São paulo Transport S.A.
The Federative Republic of Brazil

THE PREPARATORY SURVEY FOR URBAN TRANSPORT DEVELOPMENT PROJECT IN SAO PAULO

MAY 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
TOSTEMS, INC.
TONICHI ENGINEERING CONSULTANTS, INC.
NIPPON KOEI LAC CO., LTD.

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Table of Contents

List of Tables

List of Figures

Abbreviations

ABNT	Brazil Association of Technology Standards
ABRADEE	Brazil Electric Power Distributors Association
AFC	Automatic Fare Collection
AGT	Automated Guideway Transit
ANA	National Agency for Waters
APA	Environmental Protection Area
APP	Permanent Preservation Area
APRM	Water Source Protection and Restoration Area
APRM-G	Water Source Protection and Restoration Area of the Guarapiranga Hydrographic Basin
ASTM	American Society for Testing and Materials
BOD	Biochemical Oxygen Demand
BRT	Bus Rapid Transit
CADES	Municipal Council of Environment and Sustainable Development
CBH	Hydrographic Basin Committee
CEPEC	Certification of Additional Potential of Construction
CET	Traffic Engineering Company
CETESB	Environmental Sanitation Technology Company
CONAMA	National Council for the Environment
CONDEPHAAT	Council for Protection of Cultural, Archaeological, Artistic and Tourist Heritages
CPTM	Sao Paulo Metropolitan Train Company
DAEE	Department of Waters and Electric Energy
DECONT-2	Technical Division of Registration and Licensing
DECONT	Environmental Quality Control
DEPAVE	Department of Parks and Green Areas (of SVMA)
DEPRN	State Department of Natural Resources Protection
DESAP	Department of Property Expropriation
DESAP	Department of Property Expropriation
DETRAN	State Department of Traffic of Sao Paulo
DPAA	Technical Division of Environmental Protection and Evaluation
EIA	Environmental Impact Assessment
EIR	Environmental Impact Report

EIS	Environmental Impact Study
EIV	Neighborhood Impact Study
EMME/3	A transportation planning software (INRO)
EMMP	Preparation of Environmental Management and Monitoring Plan
EMPLASA	Sao Paulo Company of Metropolitan Planning
EMTU	Urban Transport Metropolitan Company
FRP	Fiber Reinforce Plastic
FURNAS	Furnas Central Electric Company (A power generation company)
GDP	Gross Domestic Product
HSST	High Speed Surface Transport
IBAMA	Brazilian Institute for Environment and Renewable Natural Resources
IBGE	Brazil Geographic and Statistics Institution
IEE	Initial Environmental Examination
IPHAN	Institute of National Historic and Artistic Heritage
ITAIPU	Itaipu Binacional (A power generation company)
JARTS	Japan Railway Technical Service
JICA	Japan International Cooperation Agency
JIS	Japan Industrial Standards
JTCA	Japan Transport Cooperation Association
LAeq	Equivalent continuous A-weighted sound pressure Level
LAI	Environmental License for Installation
LAO	Operation Environmental License
LAP	Previous Environmental License
LI	Installation License
LIM	Linear Motor Railway
LP	Previous License
LRT	Light Rail Transit
METRO	Sao Paulo Subway
NCA	Noise Consideration Algorithm
NGO	Non-Government Organization
OD	Origin and Destination
OUC	Joint Urban Operation
PAP	Project-Affected Person
PCB	Polychlorinated Biphenyls
PDDT	Transportation Development Master Plan
PDE	The Strategic Master Plan
PDPA	Environmental Development and Protection Plan
PHPDT	Peak Hour Peak Direction Trip
PITU	Integrated Urban Transportation Plan
PRAD	Degraded Areas Recuperation Plan
PSD	Platform Screen Door
RAP	Resettlement Action Plan
RESOLO	Land Legalization/Register Office
RIMA	Environmental Impact Report
RIVI	Neighborhood Impact Report
RMBS	Baixada Santista Metropolitan Region
RMC	Campinas Metropolitan Region
RMSP	Sao Paulo Metropolitan Region
ROW	Right of Way
SEHAB	Housing and Urban Development Secretariat
SEMA	State Secretary of Environment
SEMPLA	Municipal Secretariat of Planning
SIGRH	Water Resources Integrated Management System
SISNAMA	National Environmental System
SMA	Secretariat of Environment
SNJ	Secretariat of Legal Affairs
SNUC	National System of Conservation Unit
SPM	Suspended Particulate Matter
SPT	Standard Penetration Test
SPtrans	Sao Paulo Transport S.A.

STM	State Secretariat of Metropolitan Transport
SVMA	Municipal Secretariat of Green and Environment
TRANUS	(An integrated land use and transport modeling system ((c)Modelistica))
TSP	Total Suspended Particulates
TSS	Total Suspended Solid
TVM	Ticket Vending Machine
UC	Conservation Unit
UFIR	Fiscal Reference Units
UGRHI	Water Resources Management Unit
USP	University of Sao Paulo
ZEPEC	Cultural preservation special zone

CHAPTER 1 EXECUTIVE SUMMARY

1.1 PROJECT PROFILE

Table 1-1 Project Profile

No.	Item	Description				
		Phase 1		Phase 2	Phase 3	
		MB	AD			
1	Construction section	Line-1, Line-2A *Capao Redondo ~ Jardim Angela ~ Santo Amaro*		Line-2B, Line-2D *Santo Amaro ~ Largo da Batata ~ Ramal Jaguara*	Line-2C *Largo da Batata ~ Barra Funda*	
2	Open year	Oct.,2014	Mar.,2015	July, 2016	April, 2018	
3	Section length (km)	14.2	15.6	22.6	7.2	
	Tunnel section (km)	0.24	0.63	0.0	0.0	
4	Station (Number of stations including the future stations)					
	- Elevated	16	16	26	8	
	- Underground	1	3	0	0	
	Total	17	19	26	8	
5	Alignment	Minimum curve radius: Basically 100m. However, As an unavoidable case, R_{min} = 50m is applied.				
6	Gradient	Maximum gradient: Basically 6%. However, as an unavoidable case, i_{max} = 8% is applied.				
7	Track	Double track, Counterclockwise, Distance between tracks: 3,700mm				
8	Track beam (PC girder)	Length: 22m~30m, Height: 1700mm, Width: 850mm				
9	Land Acquisition (m^2)	116,520	182,630	59,655	2,240	
10	Project Cost (million JPY)				Phase 3	Phase 3-2
	- Construction cost (base cost)	122,466	133,855	161,002	38,913	9,784
	(Price escalation, contingency)	18,946	21,185	37,846	13,051	9,179
	- Consulting service	8,924	9,621	9,145	6,997	0
	- Land Acquisition	4,895	8,415	3,179	114	0
	- Administration cost	4,657	5,192	6,335	1,772	569
	- VAT	25,900	28,388	36,250	9,746	3,414
	- Import Tax	0	0	0	0	0
	- IDCP, commitment charge	7,039	10,468	11,453	3,202	441
	Total	192,827	217,123	265,209	73,795	23,385
11	Train	Straddle Type Monorail				
	- Configuration	6 car-train (Mc-M-M-M-M-Mc) or 8 car-train(Mc-M-M-M-M-M-M-Mc)				
	- Capacity	1,000 passengsers/6-car train, 1,300 passengers/8-car train (6 standees /m^2)				
	- Train length	90m / 6-car train, 120m / 8-car train				
12	Operation	Automatic Train Operation system (ATO) with a train driver				
13	Signaling	Cab signal with CBTC				
14	Electric power Feeding system	The primary substation receives an AC138kV, and the traction substation is fed by AC34kV. And it converted into DC1500V.				
15	Demand	Phase 1		Phase 2	Phase 3 + Line 1B	
	Year 2015	23,200 PHPDT		29,500 PHPDT	27,300 PHPDT	
	Year 2045	28,800 PHPDT		34,800 PHPDT	32,100 PHPDT	
16	Capacity Opening Year	25,000 PHPDT		29,600 PHPDT	31,200 PHPDT	
	Year 2045	---		---	32,500 PHPDT	
17	Minimum headway	2 minutes 15 seconds ~ 2 minutes 30 seconds in peak hour peak section				
18	Number of train sets	29 sets of 6-car train		26 sets of 6-car train 35 sets of 8-car train	7 sets of 6-car train 60 sets of 8-car train	
19	EIRR	Phase1 (MB), Phase1(AD), Entire case = 17.0 – 19.0% % > minimum rate of 12%				
	FIRR	Phase1 (MB): 1.4%, Phase1(AD): 0.5%, Entire: - 0.7%				

Note) MB: Original route (via M'Boi Mirim), AD: Area development route

1.2 THE PREPARATORY SURVEY

1.2.1 Background

The Municipality of São Paulo is the largest city in Brazil with the total population of 11 million, and its metropolitan area has the total population of 2.0 million. The Municipality of São Paulo is also the economic center in Brazil, producing approximately 12% of the Gross Domestic Product (GDP) of the country.

With the large population and economic activities, São Paulo has a huge traffic demand which causes serious traffic congestion and air pollution in the city. To reduce the traffic congestion, capacity expansion of public transport system is an urgent need of the city.

Currently, the public transport system in São Paulo consists of small capacity bus transit services (Bus Rapid Transit (BRT) and feeder buses) and a large capacity transit services (railway lines). The expansion of the railway network was planned in the Integrated Urban Transport Plan (PITU) and the expansion projects has being implemented by Metro (São Paulo Metro) and CPTM (São Paulo Metropolitan Train Company). In view of hierarchy of public transport network, BRTs complement the railway network. However, the public transport network in São Paulo needs transit systems of higher capacity than BRTs to deal with the passenger demand.

The Strategic Master Plan 2020 (PDE 2020) was formulated by the Municipality of São Paulo in 2002, in which a public transport network plan was included. In PDE 2020, introduction of a medium capacity transit system was proposed. SPTrans, a municipal company of bus services in São Paulo, had identified three routes as the priority routes for the medium capacity transit system in 2008.

Japan has developed several types of medium capacity transit system, such as monorail, AGT (Automated Guideway Transit), HSST (High Speed Surface Transport), and LIM (linear metro). There are 10 monorail lines, 10 AGT lines, and 5 LIM lines in Japan. The experiences of medium capacity transit system in Japan is expected to be very useful information for those countries which are going to introduce medium capacity transit systems. The advantageous of a medium capacity transit system is:

- Lower construction cost and construction period than metro
- Flexible alignment with higher gradient and smaller radius of curve than metro
- Higher capacity than BRT
- Less traffic impact than BRT

The Japan International Cooperation Agency (JICA) and the Municipal Secretary of Transport (SMT) agreed to start “the Preparatory Survey for Urban Transport Development Project in São Paulo” in 2008.

1.2.2 Objectives of the Study

The objectives of the Study are:

- Selection of an adequate transit system on each route of the study routes and
- Preparation of a feasibility study of an urban transport system on the proposed routes.

1.2.3 Study Routes

(1) Original Study Routes

In the beginning of the study, the study routes consisted of the following seven sections with the total length of 58km. The location of these routes is shown in Figure 1-2. The study routes are called as “original routes” in this report because some alternative routes have been proposed.

No.	Section	Length (km)
Line-1	Jardim Angela – Capelinha	5
Line-2A	Jardim Angela – Santo Amaro	8
Line-2B	Santo Amaro – Largo da Batata	12
Line-2C	Largo da Batata – Barra Funda	6
Line-2D	Largo da Batata – Ramal Jaguare	9
Line-3A	São Judas – Aguas Espraiadas Jabaquara – Aguas Espraiadas	11
Line-3B	Aguas Espraiadas – Morumbi	7
Total		58

(2) Line-3

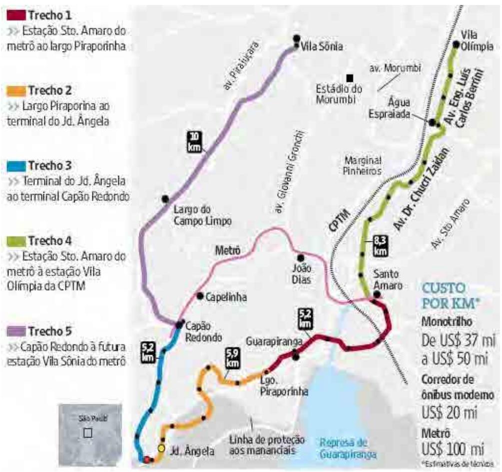
After the commencement of the study, São Paulo Metro, a state company for the underground rail system in São Paulo, took over the construction project of Line-3A and Line-3B as Metro Line-17 (Gold Line). São Paulo Metro disclose the project outline with the basic specification of the system and started to collect public opinion. The proposed system is a monorail with a capacity of 20,000 passenger per hour per direction.

Considering the progress of Line-3 project by Metro, JICA, SMT, and São Paulo Metro agreed that Line-3 would be excluded in the study routes in November, 2009.

(3) Monorail Project

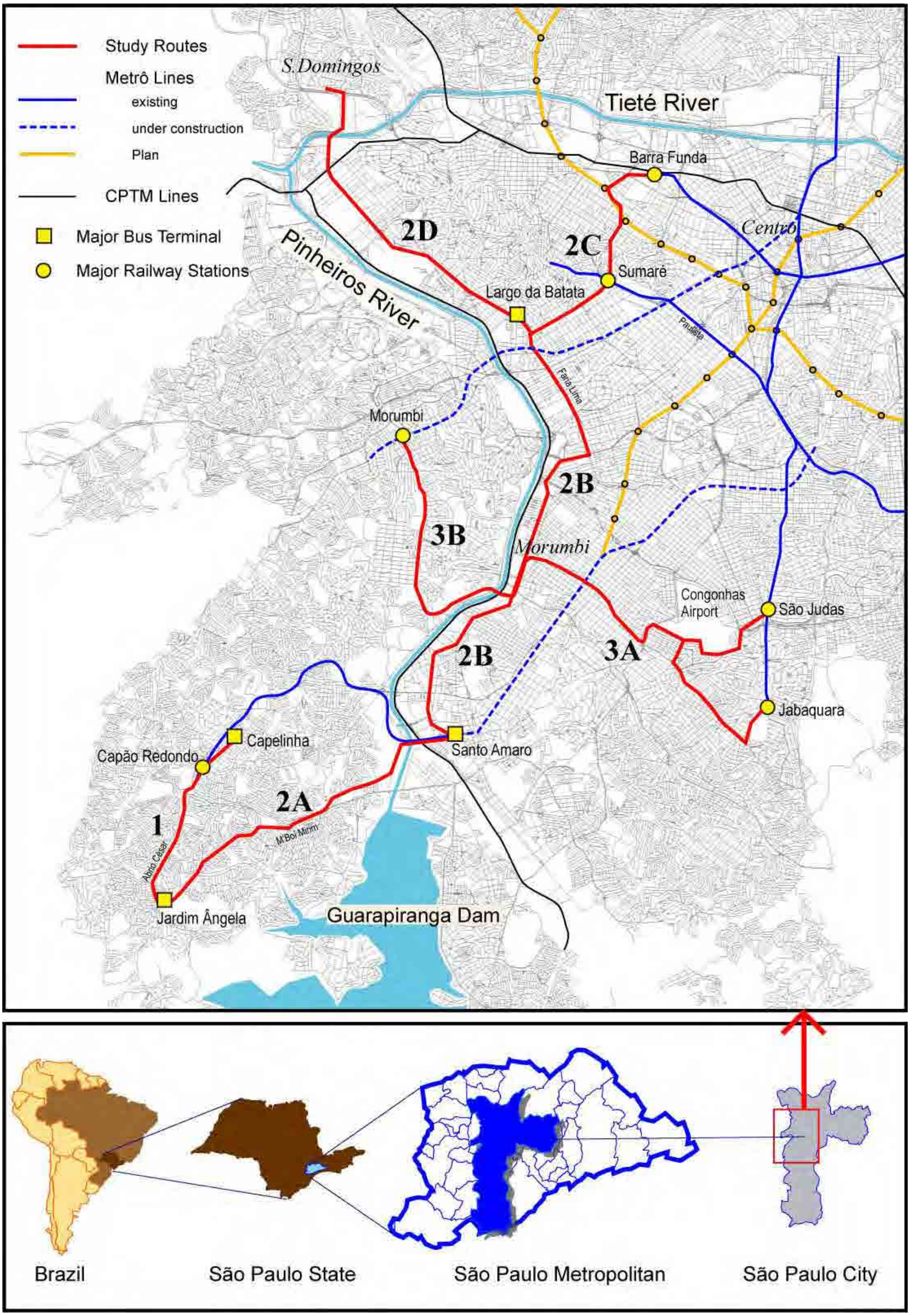
The mayor of São Paulo announced the implementation of monorail system in São Paulo at the end of August in 2009 as shown in Figure 1-1. The monorail route included a part of study routes, i.e. Line-1, and Line-2A, Line-2B. There is a new route in the monorail project between Capon Redondo and Vila Sonia with a total length of 10km. This section was named as “Line-1B” in the study. Line-1 in the original route was renamed as “Line-1A” to identify the section clearly.

Although Line-1B has not been included in the study, its impact was considered in demand forecast and economic and financial analysis.



Source: News Paper

Figure 1-1 Monorail Project



Source: JICA Study Team

Figure 1-2 Location of Study Route

1.2.4 Scope of the Study

The Scope of Works of the Study is summarized as follows. The scope of "6-4. Support of EIA" and "6-5. Support of RAP" was changed a little, because it became difficult for SPTrans to start EIA, which are supposed to be conducted by SPTrans, during the period of the JICA study. Chapters in this report does not necessary conforms to the order of the Work Item and Sub-Item in the table. The relationship between the scope items and the chapters are shown in the right column of the summary.

Work Item	Sub-Item	Chapter
1. Necessity of the Project	1-1. Land use and development trend 1-2. Public transportation problem 1-3. Policy, plans, and projects of transport sector in São Paulo 1-4. Policy of other international organization 1-5. Possibility of multi-international cooperation	2-1 & 2-2 2-3 2-4 & 2-5
2. Demand Forecast	2-1. Route study 2-2. Review of socio-economic data 2-3. Review of modal split model 2-4. Demand forecast 2-5. Study on transport mode	2-1, 2-2, 2-3, 2-6 3-1 3-2 3-2 4-2
3. Project Scope	3-1. Route Plan 3-2. Design of cars 3-3. Operation Plan 3-4. Infrastructure	4-1 4-4 4-3 5
4. Project Plan	4-1. Construction Method 4-2. Procurement 4-3. Implementation Schedule 4-4. Technical Assistance Plan 4-5. Project Cost	6-1 6-2 6-4 6-5 6-3
5. Implementation Plan	5-1. Implementation structure 5-2. Operation and Maintenance Plan	7-1 7-2
6. Consideration of Environmental and Social Impact	6-1. Alternative study 6-2. Environmental impact study 6-3. Mitigation and Monitoring Plan	8-2 8-1, 8-3, 8-4, 8-5 8-1, 8-3, 8-4, 8-5
7. Project Effects	7-1. Operation and effect indicators 7-2. Positive impact on environment 7-3. Other quantitative and qualitative impacts 7-4. Economic evaluation and financial analysis	9-1 9-3 9-2 10
8. Conclusion & Recommendations	8-1. Conclusions & Recommendations	11

1.3 SUMMARY OF THE STUDY

1.3.1 Present Situation of the Route

The Municipality of São Paulo is the largest city in Brazil with the population of 11 million, and the center of economic activity in the country accounting for approximately 11.9% of the national GDP. With the large population and the recent economic growth, traffic on roads in São Paulo is very heavy and many roads suffer from serious congestion in peak hours. The average speed in afternoon peak hours is 17.2 km/h in 2007 while it was 21.8 km/h in 1997.

Bus is the major mode of public transport in São Paulo, accounting for 65% of motorized transport while railway system accounts for 22%. There are 10 BRT routes along major corridors but most routes suffers from heavy congestion and low speed in peak hours.

The new metro line (Yellow Line) and the extension of Lilac Line and Green Line are under construction. In addition, São Paulo Metro has other future projects of three lines with a total length of 37.4km up to 2017 and other new lines by 2020.

It is expected that the intensive public transport development will improve traffic situation of major transport corridors in São Paulo. On the other hand, the study routes are not included in the future metro network.

Line-1A connects Jardim Angela Terminal and Capao Redondo Metro Station. Presently, there is no bus service for the connection. Feeder buses of the metro station uses the north section (Sant’anna Ave.) of Line-1A. Sant’anna Ave. is narrow 2-lane road having many intersections with local streets and congestion is very heavy in peak hours. Line-1A is expected to provide access to metro for the west-south of São Paulo.

Line-2A connects Jardim Angela Terminal and Santo Amaro Terminal along M’Boi Mirim Road and Guarapiranga Ave. This is the most congested route among the study routes, and traffic accident is very serious having the highest number of death accidents in roads in São Paulo. There is a BRT system on M’Boi Mirim Road connecting the two terminals. In peak hours, articulated buses on the exclusive lanes of the BRT make a long queue, and the travel speed of the BRT is as low as approximately 10km/h. The traffic demand of this corridor exceeds the maximum capacity of a BRT system.

Line-2B runs through the emerging business and commercial area in São Paulo. To promote urban development by private sector, the Joint Urban Operation (OUC) area is designated along the route. Although Emerald Line (CPTM) and Lilac Line (Metro, under construction) run north and south, high demand in public transport is expected along this corridor due to the business and commercial activity.

Line-2C connects three metro stations north and south – Barra Funda (Red Line), Sumare (Green Line) and a new station of Yellow Line.

Line-2D connects the north-west area of São Paulo and the business and commercial area along Faria Lima north and south. Currently, the access from the north-west area to the center of the city is very inconvenient because of Tiete River and the heavy congestion along the route.

1.3.2 Demand Forecast

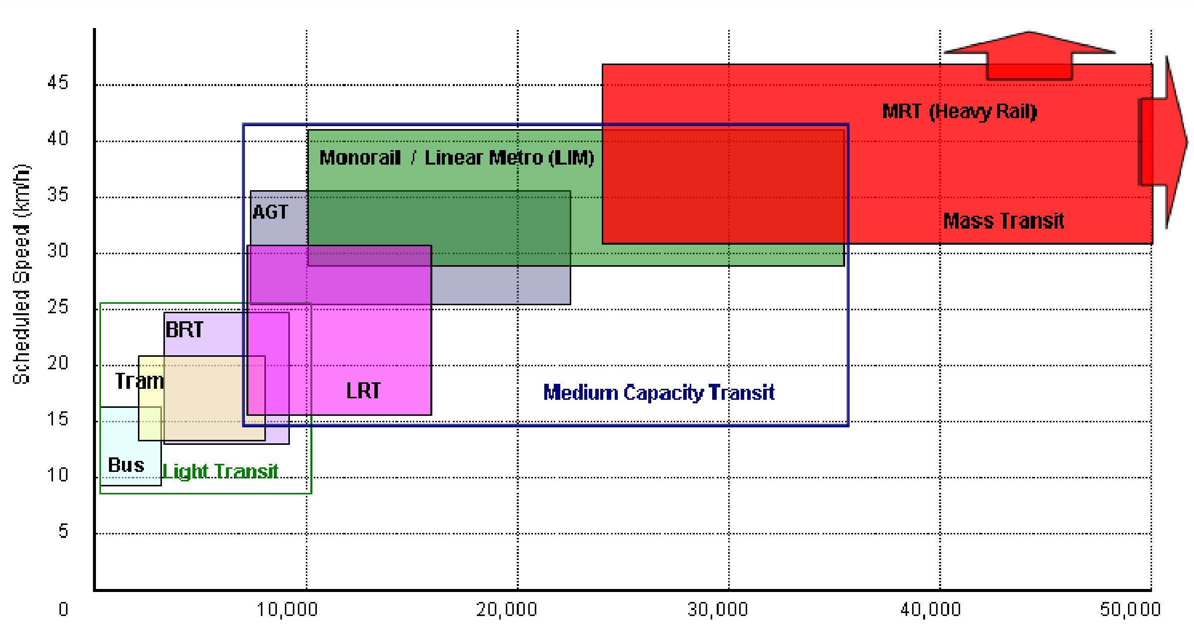
Demand forecast was carried out based on 1158 zone system in 2007 OD survey. The future socio-economic framework was estimated from Integrated Urban Transport Plan (PITU) 2025 and the population projection by Brazil Geographic and Statistics Institution (IBGE).

It was estimated that the number of trips by public transport mode in RMSP would be 1.09 times in 2015, 1.17 times in 2025, and 1.24 times in 2045 compared to the base year of 2007. The traffic demand of the study routes was estimated for three cases by assigning the future OD to the future transport network as:

		Line-1A + Line-2A		Line-1A+2A+2B+2D		All lines	
Year		2015	2045	2015	2045	2015	2045
PHPDT	Line-1A	13,900	18,800	11,200	15,500	14,600	20,100
	Line-1B	-	-	-	-	21,400	25,900
	Line-2A	23,200	28,800	29,500	34,800	27,300	32,100
	Line-2B	-	-	26,600	29,900	23,400	26,300
	Line-2C	-	-	-	-	4,600	5,700
	Line-2D	-	-	13,400	20,000	13,200	19,800
Daily Passengers		400,000	506,000	745,000	911,000	1,109,000	1,246,000
Passenger hours (000)		88	109	270	321	355	403
Passenger kilometers (000)		2,615	3,264	7,983	9,512	10,599	12,027

*PHPDT: Peak Hour Peak Direction Traffic

The traffic volume of Line-2A is highest as 32,100 passengers per hour per direction in peak hour (PHPDT) in 2045, while that of Line-2C is lowest as 5,700. If Line-2B is not constructed, the traffic volume of Line-2A increases to 34,800 PHPDT. The result shows that a medium capacity transit system is suitable for Line-1A, 1B, 2B, and 2D, while large-type monorail or linear metro are necessary as the medium capacity transit system for Line-2A. Traffic demand of Line-2C is small as a medium capacity transit system. Figure below shows the applicable system based on the traffic demand.

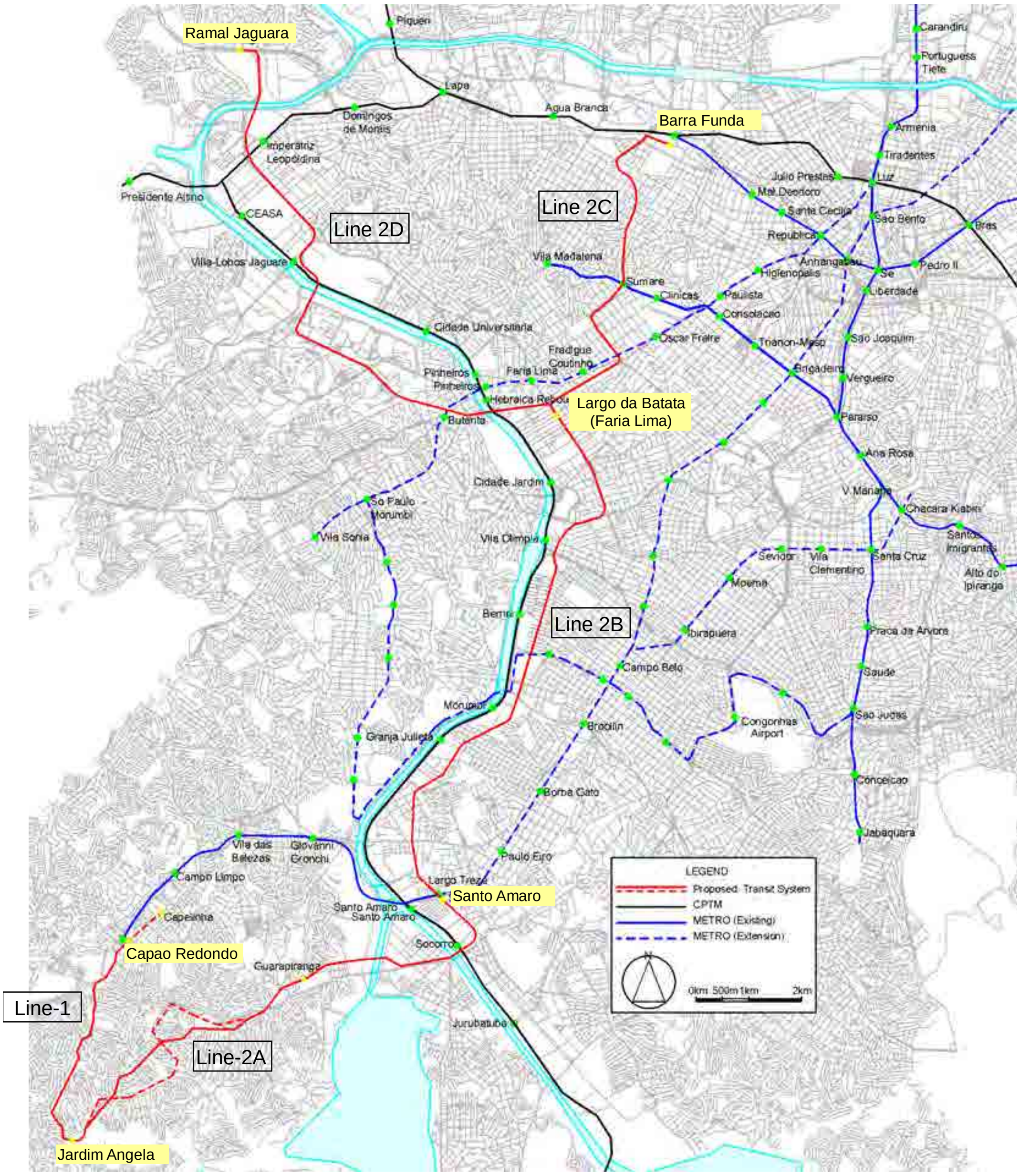


Source: JICA Study Team

Figure 1-3 System Selection Chart

1.3.3 Transport plan

(1) Route plan



Source: JICA Study Team

Figure 1-4 Route Plan

1) Line-1

Line-1 is a 4.2km section between Jardim Angela and Capao Redondo The track structures of Line-1 will be constructed within the space above 4-lane roads, Av. Simao Caetano Nunes, R. Abllio Cesar and Av. Ellis Maas, which have no median strip and the river which flows in parallel to Av. Comendador Santana.

2) Line-2A

Line-2A is approximately 10km route which connects between Jardim Angela and Santo Amaro along the M'Boi Mirim Road. Near the Guarapiranga, the alignment is installed above a river which flows at north side of the Guarapiranga bus terminal. Line-2A has 2 alternatives. One is named "Original Route" and is introduced into M'boi Mirim as above mentioned. Another alternative is named “Area Development Route” and is based on the concept of urban development. This alternative has 11km length and is a route by way of the redeveloping areas which are 500m away from M’Boi Mirim Road.

3) Line-2B

Line-2B is an 11km route which bears the new traffic axis of the south-north direction by connecting between Largo da Batata and Santo Amaro. In an about 2km section between Santo Amaro and Av. Dr. Chucri Zaidan, a newly wide road is planned by a master plan of São Paulo municipality and the proposed transit system will be installed above this road.

4) Line-2C

Line-2C is a 7.2km route between Largo da Batata and Barra Funda. A part of Av. Sumare, where the proposed route is installed, belongs to the cultural preservation special area where development is restrained, and the roadside tree of a median strip is also contained in the object of preservation.

5) Line-2D

Line-2D is an 11.6km route between Largo Batata and Ramal Jaguala, which requires the construction of 3 bridges of Pinheiros River and Tiete River.

(2) System selection

1) Candidate of the system

The candidates of the medium capacity transit system for São Paulo are Light rail transit (LRT), Linear motor railway (LIM train), Straddle type monorail, Suspended type monorail and Automated guideway transit (AGT).

LRT (Light Rail Transit)

LRT is a modern type railway system with lower capacity and lower speed than metro but higher capacity and speed than traditional tram.

LIM Train (Linear motor railway)

LIM Train is a small type railway system using magnetic force as the traction power. The capacity is lower than metro a little, but steeper slope and smaller curve are possible.

Straddle type monorail

A straddle type monorail runs on a girder using rubber tires instead of iron wheel. The capacity is as small as that of LRT in case of small type monorail but the capacity of large type monorail is as large as that of LIM.

Suspended type monorail

A suspended type monorail is suspended by a linear structure and runs using rubber tires. The capacity is a little bit smaller than a small size- straddle type monorail.

AGT (Automated Guideway Transit)

AGT is a driver-less transit system running with rubber tires automatically guided by guildeway. The capacity is similar to that of LRT.

Table 1-2 Operational Performance and Capacity

	LRT	LIM Train	Straddle type monorail	Suspended type monorail	AGT
Size					
Dimensions (L x W x H) (m)	53.4 x 2.45 x 3.65 (9 cars-train)	16.0 x 2.50 x 3.15 (Car)	15.0 x 2.98 x 5.2 (Car)	15.0 x 2.65 x 4.8 (Car)	9.0 x 2.47 x 3.34 (Car)
Train length (m)	53.4m / 9cars	96m / 6cars	90m / 6cars	90m / 6cars	54m / 6cars
Axle load	10 tons (100KN) 10 axles per 9 cars-train	11 tons (110KN) 4 axles per car	11 tons (110KN) 4 axles per car	8.5 tons (85KN) 4 axles per car	9 tons (90KN) 2 axles per car
Operational Performance in Main line					
Minimum Curve	R=20m	R=100m	R=60m	R=50m	R=50m
Maximum Gradient	i = 40‰	i = 60‰	i = 60‰	i = 60‰	i = 60‰
Transport Capacity					
Passengers per train	430	980	1,000	710	470
PHPDT by 180 sec headway	8,600 PHPDT	19,600 PHPDT	20,000 PHPDT	14,200 PHPDT	9,400 PHPDT
by 120 sec headway	12,900 PHPDT	29,400 PHPDT	30,000 PHPDT	21,300 PHPDT	14,100 PHPDT

Note) As for transport capacity, standing capacity under full loaded condition is assumed as 6 standees per m2.
Source: JICA Study Team

2) Evaluation factor for system selection

Each candidate is assessed in view of the route conditions of capacity, gradient, alignment, and impact of street trees. And it is necessary to consider integration of each line so that through operation is possible. As a consequence, Straddle type monorail is selected as the suitable medium capacity transport system for São Paulo.

Table 1-3 Proposed System by Line

Line	Length	Proposed System	Network	Proposed System considering network
1	4.15 km	- Straddle type monorail - Suspended type monorail	Future extension up to Vila Sonia	Straddle type monorail, or Suspended type monorail
2A	11.38km	- Linear motor railway - Straddle type monorail	Integrated line	Straddle type monorail
2B	11.29km	- Straddle type monorail - Linear motor railway		
2C	7.23km	- Straddle type monorail - Suspended type monorail	Through operation with 2B	
2D	11.40km	- Straddle type monorail - Suspended type monorail	Through operation with 2B	

Source: JICA Study Team

I

Features;
The vehicle straddles and runs on the track beam constructed on the space above the road by rubber tire.

Structure;
Track structure is I and/or Box-shape slender beam. Only the slender track beams are installed on the piers as the concrete structure. The elevated slab is not required except switch bridges and stations.

Figure 1-5 Appearance and example of track structure of straddle type monorail

(3) Transport plan

1) Operating policy

The operation policy of the straddle type monorail system is to make medium capacity transit services more attractive to and economical for users, the main features being:

a) Selecting the optimum frequency of train services to provide sectional capacity commensurate with the demand during peak hours on most of the sections;

b) Frequent operation like METRO is performed especially in Line-2A and Line-2B where big demands are forecasted;

c) A maximum train service frequency in peak period is designed as 6 minutes. If an estimated train service frequency in peak period exceeds 6 minutes, it shall be shortened to 6 minutes; and

d) Providing a minimum train service frequency during off-peak period (10 minutes headway) so as to keep the service attractive during off-peak periods also.

2) Track Layout

Figure 1-6 shows the track layout of the whole route.

3) Premises

a) Phasing

The target year of the operation of the entire routes of the Project is planned as 2018. However, it is desirable to put the completed sections into service one by one soon after each route is completed. Therefore, the possible combination of routes for an integrated operation was analyzed considering transportation demand, and the following phasing was established.

Table 1-4 Phasing

Phase	Section	Open Year
1	Line-1 + Line-2A	2014
2	Line-1 + Line-2A + Line-2B + Line-2D	2016
3	Line-1 + Line-2A + Line-2B + Line-2D + Line-2C	2018

Source: JICA Study Team

b) Service

Scheduled speed: 30km/h
Dwell time at the station: 20 seconds
Minimum headway: 120 seconds
Period of business hours: 19 hours from 5:00a.m. to 24:00 p.m.
Train capacity: 1,000 passengers / 6-car train
1,300 passengers / 8-car train
(6 standees / m2)

4) Operation Pattern

a) Features for operation

In phase 3, Line-2C is extended. However, since the Line-2B performs frequent operation, the train operation of Line-2C is separated from that of Line-2B in order to avoid disturbing of Line-2B. Thus, direct train operation between Line-2B and

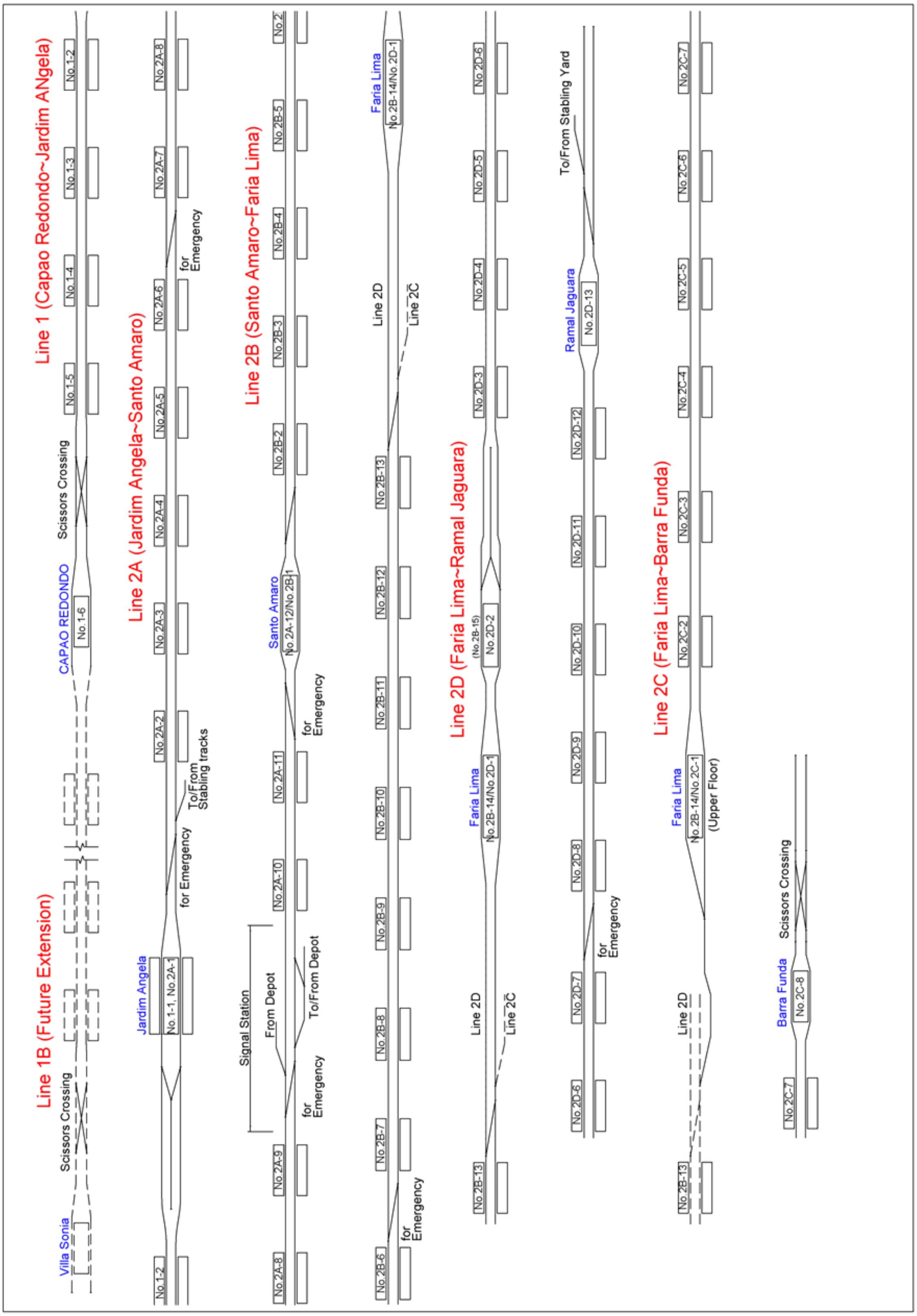
Line-2C is not planned.

b) Headway in peak period in peak section

Phase 1:	2 minutes 30 seconds (Line-1),
Phase 2:	2 minutes 15 seconds (Line-2A,-2B),
Phase 3 (by 2024):	2 minutes 45 seconds (Line-2A,-2B)
Phase 3 (After 2025):	2 minutes 30 seconds (Line-2A,-2B)

c) Train configuration

Phase 1:	Monorail operation is started by using 6-car trains.
Phase 2:	Added to phase 1, 8-car trains are installed.
Phase 3:	In Line-1, 2A, 2B, and 2D, trains are unified to 8-car train. 6-car train will remain only for Line-2C.



Source: JICA Study Team

Figure 1-6 Track Layout

1.3.4 Project scope

(1) Design criteria and policy for civil works

Following design policy is established and applied for the project design of civil works, based on the site reconnaissance and discussions with SPTrans.

1) Following design policy is established and applied for the project design of civil works, based on the site reconnaissance and discussions with SPTrans.

<Route alignments>

a) Connect with beginning point, end point and transfer stations required by the demand forecast and transport planning
b) Avoid removal of established cemetery, university, school, important churches which have negative impacts in social environment
c) Design flexible alignment, utilizing steep slope and small radius (advantage of Monorail) if necessary to match with the terrain condition of São Paulo
d) Take into account existing development plans
e) Minimize relocation/removal of utility structures such as buried pipes, high voltage lines, grade separated crossing structures, elevated structures
f) Evaluate carefully the possibility of the relocation of number of houses particularly illegal occupation because São Paulo city is implementing restructuring of land use in parallel with other development projects such as transport
g) Consider landscape aspects
h) Evaluate possibility of repercussion during the construction work

<Civil structures>

a) Generally the design shall be done in accordance with ABNT (ASSOCIACAO BRASILEIRA DE NORMAS TECNICA) standard in Brazil
b) Provide access-friendly stations for all the uses.
c) Provide attractive appearance for users and society.

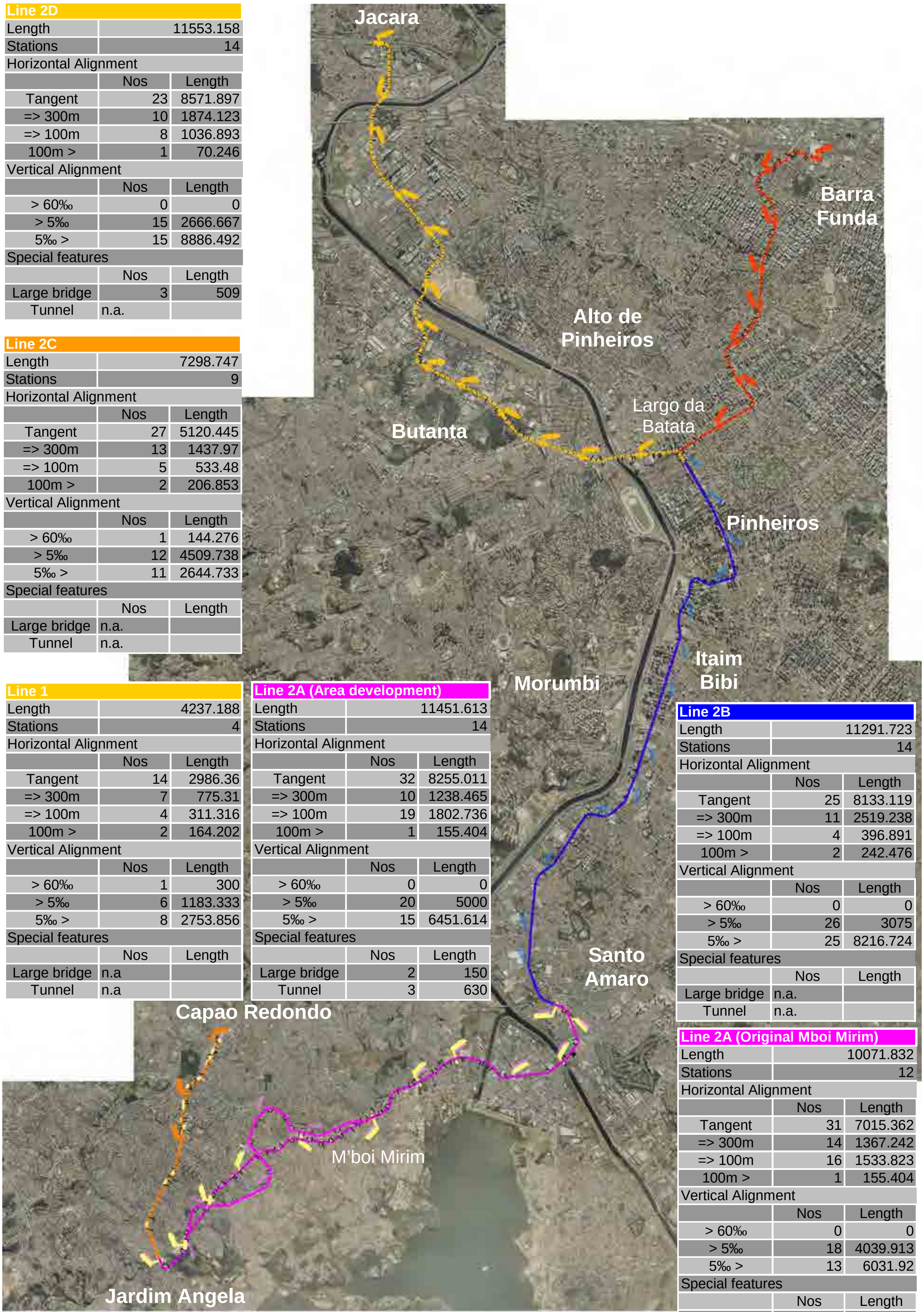
Applicable standards were established mainly using the Brazilian Law such as ABNT and complemented by Japanese standard.

Through the exhaustive site reconnaissance, design controls of each route were identified. Addition to the important infrastructures such as principal roads, schools, hospitals, other transport modes, substations, high voltage lines, cemetery and dense residential area, new road construction plans were taken into account in some sections.

(2) Route alignment

Based on the comparative analysis, final alignment of the project is set as shown in the Figure 1-7, together with its main characteristics.

Further evaluation is required in the next phase of the project to determine the feasibility of land acquisitions and environmental evaluations. Adjustments should be introduced in accordance with further studies. Some stretches such as Line-1, Line-2A area development route and Line-2B south part, new road projects along the monorail alignment. The coordination with state or municipal responsible entity has to be done to adequate both the roads and monorail system infrastructures.



Line 2D		
Length		11553.158
Stations		14
Horizontal Alignment		
	Nos	Length
Tangent	23	8571.897
=> 300m	10	1874.123
=> 100m	8	1036.893
100m >	1	70.246
Vertical Alignment		
	Nos	Length
> 60‰	0	0
> 5‰	15	2666.667
5‰ >	15	8886.492
Special features		
	Nos	Length
Large bridge	3	509
Tunnel	n.a.	

Line 2C		
Length		7298.747
Stations		9
Horizontal Alignment		
	Nos	Length
Tangent	27	5120.445
=> 300m	13	1437.97
=> 100m	5	533.48
100m >	2	206.853
Vertical Alignment		
	Nos	Length
> 60‰	1	144.276
> 5‰	12	4509.738
5‰ >	11	2644.733
Special features		
	Nos	Length
Large bridge	n.a.	
Tunnel	n.a.	

Line 1		
Length		4237.188
Stations		4
Horizontal Alignment		
	Nos	Length
Tangent	14	2986.36
=> 300m	7	775.31
=> 100m	4	311.316
100m >	2	164.202
Vertical Alignment		
	Nos	Length
> 60‰	1	300
> 5‰	6	1183.333
5‰ >	8	2753.856
Special features		
	Nos	Length
Large bridge	n.a	
Tunnel	n.a	

Line 2A (Area development)		
Length		11451.613
Stations		14
Horizontal Alignment		
	Nos	Length
Tangent	32	8255.011
=> 300m	10	1238.465
=> 100m	19	1802.736
100m >	1	155.404
Vertical Alignment		
	Nos	Length
> 60‰	0	0
> 5‰	20	5000
5‰ >	15	6451.614
Special features		
	Nos	Length
Large bridge	2	150
Tunnel	3	630

Line 2B		
Length		11291.723
Stations		14
Horizontal Alignment		
	Nos	Length
Tangent	25	8133.119
=> 300m	11	2519.238
=> 100m	4	396.891
100m >	2	242.476
Vertical Alignment		
	Nos	Length
> 60‰	0	0
> 5‰	26	3075
5‰ >	25	8216.724
Special features		
	Nos	Length
Large bridge	n.a.	
Tunnel	n.a.	

Line 2A (Original Mboi Mirim)		
Length		10071.832
Stations		12
Horizontal Alignment		
	Nos	Length
Tangent	31	7015.362
=> 300m	14	1367.242
=> 100m	16	1533.823
100m >	1	155.404
Vertical Alignment		
	Nos	Length
> 60‰	0	0
> 5‰	18	4039.913
5‰ >	13	6031.92
Special features		
	Nos	Length
Large bridge	2	150
Tunnel	1	240

Figure 1-7 Route Alignments of the Project

(3) Station

The size of the stations for the monorail system is determined by train length and passenger volume, and they will be arranged by taking into account the convenience of passengers. Barrier Free design and Universal Design shall be applied for the entire passenger's convenience. The minimum length of a platform will include the train length and 10 metres of margin.

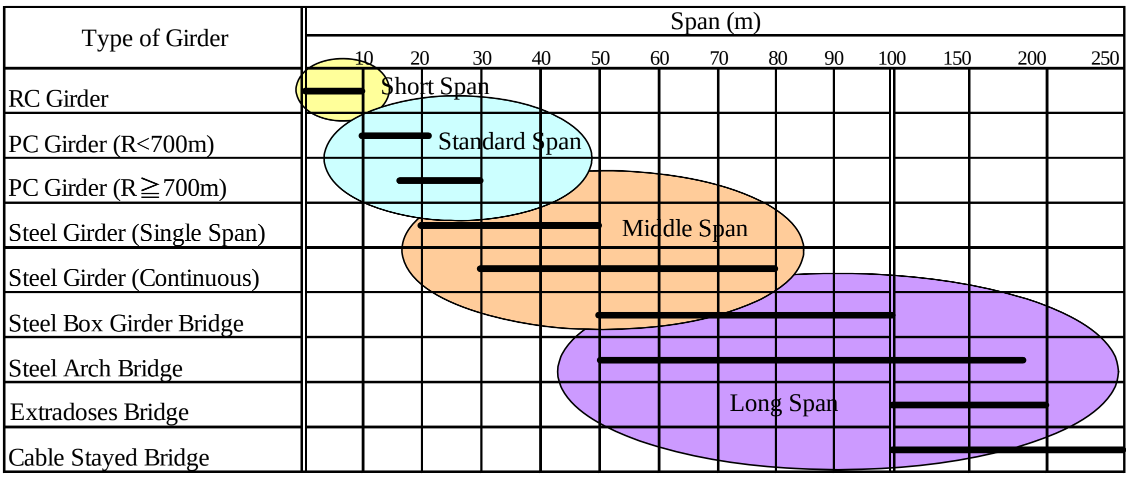
Two types of platform are proposed as the typical type of the station. One is the Island type and another is the Separated type as shown in the figure below. In this project, Separated type platform is basically applied for the intermediate station and Island type is applied for the terminal station.

(4) Guideway Structures

1) Selection of the type of the Girder for super structure

Monorail girders are classified in the following four types. The appropriate girder structure for each span type will be selected as per following figure.

1) Short Span (Span length: ~10m) : Reinforced concrete girder
2) Standard Span (Span length: 22~30m) : pre-stressed concrete girder
3) Middle Span (Span length: 30m~80m) : Steel Girder Bridge
4) Long Span (Span length: 80m~) : Steel Arch Bridge and etc.

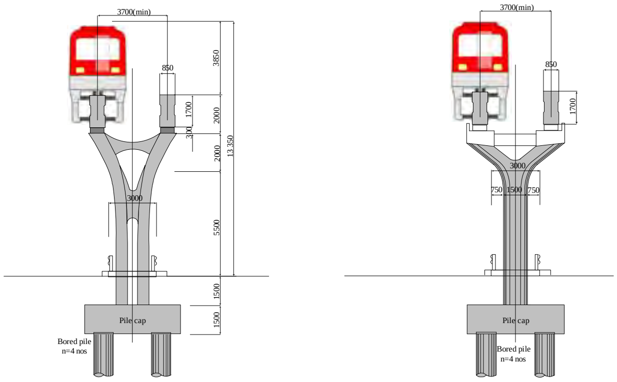


Source: JICA Study Team

Figure 1-8 Selection of superstructure

2) Substructures

Structural requirement of columns of monorail is about 1.5m diameter in case of circular piers, which are accommodated easily on the central median of the road. Typical cross sections of monorail pier are shown in figures below.

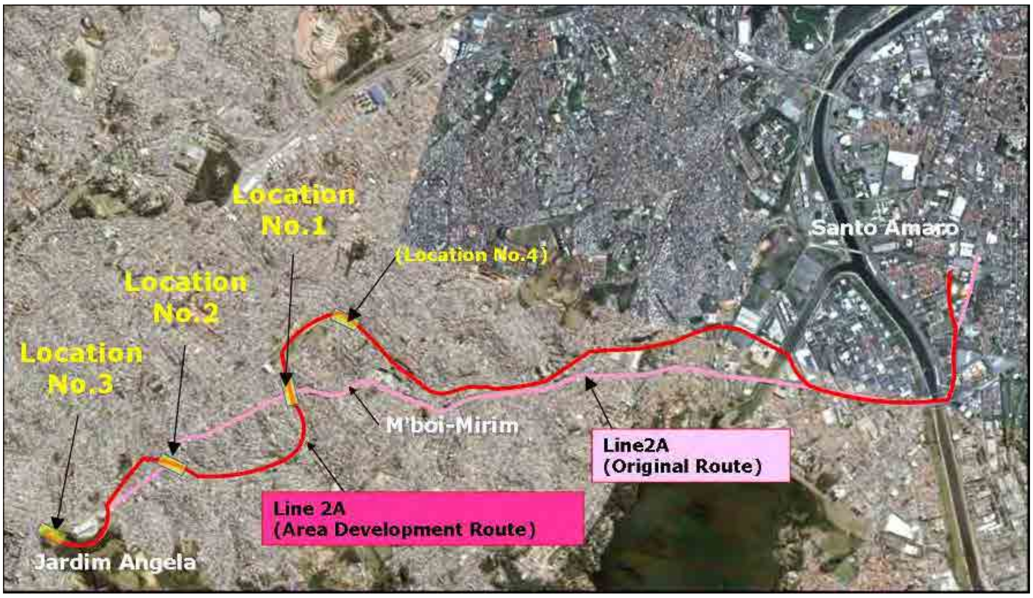


Source: JICA Study Team

Figure 1-9 Typical Cross Section of Monorail Pier

(5) Tunnel

Line-2A (Area Development Route) has four locations where tunnels are proposed as shown in Figure 1-10, while the original route of Line-2A has one of four. Comparative study has carried out in order to take the impact of tunnel into further analysis such as cost estimate, economic and financial evaluation.

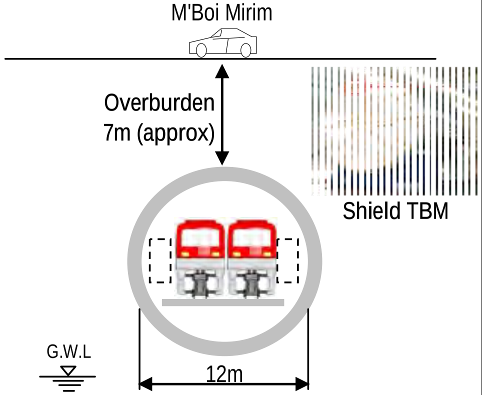
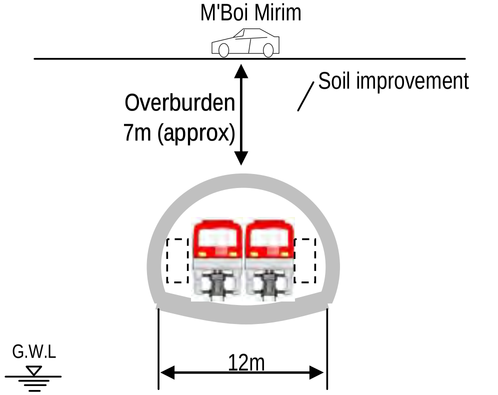
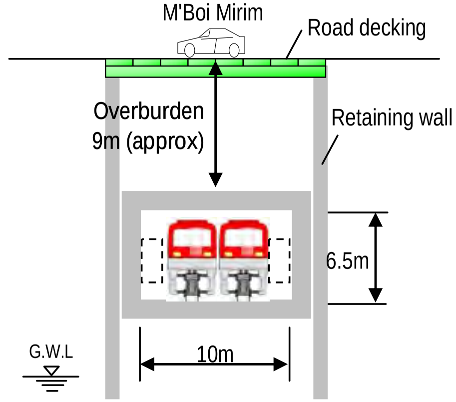


Source: JICA Study Team

Figure 1-10 Location of tunnels

Tunnel methods are compared considering site conditions, conditions of obstacles, ground conditions, work influence to surrounding area, construction period, and the economic viability of the methods to be employed. The cut and cover method is selected as the most suitable tunnelling method for all of three tunnels No.1 – No.3 as shown in Table 1-5.

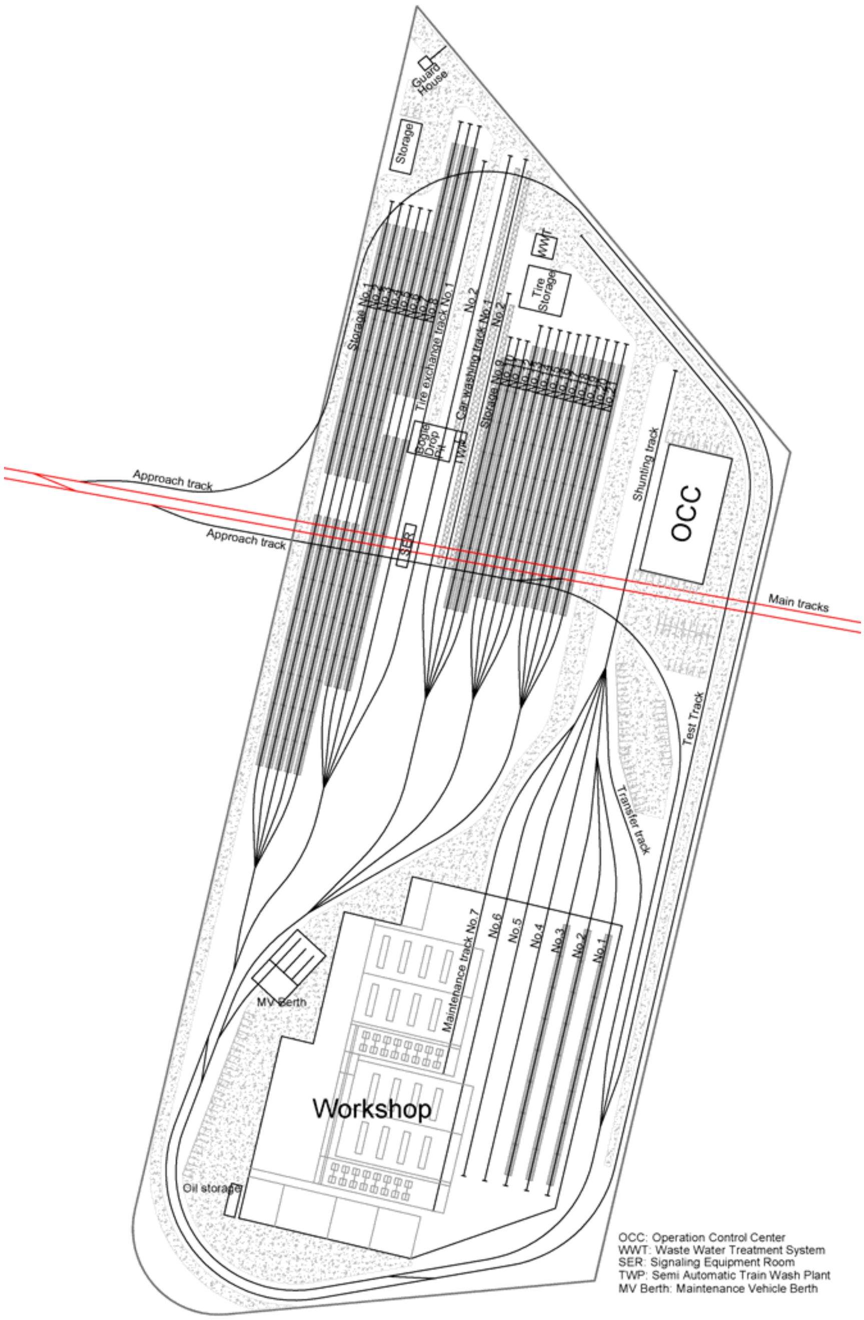
Table 1-5 Comparison table of tunneling method

	Shield method	Mountain tunneling method	Cut and cover method
Section (Approx)			
Safety	Ground settlement of M'Boi Mirim will be large because overburden is less than 1D. (1D: diameter of tunnel)	Ground settlement of M'Boi Mirim will be very large because overberden is less than 1D. Soil improvement as countermeasure will be necessity.	Ground settlement of M'Boi Mirim will be comparativery small. Observation method will be necessary.
Difficulty	Countermeasure to the exsisting retaining wall etc will be difficult.	Countermeasure to the exsisting retaining wall etc will be difficult.	Countermeasure to the exsisting retaining wall etc will not be difficult.
Experience	Construction of urban large tunnel in little overburden like this is few.	Construction of urban large tunnel in little overburden like this is very few.	There are many similar constructions.
Precondition	Land acquisition and removal of obstacle houses for construction are necessity. The area per location will be approximately 14000-16000m^2.	Land acquisition and removal of obstacle houses for construction are necessity. The area per location will be approximately 14000-16000m^2.	Land acquisition and removal of obstacle houses for construction are necessity. The area per location will be approximately 14000-16000m^2.
Construction Cost	170%	150%	100%
Construction Period	140%	100%	100%
Evaluation	Unsuitable to this site	Unsuitable to this site	Comparativery suitable to this site

(6) Depot

1) Main Depot

A main depot is constructed in an idle land along the Guarapiranga River in Jardim São Luis. This area is located along the Line-2A, between 2A-9 and 2A-10 stations. Spread of this area is 11ha by length of approximately 600m and a width of 200m.



Main Depot Facilities;

<u>Tracks</u>
1) Approach tracks (2 tracks)
2) Storage tracks (21 tracks)
3) Tire exchange tracks (2 tracks)
4) Car washing tracks (2 tracks)
5) Transfer track and shunting track
6) Test track (1 track)

<u>Workshop</u>
1) Light maintenance Tracks (4 tracks)
2) Movable dust collector (1 track)
3) Heavy maintenance tracks (2tracks)
4) Maintenance fields

<u>OCC</u>
1) Operation and Control Center
2) Administration office
3) Operation department office
4) Car maintenance department office
5) Track maintenance department office
6) Electric facilities maintenance department office
7) Signaling/Communication maintenance dep. office
8) Guard's room
9) Conference room
10) Visitors' room
11) Canteen

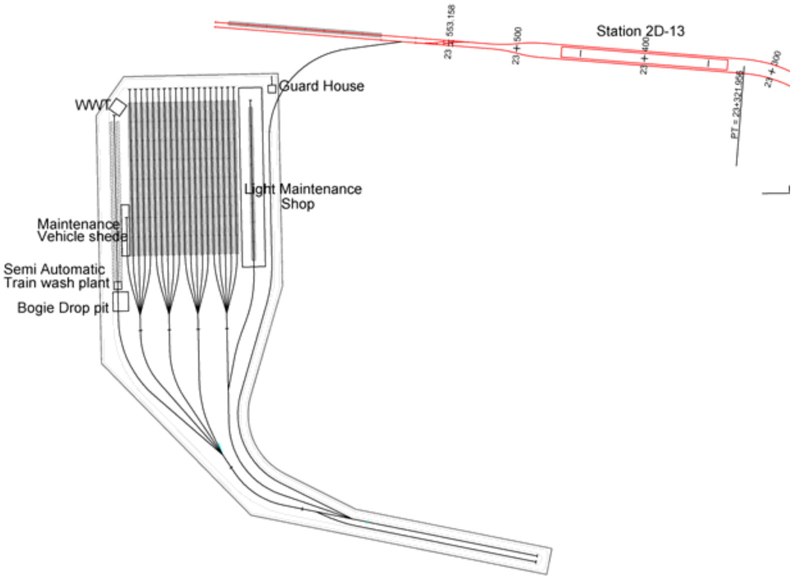
<u>Others</u>
1) Maintenance vehicle berth
2) Storage
3) etc.

Source: JICA Study Team

Figure 1-11 Main Depot Layout

2) Stabling yard in Ramal Jaguara and Jardim Angela

When phase 2 is commenced and the number of trains is increased, stabling yards are constructed in Ramal Jaguara and Jardim Angela, respectively.



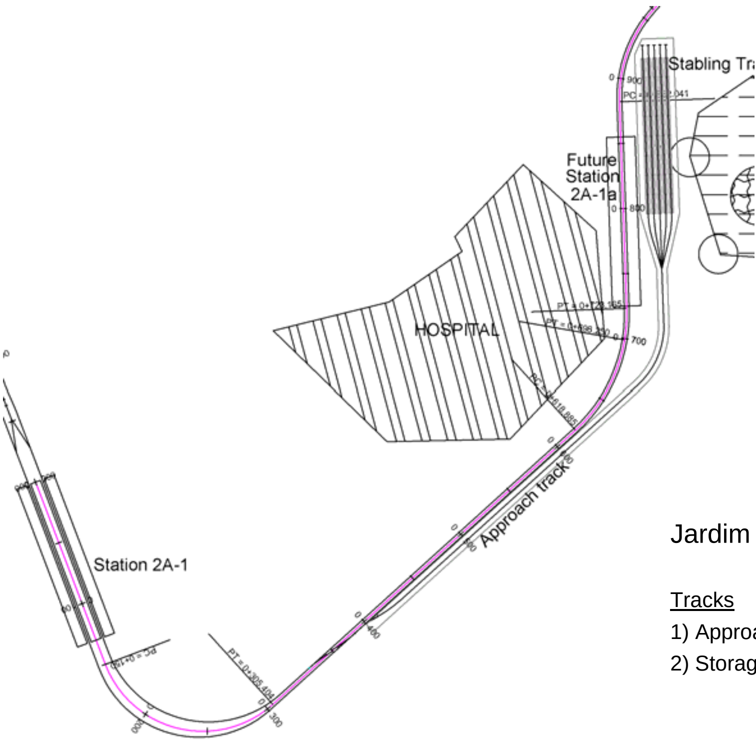
Ramal Jaguara Stabling Yard Facilities;

Tracks
1) Approach tracks (1 track)
2) Storage tracks (19 tracks)
3) Shunting track (1 tracks)
4) Car washing track (1 tracks)

Facilities
1) Light maintenance shop (1 track)
2) Tire replacement facility
3) Maintenance vehicle shade
4) etc.

Source: JICA Study Team

Figure 1-12 Ramal Jaguara Stabling Yard



Jardim Angela Stabling Yard Facilities;

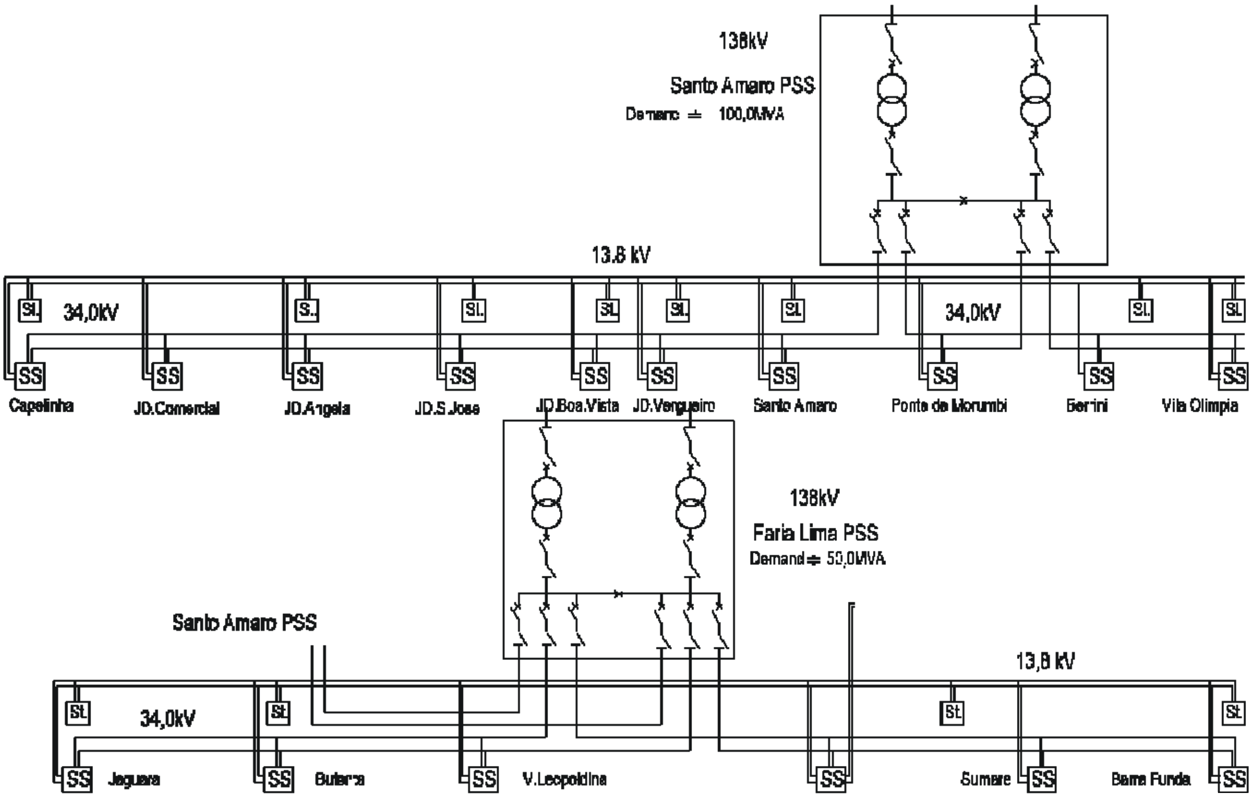
Tracks
1) Approach tracks (1 track)
2) Storage tracks (5 tracks)

Source: JICA Study Team

Figure 1-13 Jardim Angela Stabling Yard

(7) Electric Power Feeding System

The power supply system is to construct the stable primary AC substations to supply the traction substations. The proposed power supply layout is shown in the Figure 1-14.



Source: JICA Study Team

Figure 1-14 Electric Power Supply System

The outline of the power supply system for the monorail is follows. Electricity is converted from AC 60Hz into DC 1500V and then provided to monorail cars. The variation range in the monorail power supply shall be in accordance with IEC standard – the highest voltage of 1800V and the lowest voltage of 1000V.

The primary substation receives an AC 138kV, and the traction substation is fed by AC 34KV. And then it is converted into DC 1500V in the traction substation to provide the monorail cars with electric power.

The general electric power is converted into AC13.8kV in each traction substation, and supplied to the station etc. In the area of Santo Amaro, a stable power supply of 13.8kV of the primary substation is obtained at present.

If a stable power transmission lines is available at Jardim Angela district, it is highly recommended constructing another primary AC substation in the area so that the system is supplied with two primary substations from the first stage.

When all the power line of the primary substation fails, all the monorail cars stop. As a counter measure, turbine generators are set up in the traction substations, to allow the trains operate to the nearest station.

(8) Signaling and Telecommunication

1) Signaling System

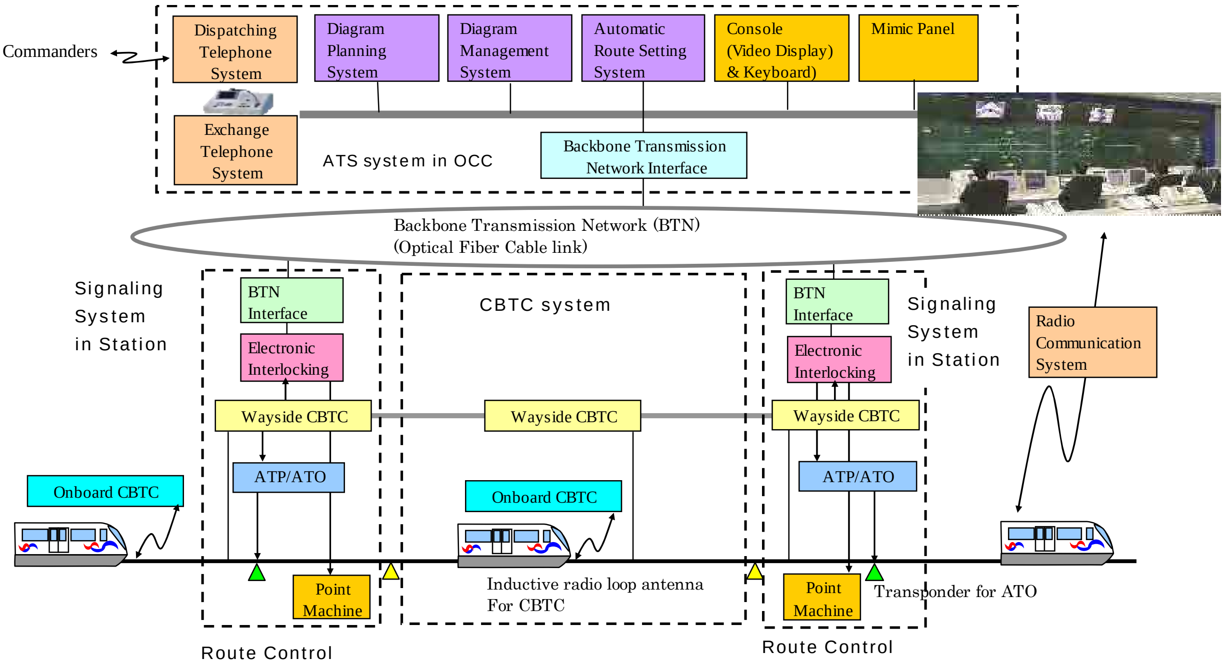
Schematic configuration of signaling system for monorail is shown in Figure 1-15.

It is proposed to introduce Automatic Train Operation system (ATO) with a train driver. The trains will be operated automatically by ATO in the main line and cab signal with Communication Based Train Control System (CBTC) will be used.

CBTC is one of the signaling systems based on the new principle that is detecting locations on-board itself and moving block system without fixed block system depending on the conventional track circuit using track rail.

CBTC is possible to minimize the interval safe length between trains ahead and following in accordance with their speed and also it is possible to increase the traffic density without modifying signaling system.

The train driver just monitors the ATO and makes sure ahead safety visually and in case of failure or emergency, he operates manually after changing from ATO mode to manual mode. On the other hand, the shunting in station yard and depot access line will be operated manually. Automatic Train Protection system (ATP) will be used between the main line and the depot storage line, while wayside signal will be used between the storage line and the workshop.



Source: JICA Study Team

Figure 1-15 Schematic Configuration of Signaling System

2) Telecommunication System

It is proposed to introduce Automatic Train Operation system (ATO) with a train driver.

a) Objectives and required telecommunication service

The objective of telecommunications system is to assist safe and efficient train operation and business environment. Following functions and system are generally required.

Table 1-6 Required telecommunication functions and systems

Required service	Required function	Required system
Telecommunication service for safety	Dispatching control Emergency protection	Radio communication system Closed Circuit Television (CCTV) system
Telecommunication service for passenger service	Monitoring of passenger Information dissemination to the passenger	Passenger Information System (PIS) that consist of Public Addressing System (PIS) and Passenger Information Display System (PIDS) Clock System
Administrative and common service	Communication among related parties Common network service	Telephone system Backbone Transmission Network (BTN)

Source: JICA Study Team

In view of system security level, full duplex system is recommended for the dispatching system and trunk communication system.

b) Network configuration and protocol

It is proposed to introduce the optimal network system, in order to reduce unnecessary traffic and to minimize the influence range of trouble at the time of failure.

c) Type of telecommunication systems

The telecommunication system consists of 7 sub-systems:

- Radio communication system.
- Telephone system
- Closed Circuit Television (CCTV) System
- Passenger Information System (PIS)
- Clock System
- Backbone Transmission Network (BTN)
- OA & IT system which consists of OA network and client PC

Radio communication system mainly deals with telecommunication system for safety that consists of dispatching telephone, emergency protection and related data transmission between Operation Control Center (OCC) and trains. Telephone system is divided into 1) Administrative & general telephone system and 2) Dispatching telephone system. Passenger Information System (PIS) consists of 2 systems; 1) Public Addressing System (PA) and Passenger Information Display System (PIDS).

In view of radio characteristic which is mentioned above, LCX radio communication system is proposed for the Project.

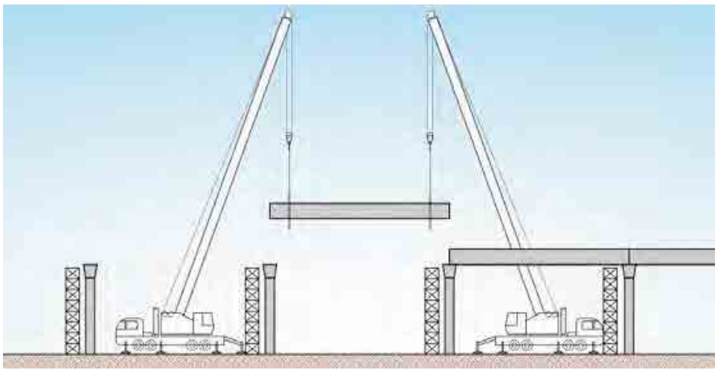
1.3.5 Project Implementation

(1) Construction Method

Track girder of the Monorail supposed to be adopted in this project is classified into two types, prestressed concrete track girder and steel track girder.

PC girder is fabricated in the PC yard which is specialized facility for PC girder fabrication. In PC yard, the mould unit which is the specialized formwork to fabricate the various shapes of the girders accurately is set.

Track girder will be transferred to the installation site during the nighttime when the road traffic volume becomes lower. Subsequently, erection of girder will be carried out by crane.



Source: JICA Study Team

Figure 1-16 Erection of PC Girder

In case of steel track girder, each member of steel girder will be fabricated in the factory, delivered to the site and installed.

As for substructure, no special construction method or structure style is needed for substructure of the Monorail as it is the same as normal support structure.

1) Procedure for pile construction

a) Install Guide Casing
b) Drill Borehole
c) Remove slime
d) Install rebar cage
e) Insert tremie pipe
f) Place concrete
g) Backfill
h) Draw out guide casing

2) Procedure for pier construction

a) Erect the scaffolding for column
b) Assemble the rebar for column
c) Install casing for column
d) Place the concrete for column
e) Erect the scaffolding for pier head
f) Install casing for pier head
g) Assemble the rebar for pier head
h) Place the concrete for pier head

Signal communication cables and electrical cables are arranged on the trays set under the track girder, and contact lines are installed in both side of the track girder. For this work, in order to secure the construction safety and efficiency, using of the service vehicle is recommended instead of assembling scaffold.

The service vehicle, which is driven by battery equipped or internal-combustion engine, and is straddled on track girder, can transport the materials, equipments and workers to the place where installation works are done. The service vehicle is designed to enable works to be done upside, lateral side and downside of track girder in safety.

Source: JICA Study Team

Figure 1-17 Cable tray and contact line

(2) Procurement of Material and Equipment

The construction materials and equipment for the Monorail system are classified into three following categories according to the procurement plan.

1) Materials and Equipments procured from domestic sources
2) Materials and Equipment procured from foreign sources
3) Procurement from foreign factory of prototype and assembly of remainder in domestic factory

(3) Project cost and Implementation schedule

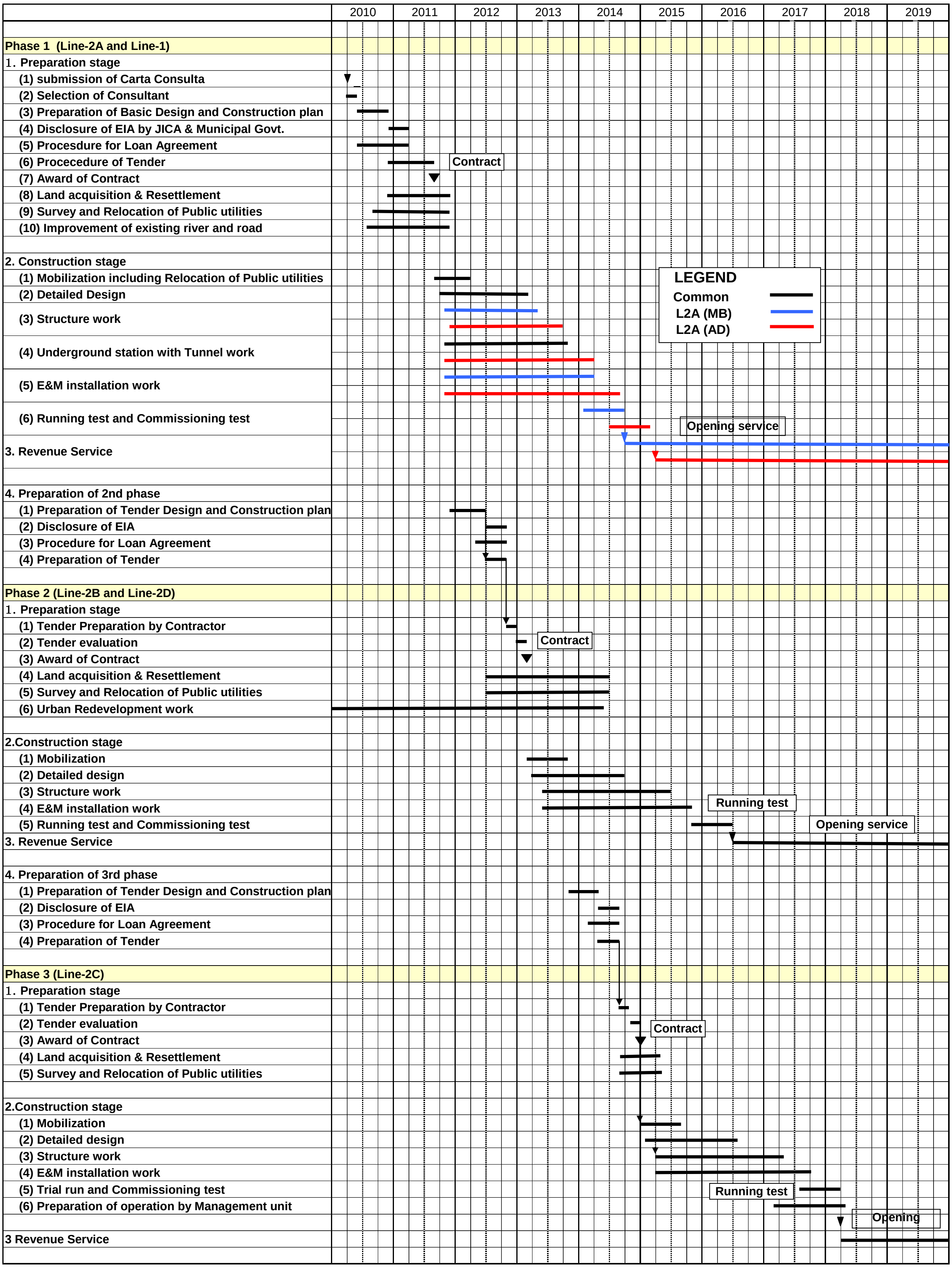
The implementation cost of whole project is shown in Table 1-7. The outline of implementation schedule is shown in Table 1-8. As for two alternatives of Phase 1, common plans are shown with black lines, the Original Route plan is with blue lines, and the Area Development Route plan is with red lines in the table.

Table 1-7 Implementation Cost of Whole Project

	Item	Phase 1 Orginal route			Phase 1 Area Development route			Phase 2			Phase 3			Phase 3-2		
		FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
		million JPY	million BRL	million JPY	million JPY	million BRL	million JPY	million JPY	million BRL	million JPY	million JPY	million BRL	million JPY	million JPY	million BRL	million JPY
A. ELIGIBLE PORTION																
I	Procurement / Construction	22,160	2,330	141,411	22,587	2,588	155,040	20,588	3,484	198,848	3,948	938	51,964	1,003	172	9,784
	Mobilization	0	53	2,708	0	62	3,161	0	71	3,622	0	22	1,124			
	Relocation of Public Utilities	0	27	1,394	0	33	1,683	0	39	1,989	0	13	655			
	Substructure	0	153	7,835	0	168	8,595	0	221	11,310	0	81	4,123			
	Superstructure	0	299	15,288	0	322	16,470	0	460	23,559	0	152	7,779			
	New Road Construction	0	0	0	0	17	856	0	0	0	0	0	0			
	Station Building	0	360	18,444	0	360	18,444	0	614	31,440	0	194	9,916			
	Station with Tunnel section	0	96	4,909	0	229	11,733	0	0	0	0	0	0			
	Switch	855	47	3,282	855	47	3,282	0	36	1,848	0	8	417			
	Depot	1,145	135	8,078	1,145	135	8,078	755	90	5,335	0	0	0			
	Rolling stock	5,257	577	34,793	5,257	577	34,793	0	897	45,891	0	130	6,656	0	164	8,408
	Power Supply system	8,831	164	17,225	9,054	172	17,845	10,226	208	20,893	2,516	59	5,526	1,003	7	1,376
	Signalling and Telecommunication system	4,247	75	8,100	4,364	80	8,451	7,474	131	14,164	928	28	2,366			
	Automatic Fare Collection system	0	8	384	0	9	435	0	12	614	0	4	205			
	Environmental Mitigation and Compensation	0	0	25	0	1	30	0	7	336	0	3	147			
	Base cost	20,335	1,996	122,466	20,675	2,212	133,855	18,455	2,786	161,002	3,444	693	38,913	1,003	172	9,784
	Price escalation	770	224	12,212	837	253	13,802	1,153	532	28,377	316	201	10,577			
	Physical contingency	1,055	111	6,734	1,076	123	7,383	980	166	9,469	188	45	2,474			
II	Consulting services	4,188	96	9,094	4,462	105	9,816	4,346	99	9,423	3,456	75	7,305			
	Base cost	3,841	82	8,012	4,086	88	8,614	3,892	79	7,910	3,009	55	5,813			
	Price escalation	147	10	649	163	11	735	248	16	1,065	282	17	1,144			
	Physical contingency	199	5	433	212	5	467	207	5	449	165	4	348			
Total A=（ I + II ）		26,348	2,426	150,506	27,049	2,693	164,856	24,935	3,583	208,271	7,403	1,014	59,269			
B. NON ELIGIBLE PORTION																
a	Land Acquisition	0	96	4,895	0	164	8,415	0	62	3,179	0	2	114			
	Base cost	0	87	4,477	0	152	7,758	0	53	2,696	0	2	87			
	Price escalation	0	4	185	0	5	256	0	6	331	0	0	21			
	Physical contingency	0	5	233	0	8	401	0	3	151	0	0	5			
b	Administration cost 3%	0	91	4,662	0	102	5,198	0	124	6,343	0	35	1,781			
c	VAT	0	506	25,909	0	555	28,398	0	709	36,264	0	191	9,763			
	VAT 18% for Procurement /Construction	0	497	25,454		545	27,907		699	35,793	0	183	9,354			
	VAT 5% for Consulting Service	0	9	455		10	491		9	471	0	7	365			
d	Import Tax	0	0	0	0	0	0	0	0	0	0	0	0			
Total B = (a+b+c+d)		0	693	35,465	0	821	42,011	0	895	45,786	0	228	11,658	0	0	0
TOTAL (A+B)		26,348	3,119	185,971	27,049	3,514	206,867	24,935	4,478	254,057	7,403	1,241	70,928	1,003	172	9,784

Source: JICA Study Team

Table 1-8 Outline of Implementation Schedule



Source: JICA Study Team

1.3.6 Operation and Maintenance

(1) Business Operation Method

Two alternatives are considered in potential methods for the monorail operation, one is the operation directly by SPTrans, and the other is the PPP (Public-private partnership) method by concessionaire. Both of these have actually been applied in the public transport of São Paulo.

Monorail is a system which has not been introduced in São Paulo. As for monorail management, compared with the concession system which SPTrans is carrying out for bus management, direct management system is more practical from the view point of responsibility and stability.

(2) Operation and Maintenance Plan and Organization

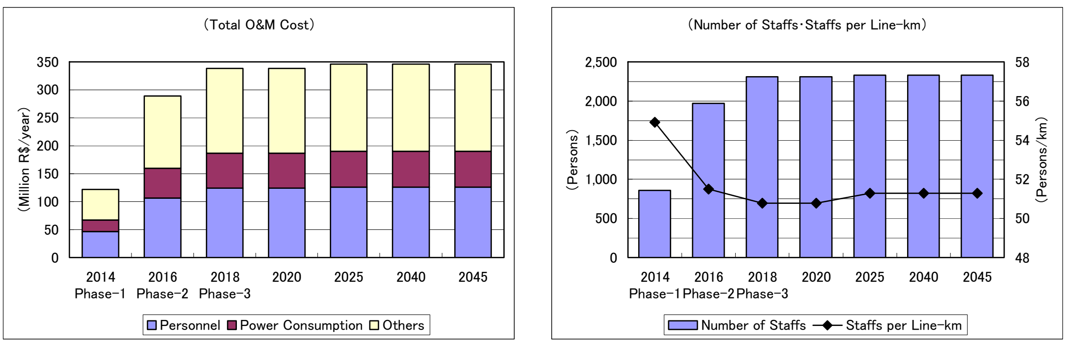
The monorail operation and maintenance work will basically be performed according to the method in Japanese monorail companies, considering this is the first time to introduce monorail in São Paulo. Especially on the basis of preventive maintenance policy, rolling stock and facilities will be inspected periodically and repaired immediately if any troubles are found.

The organization of monorail will be planned also according to the organization in Japanese monorail companies in order to execute monorail service safely and stably. However, security staffs and ticket selling staffs in stations, as the characteristic of the public transport of São Paulo, should be considered altogether.

(3) Number of Staffs and O&M Cost

Total O&M cost and the number of staffs in the monorail operation are shown in the graphs of Figure 1-18, for the principal case of "Phase1 to Phase3, Area Development Route Plan". In this case, in a period between the year 2014 and 2018, this is between opening year of phase 1 and that of phase 3, route length is extended gradually, and O&M cost and number of staffs are also increased, accordingly.

In the year 2014 the operation length is 15.6km, total O&M cost (estimated as basis cost in 2010 whole one year, following are the same) is 122 million Real, and the number of staffs is 856 persons (54.9 per operation length). In the year 2018 the operation length is 45.5km, total O&M cost is 338 million Real, and the number of staffs is 2,310 persons (50.8 per operation length). They increase in proportion to the extension ratio of the operation length (2.9 times).



Source: JICA Study Team
Note: 1.Each year's price is expressed in base year price (2010). 2.Value for 2014 is assumed to a quarter of annual value.

Figure 1-18 Total O&M Cost and Number of Staffs of São Paulo Monorail In Case of Phase1 to Phase3, Area Development Route

1.3.7 Environment

(1) Environmental Laws and Regulations

In addition to federal rules, state and municipal rules that define the environmental licensing procedures in the respective levels were reviewed. The Project is mainly located within the territory of São Paulo Municipality; and it was anticipated that the environmental licensing concerning Environmental Impact Assessment (EIA/RIMA) will be conducted by the Municipal Government mainly under municipal laws and regulations.

(2) Environmental Impact Assessment

For preliminary examination of environmental and social impacts, Environmental Examination (IEE) was conducted, and environmental scoping for the proposed lines, which clarify conceivable environmental and social impacts caused by the proposed projects, were prepared, and Scoping Matrix and Checklist were presented. Outlines for the public consultation meeting for EIA were suggested. Suggested Terms of Reference (ToR) for the EIA study was prepared by considering the results of environmental scoping. Table of contents for the EIA report was also suggested in the ToR.

(3) Preliminary Examination on Mitigation Measures for Major Environmental and Social Impacts

Mitigation measures for the potential negative impact of the Project on the surrounding environment were proposed based on the present situation of the project site and measures applied in previous similar projects. It was concluded that items “involuntary resettlement”, “land acquisition” and “tree/vegetation removal” require special considerations.

With reference to the similar cases in São Paulo City, cost for land acquisition and resettlement required for the implementing the Project was estimated. For quantification of required land acquisition and resettlement, the number of existing buildings and the necessary land area along each proposed route was identified based on the analysis of aerial photographs and of land use map. For identifying unit cost for land and building, current prices were investigated through some real estate companies in the region. For cost estimate of housing for resettlement families, mainly low-income families, the number of families to be relocated for each line was estimated, and the cost for preparing resettlement site with apartment type buildings are calculated. It was anticipated that approx. R$170 million will be required for land acquisition, and approx. R$63 million will be required for preparing resettlement sites.

Instruments for the definitions and procedures to be considered for obtaining authorizations for trees/vegetation removal by the Project were provided. Estimation of the number of roadside trees to be removed along the routes of the Project is conducted based on the analysis on aerial photographs and rapid field checking on their size and species types. The monetary value of the work and services was calculated based on the guidelines of SVMA. It was estimated that approx 3,500 trees will be affected and approx. R$10 million will be required for the mitigation and the compensation for the tree/vegetation removal.

(4) The Environmental Management & Monitoring Plan (EMMP)

With regard to the environmental guidelines and standards and the previous similar cases, the Environmental Management & Monitoring Plan (EMMP) was proposed. As main components for EMMP, three modules covering activities for environmental licensing, environmental management, environmental control and environmental monitoring were proposed. These modules are not independent but interrelated; therefore it was confirmed that a structured team with technical expertise will be employed for ensure efficient and effective coordination and implementation.

(5) Resettlement Action Plan (RAP)

Brazilian laws and regulations concerned expropriation of land or resettlement do not require preparing Resettlement Action Plan (RAP) separately from EIA report. It was confirmed that RAP will be developed within the scope of EIA/RIMA. The JICA Study Team proposed the framework of RAP in the ToR for EIA/RIMA. Separate public consultation meeting for expropriation of land or resettlement is not compulsory by Brazilian laws and regulations; however the JICA Study Team recommended having separate public consultation meetings with affected populations for expropriation of land or involuntary resettlement. Suggested outlines for the public consultation meeting for RAP were also indicated.

1.3.8 Project Effect

(1) Travel Time Reduction and Vehicle Reduction

Travel time reduction is the principal effect of this project. The project can reduce travel time by approximately 30 minutes along Line-1A, Line-2A and Line-2D as shown below.

Major Trip	Present time in peak hours	After monorail construction	Time reduction
Jardim Angela Terminal – Santo Amaro Terminal	55 minutes	20 minutes	35 minutes
Imperatriz Leopordina Station – Faria Lima/Reboucas intersection	50 minutes	15 minutes	35 minutes

Private cars also can reduce the travel time although the amount is smaller than that of public transport. The reduction in passenger-hours from “without-case” to “with-case” was calculated. The project will reduce approximately 320,000 passenger-hours per day.

The project will also reduce the number of buses. It was estimated that the reduction in vehicle-kilometers of buses in 2045 would approximately 170,000. This is larger than the increase in vehicle-kilometers of buses in “without-case” from 2015 to 2045.

(2) Environmental Benefit

While some environmental and social impacts would be arisen environmental benefits such as reduction of carbon dioxide (CO_2) and air pollutants emission with decrease of vehicle traffic amount by implementation of the Project.

Reduction amount of carbon dioxide (CO_2) emission was estimated with considering both a positive effect, reduction of CO_2 emission with decrease of vehicle traffic volume, and an offset effect, discharge of CO_2 by electrical power consumption for operation of monorail. In 2015, CO_2 reduction amount by the Project was estimated as approximately 83 ton- CO_2/day.

To examine effect of reduction of air pollutants emission by the Project, nitrogen oxide (NOx) and particulate matter (PM_{10}) reduction amount by the Project was estimated. Estimated reduction amounts of NOx and PM_{10} emission are 760 kg-NOx/day and 200 kg-PM_{10}/day, respectively.

(3) Operation and Effect Indicators

The project should be evaluated after the commencement of the operation according to operation and effect indicators. It is proposed to evaluate the performance of Phase-1.

Transport volume is used for both the operation and effect indicators. The headway of 4 minutes for Line-1A and 2 minutes 30 seconds for Line-2A is a simple operation indicators. For the effect indicators, travel time and bus speed on M'Boi Mirim Road are proposed because they represent the project impact.

1.3.9 Economic and Financial Analysis

Economic and financial appraisals were completed for the following project cases:

- The Phase-1 route defined by the alignment originally proposed for Line-2A;
- The Phase-1 route subsequently identified as the "development" alternative, involving a deviation from the original alignment; and
- The entire route incorporating sections for all three project phases.

The Phase 1 cases were evaluated as alternative cases which could proceed without the addition of Phase-2 and Phase-3.

The economic appraisal shows that all three project cases have the potential to generate economic returns, with EIRR's ranging from 17% to 19%, all higher than the assumed minimum rate of 12%. When subjected to sensitivity analysis, EIRR rates were found to be robust, slightly falling below the minimum rate only in the case where both capital costs were increased and economic benefits were reduced by 20 per cent. Time savings, both for existing road users and for commuters diverting to the monorail from other modes, account for by far the highest share (more than 80 per cent) of the project's economic benefits.

As is usually the case with urban public transport projects of this type, the potential financial returns of the project were found to be low, certainly much lower than the assumed long term cost of capital (12%). The calculated Financial Internal Rate of Return (FIRR) of the entire route case is lower than that of Phase-1 only case. These results were found to be more sensitive to a sharp fall in revenue, than to a sharp rise in costs. This suggests that, in São Paulo, bus fares, on which the monorail revenue was based, are at a comparatively high level relative to costs.

The analysis of financial sources shows that it is necessary to prepare approximately 60% of the total project cost by its own money in the case of enter routes, while it is 40% in the case of Phase-1 only.

CHAPTER 2 PRESENT SITUATION OF THE ROUTE

2.1 SOCIO-ECONOMIC SITUATION

The Municipality of São Paulo is the largest city in Brazil with the population of 11 million, and the center of economic activity with developed manufacture industry and tertiary sector like commercial and financial. The gross domestic product (GDP) of Brazil is approximately R$ 2.9 trillion in 2008, and GDP of the Municipality of São Paulo accounts for approximately 11.9% of the national GDP (2006)[1]. Table 2-1 shows the population of São Paulo.

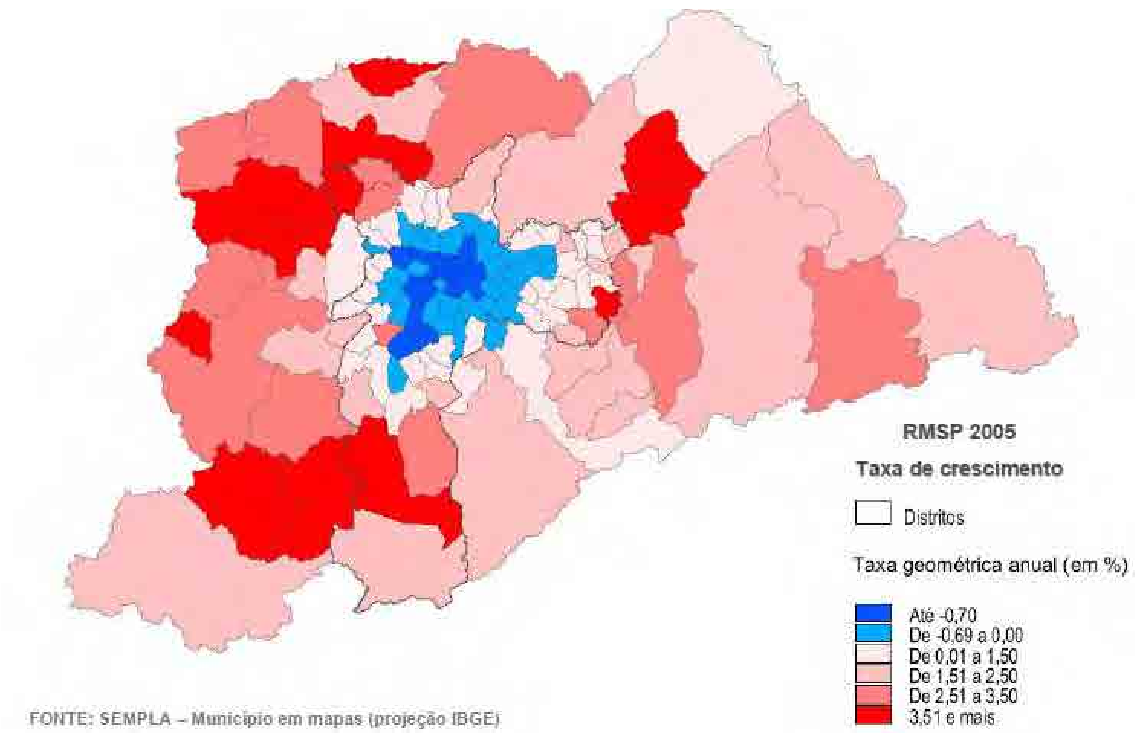
Table 2-1 Population

Unit: 000

	1980	1991	2000	2006
Brazil	119,003	146,825	169,799	186,770
São Paulo State	25,041	31,589	37,032	41,056
São Paulo Metropolitan	12,589	15,445	17,879	19,678
São Paulo Municipality	8,493	9,646	10,434	10,995

Source: www.emplasa.sp.gov.br, sempla.prefeitura.sp.gov.br/infocidade/

The population of São Paulo Metropolitan is increasing year by year and so is the population of São Paulo municipality. However, the population of the center area of the city is decreasing while the population of the suburban area is increasing as shown in Figure 2-1. The growth rates around Line-1 and Line-2A are positive while those of others are negative.



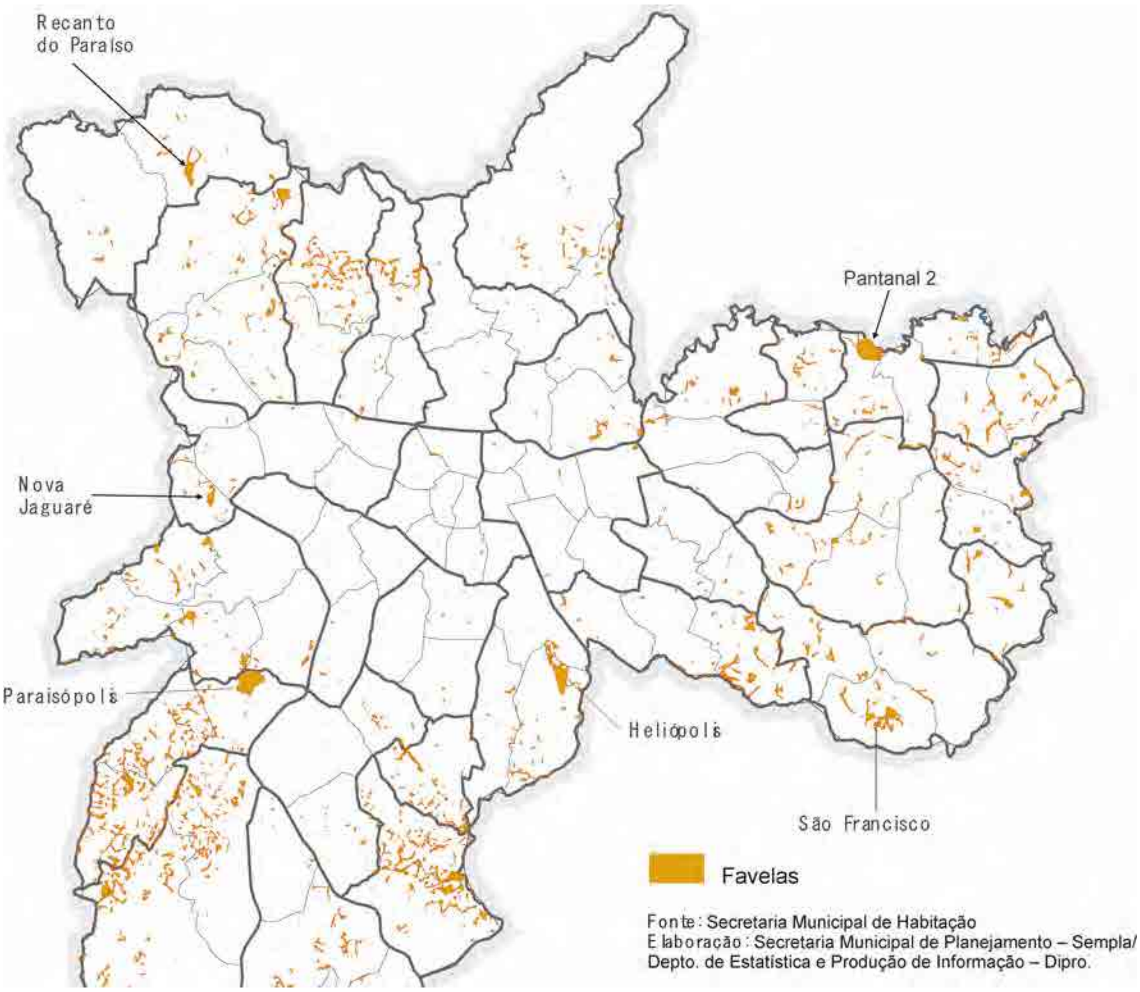
Source: SPTrans

Figure 2-1 Population Growth Rate in RMSP

Line-1, Line-2A and Line-3B go through low income communities, while other routes go through medium or high income residential area. Figure 2-2 shows the location of "Favelas", illegal settlements where income level of residents is very low and the infrastructure is very

[1] www.ibge.gov.br

poor. There are many favelas around Line-1 and Line-2A. Line-3B goes through Paraisopolis, the largest favela in São Paulo in terms of the area.



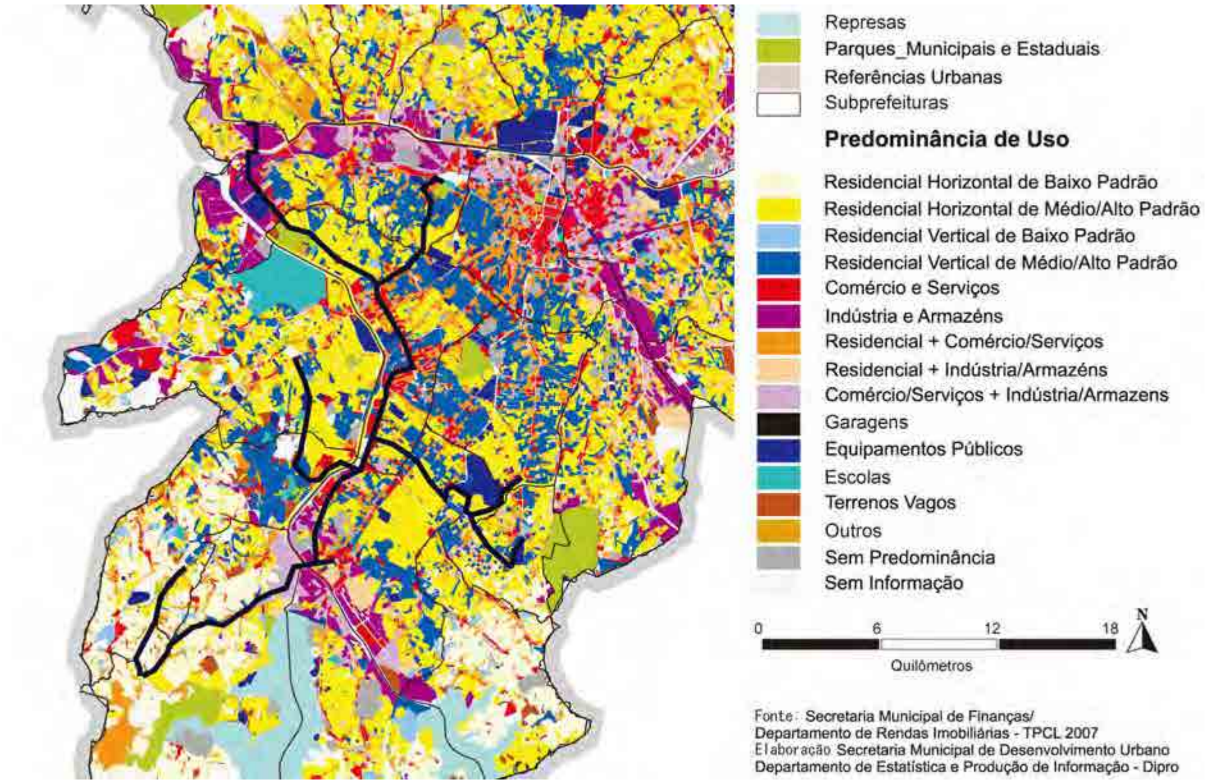
Source: sempla.prefeitura.sp.gov.br/infocidade/

Figure 2-2 Location of Favelas

2.2 LAND USE

2.2.1 Existing Land Use

Figure 2-3 shows the existing land use around the study routes. Commercial and business functions concentrate on the center of the city (Centro), Paulista Avenue, Faria Lima Avenue, and Morumbi. The industrial area stretches along Tiete River and Pinheiros River. Residential areas of mid and high-rise building stretch around the commercial and business area in Centro and along Paulista Avenue. There is a low-rise residential area between high-rise residential area in the south west of Paulista Avenue and the commercial area along Faria Lima Avenue. In addition, low-rise residential areas are located along Line-2C, Line-2D, and Line-3B. The university of São Paulo is located in the west of Pinheiros River in parallel with Line-2C.



Source: sempla.prefeitura.sp.gov.br/infocidade/

Figure 2-3 Existing Land Use

The land use condition around the project routes are summarized as:

Line	Major Land Use
1	- Low income residential area of low-rise buildings - Neighborhood commercial buildings along the route
2A	- Low income residential area of low-rise buildings - Mixed land use of commercial, business, and residential along the route - Factory
2B	- Commercial and business use of high-rise buildings along the route - Industrial area (south section)
2C	- Mid and high-rise residential buildings - Cemetery
2D	- High income residential area of low-rise buildings (south section) - Park - Industrial area (north section)
3A	- Congonhas International Airport - Favela - Residential area of mid and high income residents
3B	- High income residential area of high-rise buildings - Favela (Paraisópolis) - Low-rise residential buildings - Morumbi Stadium

2.2.2 Land Use Plan

(1) Macro-zone

The formal land use plan is described in Plano Diretor Estrategico (Lei No 13.430). There are two large zones (Macro-zone) designated in the area of the Municipality of São Paulo – Environment Protection Zone and Urban Quality Zone. In Environmental Protection Zone, preservation of the quality of natural environment is superior to urban development, while urban development in Urban Quality Zone should be complied with the regional plan. The most parts of the study routes are within Urban Quality Zone while a part of Line-1 and Line-2A is located in Environment Protection Zone.

(2) General Zone

Under the macro-zones, General Zones are designated. there are six types of general zones in Environment Protection Zone, and 10 types of general zones in Urban Quality Zone as shown in Table 2-2. The study routes run through various General Zones in Urban Quality Zone, while a part of Line-1 and Line-2A runs through ZM-p in Environment Protection Zone. There is no General Zone that prohibit construction of stations and elevated type transport system.

Table 2-2 List of General Zones in the Strategic Plan

Environment Protection Zone	Urban Quality Zone
- Central zone of Environmental protection	- Low density residential zone
- Mix zone of Environmental protection (ZM-p)	- Medium density residential zone
- Sustainable development and protection zone	- High density residential zone
- Residential zone of Environmental protection	- Industrial zone
- Leisure and tourism zone	- Low density mix zone
- Protection special zone	- Medium density mix zone
	- High density mix zone
	- Central zone (a)
	- Central zone (b)

(3) Special Zone

The following special zones are designated over the general zones. A part of Line-2C passes through ZEPEC in Lapa.

- Social interest special zone (1, 2, 3, and 4)
- Environmental protection special zone
- Special zone of mineral resource and agricultural production
- Cultural preservation special zone (ZEPEC)
- Special occupation zone

(4) Water Resource Protection Zone

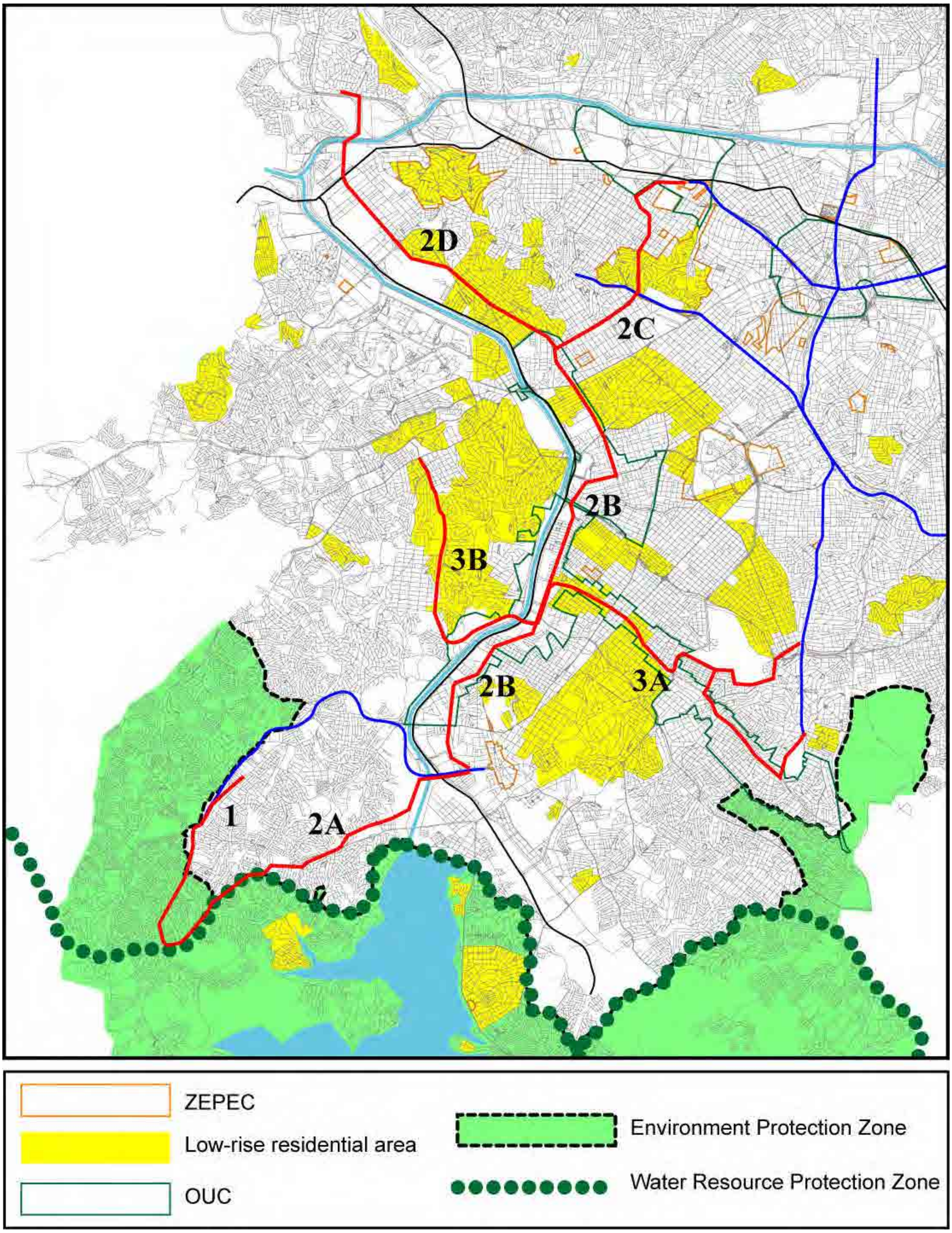
In addition to the zoning system by the Municipality of São Paulo above, Water Resource Protection Zone (APRM) is designated by the State Government. The major purpose of ARPM is to preserve and restore the water quality of Guarapiranga Dam and other water resources.

(5) Joint Urban Operation

Some Joint Urban Operation (Operacoes Urbanas Consorciadas - OUC) areas are designated in urbanized area in São Paulo to promote urban development through a partnership between public and private sector. In OUC areas, development incentives are given to private investors. The certification of additional potential of construction (CEPEC) is a tool for the incentive. It is a certification issued by São Paulo City Hall to a private developer which gives the right to use additional floor area over the limits defined in the zoning.

For the study routes, Agua Espraiada OUC is designated along Line-2B and Line-3A, and Faria Lima OUC is designated along the north section of Line-2B. These areas are the emerging commercial and business centers in São Paulo, and will be developed further using the OUC mechanism. Therefore, the development of urban transport system such as Line-2B and Line-3A will be one of the important issues in the future.

Figure 2-4 shows the location of the low density residential zone, ZEPEC, APRM, and the boundary of the Macro Zone.



Source: ZONEAMENTO São Paulo

Figure 2-4 Land Use Plan

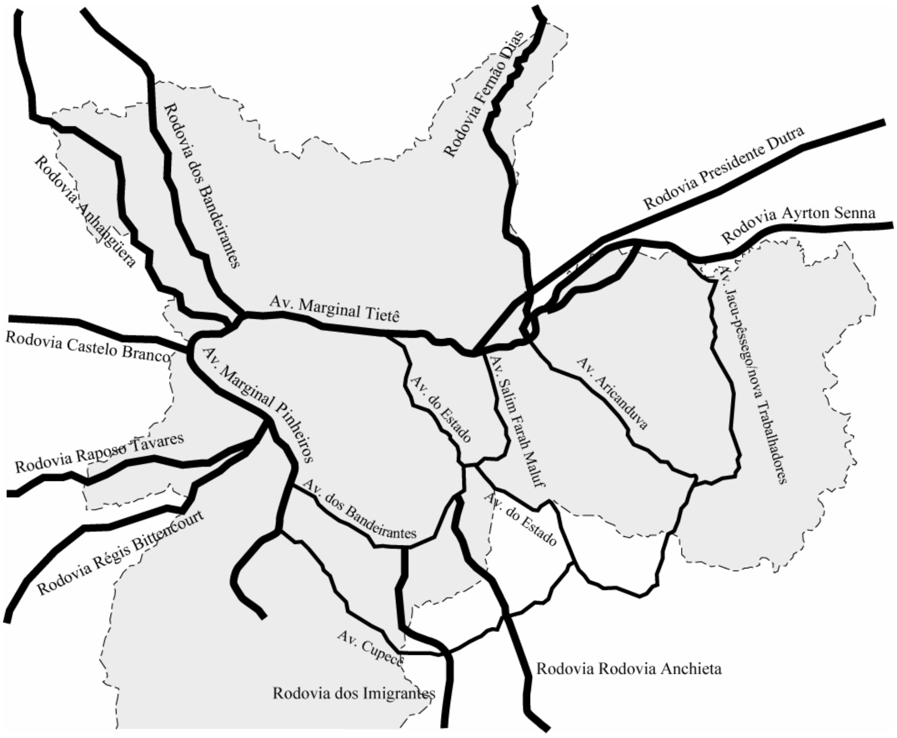
2.3 TRANSPORTATION SYSTEM

2.3.1 Road Network

There are 10 inter-city highways that connect the Municipality of São Paulo and others.

Marginal Tiete and Marginal Pinheiros Avenues along two rivers with the same name are the arterial roads that form the north and west part of a circular route, which provides the starting junction of eight inter-city highways such as Rodovia Presidente Dutra, Rodovia Fernao Dias, Rodovia Ayrton Senna, Rodovia dos Bandeirantes, Rodovia Anhanguera, Rodovia Castelo Branco, Rodovia Raposo Tavares, and Rodovia Regis Bittencourt.

Bandeirantes Avenue is one of the avenues that form the south and east section of the circular route mentioned above, which has the connection with Rodovia dos Imigrantes and Rodovia Anchieta, intercity highways between São Paulo and Santos.



Source: JICA Study Team

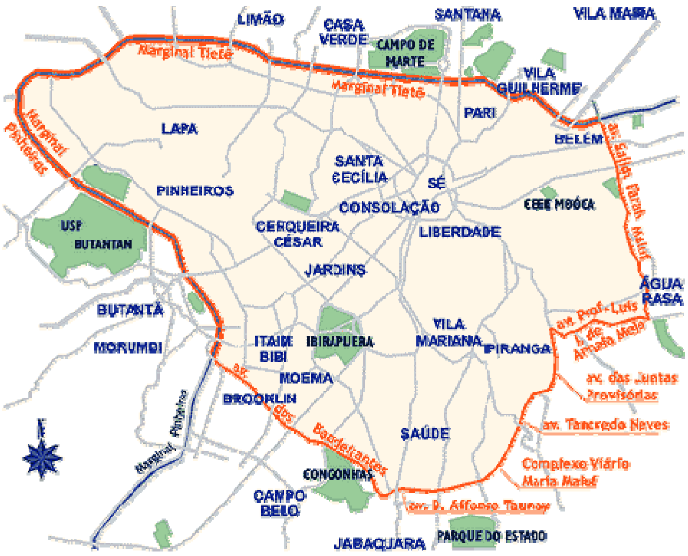
Figure 2-5 Inter-city highways and major roads

The road network system around the project area is characterized as a kind of mixture of a radial pattern from the center of the city and a ladder pattern in parallel with Pinheiros River. The important arterial roads stretch from the center of the city to radial directions, e.g. Nove de Julho Ave., 23 de Maio Ave., Reboucas Ave., and Brigadeiro Luis Antonio Ave. These avenues skewer the other avenues that run in parallel with Pinheiros River, such as Paulista Ave., Brasil Ave., and Faria Lima Ave. Other arterial roads of the vertical direction of the ladder pattern are Eng. Luis Berrini Ave., Santo Amaro Ave., Ibirapuera Ave., Washington Luis Ave., etc. In the west of Pinheiros River, major arterial roads, such as M'Boi Mirim Road and Itapecerica Road, connect suburban area in the west of São Paulo and Marginal Pinheiros Ave. east and west.

Most of these arterial roads are wide with 6 or 8 lanes, and a lot of intersections of these roads are grade-separated type. BRT route is introduced along Nove de Julho Ave., Reboucas Ave., Santo Amaro Ave, and M'Boi Mirim Road.

2.3.2 Road Traffic

Traffic on roads in São Paulo is very heavy and many roads suffer from serious traffic congestion at peak hours. The total length of congested roads in morning and afternoon peak is 85 km and 120 km, respectively, and it sometimes exceeds 250km. The average speed in afternoon peak hours is 17.2 km/h in 2007 while it was 21.8 km/h in 1997. The number of registered vehicles in the Municipality of São Paulo is 6.5 million in 2009, in which passenger cars account for 4.8 million[2]. The number of registered vehicles was 1.6 million in 1980, 3.6 million in 1991, and 5.1 million in 2000. The Municipality of São Paulo introduced a plate number restriction (*Rodizio*) in the center of the city (figure below), which restrict 20% of vehicles circulation from Monday to Friday according to the last digit of the plate number.



Source: CET (www.cetsp.com.br)

Figure 2-6 Area of Plate Number Restriction

Table 2-3 shows the comparison of traffic congestion in São Paulo and Tokyo, Japan. The number of passenger cars in São Paulo is larger than that of Tokyo where the population is as same as that of São Paulo. Although the scale of the Metropolitan of Tokyo is very larger than that of São Paulo and the condition for the comparison is quite different, the figure implies that São Paulo has big traffic problems.

Table 2-3 Comparison of Traffic in Tokyo and São Paulo

	Tokyo	São Paulo
Population	13 million	11 million
Area	2,188 km2	1,523 km2
No. of passenger cars	3.16 million (2009.3) (*1)	4.79 million (2009.3) (*3)
The average length of traffic jam on weekdays	195km in 2,406km (2007) (*2)	120km in 830km (2007) (*4)
Traffic speed at peak hours	19.9km/h (2007) (*2)	16.2km/h (2007) (*4)
Length of Metro system	304.1km	61.3km

Source: (*1) Automobile Inspection & Registration Information Association (Japan), (*2) Metropolitan Police Department (Japan), (*3) DESAP, (*4) CET

[2] DETRAN-SP

2.3.3 Railway

Railways in São Paulo are operated by Metro (São Paulo Metro) and CPTM (Paulista Company of Metropolitan Trains), which are public companies under the State Secretary for Metropolitan Transports (STM). Metro currently operates four railway lines (Red, Blue, Green and Lilac lines) with a total length of 61.3km, including 34.6 km of underground sections. On the other hand, CPTM operates seven lines with a total length of 261.7 km. Metro carries 3.3 million passengers per day, while CPTM carries 1.9 million passengers per day. Transfer between the railway lines of Metro and CPTM is free under the integrated flat fare system (R$ 2.55 per ride)[3].

Metro has contracts with car parking companies to provide discount parking ticket near Metro stations. Passengers can bring their bicycles into some trains of Metro and CPTM. For the convenience of cyclists, Metro has seven bicycle parks while CPTM has 14.

Source: São Paulo Metro

Figure 2-7 Railway Network in São Paulo

3 The fare of Metro and CPTM was revised to R$ 2.65 in January 2010.

2.3.4 Bus

Buses in São Paulo are operated by private companies under the concession scheme that was introduced after the privatization of the bus operation in São Paulo. The public authority of bus concession is SPTrans (São Paulo Transport S.A.) and EMTU (Metropolitan Company of Urban Transport). SPTrans is a municipal company under the Municipal Secretary of Transport (SMT) and responsible agency for bus system in the municipality. EMTU is a state company of bus services, responsible for inter- municipal bus services. SPTrans and EMTU carry 9.5 and 1.7 million passengers per day, respectively.

There are eight zones for concession of bus services. The concession gives exclusive right of bus operation to a private consortium in each zone. Figure 2-8 shows the zones of the concession.

The bus network of São Paulo consists of two subsystems: structural subsystem and local subsystem (Table 2-4). The structural subsystem provides trunk services connecting the central area to regional centers while the local subsystem provides feeder services to complement the structural subsystem. Bus terminals at 28 locations in the city support the trunk and feeder system.

Figure 2-8 Zone of Concession

There are 10 BRTs in São Paulo to form the structural subsystem. A BRT usually comprises exclusive lanes (one lane for each direction) in the inner sides of the road and island platforms for bus stops in the median strip. Bus movements on a BRT are interrupted by other traffic at intersections and mid-block traffic signal for bus passengers to approach to the bus stops. Tiradentes Expressway is one of the BRTs, but its bus lanes are fully segregated from other traffic. Travel speed on Tiradentes Expressway is about 35km/h while that of other BRTs is about 20km/h in off-peak hours and 10km/h in peak hours. Currently, Tiradentes Expressway carries 51,000 passengers per day.

Bus fare in the city is flat at R$ 2.3[4]. SPTrans introduced an electric ticket system. Bilhete Único is the card of the electric ticket system. Using the card, transfer between different buses is free up to three times and transfer between railway and bus can be discounted.

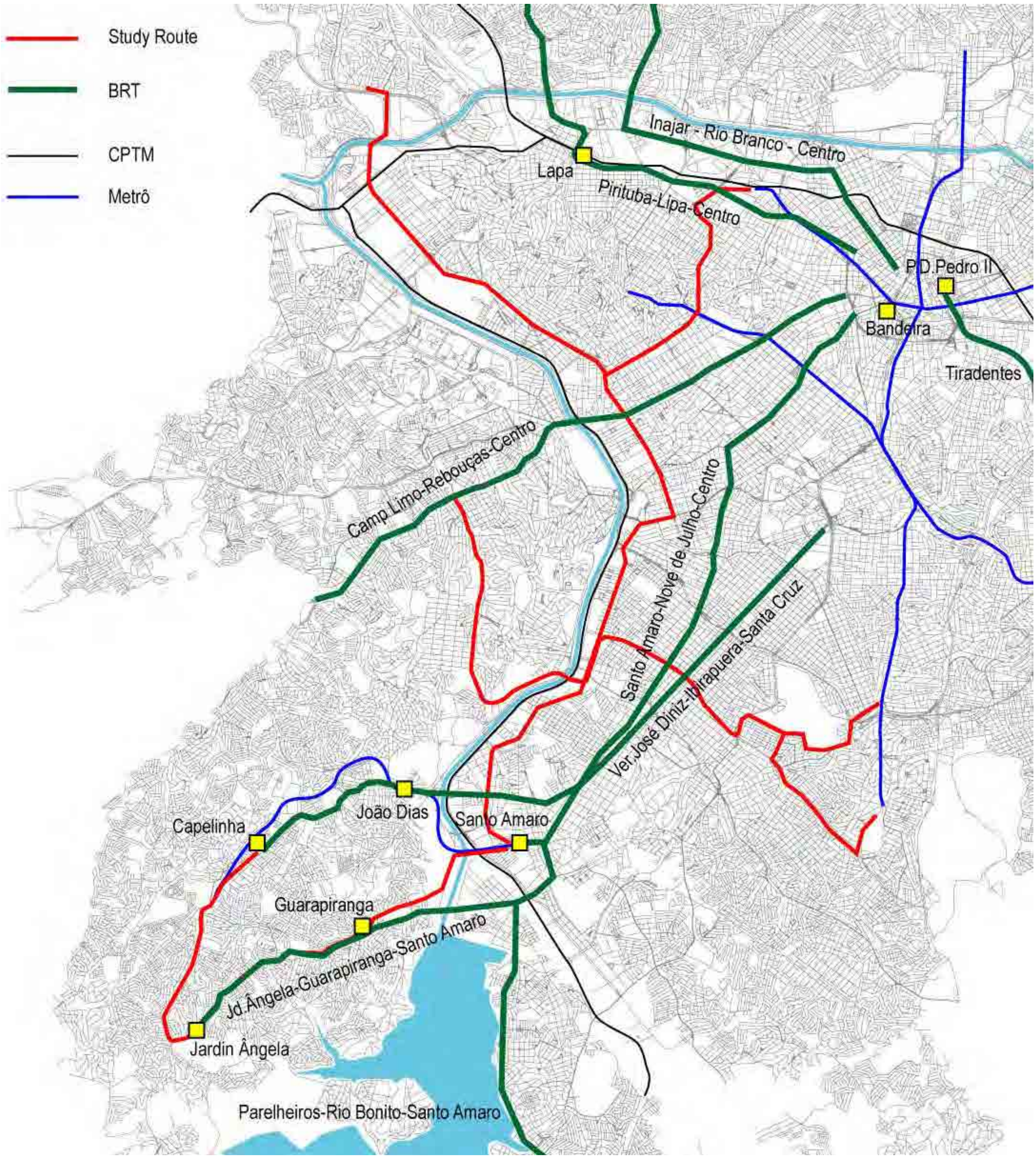
Table 2-4 No. of lines and fleets of buses by subsystem

Subsystem	No. of lines	No. of fleets
Structural	880	8,860
Local	450	5,890
Total	1,330	14,750

Source: SPTrans

Figure 2-9 shows BRT lines around the study route.

[4] Bus fare was revised to R$ 2.7 in January 2010.



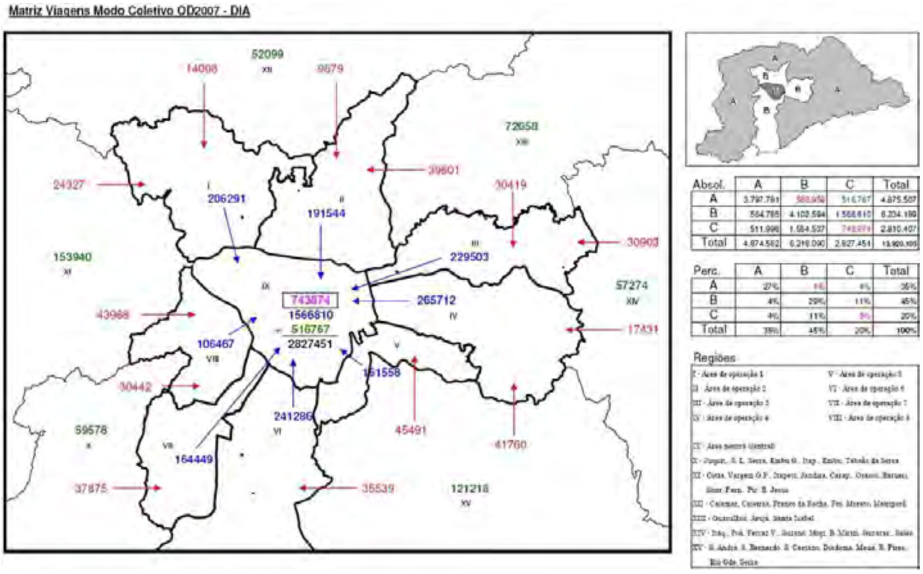
Source: JICA Study Team

Figure 2-9 Location of BRT

2.3.5 Trip Characteristics

(1) Trip distribution

Major traffic movements in the metropolitan region are the trips between the center of São Paulo and the residential area in the suburban of the city. Figure 2-10 shows major traffic movements by public transport mode in the metropolitan region. The area IX, almost equal to Rodizio area (Chapter 2), is the destination of 2.8 million trips per day in which 2.1 million trips are from outside of the area IX. From the area VIII to IX, which is the corridor relating to Line-1 and Line-2A, 0.1 million people move per day. From the area of I to IX, which is the corridor relating to Line-2D, 0.2 million people move per day.

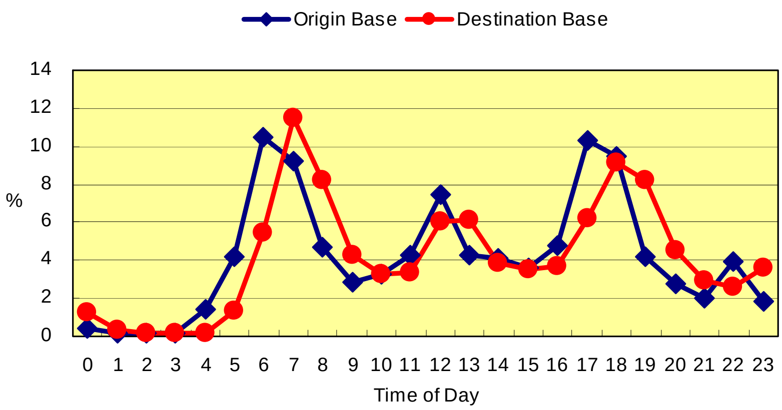


Source: SPTrans

Figure 2-10 Trip Distribution based on 2007 OD

(2) Peak Characteristics

There are three peak hours of passenger trips, morning peak, afternoon peak, and lunch time peak. The morning peak is 6 A.M. in start time base and 7 A.M. in arrival time. The peak hour rate of private and public transport in RSMP is about 10% in start time base and 12% in arrival time base as shown in Figure 2-11.



Source: OD 2007 (The chart is prepared by JICA Study Team)

Figure 2-11 Trip Distribution of Private and Public Mode by Time of Day

2.4 URBAN TRANSPORT PLANS

There are three transport plans for the development of transport infrastructure in São Paulo: 1) PDDT (Transportation Development Master Plan) at the state level, 2) PITU (Integrated Urban Transportation Plan) at metropolitan level, and 3) PDE (Strategic Master Plan) at municipal level.

2.4.1 PDDT 2020

PDDT is the transport development master plan formulated by the Secretary of Transport of the State of São Paulo (STM). It focuses on the north-south corridor connecting seaports and São Paulo. The remarkable project in PDDT is *Rodoanel*.

Rodoanel Mario Covas (or simply called as Rodoanel) is a circular motorway of São Paulo with a total length of 170km. This will provide a diversion route for trucks from or to the ports in Santos. The north-west section (32km) of Rodoanel has been completed.

Source: Dersa (www.dersa.sp.gov.br/rodoanel/especial/)

Figure 2-12 Route Map of Rodoanel

2.4.2 PITU 2025

PITU, the Integrated Urban Transport Plan, is the transport master plan for the three Metropolitan regions: São Paulo Metropolitan Region (RMSP), Campinas Metropolitan Region (RMC), and Baixada Santista Metropolitan Region (RMBS). For RMSP, PITU 2020, which target year was 2020, was formulated based on 1997 Origin-Destination Survey. The plan was reviewed and PITU 2025 was formulated in 2006. In PITU 2025, several alternative transport scenarios were analyzed based on a demand forecast model (TRANUS) and the best scenario was selected as the future transport system.

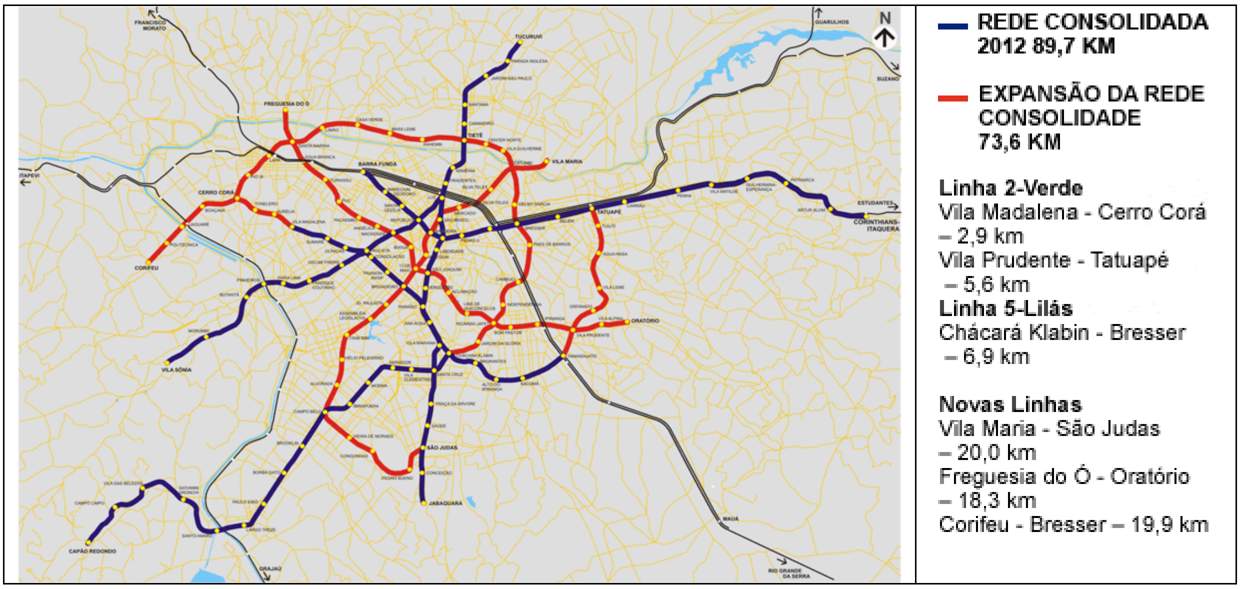
There are five policies described in PITU 2025.

- Intensive use of land around transport infrastructure
- Housing program for low income population
- Promotion of integrated logistics centers
- Funding from the development benefit
- Development of sub-centers

The idea of the intensive use of the land around transport infrastructure is to allow higher density development around stations of public transport system to promote transit-oriented development.

The total investment cost in PITU 2025 was estimated as R$ 48.7 billion, including Metro expansion, suburban railway improvement, airport access, BRTs, bus terminals, traffic demand management, and other transport development.

Figure 2-13 shows the expansion plan of Metro. The total length of the future Metro network was planned to be 110km.



Source: REDE ESSELCIAL, Metro

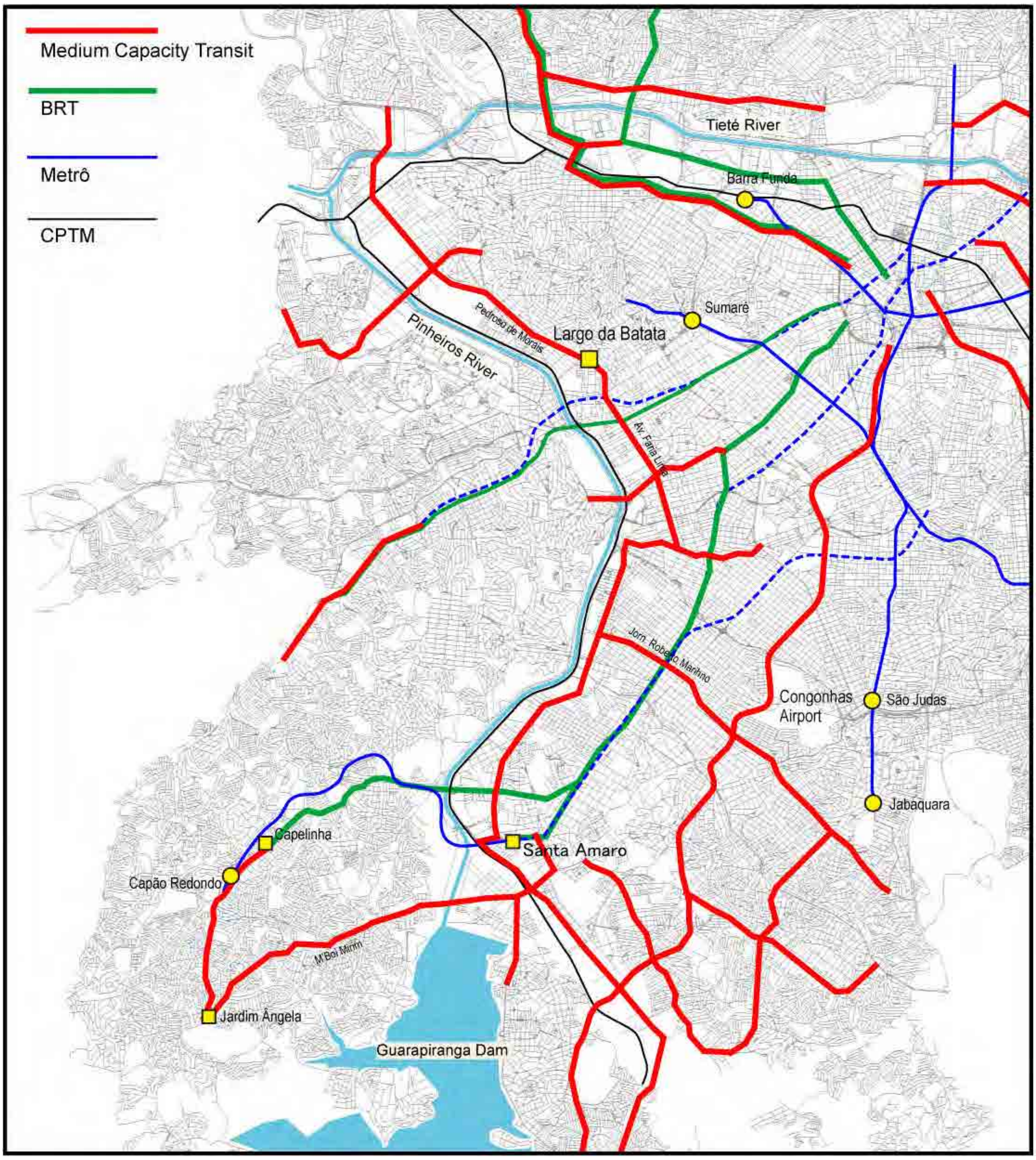
Figure 2-13 Future Metro Network

2.4.3 PDE 2020

Plano Diretor Estrategico (PDE) is the master plan of the Municipality of São Paulo, which was approved in 2002. The target year is 2020 and the revised PDE for the target year 2025 was already proposed but has not approved yet. PDE declared 12 principals including the following two principals relating to the transport sector.

- Universalization of mobility and accessibility
- Prioritization of public transport

Some medium capacity transit corridors are proposed in PDE 2020 as shown in Figure 2-14. The revised plan does not identify the type of system in its public transport plan. The routes of Line-1A, Line-2A, Line-2B, and Line-2D are proposed as the medium capacity transit corridors in PDE 2020.



Source: PDE, elaborated by the JICA Study Team

Figure 2-14 Public Transport Plan in PDE 2020

2.5 URBAN TRANSPORT PROJECTS

2.5.1 Metro Expansion

The expansion project of metro system is being undertaking such as Green Line, Yellow Line, and Lilac Line as shown in Table 2-5.

Table 2-5 Metro Expansion Project Under Construction

Line	Length	No. of stations	Open
Green Line (Line-2) Extension	4.3 km	3	2010
Yellow Line (Line-4)	12.8 km	11	2010
Lilac Line (Line-5) Extension	11.7 km	11	2012

Source: Metro (www.metro.sp.gov.br)

Metro, CPTM, and EMTU are undertaking projects in the Plan of Expansion by The State Secretary for Metropolitan Transports (SMT). The Plan of Expansion includes:

- Expansion of Line-2 (Green)
- Line-4 (Yellow)
- Expansion of Line-5 (Lilac)
- Line-6 (Orange)
- Light Metro (Congonhas Airport)
- Line-10 (Turquoise) and ABC Express
- Line-11 (Coral) – East Express and Ferraz-Mogi Light Metro
- Airport Express and Guarulhos Train
- Guarulhos – São Paulo Corridor
- Itapevi – São Paulo Corridor
- Diadema – São Paulo Corridor

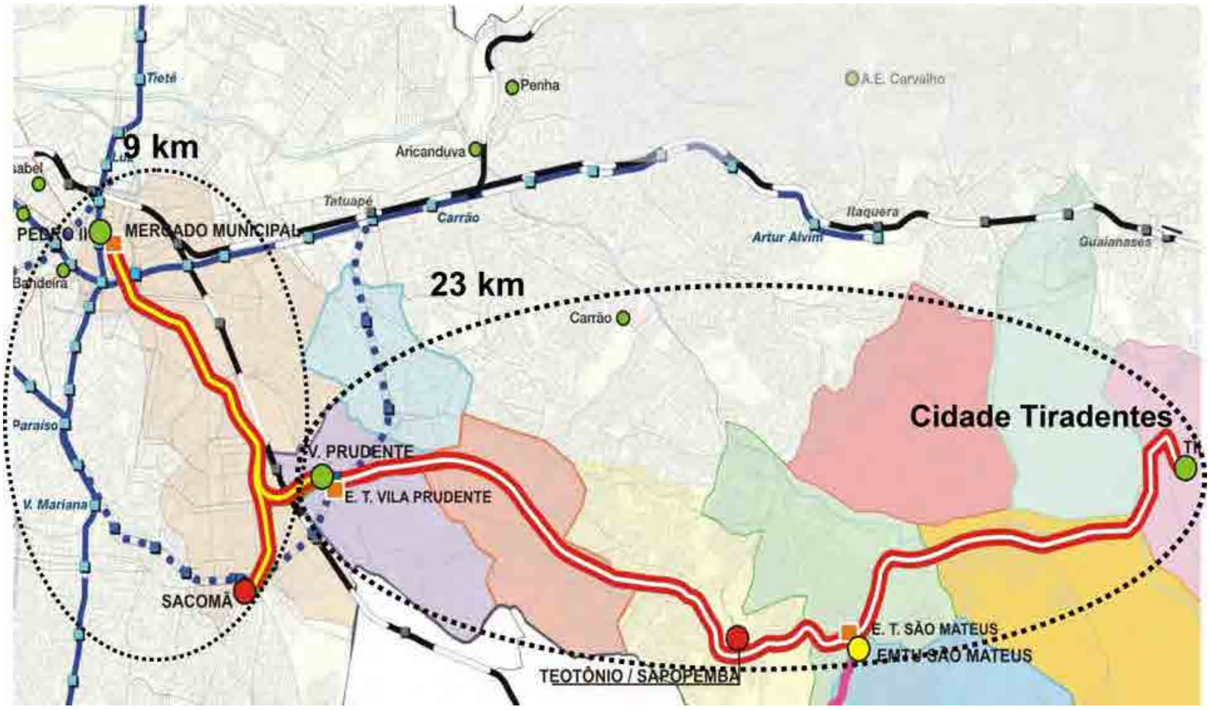
2.5.2 Tiradentes Expressway

Tiradentes Expressway is a BRT system connecting PEDRO II in the center of the city, SACOMA, and Tiradentes City in the east of São Paulo in the total length of 32km. Its segregated section (9km) of elevated structure is already put into service. The rest of 23km are planned to use bus reserved lanes along an arterial road. Figure 2-15 shows the location of Tiredentes Expressway.

Recently, the original plan as a BRT system for the rest part of Tiradentes Expressway has been changed to a monorail system which connects Metro Line-2.

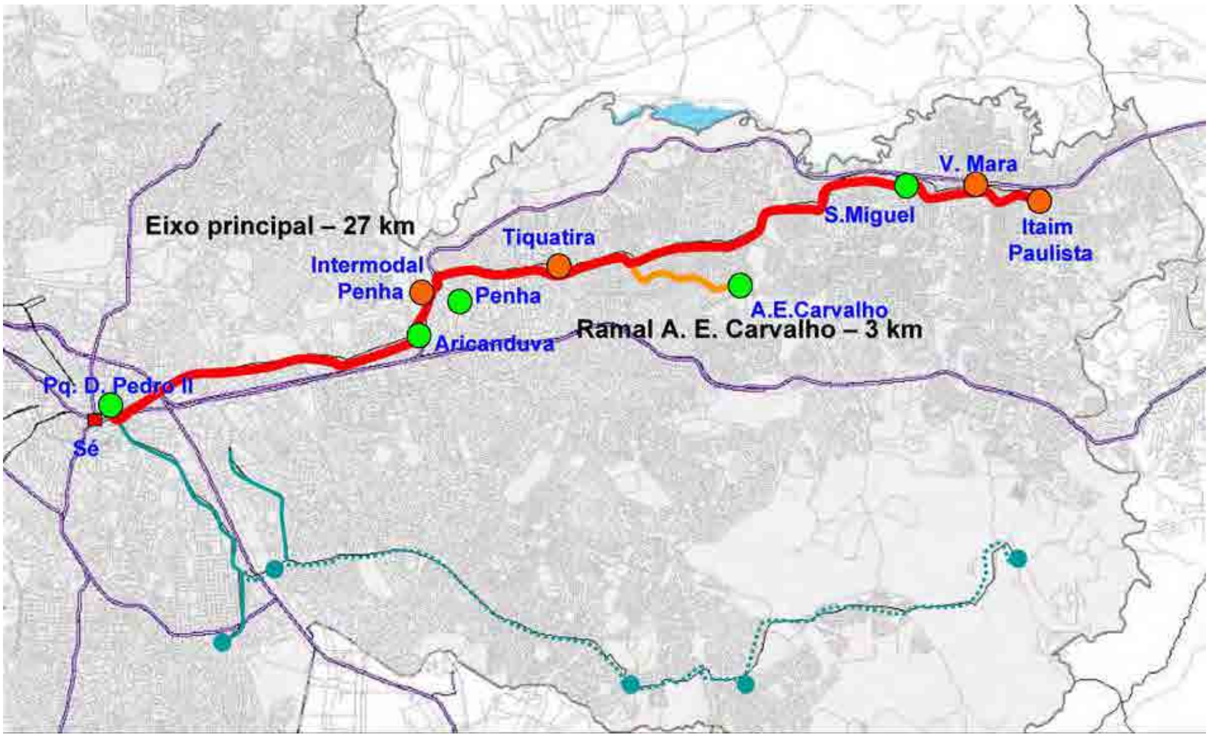
2.5.3 Celso Garcia Expressway

Celso Garsia Expressway is a new BRT project connecting the center of the city and the north-east of São Paulo in the total length of 30km. Figure 2-16 shows the location of Celso Garcia Expressway. The additional lane along the bus platform will be provided to allow overtaking movements so that express service is possible.



Source: SPTrans

Figure 2-15 Location of Tiradentes Expressway



Source: SPTrans

Figure 2-16 Location of Celso Garcia

2.6 TRAFFIC CONDITION BY LINE

2.6.1 Line-1A

Line-1A connects Jardim Angela Terminal and Capao Redondo Metro Station. Presently, there is no bus service for the connection due to the difficulty of traffic management at the intersection with M'Boi Mirim Road.

Line-1 is expected to be a part of the feeder system of Itapecerica – Joao Dias – Santo Amaro BRT. The terminal of the feeder system is Capelinha. Line-1 also has the connection with Lilac Line of Metro, which runs in parallel with the BRT route, at Capao Redondo.

Feeder buses of the metro station use the north section (Sant'anna Ave.) of Line-1A and local streets which connect Capao Redondo east and west. Peak hour traffic is heavy on the north section of Line-1 (Sant'anna Ave.), where approximately 130 buses run in the peak hour. Sant'anna Ave. is narrow 2-lane road having many intersections with local streets and congestion is very heavy in peak hours.

2.6.2 Line-2A

Currently, M'Boi Mirim Road, a part of which is the route of Line-2A, has dedicated lanes in the center of its cross section for BRT between Jardim Angela and Santo Amaro. There are 17 bus platforms on the BRT routes. Articulated buses with high capacity are operated on the BRT while normal and small size buses are operated on the other lanes of normal traffic.

Peak hour traffic is heavy on M'Boi Mirim Road. In peak hours, articulated buses on the exclusive lanes of the BRT make a long queue, and the travel speed of the BRT is low at approximately 10km/h. The normal lanes are also congested. The number of buses along Line-2A is 300-400 in the peak hour. There are many traffic accidents at intersections along M'Boi Mirim Road. The morning peak hours begin very early because trips to the center of the city take a long time after exiting M'Boi Mirim Road. The total travel time from Jardim Angela to Centro at the peak time is more than 2 hours.

Traffic volume of Line-2A is observed at 47,800 vehicles (615,00 PCUs) per day for both directions on June 3, 2009. The passenger traffic along M'Boi Mirim is calculated as approximately 21,000 per hour per direction as shown in Table.

Table 2-6 Estimation of Peak Hour Passenger Traffic along M'Boi Mirim

	No. of Vehicles per hour	Passengers per vehicle	No. of passengers
Van	120	30	3,600
Standard Bus	145	60	8,700
Articulated Bus	85	100	8,500
Total	350		20,800

Source: JICA Study Team

2.6.3 Line-2B

Emerald Line of CPTM runs along Pinheiros River, while Line-2B route is 500- 1000m east from the Emerald Line. There are 10 stations between Santa Amaro and Presidente Altino of Emerald Line. Santo Amaro – Nove de Julho – Centro BRT runs on Santo Amaro Avenue with a total length of 14.8km, located about 1.5km east of Line-2B.

Roads along Line-2B are congested in not only morning and afternoon peak hours but also in the daytime. Traffic volume in peak hour is approximately 2600 vehicles in which passenger cars account for 90%.

Traffic around Santo Amaro is the major bottleneck for the traffic in São Paulo.

2.6.4 Line-2C

Feeder bus services connect Barra Funda Station of Red Line and Sumare Station of Green Line along Line-2C. Motorcycle lanes are provided in the inner side of Sumare Avenue. Campo Limpo – Reboucas – Centro BRT is operated on Reboucas Avenue, which connect the center and the west area of the city.

Traffic is heavy on Sumare Avenue in peak hours. The majority of the traffic is private cars. The number of buses along this route is as small as 60 buses for both direction in a peak hour.

2.6.5 Line-2D

There are feeder bus services along Line-2D and its parallel avenues. Emerald Line of CPTM runs in parallel with Line-2D. The route of Line-2D was changed in the Study to the route that runs through the university of São Paulo.

The majority of the traffic is private cars along Line-2D. Traffic volume in the morning peak hour is approximately 4,500 vehicles per peak direction in which passenger cars account for 90%. Bus speed of this corridor (Dr. Gastaon Vidigal – Prof. Foncesa Rodrigues – Brigd. Faria Lima) is slow at less than 10 km/h in the morning peak.

2.6.6 Line-3A

Congonhas Airport and São Judas Station of Metro Blue Line are connected by bus services along Line-3A. Public transport along Line-3A route from the airport to the west is insufficient due to the small number of bus services.

Traffic on Washington Luis Avenue is heavy with both public and private vehicles. This road connects Congonhas Airport and Centro. Traffic on Jornal Roberto Marinho and Bandeirantes Avenue are also very heavy with cars and trucks.

2.6.7 Line-3B

There are few public transport services along Line-3C.

Most residents in the upper-class residential area use private cars, while the number of trips from the favela is small. There are irregular traffics relating to Morumbi Stadium.

2.7 ENVIRONMENTAL AND SOCIAL CONDITIONS

2.7.1 Line-1

(1) Natural Environmental Conditions

1) Topographical Conditions

The terminal of Line-1 is located at an altitude of approximately 840m, the highest point in the area as shown in Figure 2-17. Line-1 goes down in a hilly area for a distance of approximately 600m to the valley of Agua dos Brancos Stream, reaches a gentle slope area and goes through a flat route of Av. Maas Ellis and Road Itapecerica da Serra at an altitude of 770m.

2) Important Areas for Nature Conservation

The important natural area is the Santo Dias Park located beside the depot of Metro Line 5.

3) Problem of Pollution

The main source of noise and air polluation is vehicles. The heavy traffic on the roads, especially on Itapecerica da Serra Road, causes noise and air pollution. All the streams are completely polluted by domestic sewage.

(2) Social Conditions

1) Socio-economic Characteristics

The income level in the communities along the route is very low, especially along the road between M’Boi Mirim Road and Av. Ellis Maas, where some favelas are located. On the other hand, the economic condition is better along Av. Ellis Maas and Itapecerica da Serra Road, where many commercial buildings are located.

2) Historical Monuments and Archaeological Sites

There are no historical monuments and archaeological sites registered or identified by

CONDEPHAAT[5].

2.7.2 Line-2A

(1) Natural Environmental Conditions

1) Topographical Conditions

M'Boi Mirim Road lies almost along the divider of water basins of the Pinheiros River and Guarapiranga Reservoir, and the slopes in the both sides are steep at some places. The topography along the route is characterized by three land levels and three different slope types; 1) the upper section of M'Boi Mirim Road (810 – 840m altitude) for approximately 2.5km from the hill behind the Jardim Angela Hospital to the east, 2) the intermediate section of M'Boi Mirim Road (750 – 810m altitude) for approximately 2km where the slope is steep, and 3) the rest section for approximately 3.5km in gentle slope or flat area at altitudes of 730-750m.

2) Important Areas for Nature Conservation

There are few green areas along the route, although some green areas exist in large estates such as farm houses, areas of institutional buildings and condominiums. The proposed area for the terminal behind Jardim Angela has a small plantation of pine and other exotic trees.

3) Problem of Pollution

Noise and air pollution are mainly caused by the heavy traffic along the M'Boi Mirim Road, especially in the peak time in the morning and afternoon. All the streams are highly polluted by damping of domestic waste and domestic sewage without treatment.

(2) Social Conditions

1) Socio-economic Characteristics

The area of Jardim Angela is characterized by high density of population with very low income level. The commuter demand is high in this area, and workers go to the district of Santo Amaro and other districts around the city center. With regard to economic activities in M'Boi Mirim Road, business and services are major, and there are many small establishments, several of which are medium and large scale. There are stores of used cars, car repair, tire repair, bars, restaurants, furniture, clothing, household utensils, mattresses, building materials, gas stations, banks, etc.

2) Historical Monuments and Archaeological Sites

The research conducted by CONDEPHAAT did not find any historic monument protected by the body in the region.

2.7.3 Line-2B

(1) Natural Environmental Conditions

1) Topographical Conditions

This line goes over the plains of Pinheiros River, a region with very flat and approximately parallel to the path of streams, with varying distance between 200 m and

[5] Council for Protection of Cultural, Archaeological, Artistic and Tourist Heritages (Conselho de Defesa do Patrimônio Histórico, Arqueológico, Artístico e Turístico)

1,000 m. In Santo Amaro Terminal, it is at slightly higher level at about 10 m to 15 m compared to the rest of the section closer to the Pinheiros River. The entire route is well above the quota in water level of Pinheiros River.

2) Important Areas for Nature Conservation

There is no important natural area. The existing trees in sidewalks, boulevards and parks are the major green elements.

3) Problem of Pollution

The Santo Amaro Area was a major industrial area of São Paulo in the past, but the pollution from industrial sources is small at present. The major source of noise and air pollution is vehicles.

(2) Social Conditions

1) Socio-economic Characteristics

The Area of Santo Amaro was an important industrial region of São Paulo in the past. Today many of these industries, for various reasons, left the region and have several empty warehouses, factories or modified for other uses such as commerce activity and areas for events (shows, exhibitions, etc.). The Largo Treze, next to the Santo Amaro Bus Terminal, is an important center of commercial activities such as shops, works, and medical services for the population of southern part of São Paulo.

There are a large number of buildings for offices and shops along Av. Dr. Chucri Zaidan and Av. Luis Carlos Berrini. The buildings are medium and large size as a whole such as shopping Center and department stores. The number of employees is very high.

Av. Faria Lima and Av. Juscelino Kubitschek are the noblest avenues in the study routes, and major traffic corridors in São Paulo. There are many large office buildings and shopping centers of medium and large size. Iguatemi Shopping Center is considered as one of the most sophisticated shopping centers in São Paulo. Faria Lima Avenue runs through Jardim Paulistano, one of the noblest neighborhoods of the City of São Paulo, with residences of high standard. There are many employments of various sectors. There are various commercial establishments in the Pinheiros Area. There is a major bus terminal near the area, and a station of Line 4 (yellow line) of the Metro is under construction. This is a region where there is a large influx of people from south and west areas of the São Paulo City for shopping purpose.

2) Historical Monuments and Archaeological Sites

Near the path of the Line-2B, there are two districts called “Bairros Jardim” which are protected by CONDEPHAAT, Jardim Europa and Jardim Paulistano. Also there is a site called “Sede do Sitio Itaim” as historical monument.

2.7.4 Line-2C

(1) Natural Environmental Conditions

1) Topographical Conditions

This line starts from the intersection of Av. Reboucas and Av. Brigadeiro Faria Lima at an altitude of 745 m. The first part of this line goes northeast along Av. Reboucas, then turn northwest entering into Rua Henrique Schaumann. The area along Av. Reboucas is generally flat with gentle slope toward the Pinheiros River. Henrique Schaumann Road has moderate upward slope to the highest point of this line at an altitude of approximately 785m. The stretch of Av. John Paul VI / Av. Sumare goes along low area between hills toward the valley of the Tiete River. From Av. Antarctica, the terrain becomes flatter as it enters into the Plain of Tiete River.

2) Important Areas for Nature Conservation

There is no important natural area. The planted trees in square parks, in sidewalks and boulevards of central sites are the major green elements. In the median of Av. Sumare, there are large size street trees.

3) Problem of Pollution

The biggest problem of noise and air pollution is due to a large volume of vehicles, especially in the morning and afternoon peak hours.

(2) Social Conditions

1) Socio-economic Characteristics

The region consists of neighborhoods of medium and high socioeconomic standard. The neighborhood of Pinheiros has a lot of shops (furniture stores) and services (banks, shops of car accessories, pubs and restaurants), and several establishments are located along the route.

2) Historical Monuments and Archaeological Sites

CONDEPHAAT identified one historic monument called Memorial of Latin America near the end of Line-2C.

2.7.5 Line-2D

(1) Natural Environmental Conditions

1) Topographical Conditions

The area is the floodplain of Pinheiros River and Tiete River, near the marginal point where Pinheiros River merges into Tiete River. The topography throughout the line is generally flat.

2) Important Areas for Nature Conservation

This line passes near three areas with vast vegetation cover. The first is located in the Butanta Institute, the second is in the São Paulo University (known as biological forest) and the third is in the Villa Lobos Park.

3) Problem of Pollution

The main problem of noise and air pollution exists in Av. Eusebio Matoso, Av. Vital Brazil and Av. Dr. Gastao Vidigal resulting from vehicle traffic along these roads.

(2) Social conditions

1) Socioeconomic Characteristics

In the stretch of Av. Eusebio Matoso, in west side, there is Jardim Paulistano Area, high-standard residential area and the other side there is Pinheiros Area, where there is a concentration of commercial activities. Av. Vital Brasil in Butanta Area is a residential area of medium standard and with commercial activities. In the Alvarenga Street there is a concentration of establishments that sell wood products (doors, windows, parts for furniture, etc.).

2) Historical Monuments and Archaeological Sites

It has been identified two protected area/monument, the Jardim Paulistano (known as Area of gardens) and the Butanta Institute, where there are buildings of historical values. In addition, the campus of the University of São Paulo has several buildings that can be considered monuments of historical importance.

2.7.6 Line-3A

(1) Natural Environmental Conditions

1) Topographical Conditions

Av. Jabaquara is lie at an altitude of 801 - 825m as shown in Figure 2-17. The lines go down to the valley of Jabaquara Stream, which changes its name to Agua Espraiada Stream, and go through Av. Jornalista Roberto Marinho at an altitude of 751- 775m. Agua Espraiada Stream goes toward the Pinheiro River, where the level of the land is in the range between 700 - 725 m. The east portions of the two branch lines (Jabaquara/Congonhas Airport Station and St. Jude/Congonhas Airport Station) have steep slopes while the slope of the rest section is gentle.

2) Important Areas for Nature Conservation

Although street trees are planted on roads and avenues of Line-3A, there are few greens along the route.

3) Problem of Pollution

Congonhas Airport is the important source of noise and air pollution from aircraft emissions. In other parts of the line, vehicles are the largest sources of noise and air pollution.

(2) Social Conditions

1) Socio-economic Characteristics

The area around Congonhas Airport is lower-income and medium-income residential area. The branch line from Jabaquara Station goes through favelas. The line along the Av. Journalist Roberto Marinho crosses a densely populated residential area. The stretch between Av. Washington Luis and Av. Vereador Jose Diniz (Areas of Brooklin Paulista and Campo Belo) has housing of better standard.

2) Historical Monuments and Archaeological Sites

The research conducted by CONDEPHAAT found only one historical site called the Sede do Sitio da Ressaca, however, the Project does not involve the site.

2.7.7 Line-3B

(1) Natural Environmental Conditions

1) Topographical Conditions

The east section of this line is in the floodplain of the Pinheiros River. The line goes through a stretch in slope to reach the Morumbi Av. and the stretch down to the Morumbi Stadium.

2) Important Areas for Nature Conservation

The Area of Morumbi, across the Pinheiros River, in the most part, consists of residential houses of high standard with plenty of greens. This region is significant area of remaining plants as shown in Figure 2-18. One of the parks in the region is the Burle Marx Park, which is located near the Marginal of Pinheiros River.

3) Problem of Pollution

The problems of noise and air pollution are caused by vehicles in the region, such as Av. Morumbi, Av. Giovanni Gronchi, Av. Joao Jorge Saad and Francisco Morato Av.

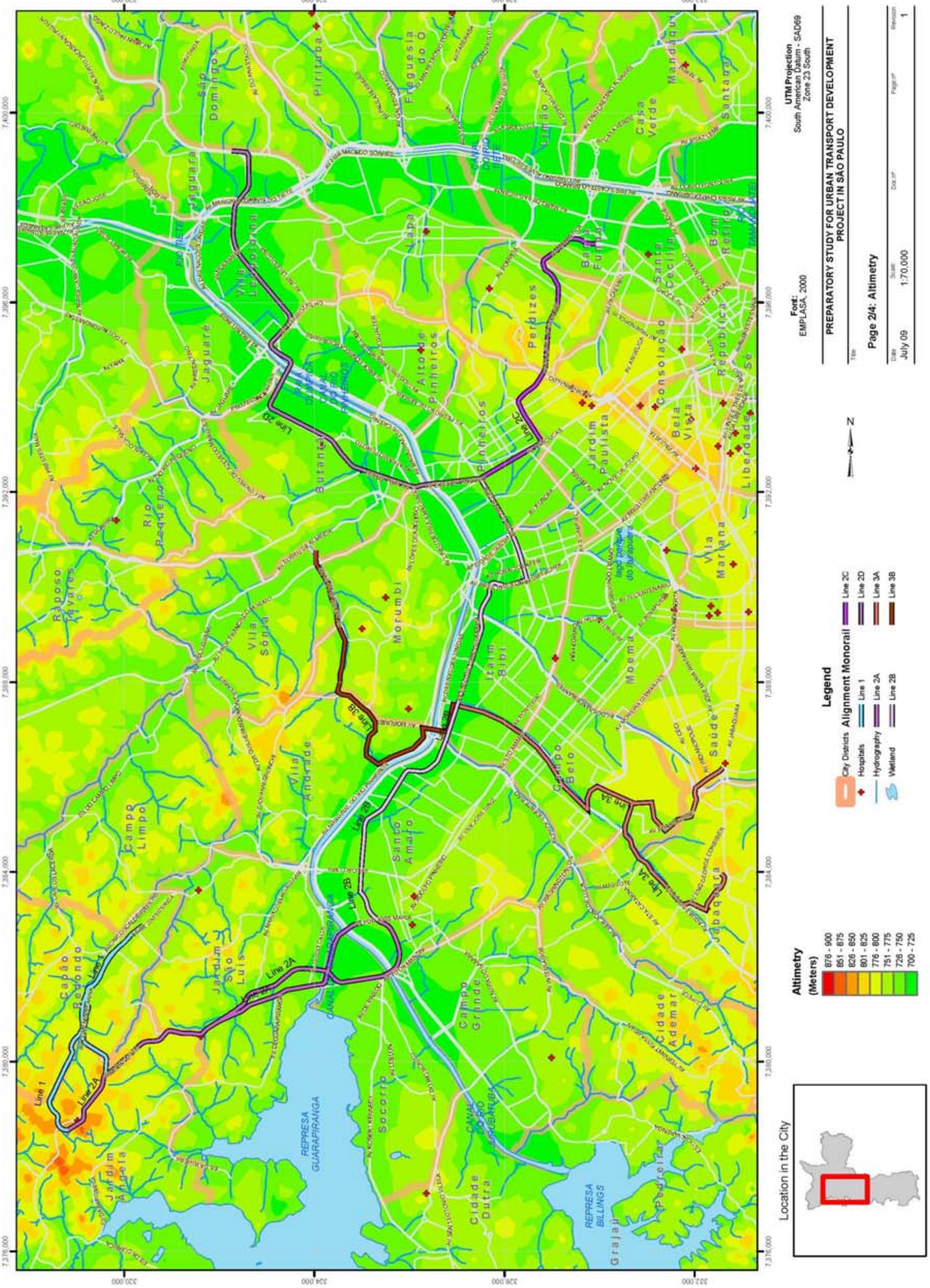
(2) Social Conditions

1) Socioeconomic Characteristics

The area around Line-3B is upper-class residential area with high-rise apartment type buildings except for Paraisopolise, the largest favela in São Paulo.

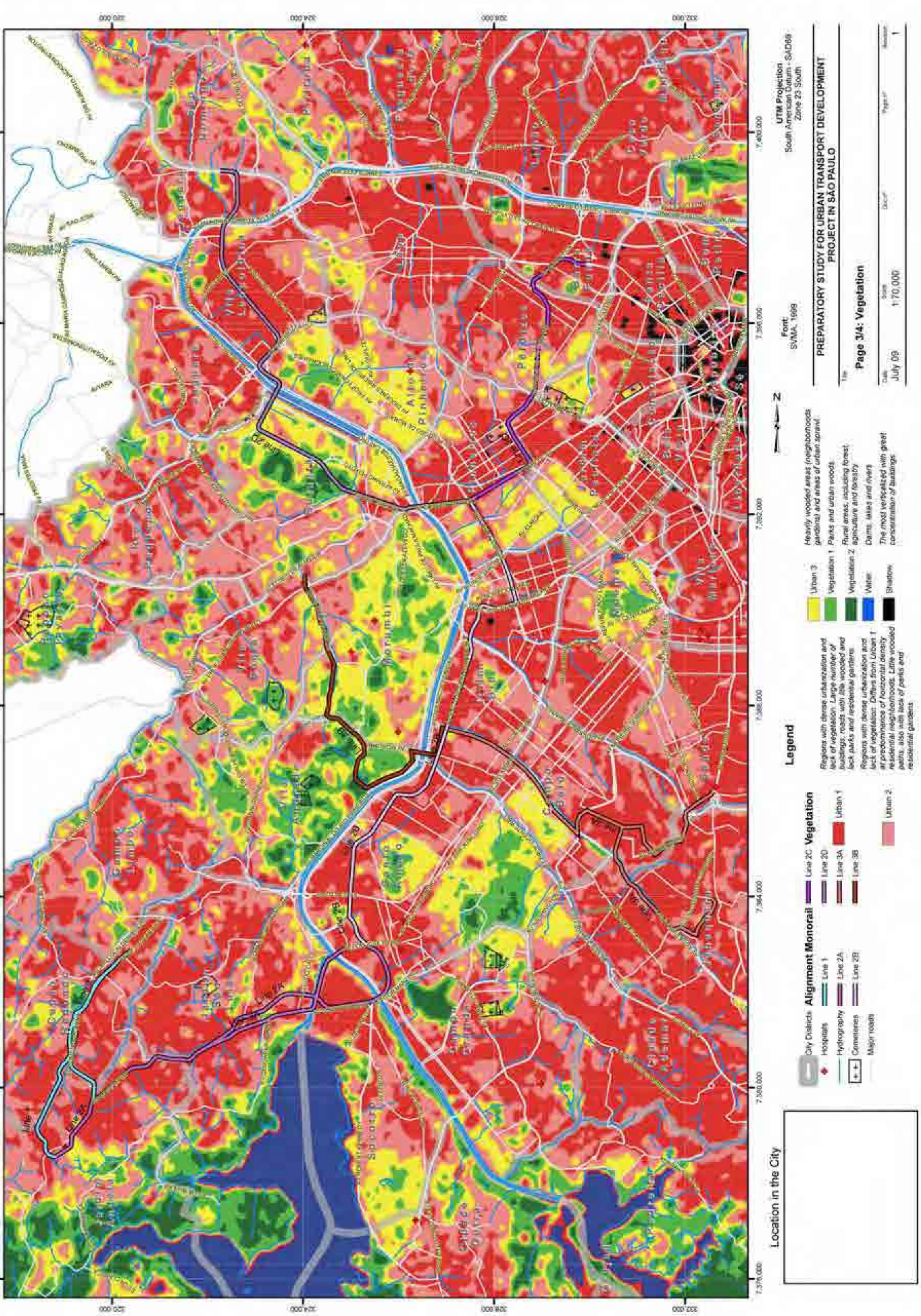
2) Historical Monuments and Archaeological Sites

The Palacio dos Bandeirantes (headquarters of the State Government) and the Morumbi Stadium are important monuments in the region.



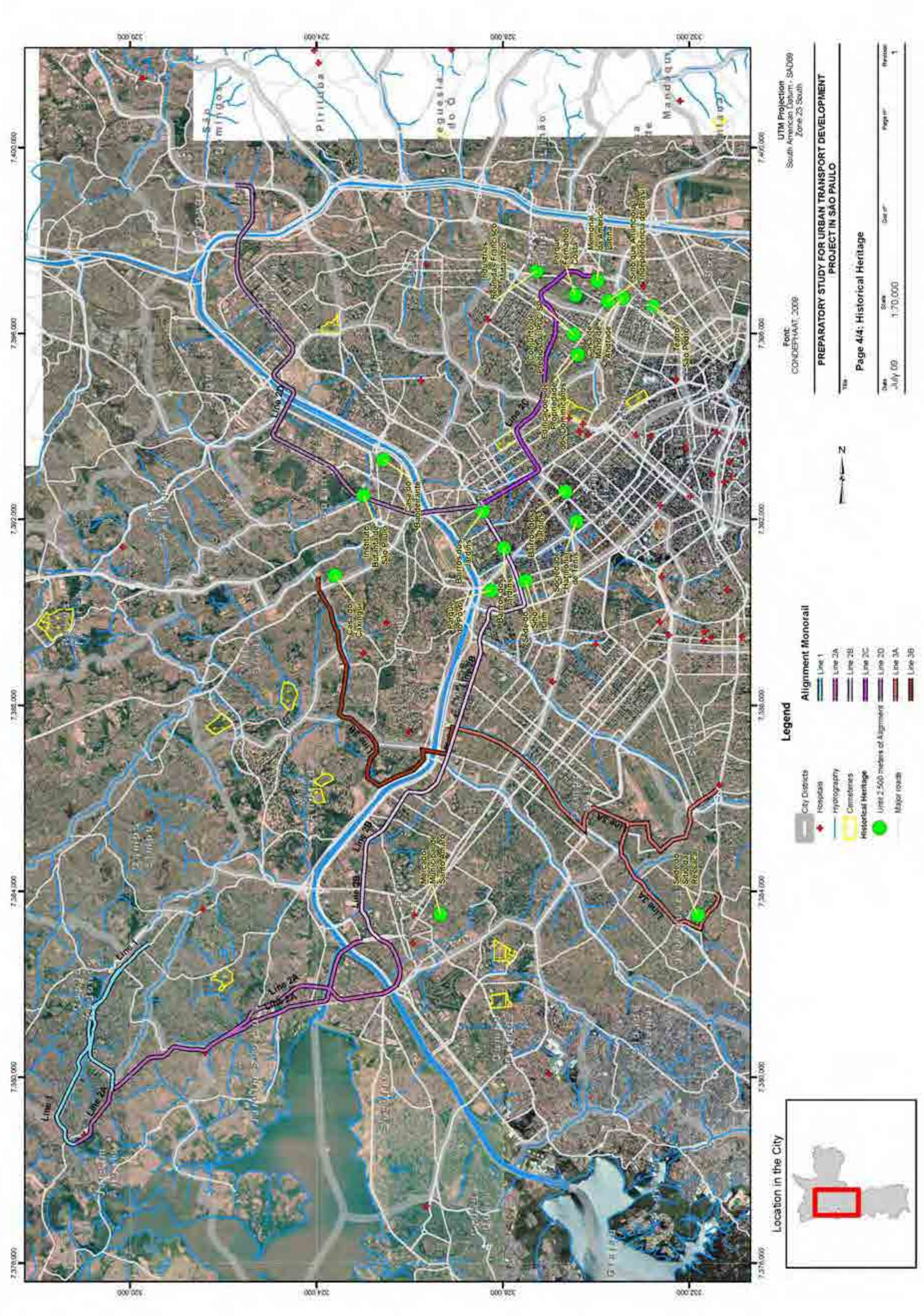
Source: EMPLASA (Empresa Paulista de Planejamento Metropolitano SA)

Figure 2-17 Altimetry



Source: SVMA (Department of Paper and Environment in São Paulo)

Figure 2-18 Vegetation Cover



Source: Council for Protection of Cultural, Archaeological, Artistic and Tourist Heritages (CONDEPHAAT)
Figure 2-19 Historical Heritage

CHAPTER 3 DEMAND FORECAST

3.1 SOCIO-ECONOMIC FRAMEWORK

The future socio-economic framework of the Metropolitan Region of São Paulo (RMSP) was analyzed in PITU 2025. The projected socio-economic framework includes the population, the number of employees, and the number of school seats for the years up to 2025. The population of RMSP was projected to increase from 19.1 million in 2005 to 23.0 million in 2025, 1.2 times increase during 20 years. On the other hand, PITU 2025 did not estimate the population after 2025.

Brazil Geographic and Statistics Institution (IBGE) projected the future population of Brazil up to 2050 and that of the State of São Paulo up to 2030. According the projection, the population of Brazil will reach its peak in 2039 at 219 million, which is 1.17 times the present population of 186.8 million (2006).

To estimate the population of the state of São Paulo, metropolitan, and municipalities in São Paulo, it was assumed that the ratio of the growth rate of lower administrative level to that of higher one would be the same as in the PITU projection up to 2025 (state to country, metropolitan to state, municipality to state). The ratios were estimated as follows:

- The State of São Paulo to the country: 0.971,
- RMSP to the state: 1.326,
- Municipality of São Paulo to RMSP: 0.362
- Other municipalities to RMSP: 1.734

The population projection of the Municipality of São Paulo and others in RMSP is shown in Table 3-1. The population by traffic zone in PITU 2025 (389 zones) was estimated assuming that the growth trend by traffic zone would continue up to 2045.

Table 3-1 Population Projection 2005 - 2045

(Unit: 000)

Year	Brazil	São Paulo State	RMSP	São Paulo Municipality	Others
2005	183,383	39,575	19,130	10,744	8,386
2010	193,151	41,343	20,310	11,015	9,294
2015	200,976	42,742	21,247	11,183	10,064
2020	207,228	43,873	22,185	11,350	10,834
2025	212,280	44,071	22,972	11,464	11,508
2030	216,505	45,534	23,521	11,558	11,963
2035	218,645	45,971	23,839	11,611	12,228
2040	219,075	46,059	23,904	11,622	12,282
2045	217,888	45,817	23,917	11,624	12,293

IBGE
PITU
JICA

Source: IBGE (dark gray), PITU (light gray), JICA Study Team

The numbers of employees and the school seats in the future up to 2045 were estimated from the projection in PITU 2025. It was assumed that the increase rate in PITU from 2005 to 2025 would continue up to 2045. Table 3-2 shows the result of the projection of the number of employees and school seats. Assuming that the same growth rate by traffic zone in PITU (389 zones) will continue, the number of employees and school seats was projected.

Table 3-2 Projection of the Number of Employees and School Seats

(Unit: 000)

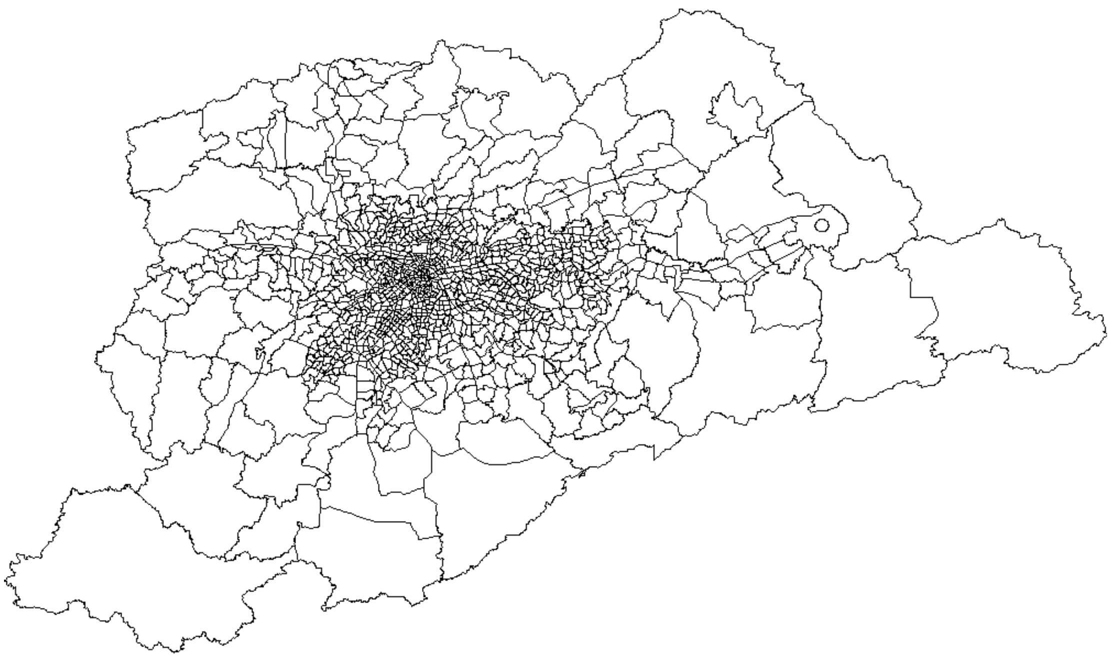
Year	Employees		School Seats	
	São Paulo	Others	São Paulo	Others
2005	5,370	2,760	3,295	2,413
2010	5,744	2,990	3,485	2,575
2015	6,058	3,189	3,636	2,704
2020	6,372	3,389	3,787	2,833
2025	6,649	3,574	3,914	2,941
2030	6,881	3,740	4,013	3,026
2035	7,064	3,885	4,084	3,085
2040	7,193	4,004	4,124	3,117
2045	7,265	4,096	4,132	3,121

Source: PITU (light gray), JICA Study Team

3.2 DEMAND FORECAST MODEL

3.2.1 OD Matrix

SPTrans has developed a demand forecast model based on the 1997 Origin-Destination survey for the planning of bus system in São Paulo, and the model has been used for new projects such as Celso Garcia Express project. In the SPTrans model, the future OD for the year 2012 was estimated from the 1997 OD and the socio-economic projection in PITU 2025 by applying fratar method. The future OD consists of private mode and public mode for peak hour traffic, covering the Metropolitan Region of São Paulo (RMSP) with 1158 zones. Figure 3-1 shows the 1158 zone map of RMSP. The OD was revised by using the 2002 and 2007 OD Survey.



Source: SPTrans

Figure 3-1 Traffic Zones

3.2.2 Trip Generations and Attractions

The future trip generation and attraction by zone were estimated from the 2012 OD (peak hour) that was prepared by SPTrans, applying the growth rates of the socio-economic data projected above. The growth rate of the population by zone was applied for the projection of trip generation, while the average of the growth rate of the number of employees and school seats by zone was applied for the projection of trip attraction. The total number of trips in RMSP was estimated as the average of the total of trip generations and that of attractions. It was estimated that the total number of trips by public transport in the peak hour would be 1.5 million in 2012, 1.6 million in 2025, and 1.7 million in 2045, as shown in Table 3-3.

Table 3-3 Projection of Trip Generation (RMSP total)

Year	2012	2015	2025	2035	2045
Private Mode	884,164	901,596	955,550	988,144	1,006,018
Public Mode	1,486,970	1,522,896	1,631,124	1,689,750	1,721,991

Souce: JICA Study Team

3.2.3 Modal Share

Public mode accounts for 55.1% of trips by motorized vehicle, according 2007 OD Survey (the rest of 44.9% is by private mode). The modal share by public mode in 1997 OD Survey was 51.2%. The recent effort to promote public transport, such as fare integration, private sector incentive under the bus concession scheme[1], and expansion of public transport network, has contributed to the increase in public mode share.

Currently, bus accounts for 65% of the trips by motorized public mode, while metro and train account for 16% and 6%, respectively. The share of bus, metro, and train in the trips by motorized vehicle is 35.9%, 8.8%, and 3.2%, respectively.

With a number of on-going and planned projects, such as construction of Metro Line-4, extension of Line-5, and Tiradentes Project, it is expected that the public transport network in São Paulo will continue to expand. On the other hand, the number of private car tips is also expected to increase due to the income increase and development in suburban area. In PITU 2025, several scenarios are examined and estimated the future share of public transport in motorized trip as 55 – 70%. In this study, the future modal share of public transport was fixed as the same share of 65% as in 2007. Future ODs of public mode were estimated from the present OD of public mode in the preliminary model.

3.2.4 Trip Distribution

The future OD matrices of 389 zones for the morning peak were estimated from the 2012 OD matrix for morning peak and the trip generation and attraction data by applying the fratar method.

[1] Previously, bus services in São Paulo was poor because private operators had few incentive to provide good service under the previous contract scheme.

3.2.5 Traffic assignment

The network data provided by SPTrans was modified so that the data conforms to the preliminary projection model. The future Metro lines in PITU 2025 were added to the network in addition to the link data of the project routes. The network data covers RMSP with approximately 13,500 links and 7,400 nodes. Figure 3-2 shows a part of the network data.

Source: JICA Study Team

Figure 3-2 Network for Traffic Assignment

The traffic assignment model in this study consists of highway network and transit line network. EMME/3 was used for the calculation of the traffic assignment. The model requires operation data such as loading capacity, frequency, speed, and fare of each transit line. On the other hand, these operation data are unknown in the beginning stage of the feasibility study, and they should be planned based on the result of the demand forecast. In other words, the demand model needs the operation plan, while the operation plan needs the result of the demand forecast.

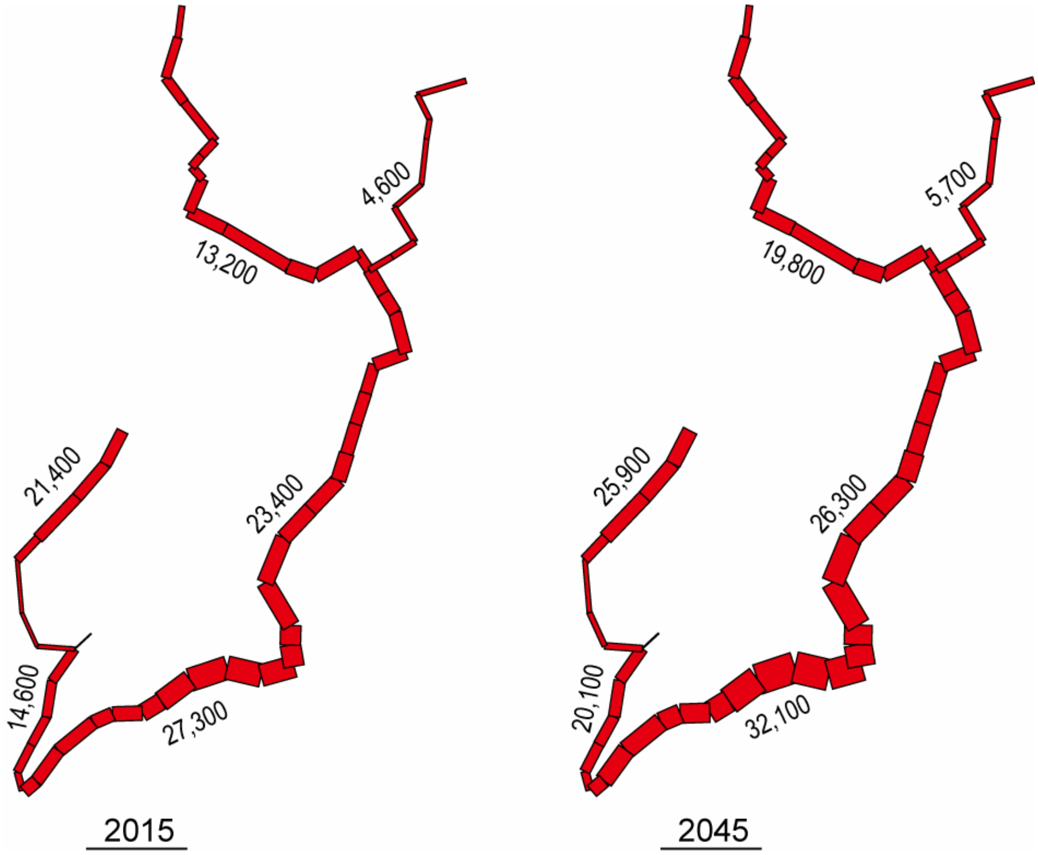
Therefore, a preliminary demand forecast was carried out before the demand forecast that needs the operation data which should be defined based on the result of the demand forecast. The preliminary demand forecast applied very simple assumptions such as:

- Travel speed of buses is calculated from speed-volume relationship
- Travel speed of railway and medium capacity transits is fix at 35km/h[2]
- Unlimited capacity for railway and medium capacity transit
- Free fare for public transport modes (or constant fare for all modes with free transfer)

[2] The travel speed was calculated as 30km/h after the analysis of the run curve

3.3 FUTURE TRAFFIC

The future traffic volume on the medium capacity transit system in 2015 and 2045 was calculated from the traffic assignment in the demand forecast model described in 3.2. Figure shows the result of the traffic assignment without the capacity constraint of the medium capacity transit system. Traffic volume in PHPDT of Line-2A was estimated as 27,300 in 2015 and 32,100 in 2045. This is relatively large traffic for a medium capacity transit system. On the other hand, the estimated traffic volume of Line-2C is small at 4,600 PHPDT in 2015 and 5,700 PHPDT in 2045.



Source: JICA Study Team

Figure 3-3 Demand Forecast in 2015 and 2045

Table 3-4 Peak Hour Peak Direction Traffic

		Line-1A + Line-2A		Line-1A+2A+2B+2D		All lines	
Year		2015	2045	2015	2045	2015	2045
PHPDT	Line-1A	13,900	18,800	11,200	15,500	14,600	20,100
	Line-1B	-	-	-	-	21,400	25,900
	Line-2A	23,200	28,800	29,500	34,800	27,300	32,100
	Line-2B	-	-	26,600	29,900	23,400	26,300
	Line-2C	-	-	-	-	4,600	5,700
	Line-2D	-	-	13,400	20,000	13,200	19,800
Daily Passengers		400,000	506,000	745,000	911,000	1,109,000	1,246,000
Passenger hours (000)		88	109	270	321	355	403
Passenger kilometers (000)		2,615	3,264	7,983	9,512	10,599	12,027

The number boarding passengers at Jardim Angela is constrained by the road capacity of M’Boi Mirim (2-lane road) in the south of Jardim Angela. It was assumed that traffic at Jardim Angela Station, which would be the transfer terminal between buses and the medium transport capacity system, would not affect the capacity of adjacent roads.

3.4 SCENARIO ANALYSIS

3.4.1 Line Composition

The proposed medium capacity transit line consists of five sections: Line-1A, 1B, 2A, 2B, and 2D. To evaluate the impact of each section on passenger transport in São Paulo, a set of traffic assignment for the year 2015 was carried out for the case that only a line is developed (for example, Line-2A only). The reduction in passenger-hours (total travel time) was calculated for each case by comparing them to the "without" case (the case when the medium capacity transit line is not constructed). The reduction in passenger-hours is one of the indices which are generally used to evaluate a transport project. The following figure shows the result of the calculation.

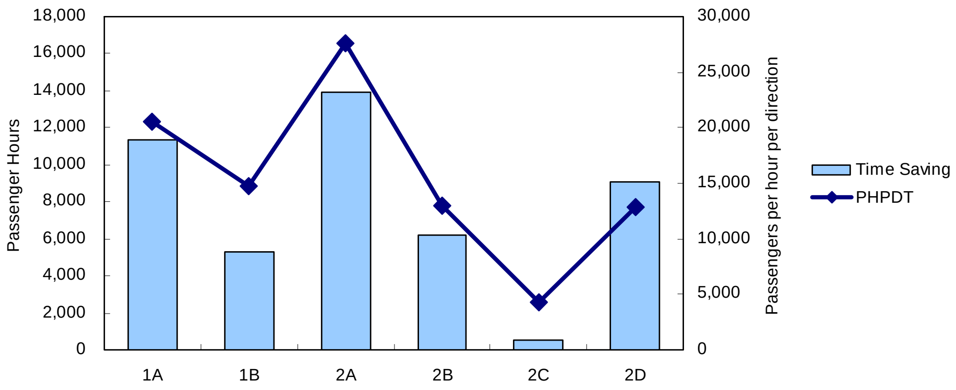


Figure 3-4 Peak Traffic and Time Saving by Line

Line-2A will reduce the largest travel time, while the travel time saving by Line-1A will be the second largest. The impact of Line-1B, 2B, and 2D is as small as approximately a half of Line-1A and 2A. The traffic volume of Line-2C is smallest and the impact of the reduction in passenger-hours is very small.

Figure 3-5 shows the result of the analysis for the combination of two lines. The three cases, Line-1A+1B, Line-1A+2A, and Line-2A+2B, have almost the same reduction in passenger-hours. The reduction in passenger-hours by the combination of Line-1A and 2A is lower than the simple total in the individual case shown in Figure 3-4, because passenger demand for Line-1A and 2A is duplicated. The largest traffic of Line-2A+2B shows that demand in through traffic of these two lines is large.

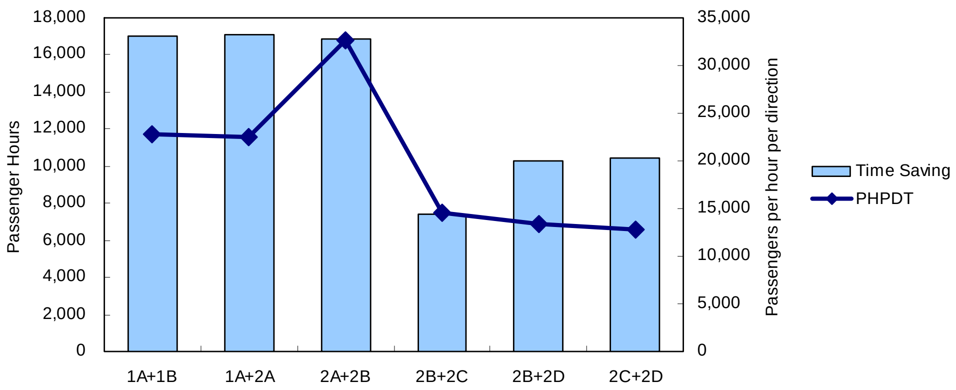


Figure 3-5 Peak Traffic and Time Saving by Line Composition (2 lines)

In addition, the reduction of passenger- hours for the case of three lines was calculated. In this case, the combination of Line-2A, 2B, and 2D will achieve highest project effect as shown in Figure 3-6. On the other hand, the project effect of the combination of Line-2B, 2C, and 2D which excludes Line-3A is lower than other combinations.

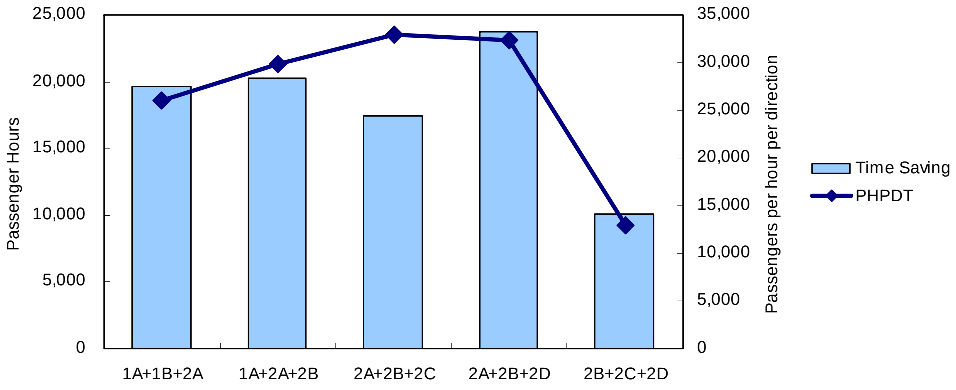


Figure 3-6 Peak Traffic and Time Saving by Line Composition (3 lines)

In case that the number of lines is four, the combination of Line-1A, 2A, 2B and 2D will reduce the largest passenger-hours among all possible combinations as shown in Figure 3-7.

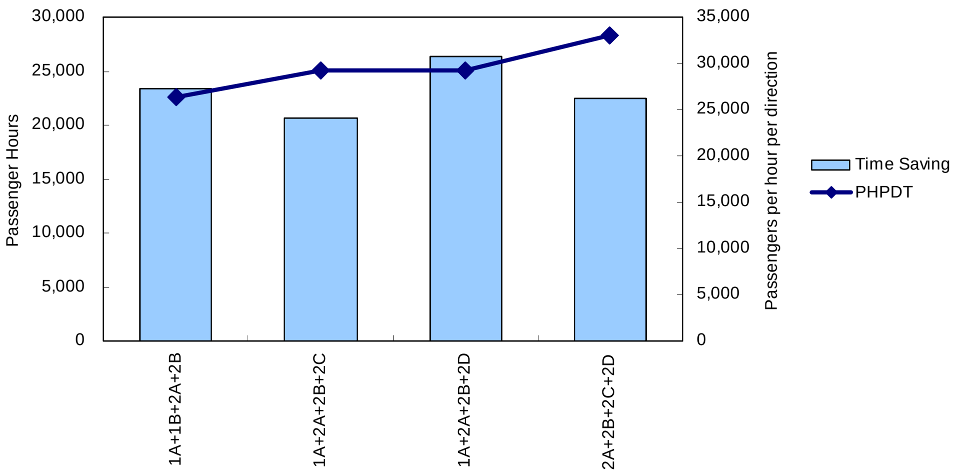


Figure 3-7 Peak Traffic and Time Saving by Line Composition (4 lines)

From the analysis above, if the six lines are allocated to three phases (2 lines in a phase) according to the priority, the following combination can be proposed.

Phase-1	Phase-2	Phase-3
1A+1B or, 1A + 2A or, 2A + 2B	1A + 2A + 2B + 2D	All

Since Line-1B is not included in Phase-2, Phase-1 should be the combination of 1A+2A or 2A+2B. In any case, Line-2A should be the highest priority route because it is included in both cases.

Note that the demand forecast model for he preliminary forecast was used for the simulation.

3.4.2 Fare Alternative

There are three different fare system of urban transport in São Paulo: 1) city bus fare at the flat fare of R$2.3, and 2) railway at the flat fare of R$2.55, and 3) inter-city bus fare which depends on the distance. For the analysis of the fare policy for the medium capacity transit system, the following three alternatives were studied:

Alternative-1: The medium capacity transit system belong to bus system with the same fare and integration benefits

Alternative-2: The medium capacity transit system belong to Metro and CPTM system with the same fare and integration benefits

Alternative-3: The medium capacity transit system is an independent system with its own fare and no discount for the transfer to other modes

Traffic assignment was carried out by transit assignment in EMME/3 for these alternatives under the following condition:

- Target year = 2045;
- The route of Line-2A = original route (straightly over M'Boi Mirim Road);
- Operation speed = 33km/h
- Headway = 1.5 minutes
- Capacity = 29,200 passengers /hours/ direction

Figure below shows the result of the alternative analysis of the fare policy. Passenger volume of Alternative-2 (Metro & CPTM fare) is higher than that of Alternative-1 (SPTrans fare) on Line-1B, 2A, and 2C. These lines have connections with metro lines and carry passengers who need transfer to metro lines for their trip from origin to destination. On the other hand, the connection with bus network is more important for Line-1A, 2B, and 2D. In case of Alternative-3 (independent fare), traffic volume of is lower than other cases expect for Line-2A and 2B. If the independent fare system is applied, passengers will avoid transfer to other mode, which increase traffic volume through Line-2A and 2B.

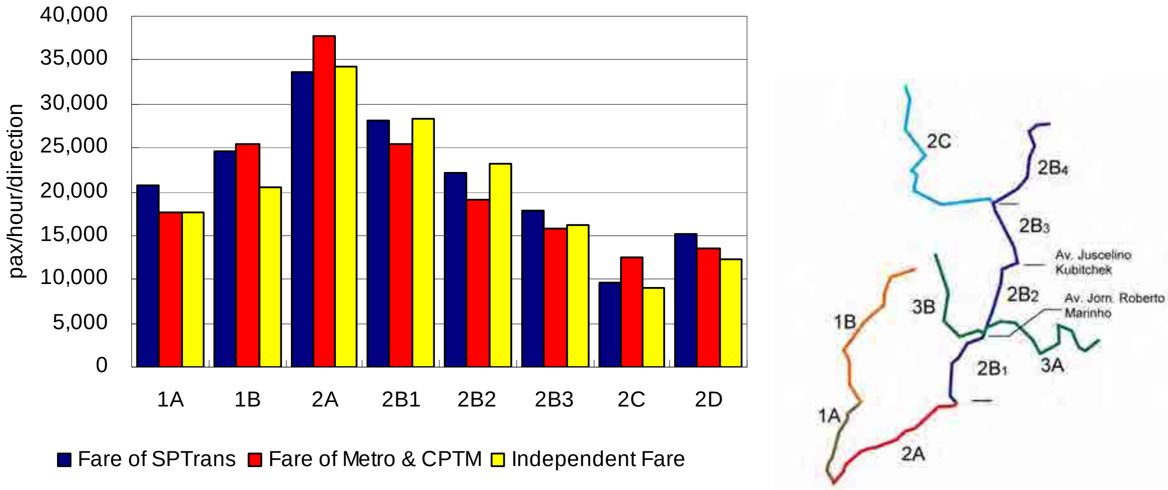


Figure 3-8 Alternative Analysis of Fare Policy

3.4.3 Impact of Line-1B

Line-1B is not included in the study route. On the other hand, the line is included in the monorail construction plan which was officially announced in October, 2009, and it is necessary to consider the impact of the line. Since Line-1B is expected to be the main feeder route of Yellow Line of Metro, high traffic demand can be expected. Figure 3-9 shows the comparison of traffic demand between "with Line-1B" case and "without Line-1B" case. Line-1B increases the traffic volume of Line-1A and decreases that of Line-2A and 2B.

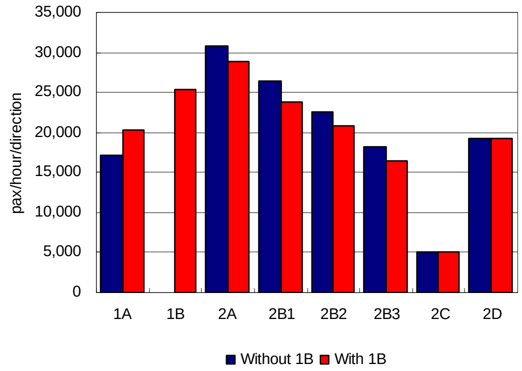
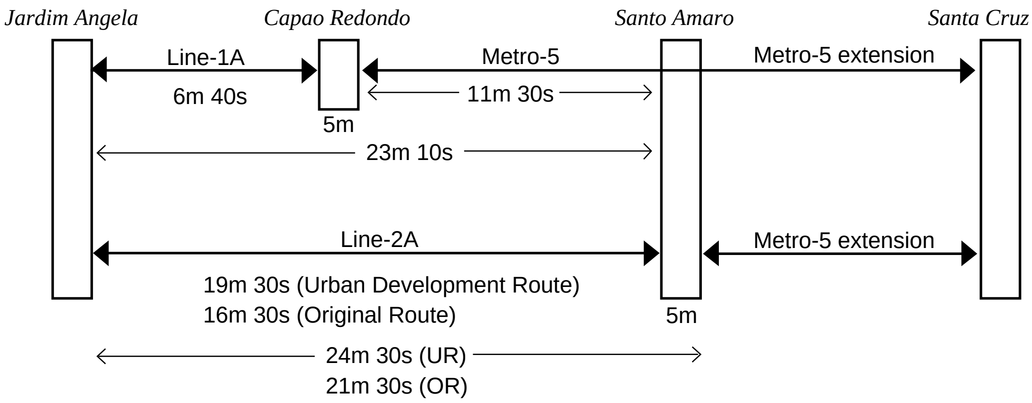


Figure 3-9 Impact of Line-1B

3.4.4 Share of Line 1 and 2

As described in 3.4.1, passenger demand of Line-1A and 2A is duplicated. The origin and destination of passenger demand from Jardim Angela to Santo Amaro in the morning peak hour was analyzed in the demand forecast. The result shows that approximately 40% of passengers came from Jardim Angela, while the rest of 60% boarded at stations between Jardim Angela and Santo Amaro.

There are two routes between Jardim Angela and Santo Amaro: 1) Line-2A and 2) Line-1A & Metro Lilac Line. The former route is preferable for passengers because the travel time is shorter and the fare is smaller. On the other hand, travel time between Jardim Angela and the destination beyond Santo Amaro is almost the same due to the transfer time at Santo Amaro as shown in Figure 3-10, and the fare condition is the same (Both routes need transfer between monorail and metro).



Source: JICA Study Team

Figure 3-10 Travel Time between Jardim Angela and Santo Amaro

The demand forecast was carried out based on the original route. In case of the urban development route, the travel time between Jardim Angela and the center of the city by using Line-1 is shorter than that of Line-2A, which increases the projected demand of Line-1A and decreases that of Line-2A. The demand of Line-2A is as large as 31,200 PHPDT in 2045, which is relatively higher than the medium capacity transit system. On the other hand, assuming that one forth of the traffic from Jardim Angela to Santo Amaro is converted to Line-1A, the traffic on Line-2A becomes 28,1000 PHPDT, which is suitable volume for a medium transit capacity system.

CHAPTER 4 ROUTE AND TRANSPORT PLAN

4.1 ROUTE PLAN

4.1.1 Network

Figure 4-1 shows the future railway network including the proposed medium capacity transit system together with existing and future Metro and CPTM lines. The route plan of the proposed transit system, Line-1, 2A, 2B, 2C and 2D, is proposed by considering passenger demand, applicable space for structures, existence of obstacles, and impact for environment, etc.

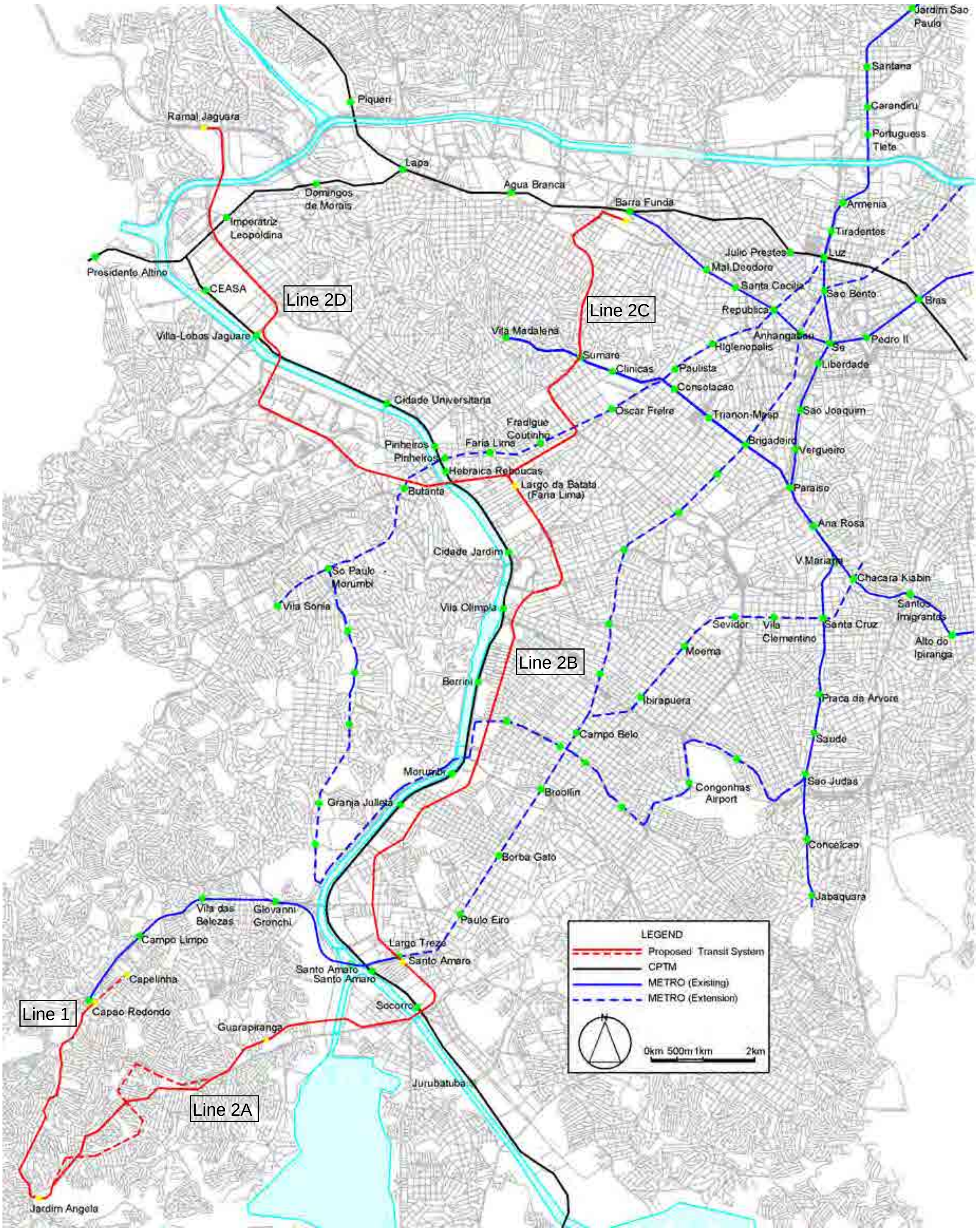
The conditions which shall be taken into consideration for the route plan are as follows:

1) Basically, tracks will be constructed within the public space above the trunk roads, supported by the piers which are constructed in the median strip of the roads. In order to minimize the land acquisition, wide roads are desirable for the route. The construction cost of this kind of structure is cheaper than that of tunnel.

2) From the perspective of passenger demand, the route shall provide the sufficient transport capacity to the future demand. As an ideal alignment to achieve the operation by over 30km/h of scheduled speed and frequent service, the following condition shall be considered.

Track:	*Double tracks, Drive on the right-hand side (counterclockwise)*
Horizontal alignment:	*Large curve is desirable. Basically, curve radii should be minimum 100m in the main line. When unavoidable, curve radius can be lessened to 50m.*
Vertical alignment:	*Basically, the maximum grade should be 6.0% in the main line. When unavoidable, 8.0% is applicable within a section between stations.*

3) From the perspective of natural and social environment, the route which has no negative impact to environment is desirable. Or, the route which can mitigate the negative impact by appropriate countermeasure is applicable.



Source: JICA Study Team

Figure 4-1 Route Plan

4.1.2 Route plan by line

(1) Line-1

Line-1 is premised as a route between Jardim Angela and Capelinha by way of Capao Redondo, with a length of approximately 5km. At Jardim Angela, a bus terminal is located in the roadside of M'Boi Mirim Road. Capao Redondo is located in approximately 800m toward southwest from Capelinha and has a station of Metro line 5. At Capelinha, a bus terminal is located along the Metro line 5 but there is no Metro station where passengers can transfer. Metro line 5 is a route between Capao Redondo and Santo Amaro and is under construction of extension towards Santa Cruz Station of Metro line 1. When extension of Metro line 5 is completed and Line-1 of the proposed transit system is introduced, Jardim Angela, Capao Redondo, Santo Amaro, and Centro area are connected by the rail based transit system.

Since the present Jardim Angela bus terminal is small compared with its large demand, new bus terminal construction plan is being considered by SPTrans. Location of the new bus terminal is on the hill located in approximately 400m southwest along M'Boi Mirim from the existing bus terminal. In Jardim Angela, a station of Line-1 will be located in the new bus terminal area in order to integrate with BRT service.

When the future extension of Line-1 to Vila Sonia is considered, since the extension section is started from Capao Redondo, the section between Capao Redondo and Capelinha will be a dead track. Furthermore, it is planned by SPTrans that an existing bus terminal in Capelinha will be relocated to Capao Redondo which has a Metro station in order to improve the integration of bus and Metro.

Therefore, it is recommendable that a 4.2km section between Jardim Angela and Capao Redondo is constructed as Line-1, excluding an 800m section between Capao Redondo and Cepelinha.

The track structures of Line-1 will be constructed within the space above 4-lane roads, Av. Simao Caetano Nunes, R. Abllio Cesar and Av. Ellis Maas, which have no median strip and the river which flows in parallel to Av. Comendador Santana.

(2) Line-2A

Line-2A is approximately 10km route which connects between Jardim Angela and Santo Amaro along M'Boi Mirim Road – a trunk road having 6 lanes with a wide median strip. Among these 6 lanes, central 2 lanes are BRT lanes. Line-2A is connected to Line-1 at Jardim Angela, and is integrated with Metro line 5 and CPTM line 9 at Santo Amaro.

Regarding geographical feature of Line-2A, there is a descent from Jardim Angela toward Santo Amaro. In particular, the section between 2.5km and 5km has a steep gradient of about 6% (The starting point 0km is the station in Jardim Angela). Between 5km and 7km section, Line-2A is distant from M'Boi Mirim and passes through above the river which flows at north side of the Guarapiranga bus terminal. With regard to this river section, a flood control project is being considered by municipality of São Paulo and its construction will be carried out prior to installation of the proposed transport system. After passing the Guarapiranga River, the Pinheiros River and CPTM line 9, Line-2A approaches to Santo Amaro. In addition, a depot of the proposed transport system will be located at an idle land beside the Guarapiranga River.

Line-2A has 2 alternatives. One is named "Original Route" and is introduced into M'boi Mirim as above mentioned. Another alternative is named "Area Development Route" and is based on the concept of urban development. This alternative has 11km length and is a route by way of the redeveloping areas which are 500m away from M'Boi Mirim Road.

(3) Line-2B

Line-2B is an 11km route which bears the new traffic axis of the south-north direction by connecting between Largo da Batata and Santo Amaro. The corridors of which the route is installed have more than 8 lanes and wide median strip where the roadside trees are growing greatly.

On the other hand, in the section between Santo Amaro and Av. Dr. Chucri Zaidan which is approximately 2km section of south side of Line-2B, no sufficient corridor for installation of the medium capacity transit system exists. However, in this section, a newly wide road is planned by a master plan of municipality of São Paulo and the proposed transit system will be installed above this road.

(4) Line-2C

The route of the proposed system branches to Line-2C and Line-2D at Largo da Batata, the northernmost of Line-2B. Line-2C is a 7.2km route between Largo da Batata and Barra Funda which passes along the east side of São Paulo cemetery. In a Barra Funda, there is a station of which the trains of Metro line 3, CPTM line 7, and line 8 depart and arrive.

As a geographical feature, Av. Paulo VI and Av. Sumare have slopes to cross a hill at the point between São Paulo cemetery and Barra Funda. At the peak of this hill, the elevated bridge of two layers is crossing over Av. Sumare. The upper bridge is the road bridge of Av. Dr. Arnaldo and the lower bridge is the Sumare station of Metro line 2.

Av. Sumare under the Sumare station of Metro line 2 has a large median strip and 8 lanes, and there is a lane for motorbikes in both sides of the median strip. The roadside trees are growing greatly in the median strip. A part of Av. Sumare belongs to the cultural preservation special area where development is restrained, and the roadside trees of a median strip are also contained in the object of preservation.

(5) Line-2D

Line-2D is an 11.6km route between Largo da Batata and Ramal Jagara, which requires the construction of 3 bridges of Pinheiros River and Tiete River.

(6) Future extension (Line-1B)

According to an announcement of mayor of São Paulo municipality, dated 1st December, 2009, northward extension of Line-1 from Capao Redondo to Villa Sonia by way of Campo Limpo is attempted.

This section has 11 km length and 2 Metro stations are located at both ends of the section. Metro stations of line 5 and line 4 are located at Capao Redondo and Villa Sonia, respectively.

4.1.3 Concept of station arrangement

Station location is designed by taking into account of passengers' convenience and safeness. At the site where stations will be located, sufficient space and an appropriate alignment are required. Moreover, it is desirable that stations are located at the flat section which has no gradient in order to ensure safe train operations.

The conditions which shall be taken into consideration for station arrangement are as follows:

a) From the perspective of passenger convenience, a station location close to high density residential areas, commercial and/or business districts is preferable.

b) From the perspective of social welfare, an accessible location to large hospital or schools is important as a station location.

c) In order to structure the public transport network of São Paulo by coordination with Metro, CPTM and buses, the stations of the proposed transport system should be located near the railway stations and/or the bus terminals.

d) In order to perform the efficient operation and to obtain the region’s neighbor demand, the distance between station is kept between 600m and 1,500m.

e) In order to avoid the necessity of land acquisition, wider road is preferable as ideal station locations.

f) The track alignment of a station section should comply with the following standards.

Horizontal alignment: A straight line is desirable. Basically, the minimum curve radius should be 300m in the station section

Vertical alignment: Level is desirable. Basically, the maximum grade should be 0.5% in the station section.

4.1.4 Station arrangement by line

(1) Station arrangement of Line-1

Table 4-1 shows the station location of Line-1.

Table 4-1 Station Location of Line-1

Station Kilometrage	*Distance (m)*	*Description of location/Corridor*	*Facilities*
L1-1(2A-1) 0+000		*New Jardim Angela bus terminal*	*Jardim Angela bus terminal Hospital*
	775m		
L1-2 0k810m		*Parallel to R. Abllio Cesar*	
	625m		
L1-3 1k450m		*Parallel to R. Abllio Cesar*	
	765m		
L1-4 2k150m		*River parallel to Av. Comendador Santana*	*Intersection*
	785m		
L1-5 2k950m		*River parallel to Av. Comendador Santana*	
	1200m		
L1-6 4k150m		*Av. Ellis Maas*	*Capao Redondo Metro station*

Source: JICA Study Team

(2) Station arrangement of Line-2A

Table 4-2 and Table 4-3 show the station location of Line-2A via Original Route and Area Development Route, respectively.

Table 4-2 Station Location of Line-2A (Original Route)

Station / Kilometrage	Distance (m)	Description of location/Corridor	Facilities
2A-1 (1-1) / 0k050m		In front of Jardim Angela bus terminal	Jardim Angela bus terminal Hospital
	(725m)		
2A-1a (Future) / 0k800m		Behind the hospital	Access to Hospital and existing bus terminal
	(895m)		
2A-2 / 1k500m		M'Boi Mirim	
	765m		
2A-3 / 2k450m		M'Boi Mirim	School
	1200m		
2A-4 / 3k650m		M'Boi Mirim	
	1350m		
2A-5 / 4k970m		M'Boi Mirim	Guarapiranga bus terminal
	1070m		
2A-6 / 6k070m		Ponte Baxia River	
	750m		
2A-7 / 6k970m			School Depot
	1100m		
2A-8 / 8k020m		Guarapiranga	
	890m		
2A-9 / 8k920m		Guarapiranga (Pinheiros River)	CPTM Socorro station
	(810m)		
2A-9a (Future) / 9k720m		Guarapiranga (Pinheiros River)	CPTM Socorro station
	(380m)		
2A-10 / 10k110m		Santo Amaro bus terminal	Santo Amaro bus terminal Metro, CPTM stations

Source: JICA Study Team

Table 4-3 Station Location of Line-2A (Area Development Route)

Station / Kilometrage	Distance (m)	Description of location/Corridor	Facilities
2A-1 (1-1) / 0k050m		In front of Jardim Angela bus terminal	Jardim Angela bus terminal Hospital
	(735m)		
2A-1a (Future) / 0k800m		Behind the hospital	Access to Hospital and existing bus terminal
	(800m)		
2A-2 / 1k600m		Crossing with M'Boi Mirim	
	1015m		
2A-3 / 2k600m			School
	885m		
2A-4 / 3k500m		Crossing with M'Boi Mirim	Church
	700m		
2A-5 / 4k200m			
	1015m		
2A-6 / 5k200m			
	1165m		
2A-7 / 6k350m		M'Boi Mirim	
	1070m		
2A-8 / 7k450m		Ponte Baxia River	Guarapiranga bus terminal
	750m		
2A-9 / 8k350m			School Depot
	1100m		
2A-10 / 9k400m		Guarapiranga	
	890m		
2A-11 / 10k300m		Guarapiranga (Pinheiros River)	CPTM Socorro station
	(810m)		
2A-9a (Future) / 11k100m		Guarapiranga (Pinheiros River)	CPTM Socorro station
	(380m)		
2A-12 / 11k490m		Santo Amaro bus terminal	Santo Amaro bus terminal Metro, CPTM stations

Source: JICA Study Team

(3) Station arrangement of Line-2B

Table 4-4 shows the station location of Line-2B.

Table 4-4 Station Location of Line-2B

Station Kilometrage	Distance (m)	Description of location/Corridor	Facilities
2B-1 0k000m		Santo Amaro bus terminal	Santo Amaro bus terminal Metro, CPTM stations
	900m		
2B-2 0k900m		Planned road by Municipality's Mater Plan	
	550m		
2B-3 1k450m		Planned road by Municipality's Mater Plan	Joao Dias Bus Corridor
	1085m		
2B-4 2k550m		Planned road by Municipality's Mater Plan	
	1280m		
2B-5 3k800m		Planned road by Municipality's Mater Plan	
	860m		
2B-6 4k750m		Av. DR.Chucri Zaidan	Shopping Morumbi CPTM station
	725m		
2B-7 5k400m		Av. DR.Chucri Zaidan	Street of office buildings
	1150m		
2B-8 6k600m		Av. Engenheiro Luis Carlos Berrini	Street of office buildings
	665m		
2B-9 7k250m		Av. Engenheiro Luis Carlos Berrini	Street of office buildings
	750m		
2B-10 7k950m		Av. Chedid Jafet	CPTM station
	885m		
2B-11 8k850m		Av.Presidente Juscelino Kubitschek	Street of office buildings
	995m		
2B-12 9k700m		Av. Brig Faria Lima	Street of office buildings
	755m		
2B-13 10k600m		Av. Brig Faria Lima	Street of Office buildings
	690m		
2B-14 11k290m		Av. Brig Faria Lima	Street of Office buildings

Source: JICA Study Team

(4) Station arrangement of Line-2C

Table 4-5 shows the station location of Line-2C.

Table 4-5 Station Location of Line-2C

Station Kilometrage	Distance (m)	Description of location/Corridor	Facilities
2C-1(2B-14) 12k000m		Av. Brig Faria Lima	Street of Office buildings
	1000m		
2C-2 13k000m		Reboucas	Metro line 4 station
	1150m		
2C-3 14k150m		Henrique Schaumann	São Paulo Cemetery
	800m		
2C-4 14k950m		Av.Sumare	Residential area
	765m		
2C-5 15k700m		Av.Sumare	Metro Sumare station Residential area
	605m		
2C-6 16k350m		Av.Sumare	Residential area
	865m		
2C-7 17k200m		Av.Sumare	Residential area
	1065m		
2C-8 18k250m		Av.Antartica	Soccer stadium
	975m		
2C-9 19k225m		Av.Auro Soares De Moura Andrade	Barra Funda station

Source: JICA Study Team

(5) Station arrangement of Line-2D

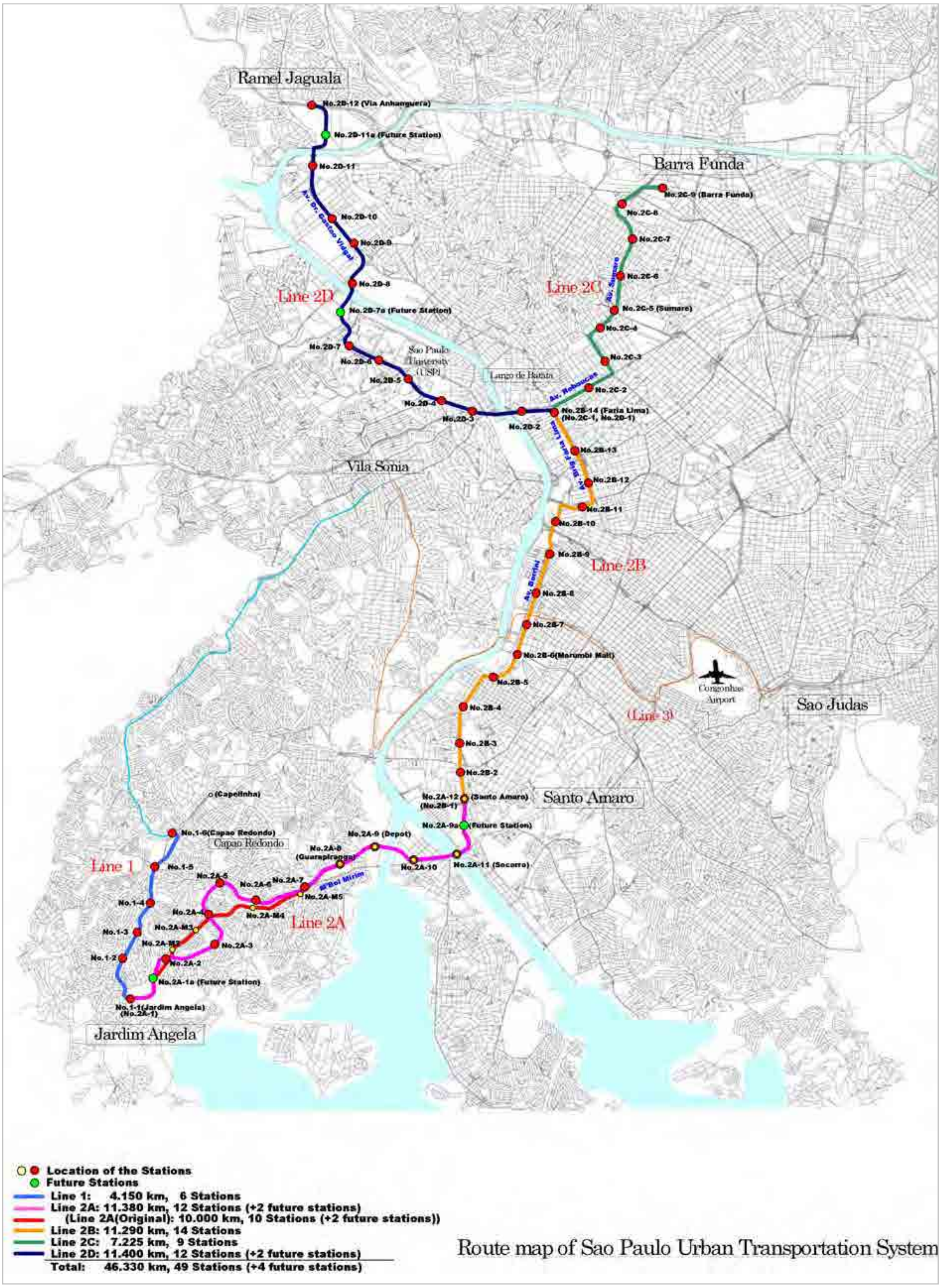
Table 4-6 shows the station location of Line-2D.

Table 4-6 Station Location of Line-2D

Station / Kilometrage	Distance (m)	Description of location/Corridor	Facilities
2D-1(2B-14) / *12k000m*		*Av. Brig Faria Lima*	*Street of Office buildings*
	830m		
2D-2 / *12k830m*		*Av.Eusebio Matoso*	
	1020m		
2D-3 / *13k850m*		*Av.Waldemar Ferreira*	*Metro line 4 station*
	715m		
2D-4 / *14k550m*		*Av.Afranio Peixoto*	
	885m		
2D-5 / *15k450m*		*Cidade Universitaria*	*São Paulo university*
	850m		
2D-6 / *16k250m*		*Cidade Universitaria*	*São Paulo university*
	650m		
2D-7 / *16k950m*		*Cidade Universitaria*	*São Paulo university*
	(870m)		
2D-7a (Future) / *17k700m*		*Av. Escola Politecnica*	*Entrance to São Paulo university*
	(765m)		
2D-8 / *18k570m*		*Av.Das Nacoes*	*CPTM station*
	1090m		
2D-9 / *19k690m*		*Av.Dr. Gastao Vidgal*	*Industrial district in Vila Leopuldina*
	790m		
2D-10 / *20k480m*		*Av.Dr. Gastao Vidgal*	*Industrial district in Vila Leopuldina*
	1285m		
2D-11 / *21k800m*		*Av.Dr. Gastao Vidgal*	
	(600m)		
2D-11a (Future) / *22k300m*		*Av.Federico Fellini*	
	(950m)		
2D-12 / *23k375m*		*Via Anhanguera*	

Source: JICA Study Team

Figure 4-2 shows the location of stations of each line.



Source: JICA Study Team

Figure 4-2 Station Location

4.2 SYSTEM SELECTION

4.2.1 System requirements

The proper system should be selected considering transport demand, route conditions, and relations with authorized plans.

According to the result of transport demand forecast (Table 4-7), the study routes except for Line-2C will require the transport capacity of more than 20,000 passengers per hour per direction in a peak hour, and Line-2A and Line-2B will require the transport capacity of approximately 30,000 passengers per hour per direction in a peak hour.

Table 4-7 Transport demand per peak direction in peak hour (passengers/hour)

Lines	Line-1	Line-2A	Line-2B	Line-2C	Line-2D
2015	14,600	27,300	23,400	4,600	13,200
2045	20,100	32,100	26,300	5,700	19,800

Source: JICA Study Team

To satisfy this transport demand, the transport system needs exclusive space which is separated from road traffic. BRT will require wide space with two or more lanes per direction to meet this demand, but it is unrealistic to provide such a wide space for BRT on the ground level or even as an elevated structure along the study routes.

From this, metro is the first candidate for the study routes. However, putting rails with proper gradient for rail wheel is difficult along Line-1 and Line-2A due to the steep slopes. There are some difficult sections for the alignment of metro along Line-2B and Line-2C in terms of constraints of curvature and road space, which makes it difficult to introduce metro system as an elevated system. Although underground system is possible for Line-2B and Line-2C, it will not be feasible considering the scale of transport demand.

Because of the alignment constraints and the transport demand that is not large enough to justify underground system, it will be difficult to introduce metro system for the study routes. On the other hand, medium capacity transit system, which is described in the next sections in this chapter, can satisfy the transport demand and can be applicable under the alignment constraints.

The plan of the future railway network is included in PITU 2020, but the study routes are not included in the future network, while the study routes are planned in the city plan (PDE) as public transport system to be developed by the city. Therefore, introduction of urban railway system requires overall review of the existing urban transport plans.

As a result, it is recommended to introduce a medium capacity transit system for the study route.

On the other hand, the transport demand of Line-2C is approximately 4,600 passengers per hour per direction in a peak hour, which is suitable for BRT system. However, since there will be a possibility that the introduction of the same system as Line-2B enables efficient and economical operation, Line-2C is studied as a medium capacity transit system.

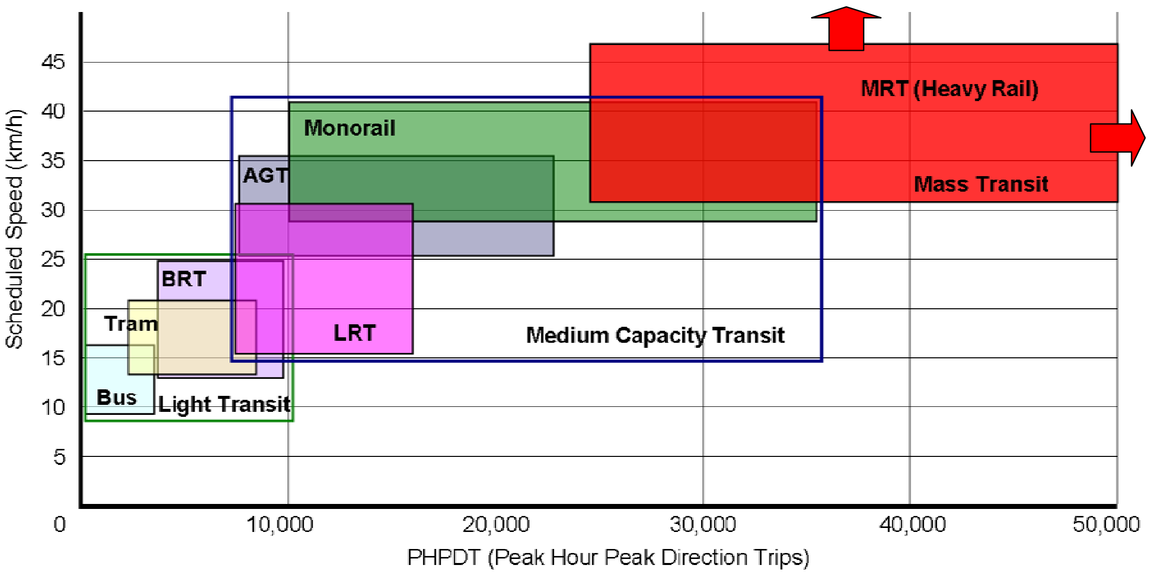
There are several types in the category of medium capacity transit system and not all types are applicable for this case. This study concluded that monorail is the best system among the medium capacity transit systems, as described in the following sections for the system selection in this chapter.

4.2.2 Concept of medium capacity transit system

Except those countries where various types of urban transit systems are operating, the main public transportation system means bus and heavy rail in many countries. In those countries, in order to fill the gap in capacity between bus and heavy rail, BRT (Bus Rapid Transit) system has been developed. The BRT has performed successful operation in many cities and spread worldwide in recent years. However, since BRT is based on bus operation, there is a limitation in capacity. Although double or triple articulated body has been adopted to increase its capacity, the capacity gap between rail and bus could not have been filled by BRT. Therefore, many cities in the world are now looking for a medium capacity transit system which has bigger capacity than BRT and can form a part of the urban transit system.

There are various types of medium capacity transit systems, such as, LRT (light rail transit), AGT (automated guideway transit), monorail (straddle and suspension types), maglev, linear Metro, etc. are operating in some countries. However, the number of those countries is very limited.

Due to the limited number of manufacturers and track records, maglev (magnetic levitation such as HSST in Japan) systems is excluded from this study and not shown on the chart. Therefore, LRT, AGT, Monorail systems and linear Metro are defined in this study as the Medium Capacity Transit Systems in which the capacity in PHPDT (peak hour peak direction trips) in ranging between 8,000 and 36,000 approximately.



Source: JICA Study Team

Figure 4-3 Urban Transit System - System Selection Chart

The transportation capacity can be shown in a combination of PHPDT and scheduled speed. PHPDT means the number of passengers at peak hour and peak direction. The scheduled speed means the average speed of a system including dwelling time at stations.

Even classified as medium capacity transit, there are differences in PHPDT and scheduled speed among monorail, AGT and LRT. When LRT is constructed at grade, i.e. same level as road vehicles, it is difficult to maintain high scheduled speed due to the traffic lights. Capacity of AGT is generally smaller than monorail because the length of AGT car body is much shorter than that of monorail.

4.2.3 Transit capacity in São Paulo

When São Paulo Metro line 1 was constructed in 1974, the system was designed in 6-car train operation, and underground stations were constructed accordingly to suite the 6 car train. Succeeding line 3 (1979, 1988) and line 2 (1991) were also constructed in the same standards.

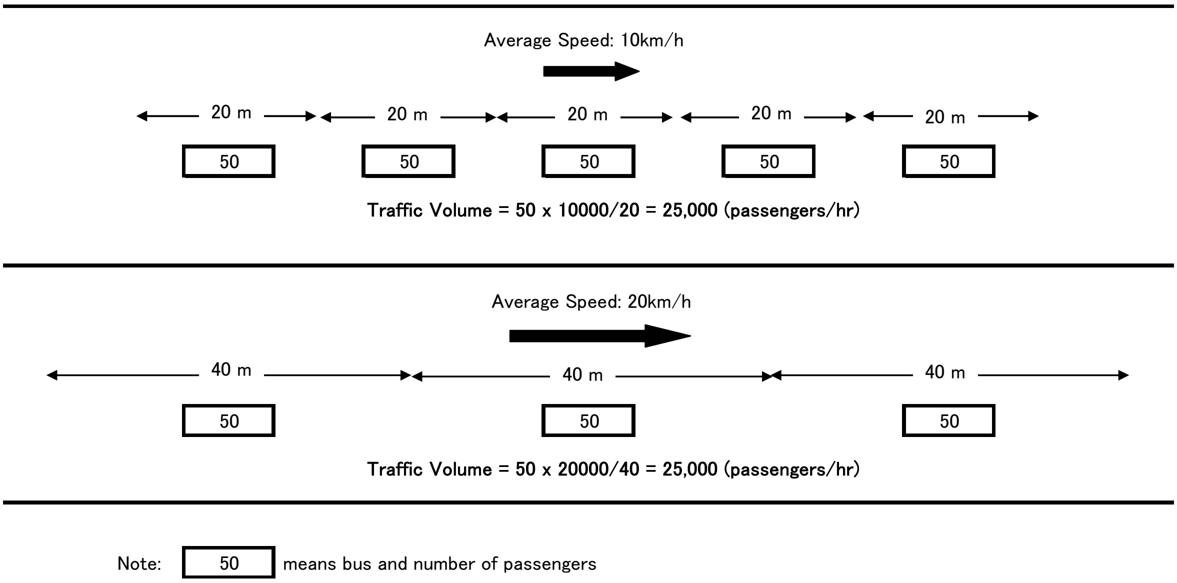
Due to the limitation of the train length, São Paulo Metro tried to shorten the headway and to increase the capacity when the demand increased more than the estimate. In these days São Paulo Metro is operating or trying to operate 90 seconds headway at the peak hour, and 76 seconds headway operation has been planned by using moving block signal system. By the shortening of headway, PHPDT has been increased, however, due to the congestion of the line itself, the scheduled speed decreased accordingly. One of the reasons of this attempt to shorten the headway is the limited space of platform. São Paulo Metro needs to put passengers in to trains to avoid overflow from station platforms.

The same situation can be seen in BRT operation in trunk lines. It is reported that PHPDT of BRT in the area of Line-2A (between Jardim Angela and Santo Amaro) in São Paulo is 25,000 approximately in the morning peak hours. However, the scheduled speed is less than 10 km/h due to heavy congestion of the road as shown in the Figure 4-4. In other wards, because the scheduled speed is quite low, PHPDT can reach to 25,000.

Source: JICA Study Team

Figure 4-4 Congestion at M'Boi Mirim

This fact can be explained by the following simplified model;



Source: JICA Study Team

Figure 4-5 BRT's Average Speed and PHPDT

If buses, which carry 50 passengers each, are running at an average speed of 10km/h in every 20 m (every 7.2 sec), PHPDT at a section is calculated as follows;

- PHPDT (10km/h) = 50 (passengers) x 10 km /20 m = 25,000

In this case, the Passenger-km is 250,000.

When same buses are running at an average speed of 20km/h in every 40 m (every 7.2 sec), PHPDT can be calculated as follows;

- PHPDT (20km/h) = 50 (passengers) x 20km/40 m = 25,000

In this case, because of the higher average speed, the Passenger-km becomes 500,000.

The above calculations mean that, even PHPDT is same, the transport capacity in the sense of "Passenger-km" changes depending on the scheduled speed. The cause of the existing traffic congestion at Jardim Angela – Santo Amaro seems to be too many buses exceeding the capacity of the road.

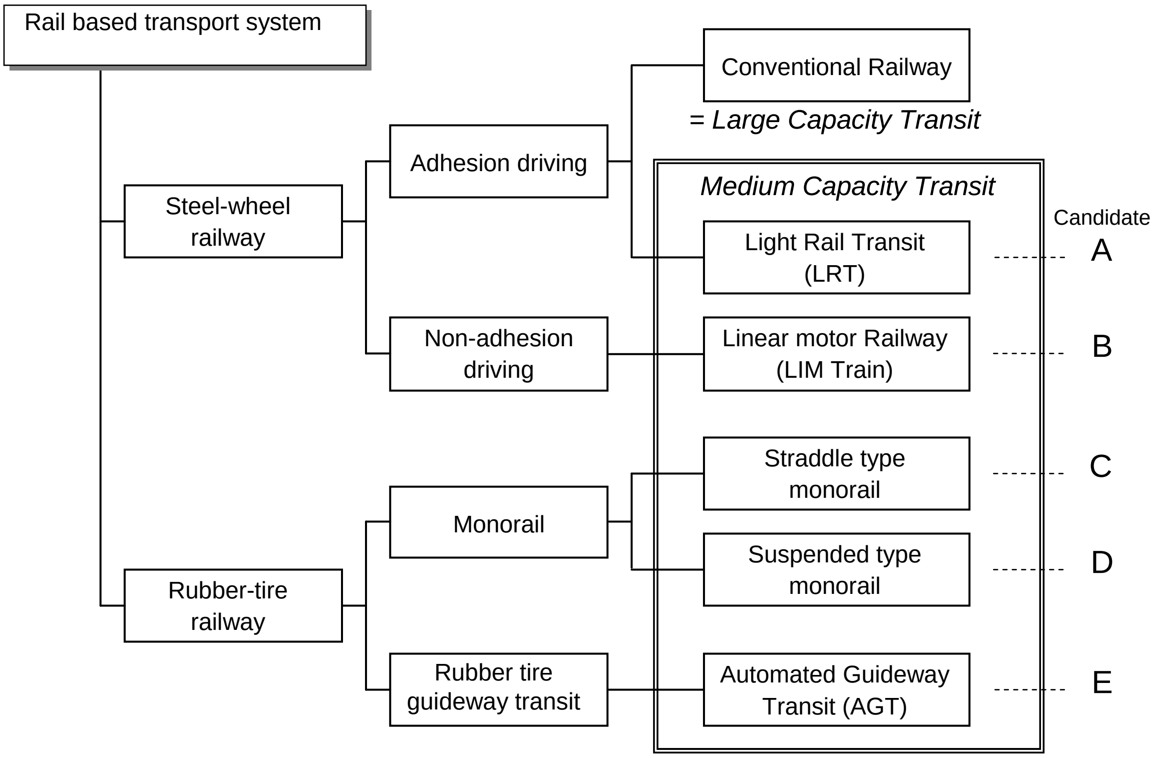
Passenger density is another factor for the planning of urban transit system. According to the information from São Paulo Metro, 6 passengers/m^2 is their planned maximum density. The actual observation at the morning peak hour is also proving the said density. However, the CPTM trains are operating in higher density due to the longer headway and longer operating distance. According to the information from CPTM, the passenger density sometime exceeds 10 passengers/m^2 at some section.

Based on the abovementioned situation in São Paulo, when planning a medium capacity transit system, the following factors shall be considered to design the transit capacity;

- Future demand
- Operation headway
- Passenger density (passengers/m2)

4.2.4 Candidate of the system

The rail based transit system which is introduced in the various cities in the world is classified as shown in Figure 4-6. The medium capacity transit system which will be introduced into São Paulo is selected from the following candidate A to E.



Source: JICA Study Team

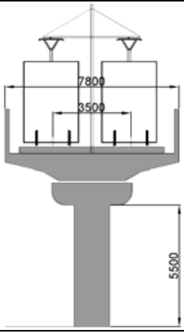
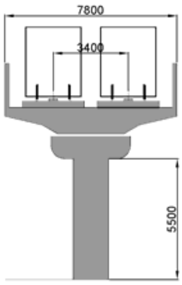
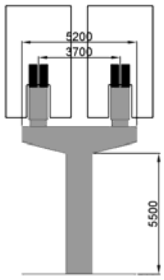
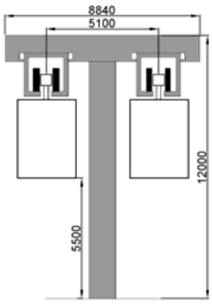
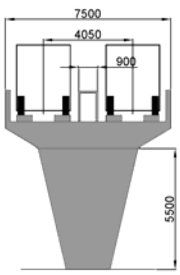
Figure 4-6 Candidate of the Medium Capacity Transit System

4.2.5 Selection of applicable system

The track structure of the transit system is mainly installed above the road space by constructing the piers in the median strip of the road. Also, the station building is constructed as elevated structure above the road. The average distance between stations is about 880m and is shorter than that of Metro.

Main features of each candidate and operational performance and capacity are described in Table 4-8 and Table 4-9, respectively.

Table 4-8 Main Features of Each Candidate

	Appearance	Example of track structure	Remarks
A	LRT 		<u>Features;</u> The track can be installed in the carriageway and/or the exclusive space on the ground. Also, this system can adapt to viaduct and underground. <u>Structure;</u> In case of elevated structure, track structure consists of the concrete slab, steel rail and piers. Steel rail is set on the elevated concrete slab. For overhead line, electric pole is required.
B	LIM Train 		<u>Features;</u> The traction power is produced by the linear motor and the reaction plate, which are equipped on the bogie and track, respectively. Steel wheel and rail are used for guide and supporting of load. <u>Structure;</u> Track structure consists of the concrete slab, steel rail, reaction plate and piers. Reaction plate is set accurately between rails of each track on the elevated concrete slab.
C	Straddle type Monorail 		<u>Features;</u> The vehicle straddles and runs on the track beam constructed on the space above the road by rubber tire. <u>Structure;</u> Track structure is I and/or Box-shape slender beam. Only the slender track beams are installed on the piers as the concrete structure. The elevated slab is not required except switch bridges and stations.
D	Suspended type Monorail 		<u>Features;</u> The vehicle is suspended from the track beam constructed on the space above the road and runs by rubber tire. <u>Structure;</u> Track structure is Box-shape beam. The structure is higher than that of other systems because the train is suspended. The elevated slab is not required except stations. Generally, the structure is made of steel.
E	AGT 		<u>Features;</u> The vehicle runs on the exclusive track constructed by concrete slab by rubber tire. <u>Structure;</u> Track structure consists of concrete slab. Road surface for train is set accurately on the elevated concrete slab.

Source: JICA Study Team

Table 4-9 Operational Performance and Capacity

	LRT	LIM Train	Straddle type monorail	Suspended type monorail	AGT
Size					
Dimensions (L x W x H) (m)	53.4 x 2.45 x 3.65 (9 cars-train)	16.0 x 2.50 x 3.15 (Car)	15.0 x 2.98 x 5.2 (Car)	15.0 x 2.65 x 4.8 (Car)	9.0 x 2.47 x 3.34 (Car)
Train length (m)	53.4m / 9cars	96m / 6cars	90m / 6cars	90m / 6cars	54m / 6cars
Axle load	10 tons (100KN) 10 axles per 9 cars-train	11 tons (110KN) 4 axles per car	11 tons (110KN) 4 axles per car	8.5 tons (85KN) 4 axles per car	9 tons (90KN) 2 axles per car
Operational Performance in Main line					
Minimum Curve	R=20m	R=100m	R=60m	R=50m	R=50m
Maximum Gradient	i = 40‰	i = 60‰	i = 60‰	i = 60‰	i = 60‰
Transport Capacity					
Passengers per train	430	980	1,000	710	470
PHPDT by 180 sec headway	8,600 PHPDT	19,600 PHPDT	20,000 PHPDT	14,200 PHPDT	9,400 PHPDT
by 120 sec headway	12,900 PHPDT	29,400 PHPDT	30,000 PHPDT	21,300 PHPDT	14,100 PHPDT

Note) As for transport capacity, standing capacity under full loaded condition is assumed as 6 standees per m^2.
Source: JICA Study Team

4.2.6 Proposed system

The suitability of the candidate systems – light rail transit (LRT), linear motor railway (LIM) straddle type monorail, suspended type monorail, and automated guideway transit (AGT) – was assessed in view of the route conditions of capacity, gradient, alignment, and impact of street trees.

(1) Line-1

The major precondition of the system selection for Line-1 is follow:

- Line-1 is proposed to be extended from Capao Redondo to Vila Sonia. The system should consider the future extension.
- Line-1 goes through a steep grade section.
- Passenger demand of Line-1 is estimated as approximately 14,000 - 20,000 PHPDT.
- The road along the route is narrow and winding.

LRT cannot be selected as the proposed system because of the second and the third condition. LIM cannot be selected due to the last condition considering the minimum curvature of LIM is 100m. AGT are not suitable to satisfy the demand. Therefore, straddle type monorail and suspended type monorail, which can cover the passenger demand, are the possible system for Line-1. The proposed system should be selected from these systems considering the connection with Line-2A.

Table 4-10 System Assessment of Line-1

	LRT	LIM	Straddle type Monorail	Suspended type Monorail	AGT
Capacity	C	A	A	A	C
Gradient	---	A	A	A	A
Alignment	A	C	A	A	A
Street trees	N.A.	N.A.	N.A.	N.A.	N.A.

Note: A= Satisfactory, B= Possible, C= Difficult and not recommendable, -- = Not possible, N.A.= No relation
Source: JICA Study Team

(2) Line-2A

The major precondition of Line-2A for the system selection is:

- The future demand would be relatively high at approximately 23,000 -35,000PHPDT.
- There are steep grade sections on M'Boi Mirim Road.

LRT cannot be selected because of the steep grade sections, and suspended type monorail and AGT are not suitable to satisfy the demand. LIM and straddle type monorail will be able to satisfy the conditions above, and these two systems are the possible systems for Line-2A.

Table 4-11 System Assessment of Line-2A

	LRT	LIM	Straddle type Monorail	Suspended type Monorail	AGT
Capacity	--	A	A	C	C
Gradient	--	A	A	A	A
Alignment	A	A	A	A	A
Street trees	N.A.	N.A.	N.A.	N.A.	N.A.

Note: A= Satisfactory, B= Possible, C= Difficult and not recommendable, -- = Not possible, N.A. = No relation
Source: JICA Study Team

(3) Line-2B

The major precondition of Line-2B for the system selection is:

- The roads along the route are flat.
- The future demand would be relatively high at approximately 23,000 - 30,000 PHPDT.
- The route needs sharp curves at intersections of roads.
- The street view along Line-2B is good with modern business and commercial buildings and street trees.

LRT, suspended type monorail, and AGT are not suitable for Line-2B because these systems cannot satisfy the demand, while LIM and straddle type monorail can. Line-2B uses many roads and some roads are cross at a sharp angle. Since the minimum curvature of LIM is larger than that of straddle type monorail, the alignment condition is unfavorable to LIM. In view of cityscape, straddle type monorail is better than LIM because the beam structure of monorail is not as depressing as the slab structure of LIM. Therefore, straddle type monorail is the proposed system for Line-2B.

Table 4-12 System Assessment of Line-2B

	LRT	LIM	Straddle type Monorail	Suspended type Monorail	AGT
Capacity	--	A	A	C	C
Gradient	A	A	A	A	A
Alignment	A	B	A	A	A
Street trees	C	C	B	B	C

Note: A= Satisfactory, B= Possible, C= Difficult and not recommendable, -- = Not possible, N.A. = No relation
Source: JICA Study Team

(4) Line-2C

The major precondition of Line-2C for the system selection is:

- The future demand is approximately 5,000 PHPDT.
- Street trees on the median of the road form a beautiful view along the route. The impact on the trees should be minimized.
- There are two right angle curves along the route.

LIM is not suitable for Line-2C because of the sharp curves at the corner of cemetery and the intersection of Reboucas Ave. Since the cityscape with street trees is an important condition of this route, monorail is more favorable than LRT and AGT.

Table 4-13 System Assessment of Line-2C

	LRT	LIM	Straddle type Monorail	Suspended type Monorail	AGT
Capacity	A	A	A	A	A
Gradient	A	A	A	A	A
Alignment	A	C	A	A	A
Street trees	B	B	A	A	B

Note: A= Satisfactory, B= Possible, C= Difficult and not recommendable, -- = Not possible, N.A. = Not relation
Source: JICA Study Team

(5) Line-2D

The major precondition of Line-2D for the system selection is:

- The future demand is 13,000 – 20,000 PHPDT.
- There are many street trees along the road in the university. The impact on the trees should be minimized.
- Line-2D crosses the river at three locations.
- A small radius is required for the corners of the routes.

LRT and AGT are not suitable to satisfy the demand. LIM is not suitable because of the requirement of the minimum curvature. The two types of monorail are possible for this route and are advantageous for this route considering the impact on cityscape as well.

Table 4-14 System Assessment of Line-2D

	LRT	LIM	Straddle type Monorail	Suspended type Monorail	AGT
Capacity	C	A	A	A	C
Gradient	A	A	A	A	A
Alignment	A	C	A	A	A
Street trees	B	B	A	A	B

Note: A= Satisfactory, B= Possible, C= Difficult and not recommendable, -- = Not possible, N.A. = No relation
Source: JICA Study Team

4.2.7 Summary of the assessment

The results of the assessment above are summarized as shown in Table 4-15. It is necessary to consider integration of each line so that through operation is possible. From this, the straddle type monorail is proposed for Line-2A, 2B, 2C and 2D. In addition to the straddle type monorail and suspended type monorail can be proposed for Line-1. Considering the location of depot, it is recommended to select the same type of Line-2A for Line-1 because the available area for the depot is limited.

Table 4-15 Proposed System by Line

Line	Length	Proposed System	Network	Proposed System considering network
1	4.15 km	- Straddle type monorail - Suspended type monorail	Future extension up to Vila Sonia	Straddle type monorail, or Suspended type monorail
2A	11.38km	- LIM train - Straddle type monorail	Integrated line	Straddle type monorail
2B	11.29km	- Straddle type monorail - LIM train		
2C	7.23km	- Straddle type monorail - Suspended type monorail	Through operation with 2B	
2D	11.40km	- Straddle type monorail - Suspended type monorail	Through operation with 2B	

Source: JICA Study Team

As a consequence, Straddle type monorail is selected as the suitable medium capacity transport system for São Paulo.

4.3 TRANSPORT PLAN

4.3.1 Operating policy

The operation policy of the straddle type monorail (hereinafter referred as "Monorail") system is to make medium capacity transit services more attractive to and economical for users, the main features being:

1) Selecting the optimum frequency of train services to provide sectional capacity commensurate with the demand during peak hours on most of the sections;
2) Frequent operation like Metro is performed especially in Line-2A and Line-2B where big demands are forecasted;
3) A maximum train service frequency in peak period is designed as 6 minutes. If an estimated train service frequency in peak period exceeds 6 minutes, it shall be shortened to 6 minutes; and
4) Providing a minimum train service frequency during off-peak period (10 minutes headway) so as to keep the service attractive during off-peak periods also.

4.3.2 Premise of transport plan

(1) Phasing and opening year

Monorail has been selected as the suitable medium capacity transport system for São Paulo. Construction of the Monorail is a matter of urgency to ameliorate the traffic condition of corridors, especially of M'Boi Mirin Road. However, since the proposed route length exceeds 50km, the Monorail construction shall be phased according to the priority from the viewpoint of demand. As for phasing, the following 3 phases are proposed.

1) Phase 1

Section: Line-1 + Line-2A
Open Year: 2014

Operation between Jardim Angela and Santo Amaro, Jardim Angela and Capao Redondo will be commenced on the year 2014.

2) Phase 2

Section: Line-1 + Line-2A + Line-2B + Line-2D
Open Year: 2016

A section between Line-2B and Line-2D will be extended on the year 2016. From the viewpoint of the demand forecast, Line-2D has a priority than Line-2C.

3) Phase 3

Section: Line-1 + Line-2A + Line-2B + Line-2C + Line-2D
Open Year: 2018

On the year 2018, Line-2C is extended.

(2) Service

Scheduled speed: 30 km/h
Dwell time at the station: 20 seconds
Minimum headway: 120 seconds
Period of business hours: 19 hours from 5:00 a.m. to 24:00 p.m.

The conditions for attaining the service of frequent operation with the scheduled speed of 30km/h are shown below.

1) Attaining the scheduled speed of 30km/h

Although a dwell-time at the station is assumed as 20 seconds, performing of readjustment based on the actual demand of each station is recommendable to shorten the time. Moreover, improvement of scheduled speed is performed by raising the acceleration of train, if needed.

In addition, although the small radius curve sections and/or steep gradient sections, which utilize the characteristic of monorail exists in a route, as for alignment, avoiding of the scheduled speed deterioration is taken into consideration as described below. Therefore, it is desirable to reflect the conditions taken into consideration by this study when the actual alignment is set up.

a) The passage speed of the curve with a radius of R=100m which is the minimum curve radius of main line is 45km/h. When unavoidable, the curve with a radius of R=50m is applied, and the passage speed falls to 25km/h. Here, above speeds are based on the conditions applying 12% of the maximum superelevation and 5% of the maximum deficiency of superelevation. In this study, in order to improve the scheduled speed, the curve radii were set as large as possible. In addition, although an R=50m curve and two of R=60m curves unavoidably exist, the insertion points of curves were made close to the stations in order to minimize the influence of speed restriction by curves.

b) For the intermediate stations, the separate type platform is planned. The separate type platform station does not have the S shape curve of the tracks at back and forth the station unlike an island type platform station. So, the separated type platform is advantageous to improve the scheduled speed.

c) Regarding the vertical alignment, the maximum gradient is 6%. And when it is unavoidable, 8% is allowed. As for the vehicle performance in the section of 8% of gradient, acceleration is decreased to 1/4 compared with flat section, and velocity balances at about 30km/h. However, in this study, it is only 2 sections of 300m section of Line-1 and 144m section of Line-2C that the gradient which exceeds 6% is applied. Moreover, although the gradient section which does not exceed 6% exists at several locations, the balanced velocity exceeds 30km/h in these sections.

2) Attaining the frequent operation

The operation headway is affected by the train length, the acceleration/deceleration ratio, the approaching speed to a station, and the dwelling time at a station. Furthermore, the headway is restricted due to the time for turning back of a train. Especially, in case of Monorail system, 20 seconds are required for switching a point machine and it is longer than that of the conventional railway. In order to perform the stabilized and frequent train operation with less than 3 minutes headway, it is necessary to install the advanced traffic signal control system and traffic management system, and accumulate operators' experiences.

As a facility for attaining the frequent train operation, in this study, CBTC is proposed for the signaling system. And the turn back facility which is described below is required as well. The turn back facilities are installed at two major intermediate stations and end stations of each phase. And train operates under the two patterns, one is operating between intermediate stations and the other is operating between two end stations. The train turned back at an end station is inserted in the operation interval of the train turned back in an intermediate station.

Moreover, as an operational ingenuity, when the train proceed to a tail track or a draw-out track for turning back, a next driver stands by at the driver's cabin at the backside of the train to shorten the time of turning back.

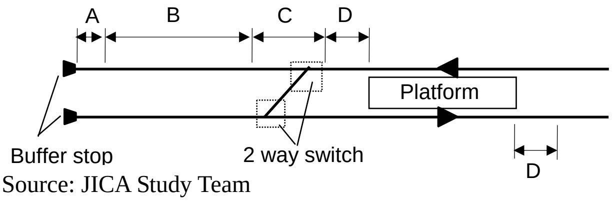
(3) Turn back facility and operation headway

The turn back facilities and the emergency crossovers are installed according to the train operation plan of each phase. As for the turn back facility, the possibilities of the future extension of the route is also taken into account, and the following 3 types are applied. The time needed to turn back the train by each facility is estimated as described below.

1) Single crossover

As the turn back facility at the end of the tracks, the single crossovers can be set. A skeleton of this facility is shown in Figure 4-7. When the route is extended, the role of this facility will change to the emergency crossover.

As for this facility, the time needed to turn back the train is assumed to be 4 minutes including the time for passengers' alighting and boarding.



Mark	Item
A	Safety margin for overrun
B	Signal block + tolerances
C	Switches
D	Safety margin for overrun

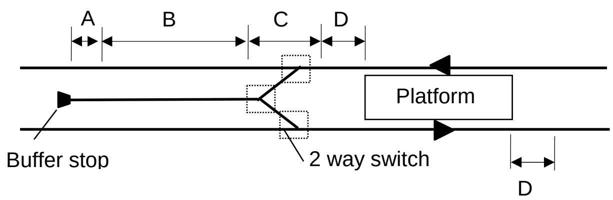
Source: JICA Study Team

Figure 4-7 Single Crossover

2) Y-shaped draw-out track

As the turn back facility adjoining the middle station, Y-shaped draw-out track is used. By this facility, train can turn at the middle station without disturbing to other train operation in main line. Figure 4-8 shows a skeleton of this facility.

The time needed to turn back the train is assumed to be 4 minutes and 20 seconds. By using standby train and turning back in the intervals of the trains which are operating on the main line, 120 seconds headway operation will be attained.



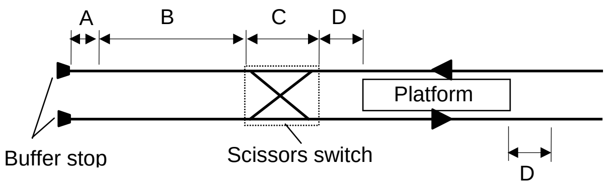
Mark	Item
A	Safety margin for overrun
B	Signal block + tolerances
C	Switches
D	Safety margin for overrun

Source: JICA Study Team

Figure 4-8 Y-shaped Draw Out Track

3) Scissors crossing

Same as the single crossover, the scissors crossing is installed adjoining the end station. By using this facility, both of tail track can store the train, so, this facility is applied at the end stations distant from the depot and the stabling yard. This facility has a capability to attain 150 seconds headway operation.



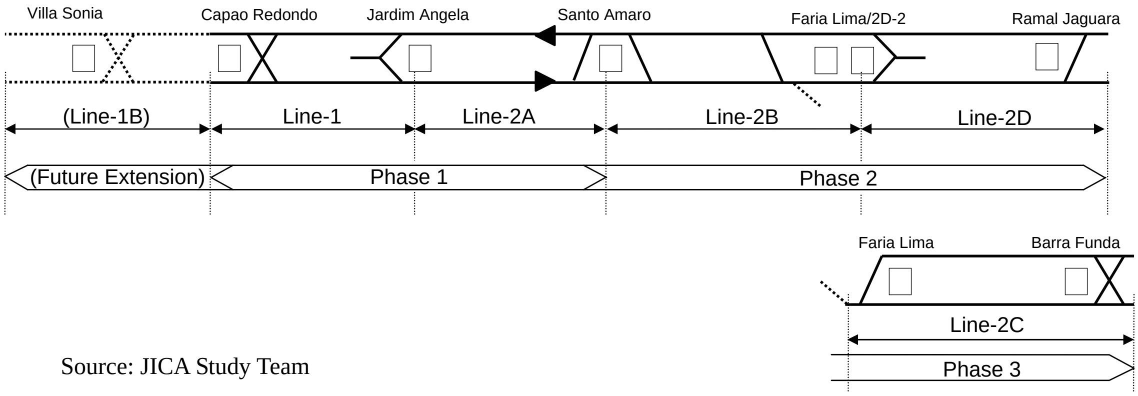
Mark	Item
A	Safety margin for overrun
B	Signal block + tolerances
C	Switches
D	Safety margin for overrun

Source: JICA Study Team

Figure 4-9 Scissors Crossing

(4) Track layout

Layout of the turn back facility is shown in Figure 4-10 and is described in Table 4-16.



Source: JICA Study Team

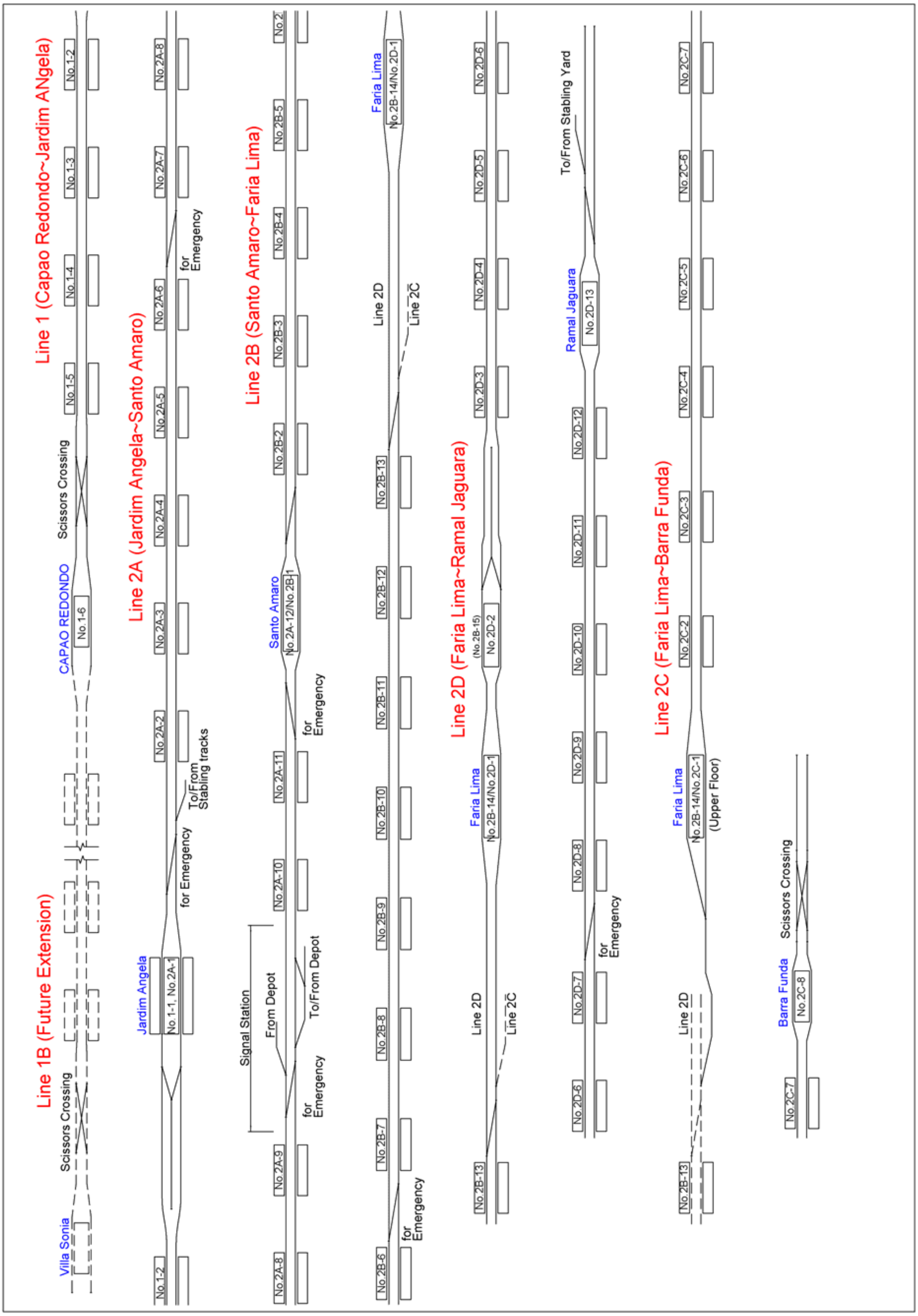
Figure 4-10 Turn Back Facility Layout

Table 4-16 Turn Back Facility Location

Phase	Location	Facility
Phase 1	Capao Redondo (No.1-6)	A scissors crossing is installed. Since the alignment of backside of Capao Redondo station has a small curve and steep gradient, the turn back facility is located before the station.
	Jardim Angela (No.2A-1)	A turn back facility for arrival trains from Santo Amaro side is installed.
	Santo Amaro (No.2A-12)	A crossover is installed after the station.
	Others	Crossovers for emergency use for 4 locations
Phase 2	No.2D-2 station	A turn back facility for arrival trains from Santo Amaro side is installed. An end station of Line-2B is No.2B-14 which is a junction station of Line-2D and Line-2C. Since the station size of No.2B-14 is large, a turn back facility is installed not at No.2B-14 but at No.2D-2.
	Ramal Jaguara (No.2D-13)	A crossover is installed after the station.
	Between No.2B-13 and No.2B-14	A crossover is installed for the deadhead train to Line-2C.
	Others	Crossovers for emergency use for 2 locations
Phase 3	Barra Funda (Line-2D)	A turn back facility for arrival trains from Santo Amaro side is installed. In order to enable the train stabling in any tail track in night-time, a scissors crossing is installed after the No.2C-8 station.
Future Extension	Villa Sonia (Line-1B)	A scissors crossing is installed. Other crossovers in Line-1B shall be considered further design stage.

Source: JICA Study Team

Figure 4-11 shows a track layout of whole line.



Source: JICA Study Team

Figure 4-11 Track Layout

4.3.3 Operation pattern

(1) Summary

The summary of this section is as follows;

1) Train capacity

Regarding the density of the standing passengers under the full load condition, 6 standees per m^2 is applied basically in accordance with the design condition of Metro. Under this condition, transport capacity of 6-car train and 8-car train are 1,000 and 1,300 passengers per train, respectively.

From the technical point of view, the Monorail which has 4 axles per car allows 9 standees per m^2 under the crash load condition. Density of 6 standees per m^2 is the target figure for operation plan providing the comfortable ride and is not an actual transport capacity.

2) Features for operation

In Phase 3, Line-2C is extended. However, since the Line-2B performs frequent operation, the train operation of Line-2C is separated from that of Line-2B in order to avoid disturbing of Line-2B. Thus, direct train operation between Line-2B and Line-2C is not planned.

3) Headway in peak period in peak section

Phase 1: 2 minutes 30 seconds (Line-1)
Phase 2: 2 minutes 15 seconds (Line-2A, 2B)
Phase 3 (by 2024): 2 minutes 45 seconds (Line-2A, 2B)
Phase 3 (After 2025): 2 minutes 30 seconds (Line-2A, 2B)

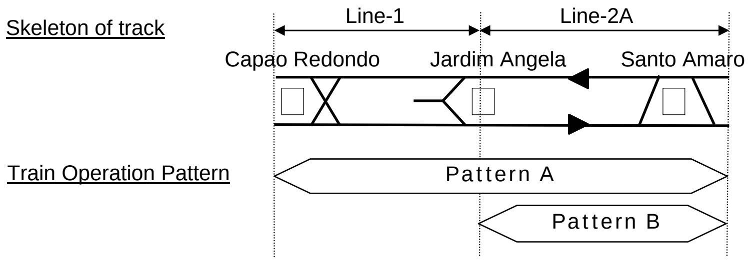
4) Train configuration

Phase 1: Monorail operation is started by using 6-car trains.
Phase 2: Added to Phase 1, 8-car trains are installed.
Phase 3: In Line-1, 2A, 2B, and 2D, trains are unified to 8-car train.
6-car train will remain only for Line-2C.

(2) Phase 1

Phase 1 is commenced on the year 2014. Table 4-17 and Table 4-18 show the train operation pattern and the transport capacity of Phase 1. As for train operation, two patterns of A and B described below are applied. Between Jardim Angela and Santo Amaro, operation headway in peak hour is about 2 minutes 20 seconds by 6-car train.

Table 4-17 Train Operation Pattern in Peak Hour of Phase 1



Pattern	Section	Train Configuration	Headway	Number of train operations per hour (trains/hr./direction)	Transport Capacity (PHPDT)
A	Capao Redondo -Santo Amaro	6-car train	4 min 00 sec	15	15,000
B	Jardim Angela -Santo Amaro	6-car train	6 min 30 sec	10	10,000

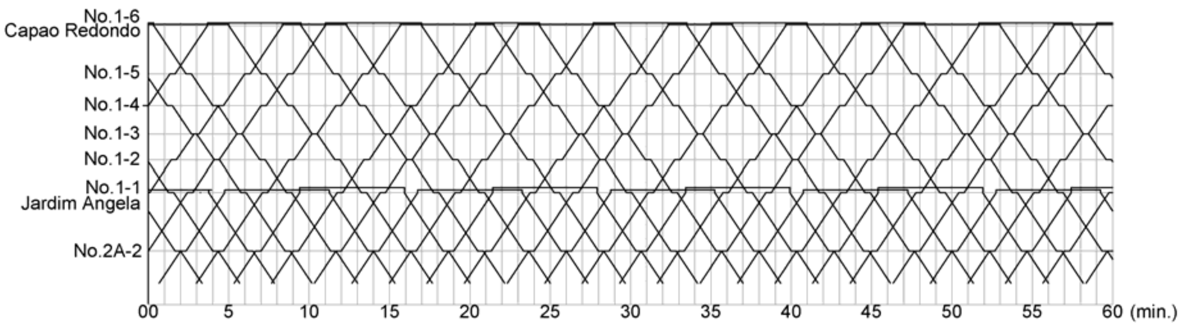
Source: JICA Study Team

Table 4-18 Capacity and Headway by Line

Line	Line-1	Line-2A
Section	Capao Redondo~ Jardim Angela	Jardim Angela~ Santo Amaro
Number of trains (trains/hour/direction)	15	25.
Headway	4 min 00sec	2min 20sec
Capacity (PHPDT)	15,000	25,000

Source: JICA Study Team

An example of the train operation diagram between No.2A-2 and No.1-6 stations of Phase 1 is shown in Figure 4-12. Trains which are operating on Pattern B turn at No.1-1 station.



Source: JICA Study Team

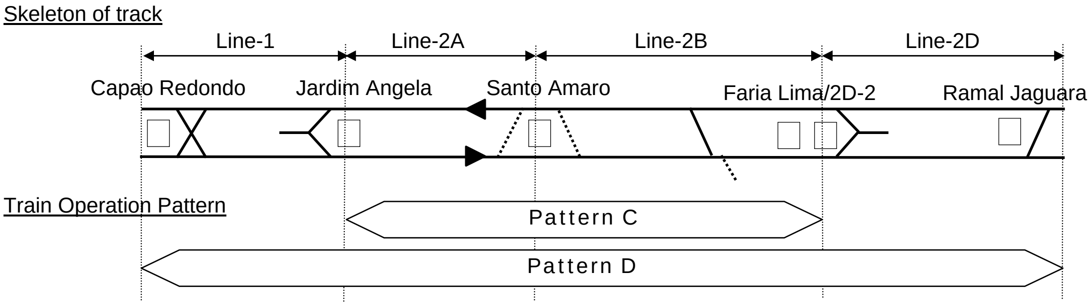
Figure 4-12 Example of Train Operation Diagram of Phase 1

(3) Phase 2

On the year 2016, Line-2B and Line-2D will be added to the Phase 1 and the Phase 2 will be commenced. Although the following phase, the Phase 3, will perform in the year 2018, introduction of 8–car train is started in phase 2 by taking into account of the future demand which exceeds 30,000PHPDT.

Table 4-19 and Table 4-20 show the train operation pattern and the transport capacity of the Phase 2. The Pattern C is 4 minutes 15 seconds headway by 6-car train, and the Pattern D is 5 minutes headway by 8-car train. The section between Jardim Angela and Faria Lima, train operates every 2 minutes 15 seconds.

Table 4-19 Train Operation Pattern in Peak Hour of Phase 2



Pattern	Section	Train Configuration	Headway	Number of train operations per hour (trains/hr./direction)	Transport Capacity (PHPDT)
C	Jardim Angela - Faria Lima(2D-2)	6-car train	4 min 15 sec	14	14,000
D	Capao Redondo – Ramal Jaguara	8-car train	5 min 00 sec	12	15,600

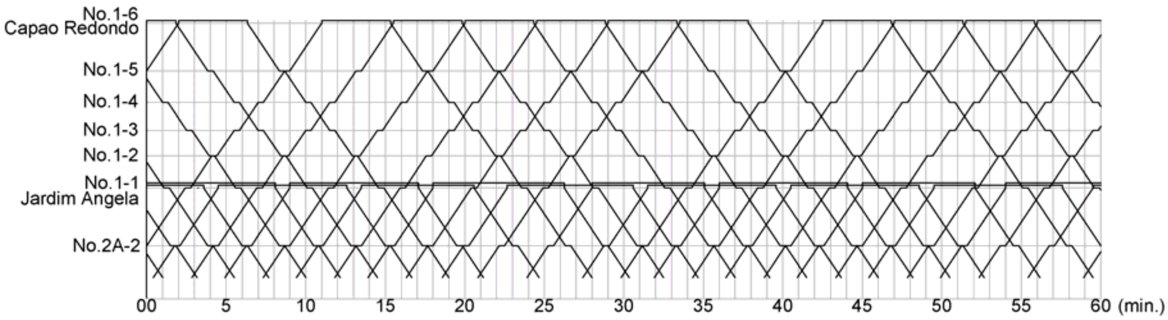
Source: JICA Study Team

Table 4-20 Capacity and Headway by Line

Line	Line-1	Line-2A, Line-2B	Line-2D
Section	Capao Redondo~ Jardim Angela	Jardim Angela~ Faria Lima	Faria Lime~ Ramal Jaguara
Number of trains (trains/hour/direction)	12	26	12
Headway	5 min 00sec	2min 15sec	5 min 00sec
Capacity (PHPDT)	15,600	29,600	15,600

Source: JICA Study Team

An example of the train operation diagram between No.2A-2 and No.1-6 stations of Phase 2 is shown in Figure 4-13. Trains which are operating on Pattern C turn at No.1-1 station.



Source: JICA Study Team

Figure 4-13 Example of Train Operation Diagram of Phase 2

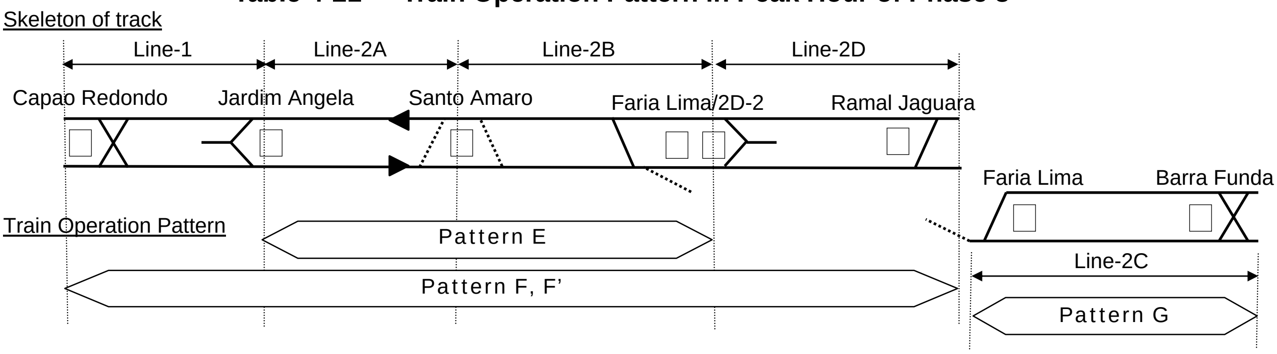
(4) Phase 3

On the year 2018, Line-2C will be added to the Phase 2 and the Phase 3 will be commenced. Since the future demand of Line-2A exceeds 30,000PHPDT, all trains which are operating in Line-2A are 8-car train, instead of 6-car train. As for Line-2C, the train operates the inside of Line-2C as shuttle service by 6-car train. The direct train operation between Line-2B, 2D and Line-2C is not considered.

Table 4-21 and Table 4-22 show the train operation pattern and the transport capacity of Phase 3. The train operation Pattern F performs 12 trains operation per hour per direction between Capao Redondo and Ramal Jaguara. After 2025, the train operation Pattern F is changed to F', and the number of trains is increased to 14.

Between Jardim Angela and Faria Lima, train operates every 2 minutes 45 seconds, up to 2024. After 2025, the headway is shortened to 2 minutes 30 seconds.

Table 4-21 Train Operation Pattern in Peak Hour of Phase 3



Pattern	Section	Train Configuration	Headway	Number of train operations per hour (trains/hr./direction)	Transport Capacity (PHPDT)
E	Jardim Angela – Faria Lima(2D-2)	8-car train	6 min 00 sec	10	13,000
F (Up tp 2024)	Capao Redondo – Ramal Jaguara	8-car train	5 min 00 sec	12	15,600
F' (After 2025)			4 min 15 sec	14	18,200
G	Faria Lima - Barra Funda	6-car train	6 min 00 sec	10	10,000

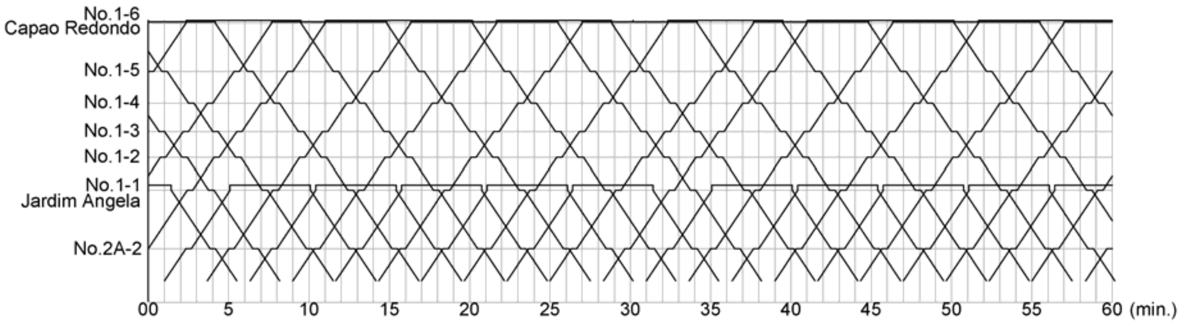
Source: JICA Study Team

Table 4-22 Capacity and Headway by Line

	Line	Line-1	Line-2A, Line-2B	Line-2D	Line-2C
	Section	Capao Redondo~ Jardim Angela	Jardim Angela~ Faria Lima	Faria Lime~ Ramal Jaguara	Faria Lima~ Barra Funda
Up to 2024	Number of trains (trains/hour/direction)	12	22	12	10.
	Headway	5 min 00sec	2 min 45sec	4 min 15sec	6 min 00sec
	Capacity (PHPDT)	15,600	28,600	15,600	10,000
After 2025	Number of trains	14	24	14	10
	Headway	4 min 15sec	2 min 30sec	4 min 15sec	6 min 00sec
	Capacity	18,200	31,200	18,200	10,000

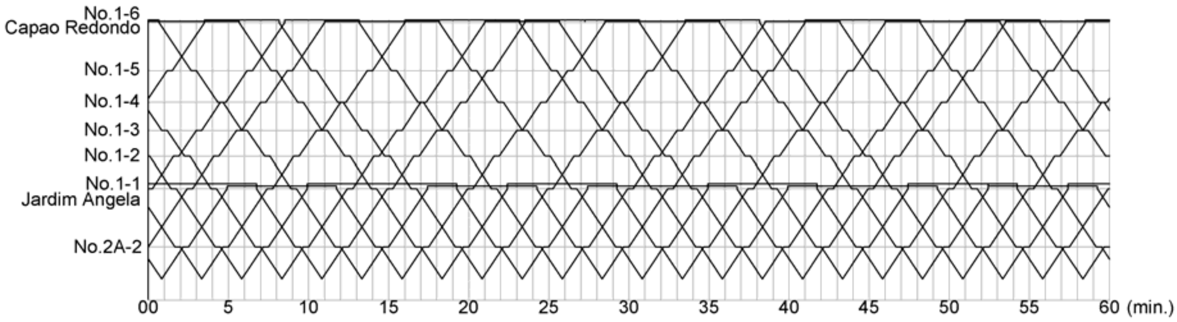
Source: JICA Study Team

An example of the train operation diagram between No.2A-2 and No.1-6 stations of Phase 3 is shown in Figure 4-14 and Figure 4-15. Trains which are operating on Pattern E turns at No.1-1 station.



Source: JICA Study Team

Figure 4-14 Example of Train Operation Diagram of Phase 3 up to 2024



Source: JICA Study Team

Figure 4-15 Example of Train Operation Diagram of Phase 3 after 2025

4.3.4 Required number of trains

A required train consists of the train sets for operation and spare trains.

a) A train number for operation is calculated from the cycle time and operation headway by each operation pattern. The cycle time is the amount of time needed to make a round-trip by train in their operation section by each operation pattern.

b) The spare train consists of the spare for maintenance and the spare for operation. The number of spare train sets is assumed to 10% of the number of operation trains.

Specifically, the required train number of Phase 1 is calculated as follows.

a) The cycle time of Pattern A is 67 minutes including the time of turning-back, and the headway is 4 minutes. The number of train sets for operation is calculated to 67 / 4 = 17 trains.

b) The cycle time of Pattern B is 51 minutes including the time of turning-back, and the headway is 6 minutes. The number of train sets for operation is calculated to 51 / 6 = 9 trains.

c) In phase I, 26 train sets are required for operation of patterns A and B. Due to addition of 3 spare train sets, the total amount of required number becomes 29 train sets.

Similarly, the total amounts of required number of Phase 2 and Phase 3 are estimated as shown in below.

Table 4-23 Number of Trains

Phase	Year			6-car train	8-car train	Remarks
1	2014	Operation	Pattern A	17	--	Total number of trains is 29. 29 sets of 6-car train are required for phase 1. (29 x 6 = 174 cars are purchased)
			Pattern B	9	--	
			Subtotal	26	0	
		Spare		3	0	
		Total		29	0	
2	2016	Operation	Pattern C	24	--	Total number of trains is 61. 3 sets of 6-car train are converted to 8-car train. 32 sets of 8-car train are added. (2 middle car x 3 + 8 x 32 = 262 cars are purchased)
			Pattern D	--	32	
			Subtotal	24	32	
		Spare		2	3	
		Total		26	35	
3	2018	Operation	Pattern E	--	17	Total number of trains is 61. 19 sets of 6-car train are converted to 8-car train. (2 middle car x 19 = 38 cars are purchased)
			Pattern F	--	32	
			Pattern G	6	--	
			Subtotal	6	49	
		Spare		1	5	
		Total		7	54	
	2025	Operation	Pattern E	--	17	Total number of trains is 67. 6 sets of 8-car train are added. (8 x 6 = 48 cars are purchased)
			Pattern F’	--	37	
			Pattern G	6	--	
			Subtotal	6	54	
		Spare		1	6	
		Total		7	60	

Source: JICA Study Team

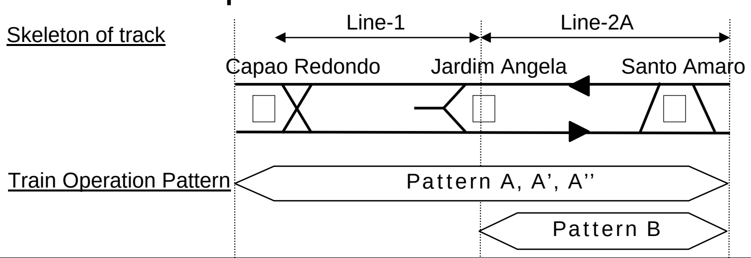
4.3.5 Additional Case 1 (Phase 1 up to 2045 W/O extension)

When extension of Phase 2 is not performed and Monorail operation continues by the section of phase 1 up to year 2045, the train operation pattern and the number of trains are estimated as follows.

(1) Operation Pattern

In Phase 1, the transport capacity by operation Patterns of A and B can cover the demand up to year 2020. In order to cover the future demand, operation headway of Pattern A is shortened to 3 minutes 20 seconds on the year 2020, and to 3 minutes and 10 minutes on the year 2040. However, on the year 2020, expansion of the turn back facility of Santo Amaro side is required.

Table 4-24 Train Operation Pattern in Peak Hour of Additional Case 1



Period	Pattern	Train configuration	Headway	Number of train operations per hour (trains/hr./direction)	Transport Capacity (PHPDT)
2014~2019	A	6-car train	4 min 00sec	15	15,000
2020~2039	A'	6-car train	3 min 20sec	18	18,000
2040~2045	A''	6-car train	3 min 00sec	20	20,000
2014~2045	B	6-car train	6 min 00sec	10	10,000

Source: JICA Study Team

Table 4-25 Capacity and Headway by Line

Period	Line name	Line-1	Line-2A
	Section	Capao Redondo~ Jardim Angela	Jardim Angela~ Santo Amaro
2014~2019	Number of trains (trains/hour/direction)	15	25
	Headway	4 min 00sec	2min 20sec
	Capacity (PHPDT)	15,000	25,000
2020~2039	Number of trains	18	28
	Headway	3 min 20sec	2min 10sec
	Capacity	18,000	28,000
2040~2045	Number of trains	20	30
	Headway	3 min 00sec	2min 00sec
	Capacity	20,000	30,000

Source: JICA Study Team

(2) Required Number of Trains

Table 4-26 Number of Trains

		2014~ 2019	2020~ 2039	2040~ 2045	Remarks
Operation	Pattern A, A', A''	17	22	25	Year 2020; 6 × 6 sets = 36 cars are added. Year 2039; 6 × 3 sets = 18 cars are added.
	Pattern B	9	9	9	
	Subtotal	26	31	34	
Spare		3	4	4	
Total		29	35	38	

Source: JICA Study Team

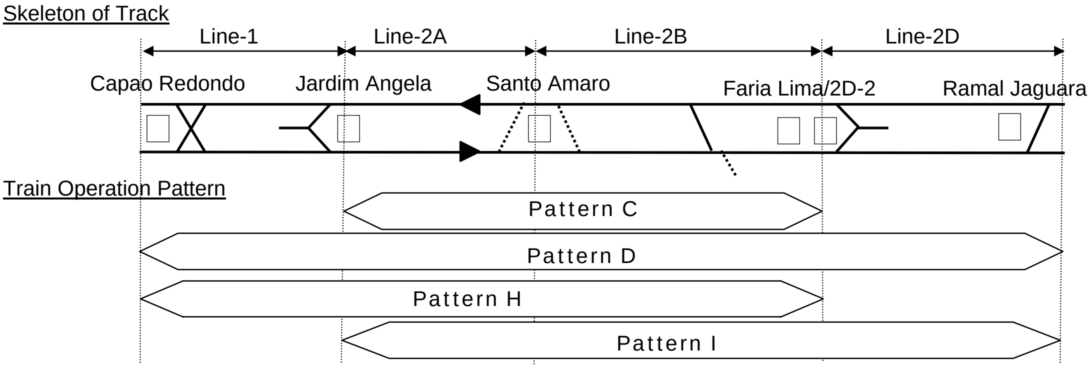
4.3.6 Additional Case 2 (Phase 2 up to 2045 W/O extension)

When extension of Phase 3 is not performed and Monorail operation continues by the section of phase 2 up to year 2045, the train operation pattern and the number of trains are estimated as follows.

(1) Operation Pattern

Pattern C and D is applied up to 2019. Subsequently, patterns are changed to H and I.

Table 4-27 Train Operation Pattern in Peak Hour of Additional Case 2



Period	Pattern	Train configuration	Headway	Number of train operations per hour (trains/hr./direction)	Transport Capacity (PHPDT)
2016~2019	C	6-car train	4min 15sec	14	14,000
	D	8-car train	5min 00sec	12	15,600
2020~2045	H	8-car train	5min 00sec	12	15,600
	I	8-car train	4min 15sec	14	18,200

Source: JICA Study Team

Table 4-28 Capacity and Headway by Line

Period	Line name	Line-1	Line-2A, 2B	Line-2D
	Section	Capao Redondo~ Jardim Angela	Jardim Angela~ Faria Lima	Faria Lima~ Ramal Jaguara
2016~2019	Number of trains (trains/hour/direction)	12	26	12
	Headway	5min 00sec	2min 15sec	5min 00sec
	Capacity (PHPDT)	15,600	29,600	15,600
2020~2045	Number of trains	12	26	14
	Headway	5min 00sec	2min 15sec	4min 15sec
	Capacity	15,600	33,800	18,200

Source: JICA Study Team

(2) Required Number of Trains

Table 4-29 Number of Trains

	Period	2016~2019		2020~2045	Remarks
	Train Configuration	6-car	8-car	8-car	
Operation	Pattern C	24			Year 2015: (Addition from phase 1) 3 train sets of 6-car train are converted to 8-car train. And 32 train sets of 8 car train are added. (2 middle car x 3+ 8 × 32 = 262cars are purchased) Year 2019: 26 train sets of 6 car-train are converted to 8 car-train.3 train sets of 8 car-train are added. (2 middle car x 26 + 8 x 3 = 76 cars are purchased)
	Pattern D		32		
	Pattern H			24	
	Pattern I			34	
	Subtotal	24	32	58	
Spare		2	3	6	
Total		26	35	64	

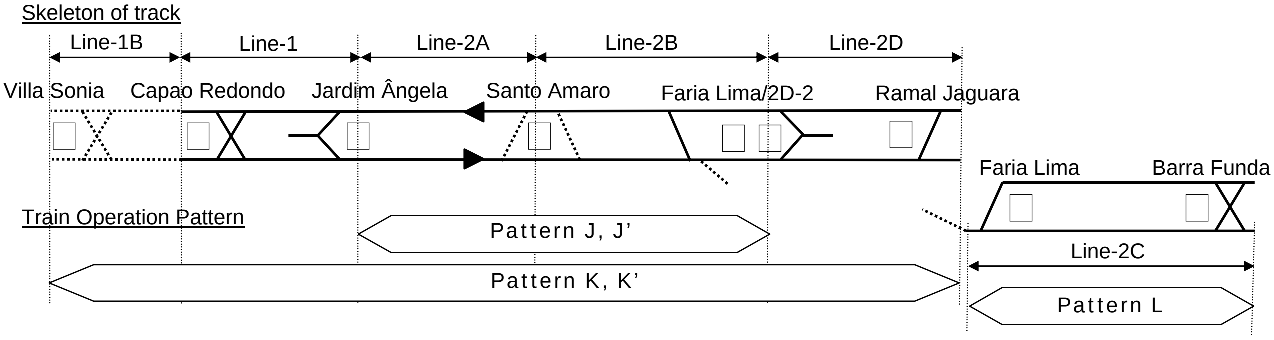
Source: JICA Study Team

4.3.7 Additional Case 3 (Phase 3 with Line-1B extension)

When Line-1B extension is performed in Phase 3, the train operation pattern and the number of trains are estimated as follows.

(1) Operation Pattern

Table 4-30 Train Operation Pattern in Peak Hour of Additional Case 3



Period	Pattern	Train configuration	Headway	Number of train operations per hour (trains/hr./direction)	Transport Capacity (PHPDT)
2018~2039	J	8-car train	15 min 00sec	4	5,200
2040~2045	J'	8-car train	12 min 00sec	5	6,500
2018~2024	K	8-car train	3 min 20sec	18	23,400
2025~2045	K'	8-car train	3 min 00sec	20	26,000
2018~2045	L	8-car train	6 min 00sec	10	10,000

Source: JICA Study Team

Table 4-31 Number of Trains

Period	Line	Line-1B, Line-1	Line-2A, Line-2B	Line-2D	Line-2C
	Section	Villa Sonia~ Jardim Angela	Jardim Angela~ Faria Lima	Faria Lime~ Ramal Jaguara	Faria Lima~ Barra Funda
2018~2024	Number of trains (trains/hour/direction)	18	22	18	10
	Headway	3 min 20sec	2 min 45sec	3 min 20sec	6 min 00sec
	Capacity (PHPDT)	23,400	28,600	23,400	10,000
2025~2039	Number of trains	20	24	20	10
	Headway	3 min 00sec	2 min 30sec	3 min 00sec	6 min 00sec
	Capacity	26,000	31,200	26,000	10,000
2040~2045	Number of trains	20	25	20	10
	Headway	3 min 00sec	2 min 20sec	3 min 00sec	6 min 00sec
	Capacity	26,000	32,500	26,000	10,000

Source: JICA Study Team

(2) Required Number of Trains

Table 4-32 Number of Trains

	Period	2018~2024		2025~2039		2040~2045		Remarks
	Train Configuration	6-car	8-car	6-car	8-car	6-car	8-car	
Operation	Pattern J, J'		7		7		9	Year 2018: Due to the extension of Line-1B, 23 sets of 8-car trains are added.
	Pattern K, K'		63		69		69	
	Pattern L	6		6		6		
	Subtotal	6	70	6	76	6	78	Year 2024: 7 sets of 8-car train is added
Spare		1	7	1	8	1	8	
Total	Trains	7	77	7	84	7	86	Year 2039: 2 sets of 8-car train is added

Source: JICA Study Team

4.4 ROLLING STOCK

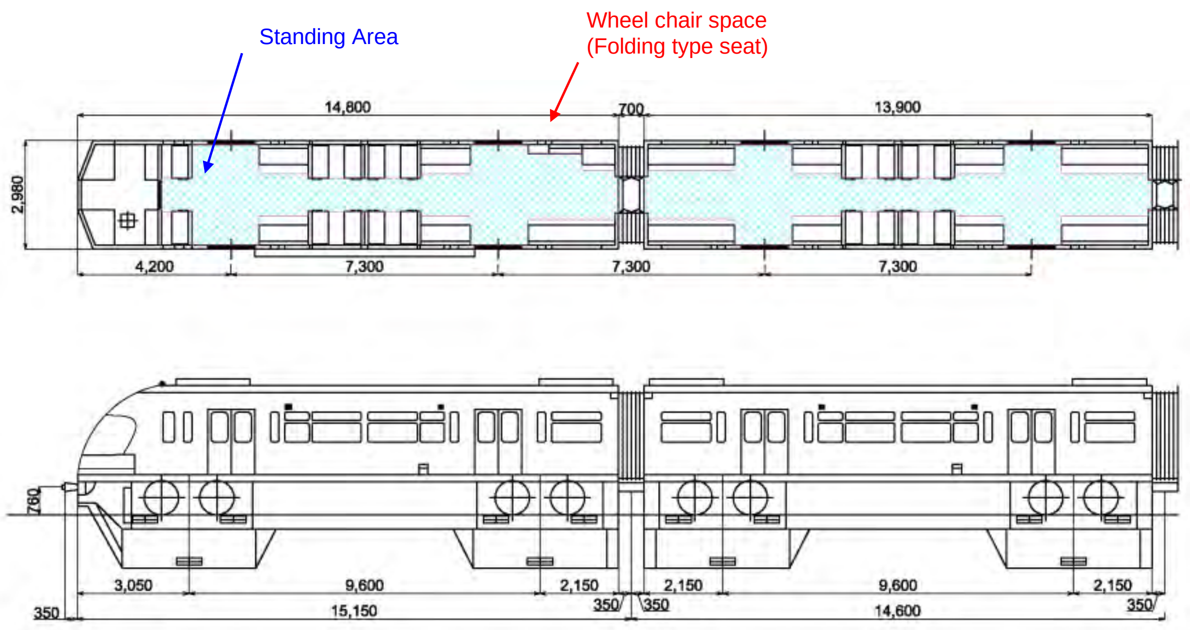
4.4.1 Transport capacity

(1) Car capacity of a large size monorail

The capacity of a large size monorail car is about 100 passengers at nominal load condition, or about 200 passengers at full load condition. The examples are Osaka Monorail, Kita-Kyushu Monorail, and Tama Monorail in Japan. The definition of a normal passenger capacity is the sum of the seating capacity and the standee capacity with three persons per square meters, while that of a full loaded capacity is the sum of the seating capacity and the standee capacity with seven persons per square meters. The full loaded capacity is used in the calculation of the maximum transport capacity of a car.

(2) Seat arrangement

Figure 4-16 shows an example of the seat arrangement of a large size monorail car. There are longitudinal seats and transverse seats in the monorail car. Wheelchair spaces and the installation of the emergency equipments such as spiral chutes will reduce the passenger capacity. The streamline design will also reduce the capacity a little. It should be considered that the streamline design makes it difficult to install an emergency door in the front and the back of a monorail. On the other hand, the adoption of longitudinal seat arrangement instead of transverse seat arrangement will slightly increase the transport capacity. However, passenger movement inside a car becomes inconvenient in case of transverse seat arrangement, which increase boarding and alighting time for the same number of boarding and alighting.



Source: JICA Study Team

Figure 4-16 Seat Arrangement of Large Size Monorail

(3) Car capacity

The car weight and the number of passengers per m^2 determine the capacity of a monorail car. Table 4-33 shows the calculation of car weight and passenger capacity of the car in Figure 4-16. The crush load of a large size monorail is 44 tons because the maximum endurance load capacity of 5.5tons per tire. As shown in the table, the car weight does not exceed the crush load with the passenger density being less than 9 passengers per m^2 (The average passenger weight of 70kg per passenger, which is used in the planning of São Paulo Metro, is applied).

The passenger density of 7 passenger per m^2 is generally used in Japan. On the other hand, the maximum number passengers 6 per m^2 is used for the planning of this project because:

- São Paulo Metro applies 6 passengers per m^2
- Instead of crowding passengers into a monorail car as much as possible, São Paulo Metro applies short dwell time and high frequency, which enable passengers to select next trains.

Table 4-33 Capacity and Car Mass

Paramiter		65 kg /person				70 kg /person			
		End Car		Middle Car		End Car		Middle Car	
Tare weight (t)		28.2		27.6		28.2		27.6	
Space for standees (m2)		19.7		20.3		19.7		20.3	
Number of seats		39		48		39		48	
Condition	Persons/m2	Persons	Weight (t)	Persons	Weight (t)	Persons	Weight (t)	Persons	Weight (t)
Tare	0	0	28.2	0	27.6	0	28.2	0	27.6
Nominal	3	98	34.6	108	34.7	98	35.1	108	35.2
	4	117	35.9	129	36.0	117	36.4	129	36.7
	5	137	37.2	149	37.3	137	37.8	149	38.1
	6	157	38.5	169	38.6	157	39.2	169	39.5
Full loaded	7	176	39.7	190	40.0	176	40.6	190	40.9
	8	196	41.0	210	41.3	196	42.0	210	42.3
Crush loaded			44.0		44.0		44.0		44.0

Source: JICA Study Team

(4) Train capacity

Table 4-34 shows the train capacity with the fully loaded condition (6 and 7 passengers per m^2). The train capacity of large size monorail is high as a medium capacity transit system, although it is lower than that of 6-car train of Metro.

Table 4-34 Train Capacity

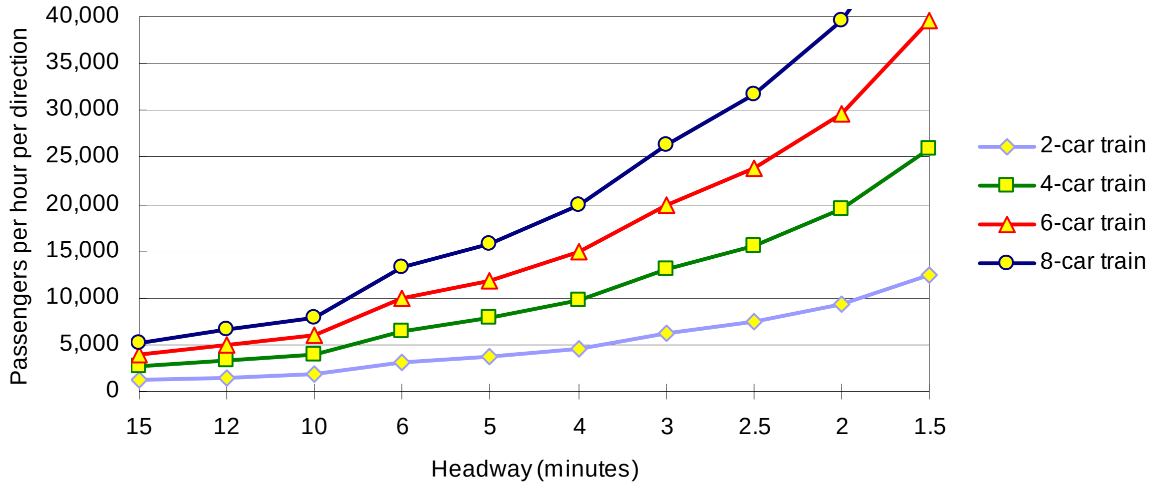
Unit: person

Condition	2-car train	4-car train	6-car train	8-car train
Nominal (3 pax/m^2)	200	410	620	840
6 pax/m^2	310	650	990	1,320
7 pax/m^2	350	730	1,100	1,500

Source: JICA Study Team

(5) Hourly capacity

Based on the train capacity, the transport capacity by headway is calculated as illustrated in Figure 4-17. For Line-2A, 8-car train operation with 3 minutes headway or 6-car train operation with 2 minutes headway would be necessary, since the future demand of Line-2A exceeds 30,000 passengers per hour per direction. The transport capacity of a 4-car train is 26,000 passengers per hour per direction with 1.5 minutes headway. Since the operation of a monorail with the headway less than 1.5 minutes is difficult due to engineering problem, a 4-car train can not deal with the demand of Line-2A.



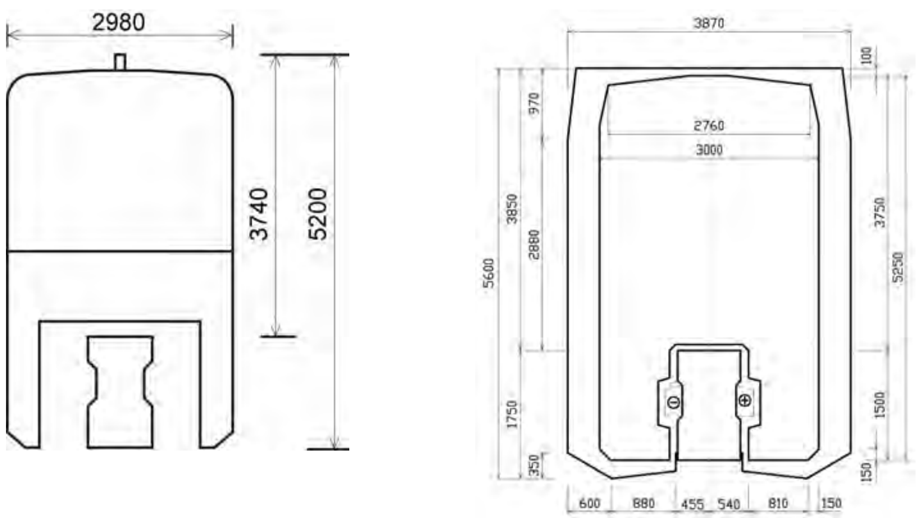
Source: JICA Study Team

Figure 4-17 Transport Capacity of Large Size Monorail

4.4.2 Specification of Rolling Stock

The required capacity of the medium transit system of this project is as large as more than 30,000 PHPDT. This traffic volume is larger than the transport capacity of most medium capacity transit system. Only a large-size monorail operated in Japan can carry this number of passengers within the category of "medium capacity transit system". Therefore, the specification of rolling stock was proposed based in the monorail system in Japan.

The vehicle gauge and construction gauge are shown in Figure 4-18. The construction gauge are the same as that of large size monorails in Japan.



Source: Illustrated by JICA Study Team from the exhibitions in Urban Monorail Structure Standard (1975)

Figure 4-18 Vehicle Gauge and Construction Gauge

There are steep slope along Line-1A and Line-2A with approximately 10% gradient in this project. In the alignment plan, the minimum gradient of 7 to 8% will be necessary for these lines considering the location of stations and economical design, although gradient should be as small as possible. From this, the maximum gradient of 8% is applied in the specification. On the other hand, this maximum gradient should be the exceptional case in order to avoid the reduction in speed due to the steep slope, and the gradient should be less than 6% in principal.

The maximum gradient of 6% is specified for a monorail system in "Urban Monorail Structure Standard, 1977, Ministry of Transportation and Ministry of Construction, Japan", which allows the maximum gradient of 10% in exceptional case.

The project route has right angle curves because the project uses the space over roads. It is necessary to use small radius curves in order to reduce the volume of land acquisition. From this, this project applies the curve radius of 50m, which is the minimum curve radium of monorail in technical view point[1], as the minimum curve radius. However, curve radiuses should be of not less than 100m in principal and 50m-radius should be the exceptional case because it causes speed down.

In this project, the speed does not exceed 70km/h due to the distance between stations and the speed limitation of curves and other conditions. Therefore, the maximum speed of 70km/h is applied for the project.

Table 4-35 Specification of Rolling Stock

Item	Feature
Length	Mc: 15.5m, M: 14.6m , Train: 88.7m (6-car), 117.9m (8-car)
Width	2,980mm
Maximum Height	Mc: 5,200mm, M: 5,140mm
Body height above girder	3,740mm
Floor height above girder	1,130mm
Axle-to-axle length	9,600mm
Weight	Mc: 26.3t, M: 26.0t
Normal passengers capacity (3 standeess/m2)	Mc: 83 (standee = 53, seated = 30) M: 88 (standee = 56, seated = 32)
Electrical method	DC 1500V, side catenary wire method
Motor control	VVVF inverter control (with regenerative brake)
Traction motor	Three phase squirrel-cage induction motor 100kW
Brake unit	Electric command electromagnetic straight liquid pressure converter air brake equipment
Maximum operation speed	75km/ h
Acceleration	3.0 km/ h
Deceleration	4.0 km/ h
Maximum gradient	8%
Minimum curve radius	50m
Body material	Lightweight aluminum alloy/ Fire- resistant
Seat arrange	Bench seat
Door	2 doors / side
Emergency door	The center of face
Air condition	Unit cooler on roof
Truck type	2 axle bogie straddle type
Running wheel	Nitrogen gas tubeless tire
Guided wheel	Air Rubber tire
Stabled wheel	Air Rubber tire

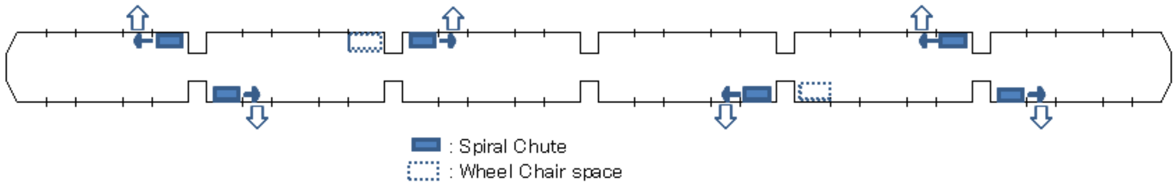
Source: JICA Study Team

[1] The radium of 50m is used in Tama Monorail Deport in Japan.

4.4.3 Safety

(1) Emergency Evacuation

There are various methods for passenger evacuation when a monorail train becomes immovable on the track due to certain cause. Using "spiral chute" is one of the evacuation methods. Figure 4-19 shows the idea to install the spiral chute in three places of the one side of a 6 car-train.



Source: JICA Study Team

Figure 4-19 Spiral Chute Arrangement

The basic operation for an emergency case of monorail is somehow to move the disable train to the nearest station.

(2) Fire protection measures

It is fundamental in car construction that, by utilizing nonflammable material or the fire retarding material for the material of each part of car body and fixtures, the fire is not likely caused but also spread or blazed up even a fire anyway occurs on the car.

The principle of train operation in case of occurrence of fire is that the train is forced to make a stop instantaneously, when the fire occurrence is detected immediately after the train leaves the station, and that the train is required to proceed to the next station in someway, when it is detected while the train is running between the stations. Since the average distance between the stations is about 1km and the running speed is about 30 km/h, the train can arrive at the nearest station within two minutes after a fire occurs.

When the train is fallen into a standstill between the stations due to the simultaneous happenings of the fire on a car and the propulsion power failure, fire is to be extinguished with the fire extinguisher and the lighting and the ventilator are to be operated by the battery power supply (up to 30 minutes under current capability) for waiting for the recovery of power supply. As the worst case, no recovery of power supply is anyway envisaged. In such event, passenger evacuation to the ground will be carried out by using "Spiral chute". The same procedure will be applied for the case of the fire caused by a terrorism attack.

4.4.4 Scheduled Speed

(1) Scheduled Speed of Monorail

The scheduled speed of monorail is approximately 27km/h with the average distance between stations of 800m, and 35km/h with that of 1,600m. Tokyo Monorail is operated at the scheduled speed of 44km/h with the average distance between stations of 1,987m. The maximum speed of monorail is 75km/h. The scheduled speed depends on the horizontal and vertical alignment as well as the distance between stations. Since the study routes utilize the advantageous of monorail such as small radius curve and steep gradient, it is necessary to prepare train run curve to estimate the scheduled speed.

Table 4-36 Scheduled Speed of Medium Capacity Transit in Japan

	Standard size monorail	Large size monorail			AGT
	Tokyo monorail	Tama Monorail	Osaka Monorail	Kita-kyusyu monorail	Yurikamome
Line length	17.8km	16.0km	21.2km	8.8km	14.7km
No. of stations	10	19	14	13	16
Average distance between stations	1,987m	889m	1,631m	733m	986m
Scheduled Speed	44km/h	27km/h	35km/h	27km/h	28km/h

Source:

(2) Speed in Curve Section

The minimum radius of a curve of monorail is 50m in the main line. The speed in a curve section depends on the cant of the curve and acceptable centrifugal force for passengers. The monorail structure allows high transversal slope because monorail train does not overturn. In the technical standard for monorail in Japan, the maximum cant of 12% is proposed considering passengers' acceptance to slope in case of an emergency stop in curve sections. For passengers' comfortable ride in curve sections, the maximum cant differency is proposed as 5% in the Japanese standard. On the other hand, the cant difference of 7.5% is possible in depot. Table below shows the proposed permissible speed in curve section.

Table 4-37 Permissive Passing Speed in Curve Section

Unit: km/h

R (m)	Cd (%)	2.5				5				7.5			
	Ca (%)	0	5	10	12	0	5	10	12	0	5	10	12
50		10	20	25	30	15	25	30	30	20	25	30	35
60		10	20	30	30	15	25	30	35	20	30	35	35
70		10	25	30	35	20	25	35	35	25	30	35	40
80		15	25	35	35	20	30	35	40	25	35	40	40
90		15	25	35	40	20	30	40	40	25	35	40	45
100		15	30	35	40	25	35	40	45	30	35	45	45
120		15	30	40	45	25	35	45	50	30	40	50	50
140		20	35	45	50	25	40	50	50	35	45	55	55
160		20	35	50	50	30	45	55	55	35	50	55	60
180		20	40	50	55	30	45	55	60	40	50	60	65
200		25	40	55	60	35	50	60	65	40	55	65	70
250		25	45	60	65	35	55	65	70	45	60	70	75
300		30	50	65	70	40	60	75	80	50	65	80	85
350		30	55	70	80	45	65	80	85	55	70	85	90
400		35	60	75	85	50	70	85	90	60	75	90	95
450		35	65	80	90	50	75	90	95	65	80	100	105
500		35	65	85	95	55	75	95	100	65	85	105	110

Source: JICA Study Team

Note:

Equation: Ve = 3.6*SQRT(9.807*R*(Ca+Cd)/100)
where, Ve = Equilibrium Cant Speed including cant deficiency (km/h), R= Curve radius (m)
Ca = Actual cant (%), Cd = Cant deficiency (%)

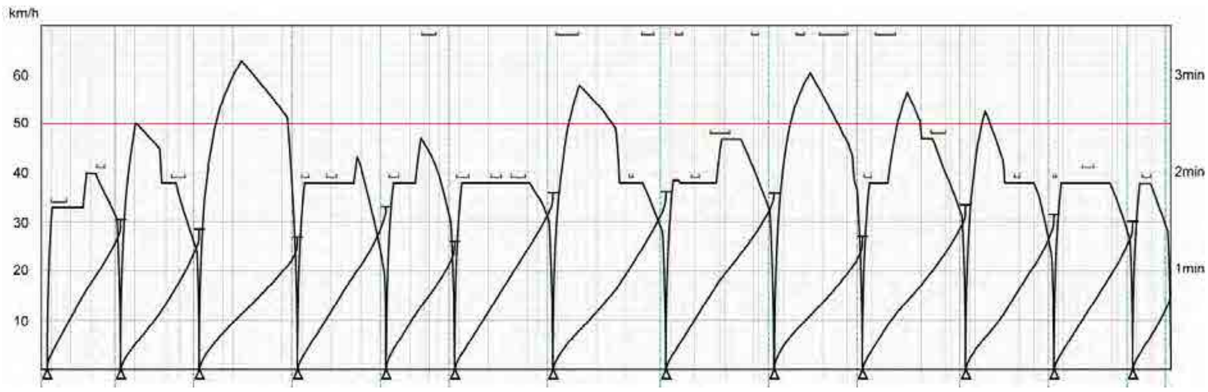
The speed is applied for the main line at the maximum cat of 12% with the cant deficiency of 5%.

The speed is applied for the small radius curve of the main line so as not to cause large centrifugal force from car body to bogie.

The speed is applied for the small radius with high cant deficiency of 7.5%.

(3) Train Running Curve

The scheduled speed was estimated for 8-car train and 6-car train by train running curves. The calculated time from a station to the next station was round up to a multiple of 15 seconds. Figure below shows the running curve of Line-2A (Urban Development Case) from Jardim Angela to Santo Amaro.



Source: JICA Study Team

Figure 4-20 Running Curve for Line-2A (From Jardim Angela to Santo Amaro)

The scheduled speed of the study routes was calculated as shown in Table below. The scheduled speed of a 6-car train is faster than that of 8-car train although the difference is very small. The scheduled speed below can be increased to approximately 30km/h if the schedule time is the multiple of 5 seconds instead of 15 seconds.

Table 4-38 Calculated Scheduled Speed

	8-car train		6-car train	
	Capan Redondo → Remel Jaguala	Ramal Jaguala → Capan Redondo	Capan Redondo → Remel Jaguala	Ramal Jaguala → Capan Redondo
Line-1A	27.2 km/h	28.2 km/h	27.9 km/h	28.2 km/h
Line-2A (UD)	27.2 km/h	28.6 km/h	27.5 km/h	28.6 km/h
Line-2A (OR)	27.3 km/h	28.6 km/h	28.3 km/h	29.0 km/h
Line-2B	29.1 km/h	28.8 km/h	29.1 km/h	29.1 km/h
Line-2D	29.4 km/h	29.7km/ h	29.4 km/h	29.7 km/h
	Faria Lima → Barra Funda	Barra Funda → Faria Lima	Faria Lima → Barra Funda	Barra Funda → Faria Lima
Line-2C	28.3km /h	27.4 km/h	28.3 km/h	27.8 km/h

Source: JICA Study Team