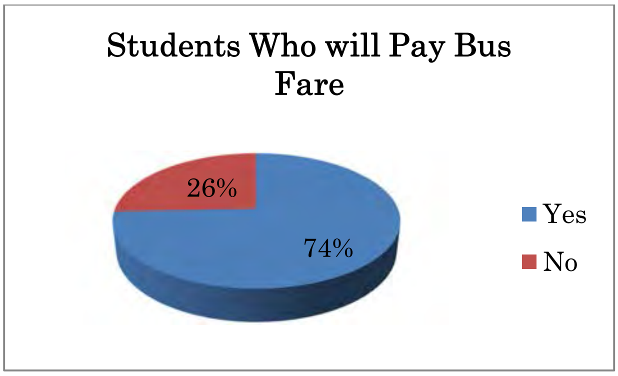
Items	Public Experiment Feb. 2014		Bus Passenger Interview Survey Dec. 2014	
	Number of Samples	Percentage	Number of Samples	Percentage
Motorcycle	603	54.8%	204	50.9%
Car	126	11.5%	45	11.2%
Motodop	246	22.4%	119	29.7%
Tuk-tuk	79	7.2%	25	6.2%
Others	46	4.1%	8	2.0%
Total	1,100	100.0%	401	100.0%

Actual Bus Passenger Survey

1) On Survey regarding students who are willing to pay bus fare

Starting December 2014, students were given free bus rides on all bus lines. In view of this, 105 students were surveyed for the three bus lines in order to know how they would respond if the bus ride was not free and they had to pay 1,500 riels for their fare. Results showed that 74% of the students who participated in the survey answered they will pay the bus fare and continue to ride the bus even if there is no “free ride” for students.

Students Riding on the Bus



Code	Answer	No.
Y	Yes	78
N	No	27
	TOTAL	105

2) On GPS survey for the three bus lines

The GPS Survey was conducted for the three bus lines in order to know the speed of the bus of each trip. Six GPS units were installed on 6 buses per line. Based on the data recorded, which are shown in Table 4.4-2 below, the average speed showed from 6.5 km/h to 17.4 km/h.

Table 4.4-2 Bus Operating Speed Survey

			GPS #1 (2nd)					GPS #2 (5th)					GPS #3 (6th)				
Busline No.	Date	Trip	Survey Route	Time		Ave. Speed	Total Distance	Survey Route	Time		Ave. Speed	Total Distance	Survey Route	Time		Ave. Speed	Total Distance
				Start	Finish	(km./hr.)	(km.)		Start	Finish	(km./hr.)	(km.)		Start	Finish	(km./hr.)	(km.)
1	1/8/2015	1	1	06:30:43	08:05:26	10.11739	15.35792	1	07:57:58	09:13:58	14.95308	19.24461	1	08:23:02	09:47:02	11.56233	16.40694
		2		08:26:30	09:56:31	10.72565	16.28154		09:35:25	10:45:25	12.64667	15.02424		09:57:29	11:27:29	12.28826	18.65358
2	1/8/2015	1	3	14:15:26	15:27:27	15.02378	18.34404	3	15:01:44	16:37:44	12.64449	20.44614	2	12:17:10	13:23:10	17.74176	19.90626
		2		15:42:12	17:24:12	9.22885	15.83670		16:45:20	19:05:20	7.15254	16.75839		14:12:42	15:22:42	14.09972	16.75047
3	1/8/2015	1	2	10:31:52	12:09:52	7.63800	12.60270	2	12:17:08	13:35:08	9.36525	12.36213	3	15:56:56	17:05:50	10.86686	12.55122
		2		12:46:00	14:13:18	9.91977	14.40351		13:48:41	14:50:41	11.03281	11.65065		17:47:59	18:59:59	6.35757	7.76259

			GPS #4 (4th)					GPS #5 (3rd)					GPS #6 (1st)				
Busline No.	Date	Trip	Survey Route	Time		Ave. Speed	Total Distance	Survey Route	Time		Ave. Speed	Total Distance	Survey Route	Time		Ave. Speed	Total Distance
				Start	Finish	(km./hr.)	(km.)		Start	Finish	(km./hr.)	(km.)		Start	Finish	(km./hr.)	(km.)
1	1/8/2015	1	1	07:43:22	8:27:22	11.37364	16.51452	1	7:21:28	8:47:55	13.08114	18.99381	1	06:24:49	07:42:50	13.83800	18.26616
		2		09:02:39	10:06:39	12.64303	13.76826		09:16:06	10:34:07	13.84850	18.28002		08:08:28	09:24:28	14.30026	18.40443
2	1/8/2015	1	2	11:26:48	13:02:48	11.49551	18.58824	3	15:17:44	16:39:44	12.76881	17.69757	2b	11:23:15	13:51:15	11.42253	28.27077
		2		13:08:12	14:30:12	10.75024	14.89983		17:00:32	18:55:38	7.00649	13.17921					
3	1/8/2015	1	3	14:32:29	15:36:29	8.996364	9.79704	2	11:38:53	12:44:53	11.69206	13.11849	2a	09:57:53	11:21:53	11.43465	16.22577
		2		15:54:39	16:58:40	9.216061	10.03629		13:21:06	14:47:07	6.49477	9.43041	3	13:59:15	15:19:15	8.90625	11.75625

Actual GPS Unit attached to bus

5 Comparison between Two Survey Results (Interviewee's Characteristics and Awareness of Modal Choice)

5.1 Interviewee's Characteristics (refer to page 20 to 25)

Q.1 Age and Q.2 Sex

Age of SP survey interviewees is a little younger than bus passengers' and number of female interviewees is bigger than male's.

Q.3 Number of family members

Average number of family members is 4.8.

Q.4 Number of motorcycles pe,r family

Number of motorcycles per family of SP survey and Bus Passenger Interview are 1.97 and 1.43, respectively. In the case of SP survey result, every 2.4 family members have one motorcycle.

Q.5 Owning motorcycle or not

84% of motorcycle users of SP survey interviewees have his/hers own motorcycle.

Q.6 Holding motorcycle license

Even 61% of motorcycle users of SP survey interviewees (currently use) has not motorcycle license. This is one of the serious issues for the driver's education.

Q.7 Number of cars per family

There is about 0.6 cars per family for both surveys. The highest is the car users (1.15 – 1.33/family).

Q.8 Owning car or not

63% of car users of SP survey interviewees have his/hers own car.

Q.9 Holding car license

18% of current car users have not car license even when he/she drives.

Q.10 Occupation

About 50% of interviewees are students and company staff.

Q.11 Monthly income

Average monthly income of SP survey interviewees and bus passenger interviewees are USD206 and USD167, respectively. Those with the highest monthly income are car users (about USD300).

5.2 Consciousness to Modal Choice (refer to page 26 and 27)

From the consciousness survey of 15 items such as “short waiting time” for bus users and current mode users (SP survey), the findings are described below and shown in Table 5.2-1.

1) All interviewees of the two surveys are most conscious of “low rate of accidents” (average rate: 1.70), “cheap fare” (1.48), “avoidance of exhaust gas and dust” (1.46) and “assurance of punctuality” (1.41).

2) Many of current motorcycle and para-transit users are satisfied with their modes.

3) Many of the bus users are conscious of “avoidance of exhaust gas and dust”.

4) A big difference of items of consciousness between bus and current mode users are “current mode is most satisfactory (-0.65: ‘minus’ means that current mode users are higher than bus users)”, “low rate of snatching (-0.57)” and “want to try the mode of transport in foreign countries (-0.48)”.

Table 5.2-1 Consciousness Survey Results

Item	Motorcycle			Car			Para-transit			Total		
	Bus *1	Current *2	B-C	Bus	Current	B-C	Bus	Current	B-C	Bus	Current	B-C
(1) Short waiting time	1.22	1.26	-0.04	1.40	1.34	0.06	1.07	1.44	-0.37	1.35	1.19	0.16
(2) Fast travel speed	0.94	1.36	-0.42	1.20	1.31	-0.11	0.71	1.27	-0.56	1.32	0.89	0.43
(3) Assurance of punctuality	1.47	1.33	0.14	1.67	1.40	0.27	1.24	1.36	-0.12	1.36	1.41	-0.05
(4) Cheap fare	1.49	1.49	0.00	1.36	1.34	0.02	1.48	1.60	-0.12	1.48	1.47	0.01
(5) Low rate of traffic accident	1.73	1.67	0.06	1.82	1.66	0.16	1.76	1.63	0.13	1.75	1.65	0.10
(6) Low rate of snatching	0.65	1.20	-0.55	0.73	1.10	-0.37	0.47	1.17	-0.70	0.59	1.16	-0.57
(7) Avoidance rain and sunshine	1.22	1.33	-0.11	1.09	1.31	-0.22	1.17	1.30	-0.13	1.19	1.31	-0.12
(8) Avoidance exhaust gas and dust	1.45	1.34	0.11	1.60	1.28	0.32	1.42	1.35	0.07	1.46	1.33	0.13
(9) Environmental consideration	1.11	0.92	0.19	1.07	0.95	0.12	0.88	0.91	-0.03	1.02	0.93	0.09
(10) No long walking	0.50	0.83	-0.33	0.71	0.46	0.25	0.67	0.89	-0.22	0.59	0.73	-0.14
(11) Affected by modal choice of other people	0.40	0.80	-0.40	0.62	0.69	-0.07	0.44	0.88	-0.44	0.44	0.79	-0.35
(12) Status symbol	0.14	0.36	-0.22	0.16	0.32	-0.16	0.01	0.42	-0.41	0.08	0.37	-0.29
(13) Want to try the mode of transport in foreign countries	0.32	0.77	-0.45	0.29	0.85	-0.56	0.21	0.64	-0.43	0.27	0.75	-0.48
(14) Want to try the new mode of transport	0.95	1.03	-0.08	0.96	1.01	-0.05	0.74	1.02	-0.28	0.87	1.02	-0.15
(15) Current mode is most satisfactory	0.68	1.48	-0.80	0.76	1.16	-0.40	0.79	1.49	-0.70	0.73	1.38	-0.65

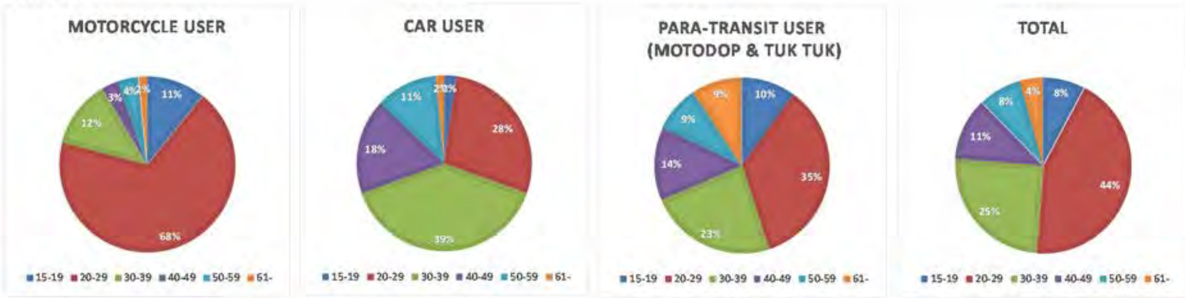
Note *1: Average score of bus passenger interviewees
*2: Average score of SP survey interviewees
B – C: *1 - *2
: Highest 3 items

5.3 Evaluation of Bus Service by Bus Passenger (refer to page 28)

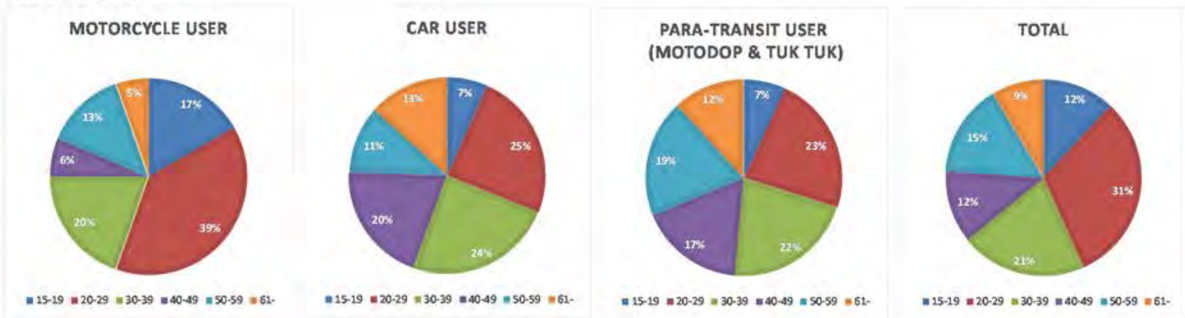
For evaluation of bus service of bus passengers who used either a motorcycle, a car or para-transit (motodop or tuk tuk) previously, para-transit users gave the bus the highest score (refer to Q.13, page A2-1-27).

Q. 1 Age

Current

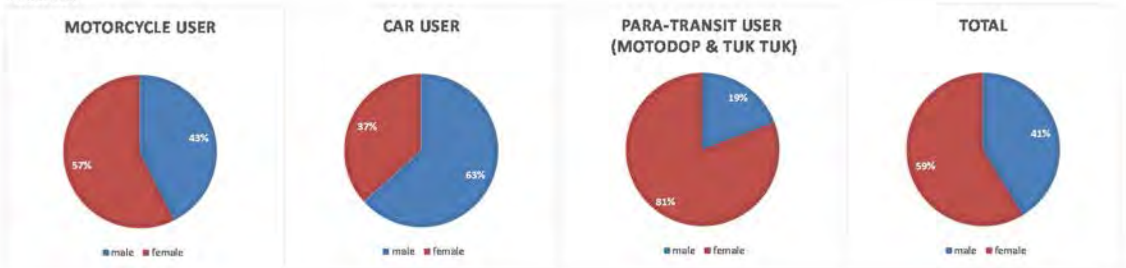


Bus Passenger

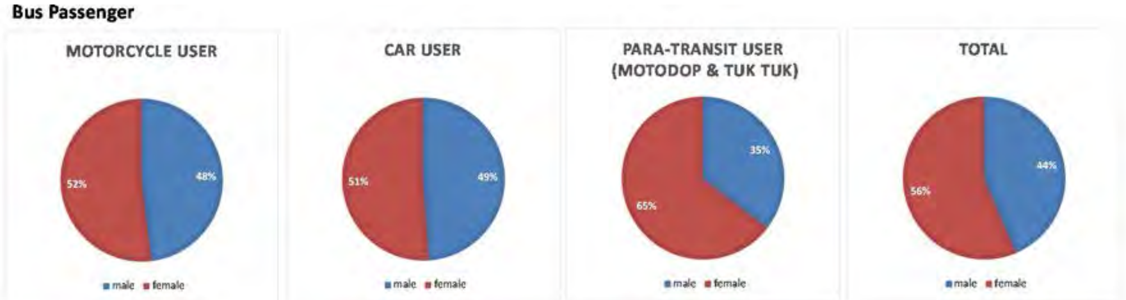


Q. 2 Sex

Current

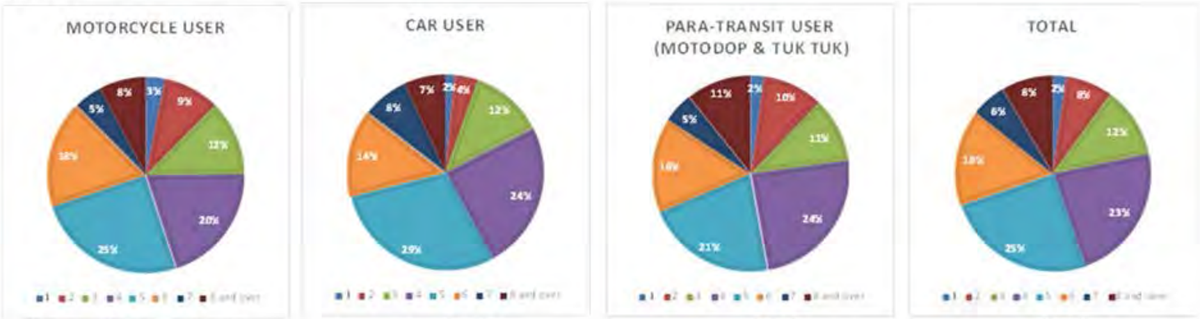


Bus Passenger



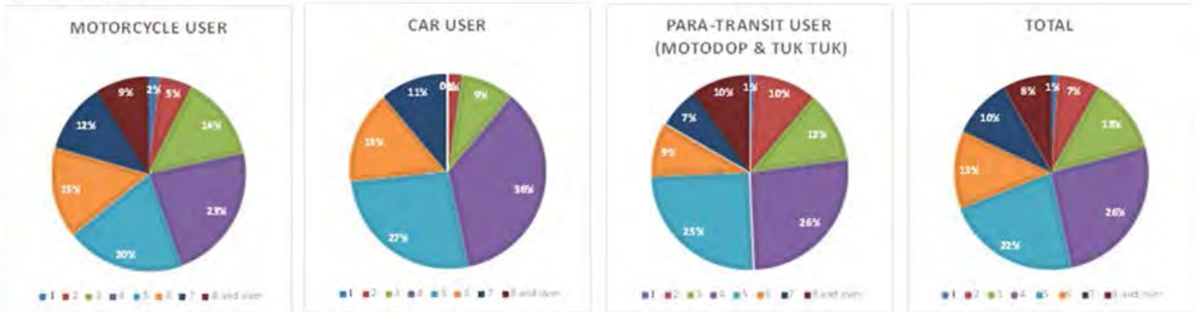
Q. 3 Number of Family Members

Current



Ave. = 4.65 persons | 4.84 | 4.74 | 4.74

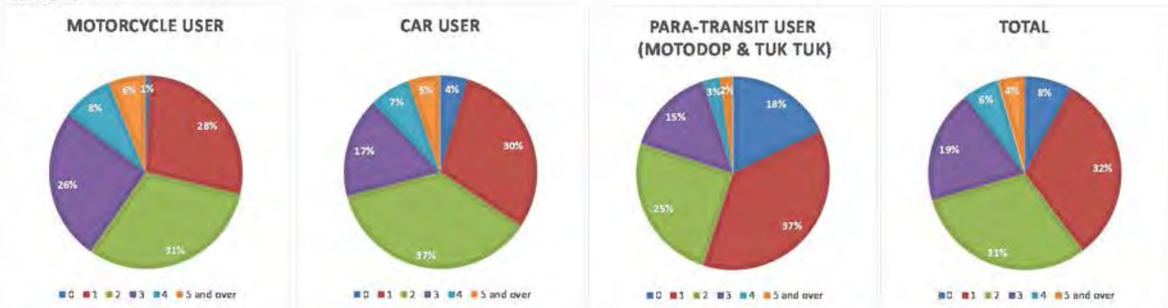
Bus Passenger



Ave. = 4.90 persons | 4.78 | 4.68 | 4.80

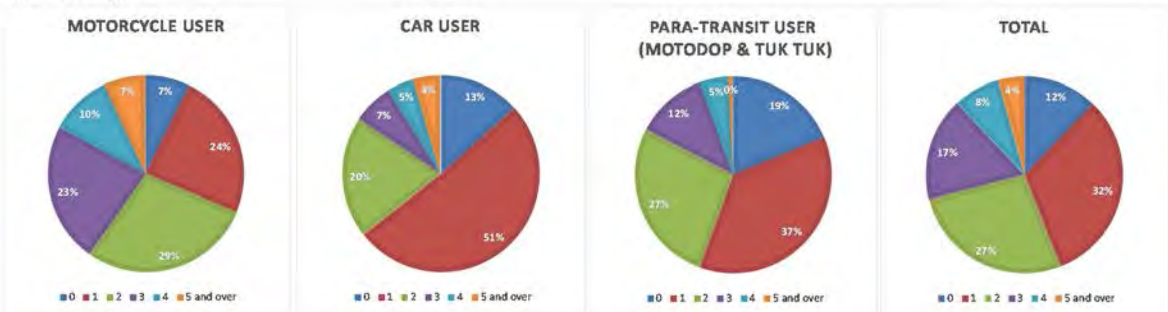
Q. 4 Number of Motorcycles per Family

Current



Ave. = 2.32 | 2.08 | 1.54 | 1.97

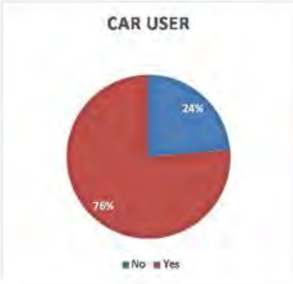
Bus Passenger

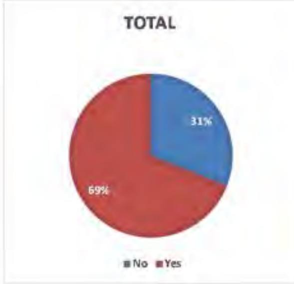


Ave. = 1.64 | 1.15 | 1.27 | 1.43

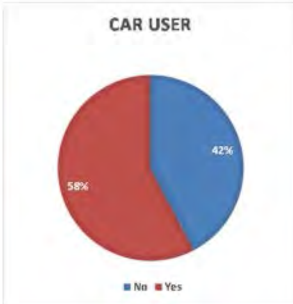
Q. 5 Owning Motorcycle or Not

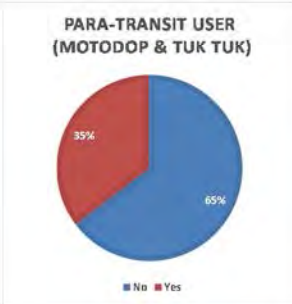
Current

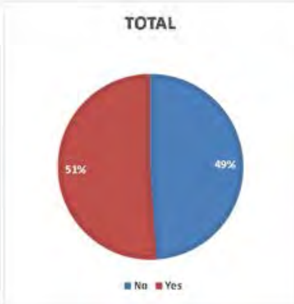




Bus Passenger

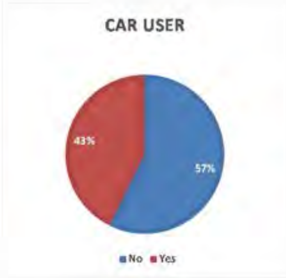


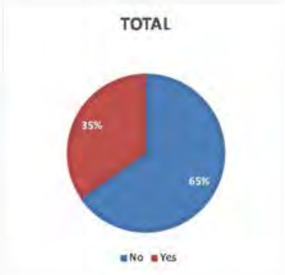




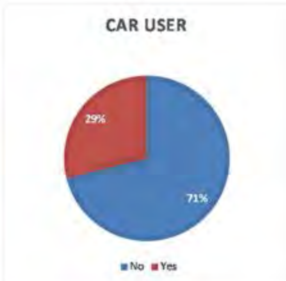
Q. 6 Holding Motorcycle License

Current



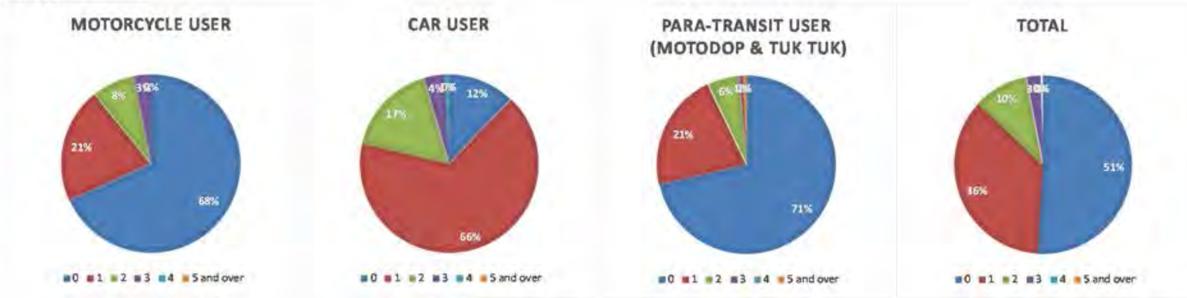


Bus Passenger



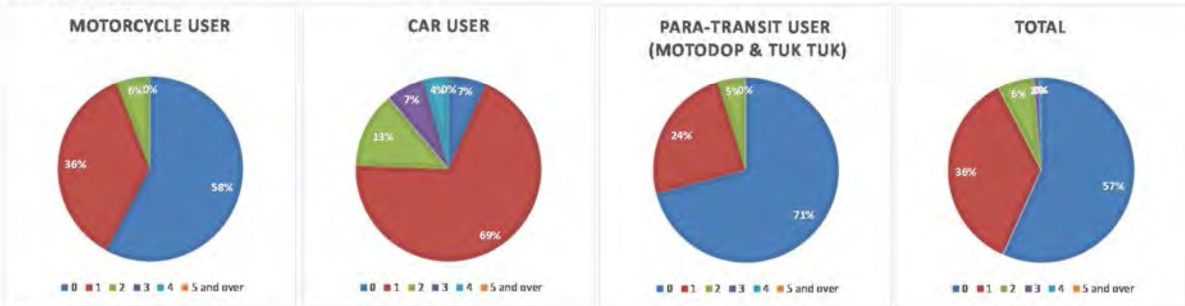
Q.7 Number of Cars per Family

Current



Ave. = 0.46 1.15 0.39 0.66

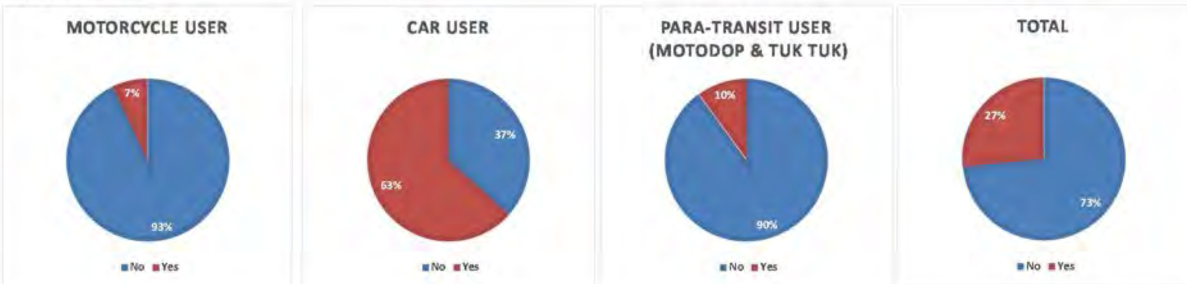
Bus Passenger



Ave. = 0.48 1.33 0.34 0.53

Q. 8 Owning Car or Not

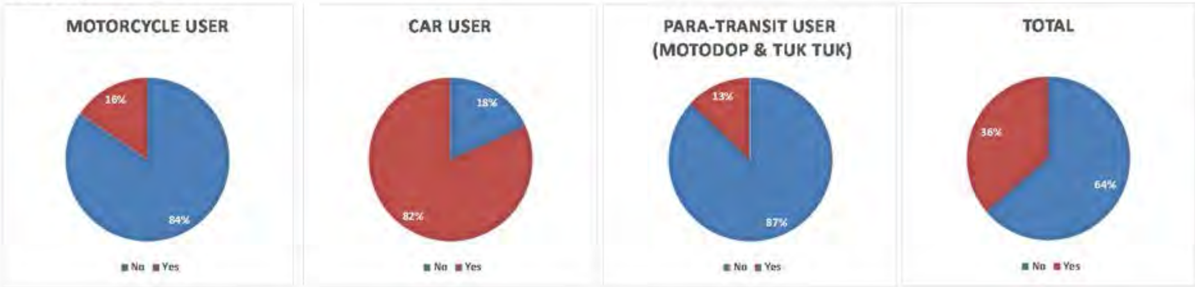
Current



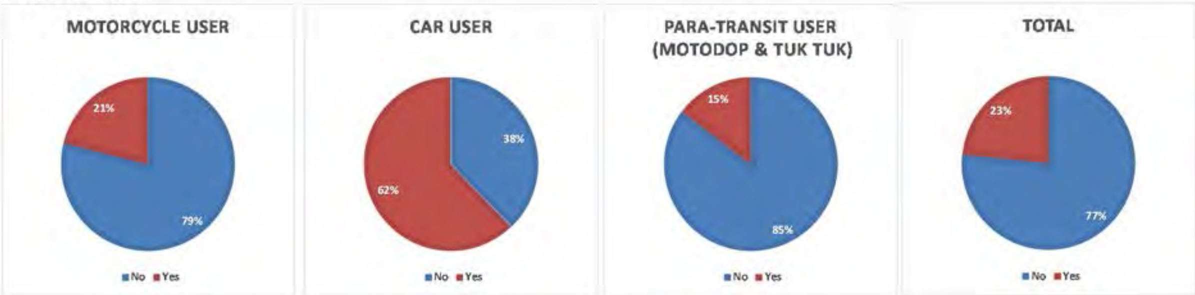
Bus Passenger

Q. 9 Holding Car License

Current

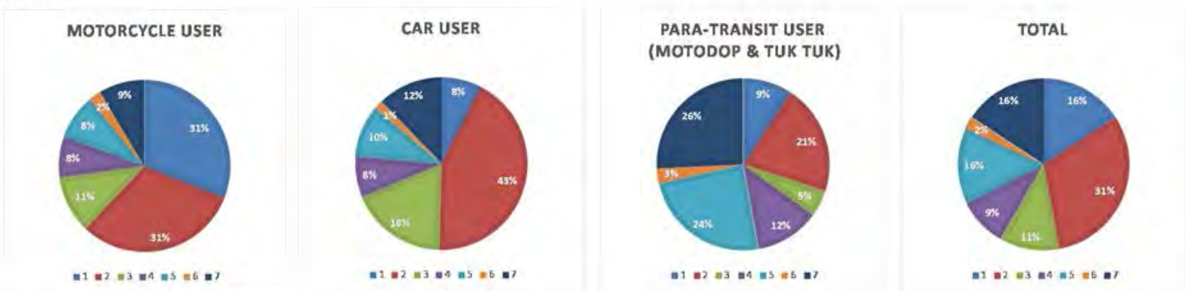


Bus Passenger



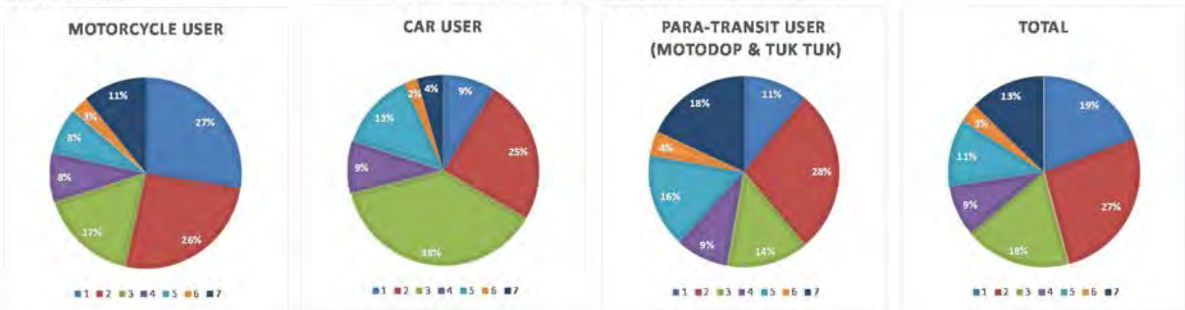
Q. 10 Occupation

Current



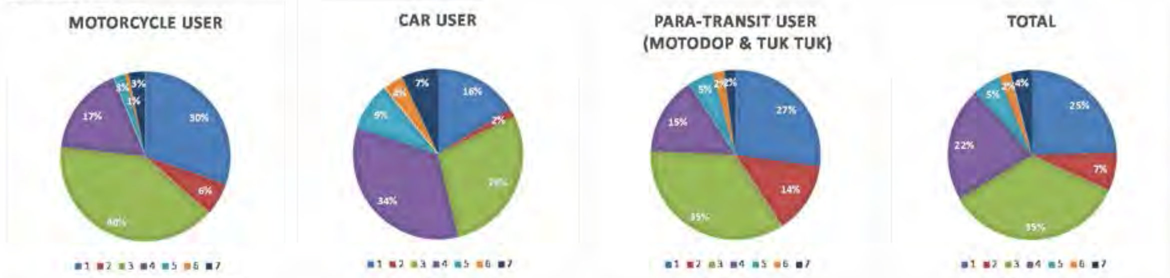
Legend
1: Student, 2: Company Staff, 3: Government Staff, 4: Shop Owner,
5: House Wife, 6: Jobless and 7: Others

Bus Passenger



Q.11 Monthly Income

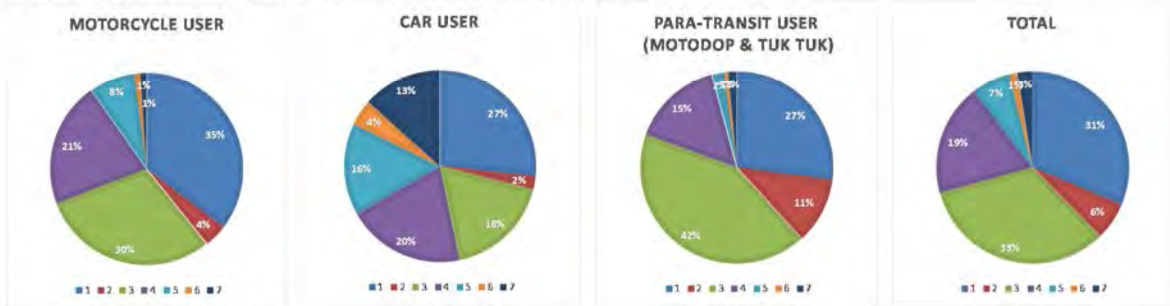
Current



Ave. = USD188 USD288 USD163 USD206

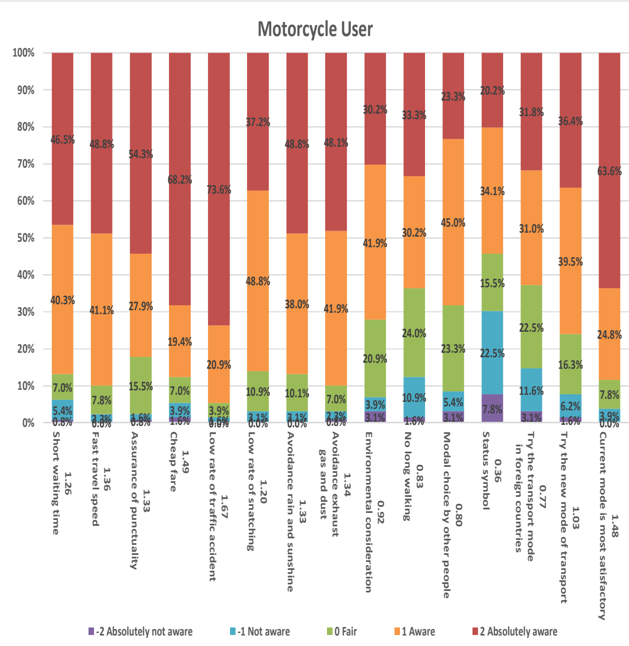
Legend 1: Under USD49, 2: USD50 - 99, 3: USD100 - 249, 4: USD250 - 499, 5: USD500 - 749, 6: USD750 - 999 and 7: Over USD1,000

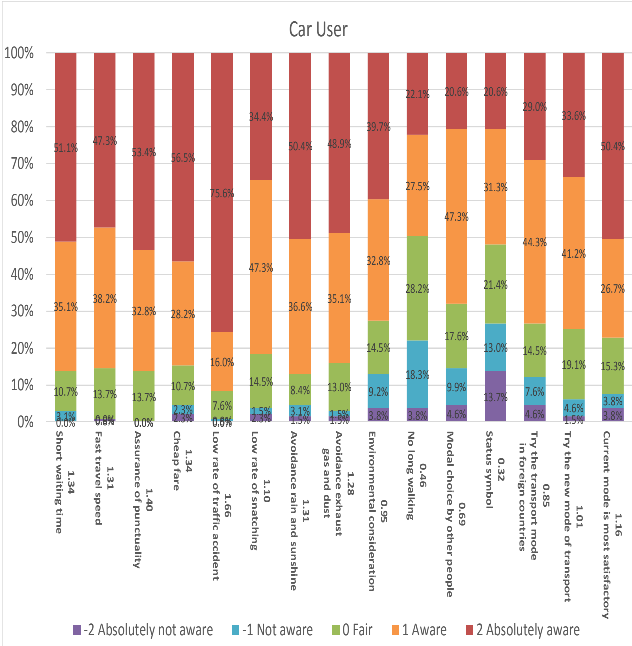
Bus Passenger



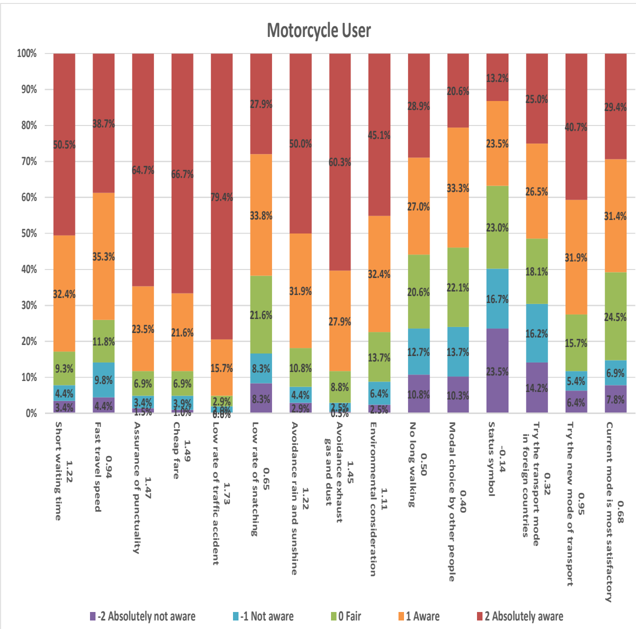
Ave. = USD149 USD311 USD149 USD167

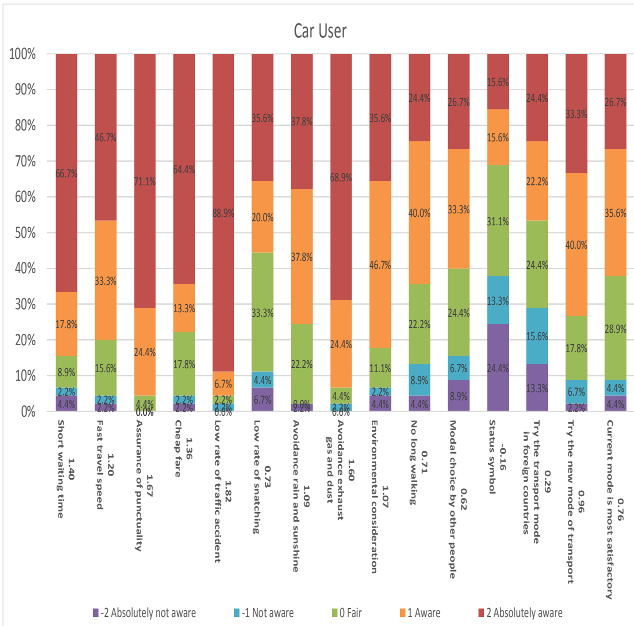
Q. 12 Awareness Survey of Modal Choice : Current



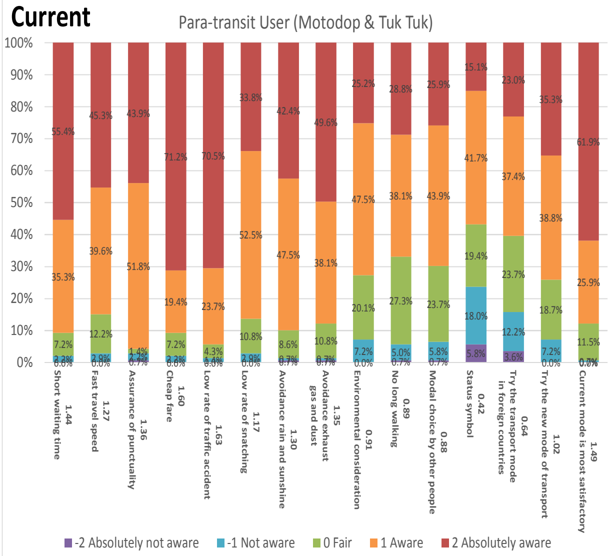


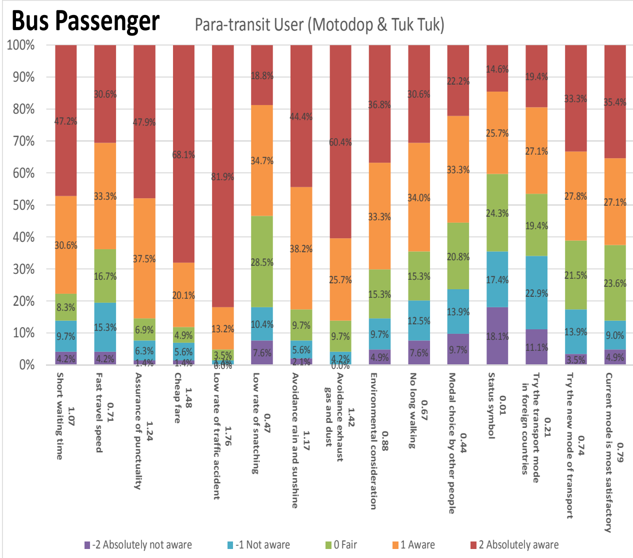
Bus Passenger

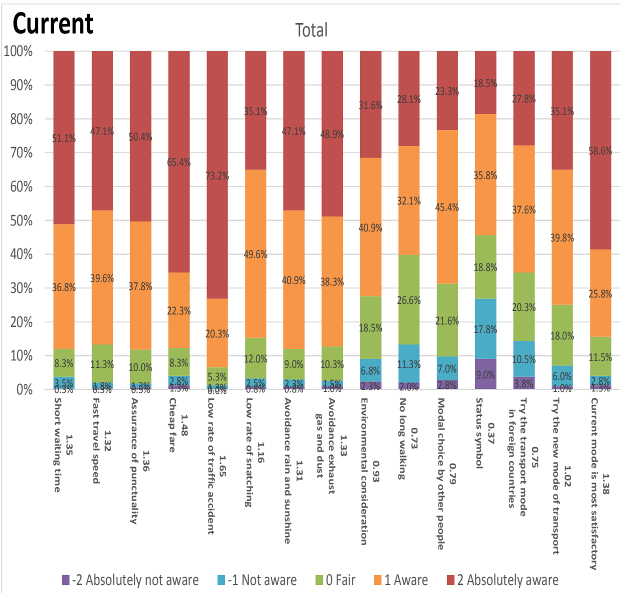


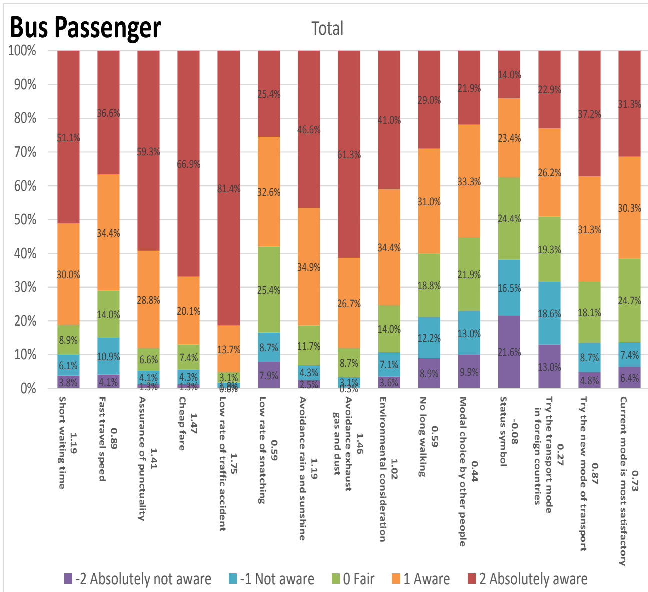


Q. 12 Awareness Survey of Modal Choice (contd.)

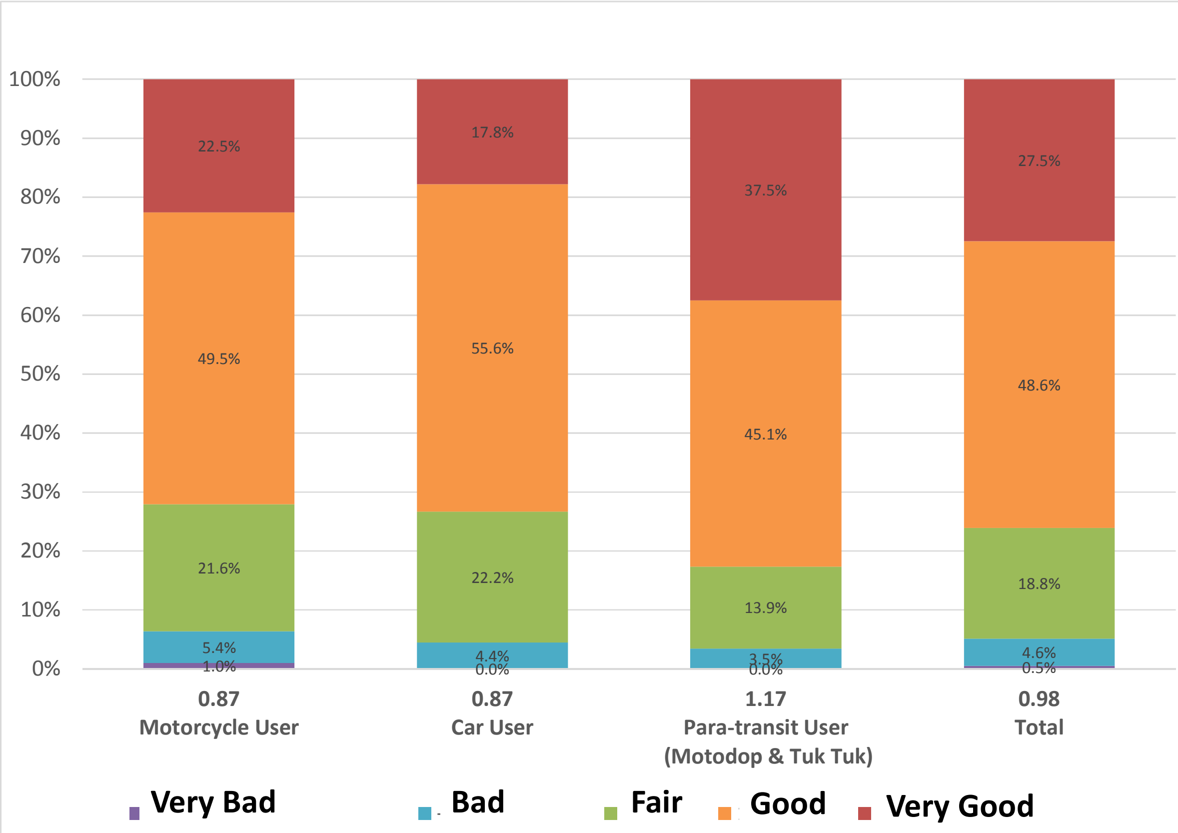








Q. 13 Evaluation of Bus Service by Bus Passenger



6 ANALYSIS OF SP SURVEY FOR DEVELOPING THE LOGIT MODEL

6.1 Sample Characteristics of Collected Data

An outline of the sample characteristics of collected data by surveys is shown in Chapter 5.

6.2 Analysis of SP Data

(1) Development of SP Data

Based on the current transport modes in Phnom Penh, 3 types of data sets, namely, a) Motorcycle to Mass Transit, b) Car to Mass Transit and c) Para-transit to Mass Transit, were prepared and analyzed. To minimize the work period of the analysis, only the conditions of level of service of "time" and "cost" were selected for the explanatory variable, even though it is possible to consider adding the personal characteristics.

(2) Binary Logit Model

A Binary Logit Model was selected for modeling of modal choice, and the function variables of the binary logit model are as follows:

1) a: Transfer from M/C to mass transit, b: Transfer from car to mass transit

Current Mode	$V = a_1 * X_1 + a_3 * X_3$
Mass transit	$V = a_1 * X_1 + a_2 * X_2 + B$

X_1: Travel time (Perfect common variable)
X_2: Travel cost (Alternative inherent variable)
B: Alternative inherent constant
X_3: Travel cost (Alternative inherent variable)
Note: M/C is motorcycle.

2) c: Transfer from para-transit to mass transit

Current Mode	$V = a_1 * X_1 + a_2 * X_2$
Mass transit	$V = a_1 * X_1 + a_2 * X_2 + B$

X_1: Travel time (Perfect common variable)
X_2: Travel cost (Partially common variable)
B: Alternative inherent constant

(3) Estimation of the Model Parameters

Results of the parameter calculation adopting the "Maximum Likelihood Estimation Model" using "R", which is the statistical analysis software, are as follows:

【MC Transfer Model】

Setting the Conditions	MC	UMT
Time (min)	30	30
Cost (Riel)	3000	5000

【MC Transfer Model】	Estimation Value of Parameter		t value	Remarks
x1: Time (min)	-0.007018935	-0.007018935	-0.8006026	Common variable
x2: Cost (Rciel)		-0.000271279	-8.3504354	Alternative variable
x3: UMT inherent constant value		-0.079774107	-0.6373116	Alternative variable
x4: Cost (Rciel)	-0.000139276		-3.1462638	Alternative variable
Valuable value	0.533447051	0.192677269		
Estimated Modal Share	0.734649751	0.265350249		

【Car Transfer Model】

Setting the Conditions	Car	UMT
Time (min)	30	30
Cost (Riel)	5000	5000

【Car Transfer Model】	Estimation Value of Parameter		t value	Remarks
x1: Time (min)	-0.00489055	-0.00489055	-0.5611167	Common variable
x2: Cost (Rciel)		-0.000248045	-7.6132729	Alternative variable
x3: UMT inherent constant value		-0.040855525	-0.3375972	Alternative variable
x4: Cost (Rciel)	-0.000100422		-2.3105925	Alternative variable
Variable value	0.52265876	0.239837056		
Estimated Modal Share	0.685457873	0.314542127		

【PT Transfer Model】

Setting the Conditions	PT	UMT
Time (min)	30	30
Cost (Riel)	5000	5000

【PT Transfer Model】	Estimation Value of Parameter		t value	Remarks
x1: Time (min)	-0.106021828	-0.106021828	-11.5235249	Common variable
x2: Cost (Riel)	-0.000250556	-0.000250556	-10.63881501	Common variable
x3: UMT inherent constant value		-0.006864901	-0.08535164	Alternative variable
Variable value	0.011873647	0.011792415		
Estimated Modal Share	0.501716219	0.498283781		

Note: MC (Motorcycle), UMT (Mass transit) and PT (Para-transit)

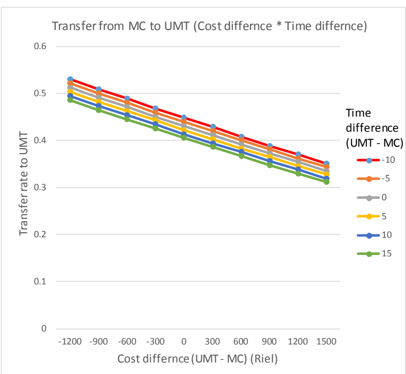
(4) Model Calibration

Model calibration by current mode is as follows:

A. Motorcycle (MC)

Setting the basic value (cost: riel and time: min.) of the current mode

	Cost		Time								UMT					
	MC	UMT	MC	UMT												
Cost	1500		20	-10	-5	0	5	10	15		-10	-5	0	5	10	15
1	1500	300	20.0	10.0	15.0	20.0	25.0	30.0	35.0	-1200	0.5294523	0.5207009	0.5119368	0.5031653	0.4943919	0.485622
2	1500	600	20.0	10.0	15.0	20.0	25.0	30.0	35.0	-900	0.5091394	0.5003668	0.4915939	0.4828262	0.4740691	0.4653279
3	1500	900	20.0	10.0	15.0	20.0	25.0	30.0	35.0	-600	0.4887964	0.4800315	0.4712789	0.4625438	0.4538317	0.4451478
4	1500	1200	20.0	10.0	15.0	20.0	25.0	30.0	35.0	-300	0.4684904	0.4597621	0.4510585	0.4423847	0.4337458	0.4251471
5	1500	1500	20.0	10.0	15.0	20.0	25.0	30.0	35.0	0	0.4482883	0.439625	0.4309985	0.4224136	0.4138753	0.4053884
6	1500	1800	20.0	10.0	15.0	20.0	25.0	30.0	35.0	300	0.4282553	0.4196848	0.4111624	0.4026929	0.3942812	0.3859316
7	1500	2100	20.0	10.0	15.0	20.0	25.0	30.0	35.0	600	0.4084548	0.4000033	0.3916109	0.383282	0.3750212	0.3668324
8	1500	2400	20.0	10.0	15.0	20.0	25.0	30.0	35.0	900	0.3889471	0.3806394	0.3724011	0.3642362	0.3561488	0.3481426
9	1500	2700	20.0	10.0	15.0	20.0	25.0	30.0	35.0	1200	0.3697885	0.3616479	0.353586	0.3456065	0.337713	0.3299088
10	1500	3000	20.0	10.0	15.0	20.0	25.0	30.0	35.0	1500	0.3510316	0.3430791	0.3352138	0.3274388	0.3197575	0.3121727



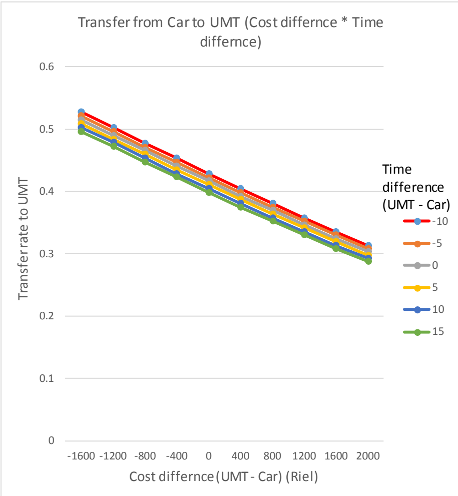
Cost difference	Time difference (UMT－MC) (min.)					
	-10	-5	0	5	10	15
-1200	52.9%	52.1%	51.2%	50.3%	49.4%	48.6%
-900	50.9%	50.0%	49.2%	48.3%	47.4%	46.5%
-600	48.9%	48.0%	47.1%	46.3%	45.4%	44.5%
-300	46.8%	46.0%	45.1%	44.2%	43.4%	42.5%
0	44.8%	44.0%	43.1%	42.2%	41.4%	40.5%
300	42.8%	42.0%	41.1%	40.3%	39.4%	38.6%
600	40.8%	40.0%	39.2%	38.3%	37.5%	36.7%
900	38.9%	38.1%	37.2%	36.4%	35.6%	34.8%
1200	37.0%	36.2%	35.4%	34.6%	33.8%	33.0%
1500	35.1%	34.3%	33.5%	32.7%	32.0%	31.2%

B. Car

Setting the basic value (cost: riel and time: min.) of the current mode

	Cost		Time							
	Car	UMT	Car	UMT						
Cost	2000		20	-10	-5	0	5	10	15
1	2000	400	20.0	10.0	15.0	20.0	25.0	30.0	35.0
2	2000	800	20.0	10.0	15.0	20.0	25.0	30.0	35.0
3	2000	1200	20.0	10.0	15.0	20.0	25.0	30.0	35.0
4	2000	1600	20.0	10.0	15.0	20.0	25.0	30.0	35.0
5	2000	2000	20.0	10.0	15.0	20.0	25.0	30.0	35.0
6	2000	2400	20.0	10.0	15.0	20.0	25.0	30.0	35.0
7	2000	2800	20.0	10.0	15.0	20.0	25.0	30.0	35.0
8	2000	3200	20.0	10.0	15.0	20.0	25.0	30.0	35.0
9	2000	3600	20.0	10.0	15.0	20.0	25.0	30.0	35.0
10	2000	4000	20.0	10.0	15.0	20.0	25.0	30.0	35.0

	UMT					
	-10	-5	0	5	10	15
-1600	0.5273915	0.5212929	0.5151879	0.5090784	0.5029662	0.4968531
-1200	0.5026145	0.4965014	0.4903893	0.4842801	0.4781756	0.4720776
-800	0.4778246	0.471727	0.4656379	0.459559	0.4534921	0.447439
-400	0.4531434	0.4470911	0.4410545	0.4350353	0.4290351	0.4230557
0	0.4286905	0.4227123	0.4167568	0.4108254	0.4049198	0.3990417
400	0.4045808	0.3987043	0.3928568	0.3870398	0.3812549	0.3755035
800	0.3809231	0.3751737	0.3694592	0.3637811	0.3581407	0.3525393
1200	0.3578174	0.3522183	0.3466595	0.3411422	0.3356676	0.3302369
1600	0.335354	0.3299258	0.3245425	0.3192053	0.3139151	0.3086727
2000	0.3136121	0.3083726	0.3031819	0.2980409	0.2929505	0.2879114



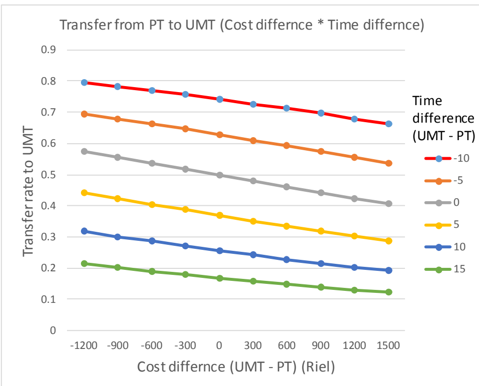
Cost difference	Time difference (UMT－Car) (min.)					
	-10	-5	0	5	10	15
-1600	52.7%	52.1%	51.5%	50.9%	50.3%	49.7%
-1200	50.3%	49.7%	49.0%	48.4%	47.8%	47.2%
-800	47.8%	47.2%	46.6%	46.0%	45.3%	44.7%
-400	45.3%	44.7%	44.1%	43.5%	42.9%	42.3%
0	42.9%	42.3%	41.7%	41.1%	40.5%	39.9%
400	40.5%	39.9%	39.3%	38.7%	38.1%	37.6%
800	38.1%	37.5%	36.9%	36.4%	35.8%	35.3%
1200	35.8%	35.2%	34.7%	34.1%	33.6%	33.0%
1600	33.5%	33.0%	32.5%	31.9%	31.4%	30.9%
2000	31.4%	30.8%	30.3%	29.8%	29.3%	28.8%

C. Para-transit (PT)

Setting the basic value (cost: riel and time: min.) of the current mode

	Cost		Time							
	PT	UMT	PT	UMT						
Cost	1500		20	-10	-5	0	5	10	15
1	1500	300	20.0	10.0	15.0	20.0	25.0	30.0	35.0
2	1500	600	20.0	10.0	15.0	20.0	25.0	30.0	35.0
3	1500	900	20.0	10.0	15.0	20.0	25.0	30.0	35.0
4	1500	1200	20.0	10.0	15.0	20.0	25.0	30.0	35.0
5	1500	1500	20.0	10.0	15.0	20.0	25.0	30.0	35.0
6	1500	1800	20.0	10.0	15.0	20.0	25.0	30.0	35.0
7	1500	2100	20.0	10.0	15.0	20.0	25.0	30.0	35.0
8	1500	2400	20.0	10.0	15.0	20.0	25.0	30.0	35.0
9	1500	2700	20.0	10.0	15.0	20.0	25.0	30.0	35.0
10	1500	3000	20.0	10.0	15.0	20.0	25.0	30.0	35.0

	UMT					
	-10	-5	0	5	10	15
-1200	0.7947862	0.695066	0.5729267	0.4411967	0.3172549	0.2147504
-900	0.7822546	0.6789051	0.5544422	0.4227551	0.3012015	0.2023466
-600	0.76918	0.6623038	0.5358058	0.4045263	0.2856207	0.1904855
-300	0.7555657	0.6452927	0.5170688	0.3865572	0.2705337	0.1791634
0	0.7414183	0.6279061	0.4982838	0.3688918	0.2559582	0.1683744
300	0.7267482	0.610182	0.4795036	0.351571	0.2419075	0.1581099
600	0.7115697	0.5921621	0.4607811	0.3346323	0.2283914	0.1483595
900	0.6959008	0.5738909	0.4421687	0.3181093	0.2154158	0.1391111
1200	0.6797637	0.5554157	0.4237172	0.3020318	0.2029835	0.1303509
1500	0.6631848	0.536786	0.4054761	0.2864256	0.191094	0.1220642

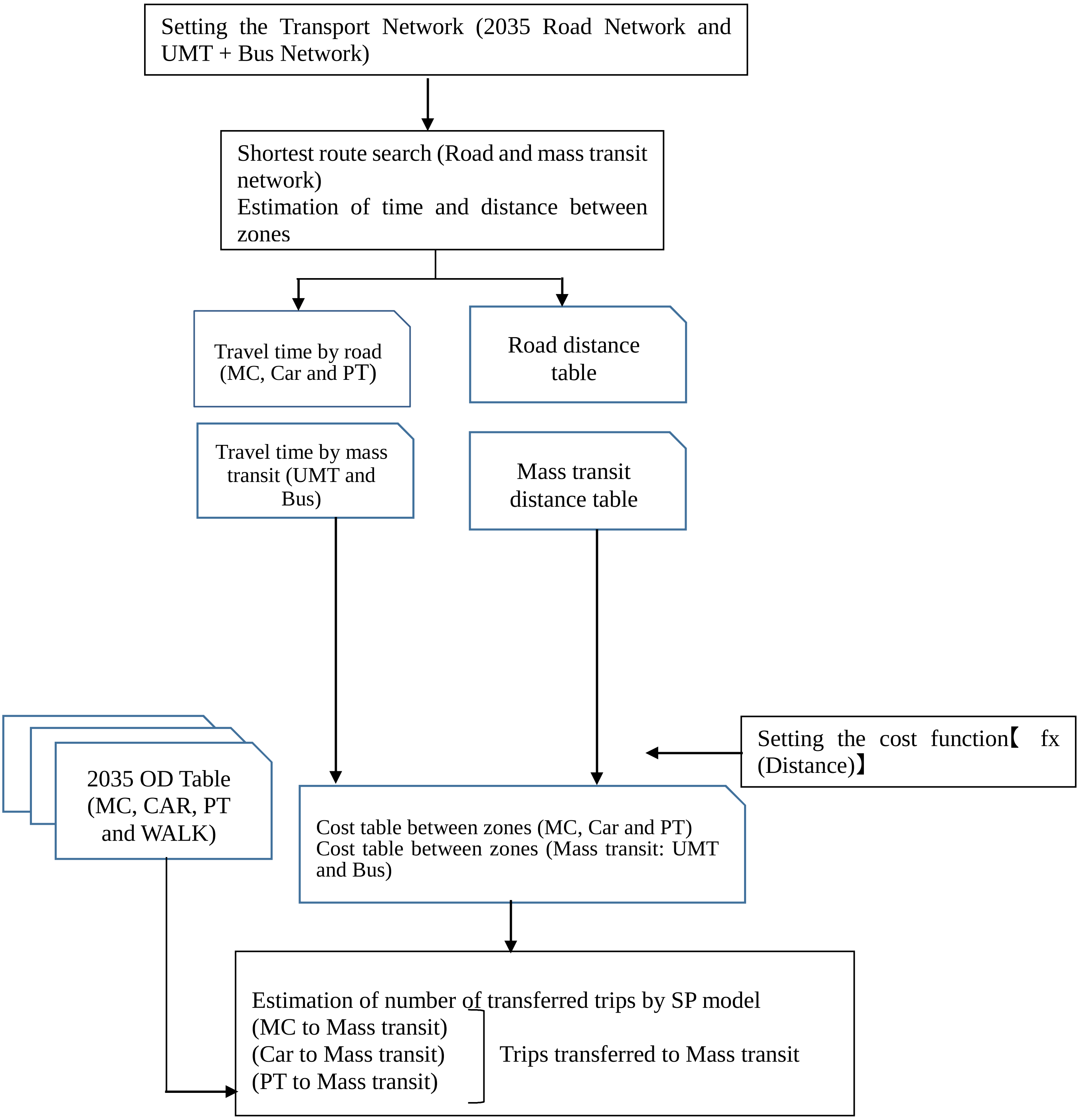


Cost difference	Time difference (UMT－PT) (min.)					
	-10	-5	0	5	10	15
-1200	79.5%	69.5%	57.3%	44.1%	31.7%	21.5%
-900	78.2%	67.9%	55.4%	42.3%	30.1%	20.2%
-600	76.9%	66.2%	53.6%	40.5%	28.6%	19.0%
-300	75.6%	64.5%	51.7%	38.7%	27.1%	17.9%
0	74.1%	62.8%	49.8%	36.9%	25.6%	16.8%
300	72.7%	61.0%	48.0%	35.2%	24.2%	15.8%
600	71.2%	59.2%	46.1%	33.5%	22.8%	14.8%
900	69.6%	57.4%	44.2%	31.8%	21.5%	13.9%
1200	68.0%	55.5%	42.4%	30.2%	20.3%	13.0%
1500	66.3%	53.7%	40.5%	28.6%	19.1%	12.2%

7 Estimation of Public Transport Modal Share in 2035

7.1 Work Flow

Work flow of the estimation of public transport modal share is shown in Figure 7.1-1.



Note: MC (Motorcycle), PT (Para-transit), UMT (Urban rail transit)
Source: PPUTMP Project Team

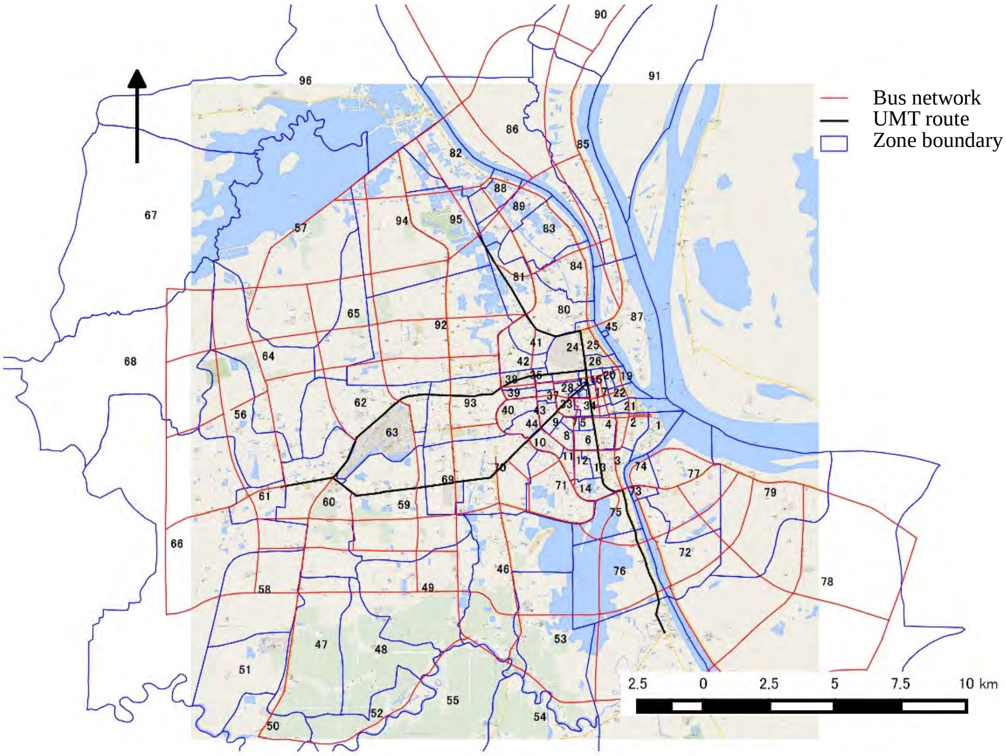
Figure 7.1-1 Work Flow

7.2 Estimation of Future Public Transport Modal Share

(1) Preparatory Work

Conditions of the transport network are stated below and shown in Figure 7.2-1.

1) Road network: 2035 Master plan network
2) Public transport network: Rail transit (UMT) network and bus network as illustrated in Figure 7.2-1



Source: PPUTMP Project Team

Figure 7.2-1 2035 Transport Network in Project Area

Trip time and distance between zones are estimated using Dijkstra's shortest path algorithm based on the 2035 master plan road network and public transport network.

The criteria of the shortest route research are the shortest route of time between zones and consideration the condition of link evaluation as shown in Table 7.2-1.

The distance and travel time of internal trips within a zone adopt the radius (distance) of a circle which is the same area with the zone, and is divided by the speed (mass transit: 4 km/h. and MC and Car: 20 km/h.).

Table 7.2-1 Criteria of the Shortest Route Research

Type of link	Length of link	Speed	Remarks
1.Road	Length of line on GIS		Congestion rate which came from assignment results is substituted for BPR formula and changing the speed
2.Mass transit (UMT)	ditto	30 km/h	Full network
3.Mass transit (Bus)	ditto	Same as road network	

4.Zone access	ditto	4 km/h	
5.Mass transit (UMT access)	Measuring the length of line on GIS from zone node to the station	4 km/h	
6.Mass transit (Dummy link access)	Same as road network	4km/h.	The research between zones is possible only for the UMT and bus network: therefore, the road network is set as dummy links and travel speed is constant (4 km/h.).

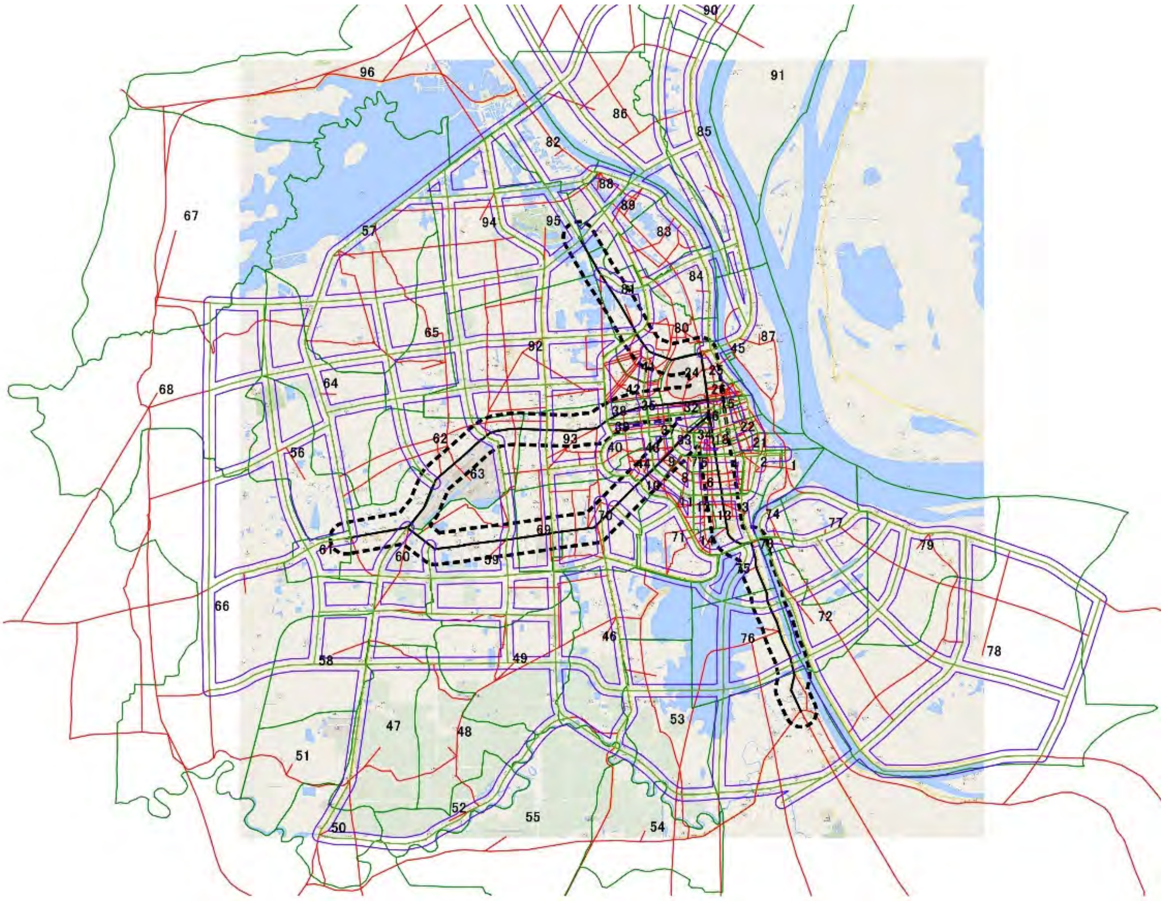
Source: PPUTMP Project Team

(2) Results of the Simulation

1) Estimation result of number of transferred trips by mode adopting Binary Logit model
Number of mass transit (UMT and bus) trips is 1,656,327 trips/day.
Public transport modal share is 28.4% excluding walk.

2) Estimation result of number of transferred trips by mode considering the mass transit coverage area (for verification of 1))

For the verification of results by Binary Logit Modal, an estimation is made of the transferred trips by considering the mass transit coverage areas, namely, UMT coverage area = 500 m from the UMT route and Bus coverage area = 200 m from bus route. The estimation result of this case is 1,656,241 trips/day. This is almost the same number of trips as calculated by the Binary Logit Model.

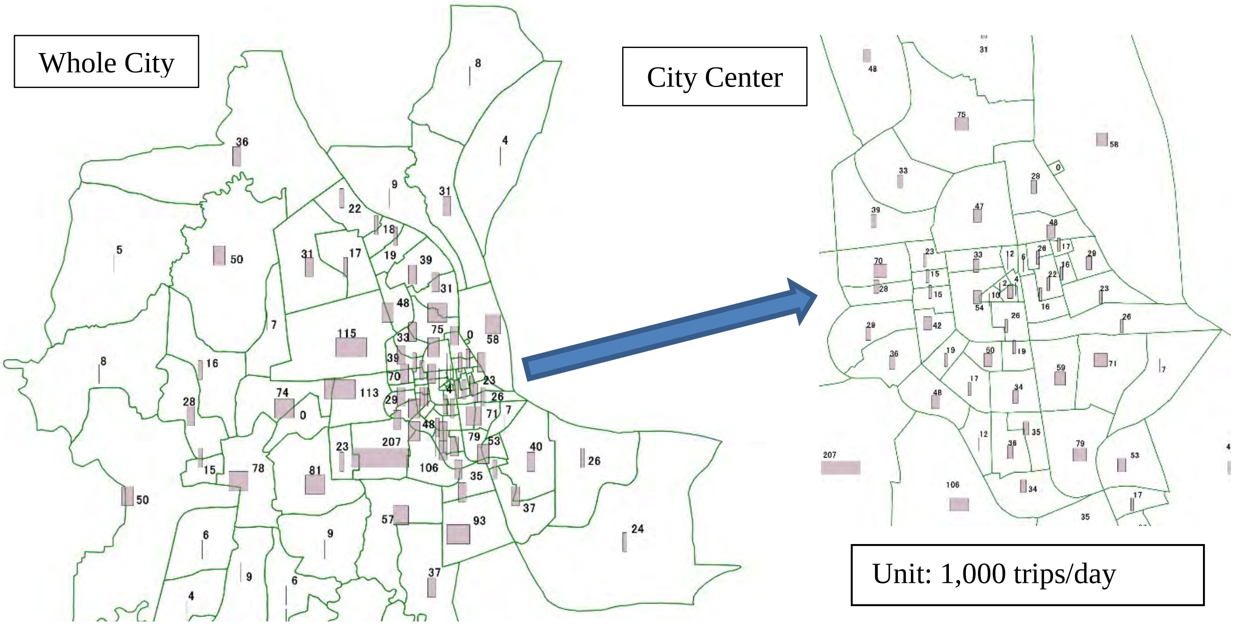


Source: PPUTMP Project Team

Figure 7.2-2 Urban Rail Transit and Bus Coverage Area

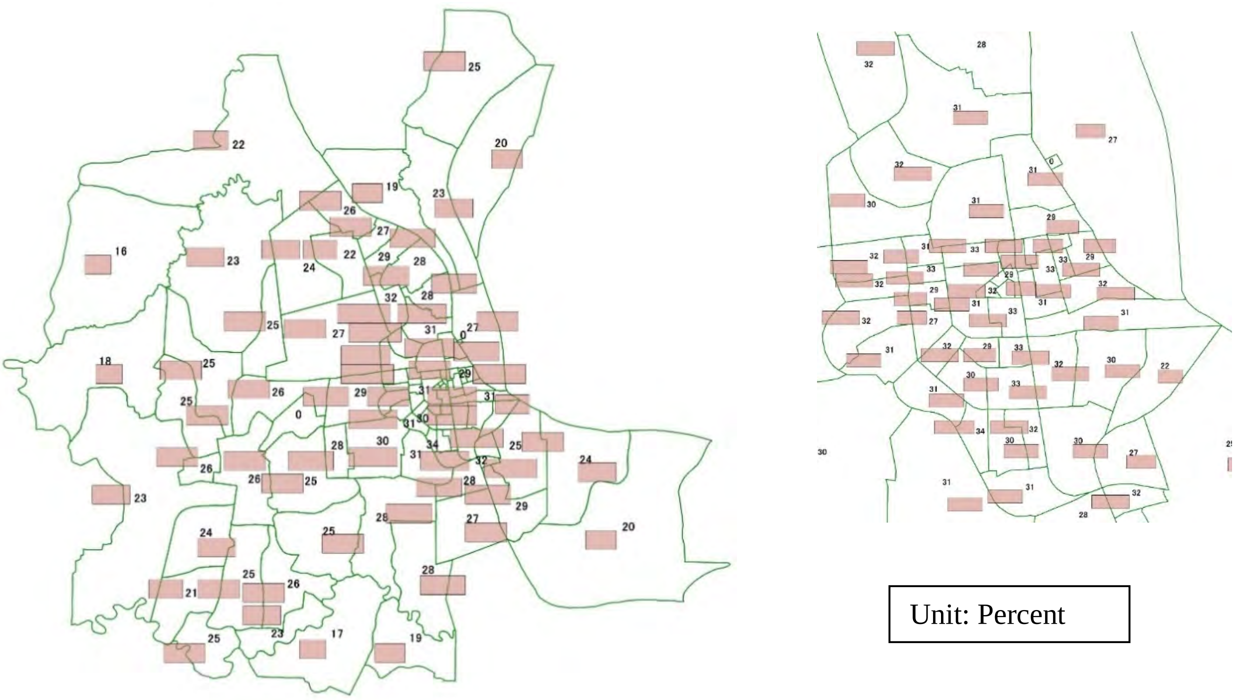
3) Distribution of Mass Transit Users' Trips

Based on the estimated mass transit transferred trips, the zonal distribution is as follows.



Source: PPUTMP Project Team

Figure 7.2-3 Distribution of Mass Transit Generated and Attracted Trips



Source: PPUTMP Project Team

Figure 7.2-4 Distribution of Mass Transit Modal Share

(3) Factors Affecting the Public Transport Modal Share

Conditions which were taken into account for the abovementioned analysis of the transferred trips by current mode using the binary logit model are as follows:

1) Service level of the rail transit (operational speed) is 30 km/h and that of bus is same as road traffic's.

2) Transfer time to mass transit (transfer and waiting time) is 10 minutes; and

3) Base fare is 1,500 riels.

Important factors of the modal choice for Phnom Penh citizens based on the interview surveys are "low rate of traffic accident", "cheap fare", "assurance of punctuality" and "avoidance of exhaust gas and dust".

On the other hand, 3 conditions for the analysis of the transferred trips mentioned above correspond to 1) Fast travel speed, 2) Short waiting time and 3) Cheap fare. Having 2 out of 3 does not indicate much from the result of the interview survey. However, these are also important factors to choice of mode.

The following analysis show how these factors affect transferred trips with a change of figures:

1) Increase of level of service of the rail transit (Operational Speed)

"Fast travel speed" is not an important factor to modal choice for Phnom Penh citizens. However, for the modelling coming from the SP survey, a change of travel speed will great affect the transferred trips.

When there is a 17% increase (from 30 km/h to 35 km/h) in operation speed of rail transit planned along major transport corridors in Phnom Penh, the public transport modal share increases by 5.6% (322 thousand).

Table 7.2-2 Increase of Level of Service of the Rail Transit (Operational Speed)

Operating speed of UMT	Number of mass transit users	Modal share (excluding walk)	Remarks
30km/h	1,656,327	28.4%	
35km/h	1,977,893	34.0%	

Source: PPUTMP Project Team

2) Increase of transfer time during the transfer to mass transit

"Short waiting time" does not much affect the modal choice of Phnom Penh citizens. The same tendency can be observed in the result of number of transferred trips to public transport by the binary logit modelling.

Even if transfer time becomes twice as long (from 10 min to 20 min), decrease of the number of transferred trips is only 1.5% (91 thousand).

Table 7.2-3 Increase of Transfer Time During the Transfer to Mass Transit

Transfer time (min)	Number of mass transit users	Modal share (excluding walk)	Remarks
+10	1,656,327	28.4%	Transfer and waiting time
+15	1,607,743	27.6%	ditto
+20	1,564,612	26.9%	ditto

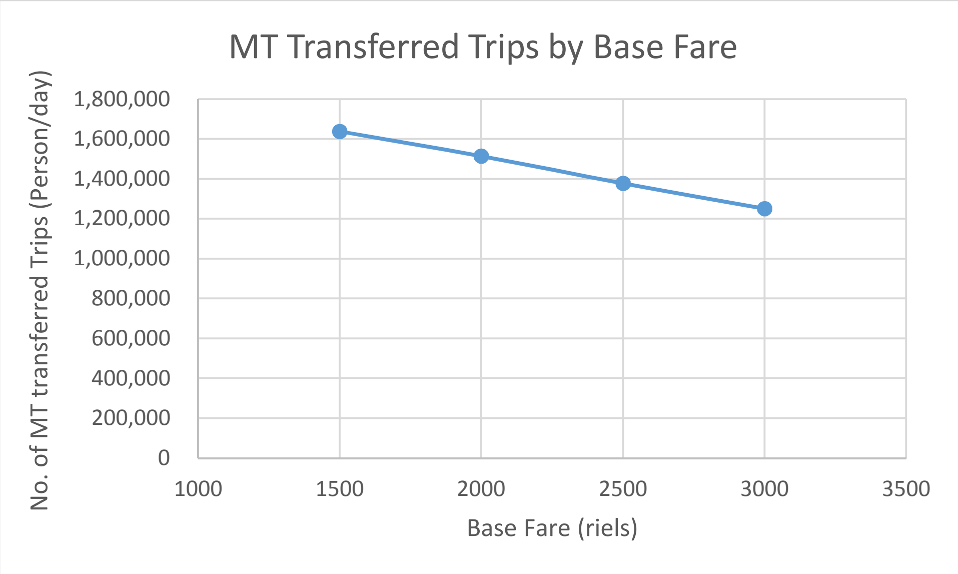
Source: PPUTMP Project Team

3) Change of Base Fare

"Cheap fare" is one of the important factors that affect the modal choice and the result of transferred trip numbers by binary logit modelling. For instance, when a base fare of 1,500 riels is increased to twice as much to 3,000 riels, the number of transferred trips to public transport decreases 6.9% (406 thousand).

Table 7.2-4 Change of Base Fare and MT Transferred Trips

Base fare level (riel)	Number of mass transit users	Modal share (excluding walk)	Remarks (JPY)
1,500	1,656,327	28.4%	45
2,000	1,513,259	26.0%	60
2,500	1,377,741	23.7%	75
3,000	1,250,226	21.5%	90



Source: PPUTMP Project Team

(4) Proposed Cases

Considering the above discussion, an examination is made of the following case models using the target indicators of public transport modal share shown in Table 7.2-5. The table shows that 30% of the target public transport modal share which was proposed during master plan formulation can be a reachable target indicator considering the SP survey results analyses, which reflect the Phnom Penh citizens' modal choice behaviour and the master plan.

1) Increase of level of service of rail transit (operation speed) is from 30km/h to 35 km/h.

Planning operation speed of rail transit during the pre F/S, is 30k m/h. And the operation speed of the rail transit can increase 35 km/h as a system.

On the other hand, bus operation speed is the same as the road traffic's, and it is possible to increase the bus operation speed by bus priority measures such as implementation of bus priority lanes and a bus rapid transit system. However, these measures are not considered due to the limitation of the public transport network system in this project.

2) Transfer time to mass transit is 10 min (transfer and waiting time).

It is assumed that the transfer time can be kept at the minimum level because of the increase of the level of service of public transport systems such as development of mode interchange areas.

3) Base Fare Level

In this examination, only one base fare can be set because the mass transit network system is limited. Considering the base fare of rail transit (3,000 riels) and bus (1,500 riels) during the pre F/S, it can be estimated that the base fare of the total mass transit network is 2,000 riels to 2,500 riels.

Table 7.2-5 Proposed Case Models

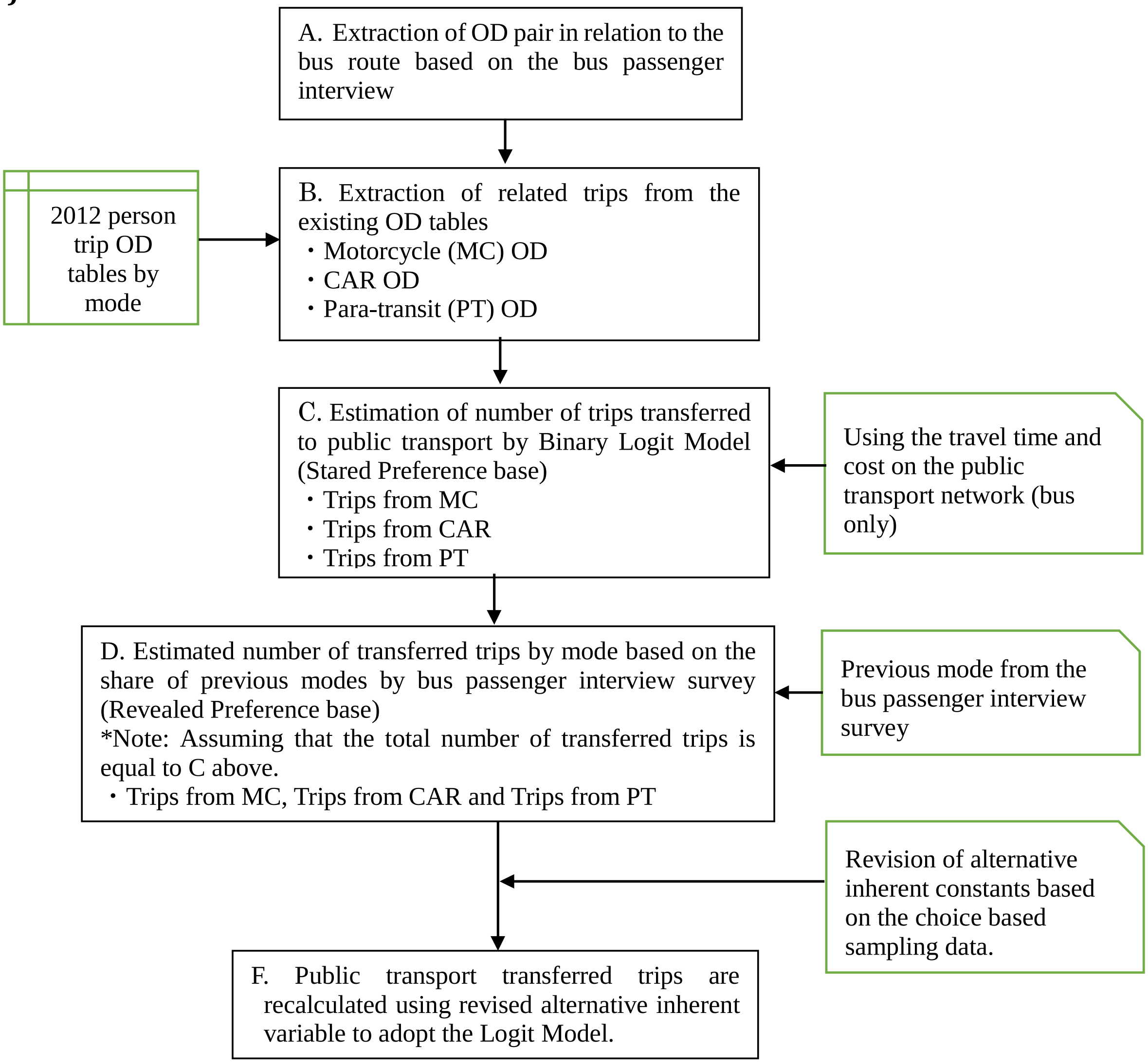
Case	Conditions Set		Result of the Examination	
	UMT operation speed	Level of base fare	Number of mass transit users	Public transport modal share (excluding walk)
(1)	30 km/h	2,000R	1,513,259	26.0%
(2)	35 km/h	2,000R	1,812,970	31.1%
(3)	30 km/h	2,500R	1,377,741	23.7%
(4)	35 km/h	2,500R	1,655,730	28.4%

Note: Transfer time of all cases is +10 min.
Source: PPUTMP Project Team

7.3 Correction of the Parameters of the Binary Logit Model

There seems to be a selectivity bias in the stated preference (SP) survey results analysis in the case of users of private mode, such as motorcycles and cars, because of their lack of experience of using public transport. Therefore, an examination and correction of the parameters of the Binary Logit Model are performed assuming the previous mode share as the revealed preference (RP) data.

(1) Work Flow



Source: PPUTMP Project Team

Figure 7.3-1 Work Flow

(2) Estimation of Bus Passengers in 2012 based on RP

1) Work Flow for the Estimation of Bus Passengers in 2012

In order to obtain the figures for "D" in Figure 7.3-1 above, the RP-based bus passengers are estimated using the following procedure:

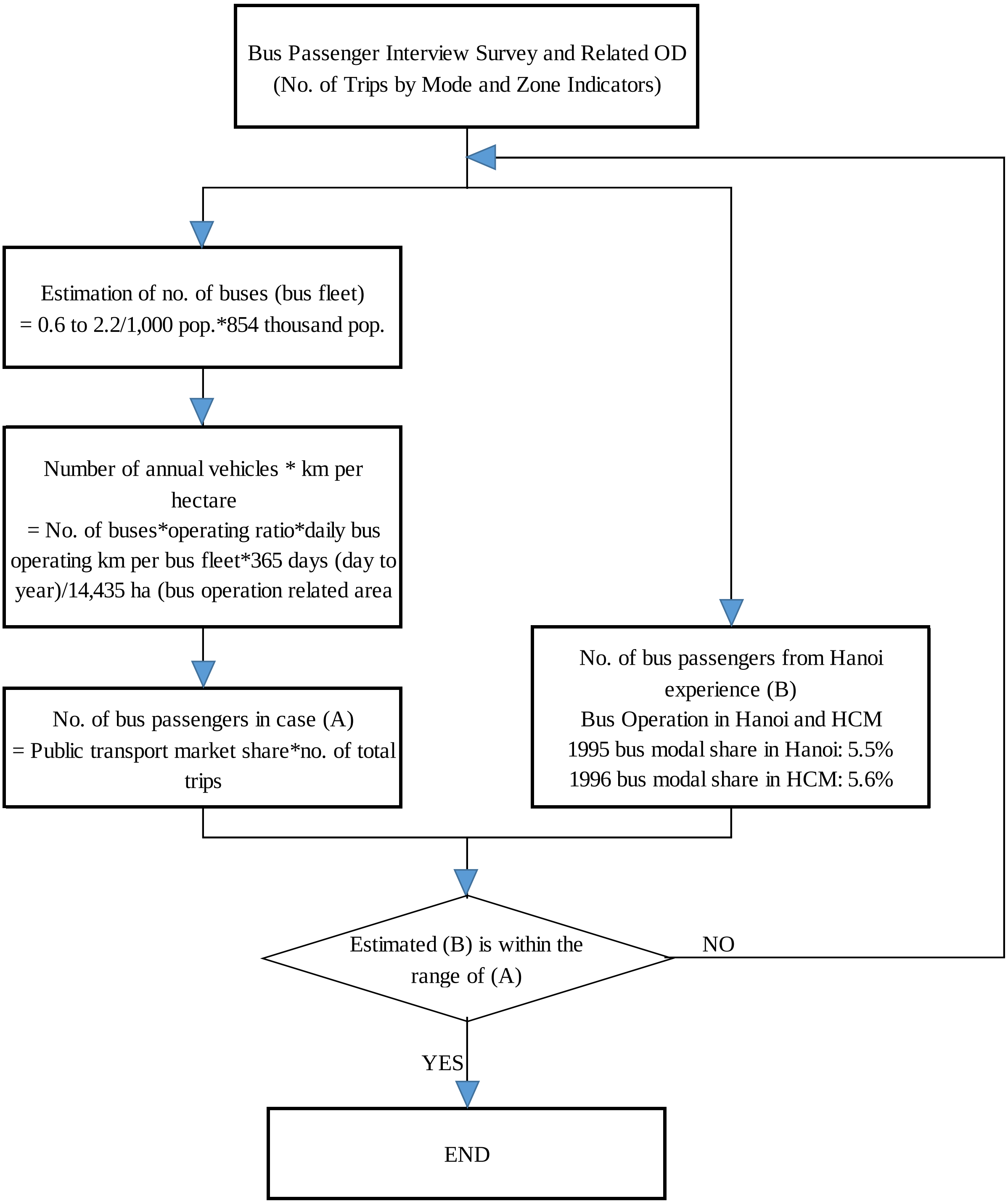


Figure 7.3-2 Work Flow for the Estimation of RP-based Bus Passengers in 2012

2) Bus Route related to Bus Passenger Interview Survey and Related OD

Current bus route-related OD trips between zones were extracted from existing OD data (2012). Figure 7.3-3 shows current bus routes and zones in Phnom Penh.

The extracted number of trips by mode is as follows:
MC: 709,840 (67.4%)
CAR: 125,210 (11.9%)
Para-transit: 218,358 (20.3%)

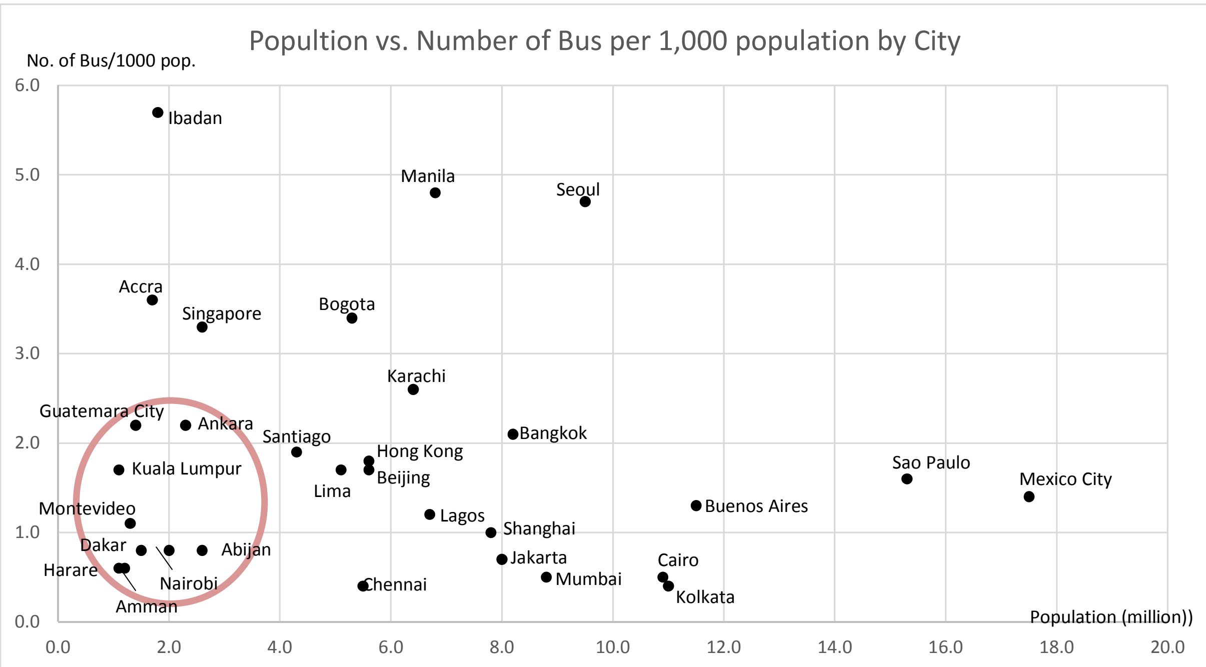
And the zone indicators of the related zones are as follows:
Area (sq. km): 144.35
Population in 2012: 854,100

Source: PPUTMP Project Team

Figure 7.3-3 Zoning Map and Current Bus Routes in Phnom Penh

3) Number of Buses per 1,000 Population

The relationship between a city's population and number of buses per 1,000 population based on data from the World Bank is shown below. It can be observed that a city with 1.0 to 3.0 million population has 0.6 to 2.2 buses/1,000 population.

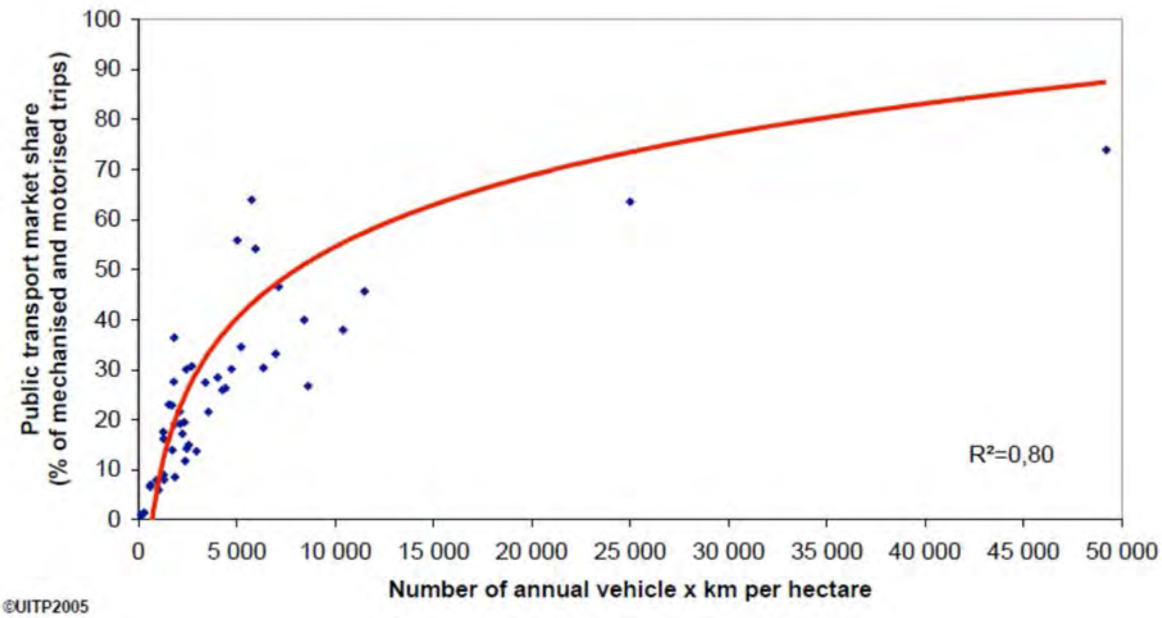


Source: World Bank and PPUTMP Project Team

Figure 7.3-4 Population vs. Number of Bus per 1,000 Populations by City

4) Public Transport Market Share vs. Public Transport Supply

Based on Jean Vivier's "Mobility in Cities Database", the relationship between Public transport market share and Public transport supply is as follows:



Source: Mobility in Cities Database, 2005 (Jean Vivier, International Association of Public Transport (UITP))

Figure 7.3-5 Number of Annual Vehicle * km per Hectare vs. Public Transport Market Share

5) Result of the Trial

Based on the above analysis, the estimation of bus passengers for (A) and (B) are done. Bus passengers (A) is estimated based on the number of annual vehicles per hectare and (B) uses the bus modal share in Hanoi in 1995, which was the year when bus operation in Hanoi started. If the result of Estimation (B) is within the range of Estimation (A), this can be adopted as the number of RP-based bus passengers in 2012 in Phnom Penh. The result is that (B) is within the range of (A). Considering these two trial cases, 180,000 trips are applied to the number of bus passengers in 2012 based on RP.

Table 7.3-1 Result of the Trial

Item	Figure	Unit
Number of Annual Vehicles* km per Hectare	1,271	Vehicle*km/ha
Public Transport Market Share from Graph in 4)	15 to 20	Percent
Public Transport Market Share* Total No. of Trips	158,000 – 210,000	Trips (Estimation (A))
No. of Bus Passengers from the Experience of Hanoi	180,100	Trips (Estimation (B))
Applied No. of Bus Passengers	**180,000**	**Trips**

Source: PPUTMP Project Team

(3) Comparison of Number of Public Transport Transferred Trips and Ratio between SP-based and RP-based

Considering the RP-based public transport transferred trips of 180,000 trips and the result of bus passenger interview survey, number of bus passengers by mode is shown in the following Table 7.3-2. The comparison between SP-based and RP-based results is shown in Table 7.3-3.

Table 7.3-2 Summary of RP-Based PT Transferred Trips and Share

Mode	Previous Modal Share (Bus Passenger Interview Survey)	ımber of Bus Passengers by Mode	Share of Bus Passengers by Mode
MC	53%	95,400 =180,000*53%	13.44% =95,400/709,840
CAR	10%	18,000 =180,000*10%	14.38% =18,000/125,210
Para-transit	37%	66,600 =180,000*37%	30.50% =66,600/218,358
Total	100%	180,000	17.09%

Source: PPUTMP Project Team

Table 7.3-3 Comparison of PT Transferred Trips and Share between SP Based and RP Based

Mode	Total Trips	Number of Public Transport Transferred Trips (Transferred Ratio)	
		SP-based (from SP Survey)	RP-based (from Bus Passenger Interview Survey)
MC	709,840	282,852 (35.6%)	95,400 (13.44%)
CAR	125,210	55,658 (44.5%)	18,000 (14.38%)
Para-transit	218,358	45,753 (21.8%)	66,600 (30.50%)
Total	1,053,408	356,023	180,000

Source: PPUTMP Project Team

(4) Result of Recalculation of the Public Transport Users' Trips by the Adoption of the Transferred Model after the Correction of Parameters

As mentioned earlier, because of the selectivity bias found in the SP survey results, an examination and correction of the parameters of the Binary Logit Model are done assuming the share by previous modes as the revealed preference data. However, correction of parameters of Binary Logit Model does not directly use the RP-based figures because the public transport system in 2035 is not only bus but rail transit + bus. Therefore, the figure from RP is corrected and shifted to the SP-based figure side.

Table 7.3-4 Estimated Number of Public Transport Trips and Modal Share in 2035 in Comparison between Before and After Correction

Items	Before Correction	After Correction
Estimated Number of Public Transport Trips in 2035	1,656,327	1,377,821
Modal Share of Public Transport (excluding walk)	28.4%	23.6%

Source: PPUTMP Project Team

The re-estimated alternative inherent variable to match the correction figures by changing the corrected transferred ratio curvature by mode is shown in the following table.

Table 7.3-5 Correction of Transferred Ratio Curvature of the Mode of Transport in Base Case

Mode	Correction of Alternative Inherent Variable	
	Before Correction	After Correction
Transferred Model from MC	-0.079774107	-0.55977
Transferred Model from CAR	-0.040855525	-0.7608555
Transferred Model from PT	-0.006864901	+0.173135

Source: PPUTMP Project Team

(5) Sensitivity Analysis

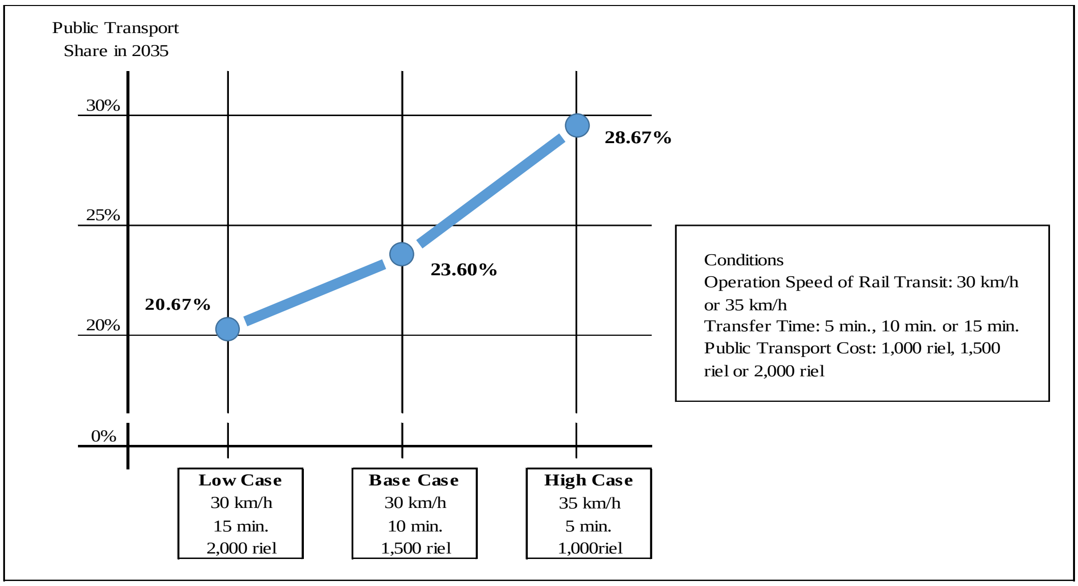
As discussed in Section 7.2 (3), the factors that affect the public transport share are operational speed of rail transit, transfer time and public transport fare. Based on this, the sensitivity analysis using the change of the service level of the public transport is adopted in order to observe the change of the public transport share using the following 3 cases.

Table 7.3-6 Conditions and Cases by the Influence Factor for the Sensitivity Analysis

Case	Operation Speed of the Rail Transit (km/hour) *	Transfer Time (minutes)	Public Transport Fare (riel)
High Case	35.0	+5.0	1,000
Base Case	30.0	+10.0	1,500
Low Case		+15.0	2,000

Note: According to the pre-F/S of the trail transit, planning operation speed of rail transit is 30km/hour and it is possible to increase up to 35km/hour.
Source: PPUTMP Project Team

The result of the sensitivity analysis is shown in Figure 7.3-6. It can be said that the target public transport share in 2035 of 30% can be achieved by the improvement of operational services of the rail transit, development of convenient mode interchange areas such as stations, terminals and bus stops and the effort of the public transport fare policy based on the public transport system development.



Source: PPUTMP Project Team

Figure 7.3-6 Result of the Sensitivity Analysis