The Republic of Panama
Secretaría del Metro de Panamá

THE FEASIBILITY STUDY ON PANAMA CITY URBAN TRANSPORTATION LINE-3 PROJECT

Final Report

September 2014

JAPAN INTERNATIONAL COOPERATION AGENCY

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

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Exchange Rate (October 2013)

1 Balboa (B/.)	= 99.7 Yen (JPY)
1 Yen	= 0.01003 Balboa
1 US Dollar (US$)	= 99.7 Yen
1 US$	= 1 Balboa

Republic of Panama
Panama city
Burunga
Autopista
Nuevo Chorrillo
Panamericana
Arraijan
4th bridge
Panama Canal
Nuevo Arraijan
Panamericana
Autopista
Depot
Panama
Pacifico
Vacamonte
Veracruz
N
0
2
4km
La Chorrera
Puerto Caimito


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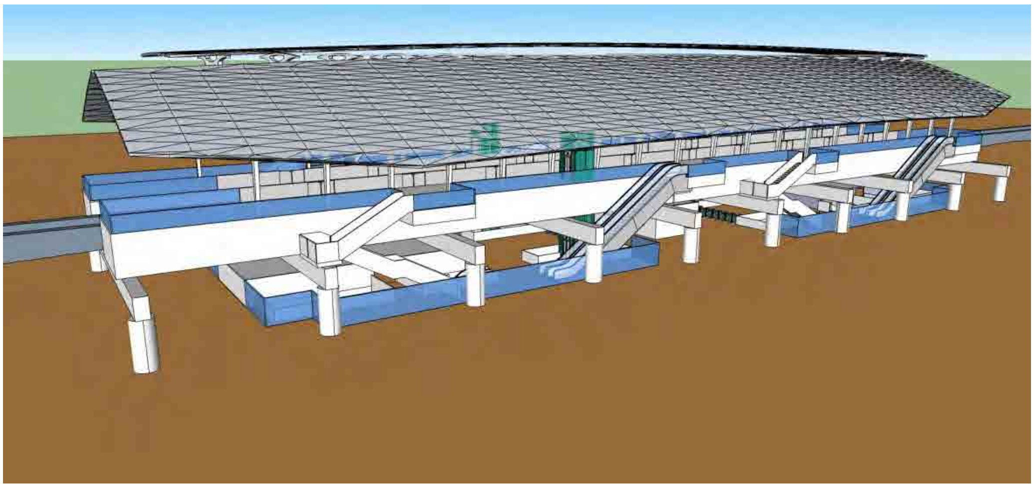

Albrook Station

Standard Station

THE FEASIBILITY STUDY
ON
PANAMA CITY URBAN TRANSPORTATION LINE-3 PROJECT

FINAL REPORT

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ABBREVIATIONS

Abbreviation	Official Term
AASHTO	American Association of State Highway and Transportation Officials
ABEI	Central American Bank for Economic Integration
ACP	Autoridad del Canal de Panama
AFC	Automatic Fare Collection
AGT	Automated Guideway Transit
AMP	Panama Maritime Authority
ANA	National Customs Authority
ANAM	Autoridad Nacional del Ambiente
ANAPYME	Authority of Macro, Small and Medium Enterprises
ANATI	Autoridad Nacional de Administración de Tierras
AP	Autopista
ARAP	Autoridad de Recursos Acuáticos de Panamá
ASCE	American Society of Civil Engineers
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiomete
ATO	Automatic Train Operation
ATP	Automatic Train Protection system
ATS	Automatic Traffic Supervision system
ATTT	Autridad del Transito y Transporte Terrestrede Panama
AVM	Add Value Machine
B/D	Basic Design
BBA	British Bankers Association
BOT	Build Operate Transfer
BP	Beginning Point
BRT	Bus Rapid Transit
BTN	Backbone Transmission Network
BTO	Build Transfer Operate
CAF	Corporation Andina de Fomento
CAP	Corrective Action Plan
CBTC	Communication Based Train Control
CCR	Central Control Room
CCTV	Closed Circuit Television
CDM	Clean Development Mechanism
CELADE	Latin America Demographic Center
CGP	Panamanian General
CO2	Carbon dioxide
COD	Chemical Oxygen Demand
CPS	Country Partnership Strategy
CTC	Centralized train control
D/D	Detailed Design
DC	Direct Current
DDR	Due Diligence Report
E&M	Electric and Mechanical
EED	Emergency Escape Door
EIA	Environment Impact Assessment
EIB	European Investment Bank
EIRR	Economic Internal Rate of Return
EL	Elevation Level

EMP	Environmental Management Plan
EN	Exchange of Notes
ENA	Empresa Nacional de Autopistas
EP	End Point
ESAL	Equivalent Single Axle Load
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
F/S	Feasibility Study
FC	Foreign Currency
FEM	Finite Element Method
FHWA	Federal Highway Administration
FIRR	Financial Internal Rate of Return
FP	Fixed Screens
GDP	Gross Domestic Product
GIS	Geographic Information System
GOP	The Government of Panama
GPS	Global Positioning System
HDI	Human Development Index
HDM	Highway Design and Maintenance Standards Model
IALA	International Association of Lighthouse Authorities
IBRD	International Bank for Reconstruction and Development
IC	Integrated Circuit
ICB	International Competitive Bidding
IDB	Inter-American Development Bank
IDC	Interest During Construction
IDDAN	Instituto de Acueductos y Alcantarillados Nacionales
IEC	Integrated Electric Control
IEE	Initial Environmental Examination
IL	Interlocking System
INEC	National Institute of Statistics and Census
IP	Internet Protocol
IR	Inductive Radio
ITBMS	Impuesto a las Transferencias de Bienes Corporales Muebles y la Prestacion de Servicios
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
LC	Local Currency
LCC	Life Cycle Cost
LCD	Liquid Crystal Display
LCX	Leakage Coaxial Cable
LF	Low Frequency
LIBOR	London InterBank Offered Rate
LMA	Limit of Moving Authority

LRFD	Load and Resistance Factor Design
LRT	Light Rail Transit
Maglev	Magnetic levitation
MEF	Ministry of Economy and Finance
METI	Ministry of Economy, Trade and Industry
MIDES	Ministry of Social Development
MIGA	Multilateral Investment Guarantee Agency
MITRADEL	Ministry of Works and Labor Development
MLWS	Mean Low Water Spring
MOP	Ministry of Public Works
MRT	Mass Rapid Transit
MSD	Manual Secondary Door
NPV	Net Present Value
O&M	Operation & Maintenance
OCC	Operation Control Center
OD	Origin and Destination
OSHA	Occupational Safety & Health Administration
P/Q	Pre Qualification
PA	Panamericana
PAS	Public Addressing System
PC	Pre-stressed Concrete
PCDP	Public Consultation and Disclosure Plan
PCRC	Panama Canal Railway Company
PGA	Peak Ground Acceleration
PHPDT	Peak Hour Peak Direction Traffic
PIDS	Information Display System
PIS	Passenger Information System
PPIAF	Public-Private Initiative Advisory Facility
PPP	Public Private Partnership
Pre-F/S	Pre-Feasibility Study
PSC	Public Sector Comparator
PSD	Platform Screen Door
PTS	Pentax Total Station
PVC	Polyvinyl Chloride
PWS	Parallel Wire Strand
RAMS	Reliability, Availability, Maintainability and Safety
RAP	Resettlement Action Plan
RC	Reinforced Concrete
REP	Reglamento de la Construccion Panama
RoW	Right of Way
RQD	Rock Quality Designation
RSS	Receiving SubStations
S&C	Signaling and Telecommunication equipment
SBHS	Steel for Bridge High Performance Structures

SCADA	Supervisory Control and Data Acquisition system
SCR	Station Control Room
SDH	Synchronous Digital Hierarchy
SFRL	Social and Fiscal Responsibility Law
SIV	Static Inverter
SMP	Secretaria del Metro de Panama
SP	Stated Preference
SPF	Shadow Pricing Factor
SPT	Standard Penetration Test
SR	Space Wave Radio
SRAP	Strategic Resettlement Action Plan
STM	Synchronous Transport Module
TD	Train Detection System
TOM	Ticket Office Machine
ToR	Terms of Reference
TSS	Transmission SubStation
TTC	Travel Time Cost
TVM	Ticket Vending Machine
UABR	Administrative Unit of Reverted Properties
UAS	Environmental Sectrial Unit
UHF	Ultra High Frequency
UTM	Universal Transverse Mercator
UTO	Un-attendant train Operation
VCR	Vertical Curve Radius
VFM	Value For Money
VHF	Very High Frequency
VOC	Vehicle Operating Cost
VOT	Value of Time
VVVF	Variable Voltage Valuable Frequency
WACC	Weighted Average Cost of Capital
WGS84	World Geodetic System 84 (1984)

Chapter 1 Outline of the Project

1.1 Background of the Project

Traffic congestion in Panama City, the capital of the Republic of Panama, and surrounding areas has become worse year by year due to the rapid increase in the number of cars following high economic growth of the country. To alleviate this problem, in 2009, the Government of Panama established the "Secretaria del Metro de Panama" (SMP) under the Presidential Office, and SMP has drawn up a metro network plan consisting of four metro lines. Line-1, Line-2 and Line-4 are planned within Panama City, while Line-3 is planned for the west side of the Panama Canal, to connect Panama City and the suburban areas such as Araijan and La Chorrera.

The population of the districts of Arraijan and La Chorrera has been growing rapidly in recent years, and the congestion of the road connecting Panama City with these districts has become a serious problem. In order to solve this problem, the Government of Panama (GOP) is planning to construct Line-3 concurrently with Line-2.

Under such situation, the Ministry of Economy, Trade and Industry (METI) of Japan carried out a study for the Line-3 Project. The METI study proposed a monorail system for Line-3, which would follow the Pan-American and "Autopista" Highways and cover the demand on the west side of the Panama Canal.

The GOP plans to construct a bridge across the canal in parallel with the Bridge of Americas. The Panama Canal Authority (ACP) has been conducting the Pre-F/S for the 4th Panama Canal Bridge since 2012. The GOP plans to provide track space on the 4th Panama Canal Bridge for Line-3.

In March 2013, the Japan International Cooperation Agency (JICA) and the GOP agreed to conduct a feasibility study for the Line-3 Project, and the study started in July 2013. The study on the section of the 4th Panama Canal Bridge was not included in the study scope in the beginning because the 4th Panama Canal Bridge had been studied by ACP as mentioned above. Meanwhile, GOP expressed its interest to fund the 4th Panama Canal Bridge Construction Project - with a Japanese Yen Loan. Therefore, GOP and Government of Japan (GOP) held a meeting on July 12, 2013 and agreed that GOJ will conduct its study. . As a result, the Study for the 4th Panama Canal Bridge Construction Project was commenced under JICA's technical assistance from September, 2013.

1.2 Project Scope

JICA and GOP agreed on the scope of the "Panama City Urban Transportation Line-3 Project" (hereinafter referred to as the "Project"). The Project will introduce an urban transit system connecting Nuevo Arraijan and Albrook via the planned 4th Panama Canal Bridge, and consists of the following components;

- Civil Works (including Stations, Track works, a Depot, Workshops, and Intermodal Facilities)
- E&M (Power Supply, Signal & Telecommunication, Operation Control, etc.)
- Rolling Stock
- Consulting Services

1.3 Study Purpose

1.3.1 Urban Transportation Line-3

The purpose of this study is as follows:

- Confirmation of the necessity/validity of the Panama City Urban Transportation Line-3 Project;
- Undertaking of a feasibility study including a preliminary design and cost estimate for the Project; and
- Selection of the most suitable urban transit system that would reinforce the connectivity of the East-West axis of the Panama Metropolitan Area.

1.3.2 4th Panama Canal Bridge

Pre-F/S was conducted by ACP based on the cable-stayed bridge option; however, the comparative study on the selection of the main bridge type was not conducted.

Main purposes in this Study are as follows:

- Review Pre-F/S on the Project
- Conduct alternative study on the main bridge type of 4th Panama Canal Bridge
- Conduct preliminary design of the selected main bridge type and approach sections
- Determine Project scope
- Estimate Project cost
- Compare the main bridge type of 4th Panama Canal Bridge
- between the option proposed by the Pre-F/S and the option proposed by this Study
- Prepare reports and documents on project evaluation

1.4 Study Scope

Study scope is in accordance with the following minutes of meeting between GOP and GOJ:

- Minutes of Meeting on the 4th Panama Canal Bridge Study (September 3, 2013)
- Minutes of Meeting on the 4th Panama Canal Bridge Study (December 6, 2013)

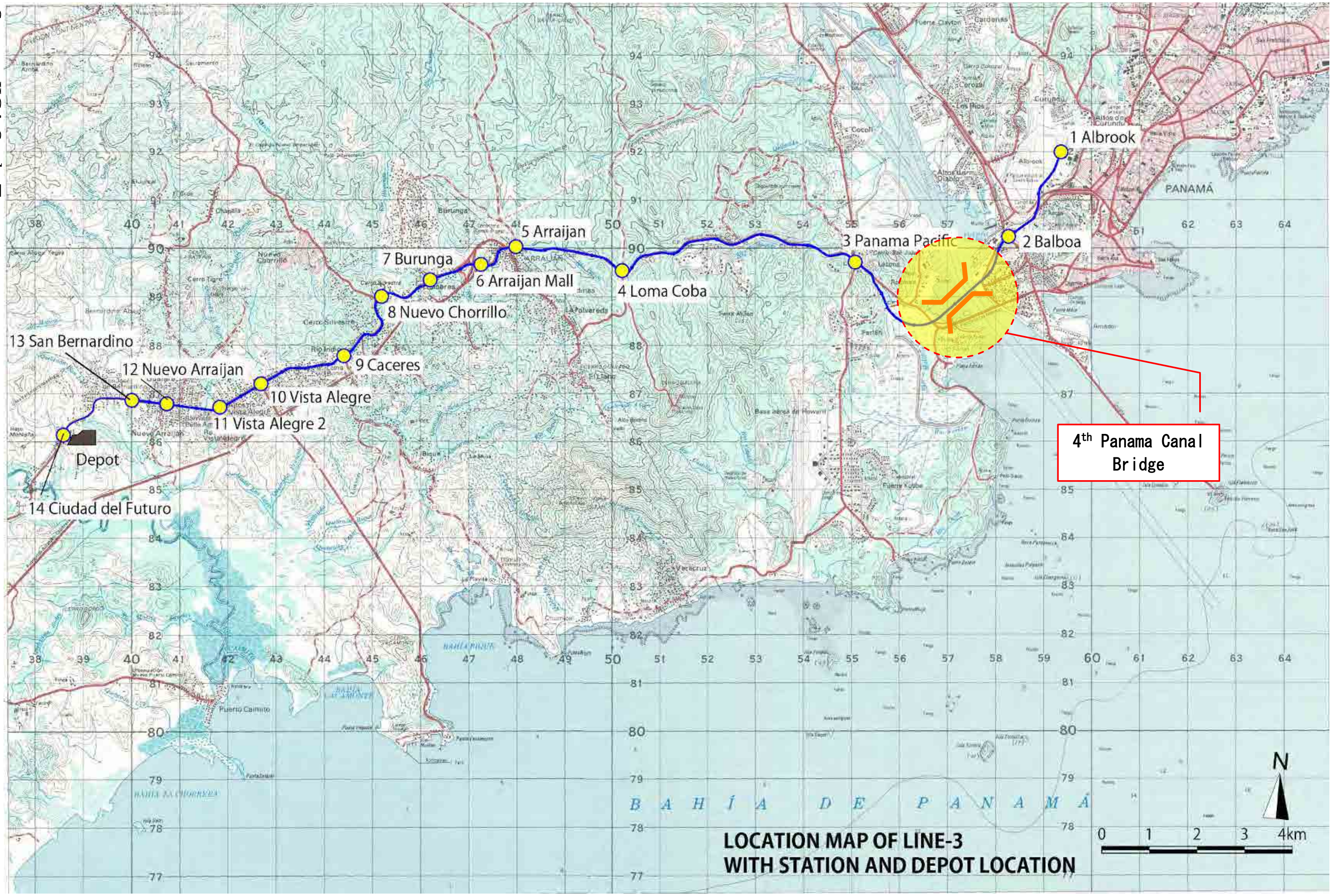
Summary of study scope in the above minutes of meeting is as follows:

- Confirmation of the project background and necessity
- Demand forecast
- Review of existing studies and the implementation of additional studies
- Proposal of the project framework
- Consideration of environmental and social impacts
- Assessment of the project’s effectiveness
- Recommendation for the project implementation and operation phase (risks and issues), including the identification of matters which may require further development

1.5 Survey Area

The survey area is shown in

Figure 1.1. The survey area for the demand forecast covers the metropolitan area of Panama City including La Chorrera, Arraijan, Panama, and San Miguelito districts, while the survey area for the route study covers the corridor between Albrook and Arraijan.

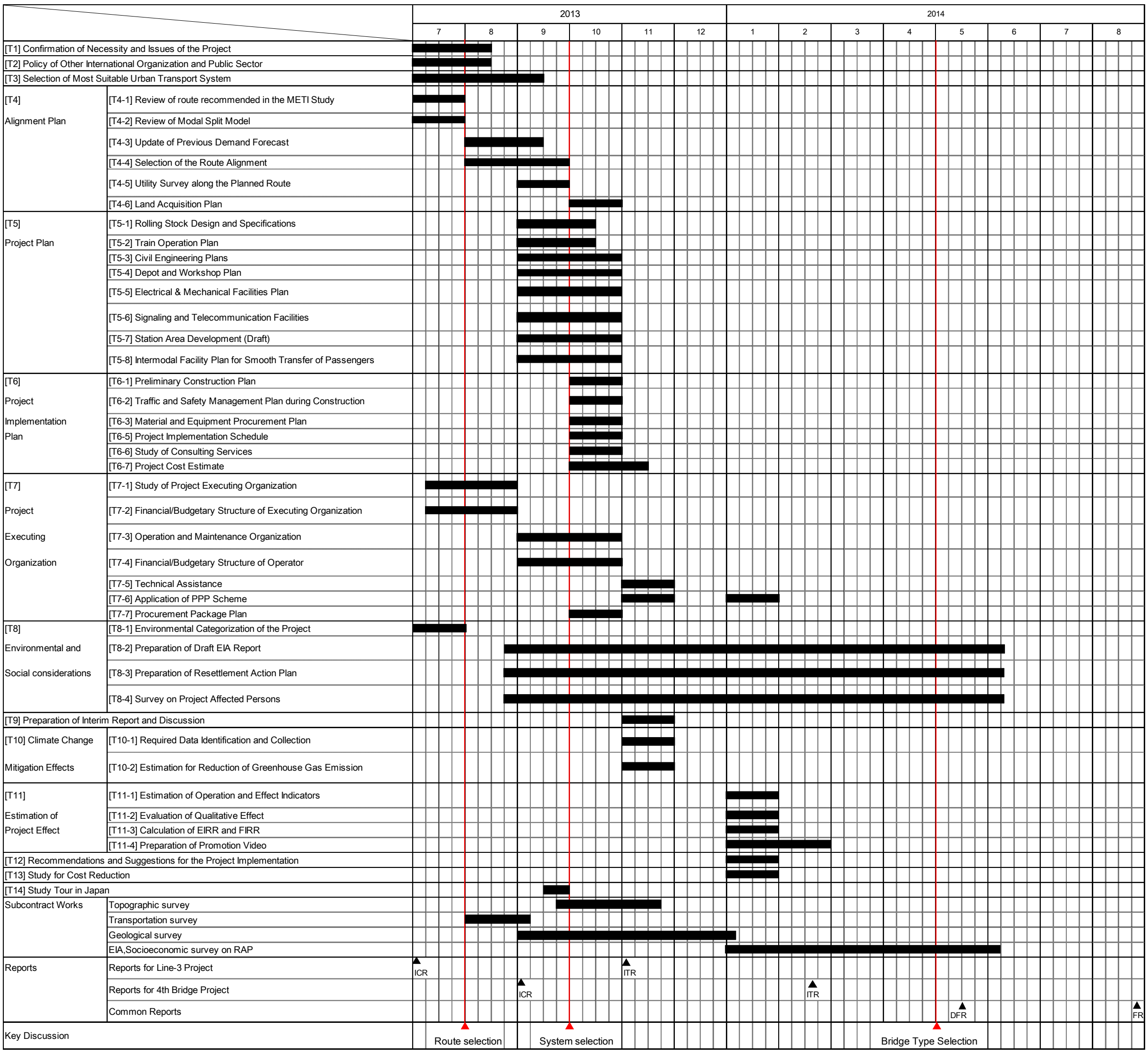


Source: JICA Study Team

Figure 1.1 Survey area for route study

1.6 Work Schedule

The study was commenced at the end of July 2013; the Inception Report and Interim Report were submitted in July 2013 and November 2013, respectively. The study on the 4th Bridge was added to the original scope in August 2013, and the amendment of the contract between the JICA Study Team and JICA was signed on February and April 2014 for Environmental Impact Assessment and other tasks. The work was completed in August 2014.



Source: JICA Study Team

Figure 1.2 Work Schedule

1.7 Stakeholder Meeting

A stakeholder meeting for the Project was held by SMP and the JICA Study Team on August 6, 2013 at Hotel Holiday Inn, Panama City. The team leader of the JICA Study Team made a presentation on the project, focusing on the necessity of the project, route alternatives, system alternatives, and the necessary studies for environmental considerations. After the presentation, eight participants expressed their opinion and questions as follows:

1) The project would have social impacts from the resettlements around the project area.

2) The present public transportation system and its connection with the project's system should be considered.
3) Information on the location of Panama Pacifico is necessary.
4) The Line-3 should provide a safe transportation system for making a modal shift from car to public transportation.
5) Arraijan and La Chorrera municipalities should take advantage of the project for their urban development plans.
6) Passenger volume should be considered in the planning of the Albrook Station where Line-1 and Line-3 connect.
7) There is no space to accommodate a mass transit system on the streets in the center of La Chorrera.
8) Information on the alignment is necessary because there is a possibility that it may affect the concessions of the Administrative Unit of Reverted Properties (UABR).
9) Although the future population in the western area such as Arraijan and La Chorrera will be very large, the project will contribute to proper urban development.
10) The municipalities along the project route should update their regulatory plan for urban development to incorporate the project.
11) Information on the project, especially the resettlement plan, should be given to relevant municipalities.
12) The experience of Line-1 regarding traffic management can be used for traffic management of Line-3, which is one of the important areas of the project.

1.8 Study Tour in Japan

Study tour has taken place in Japan from 21 to 30 September 2013 to be understood Japanese technology regarding Line-3 and 4th Panama Canal Bridge project. The tour invited four and two staffs belong to SMP and ACP, six participants in total as shown in Table 1.1 and Table 1.2. The tour introduced urban transportation system such as monorail, railway, AGT and liner metro in Japan. In addition to the system, the tour included visiting schedule about 4th Panama Canal Bridge such as girder assembling factory and Rainbow Bridge, which has road and AGT system and so on.

Table 1.1 Attendance List of Study Tour in Japan.

No	Name	Organization	Position
1	Mr. Agustin Arias	SMP	Chief technical advisor
2	Mr. Ciro Limone	SMP	Technical advisor (Railway technology)
3	Ms. Ana Laura Morais	SMP	Technical advisor (Transport/ Urban planning)
4	Mr. Alvaro Uribe	SMP	Technical advisor (Urban planning)
5	Mr. Máximo Molina	ACP	Supervisor structural engineering unit of ACP
6	Ms. Gloribel Céspedes	ACP	Structural engineer of ACP

Source: JICA Study Team

Table 1.2 Study Tour Schedule

Month	Date	Day	Day:	Time	Contents	Contacting agency	Place for the invitation	Purpose
Sep	21	Sat	1	Dept. Panama	Travel day AM7920/ AM058 11:36 Panama - 15:26 Mexico 23:15 Mexico - (6:45(+2)NRT)			Traveling from Panama to Japan
	22	Sun	2	Via Mexco	Travel day			
	23	Mon	3	6:45	Arrival at NRT	JICA Study Team		
				7:30-8:30	Move from NRT to Hotel			
	24	Tue	4	8:45-9:00	Move from Hotel to JICA HQ by Bus	JICA Study Team	Kasumigaseki, Tokyo	
				9:00-9:30	Courtesy visit to JICA HQ	JICA	Kasumigaseki, Tokyo	
				10:00-10:30	Courtesy visit to Ministry of Foreign Affairs(MFA)	MFA	MFA HQ Kasumigaseki 2-2-1, Chiyoda-ku, Tokyo Tel.+81-3-3580-3311	
				11:00-11:30	Courtesy visit to Ministry of Land, Infrastructure, Transport and Tourism (MLITT)	MLITT	MLITT HQ 6F Room of the Executive technical advisor on the city bureau Tel.+81-3-5253-8111 2-1-3 Kasumigaseki, Chiyoda-ku, Tokyo	
				11:30-13:15	Lunch		Around Hibiya park	
				13:15-13:45	Courtesy visit to Ministry of Economy, Trade and Industry (METI)	METI	METI HQ Kasumigaseki 1-3-1, Chiyoda-ku, Tokyo +81-3-3501-1511	
				13:45-15:15	Move from METI HQ to Tachikawa-kita Sta. by bus	JICA Study Team		
				15:15-15:45	Experience of Tama monorail ride from Tachikawa-kita sta. to Tama center sta.	JICA Study Team		Conform a case of monorail in hills and understand the monorail.
				15:45-17:15	Move by bus from Tama center sta. to the Hotel			
				18:00	Welcome Party	JICA Study Team	Kojimachi, Tokyo	
	25	Wed	5	9:30-9:40	Move from the Hotel to Iidabashi sta. by bus	JICA Study Team		
				9:40-10:20	Experience of Toei Oedo line from Iidabashi sta. to Shiodome sta. via Tochomae sta.			Experiencing Linear metro and conform actual conformability and operation system.
				10:20-10:40	Experience of New-Transit Urikamome from Shiodome sta. to Diba sta.			Experiencing AGT and conform actual conformability and operation system.
				10:40-11:30	Observation of the Rainbow bridge		Daiba, Tokyo	Understand the structure of the bridge which have a road and AGT system both by watching from a distance.
				11:30-12:30	Lunch		Daiba, Tokyo	
				12:30-13:30	Move from Daiba to Hamamatsucho			
				13:30-16:30	Experience of Tokyo monorail ride, the depot and OCC	Tokyo Monorail Co., Ltd.	Hamamatsucho depot	Experiencing an urban monorail and understand actual train operation, conformability, headways, turnout and etc.
				16:30-17:00	Move from Hamamatsu depot fo JICA HQ			
				17:00-17:30	Meeting	JICA	JICA HQ	
	26	Thu	6	8:30-9:30	Move from the hotel to Haneda airport by hotel limousine bus		Tokyo	
				10:30-11:35	Flight from Haneda to Itami airport by JAL113		Haneda airport	
				11:35-13:30	Meet Mr. Hino, MD of Japan Monorail Association and take Lunch and move from the airport to Osaka airport sta. on foot		Itami airport	
				13:30-13:43	Station facility introduction and Observation of the monorail turnout	Osaka Monorail Co., Ltd.	Osaka airport sta.	Understand station facility functions and turnout
				13:43-14:19	Experience of Osaka monorail ride from Osaka airport sta. to Kadomashi sta. and turnout on the sta.			Experiencing monorail train ride and understand and understand actual train operation, conformability, headways and also visit Yodogawa bridge having Nielsen-Lohse structure with 632m long.
				14:23-14:50	Experience of Osaka monorail ride from Kadomashi sta. to Bamoaku-kinen koen sta. and move to the depot on foot			
				14:50-15:20	Visit the depot, OCC and the Q&A		Bampaku depot	Understand the deport operation and O&M.
				15:20-16:00	Company overviews and history introduction and visit the workshop		Workshop	
				16:00-16:30	Move from the workshop to the hotel in Osaka			
	27	Fri	7	7:00-8:00	Move from the hotel to the girder factory of IHI Infrastructure systems Co., Ltd.		Sakai, Osaka	
				8:00-9:15	The company and factory introduction, presentation of the Sumidagawa bridge, etc.	IHI infrastructure system Co., Ltd. 3-banchi, Ohama-nishimachi, Sakai-ku, Sakai city, Osaka Tel.+81-72-223-0981		Visit SBHS girder production line and understand of the steel bridge materials to apply for 4th bridge
				9:30-10:45	Factory visit			
				11:00-11:50	Lunch and Q&A			
				11:50-12:30	Move from the factory to Shin-kidugawa bridge			
				12:30-13:00	Observation of the Shin-kidugawa bridge			Visit shin-kidugawa half-through arch bridge having 495m long span, to apply for 4th bridge
				13:00-13:45	Move from the bridge to Shin-Osaka sta.			
				14:27-17:03	Traveling from Shin-Osaka sta. to Tokyo sta. by bullet train(Nozomi-364)			
				17:30-18:00	Move from Tokyo sta. to the hotel by taxi			
	28	Sat	8		Experiencing transport in Tokyo			
	29	Sun	9		Visit property development sites			
	30	Mon	10	Dept. Tokyo	Travel day AM057/AM7921 15:25 Narita - 14:20 Mexico 16:30 Mexico - 20:18 Panama			

Source: JICA Study Team

Source: JICA Study Team

Figure 1.3 Shots of Courtesy Visit

Source: JICA Study Team

Figure 1.4 Shots of OCC(Left) and Garter Assembling Factory(Right) Visit

Chapter 2 Necessity of the Project

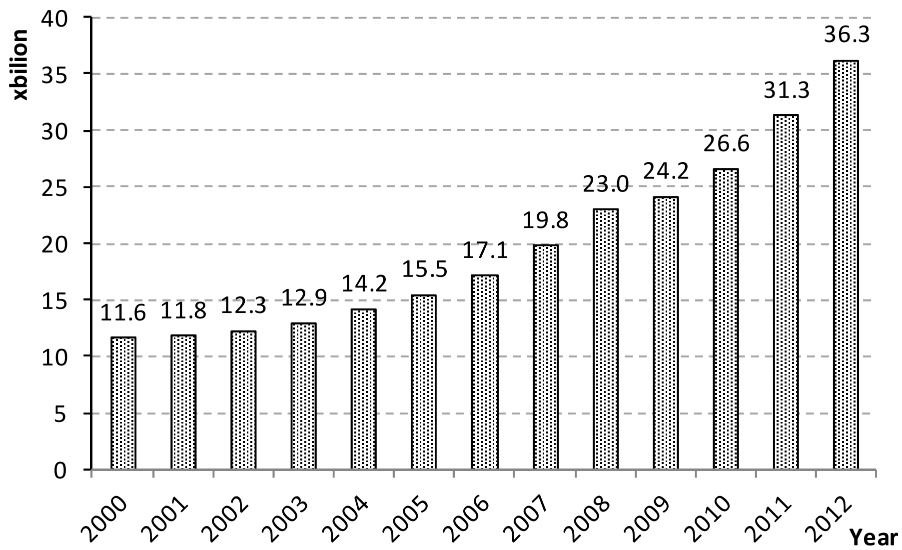
2.1 Current Situation and Issues of Urban Transportation Sector

2.1.1 Socioeconomic Situation and Urban Development

(1) Socioeconomic Situation

The Republic of Panama is the southernmost country of Central America connecting North and South America. It is bordered by Costa Rica to the west, Colombia to the southeast, the Caribbean Sea to the north and the Pacific Ocean to the south. The capital is Panama City. The country boasts the world-renown Panama Canal connecting the Pacific Ocean and Atlantic Ocean. Tolls paid by ships passing through the Panama Canal totaled USD 2.4 billion, with a total traffic of 320.6 million tons, in the fiscal year 2013[1] (October 1, 2012 - September 30, 2013)

The country is categorized as an upper-middle income country with a GDP of USD36.25 billion and a 10.8% annual growth rate. As shown in Figure 2.1, Panama's economy has grown rapidly in recent years. The nominal GDP per capita of Panama is USD 9,850 surpassing that of Costa Rica, at USD 8,740 in 2012 (2012, The World Bank).



Source: JICA Study Team based on the World Bank Database

Figure 2.1 Annual GDP (current USD) of Panama

Panama's total population is 3.4 million with 1.7 million in the metropolitan area (Panama City, San Miguelito, Arraijan and La Chorrera Districts). 51% of the total population is in the Panama City metropolitan area as shown in Table 2.1. The population growth rate is 1.84% per year for the last 10 years (National Census, 2010). The population increase and concentration in the metro area have multiplied the number of cars resulting in serious traffic congestion.

[1] ACP Annual Report 2013

Table 2.1 Population breakdown of Panama

Area	Population in 2010	Ratio
Panama Metropolitan Area	1,723,284	51%
Arraijan District	230,311	13%)
La Chorrera District	167,799	10%)
Panama District	989,100	57%)
San Miguelito District	336,074	20%)
Other Districts	1,682,529	49%
Panama Total	3,405,813	100%

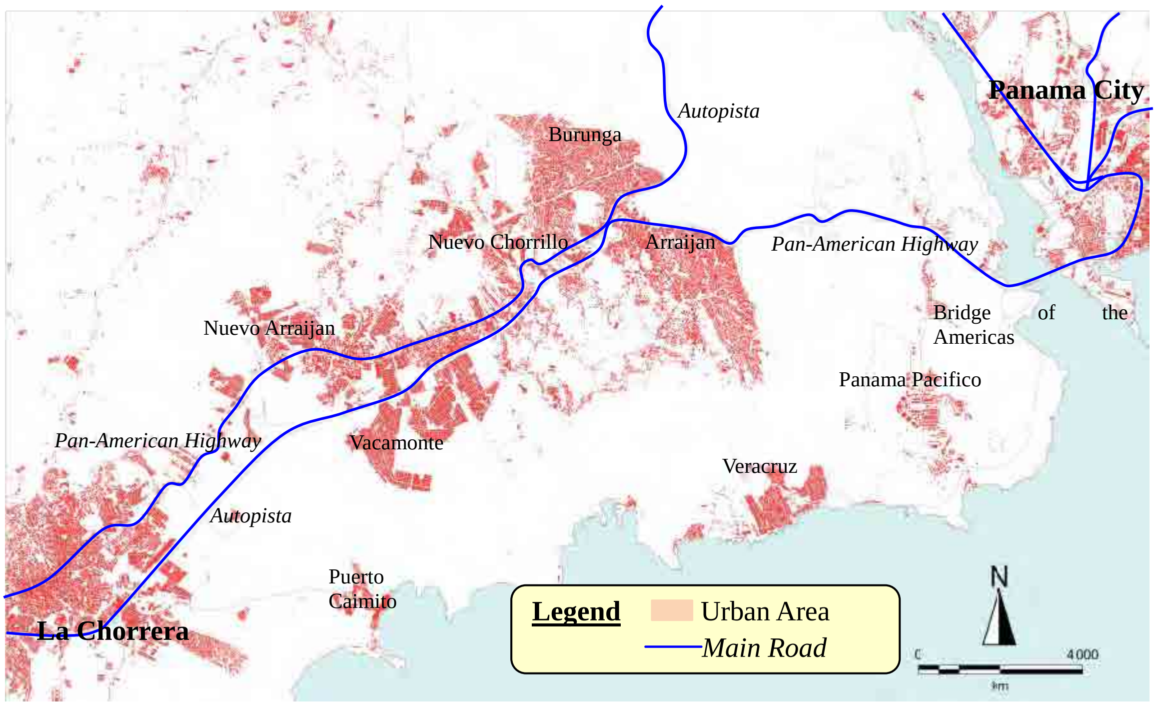
Source: JICA Study Team

The main industry in the west area is agriculture. But the main source of employment for the inhabitants of these districts is Panama City highlighting the need for efficient public transportation.

(2) Urban Development

Two roads run east and west in the study area. These are the old Pan-American Highway and the newly constructed "Autopista" Highway. The Pan-American Highway is an old main corridor which runs from the western border of Panama and Costa Rica to Yaviza at the eastern border of the country over the Bridge of the Americas crossing the Panama Canal. On the other hand, the "Autopista" connects La Chorrera with Panama City and Colon, located at the north of the country touching the Caribbean Sea.

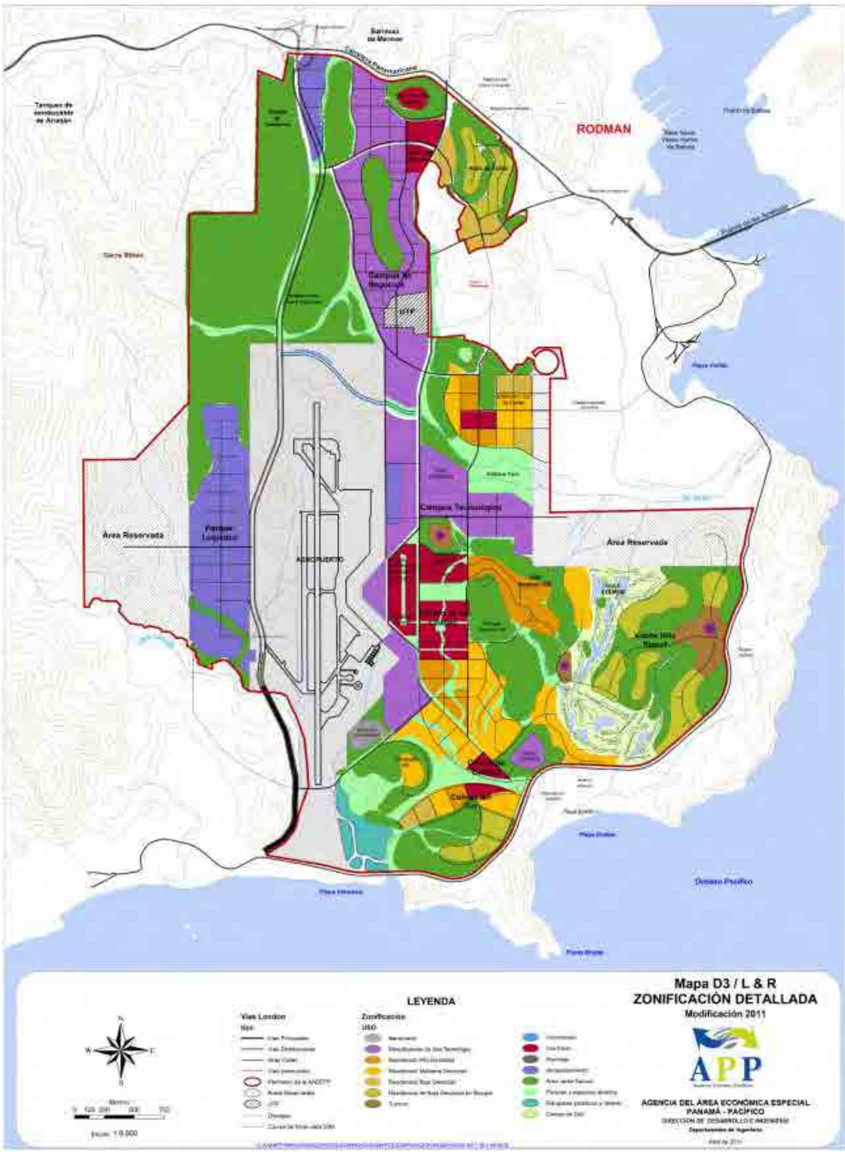
La Chorrera and Arraijan districts have been urbanized mainly along the Pan-American Highway. Furthermore, the area along the "Autopista" was urbanized in recent years as shown in Figure 2.2. This figure also shows that urbanizations in several areas have spread vertically from the main corridors, such as in Burunga, Arraijan and Vacamonte.



Source: JICA Study Team

Figure 2.2 Map of Urbanized Areas and Main Roads

Panama Pacifico, located to the southwest of the Panama Canal, has planned an urban development project for the future. Howard airport is located in the area, but only a few chartered aircrafts use the airport. The area will have 20,000 houses and 40,000 employees according to the master plan.



Source: Panama Pacifico

Figure 2.3 Master Plan of Panama Pacifico

2.1.2 Transportation Network

(1) Bridge of Americas

The Bridge of Americas is a 4-lane road bridge (2-lanes in each direction) opened in 1962, which is located on the Pacific side of the Panama Canal, connecting the center of Panama City and the western area such as Arraijan and La Chorrera by the Pan-American Highway and the Autopista. The total length of the bridge is 1,654m with the longest span having 344m, with a clearance under the main span of 61.3m. The daily traffic flow is approximately 50,000 vehicles and the congestion in the morning and evening peak hours is very heavy. Besides the Bridge of Americas, the Centennial Bridge crosses the Panama Canal, however its function as an alternative route is limited because it is located 15km north of the Bridge of Americas and accesses Panama City approximately 10km east of the Bridge of Americas.

There were one-way operations and night time closures of the bridge due to rehabilitation works, and such rehabilitation work will continue to take place consecutively in the future.

(2) Centenario Bridge

The Centenario Bridge is a 6-lane road bridge (3-lanes in each direction) crossing the Panama Canal, which opened in 2004. It is a cable-stayed bridge with a total length of 1,052m, the longest span having 420m, with a clearance of 80m. As a part of the Autopista, the bridge connects the Pan-American Highway near Burunga in Arraijan on the west side with the center of Panama City after crossing Corredor Norte on the east side. The daily traffic of the Centenario Bridge is approximately 30,000 vehicles, most of which are private cars, and the number of buses is very small.

(3) Express Roads

There are two toll roads in Panama, namely, Corredor Norte and Corredor Sur. The former starts at Albrook connecting the northeast area of Panama City on the mountain side of the city, while the latter is a seaside expressway connecting Balboa Avenue along the seaside and the international airport. In the plan for the 4th Bridge, the bridge will connect to the Corredor Norte on the east side. In Arraijan and La Chorrera, the Autopista - an expressway but not a toll road - runs east and west accessing Panama City across the Centenario Bridge.

(4) Pan-American Highway

The Pan-American Highway is a 4-lane road passing through the urban areas of Arraijan and La Chorrera to the west of the canal, connecting to the Bridge of Americas. The 4th Bridge is also planned to connect to the Pan-American Highway. The section between the Bridge of Americas and Loma Coba near Arraijan is a hilly non-urban area, and the traffic on this section is very heavy in the morning and evening peak hours. According to the Ministry of Public Works, this section between the Bridge of Americas and Arraijan will be widened from 4-lane to 6-lane together with the completion of the 4th Bridge. Since the 4th Bridge will be a 6-lane bridge, if this section remains 4-lanes it will be a bottleneck for traffic flow. Therefore, this section needs to be widened to 6-lanes.

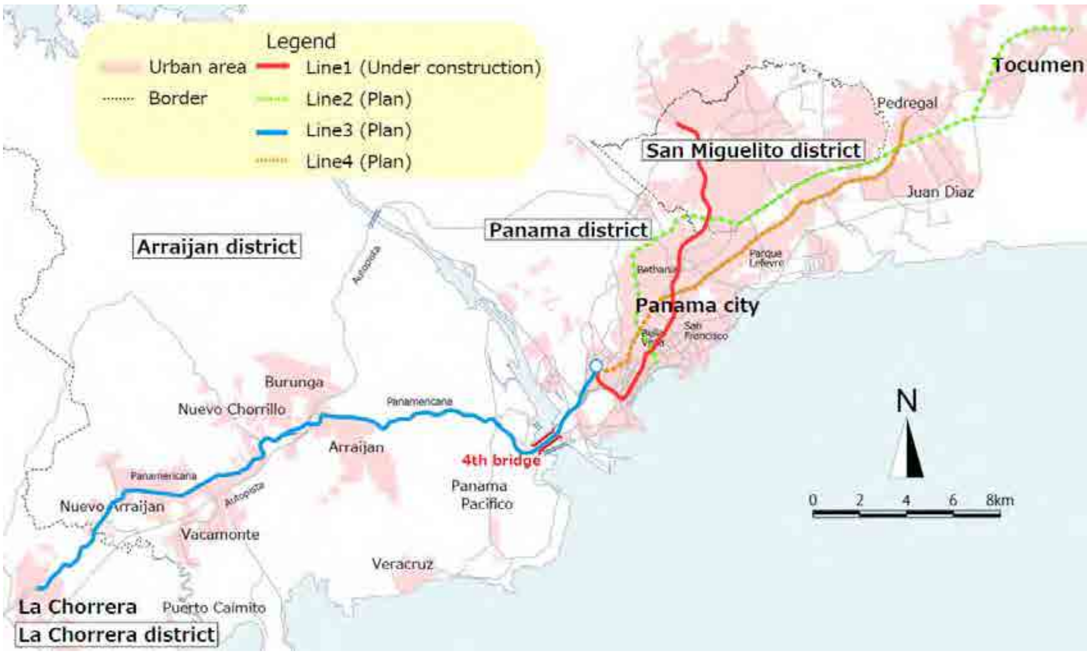
(5) Albrook Bus Terminal

This is the large national bus terminal located in the western part of Panama City, where the bus routes from Arraijan and La Chorrera as well as from the interior of the country concentrate. In order to access the terminal, which is located in a narrow area between Albrook Airport and Corredor Norte, there is an intersection to the south of the terminal with a very complex combination of a roundabout and flyovers. This intersection is one of the issues in planning the access road to the 4th Bridge. The terminal station for Line-1 is constructed in front of the bus terminal, and the station for Line-3 is planned to be in the same location as Line-1. Bus routes will remain even after the construction of Line-3 and their access to the bus terminal will still be necessary. This should be taken into account when planning the access road to the 4th Bridge.

2.1.3 Public Transport

(1) Metro

This is a Metro project to reduce worsened traffic congestion in Panama City. The first line of an urban railway system in Panama City, Metro Line 1, opened in 2014. The total route length is 13.7km (underground: 7.2km and viaduct: 5.3km) with 12 stations at opening, and to be extended to 15km with 14 stations by 2025. Loans from the Inter-American Development Bank and Corporación Andina de Fomento (CAF) are included in the project, which costs estimated as USD1,880.5 million. A total of four metro lines are proposed as shown in the Figure 2.4: Line-1, 2 and 4 will cover Panama City, and Line-3, the target of this study, will connect Panama City to Arraijan and La Chorrera, to the west, by crossing the Panama Canal which is the bottleneck of the traffic connected between east and west side of the canal.



Source: JICA Study Team based on SMP plan

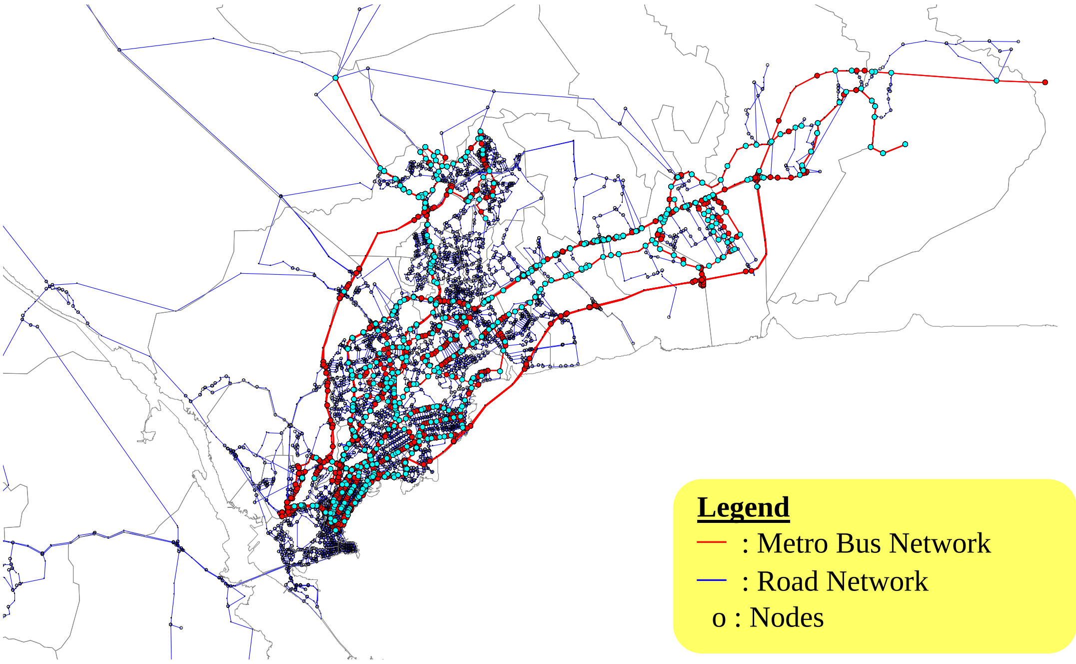
Figure 2.4 Metro Plan

(2) Metro bus

The Metro bus project is one of the urban transportation systems, together with the Metro, being promoted by the current president of Panama for the Metropolitan area. The Metro bus project replaced the former "Diablo Rojo" buses with 1,200 air-conditioned, low-level buses (VOLVO) and it is operated by private company, Mibus.

Mibus is the operating company responsible for managing the buses and bus operators. ATTT is the governmental authority supervising the various contracts established for the bus system. Mibus transports more than 730,000 passengers daily with more than 9,000 daily services[2]. The first service started in 2010 in Corredor Sur and the number of service routes has since increased to more than 150. The routes are shown in the Mibus website and identified in the report as shown in the figure below.

2 Mibus website at http://www.mibus.com.pa/



Source: JICA Study Team

Figure 2.5 Metro Bus Network

Source: JICA Study Team

Figure 2.6 Metro Bus (center) with the Fare Collection Gate (right) and Exit (left)

The fixed fare is USD0.25 for regular routes and USD1.25 for the north and south corridor routes. Two free transfers can be made to another bus going in the same direction, within 40 minutes of alighting each bus. The fare system uses a contactless IC card that was introduced in 2012. The cards can be purchased for USD2.00 at bus terminals and supermarkets and comes without value. The purchaser needs to add value to the card at a charging machine or charging counter before use. Passengers touch the card on the fare collection equipment at the entrance of the bus to enter the cabin as shown in the right photo in Figure 2.6. Also, by touching the equipment at the exit door (left photo in Figure 2.6) before alighting the bus, passengers can make a free transfer to another bus within 40 minutes.

Table 2.2 Contactless IC Card for the Metro bus

	Chargeable pre-paid card for the Metro bus	
	Price of card	US$2.00 (Deposit)
	Fare	US$ 0.25 per trip
	Transfer	Free up to 40min. after alighting
	Payment period	At boarding time
	Type	A

Source: JICA Study Team

Source: JICA Study Team

Figure 2.7 Contactless IC Card charging machines and charging counter

(3) Pirata

The "Pirata" is an unlicensed public transportation provider using a private van. The fee from La Chorrera to Albrook is generallyUSD0.90 and USD1.50 for a higher quality vehicle. Thus, the fare depends on the quality of the vehicle. The van windows are darkened with black film. The Piratas stop at the Metro bus stops to pick up passengers. The Metro bus service cannot cover all the target areas or rider demand and the Piratas cover areas that are inconvenient for large buses, or at peak hours when bus service is insufficient. The number of Pirata users has increased according to SMP, but its quantification is difficult.

(4) Taxi

Many yellow cabs can be seen in the suburban and metropolitan areas of Panama City. Taximeters are not installed in the taxis and passengers negotiate the fare with the driver according to the official fare zone of the destination.

Source: JICA Study Team

Figure 2.8 Examples of a typical Pirata (left) and taxi (right)

2.1.4 Current Situation and Problems of Urban Transportation

There is serious traffic congestion in Panama City not only in commuter hours but also other day times due to the high concentration of urban functions. Traffic congestion afflicts not only Panama City, but also the Pan-American Road, specifically between the Bridge of the Americas and Arraijan, during the morning and evening hours. This section becomes so congested that drivers use the shoulder as a traffic lane during peak hours because the capacity of 2-lane per direction is insufficient as shown in Figure 2.9.

Source: JICA Study Team

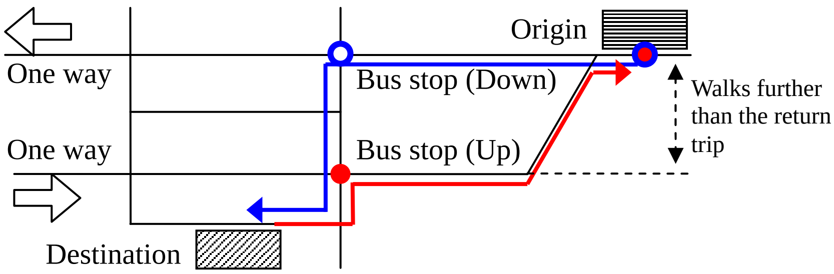
Figure 2.9 Congested conditions during morning peak hour on the Pan-American Highway

The Metro Bus of Panama City is a functional public transportation system, but the buses do not operate with a time schedule. Many times the buses cannot carry all the waiting passengers at peak hours due to traffic congestion and overcrowded buses. This requires bus users to leave their homes at earlier hours in the morning to be able to arrive at work on time, with 2-hour or longer commutes being common.

Source: JICA Study Team

Figure 2.10 Fully loaded Metro Bus and a waiting passenger

Moreover, there are many one-way streets in Panama City center, which complicates the bus network, so that bus stops for "up" and "down" buses are not on same road. Some parallel one-way roads are distant from each other making it inconvenient for passengers. Figure 2.11 shows that the walking distance from a bus stop to the destination on the forward trip is longer than the walking distance to a bus stop on the return trip. It is expected that passengers take a roundabout route to avoid walking longer distances.

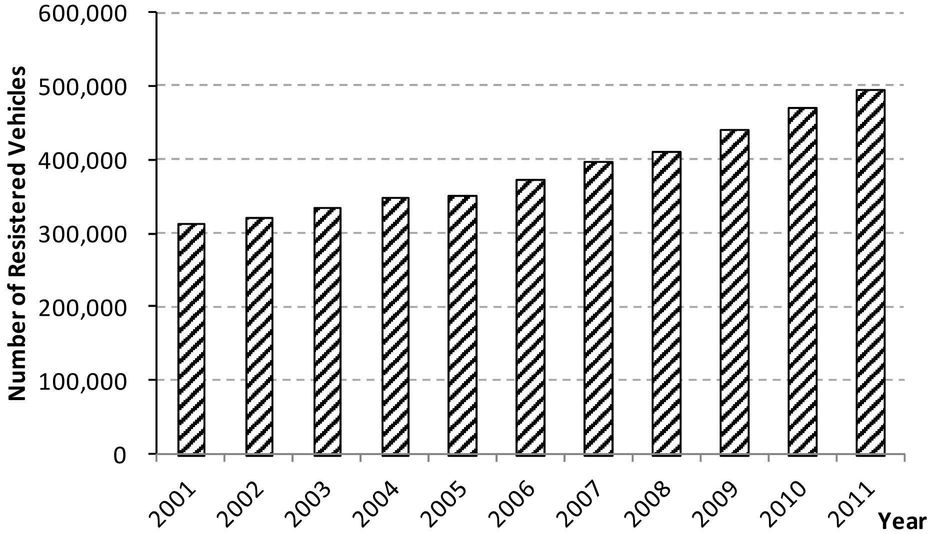


Source: JICA Study Team

Figure 2.11 Difference in walking distance

Once an urban transportation system with improved up-and-down routes can be established, the walking distance for passengers can be reduced, thereby increasing passenger convenience. Consequently, an urban transportation system having a dedicated lane is required as soon as possible.

In addition to the above urban transportation problems, the number of cars is increasing year by year in Panama as shown in Figure 2.12, but the frequency of buses between Panama City, Arraijan and La Chorrera is low. This is another reason the number of cars continue to increase.



Source: INEC – National Institute of Statistics and Census - Panama

Figure 2.12 Number of Registered Vehicles by year

2.2 Policies and Plans for the Urban Transportation Sector

(1) Line-1 Project

Line-1 is the first urban railway system in Panama. The system characteristics are 1435mm standard gauge, DC 1500 V power supply through overhead wires, 3-car train (600 passengers with 6 persons per m^2), CBTC system, and so on. SMP has implemented the Line-1 project in the metro network plan. Figure 2.13 shows the Line-1 route, running from the Albrook bus terminal to 5 de Mayo to the south and then going northeast through the metropolitan area and finally reaching Los Andes. It will have 13 stations (with 1 future station site) with a total length of 13.7km.

Source: SMP[3]

Figure 2.13 Location of Line-1 Stations

Table 2.3 Line-1 Features

System	MRT	
Number of Stations	Initially 12 Stations	
Length	13.7 km	
Underground	7.2km	From Albrook to after Fernandez de Cordoba
Elevated	5.3km	From before 12 de Octubre to Los Andes
Estimated Construction Cost (in Mil. USD)	Line 1	1758.1
	Utilities Relocation	61.1
	Transitory Investment	61.3
	Total	1880.5
Operation time	24min. (Albrook to Los Andes)	
Opening	2014	
Construction	Odebrecht (Brazil), FCC (Spain), Alstom (France)	
Rolling stock manufactured by:	ALSTOM (France)	

Source: JICA Study Team

The section between Los Andes and 12 de Octobre is elevated and the rest of the track is constructed underground. The total cost for Line-1 is estimated to be USD1,880.5 million. Its major features are summarized in Table 2.3. Scheduled opening is early 2014. Table 2.4 shows the cost breakdown for Line-1.

3 SMP website: http://www.elmetrodepanama.com/imagesrm/LineaUno.pdf, accessed in October 2013.

Table 2.4 Cost Breakdown for Line-1

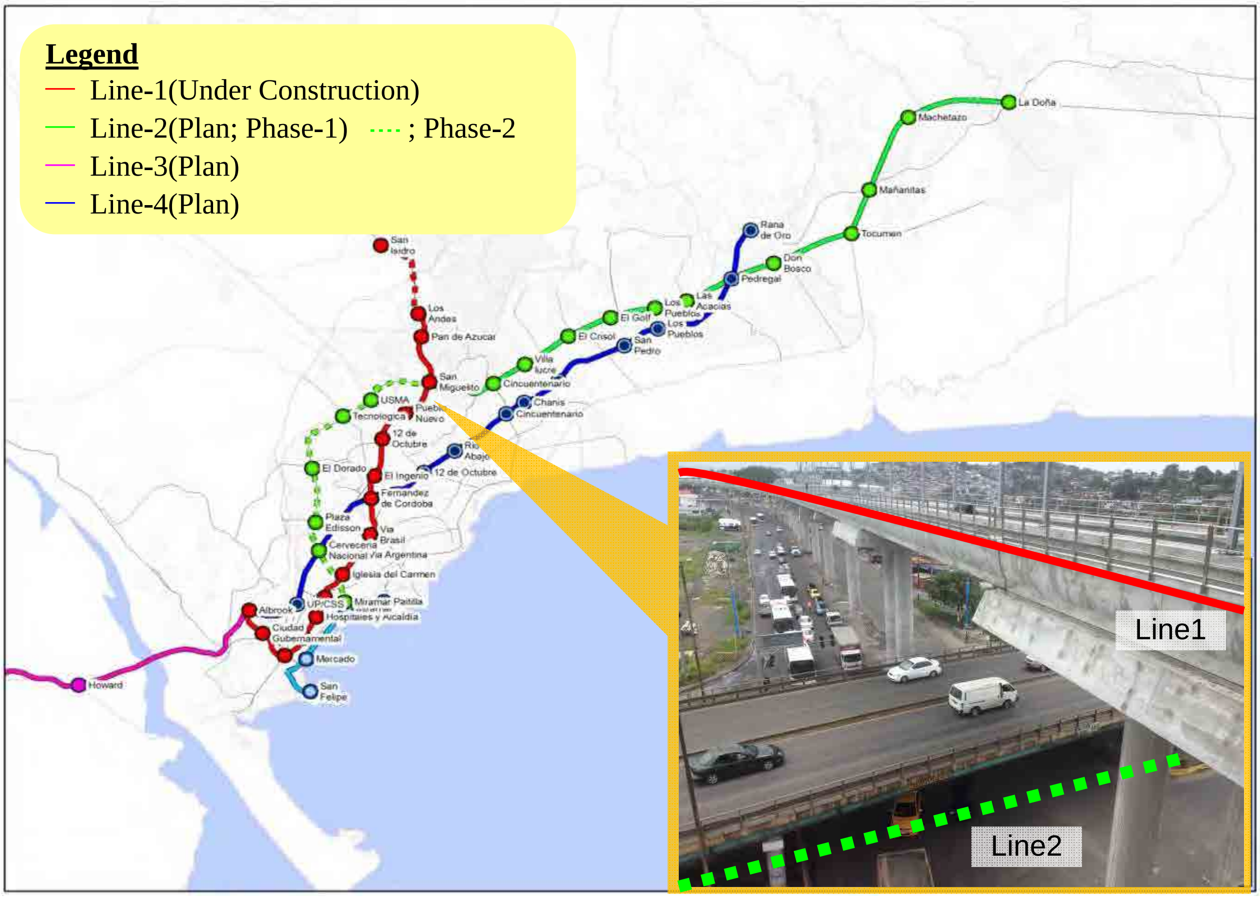
Design	Line 1 Construction and Equipment	Millions USD	
Panama Metro Line 1	Civil Works: Tunnels, stations, viaducts, Operation Control Center	966.2	1,758.1
	Integrated Railway System: Design, supply and installation of rails, cables, controls, signaling and trains	431.8	
	Design and Engineering: Electromechanical systems and other civil works	211.1	
	Depots and Workshops: Earthworks, infrastructure, buildings and pavements	96.5	
	Variation of international prices of indexed material (Steel, cement, concrete, diesel)	23	
	Elevation systems: Escalators and elevators	21.4	
	Provisions for strengthening structures, changes in soil conditions and inspections	5	
	Environmental Management Plan	3	
Relocation of Public Utilities	Relocation and burying of public utilities	43.8	61.1
	New 54 inch waterline for Panama City	17.2	
Transitory Investments	Project Management	29.5	61.3
	OCIP - Insurance policy of the State	16.2	
	Transitory expenses of SMP (administration, Metro culture, Clearing of roads, etc.)	15.6	
Total Cost of Line 1 of Panama Metro		1,880.50	

Source: SMP[4]

(2) Line-2 Project

The Line-2 project is planned to run from San Miguelito to the north of Tocumen International Airport in Phase-1, and from San Miguelito station to Miramar Paitilla in Phase-2 as shown in Figure 2.14. The San Miguelio station is a transfer station where Line-2 will pass under Line-1 as shown in the lower-right figure of Figure 2.14. Line-2 is still under study, but the same system as Line-1 will be used in Line-2.

4 http://www.elmetrodepanama.com/pdf_doc/Metro-cuadro-gastos.pdf, accessed in October 2013.



Source:SMP, JICA Study Team

Figure 2.14 Metro System and interconnection at San Miguelito Station

(3) Development of Pre-paid Zones for Metro Bus

The Metro Bus is developing pre-paid zones at major bus stops. For example, the 5 de Mayo Pre-paid Zone opened in October of this year. Passengers use the contactless IC car to pay their fare and enter the pre-paid zone where they can board their buses at the respective bus bay without touching the fare collection equipment on the bus.

Source: JICA Study Team

Figure 2.15 Entrance gate of the 5 de Mayo Pre-paid Zone for Metro Bus

The pre-paid zones attract a huge number of passengers and have the potential for business development. An example of successful integration of bus service and commercial development is the Grand Transportation Terminal in Albrook, shown in Figure 2.16. It is the main terminal for Metro Bus, all bus lines to the interior of the country and will connect to the Metro Line 1 station as well. Besides having its own commercial area, it also provides convenient access to a mall, hotel and the nearby domestic airport.

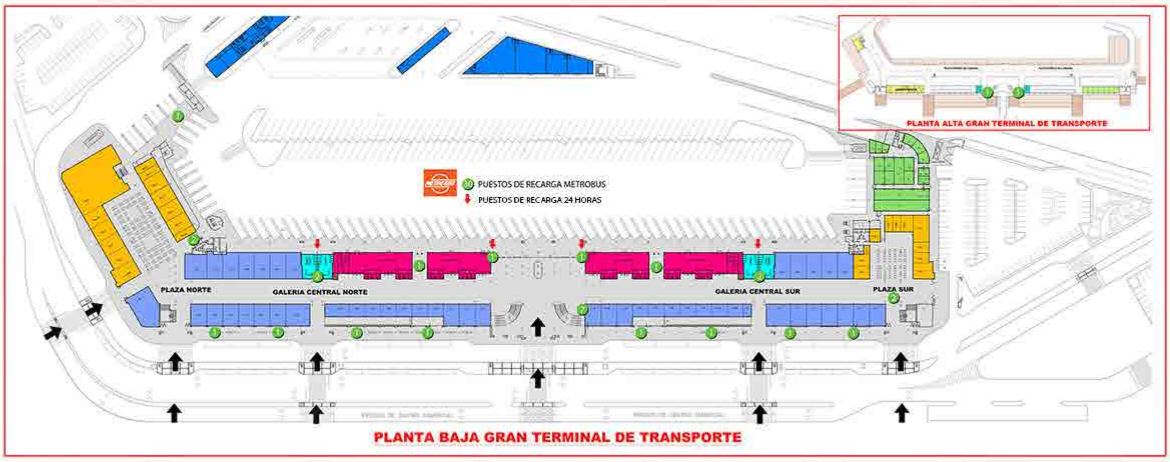


Figure 2.16 Layout of Albrook Terminal

2.3 International Assistance in Transportation Sector

(1) Strategy of Public Debt Reduction

The Social and Fiscal Responsibility Law (SFRL), passed in 2008, sets limits on public borrowing level and is aimed at reducing debt level to less than 40% of the GDP by 2014. According to the Ministry of Economy and Finance (MEF), the debt level was 42.8% of the GDP in 2012, and as of April, 2013, 37.9% of the GDP projection for 2013.

(2) Main Donors

The main international donors to the Government of Panama are the Inter-American Development Bank (IDB), Corporacion Andina de Fomento (CAF), International Bank for Reconstruction and Development (IBRD), European Investment Bank (EIB) and Central American Bank for Economic Integration (CABEI). Among them, IDB is the major financing source, which represents 12% of total public debt and 65% of total external debt from multilateral financial organizations in 2012. CAF has approved US$1,989 million in five years from 2008 to 2012 with US$906 million designated for financing the transportation sector, which is almost 2 times the amount approved by IDB in the same period.

Private financing is utilized for the Panama Canal Expansion Project, and some road development projects have also been carried out by private initiative.

Table 2.5 Donor Approval of loans to Panama in the last 5 years (cumulative)

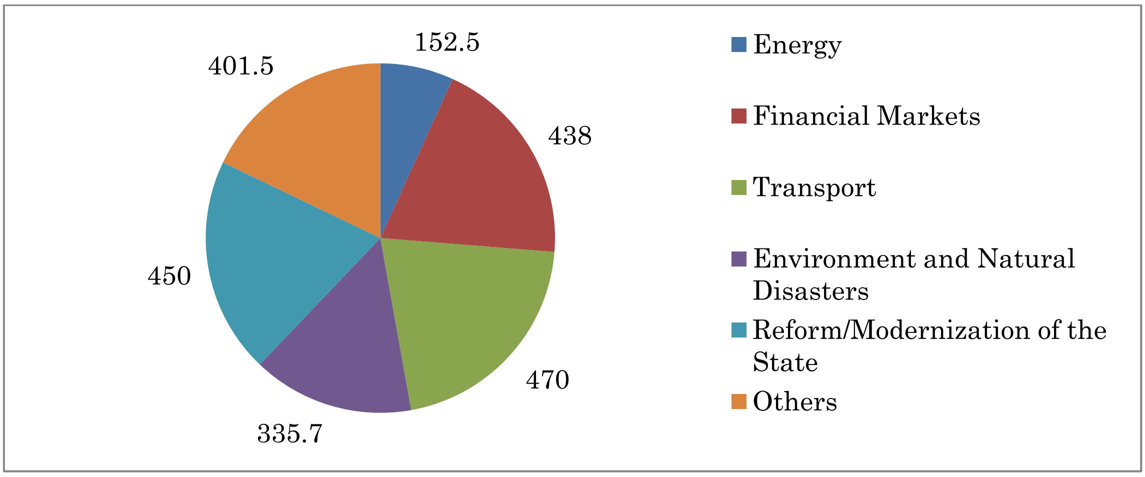
(US$ million)

	IDB	CAF	IBRD	EIB	CABEI
Approved	1,593.69	1,989.30	516.00	711.00	25.00
No. of Projects	33	20	8	2	1
Transportation Sector	470	906	0	0	0
No. of Project	2	4	0	0	0

Source: Web page of each organization

(3) IDB Support for Panama

In accordance with the IDB Country Strategy with Panama 2010-2014 (CS), the Bank's financial framework for sovereign-guaranteed approvals during the period is estimated at US$990 million and focuses on the following 6 sectors: public finance, transport, water and sanitation, energy, education, and health. A total of US$13,342 million was loaned to Panama from 1961 to 2012, which is the 7th place among IDB member countries, and US$566 million total was financed in 2012 as sovereign/non-sovereign-guaranteed loans and grant facility, which is the 8th place among other members. The bank's portfolio in Panama for the past 5 years totals US$2,248 million and the transportation sector accounts for 21%, or US$470 million.



Source: IDB Web page

Figure 2.17 IDB Portfolio for the past 5 years in Panama

(4) IDB Support for the Transport Sector in Panama

The CS raises the issue of the fragmented urban transportation system in Panama. It aims to improve the quality of road infrastructure and its maintenance by providing technical support for the design and implementation of a comprehensive transportation and transit plan for Panama, and by supporting the institutional strengthening of the Ministry of Public Works (MOP) in carrying out the projects. In 2010, the bank approved a US$70 million loan to a project for the rehabilitation and maintenance of priority corridors and rural roads in Panama. The bank set up in the CS that road rehabilitation in Panama will be carried out in coordination with CAF.

In July 2013, SMP announced the request for expressions of interest for the study of the Comprehensive Plan for Sustainable Urban Mobility for the metropolitan area of Panama with IDB financing. 44 consulting companies expressed their interests and the study will be completed during the following year by the selected consultant.

(5) CAF Support for Panama

Since becoming a full member of CAF in 2008, Panama has received a total of US$1,989 million in loans in 5 years. Transportation, health and sanitation are the principal sectors of the bank's assistance, as can be appreciated from the fact that it financed a total of US$296 million of the Panama Bay Sanitation Project and US$100 million of the program to improve potable water and sewage network in the province of Panama.

(6) CAF Support for the Transportation Sector in Panama

The bank approved a US$400 million loan for the Panama Canal Expansion Project in 2008 and a total loan of US$500 million in 2011 and 2012 for the construction of Panama Metro Line-1. Since it financed US$1 million of the on-going Feasibility Study for Panama Metro Line-2, it is thought that the bank intends to finance the project's implementation as well. Co-financing with IDB for the project is prospected from the fact that IDB also financed US$1.5 million of the aforementioned study.

(7) IBRD Support for Panama

To support the governmental policy to reduce fiscal deficit, the bank's assistance focuses on the projects aimed at strengthening the management of financial operations, improving transparency, enhancing efficiency of public expenditures, and strengthening social protection.

(8) IBRD Support for the Transportation Sector in Panama

According to the Progress Report of the Country Partnership Strategy (CPS) for Panama for FY11-14, the Government relied primarily on other sources of financing for the transportation sector, thus no bank engagement in support of road expansion and improvement is planned for the remainder of CPS. Secondary Roads Development Project, which was planned to be carried out in 2014, has been dropped due to the execution of rigorous debt management and fiscal space limits set by the SFRL.

On the other hand, MIGA (Multilateral Investment Guarantee Agency) of the World Bank Group has issued a guarantee of US$320 million in June 29, 2012 to cover a loan arranged by Citi Bank Group for the construction of Panama Metro Line-1.

(9) EIB support

The bank set a lending ceiling of US$3.8 billion for the Latin America Region in the mandate covering 2007-2013. Panama had received a loan from the bank during the 1993-2010 period for a total of US$970 million, which was the second largest operation in the region next to Brazil. US$542 million was approved for the Panama Canal Expansion Project in 2009, US$192 million for the Dos Mares Hydroelectric Plant Construction in 2009, and in 2007 US$37 million for financing the Panama Bay Sanitation Project. Initially, the bank intended to finance the construction of Panama Metro Line-1, however, it did not succeed in doing so.

2.4 Necessity of the Project

2.4.1 Necessity of transport infrastructure crossing the canal

The urbanized area in and around Panama City is shown in the pink color area in Figure 2.2, which clearly shows that the development of Panama City is distributed in the east of the city and that to the west of the canal delays due to hilly area along the canal. However, commuter time is getting longer and longer recently becaue the development area to the east of the canal has reached beyond the Tocumen International Airport, which focuses on the nearer areas such as Arraijan and La Chorrera where development becomes active.


Source: SMP

The population of Panama Metropolitan area (Panama, City, San Miguelito, Arraijan and La Chorrera Districts) is 1.72 million at present (2010), and it is forecasted that the population would reach 2.17 million in 2020 and 2.87 million in 2050 (Chapter 3). The population of Arraijan and La Chorrera in total is 398,000 at present (2010) and is forecasted to reach 553,000 in 2020 and 778,000 in 2050. In Panama Metropolitan area, car ownership shows rapid expansion and the suburban style residential development which subjects to usage of cars is very active in the west of the Study Area as shown in the photo above. From these, it is expected that the traffic connecting the western side of the canal as a suburban residential area and the eastern side as the commercial and business district would continue to increase.

Presently, the Bridge of Americas, the age of which has exceeded more than 50 years, and the access roads of the both sides of the bridge cannot respond to the increasing traffic demand, which causes heavy traffic congestion every day. Since the congestion will become heavier and heavier, development of transport infrastructure crossing the canal is necessary for the development in the west area. Under the circumstances mentioned above, the Government of Panama plans to construct a new bridge crossing the canal near the Bridge of Americas and an urban transportation system. The necessity and justification of these transport infrastructures is described in the subsequent sections.

2.4.2 Necessity of the 4th Bridge

The 4th Bridge is necessary because of the following reasons.

1) For Post-Panamax vessels
2) Expansion of road capacity across the Panama Canal
3) Construction of Metro Line-3
4) Alternative to the Bridge of Americas

(1) For Post-Panamax

Once the Panama Canal Expansion Project is completed, the New Panamax ships, larger than the current Panamax ships, will be able to transit the canal, with an increased transportation capacity per ship of approximately 5,000 TEU to 12,000 TEU. On the other hand, some Post-Panamax ships will not be able to use the canal due to the limit of the air draft of the Bridge of Americas (57.91m), which could result in insufficient economic benefit from the canal expansion. In order to enable the transit of such Post-Panamax ships, the height restriction of the bridge should be 70m, the same as the Centennial Bridge. This means the removal of the Bridge of Americas and the construction of a new bridge. Although there is no committed plan for its removal, preparation should be made by constructing the 4th Bridge in line with the canal expansion to deal with market changes, such as the increasing size of vessels.

(2) Expansion of the capacity of roads crossing the Panama Canal

Presently, traffic on the Bridge of Americas (4-lanes in both directions) at peak hours is almost saturated with a traffic flow of approximately 2,800 vehicles per hour for peak direction. The traffic demand is increasing because of recent, rapid urban development in the area west of the canal. As a result, traffic congestion extends from the Bridge of Americas toward Arraijan in the western direction in the morning peak and toward the city center in the evening peak hour. It is expected that longer travel times due to traffic congestion will increase the duration of the peak hours. In the western area of the canal, the population is increasing with rapid housing developments, and Panama Pacifico, which is the former Howard Air Force Base, is attracting companies. However, it is expected that the population increase and urban development could cease due to the constraint caused by the traffic congestion of the Bridge of Americas resulting in greater economic disparity between the eastern and western areas. For these reasons, a new road besides the Bridge of Americas is necessary to 1) reduce the traffic congestion and 2) encourage the regional development of the western area.

(3) Construction of Metro Line-3

The Metro Line-3, planned by SMP, is to connect the east and west of the canal and is expected to improve the public transport system and encourage the regional development of the western area by connecting Arraijan and La Chorrera with the center of Panama City. Since Line-3 needs to cross the canal, whether by a tunnel or bridge, if it is constructed as an independent project an additional investment of several hundreds of million dollars will be required. To make for a more efficient investment, it would be desirable to construct Line-3 together with the road bridge that needs to be constructed in the near future any way. Since Line-3 will be an important transit system in around 2020 due to the increasing transportation demand, it is necessary to implement the 4th Bridge project to accommodate Line-3.

(4) Alternative to the Bridge of Americas

Over half a century has passed since the Bridge of Americas opened in 1962, and the bridge requires regular maintenance work. Traffic regulation and night-time closures are necessary during the maintenance of the bridge’s road surface. Presently, there is no alternative route other than the Centennial Bridge, which means that the economic loss due traffic restrictions will continue to increase year by year with increased traffic demand. The economic loss will occur until the Bridge of Americas is replaced with the new bridge in the future. Therefore, an alternative road bridge to the Bridge of Americas is necessary on the Pacific Ocean side of the Panama Canal.

2.4.3 Necessity of Urban Transportation Line-3

Urban Transportation Line-3 is necessary from the following views:

1) To alleviate congestion in the area to the west of the canal
2) To improve public transport services
3) To promote public transport

(1) Alleviation of congestion in the area to the west of the canal

Even the number of lanes becomes 10 after the construction of the 4th Bridge as a 6-lane road in addition to the Bridge of Americas as a 4-lane road, the congestion will not be alleviated if the number of lanes between Arraijan and the Bridge of Americas remains four. Therefore, there is a plan to widen the hilly section between Arraijan and the Bridge of Americas from 4-lane to 6-lane in parallel with the construction of the 4th Bridge, although the capacity will become insufficient in the future even if the section is widened to 6-lane. In addition, since the capacity expansion such as road widening and bypass construction for Arraijan - La Chorrera section is difficult, traffic situation in the area would be worsen. Therefore, it is necessary to introduce a high capacity public transport system.

(2) Improvement of public transport services

The urbanized area to the west of the canal is far from the center of the city with the distance of approximately 15km between Albrook and Arraijan, and 30km between Albrook and La Chorrera, and express buses are operated in the area. However, the level of service is very low. The service is deteriorated and not reliable due to the traffic congestion, and the transport capacity is small. In addition, the fare is high due to the long distance. Although housing development for car-owning households in the area to the west of the canal is expanding, many residents who lived there for a long time depend on public transport. Therefore, it is necessary to improve the public transport services in the area.

(3) Promotion of public transport

Line-2 construction is planned after Line-1 in Panama. These urban transport lines contribute not only to traffic relieve but also the environment with the smaller CO_2 emission rate per passenger than cars and buses. It is necessary to formulate the public transport network by constructing an urban transportation system in the area to the west of the canal to promote public transport use.

2.5 Evaluation of Alternatives

2.5.1 Without Project Case

In the “Without Project Case”, the problems mentioned above will become aggravated, namely: 1) the size of ships that can transit the Panama Canal will be restricted to the New Panamax size in the future, 2) Traffic congestion will worsen, which will cause inactivity in the development of the western area and increase the economic disparity between the east and west, and 3) economic loss because of the lack of an alternative road in case of the closure of the Bridge of Americas.

2.5.2 Metro Line-3 as a Separate Project

Even if only Line-3 is developed independently without the construction of a new road, it will contribute to the reduction of traffic congestion. However, even if Line-3 is constructed it is expected that the traffic on the Bridge of Americas will become similar to the present situation because car traffic would increase along with the increased number of households owning cars. This means that the demand of Line-3 will be larger than the demand forecast as the population in the western area continues to increase. The demand forecast of Line-3 shows that Line-3 will carry approximately 20,000 passenger per hour for peak direction in peak hours in Phase-1, and approximately 25,000 in case of the Phase-2 line extension to La Chorerra. If the demand of Line-3 increases more than this, the present plan should be reviewed, which would cause an increase in the project cost. If Line-3 is constructed separately, a bridge or tunnel will be necessary to cross the canal. Greater passenger capacity and the additional infrastructure for crossing the canal will increase the project cost, and there is a possibility that the economic benefit from the project would become negative.

In addition, the problem would remain that the size of ships transiting the Panama Canal are restricted by the clearance of the Bridge of Americas.

2.5.3 Tunnel

In the case of a road being constructed with a tunnel under the canal, it is possible to compare this with the bridge plan under the same conditions because it would satisfy the necessity described in 4.2.1.

In the case of the tunnel plan, it would be rational that the road and Line-3 each have a separate tunnel; the road tunnel would be a twin tunnel consisting of a tunnel for each direction. In this case, the plan would be two road tunnels with a diameter of 16m for 3-lanes, and two tunnels with a diameter of 7.6m for Line-3. Although other types of tunnels are possible, the selection of the tunnel type is not necessary for comparison purposes because the difference of tunnel type is not a large factor. The route of the tunnels would be almost the same as that of the bridge, but it is possible to shorten the distance a little.

The advantages of the tunnel plan are: 1) there is no restriction to the air surface of Albrook Airport; 2) there is no impact on the urban landscape; and 3) there is no risk of channel closure of the Panama Canal.

On the other hand, the disadvantages of the tunnel are: 1) the project cost is higher than that of the bridge plan; 2) regular maintenance of facilities such as ventilation, lighting and pumping is necessary; 3) the construction will generate a huge amount of excavated material, and 4) there is a risk of a catastrophic disaster such as a fire in the tunnel caused by a traffic accident.

The length of the tunnel is approximately 3km. The cost is estimated at approximately USD1.5 billion as shown the table below, which is 50% greater than the cost of the 4th Bridge.

Table 2.6 Preliminary Construction Cost for Tunnel

Item	Work	Dimensions	Quantities	Unit cost (US$/m^3)	Cost (Million US$)
Road	Launch and Arrival Shaft (Cut and Cover)	40m×20m×20m×2	32,000m^3	500	16
	Tunnel	ϕ16, 3km×2	1,206,372m^3	800	965.1
Line-3	Launch and Arrival Shaft (Cut and Cover)	20m×15m×15m×2	9,000m^3	500	4.5
	Tunnel	ϕ7.6, 3km×2	272,188m^3	800	217.75
Subtotal					1,203
Contingency*					240
Total					1,443

* Note: Although the tunnel work requires cross passage, improvement of access roads, facilities such as ventilation and others not mentioned above, and the project requires design, land acquisition, utility relocation and others, it is simply assumed that these costs are 20% of the subtotal.

Source: JICA Study Team

2.6 Conclusion

The Project will implement the construction of the 4th Bridge and Urban Transportation Line 3 as a unified project. The objective of the Project is to meet the increase in traffic demand crossing the Panama Canal by expanding the transportation capacity connecting the east and the west areas of the Panama Canal.

The metropolitan area of Panama is growing as one of the economic centers in the Central America, and the west area of the canal is emerging as the suburban area of the metropolitan. On the other hand, the traffic on the Bridge of Americas, connecting the west and the east of the Panama Canal, has rapidly increased and the congestion in the morning and evening peak hours is getting heavier and heavier due to the capacity limitation, which becomes a threaten to the economic development of the metropolitan area of Panama. In addition, public transport services in the west area is very poor presently depending on buses and taxis, which causes increase in car usage and deteriorate the traffic congestion.

The Project is necessary in order to respond the increasing traffic demand in the metropolitan area of Panama and alleviate traffic congestion, and encourage the urban development in the west area of the Panama Canal. In addition, the urban transport Line-3 is necessary to improve public transportation in the west area of the canal and to reduce CO_2 emission.

Chapter 3 Demand Forecast

3.1 Methodology

3.1.1 Introduction

The traffic demand of Line-1 was estimated by SMP in 2011[1], in which the peak hour peak direction traffic (PHPDT) in 2035 is estimated to be 18,034 between 12 de Octubre and F. de Cordoba stations in the direction of Albrook. Since Line-1 runs through a high demand corridor within Panama City, the demand for Line-3 would be lower than that of Line-1.

The demand forecast for Line-3 was carried out for a 1) full development case and 2) Phase-1 case in the Study. In the full development case, Line-3 runs from Albrook to La Chorrera, while in the Phase-1 case the line is between Albrook and Nuevo Arraijan.

The traffic demand forecast for the 4th Bridge was carried out by ACP in 2013. In the beginning of the Study, the traffic demand forecast for the 4th Bridge was not included in the Study, although it was carried out after the study of the 4th Bridge was added to the Study.

The horizontal years for the demand forecast in the Study are 2020, 2025, 2030, 2035, 2040, and 2050, while the base year of the demand forecast is 2013.

3.1.2 Origin and Destination Matrix

An origin and destination (OD) matrix of private and public transportation modes during peak hours (6:00 to 8:00) was prepared by SMP in 2009 based on estimations. It is not the result of origin and destination surveys, but the product of a demand and supply model based on socioeconomic data and transport infrastructures using TRANUS software. Another OD matrix was prepared in the study for the 4th Bridge, however it cannot be used for the demand forecast of Line-3 because it focuses on vehicle traffic crossing the Bridge of Americas.

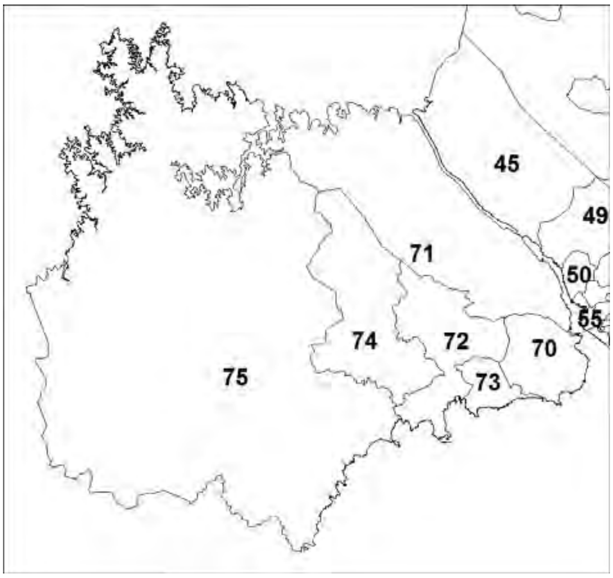
To make an OD matrix from actual surveys requires a large number of samples and time, and given the schedule of this Study it was not feasible to conduct a home interview survey which is usually applied to a traditional demand forecast modeling. Therefore, a demand forecast model for Line-3 was formulated by using the 2009 OD matrix of SMP and making supplementary traffic surveys.

3.1.3 Modifying the SMP 2009 OD

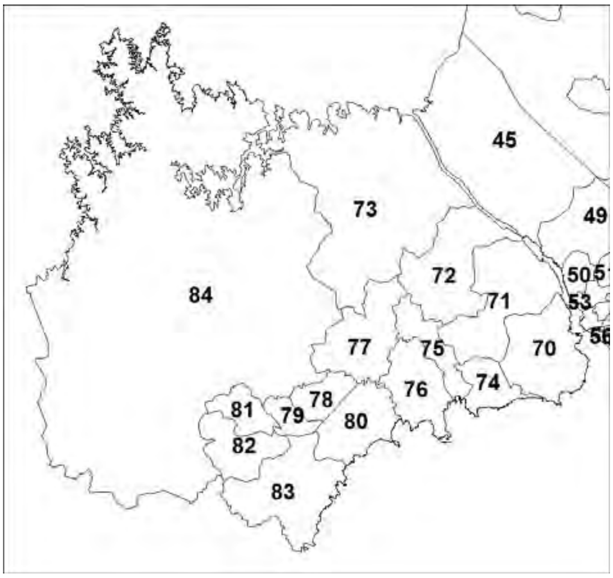
The Study’s OD matrix was prepared by modifying the SMP 2009 OD matrix, which consists of 75 zones, with 5 zones in the Arraijan District and one zone in the La Chorrera District. In the Study, nine zones were added by subdividing the zones in Arraijan and La Chorrera Districts based on the political divisions called “corregimiento”. In the Arraijan District, Nuevo Emperador and Santa Clara Corregimientos were combined into Zone No. 73, while in the Chorrera District, 14 Corregimientos were combined into Zone No. 84.

The 84-traffic zone system was further subdivided taking into consideration the areas of the future stations for trip assignment.

1 Final Report “Updating of Demand, Operation Costs, and Various Indicators required by EIB for the new configuration of Panama Metro Line-1.” (Actualización de la Demanda, Costos de Operación e Indicadores Varios requeridos por el BEI para la nueva configuración de la Línea 1 del Metro de Panamá. Informe de Final)



75 Zones of the 2009 SMP OD

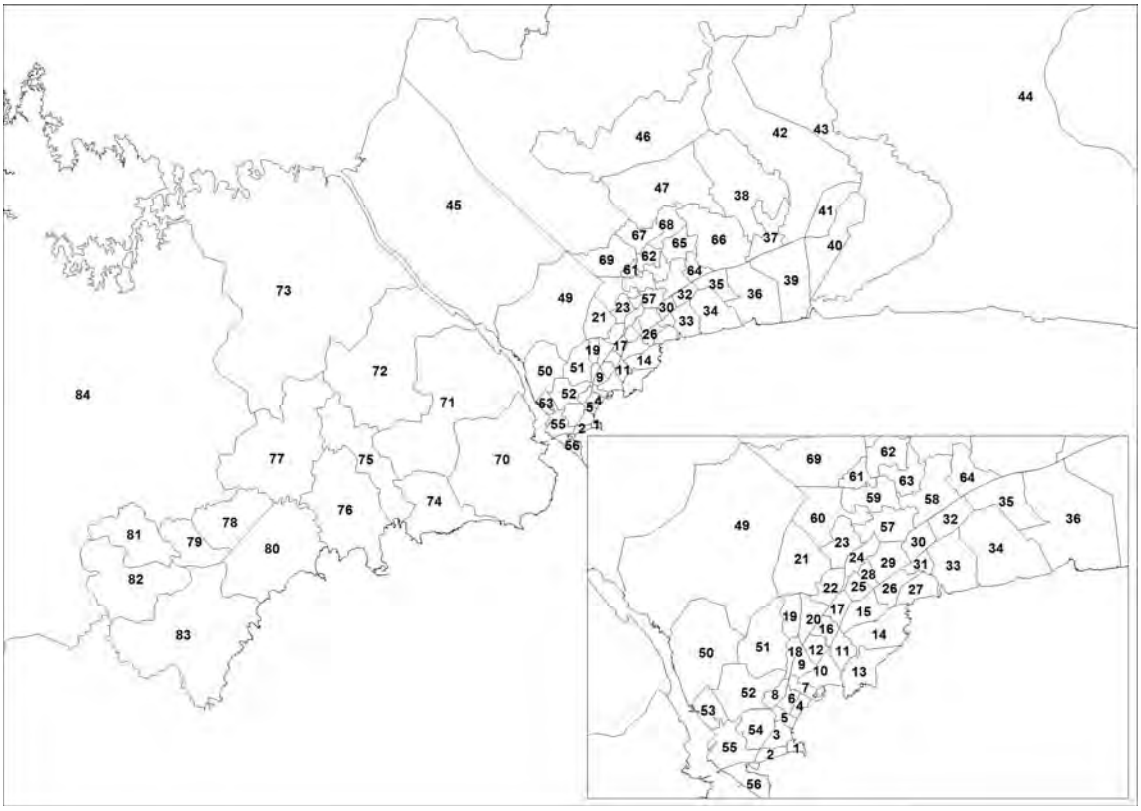


84 Zones of the Study

Source: JICA Study Team. Left – based on SMP reports, Right – based on Corregimiento boundary map.

Figure 3.1 Zone Divisions west of the Canal

Figure 3.2 shows the OD zoning system with the zone numbers used in the demand forecast model for the Study. The traffic zones from 1 to 69 are the same as those in the demand forecast model for Line-1.

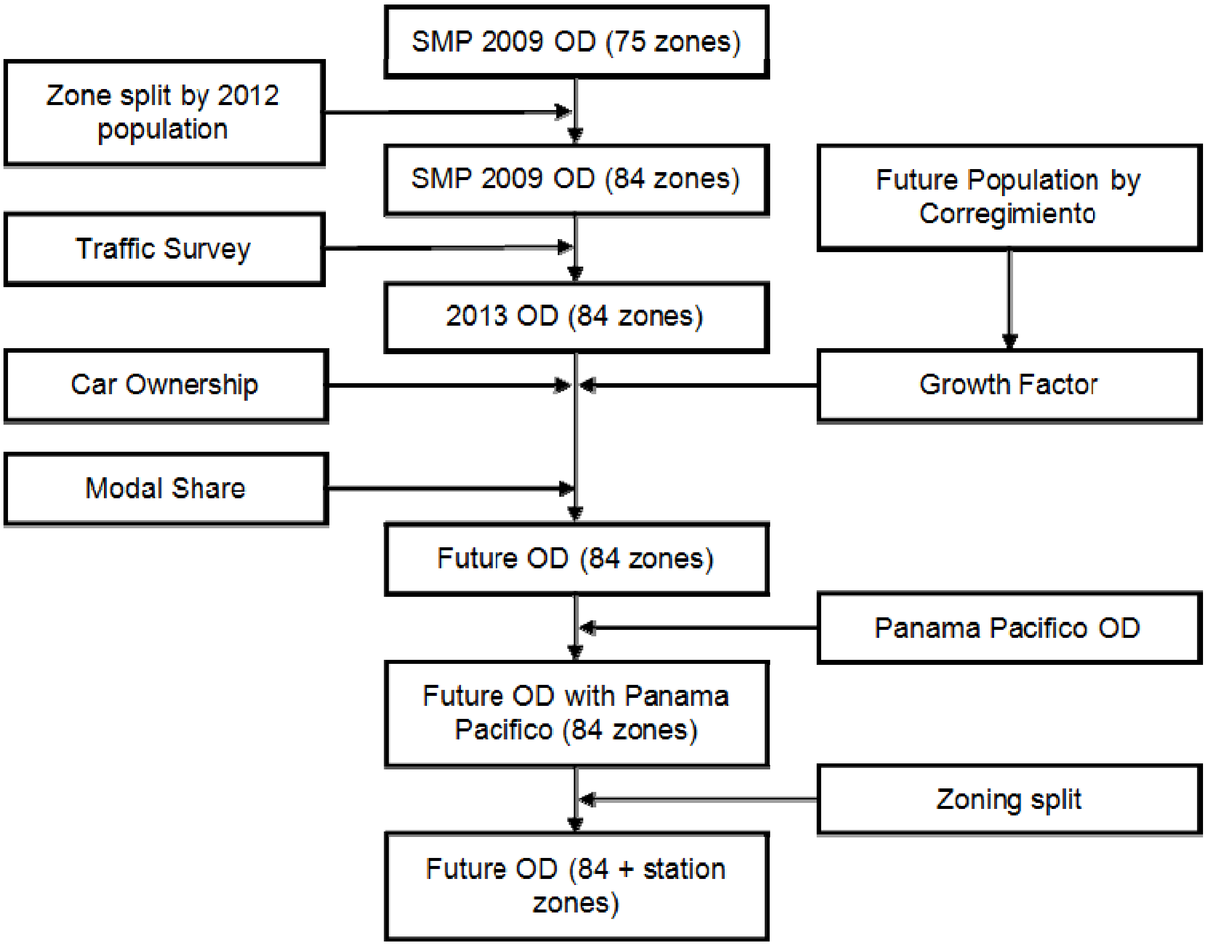


Source: JICA Study Team

Figure 3.2 Traffic Zoning System

The process for projecting the future OD matrix is shown in Figure 3.3. The major points of the flowchart are:

1) Replaces the OD that crosses the canal with the estimated OD based on the traffic survey.
2) Modal shift from public mode to private mode takes into account the increasing number of cars.
3) Increases the OD data by including the population growth.
4) Adds new traffic related to the development of Panama Pacifico.
5) Makes new traffic zones within the walking distance of stations by splitting the OD.
6) Modal shifts made from private mode to public mode for the OD pairs along Line-1, 2, and 3.



Source: JICA Study Team

Figure 3.3 Flow for making the OD Matrix

Note that the estimated OD is the morning peak hour OD.

3.1.4 Transit Assignemnt

Transit network models were developed and the estimated OD matrix was applied to the transit network by using JICA STRADA[1].

[1] JICA STRADA is a package software for demand forecast developed by JICA.

3.2 Demand Forecast of ACP's Pre-Feasibility Study

3.2.1 Result of the Demand Forecast in ACP's Study

The ACP's Study estimated the future traffic on the 4th Bridge for the years from 2017 to 2036 in terms of AADT. The result of the forecast is shown in Table 3.1. The result shows that traffic flow on the Bridge of Americas would be approximately 1.9 times larger than that of the 4th Bridge. The traffic flow on the 4th Bridge was estimated at 25,328 vehicles in 2020 and 35,431 vehicles in 2035 in terms of AADT. It is estimated that the traffic flow on the Bridge of Americas would reach almost the same level as the present traffic in 2020 even if the 4th Bridge is constructed. The traffic flow in the case of "4th Bridge without Bridge of Americas" is estimated to be the same as the sum of the traffic flow on the 4th Bridge and the Bridge of Americas in case that the 4th Bridge is constructed.

Table 3.1 Traffic Projection in ACP's Study (vehicles per day)

Year	4th Bridge	Bridge of Americas	Centenario Bridge	Pan-American Highway	4th Bridge Without Bridge of Americas
2020	25,328	48,056	28,251	73,384	73,384
2025	28,129	53,370	31,375	81,499	81,449
2030	31,240	59,272	34,845	90,512	90,512
2035	35,431	67,223	39,518	102,654	102,654

Source: ACP's Feasibility Study

Based on the demand forecast above, Level of Services (LOSs) are calculated for the Bridge of Americas, the 4th Bridge, and the Panamerican Road, and Equivalent Single Axle Loads (ESALs), which is generally used for the pavement design, are also calculated

The Highway Capacity Manual (USA) is used to evaluate the LOSs. Six LOSs are defined, represented by letters A to F. LOS "A" means the best operating conditions, and LOS "F" means the worst. In the ACP's Study, it is estimated that the 4th Bridge would reach "D" level in 2037 while the Bridge of Americas would reach "F" level in 2021.

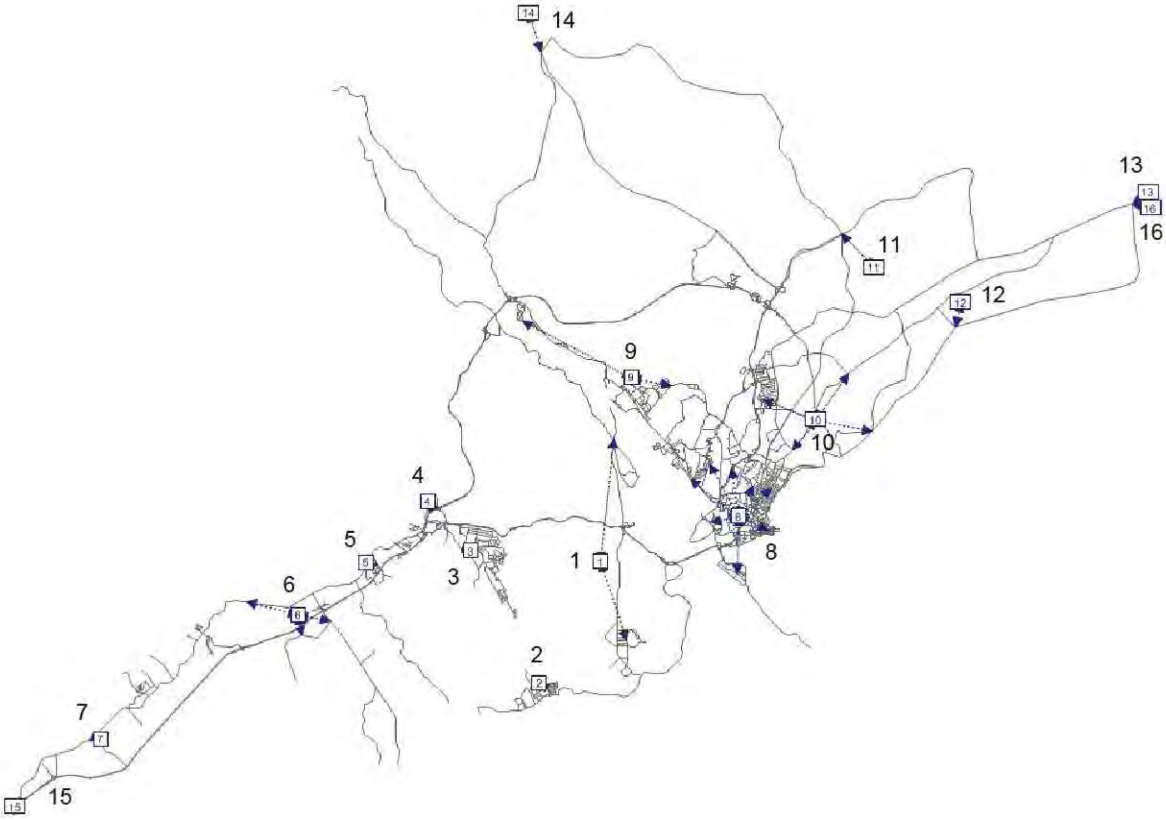
3.2.2 Demand Forecast Method in ACP's Study

The origin-destination (OD) matrices used in the ACP's Study were developed from OD data in "Feasibility Study for the Project Panama Canal Crossing, 2001, Ministry of Public Works (MOP's Study)". The OD matrix in MOP's Study consists of 10 traffic zones, in which only two zones represent the west area of the canal. The MOP's Study estimated the OD matrices based on an interview survey at a survey point along the Pan-American Highway. This means that only OD information between the west and the east of the canal was taken and the OD information within Panama City and within the west area was not estimated. However, such internal movement is not necessary for the estimation of traffic demand on the 4th Bridge.

The ACP's Study divided one of the zones west of the canal into 7 zones and applied a 16 traffic zone system for the demand forecast. Since the OD matrix in MOP's Study represents the traffic in 2000, ACP's Study applied an annual growth rate to each traffic zone to estimate the OD in 2012. The estimated OD matrix in 2012 was calibrated by the result of the traffic count survey conducted in 2012 in the ACP's Study. The OD information is sufficient for the demand forecast of the 4th Bridge in the ACP's Study, in which the approach road to the 4th Bridge is directly connected to Corredor Norte.

However, the OD information of ACP's Study is insufficient for the traffic simulation at

Omar Torrijos Interchange which is included in the TOR of the Study. A shown in Figure 3.4, the east area of the canal belongs to the zone 8 in the 16 zoning system in the ACP' Study, the traffic demand forecast by direction using the same zoning system at Omar Torrijos Intersection is difficult.



Source: ACP's Pre-F/S (Numbers are added for better understanding)

Figure 3.4 Traffic Zoning in ACP's Pre-F/S

The ACP's Study forecasted the future traffic assuming the population growth rate from 2012 to 2036 to be 2.12% per year. Using the growth rate, the traffic in 2036 is calculated at 1.65 times that of 2012. However, it is expected that the traffic growth rate would be higher than the estimation sue to the rapid increase in the number of cars in Panama, especially in the west area of the canal.

The review is summarized as:

- ACP' Study lacks the forecast years because the Study need the demand forecast for 20 years after the opening of the bridge while ACP's Study estimated it till 2026.
- Since the area of traffic zone is very large, the zoning cannot be used for the traffic simulation at Omar Torrijos Intersection which is required in the Study.
- Since traffic growth rate is estimated based on the population growth only, the rapid growth in the number of cars is not taken into account.
- It is not clear how Line-3, which is planned to be constructed with the 4th Bridge, is considered in the ACP's Study.

3.3 Traffic Surveys

3.3.1 Present Traffic

Three traffic count surveys were available for the Study.

1) METI Study: August 9 (Thursday), 2012
2) ACP[1]: October 23 (Tuesday), 2012
3) ATTT: July 8-14 (Monday-Sunday), 2013
4) This Study: August 13 (Wednesday), 2013

In the METI Study, the vehicles were classified into three types: sedans, buses, and trucks. Taxis were included in sedans. In the ACP's Study, buses and trucks were counted as the same category. The data of ACP's Study and ATTT were obtained after the commencement of the Study.

(1) Bridge of Americas

In the ACP's Study, the number of vehicles passing the Bridge of Americas was counted on October 20th, 2012 (Saturday) and October 23rd, 2012 (Tuesday), and the traffic flow in Annual Average Daily Traffic (AADT) on the Bridge of Americas was calculated at 49,834 vehicles as shown in Table 3.2. AADT represents the average traffic in a year, calculated by dividing the total yearly traffic volume by 365. In the ACP's Study, 16-hours of traffic (5:00-21:00) is considered to be the daily traffic. The peak hour is 6:00-7:00.

Table 3.2 AADT of Bridge of Americas (no. of vehicles per day)

	East → West	West → East	Total
Cars	22,540	24,235	46,776
Buses + Trucks	2,102	2,273	4,375
Total	23,326	26,508	49,834

Source: Pre-F/S (Draft Final Report, November 2013)

A traffic count survey on August 9th, 2012 (Thursday) in the METI Study shows the traffic flow on the Bridge of Americas for the same period (5:00-21:00) was 58,337 vehicles, which is 17% greater than that of the ACP's Study. The result of the traffic survey in the METI Study is shown in Table 3.3. The result shows that heavy traffic was observed from the east to the west in the early morning, which is usually not the peak direction, and the number of buses counted was very high compared to other surveys. The peak hour of bus traffic was from 5:00 to 6:00 in the direction toward Albrook. The number of buses at peak hour was 334.

A traffic count survey in the Study, conducted on August 30th, 2013 (Wednesday), shows that the traffic flow on the Bridge of Americas for 16 hours was 45,557 vehicles for both directions, which is 8.6% less than that of the ACP's Study. The number of buses from 5:00 to 6:00 (the peak hour) for the Albrook direction was 210 as shown in Table 3.4.

The ATTT traffic survey (Table 3.5) shows that the volume of buses at this same time in the same direction was between 122 and 179 depending on the day of the week. Although hourly traffic data is not given in the ACP report, the bar chart in the report shows that the number of buses was 100-150 at the peak hour.

1 Studies and Preliminary Design for a New (Fourth) Bridge over the Panama Canal at the Pacific Side

Table 3.3 Traffic Count Survey (2012)

	From Albrook To Arraijan				From Arraijan To Albrook			
Time	Car	Bus	Truck	Total	Car	Bus	Truck	Total
4:00-5:00	155	48	4	207	878	147	31	1,056
5:00-6:00	499	171	28	698	2,444	334	36	2,814
6:00-7:00	1,253	245	39	1,537	2,965	271	25	3,261
7:00-8:00	1,231	199	68	1,498	2,593	235	28	2,856
8:00-9:00	1,294	142	48	1,484	2,515	215	47	2,777
9:00-10:00	1,051	133	88	1,272	1,503	182	52	1,737
10:00-11:00	1,239	144	116	1,499	1,555	164	73	1,792
11:00-12:00	953	150	88	1,191	1,281	146	75	1,502
12:00-13:00	1,177	137	78	1,392	1,342	182	51	1,575
13:00-14:00	1,310	152	92	1,554	1,202	168	57	1,427
14:00-15:00	1,396	152	88	1,636	1,298	150	65	1,513
15:00-16:00	1,898	122	78	2,098	1,445	230	53	1,728
16:00-17:00	2,372	164	58	2,594	1,645	209	39	1,893
17:00-18:00	2,310	233	41	2,584	1,496	240	33	1,769
18:00-19:00	2,745	253	27	3,025	1,147	230	18	1,395
19:00-20:00	2,220	262	51	2,533	821	170	26	1,017
20:00-21:00	1,842	154	12	2,008	538	128	12	678
21:00-22:00	1,190	88	16	1,294	507	89	7	603
Total	26,135	2,949	1,020		27,175	3,490	728	

Source: Traffic Survey, METI F/S (2012)

Table 3.4 Traffic Count Survey (2013)

	From Albrook To Arraijan					From Arraijan To Albrook				
Time	Cars	Taxis	Buses	Trucks	TOTAL	Cars	Taxis	Buses	Trucks	TOTAL
00:00-01:00	273	84	8	1	366	124	57	6	10	197
01:00-02:00	111	34	1	2	148	53	25	1	11	90
02:00-03:00	73	21	0	3	97	64	33	6	11	114
03:00-04:00	53	21	0	3	77	165	57	13	12	247
04:00-05:00	72	17	7	6	102	686	223	82	20	1,011
05:00-06:00	194	34	37	5	270	2,018	401	210	26	2,655
06:00-07:00	354	33	82	9	478	2,362	291	124	17	2,794
07:00-08:00	571	72	97	26	766	1,647	104	144	13	1,908
08:00-09:00	530	45	58	37	670	1,350	166	118	94	1,728
09:00-10:00	668	52	63	72	855	1,210	207	84	73	1,574
10:00-11:00	811	63	73	60	1,007	1,107	169	113	107	1,496
11:00-12:00	804	58	73	73	1,008	912	152	103	91	1,258
12:00-13:00	837	63	90	59	1,049	905	145	85	77	1,212
13:00-14:00	908	76	86	72	1,142	948	143	92	103	1,286
14:00-15:00	878	90	85	59	1,112	837	118	96	85	1,136
15:00-16:00	1,570	240	140	81	2,031	894	104	98	65	1,161
16:00-17:00	1,787	238	167	65	2,257	868	161	145	59	1,233
17:00-18:00	1,810	204	149	40	2,203	830	118	133	43	1,124
18:00-19:00	2,096	190	170	33	2,489	959	98	124	21	1,202
19:00-20:00	1,871	237	184	26	2,318	705	111	94	19	929
20:00-21:00	1,750	259	167	13	2,189	810	133	79	15	1,037
21:00-22:00	958	200	91	10	1,259	822	143	37	18	1,020
22:00-23:00	624	123	47	3	797	428	99	19	5	551
23:00-24:00	422	82	14	0	518	249	78	3	7	337
TOTAL	19,544	3,017	1,889	758	25,208	20,953	3,336	2,009	1,002	27,300

Source: Traffic Survey, JICA (2013)

Table 3.5 No. of Buses (Monday-Friday) in Traffic Survey by ATTT

	From Albrook To Arraijan					From Arraijan To Albrook				
Time	Monday	Tuesday	Wednesday	Thurs	Friday	Monday	Tuesday	Wednesday	Thurs	Friday
00:00-01:00	2	5	3	0	7	12	13	16	16	17
01:00-02:00	4	4	2	0	3	7	16	8	9	9
02:00-03:00	3	4	3	0	10	7	14	14	17	8
03:00-04:00	2	16	8	2	14	36	31	34	34	25
04:00-05:00	25	35	33	10	12	34	113	134	130	134
05:00-06:00	57	94	58	38	10	122	167	158	128	179
06:00-07:00	31	55	37	38	26	103	126	83	48	106
07:00-08:00	76	79	10	26	51	103	11	120	31	101
08:00-09:00	59	54	87	31	101	107	34	101	68	120
09:00-10:00	45	49	92	61	107	113	137	126	90	98
10:00-11:00	35	64	142	53	105	108	118	125	99	134
11:00-12:00	42	51	122	62	104	122	89	134	107	134
12:00-13:00	35	46	88	72	107	116	111	134	118	130
13:00-14:00	44	57	71	49	104	123	126	127	126	146
14:00-15:00	78	79	61	44	116	103	101	124	121	147
15:00-16:00	119	90	105	84	92	94	130	135	126	160
16:00-17:00	160	113	110	94	96	142	127	156	140	141
17:00-18:00	139	101	113	92	60	141	141	152	143	134
18:00-19:00	128	103	65	53	60	112	107	96	119	111
19:00-20:00	117	106	53	60	74	95	90	101	88	122
20:00-21:00	28	15	21	35	103	65	57	71	80	87
21:00-22:00	35	25	17	26	87	45	54	38	35	78
22:00-23:00	32	16	8	14	55	26	18	22	20	30
23:00-24:00	20	9	3	10	33	15	14	22	16	17
Total	1,316	1,270	1,312	954	1,537	1,951	1,945	2,231	1,909	2,368

Source: Traffic Survey, ATTT (2012)

(2) Centenario Bridge

In the ACP's Study, the traffic flow in AADT on Centenario Bridge was calculated at 31,405 vehicles based on a traffic count survey conducted on September 1st, 2nd, and 3rd, 2012 (Saturday, Sunday, and Monday) as shown in Table 3.6.

Table 3.6 AADT of Centenario Bridge (no. of vehicles)

	East → West	West → East	Total
Cars	12,816	14,532	27,348
Buses + Trucks	1,971	2,085	4,056
Total	14,787	16,618	31,405

Source: Pre-F/S (Draft Final Report, November 2013)

The traffic survey data in the METI Study (Table 3.7) shows that the traffic for the same period was 29,529 vehicles, which is 6% less than that of the ACP's Study. The number of buses was as small as 17 even in the peak hour (5:00-6:00) for the peak direction.

The Study did not conduct the traffic survey at Centenario Bridge.

Table 3.7 AADT of Centenario Bridge (no. of vehicles)

Time	From Panama City To Arraijan				From Arraijan To Panama City			
	Car	Bus	Truck	Total	Car	Bus	Truck	Total
4:00-5:00	67	1	56	124	206	1	105	312
5:00-6:00	180	4	59	243	982	17	110	1,109
6:00-7:00	354	2	106	462	1,964	6	32	2,002
7:00-8:00	433	8	107	548	2,242	0	38	2,280
8:00-9:00	475	7	87	569	1,035	2	149	1,186
9:00-10:00	468	1	132	601	534	0	135	669
10:00-11:00	470	1	125	596	452	1	128	581
11:00-12:00	428	1	122	551	401	2	171	574
12:00-13:00	502	0	126	628	361	2	157	520
13:00-14:00	449	1	153	603	477	2	186	665
14:00-15:00	609	5	195	809	684	5	242	931
15:00-16:00	868	7	125	1,000	642	5	215	862
16:00-17:00	1,269	11	128	1,408	643	6	187	836
17:00-18:00	2,175	8	103	2,286	619	6	159	784
18:00-19:00	1,937	8	97	2,042	456	6	84	546
19:00-20:00	1,394	7	136	1,537	282	5	110	397
20:00-21:00	559	6	92	657	206	2	91	299
21:00-22:00	407	1	63	471	195	2	76	273
Total	13,044	79	2,012	15,135	12,381	70	2,375	14,826
5:00-21:00	12,570	77	1,893	14,540	11,980	67	2,194	14,241

Source: Traffic Survey, METI F/S (2012)

(3) Pan-American Highway

Table 3.8 (Arraijan - Nuevo Arraijan) and Table 3.9 (Nuevo Arraijan - Chorrera) show the traffic along the Pan-American Highway. Compared to traffic of the Bridge of Americas, the number of taxis of Pan-American Highway is larger and the number of buses is smaller.

In the section of Arraijan - Nuevo Arraijan, the daily traffic of taxis is approximately 12,600 while that of buses is approximately 1,400. The peak hour of the traffic toward Panama City is 5:00-6:00 for buses and 7:00-8:00 for cars.

In the section of Nuevo Arraijan - Chorrera, the daily traffic of taxis is approximately 19,100 while that of buses is approximately 810.

(4) Autopista

A traffic count survey of Autopista was conducted in the METI Study, the result of which is shown in Table 3.10. Traffic in the period of 4:00-22:00 is approximately 51,900 in which the number of cars accounts for approximately 46,200. Express buses are operated along Autopista with a daily traffic of approximately 1,500.

Table 3.8 Traffic Volume between Arraijan and Nuevo Arraijan

	From Arraijan To Nuevo Arraijan					From Nuevo Arraijan To Arraijan				
Time	Cars	Taxis	Buses	Trucks	TOTAL	Cars	Taxis	Buses	Trucks	TOTAL
00:00-01:00	157	88	9	0	254	129	85	3	0	217
01:00-02:00	66	37	3	1	107	65	48	1	4	118
02:00-03:00	39	38	4	1	82	42	35	0	3	80
03:00-04:00	56	52	16	3	127	73	54	11	5	143
04:00-05:00	97	69	32	0	198	378	177	47	9	611
05:00-06:00	187	114	29	8	338	793	259	68	14	1,134
06:00-07:00	447	234	38	12	731	794	266	41	8	1,109
07:00-08:00	721	298	33	23	1,075	1,078	297	37	50	1,462
08:00-09:00	480	213	49	41	783	823	301	34	53	1,211
09:00-10:00	550	246	39	28	863	738	345	32	41	1,156
10:00-11:00	509	303	36	46	894	787	419	36	47	1,289
11:00-12:00	574	277	32	42	925	847	501	30	58	1,436
12:00-13:00	624	253	38	46	961	981	409	38	59	1,487
13:00-14:00	604	302	32	48	986	869	395	37	48	1,349
14:00-15:00	615	257	26	35	933	1,106	413	20	68	1,607
15:00-16:00	682	354	38	22	1,096	897	420	32	49	1,398
16:00-17:00	638	420	44	29	1,131	867	412	42	42	1,363
17:00-18:00	742	483	32	19	1,276	917	482	37	35	1,471
18:00-19:00	768	375	29	5	1,177	973	351	28	25	1,377
19:00-20:00	772	288	40	12	1,112	907	338	23	12	1,280
20:00-21:00	720	295	46	8	1,069	765	326	31	19	1,141
21:00-22:00	516	257	19	1	793	634	278	26	14	952
22:00-23:00	340	209	16	2	567	457	201	15	3	676
23:00-24:00	281	123	14	4	422	238	156	5	4	403
Total	11,185	5,585	694	436	17,900	16,158	6,968	674	670	24,470

Source: Traffic Survey, JICA (2013)

Table 3.9 Traffic Volume between Nuevo Arraijan and La Chorrera

	From Nuevo Arraijan To La Chorrera					From La Chorrera To Nuevo Arraijan				
Time	7	Taxis	Buses	Trucks	TOTAL	Cars	Taxis	Buses	Trucks	TOTAL
00:00-01:00	67	26	1	4	98	101	12	0	1	114
01:00-02:00	36	13	0	1	50	88	7	0	4	99
02:00-03:00	36	16	1	3	56	51	9	1	5	66
03:00-04:00	30	13	0	3	46	126	21	9	5	161
04:00-05:00	38	19	3	5	65	170	58	28	18	274
05:00-06:00	143	31	2	6	182	471	53	37	16	577
06:00-07:00	472	75	6	15	568	596	84	24	12	716
07:00-08:00	671	49	12	62	794	786	150	25	62	1,023
08:00-09:00	480	62	9	52	603	557	100	22	52	731
09:00-10:00	471	57	6	57	591	560	137	20	70	787
10:00-11:00	328	32	8	51	419	480	108	17	57	662
11:00-12:00	409	37	8	50	504	462	102	17	58	639
12:00-13:00	464	52	4	66	586	568	122	17	56	763
13:00-14:00	395	29	10	43	477	531	96	20	65	712
14:00-15:00	421	44	10	50	525	623	107	13	58	801
15:00-16:00	457	66	14	46	583	639	126	41	57	863
16:00-17:00	522	91	27	30	670	644	104	46	42	836
17:00-18:00	641	118	28	30	817	720	123	46	35	924
18:00-19:00	581	107	21	14	723	760	120	24	14	918
19:00-20:00	431	67	22	5	525	594	88	44	14	740
20:00-21:00	424	61	21	10	516	509	65	37	12	623
21:00-22:00	336	71	22	3	432	466	77	48	9	600
22:00-23:00	234	63	7	5	309	302	47	26	7	382
23:00-24:00	102	29	4	2	137	150	32	2	10	194
Total	8,189	1,228	246	613	10,276	10,954	1,948	564	739	14,205

Source: Traffic Survey, JICA (2013)

Table 3.10 Traffic Volume of Autopista (between Arraijan and La Chorrera)

	From Arraijan To Chorrera				From Chorrera To Arraijan			
Time	Car	Bus	Truck	Total	Car	Bus	Truck	Total
4:00-5:00	1,068	51	92	1,211	85	6	42	133
5:00-6:00	3,953	105	55	4,113	242	32	77	351
6:00-7:00	3,721	51	16	3,788	686	61	117	864
7:00-8:00	2,501	36	63	2,600	1,126	56	161	1,343
8:00-9:00	1,388	30	150	1,568	832	45	127	1,004
9:00-10:00	1,223	33	159	1,415	833	41	198	1,072
10:00-11:00	971	20	120	1,111	904	55	180	1,139
11:00-12:00	1,674	14	147	1,835	848	35	169	1,052
12:00-13:00	727	18	118	863	544	33	162	739
13:00-14:00	871	34	135	1,040	1,106	39	216	1,361
14:00-15:00	867	50	191	1,108	1,430	43	153	1,626
15:00-16:00	795	39	101	935	1,669	49	170	1,888
16:00-17:00	1,013	70	132	1,215	2,186	56	153	2,395
17:00-18:00	737	57	103	897	2,971	52	119	3,142
18:00-19:00	642	44	47	733	2,931	61	94	3,086
19:00-20:00	465	32	52	549	2,118	60	103	2,281
20:00-21:00	387	17	50	454	1,465	40	101	1,606
21:00-22:00	316	14	41	371	914	15	61	990
Total	23,319	715	1,772	25,806	22,890	779	2,403	26,072
5:00-21:00	21,935	650	1,639	24,224	21,891	758	2,300	24,949

Source: Traffic Survey, METI F/S (2012)

3.3.2 Passenger OD Survey

A Passenger OD Survey was carried out at Albrook Terminal and major bus stops along the Line-3 route. Table 3.11 shows the locations where the surveys were made. Passengers in taxis and "pirata" buses (unauthorized buses) were interviewed at site No. 3 (Calle 25-Calidonia). In total, 5,042 samples were collected.

Table 3.11 Locations of Passenger OD Surveys

No.	Location	No. of Samples	Target	Direction	Time
1	Albrook Terminal	1,285	Bus	To Chorrera	0:00-20:00
2	Xtra supermarket in Arraiján	929	Bus	Both directions	6:00-14:00
3	Calle 25- Calidonia	93	Taxi	To Chorrera	16:00-20:00
4	Nuevo Chorrillo	319	Bus	To Albrook	6:00-14:00
5	Rey supermarket in Vista Alegre	424	Bus	To Albrook	6:00-14:00
6	Tajonaso bus stop in Vista Alegre	83	Bus	To Albrook	6:00-14:00
7	HOPSA in Vista Alegre	72	Bus	To Albrook	6:00-14:00
8	Super 99 supermarket in Valle Hermoso	329	Bus	To Albrook	6:00-14:00
9	Bus stop in San José	95	Bus	To Albrook	6:00-14:00
10	Ciudad del Futuro	94	Bus	To Albrook	6:00-14:00
11	Bus stop at El Machetazo	61	Bus	To Albrook	6:00-14:00
12	Plaza Italia	80	Bus	To Albrook	6:00-14:00
13	El Pueblo supermarket	32	Bus	To Albrook	6:00-14:00
14	Rey supermarket in La Chorrera	1,146	Bus	To Albrook	6:00-14:00

Source: Traffic survey, JICA Study Team (2013)

It was found that the majority of the trips along the route are long distance trips between the western areas (La Chorrera and Arraijan) and Albrook. Since the number of samples for short distance trips was very small, the internal trips in the OD matrix could not be estimated.

In the Passenger OD Interview Survey, the average travel time of the interviewees was 110 minutes, and the average fare they paid was USD2.00.

Table 3.12 shows the modal share of feeder transport along Panamerican Highway taken from the Passenger OD Interview Survey. The feeder bus is an important transport mode to bus stops along the road, and taxi also plays an important role as the feeder mode. Car accounts for approximately 5% of the feeder modes, which means that pick-up and drop-off by private car is necessary for some people. Taxi and car use implies that public transport system as the feeder system is poor in this area.

Table 3.12 % of Modal Share of Feeder Transport

Mode	Arraijan	Burunga	Nuevo Chorrillo	Vista Alegre	Ciuda de Futuro	Rey Chorrera
Walk	30.4%	10.3%	24.1%	42.3%	78.1%	7.9%
Car	4.6%	4.6%	4.2%	7.1%	3.5%	5.3%
Taxi	23.6%	38.6%	29.6%	22.5%	6.7%	19.9%
Pirata	1.1%	1.2%	0.3%	0.7%	0.7%	0.5%
Bus	39.9%	45.0%	41.7%	27.1%	9.5%	66.0%
Others	0.4%	0.2%	0.0%	0.3%	1.6%	0.4%

Source: JICA Study Team

3.3.3 Stated Preference Survey

The Stated Preference Survey (SP) was carried out for bus passengers, taxi passengers, and car users. This is a survey where travelers were asked their choice between using a metro system and a bus (or car). Although different transportation conditions were presented to the interviewees, the tendency shows a strong preference for the metro system as shown in Table 3.13.

Table 3.13 Mode Preference in the SP Survey

Preference mode	Bus passengers	Taxi passengers	Car drivers
Metro	39.6%	36.3%	55.6%
Bus	60.4%	-	-
Taxi	-	63.7%	-
Car	-	-	44.4%

Note: These are the percentages of all the samples consisting of the different travel conditions (travel time, fare, etc.).
Source: Traffic Survey, JICA Study Team (2013)

The SP survey shows that bus passengers in the western area pay an average fare of USD1.70 per trip, while taxi passengers pay USD3.20 in average.

A disaggregated model analysis was carried out and the value of time of bus passengers was calculated to be 19.2 minutes per dollar (or USD3.10 per hour). The value of time of taxi passengers and car drivers was not estimated because the “t-value” of each parameter in the disaggregated model analysis was very low. Table 3.14 shows that the result of the logit model analysis for bus and taxi users.

Table 3.14 Result of Logit Model Analysis

Variable	Bus	Taxi
Travel Time (minutes)	-0.01766 (t = -5.54)	-0.05617 (t = -5.29)
Fare (USD)	-0.3388 (t = -3.4)	-0.7969 (t= -5.16)
Seat availability (0=seat, 1=standing)	-0.404 (t = -5.1)	-0.3991 (t = -1.02)
Constant (Line-3 = 1, the other =0)	-0.3344 (t = -2.32)	-0.8351 (t = -3.84)
No. of data	1,428	226
Goodness-of-fit	63.5%	73.5
Chi-square	134	85.3
Rho-square	0.068	0.267

Note: t = Student's T Value
Source: JICA Study Team

3.3.4 Travel Time Survey

A travel time survey was carried out along the Panamericana Road for normal buses and along the Autopista for express buses. In the morning peak hours, it took 130 minutes from La Chorrera to Albrook along the Panamericana while it took 100 minutes along the Autopista. It took 70 minutes from Arraijan to Albrook (approximately 15km/h). The travel time of passenger cars was also measured and the speed between Arraijan and Albrook by car was calculated to be 17 km/h.

At the evening peak hours, it took 110 minutes from Albrook to La Chorrera along the Panamericana while it took 100 minutes along the Autopista. The travel time from Albrook to Arraijan was 40-50 minutes (21-27km/h).

3.4 Socioeconomic Framework

3.4.1 Economic Growth Rate

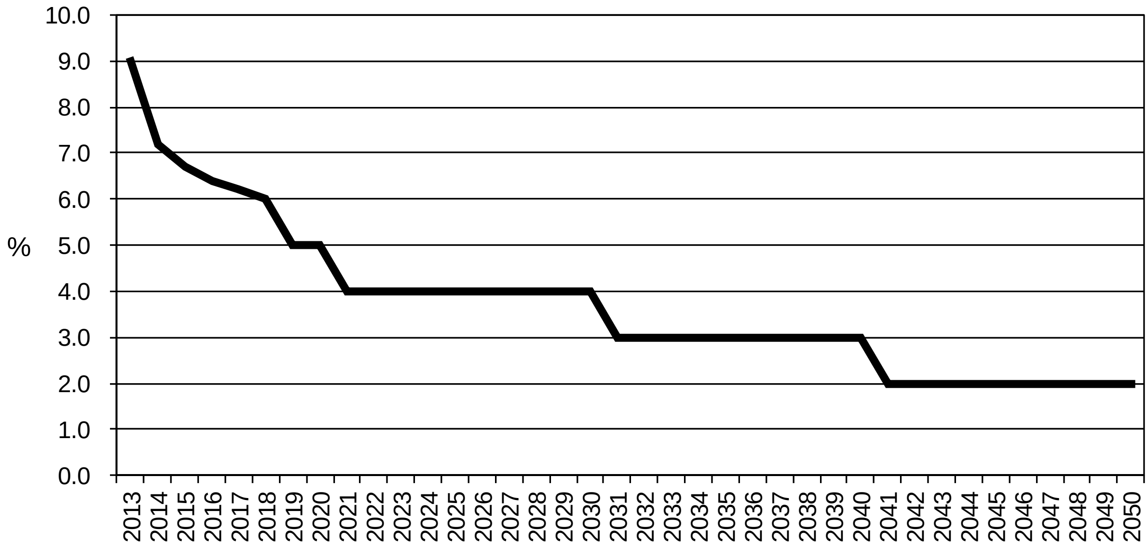
The assumption on the economic growth rates are applied to the estimation of the future car ownership and truck traffic in the Study. IMF estimated the economic growth rate (real GDP) of Panama from 2013 to 2018 as shown Table 3.15. The World Bank' estimation is similar to that of IMF.

Table 3.15 Economic Growth Rate Projection from 2013 to 2018 (%)

	2013	2014	2015	2016	2017	2018
IMF	9.0	7.2	6.7	6.4	6.2	6.0
World Bank	7.9	7.3	6.9	6.5	-	-

Source: IMF Web page, The World Bank Web Page

The Study employed the forecast by IMF for the economic growth rates from 2013 to 2018. The economic growth rates after 2018 need to be assumed in the Study because there is no official prospect. Although IMF forecasted that a high economic growth would continue up to 2018, it is not sure that such high growth rates continue in long term. In the study, the economic growths after 2018 were assumed as 5.0% (2019, 2020), 4.0% (2021-2030), 3.0% (2031-2040), and 2.0% (2041-2050) as shown in Figure 3.5. Under this assumption, the GDP of Panama in 2050 would be four times that of 2012 and the per capita GDP would be approximately 2.7 times, becoming the level in developed countries at present.



Source: IMF (2013-2018), JICA Study Team (2019-2050)

Figure 3.5 Assumption of Economic Growth Rate

3.4.2 Population Projection

Presently, Arraijan and La Chorrera districts have a population of 230,000 and 168,000, respectively, according the Census of 2010. The total population of both districts is 398,000. The metropolitan area (Panama, San Miguelito, Arraijan, and La Chorrera districts) has a population of 1.7 million in total.

The National Institute of Statistics and Census (INEC) estimated the population in Panama at the district level up to the year 2020. The same methodology as the INEC projection was used to estimate the population up to 2050 for the Study Area. There are three variables for projecting the population: 1) birth rate, 2) mortality rate, and 3) migration rate. With the combination of these variables, low, medium, and high case projections were made. PRODEM, which was developed by the Latin America Demographic Center (CELADE), was used for the calculations.

In the high case projection, the population of the western area (Arraijan and La Chorrera) in 2050 is estimated at 778,000, which is 1.96 times the population in 2010.

In planning for an urban transportation system, it is necessary to evaluate the capacity of the candidate systems whether or not they can satisfy the future demand. Therefore, the high case of population projection is used for the Line-3 demand forecast.

Table 3.16 Population Projection

High Case

Year	Panamá	San Miguelito	Arraijan	La Chorrera	Subtotal	Metropolitan
2010	989,100	336,074	230,311	167,799	398,110	1,723,284
2015	1,109,286	362,484	287,329	197,659	484,988	1,956,758
2020	1,231,582	390,810	333,072	219,971	553,043	2,175,435
2025	1,324,951	413,951	373,677	239,373	613,050	2,351,952
2030	1,399,486	437,855	403,452	253,486	656,938	2,494,279
2035	1,462,119	458,500	431,054	266,288	697,342	2,617,961
2040	1,514,134	476,896	453,973	277,659	731,632	2,722,662
2045	1,555,295	493,774	471,981	287,124	759,105	2,808,174
2050	1,584,017	506,836	484,499	293,927	778,426	2,869,279
Growth Rate						
2010-15	2.3%	1.5%	4.5%	3.3%	4.0%	2.6%
2015-20	2.1%	1.5%	3.0%	2.2%	2.7%	2.1%
2020-25	1.5%	1.2%	2.3%	1.7%	2.1%	1.6%
2025-30	1.1%	1.1%	1.5%	1.2%	1.4%	1.2%
2030-35	0.9%	0.9%	1.3%	1.0%	1.2%	1.0%
2035-40	0.7%	0.8%	1.0%	0.8%	1.0%	0.8%
2040-45	0.5%	0.7%	0.8%	0.7%	0.7%	0.6%
2045-50	0.4%	0.5%	0.5%	0.5%	0.5%	0.4%

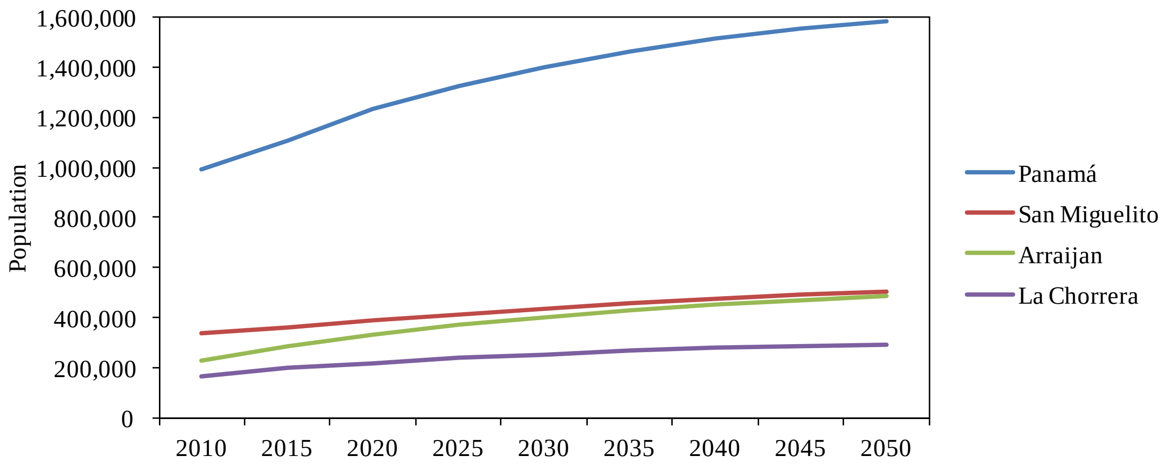
Medium Case

Year	Panamá	San Miguelito	Arraijan	La Chorrera	Subtotal	Metropolitan
2010	989,100	336,074	230,311	167,799	398,110	1,723,284
2015	1,098,068	335,429	270,191	186,640	456,831	1,890,328
2020	1,206,774	380,899	300,979	201,301	502,280	2,089,953
2025	1,284,681	407,878	317,368	213,761	531,129	2,223,688
2030	1,343,430	429,725	328,637	223,301	551,938	2,325,093
2035	1,389,161	447,677	336,102	230,773	566,875	2,403,713
2040	1,423,801	461,748	340,621	236,434	577,055	2,462,604
2045	1,447,456	471,695	342,369	240,296	582,665	2,501,816
2050	1,458,992	477,303	341,670	242,149	583,819	2,520,114
Growth Rate						
2010-15	2.1%	0.0%	3.2%	2.2%	2.8%	1.9%
2015-20	1.9%	2.6%	2.2%	1.5%	1.9%	2.0%
2020-25	1.3%	1.4%	1.1%	1.2%	1.1%	1.2%
2025-30	0.9%	1.0%	0.7%	0.9%	0.8%	0.9%
2030-35	0.7%	0.8%	0.5%	0.7%	0.5%	0.7%
2035-40	0.5%	0.6%	0.3%	0.5%	0.4%	0.5%
2040-45	0.3%	0.4%	0.1%	0.3%	0.2%	0.3%
2045-50	0.2%	0.2%	0.0%	0.2%	0.0%	0.1%

Low Case

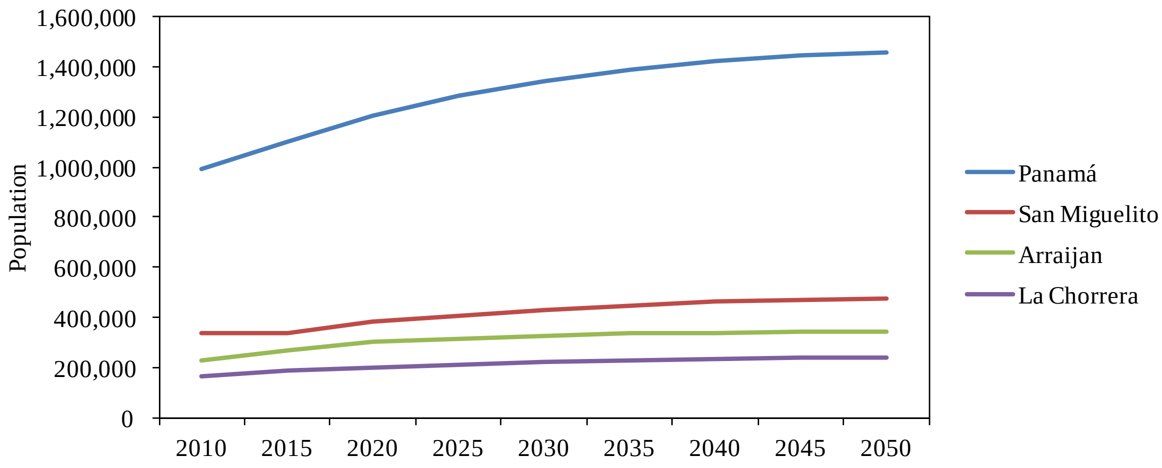
Year	Panamá	San Miguelito	Arraijan	La Chorrera	Subtotal	Metropolitan
2010	989,100	336,074	230,311	167,799	398,110	1,723,284
2015	1,086,850	348,374	253,048	175,619	428,667	1,863,891
2020	1,181,967	370,988	286,235	188,290	474,525	2,027,480
2025	1,244,411	401,804	300,036	200,954	500,990	2,147,205
2030	1,287,373	421,594	309,805	213,240	523,045	2,232,012
2035	1,316,203	436,854	317,601	220,625	538,226	2,291,283
2040	1,333,468	446,600	324,793	228,186	552,979	2,333,047
2045	1,354,617	455,616	331,538	233,607	565,145	2,375,378
2050	1,375,967	465,769	335,837	236,972	572,809	2,414,545
Growth Rate						
2010-15	1.9%	0.7%	1.9%	0.9%	1.5%	1.6%
2015-20	1.7%	1.3%	2.5%	1.4%	2.1%	1.7%
2020-25	1.0%	1.6%	0.9%	1.3%	1.1%	1.2%
2025-30	0.7%	1.0%	0.6%	1.2%	0.9%	0.8%
2030-35	0.4%	0.7%	0.5%	0.7%	0.6%	0.5%
2035-40	0.3%	0.4%	0.4%	0.7%	0.5%	0.4%
2040-45	0.3%	0.4%	0.4%	0.5%	0.4%	0.4%
2045-50	0.3%	0.4%	0.3%	0.3%	0.3%	0.3%

Source: JICA Study Team



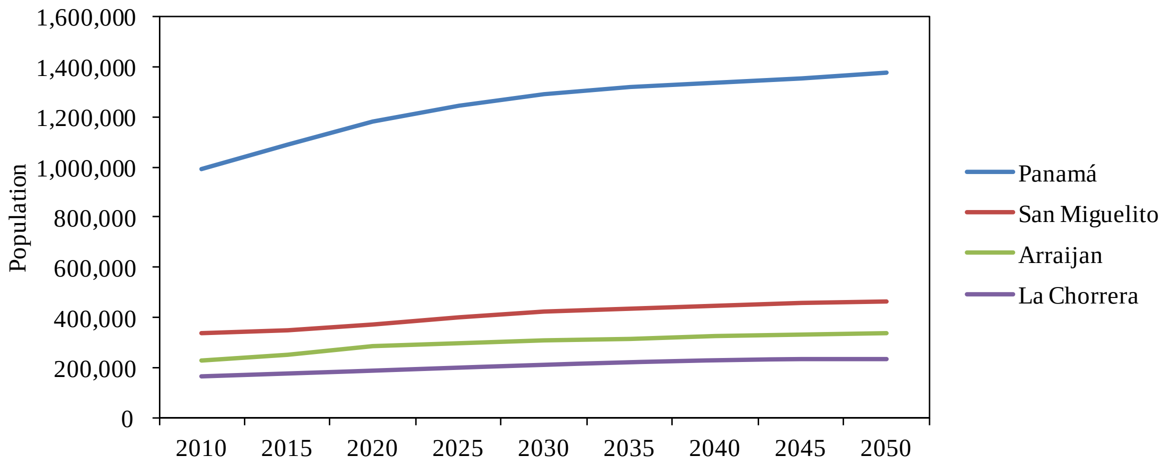
Source: JICA Study Team

Figure 3.6 Population Forecast (High Case)



Source: JICA Study Team

Figure 3.7 Population Forecast (Mid Case)



Source: JICA Study Team

Figure 3.8 Population Forecast (Low Case)

3.4.3 Car ownership

The number of cars in Panama has been rapidly increasing in recent years. The number of vehicles per 1,000 inhabitants is calculated to be 129 (2010). Although this rate is high compared to other neighboring countries, car ownership in Panama is still lower than most developed countries. Table 3.17 shows the number of vehicles per 1000 inhabitants for several countries.

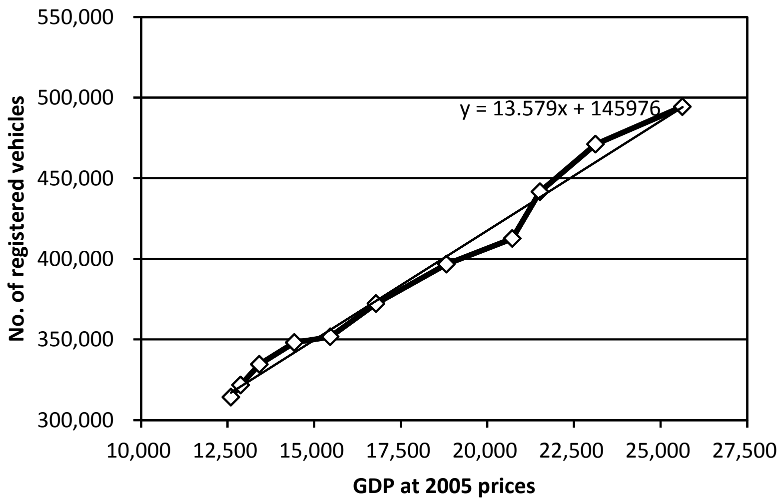
Table 3.17 No. of Vehicles per 1000 Inhabitants in different countries

USA	Italia	Japan	German	Netherlands	Malaysia	Argentina
797	679	591	572	527	393	314

Source: The World Bank (web database)

Figure 3.9 shows the time series data of the GDP and the number of vehicles of Panama, which shows that the number of cars has a strong correlation with the GDP.

Year	GDP at 2005 prices	No. of vehilces
2001	12,596	314,229
2002	12,876	321,690
2003	13,418	334,525
2004	14,427	348,070
2005	15,465	351,649
2006	16,783	372,224
2007	18,816	396,705
2008	20,720	412,625
2009	21,519	441,558
2010	23,123	471,118
2011	25,631	494,354



Source: JICA Study Team

Figure 3.9 No. of Vehicles in Panama

The future number of vehicles was estimated by using the linear function based on the regression analysis as shown in Table 3.18. It is estimated that car ownership will be 2.08 times the current rate in 2050. Under this projection, even in 2050 the number of vehicles per 1000 inhabitants will still be lower than that of developed countries.

Table 3.18 No. of Vehicles per 1000 inhabitants (Projection)

Year	Population ('000)	No. of vehilcles ('000)	No. of vehicles per 1000	Ratio to 2013
2013	3,851	566	146.9	1.00
2020	4,279	780	182.3	1.24
2030	4,835	1,084	224.3	1.53
2040	5,230	1,407	269.0	1.83
2050	5,507	1,683	305.6	2.08

Source: Projection by JICA Study Team

3.5 Demand Forecasting Model

3.5.1 Present OD

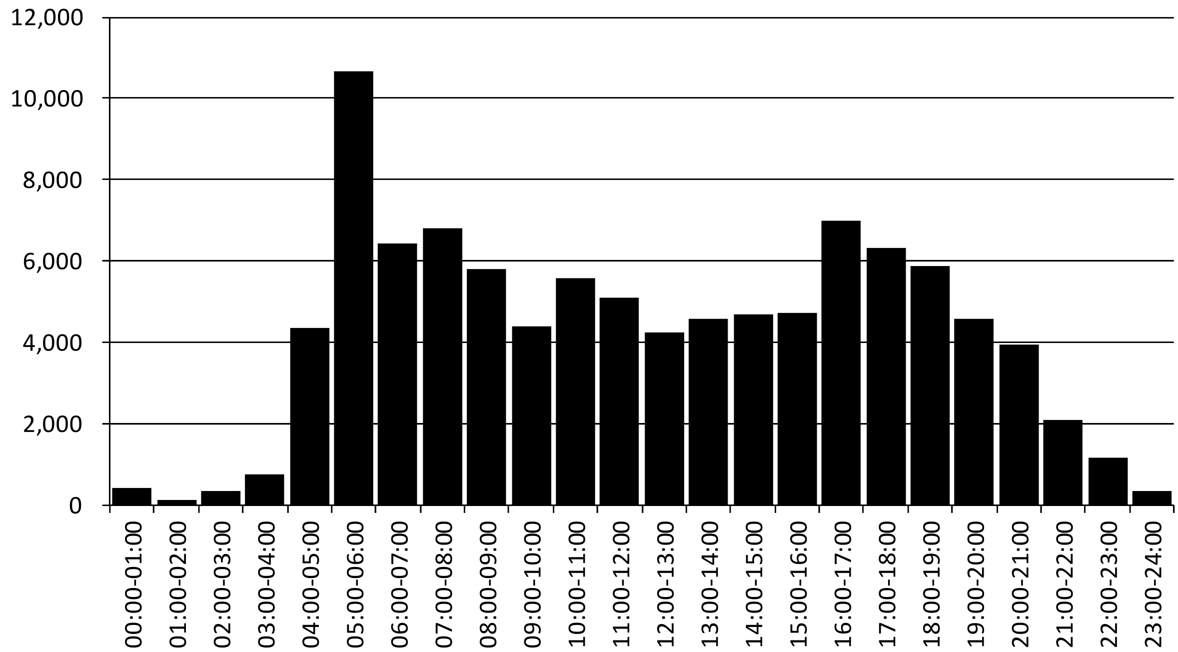
(1) Traffic Volume crossing the Panama Canal

The number of passengers (public transportation) crossing the Panama Canal in the morning peak hour peak direction was estimated to be 10,653 (5:00-6:00), 6,453 (6:00-7:00), and 6,792 (7:00-8:00), based on the results of the traffic count survey. The number of buses using the Centenario Bridge in the peak hour was as little as 17 (2012) carrying an estimated 935 passengers (55 passengers per bus). Table 3.19 and Figure 3.10 show the estimated number of passengers traveling from the west to east of the canal, while Table 3.21 shows that for the east- west direction.

Table 3.19 Estimation of Passenger Volume from West to East

Time	Public					Private	
	Vehicles		Passengers			Car	
	Bus	Taxi	Bus 45/bus	Taxi 3/taxi	Total	Vehicles	Passengers 1.5/car
5:00-6:00	210	401	9,450	1,203	10,653	2,018	3,027
6:00-7:00	124	291	5,580	873	6,453	2,362	3,543
7:00-8:00	144	104	6,480	312	6,792	1,647	2,471
2 hour (5-7)	334	692	15,030	2,076	17,106	4,380	6,570
2 hour (6-8)	268	395	12,060	1,185	13,245	4,009	6,014
Peak Centenario	23	-	1,265	-	1,265	2,946	4,419
Peak (2 hour)					18,371		10,989

Note: Large size buses (seating capacity of 55) account for 50% according to another traffic survey by COTRANS at the same place. Since seating capacity of small buses is 35 in general, the average occupancy rate of a bus is calculated at 45 (55*0.5+35*0.5).
Source: Traffic Count Survey in August 2013, JICA Study Team



Source: Traffic Count Survey in August 2013, JICA Study Team

Figure 3.10 Estimation of Passenger Volume from West to East

Table 3.20 Estimation of Passenger Volume from East to West

Time	Public					Private	
	Vehicles		Passengers			Car	
	Bus	Taxi	Bus	Taxi	Total	Vehicles	Passengers
			45/bus	2/taxi			1.5/car
5:00-6:00	37	194	1,665	388	2,053	194	291
6:00-7:00	82	33	3,690	66	3,756	354	531
7:00-8:00	97	72	4,365	144	4,509	571	857
2 hour (5-7)	119	227	5,355	454	5,809	548	822
2 hour (6-8)	179	105	8,055	210	8,265	925	1,388
Peak Centenario	8	-	440	-	440	433	650
Peak (7-8)					4,949		1,506

Source: Traffic Count Survey in August 2013, JICA Study Team

(2) Peak 2 hours OD Matrix

At present, the travel time from Arraijan to Albrook at the peak hour is approximately 30 minutes longer than that of off-peak hours. In order to save on travel time, people travel in the early morning hours to avoid the congestion creating a higher traffic demand before the peak hour. If the urban transport system were not affected by traffic congestion, more people could travel in the peak hour, although a part of the passengers would still need to make early morning trips because of the congestion in the center of Panama City.

This logic does not apply to the traffic demand for the opposite direction in the same period because the opposite direction is not congested in the morning peak hour; therefore the peak hour traffic still represents the traffic demand at peak hour even if the urban transport system is introduced. In addition, the peak hour traffic using the Centenario Bridge is considered to be the peak hour demand because traffic congestion is not observed along the route.

The SMP 2009 OD consists of trips in the peak 2 hours from 6:00 to 8:00. However, according to the traffic survey, the peak hour in the west area appears one hour earlier (5:00-6:00) than the peak time in the center of the city.

The number of trips by zone pair between the west and east of the canal in the peak 2 hours from 5:00 to 7:00 was estimated from the passenger interview survey and the traffic count survey in 2013. The corresponding OD pairs in the SMP 2009 OD were replaced with the estimated OD.

For the traffic assignment, the 2 hours OD is used as the peak hour demand, although its justification needs to be reviewed in the sensitivity analysis of the economic and financial analysis.

3.5.2 Modal Share

(1) Private Mode in the Without Case

The share of the private mode is very high in Panama City, although neither statistics nor reliable estimation of modal share in Panama are available. Table 3.21 shows the modal share that was estimated by using the SMP 2009 OD matrix. The calculated private mode share is as high as 41.6% for the total metropolitan area, while the private mode share is only 23.3% in Arraijan and La Chorrera.

Table 3.21 Modal Share in SMP 2009 OD (6:00-8:00, 2 hours)

	Total			Arraijan and La Chorrera		
	Private	Public	Total	Private	Public	Total
No. of trips	137,826	193,717	331,543	12,191	40,292	52,483
%	41.6%	58.4%	100%	23.2%	76.8%	100%

Source: SMP

In this Study, the modal share is calculated based on the traffic survey of 2013 as shown in Table 3.22. The public mode share in 2013 is estimated to be 66%.

The private mode share in Panama and San Miguelito districts is already high and it is assumed that the share will remain the same. On the other hand, the private mode share in Arraijan and La Chorrera is assumed to increase in proportion to the car ownership rate of the country. In the case that the urban transport system is not developed, the private mode share is estimated to be 54.4% in 2050 for Arraijan and La Chorrera as shown in Table 3.22.

Table 3.22 Estimation of Modal Share in Araijan and La Chorrera

Year	No. of trips (2hours)		% trips		Ratio of car ownership to 2013
	Public	Private	Public	Private	
2013	21,316	10,972	66.0	34.0	1.00
2020	27,716	19,388	58.8	41.2	1.24
2025	30,307	24,401	55.4	44.6	1.37
2030	31,873	29,196	52.2	47.8	1.53
2035	32,484	32,672	49.9	50.1	1.66
2040	34,249	35,312	49.2	50.8	1.83
2050	35,765	42,651	45.6	54.4	2.08

Source: Estimation by JICA Study Team

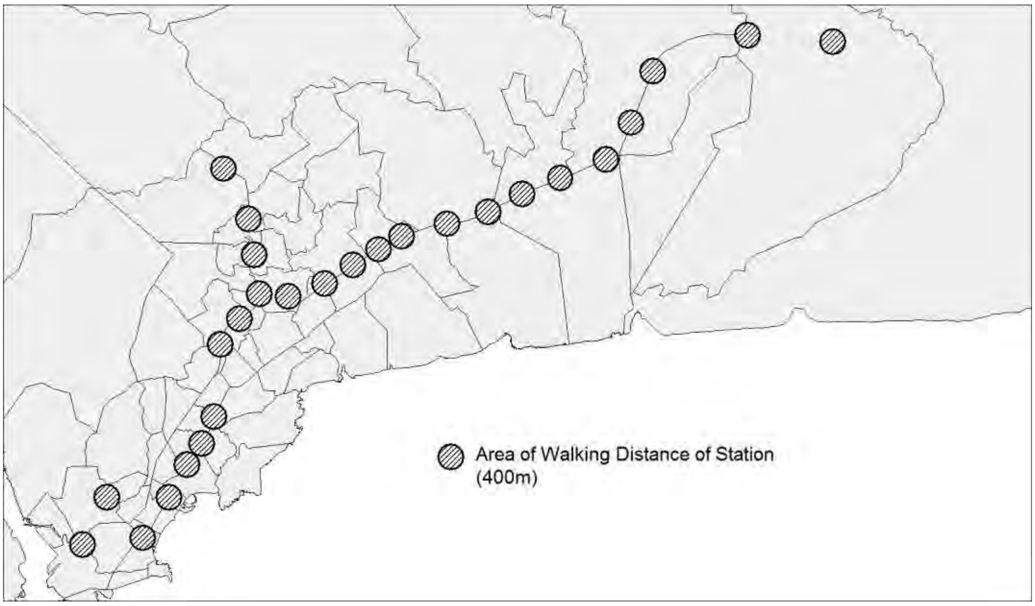
(2) Modal Shift from Car to Line-3

The stated preference survey for passenger car users shows that half of the car users will select the metro system if it is faster than cars by more than 20 minutes. The Park & Ride scenario also shows the same preference. This means that if the destination is within walking distance, approximately half of the car users will shift to the metro system. Figure 3.11 shows the areas within walking distance from the metro stations. The number of trips to these areas was estimated based on the proportion of the area to the intersect zones. The number of trips that shift to Line-3 was assumed to increase from 55% to 70% of the estimated trips as shown in Table 3.23.

Table 3.23 Modal Shift Rate from Car to Line-3

2020	2025	2030	2035	2040	2050
55%	57.5%	60%	62.5%	65%	70%

Source: JICA Study Team



Source: JICA Study Team (Station Location is based on SMP)

Figure 3.11 Area of Walking Distance for Modal Shift

3.5.3 Demand of Panama Pacifico

(1) Trip Generation and Attraction

Panama Pacifico will have 20,000 houses and 40,000 employees in the future according to the master plan. The peak hour trips from/to Panama Pacifico were estimated based on several assumptions as shown in Table 3.24.

Table 3.24 Trip Generation and Attraction in Panama Pacifico

From Panama Pacifico			
No. of households	20,000		
No. of persons per household	3.8		
Population	76,000		
% of economically active population	41.5%		
Economically active population	31,540		
% commuters to outside of Panama Pacifico	67% (2/3)		
No. of commuters from Panama Pacifico	21,000		
No. of commuters within Panama Pacifico	10,540		
Peak hour rate	40%		
Peak hour trips from Panama Pacifico	8,400		
Public mode share	2030	2040	2050
	50%	65%	70%
Public transport demand in peak hour	4,200	5,460	5,880
To Panama Pacifico			
No. of employees	40,000		
No. of commuters from outside	29,460		
Peak hour rate	40%		
Peak hour trips to Panama Pacifico	11,784		
Public mode share	2030	2040	2050
	50%	65%	70%
Public transport demand in peak hour	5,900	7,670	8,260

Source: Estimation by JICA Study Team

(2) Intermediate Year Forecast

Since the development schedule of Panama Pacifico is not clear, it is assumed that the number of trips would reach 50% of the estimated number of trips in 2020, 80% in 2025, and 100% in 2030. The intermediate year forecast of the demand of Panama Pacifico is shown in Table 3.25.

Table 3.25 Intermediate Year Forecast of Public Transport Trips from/to Panama Pacifico

	2020	2025	2030	2035	2040	2050
Generation	2,100	3,360	4,200	4,200	5,460	5,880
Attraction	2,950	4,720	5,900	5,900	7,670	8,260

Source: Estimation by JICA Study Team

(3) Trip Distribution

The OD matrix relating to Panama Pacifico was estimated by applying the following trip distribution model.

No. of trips = $V/x_{ij}^{0.12}$, where x = distance between the center of zone *i* and *j* (m)

V is the trip generation of Panama Pacifico when *i* is the zone of Panama Pacifico, while it is the trip attraction when *j* is the zone of Panama Pacifico. This model was developed using the data in the SMP 2009 OD.

Since the sum of the calculated number of trips ($\sum V/x_{ij}^{0.12}$) does not meet the number of trips (V) estimated in Table 3.24, the number of trips was adjusted by the ratio of V and $\sum V/x_{ij}^{0.12}$.

3.5.4 Transit Assignment

(1) Transit Assignment Model

JICA STRADA is a package of demand forecast applications. The Transit Assignment component of JICA STRADA was used in the Study. The transit assignment model applies a multipath search with the generalized cost of each transit route. The generalized cost consists of: 1) in-vehicle travel time, 2) walking time, 3) waiting time, and 4) fare. Alternative transit routes with a generalized cost less than 110% of the minimum generalized cost are selected for each OD pair and the traffic is assigned according to the route share calculated as:

Route Share of route *i* = $\exp(GC_i) / \sum \exp(GC_j)$, where GCj = generalized cost of route *j*

The maximum number of transfers is five.

(2) Transit Lines

The Metro Bus routes, which were identified in the Mibus (operator of Metro Bus) web page, were incorporated into the network model. Table 3.26 shows the list of Metro Bus routes in the transit network data. In Arraijan and La Chorrera, express bus services and standard services are built into the model. Figure 3.12 and Figure 3.13 show the bus routes in the transit network model.

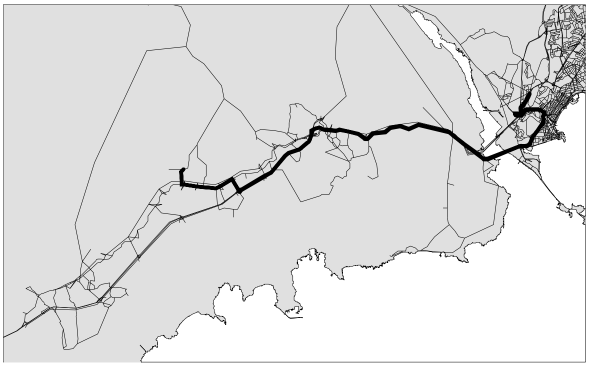
Table 3.26 Transit Lines in Network Model

No.	Route Name	Name of Line in Transit Network	Remark
MB01	Albrook-Via España-Balboa-Directo	-	Route is included in MB10.
MB02	Alcalde Díaz-Corredor Norte	MB02A, MB02B	-
MB03	Alcalde Díaz-Transistmica	MB03A, MB03B	-
MB04	Alcalde Díaz-Vía España	MB04A, MB04B	-
MB05	Boca La Caja-Marañón-Calle 50-Circular	MB05	-
MB06	Ciudad Bolívar-Corredor Norte Albrook	-	Route is included in MB02.
MB07	Chilibre-Transistmica	-	Route is included in MB03.
MB08	Ciudad Bolívar-Tumba Muerto	MB08A, MB08B	-
MB09	Concepción-Circular	-	Route is excluded due to short length.
MB10	Concepción-Via España	MB10A, MB10B	-
MB11	Don Bosco-Corredor Sur-Mercado de Marisco	MB11A, MB11B	-
MB12	Don Bosco-Transístmica-Albrook	MB12A, MB21B	-
MB13	Don Bosco- Via España -Albrook	MB13A, MB13B	-
MB14	El Dorado-Betania-Ave. La Paz	MB14	-
MB15	Felipillo-Corredor Sur-Albrook	MB15A, MB15B	-
MB16	Gran Estación – Transístmica – Albrook - Directo	-	Route is included in MB08.
MB17	La Doña-Corredor Sur-Albrook	-	Route is included in MB15. Difference is inside the same zone and it does not have impact on demand model.
MB18	La Doña-Costa Del Este-Corredor Sur-Urracá	-	ditto
MB19	Los Andes - Corredor Norte – Albrook	MB19A, MB19B	-
MB20	Los Andes – Tumba Muerto - Albrook	MB20A, MB20B	-
MB21	Los Andes- Via España -Albrook	MB21A, MB21B	-
MB22	Mañanitas-Corredor Sur-Albrook	-	Route is included in MB23.
MB23	Mañanitas-Hora Valle-Albrook	MB23A, MB23B	-
MB24	Parque Real – Corredor Sur – Albrook	-	Route is included in MB23.
MB25	Mañanitas-Tumba Muerto-Albrook	MB25A, MB25B	-
MB26	Mañanitas- Via España –Albrook	MB26A, MB26B	-
MB27	Mano de Piedra-Corredor Norte-Albrook	MB27A, MB27B	-
MB28	Pacora-Corredor Sur-Albrook	-	Route is included in MB15.
MB29	Padregal-Corredor Sur-Mlechi	MB29A, MB20B	-
MB30	Pedregal-Transístmica-Albrook	MB30A, MB30B	-
MB31	Pedregal-Tumba Muerto-Albrook	-	Route is included in MB25.
MB32	Pedregal-Via España –Albrook	-	Route is included in MB26.
MB33	Panamá Viejo-Ave. Balboa	MB33A, MB33B	-
MB34	Panamá Viejo-Vía Porras-Albrook	MB34A, MB34B	-
MB35	San Pedro-Circular	-	Route is excluded because it is short in the same zone.
MB36	San Pedro-Corredor Sur-Ancón	MB36A, MB36B	-
MB37	San Pedro-Via Espaná	MB37A, MB37B	-
MB38	Santa Librada-Corredor Norte-Albrook	MB38A, MB38B	-
MB39	Santa Librada- Transístmica-Albrook	MB39A, MB39B	-
MB40	Santa Librada- Tumba Muerto-Albrook	MB40A, MB40B	-
MB41	Santa Librada- Vía Espanañ-Albrook	MB41A, MB41B	-
MB42	Tocumen-Corredor Sur-Albrook	MB42A, MB42B	-
MB43	Tocumen-Transístmica-Albrook	MB43A, MB43B	-
MB44	Tocumen-Tumba Muerto-Albrook	MB44A, MB44B	-
MB45	Tocument-Vía España-Albrook	MB45A, MB45B	-
MB46	Torrijos Carter-Corredor Norte-Albrook	MB46A, MB46B	-
MB47	El Valle-Corredor Norte-Albrook	-	Service area is covered by MB38.
MB48	El Valle- Transístmica -Albrook	-	Service area is covered by MB39.
MB49	El Valle- Vía España-Albrrok	-	Service area is covered by MB41.
MB50	Vía Brasil Federico Boyd	MB50	-
MB51	Villa Rica-12 de Octubre Vía Porras	MB51	-
MB52	Villa Rica-Circular-Vía España	MB52	

Source: JICA Study Team (Bus route: http://www.mibus.com.pa/rutas/)

Autopista –- Bridge of Americas - Albrook

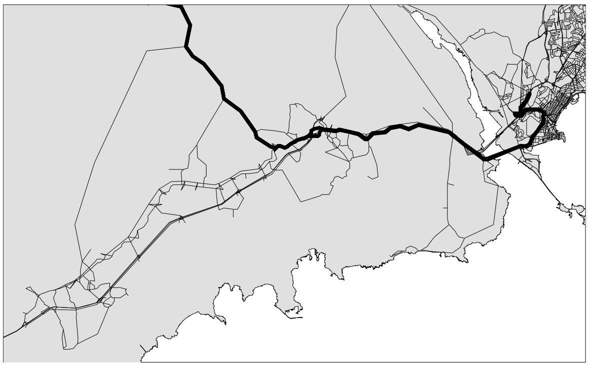
Panamericana - Autopista - Bridge of Americas - Albrook



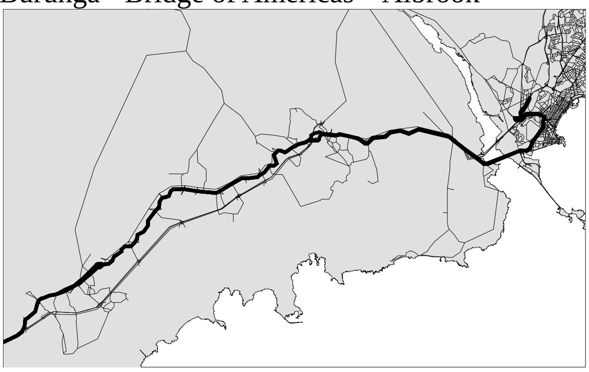
Ciudad del Futuro - Autopista – Bridge of Americas - Albrook

Veracrus - Bridge of Americas - Albrook

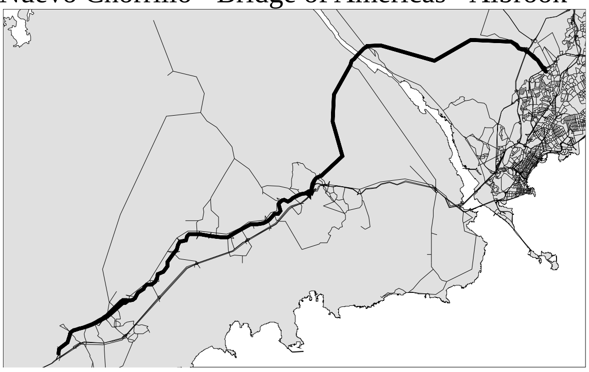
Burunga - Bridge of Americas – Albrook



Nuevo Chorrillo - Bridge of Americas - Albrook



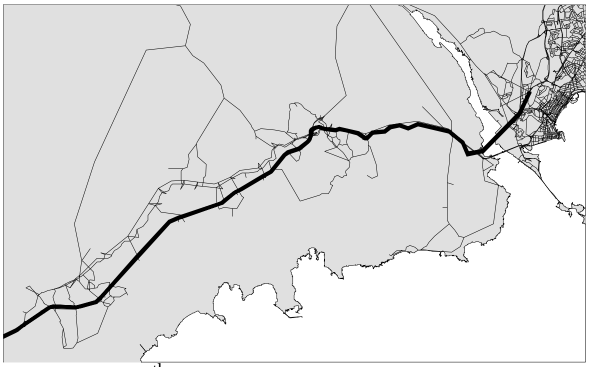
La Chorrera - Panamericana - Bridge of Americas - Albrook



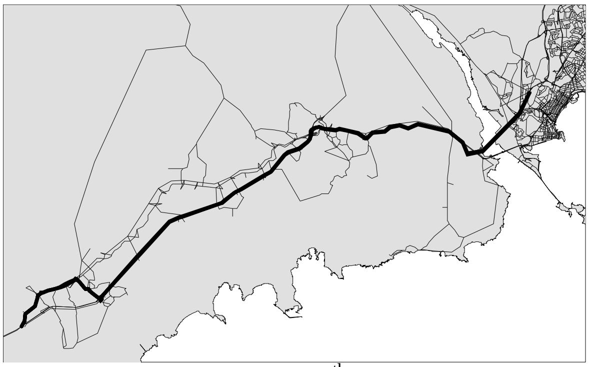
La Chorrera - Panamericana - Centerario Bridge -Albrook

Source: JICA Study Team

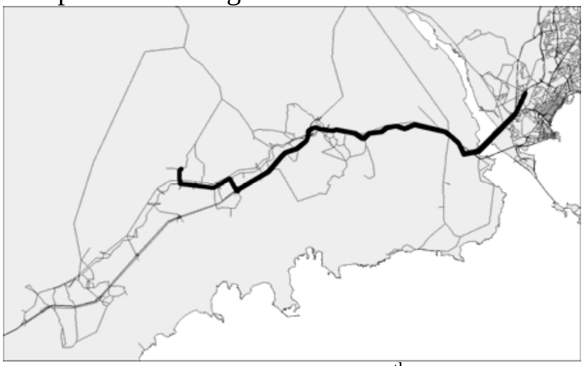
Figure 3.12 Transit Network in West Area (1)



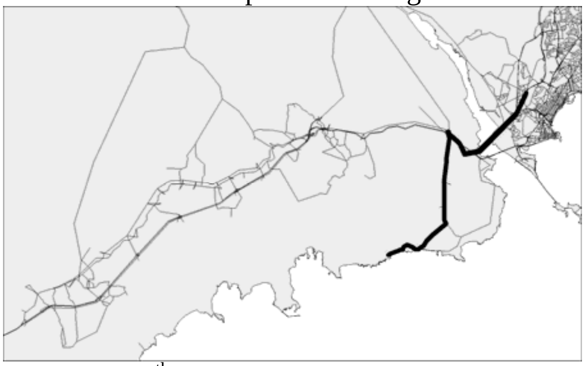
Autopista - 4th Bridge - Albrook



Panamericana - Autopista- 4th Bridge- Albrook



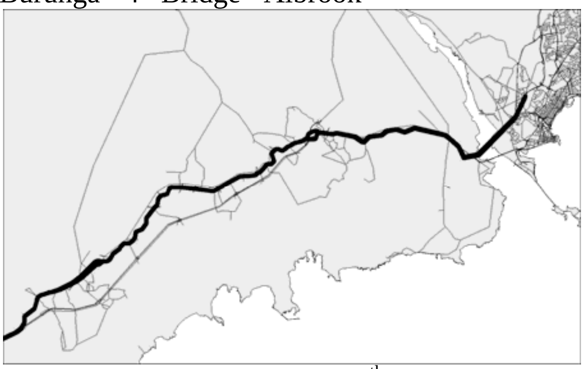
Ciudad del Futuro - Autopista – 4th Bridge- Albrook



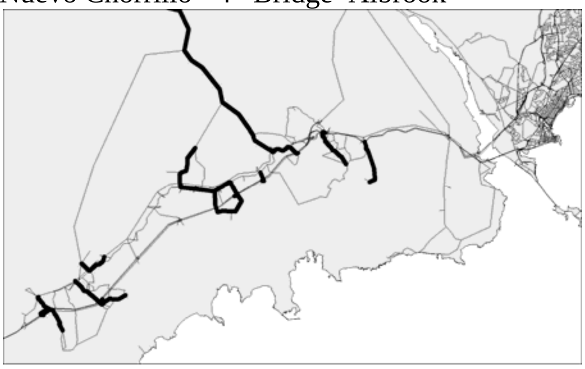
Veracurus - 4th Bridge - Albrook

Burunga - 4th Bridge - Albrook

Nuevo Chorrillo - 4th Bridge- Albrook



La Chorrera - Panamericana - 4th Bridge - Albrook



Other feeder routes

Source: JICA Study Team

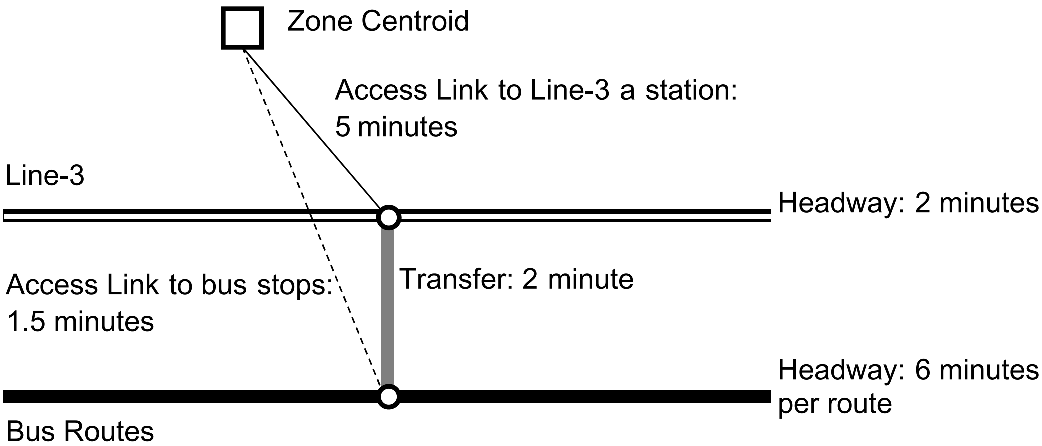
Figure 3.13 Transit Network in West Area (2)

Figure 3.14 shows the underlying link data for the transit data. Length and speed in the link data are used for the transit network data.

Source: JICA Study Team

Figure 3.14 Links in the Network Model

In the demand forecast model, each Line-3 station has a zone centroid that represents the trip generation and attraction point within the walking distance of the station. The zone centroids are also connected to the nodes of bus routes, although each node does not necessarily mean a bus stop. The nodes of the bus routes are considered as representative nodes of several bus stops of the routes. Figure 3.15 illustrates the network model of the connection of zone centroid to Line-3 and bus routes.



Source: JICA Study Team

Figure 3.15 Connection of Zone Centroid and Transit Routes

(3) Speed

In the transit assignment model, the travel speed is defined by line speed and link speed. The lower speed is applied for the calculation. Table 3.27 shows the setting of the speed in the transit network data. According to the Ministry of Public Works (MOP), the Panamericana Highway between Arraijan and the canal will be widened to a 6-lane road after the construction of the 4^{th} Bridge, which will increase the travel speed. However, since the number of private cars will also increase in the future, it is assumed that the travel speed will be the same for the period from 2020 to 2050.

Table 3.27 Speed Setting

Mode	Maximum*	Expressway	In Panama City	In Arraijan & La Chorrera	Rail Link
Metro Bus	40km/h	40km/h	10km/h	20km/h	-
Bus	40km/h	40km/h	10km/h	20km/h	-
Bus (Express)	60km/h	60km/h	10km/h	20km/h	-
Line-1	35km/h	-		-	35km/h
Line-3	40km/h	-		-	40km/h*2 35km/h

*2: Long distance sections
Source: Setting by JICA Study Team

(4) Transit Fare

Presently, the bus fare between Arraijan and Albrook is USD0.35. Table 3.28 shows the present transit fare in the Study Area. From this information, the fare per kilometer between Arraijan and La Chorrera (18.7km) is estimated at (0.8-0.35)/18.7 = USD 0.0024/km. The fares of air-conditioned buses and express buses are more expensive.

Table 3.28 Transit Fare between Albrook and La Chorrera

Section	Present Transit Fare
Albrook – Arraijan	USD 0.35 Extra supermarket USD 0.60 Vista Alegre USD 0.75 Express (Ciudad Futuro) USD 1.50 Express (Ciudad Futuro, Autopista)
Albrook – La Chorrera	USD 1.50 Autopista USD 0.80 Panamericana USD 2.00 Air-conditioned

Source: Surveyed by the JICA Study Team

In JICA STRADA, the fare setting is modeled as following formula.

Fare = F + R * Max(Distance – X, 0)

The fare setting applied in the Study is shown in Table 3.29. The fare of Line-3 is assumed to be approximately USD 1.2 between Albrook and La Chorrera, which is higher than the normal bus along Panamericana Road and lower than express bus services.

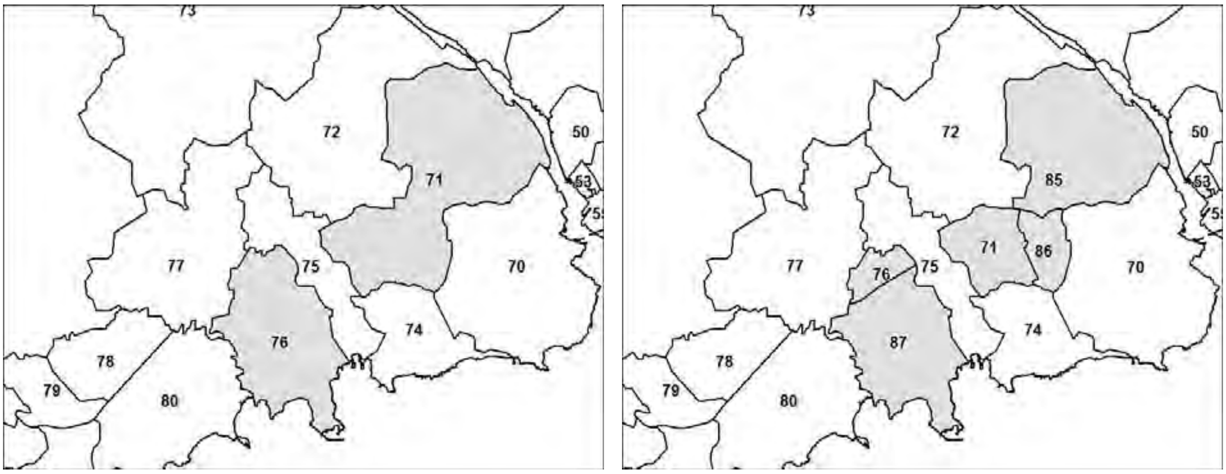
Table 3.29 Fare Setting

No.	Mode	F: Fix Rate (USD)	X:	R: Variable Rate	Transfer among same modes
1	Metro Bus	0.25	-	-	Free
2	Bus	0.35	18km	0.024	-
3	Express (Autopista)	1.50	-	-	-
4	Express (Panamericana)	0.75	-	-	-
5	Express (Corredor Norte, Corredor Sur)	1.25	-	-	-
6	Feeder	0.25	-	-	-
7	Access dummy	0.0	-	-	-
8	Metro	0.65	-	-	Free
9	Line-3*	0.65	18km	0.042	-

*: Fare of Line-3 between Albrook and La Chorrera (31km) = 0.65 + 0.042 (31-18) = USD 1.2
Source: JICA Study Team

(5) Traffic Zones for Stations

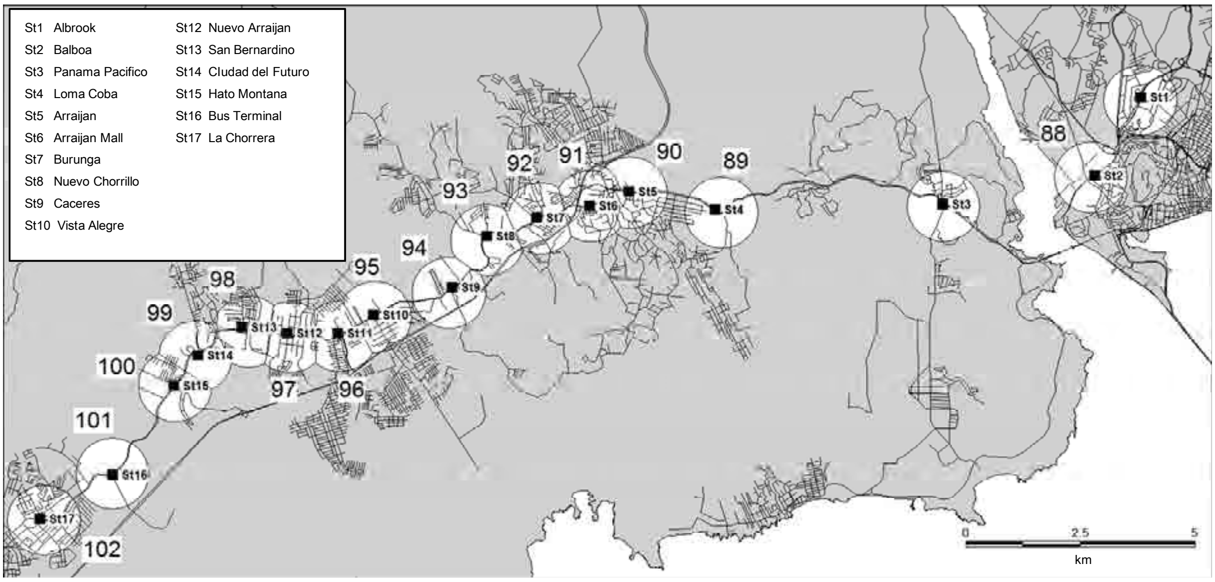
There are 14 stations in the Phase-1 section and 3 stations in the Phase-2 section of Line-3. The 84 traffic zoning system, which was prepared based on corregimiento boundaries, was further subdivided to take into account the stations for the demand forecast. Firstly, Arraijan and Vista Alegre Corregimientos (Zone 71 and 76) were subdivided and new zones 85, 86 and 87 were added as shown in Figure 3.16. The trip generation of each Corregimiento was distributed in proportion to the number of buildings in each zone. The number of buildings was calculated using a GIS data provided by ANATI.



Source: JICA Study Team

Figure 3.16 Zone Division of Arraijan and Vista Alegre

Secondly, each station was given a new traffic zone as a circle with a radius of 800m (walking distance) as shown in Figure 3.17. Zone codes in the 87 traffic zones were used for St1 (Albrook) and St3 (Panama Pacifico) stations.



Note: Numbers in the circles are the zone codes for stations.
Source: JICA Study Team

Figure 3.17 Locations of Stations

3.5.5 Traffic Assignment

(1) Traffic Assignment Model

The traffic assignment of private modes (private cars) was done by JICA STRADA applying the incremental assignment method. In the traffic assignment, the number of buses was added to the link flow before the private car assignment, and the private OD matrix (peak hour) was assigned to the minimum path of the road network. The passenger car unit (PCU) of a bus is assumed to be 2.0.

(2) Road Network

1) Link Classification

Each link has a link cost function that calculates the travel time from the traffic volume on the link. The proper link cost function was applied to each link in the road network model in the Study Area taking into account the link parameters such as lane capacity, number of lanes, and maximum speed. For this, the road links are classified into seven categories in this study. Table 3.30 shows the classification of links with corresponding capacity and speed settings used in this study.

Table 3.30 Link Classification with Capacity and Speed

No.	Classification	Base (a)	Adjustment Factor Roadside (b)	Adjustment Factor Signal (c)	Capacity per lane (a)*(b)*(c)	Speed (km/h)
1	Motorway	2,000	0.95	1.00	1,900	120
2	Trunk	2,000	0.95	0.85	1,600	80
3	Primary	2,000	0.90	0.70	1,200	60
4	Secondary	2,000	0.85	0.60	1,000	60
5	Collector	2,000	0.80	0.50	800	50
6	Local-1	2,000	0.70	0.45	600	40
7	Local-2	2500*	0.70	0.45	400	30

Source: Setting by the JICA Study Team

2) Link Cost Function

For the link cost function, the BPR formula, which is commonly used in traffic demand forecast models, shown below, was employed.

$$T = T_0 \left[1 + \alpha \left(\frac{V}{C} \right)^{\beta} \right]$$

Where,

T : Travel time on link
T_0 : Free flow travel time on link
α, β : Parameters
V : Traffic volume on link in terms of Passenger Car Unit (PCU)
C : Capacity of link (PCU)

The constant values (α, β) were prepared by the maximum speed of each link as shown in Table 3.31. The congestion speed in the table represents the speed at the volume to capacity rate of 1.0, and was assumed for each maximum speed. It was assumed that the speed becomes 4km/h at the volume to capacity ratio of 2.0.

Table 3.31 BPR Parameters

Free Speed (km/h)	Congestion Speed	Speed at V/C=2.0	alpha	beta
120	30	4	3.000	3.273
100	30	4	2.333	3.363
80	30	4	1.667	3.511
60	25	4	1.400	3.322
50	20	4	1.500	2.939
40	18	4	1.222	2.880
30	15	4	1.000	2.700

Source: Setting by the JICA Study Team

3) Fare

There are two toll roads in Panama City: 1) Corredor Norte and 2) Corredor Sur. The fare cost was converted to "time" by applying a value of time (USD 6.57 per car) which is estimated in Chapter 18 (18.4.6).

Table 3.32 Toll Road Rate

	Toll Gate	Fare
Corredor Norte	Ascanio Entrance	$0.90
	Ascanio Exit	$0.90
	Martin Sosa Entrance	$0.90
	Martin Sosa Exit	$0.90
	Juan Pablo Entrance	$0.50
	El Dorado Exit	$0.25
	La Amistad Entrance (Albrook)	$0.25
	Patacon Entrance	$0.75
	Patacon Exit	$0.75
	Madden Entrance from Tinajitas	$2.00
	Madden Entrance rest of the Corredor	$2.50
	Madden Exit toward Tinajitas	$2.00
	Madden Exit rest of the Corredor	$2.50
	Tinajitas Entrance	$1.50
	Tinajitas Exit	$1.50
	Transistmica Entrance to Tocumen	$0.50
	Transistmica Entrance to Tocumen	$0.50
	Brisas del Golf Entrance	$1.25
	Brisas del Golf Exit	$1.25
	Villa Lucre Entrance	$1.25
	Villa Lucre Exit	$1.25
Corredor Sur	Ciudad Radial A tollgate (toward Tocumen)	$0.55
	Ciudad Radial A tollgate (from Paitilla)	$0.75
	Ciudad Radial B tollgate (from Tocument)	$0.55
	Ciudad Radial B tollgate (toward Paitilla)	$0.75
	Ciudad Radial main tollgate (both directions)	$1.25
	Costa del Este A and B tollgates	$0.50
	Chanis A and Chanis B tollgates	$0.25
	Atlapa main tollgate (both directions)	$1.40
	Atlapa A and Atlapa B tollgates	$1.25
	Via Israel A tollgate	$0.35
	Via Israel B tollgate	$0.60

Source: ENA

(3) Network Scenarios

There are three network scenarios in the Study: 1) Present, 2) 4th Bridge, and 3) 4th Bridge and Line-3 scenarios. It is assumed that the Bridge of Americas remains in these scenarios, although the fourth scenario prepared from the third scenario excluding the Bridge of Americas was also studied. Cinta Costera III, which is under construction, is included in all network scenarios. The elements of the different scenarios are as follows:

- No. of lanes of Pan-American Highway between Arraijan and the Bridge of Americas
- Existence of the 4th Bridge with new bus routes on the bridge
- Existence of the Line-3
- Improvement of Omar Torrijos Roundabout

These scenarios are summarized as show in Table 3.33.

Table 3.33 Network Scenarios

	Scenario			
	1) Present	2) 4th Bridge	3) 4th Bridge and Line-3	4) 4th Bridge and Line-3 without the Bridge of Americas
No. of lanes of Pan-American Highway	4	6	6	6
4th Bridge	Non existant	Exists	Exists	Exists
Line-3	Non existant	Non existant	Exists	Exists
Omar Torrijos Roundabout Improvement	Non existant	Exists	Exists	Exists
Bridge of Americas	Exists	Exists	Exists	Non existant

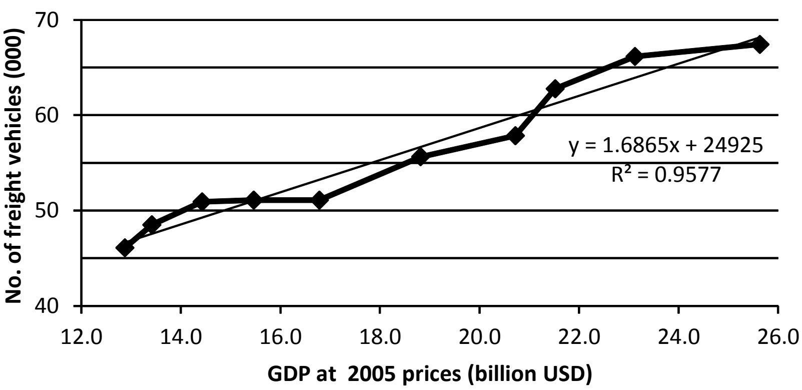
Source: JICA Study Team

(4) Truck Assignment

In the peak hour, the number of trucks is very small - according to the 2013 traffic survey of this study, trucks account for only 0.8% in the peak hour (6:00-7:00). Therefore, it is assumed that trucks in peak hours are included in the private mode OD. Since freight transportation avoid the congestion hours, the peak hour of the truck traffic is different from that of cars, and the truck traffic is very small in the peak hours of cars. From this, daily traffic volume of trucks was estimated separately considering the difference of the peak hour rate.

To estimate the future growth rates of cargo traffic, a regression model between Panama's GDP and the number of cargo vehicles in Panama Province was made as shown in Figure 3.18.

Year	GDP at 2005 prices (Million)	No. of vehilces (No.)
2002	12,876	46,091
2003	13,418	48,495
2004	14,427	50,910
2005	15,465	51,084
2006	16,783	51,087
2007	18,816	55,639
2008	20,720	57,849
2009	21,519	62,770
2010	23,123	66,158
2011	25,631	67,417



Source: INEC database and JICA Study Team

Figure 3.18 Regression Analysis for Cargo Vehicles

The result of the projection of the number of trucks crossing the canal is shown in Table 3.34 using the linear regression model above. The assumption of the future GDP growth rates are explained in 3.3.1. It was assumed that the number of trucks on the Bridge of Americas and the 4th Bridge would be the same.

Table 3.34 Projection of Future Truck Traffic (No. of Vehicles per Day)

Year	Growth Ratio (2013=1)	Present Case		4th Bridge Case			4th Bridge and Line-3 Case		
		Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge
2013	1.00	4,387	1,760	4,387			4,387		
2020	1.35	5,901	2,367	5,901	1,184	1,184	5,901	1,184	1,184
2025	1.57	6,872	2,757	6,872	1,379	1,379	6,872	1,379	1,379
2030	1.84	8,054	3,231	8,054	1,616	1,616	8,054	1,616	1,616
2035	2.08	9,110	3,655	9,110	1,827	1,827	9,110	1,827	1,827
2040	2.36	10,335	4,146	10,335	2,073	2,073	10,335	2,073	2,073
2045	2.57	11,263	4,519	11,263	2,259	2,259	11,263	2,259	2,259
2050	2.80	12,288	4,930	12,288	2,465	2,465	12,288	2,465	2,465

Source: JICA Study Team

Although there are many types of trucks, trucks were classified into one category in the traffic surveys mentioned in this report. To estimate ESALs for the pavement design, the proportion of small trucks, whose ESAL is very small, was assumed to be 67%, which was calculated from the INEC statistics on the number of trucks in the country. In the statistical data, "Pickup and Delivery" were considered as small trucks while "Trucks, Heavy Trucks, and Trailers" were others.

3.6 Future Passenger Demand

3.6.1 Fare Scenario

(1) Distance base Fare

To determine the fare level for the demand forecast, transit assignment was carried out for several fare scenarios. In view of financial sustainability, the fare should be determined at the level that maximizes the total revenue. Table 3.35 shows the estimation of the fare revenue in the peak hour for different fare levels in the case of the Panamericana Route in 2050. The revenue is maximized when the fixed fare is USD0.90. It is recommended that the fare be set at this level in view of the financial aspect. However, the economic benefit may be as important as the financial stability.

Table 3.35 Peak Hour Fare Revenue by Fixed Rate (Full development case, 2050)

Fixed Rate (USD)	No. of boarding passengers	Fare Revenue (USD)	PHPDT
0.6	32,315	23,285	24,492
0.7	30,419	25,115	23,555
0.8	28,535	26,550	22,694
0.9	26,117	26,996	21,104
1.0	23,348	26,554	19,574
1.1	20,899	25,888	17,626
1.2	19,141	25,745	16,316

Note: Since the number of passengers shifting from car to Line-3 is estimated irrespective of the fare, the fare revenue from these passengers increases in proportion to the fixed rate.
Source: JICA Study Team

(2) Fare Integration

For the initial assessment of Line-3, the fixed fare is set at USD 0.65, which is the same as that in the METI F/S. In the case of the USD0.65 fixed rate, the fare revenue is 90% of the maximum fare revenue from the USD0.90 fixed rate.

The impact of a flat fare system and fare integration with Line-1 and Line-2 were evaluated as shown in Table 3.36. PHPDT in 2050 was estimated at 24,519 in the case of the distance base fare (Fare=0.65+0.042X). This feasibility study is conducted based on this fare scenario. The difference in demand between the distance base fare and the flat fare is small. In the case of fare integration, PHPDT exceeds 25,000.

Table 3.36 Demand Forecast in Fare Integration and Flat Fare Cases

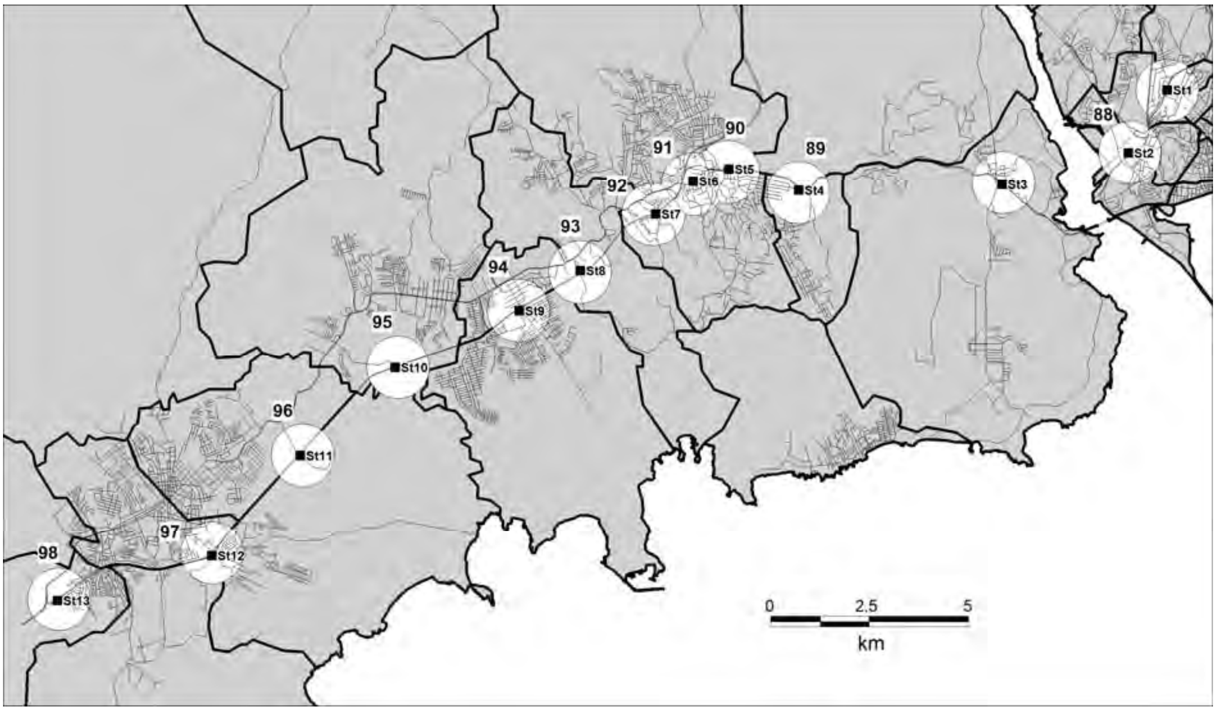
Integration	Fare (USD)	No. of boarding passengers	Fare Revenue (USD)	PHPDT
Not integrated	Fare=0.65+0.042X	31,862	25,919	24,519
	Fare=0.65	33,190	21,574	24,789
Integrated	Fare=0.65+0.042X	34,994	*	25,542
	Fare=0.65	37,221	*	25,741

Note: Full Development Case
* Revenue is not calculated in the integrated fare case because passenger revenue should be shared among Line-1, 2, and 3.
Source: JICA Study Team

3.6.2 Peak Hour Passenger Demand

(1) Comparison of Panamericana and Autopista Routes

For route comparison between Panamericana and Autopista, a passenger demand forecast was carried out for the Autopista Route using the same method as the Panamaricana route. In this case, the end station is assumed to be Guadalupe, near the intersection of the Autopista and Panamericana. The number of stations is 13 as shown in Figure 3.19.



Source: JICA Study Team

Figure 3.19 Station Locations of Autopista Case

The following table shows the results of the demand forecast in peak hour. The passenger demand in the Panamericana route is estimated to be higher than that of the Autopista route. This is one of the reasons for the justification of the Panamerian route.

Table 3.37 Comparison of Passenger Demand between Panamericana and Autopista (2050)

Route	No. of boarding passengers (peak)	PHPDT
Panamericana	31,862	24,519
Autopista	27,186	21,431

Source: JICA Study Team

(2) Section Traffic

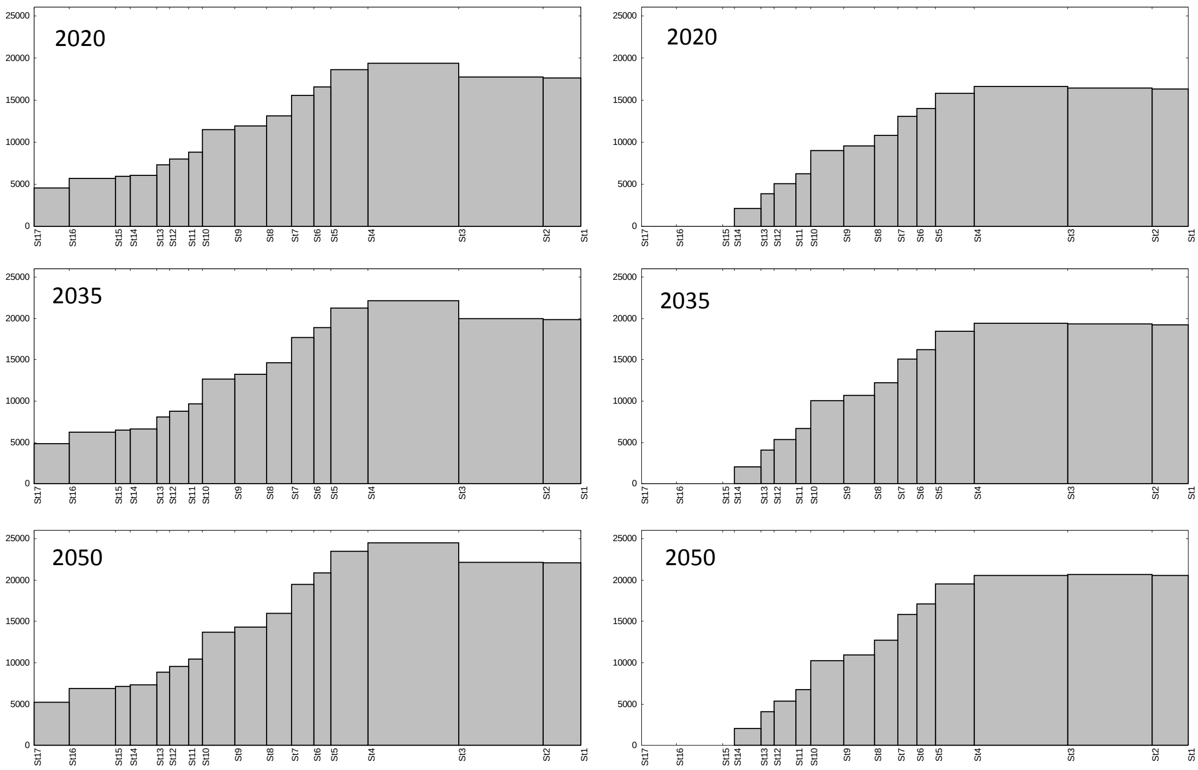
The peak hour traffic in the full development case is estimated at 19,359 in 2020, 22,153 in 2035, and 24,519 in 2050 as shown in Table 3.38. It is estimated that the modal share of public transport will decrease in accordance with the increase in the number of vehicles per inhabitant. However, the modal share of public transport will be higher than that in the without project case.

Table 3.38 Forecast of Peak Hour Traffic

	Full Development Case			Phase-1 Case		
	Public Mode Share (%)	No. of boarding passengers	PHPDT	Public Mode Share (%)	No. of boarding passengers	PHPDT
2013	66.0	-	-	66.0	-	-
2020	61.7	23,703	19,359	60.6	19,015	16,578
2025	58.5	25,375	20,493	57.4	20,664	17,824
2030	55.6	26,765	21,367	54.4	21,794	18,620
2035	53.7	28,034	22,153	52.3	22,881	19,408
2040	53.7	29,336	22,905	52.0	23,684	19,945
2050	50.9	31,862	24,519	48.8	24,740	20,667

Note: Fare= 0.65 + 0.042 * MAX(0, x-18), where x = distance of travel
Source: JICA Study Team

Figure 3.20 shows the traffic volume by section in the case of full development. The peak section is found between St3 (Panama Pacifico) and St4 (Loma Coba), due to the development of Panama Pacifico.



Note: Left=Full development case, Right=Phase-1 Case (Both are high population growth case)
Source: JICA Study Team

Figure 3.20 Section Traffic for Peak Direction

(3) Station-to-station Matrix

The station-to-station matrix of the peak hour is shown in Table 3.39 and Table 3.40 for the full development case and phase-1 case, respectively. For the phase-1 case, the results of medium growth case and low growth case of population are shown in Table 3.41 and Table 3.42, respectively.

Table 3.39 Station-to-Station Matrix (Full development case)

Y2020

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	ST15	ST16	ST17	Boarding
ST1	0	318	0	34	117	63	235	303	94	347	137	118	165	58	104	61	508	2662
ST2	76	0	2	3	8	1	5	0	0	1	0	0	0	0	3	3	33	135
ST3	106	10	0	13	58	4	32	24	3	7	4	0	5	0	3	4	98	371
ST4	750	7	39	0	0	0	1	0	0	0	0	0	0	0	0	2	29	828
ST5	2007	16	145	0	0	0	19	0	0	5	2	1	3	0	7	19	89	2313
ST6	912	8	119	0	0	0	0	0	0	0	0	0	1	0	0	0	10	1050
ST7	2466	20	274	0	0	0	0	0	0	0	0	0	1	1	1	45	133	2941
ST8	1180	2	95	0	0	0	0	0	0	0	0	0	0	0	0	0	50	1327
ST9	445	2	47	0	3	0	0	0	0	0	0	0	0	0	0	0	13	510
ST10	2403	15	244	0	22	1	0	0	0	0	0	0	0	0	0	0	26	2711
ST11	742	12	40	1	8	1	2	1	0	0	0	0	0	0	0	0	29	836
ST12	531	6	98	2	12	1	8	1	0	0	0	0	0	0	0	0	10	669
ST13	1122	7	125	4	16	2	12	1	1	0	0	0	0	0	0	0	16	1306
ST14	100	1	19	1	2	0	0	1	0	0	0	0	0	0	0	0	0	124
ST15	181	1	24	1	3	0	6	3	0	0	0	0	0	0	0	0	2	221
ST16	939	26	102	0	14	0	22	6	0	0	0	0	0	0	0	0	0	1109
ST17	3621	81	385	22	65	18	244	100	32	9	11	0	2	0	0	0	0	4590
Alighting	17581	532	1758	81	328	91	586	440	130	369	154	119	177	59	118	134	1046	23703

Y2025

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	ST15	ST16	ST17	Boarding
ST1	0	331	0	43	126	69	266	343	105	375	152	133	194	67	118	68	556	2946
ST2	100	0	5	4	9	1	6	0	0	1	0	0	0	3	6	6	31	172
ST3	149	15	0	14	88	5	38	32	4	9	6	1	7	0	7	9	124	508
ST4	781	7	54	0	0	0	1	0	0	0	0	0	1	0	0	2	34	880
ST5	2086	17	185	0	0	0	20	0	0	5	4	1	3	0	9	22	89	2441
ST6	948	9	149	0	0	0	0	0	0	0	0	0	1	0	0	0	13	1120
ST7	2592	23	349	0	0	0	0	0	0	0	0	0	1	1	1	49	139	3155
ST8	1238	2	123	0	0	0	0	0	0	0	0	0	0	0	0	0	57	1420
ST9	465	2	60	0	3	0	0	0	0	0	0	0	0	0	0	0	13	543
ST10	2516	17	317	0	24	1	0	0	0	0	0	0	0	0	0	0	28	2903
ST11	772	12	50	1	9	1	3	1	0	0	0	0	0	0	0	0	29	878
ST12	537	6	120	3	14	1	9	1	0	0	0	0	0	0	0	0	11	702
ST13	1151	7	159	4	17	3	13	3	1	0	0	0	0	0	0	0	17	1375
ST14	106	1	24	1	2	0	0	2	0	0	0	0	0	0	0	0	0	136
ST15	186	1	29	1	4	0	6	4	0	0	0	0	0	0	0	0	2	233
ST16	1059	29	147	0	16	0	24	6	0	0	0	0	0	0	0	0	0	1281
ST17	3651	85	421	24	68	20	253	102	32	9	13	0	4	0	0	0	0	4682
Alighting	18337	564	2192	95	380	101	639	494	142	399	175	135	211	71	141	156	1143	25375

Y2030

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	ST15	ST16	ST17	Boarding
ST1	0	358	0	46	140	77	303	382	115	391	168	154	216	71	137	88	619	3265
ST2	128	0	7	4	11	1	6	0	0	1	0	0	0	4	7	9	34	212
ST3	182	17	0	19	93	5	44	36	5	9	8	1	8	0	10	14	133	584
ST4	827	7	63	0	0	0	1	0	0	0	0	0	1	0	0	2	35	936
ST5	2186	18	205	0	0	0	21	1	0	5	5	1	3	0	9	22	99	2575
ST6	995	10	169	0	0	0	0	0	0	0	0	0	1	0	0	0	13	1188
ST7	2749	25	401	0	0	0	0	0	0	0	0	0	1	1	1	55	147	3380
ST8	1319	2	142	0	0	0	0	0	0	0	0	0	0	0	0	2	68	1533
ST9	489	3	66	0	3	0	0	0	0	0	0	0	0	0	0	0	16	577
ST10	2576	17	351	1	25	1	0	0	0	0	0	0	0	0	0	0	29	3000
ST11	783	14	54	1	10	1	4	2	0	0	0	0	0	0	0	0	33	902
ST12	530	6	127	3	14	1	9	1	0	0	0	0	0	0	0	0	11	702
ST13	1173	7	174	5	18	4	13	3	1	0	0	0	0	0	0	0	17	1415
ST14	105	1	25	1	2	0	0	1	0	0	0	0	0	0	0	0	0	135
ST15	189	1	32	1	4	0	6	4	0	0	0	0	0	0	0	0	2	239
ST16	1124	30	164	0	18	0	25	6	0	0	0	0	0	0	0	0	0	1367
ST17	3655	88	465	27	71	23	263	102	30	10	15	0	6	0	0	0	0	4755
Alighting	19010	604	2445	108	409	113	695	538	151	416	196	156	236	76	164	192	1256	26765

Y2035

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	ST15	ST16	ST17	Boarding
ST1	0	375	0	53	156	83	340	425	125	430	180	173	242	86	157	102	670	3597
ST2	144	0	7	5	12	1	7	0	0	2	0	0	1	4	8	17	30	238
ST3	218	17	0	20	98	7	45	37	5	10	8	1	9	0	11	44	107	637
ST4	882	8	64	0	0	0	1	0	0	0	0	0	1	0	0	3	37	996
ST5	2273	18	207	0	0	0	23	1	1	5	5	1	4	0	11	22	100	2671
ST6	1072	10	171	0	0	0	0	0	0	0	0	0	1	0	0	1	15	1270
ST7	2929	26	412	0	0	0	0	0	0	0	0	0	1	1	1	58	155	3583
ST8	1394	2	146	0	0	0	0	0	0	0	0	0	0	0	0	3	72	1617
ST9	513	3	67	0	4	0	0	0	0	0	0	0	0	0	0	0	17	604
ST10	2656	17	348	1	27	1	0	0	0	0	0	0	0	0	0	0	32	3082
ST11	806	15	52	1	11	2	4	2	0	0	0	0	0	0	0	0	35	928
ST12	533	6	128	4	14	1	9	1	0	0	0	0	0	0	0	0	12	708
ST13	1207	8	167	5	19	4	13	4	1	0	0	0	0	0	0	0	18	1446
ST14	109	1	25	1	2	0	0	1	0	0	0	0	0	0	0	0	0	139
ST15	193	1	32	2	4	0	6	5	0	0	0	0	0	0	0	0	3	246
ST16	1181	29	159	0	21	0	28	5	0	0	0	0	0	0	0	0	0	1423
ST17	3746	91	446	30	77	23	271	106	27	10	15	0	7	0	0	0	0	4849
Alighting	19856	627	2431	122	445	122	747	587	159	457	208	175	266	91	188	250	1303	28034

Y2040

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	ST15	ST16	ST17	Boarding
ST1	0	398	0	63	175	93	382	473	136	486	203	187	256	97	175	119	726	3969
ST2	155	0	5	5	14	1	8	0	0	2	0	0	2	4	10	18	34	258
ST3	264	20	0	21	117	7	50	44	6	11	10	1	9	0	16	50	119	745
ST4	926	8	73	0	0	0	1	0	0	0	0	0	1	0	0	3	42	1054
ST5	2370	21	230	0	0	0	21	1	1	5	5	2	4	0	14	23	112	2809
ST6	1128	11	191	0	0	0	0	0	0	0	0	0	1	0	0	1	15	1347
ST7	3057	26	444	0	0	0	0	0	0	0	0	0	1	1	2	62	160	3753
ST8	1437	2	159	0	0	0	0	0	0	0	0	0	0	0	1	5	75	1679
ST9	525	3	69	0	4	0	0	0	0	0	0	0	0	0	0	0	20	621
ST10	2687	17	372	1	28	1	0	0	0	0	0	0	0	0	0	0	33	3139
ST11	812	16	57	1	12	2	4	2	0	0	0	0	0	0	0	0	35	941
ST12	521	6	139	4	15	1	9	1	0	0	0	0	0	0	0	0	12	708
ST13	1225	8	178	5	19	5	13	4	1	0	0	0	0	0	0	0	20	1478
ST14	112	1	27	1	3	0	0	1	0	0	0	0	0	0	0	0	1	146
ST15	194	1	34	2	5	1	7	5	0	0	0	0	0	0	0	0	3	252
ST16	1252	29	195	0	23	0	31	4	0	0	0	0	0	0	0	0	0	1534
ST17	3765	93	484	34	80	25	261	103	27	11	13	0	7	0	0	0	0	4903
Alighting	20430	660	2657	137	495	136	787	638	171	515	231	190	281	102	218	281	1407	29336

Y2050

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	ST15	ST16	ST17	Boarding
ST1	0	456	0	74	210	101	450	551	167	473	232	221	307	119	200	136	854	4551
ST2	185	0	6	7	17	2	10	0	0	2	0	0	2	5	12	12	49	309
ST3	357	21	0	24	122	8	55	48	7	12	10	2	12	1	27	33	147	886
ST4	991	8	84	0	0	0	1	0	0	0	0	0	1	0	0	6	46	1137
ST5	2555	23	251	0	0	0	29	1	1	6	6	3	5	0	19	26	119	3044
ST6	1219	11	207	0	0	0	0	0	0	0	0	0	1	0	0	2	16	1456
ST7	3315	29	483	0	0	0	0	0	0	0	0	0	2	1	2	64	183	4079
ST8	1611	3	173	0	0	0	0	0	0	0	0	0	0	0	1	8	89	1885
ST9	566	3	71	0	4	0	0	0	0	0	0	0	0	0	0	0	24	668
ST10	2818	20	376	1	31	1	0	0	0	0	0	0	0	0	0	0	35	3282
ST11	833	16	56	1	13	2	4	2	0	0	0	0	0	0	0	0	40	967
ST12	530	7	144	4	16	1	10	2	0	0	0	0	0	0	0	0	14	728
ST13	1304	8	178	5	21	5	15	5	1	0	0	0	0	0	0	0	21	1563
ST14	120	1	27	1	3	0	0	1	0	0	0	0	0	0	0	0	1	154
ST15	208	2	33	2	6	1	7	6	0	0	0	0	0	0	0	0	3	268
ST16	1404	29	198	0	27	0	31	2	0	0	0	0	0	0	0	0	0	1691
ST17	4038	100	466	38	91	28	275	102	23	13	13	0	7	0	0	0	0	5194
Alighting	22054	737	2753	157	561	149	887	720	199	506	261	226	337	126	261	287	1641	31862

Source: JICA Study Team

Table 3.40 Station-to-Station Matrix (Phase-1 development case: High Growth)

Y2020

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	126	0	12	33	44	62	289	106	193	123	130	186	286	1590
ST2	97	0	0	3	8	1	5	0	0	1	0	0	0	42	157
ST3	114	7	0	13	68	4	30	25	3	8	4	2	13	118	409
ST4	790	7	0	0	0	0	1	0	0	0	0	0	0	0	798
ST5	1,898	18	14	0	0	1	18	1	0	6	5	5	24	60	2050
ST6	892	10	0	0	0	0	0	0	0	0	0	0	1	1	904
ST7	2,274	23	30	0	0	0	0	0	0	0	0	0	1	1	2329
ST8	1,205	2	7	0	0	0	0	0	0	0	0	0	0	0	1214
ST9	513	5	18	0	3	0	0	0	0	0	0	0	0	0	539
ST10	2,699	27	43	0	23	1	0	0	0	0	0	0	0	0	2793
ST11	1,137	25	20	1	9	1	2	0	0	0	0	0	0	0	1195
ST12	1,073	24	28	3	16	1	10	1	0	0	0	0	0	0	1156
ST13	1,638	30	51	5	19	4	15	3	0	0	0	0	0	0	1765
ST14	1,959	55	63	1	37	0	0	1	0	0	0	0	0	0	2116
Alighting	16289	359	274	38	216	57	143	320	109	208	132	137	225	508	19015

Y2025

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	140	0	14	38	48	67	326	116	217	141	155	205	291	1758
ST2	123	0	0	4	10	1	5	0	0	2	2	2	2	43	194
ST3	166	8	0	16	97	6	40	35	4	12	5	10	20	155	574
ST4	853	8	0	0	0	0	1	0	0	0	0	0	0	0	862
ST5	2,042	19	18	0	0	1	21	1	1	6	6	6	23	66	2210
ST6	981	11	3	0	2	0	0	0	0	0	0	0	1	1	999
ST7	2,475	24	34	0	0	0	0	0	0	0	0	0	1	1	2535
ST8	1,308	2	7	0	0	0	0	0	0	0	0	0	0	0	1317
ST9	563	5	19	0	4	0	0	0	0	0	0	0	0	0	591
ST10	2,960	28	48	1	27	1	0	0	0	0	0	0	0	0	3065
ST11	1,209	28	21	1	12	2	2	0	0	0	0	0	0	0	1275
ST12	1,135	25	33	4	17	1	11	1	0	0	0	0	0	0	1227
ST13	1,764	31	53	5	21	5	16	4	0	0	0	0	0	0	1899
ST14	1,990	62	65	1	39	0	0	1	0	0	0	0	0	0	2158
Alighting	17569	391	301	46	267	65	163	368	121	237	154	173	252	557	20664

Y2030

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	152	0	13	42	52	74	360	126	243	154	175	231	302	1924
ST2	155	0	0	4	12	1	5	0	0	4	4	4	4	43	236
ST3	204	8	0	22	109	7	46	39	5	12	8	12	28	171	671
ST4	913	8	0	0	0	0	1	0	0	0	0	0	0	0	922
ST5	2,177	22	20	0	0	1	21	2	1	6	8	7	23	76	2364
ST6	1,057	11	3	0	2	0	0	0	0	0	0	0	1	3	1077
ST7	2,641	26	36	0	0	0	0	0	0	0	0	0	1	1	2705
ST8	1,434	3	9	0	0	0	0	0	0	0	0	0	0	0	1446
ST9	593	6	21	0	4	0	0	0	0	0	0	0	0	0	624
ST10	3,076	30	50	1	29	1	0	0	0	0	0	0	0	0	3187
ST11	1,250	29	21	1	13	2	2	0	0	0	0	0	0	0	1318
ST12	1,163	27	33	4	18	1	12	1	0	0	0	0	0	0	1259
ST13	1,806	31	52	5	23	5	16	5	0	0	0	0	0	0	1943
ST14	1,947	61	64	1	44	0	0	1	0	0	0	0	0	0	2118
Alighting	18416	414	309	51	296	70	177	408	132	265	174	198	288	596	21794

Y2035

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	161	0	13	48	56	83	396	140	265	165	194	249	321	2091
ST2	175	0	0	5	14	1	5	0	0	6	4	4	5	47	266
ST3	245	8	0	22	111	7	47	42	6	12	8	14	36	176	734
ST4	962	9	0	0	0	0	1	0	0	0	0	0	0	0	972
ST5	2,303	23	23	0	0	1	25	2	1	8	10	8	27	85	2516
ST6	1,137	12	4	0	3	0	0	0	0	0	0	0	1	3	1160
ST7	2,820	29	41	0	0	0	0	0	0	0	0	0	2	1	2893
ST8	1,531	3	9	0	0	0	0	0	0	0	0	0	0	0	1543
ST9	635	6	21	0	4	0	0	0	0	0	0	0	0	0	666
ST10	3,207	34	52	1	32	1	0	0	0	0	0	0	0	0	3327
ST11	1,285	29	20	1	15	2	2	0	0	0	0	0	0	0	1354
ST12	1,184	28	35	4	19	1	15	1	0	0	0	0	0	0	1287
ST13	1,858	32	51	5	24	5	18	6	0	0	0	0	0	0	1999
ST14	1,906	62	57	1	46	0	0	1	0	0	0	0	0	0	2073
Alighting	19248	436	313	52	316	74	196	448	147	291	187	220	320	633	22881

Y2040

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	171	0	17	49	59	89	426	152	286	178	209	272	334	2242
ST2	186	0	0	5	17	1	6	0	0	6	4	5	6	50	286
ST3	293	8	0	24	112	8	50	43	6	14	9	15	37	183	802
ST4	1,010	10	0	0	0	0	1	0	0	0	0	0	0	0	1021
ST5	2,401	24	23	0	0	2	25	2	1	7	11	9	35	91	2631
ST6	1,180	12	4	0	2	0	0	0	0	0	0	0	1	4	1203
ST7	2,953	31	43	0	0	0	0	0	0	0	0	0	2	1	3030
ST8	1,614	3	9	0	0	0	0	0	0	0	0	0	0	0	1626
ST9	647	5	23	0	5	0	0	0	0	0	0	0	0	0	680
ST10	3,280	31	53	1	32	1	0	0	0	0	0	0	0	0	3398
ST11	1,297	29	19	2	16	2	3	0	0	0	0	0	0	0	1368
ST12	1,181	30	34	4	19	2	17	1	0	0	0	0	0	0	1288
ST13	1,893	35	52	5	24	5	21	6	0	0	0	0	0	0	2041
ST14	1,897	64	58	1	47	0	0	1	0	0	0	0	0	0	2068
Alighting	19832	453	318	59	323	80	212	479	159	313	202	238	353	663	23684

Y2050

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	179	0	18	53	65	97	475	173	318	194	235	309	356	2472
ST2	205	0	0	6	19	2	8	0	0	6	4	6	6	56	318
ST3	384	8	0	24	124	8	52	45	6	14	13	20	46	182	926
ST4	1,068	11	0	0	0	0	1	0	0	0	0	0	0	0	1080
ST5	2,528	25	24	0	0	2	24	3	1	7	13	12	37	94	2770
ST6	1,247	12	4	0	3	0	0	0	0	0	0	0	1	5	1272
ST7	3,108	32	46	0	0	0	0	0	0	0	0	0	3	1	3190
ST8	1,739	4	10	0	0	0	0	0	0	0	0	0	0	0	1753
ST9	678	5	23	0	5	0	0	0	0	0	0	0	0	0	711
ST10	3,396	31	52	1	36	1	0	0	0	0	0	0	0	0	3517
ST11	1,295	31	18	2	16	2	3	0	0	0	0	0	0	0	1367
ST12	1,152	31	31	5	20	2	17	2	0	0	0	0	0	0	1260
ST13	1,943	36	49	5	26	5	21	7	0	0	0	0	0	0	2092
ST14	1,839	64	52	3	53	0	0	1	0	0	0	0	0	0	2012
Alighting	20582	469	309	64	355	87	223	533	180	345	224	273	402	694	24740

Source: JICA Study Team

Table 3.41 Station-to-Station Matrix (Phase-1 development case: Mid Growth)

Y2020

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	123	0	11	33	42	63	281	103	185	125	125	180	284	1555
ST2	95	0	0	3	8	1	5	0	0	1	0	0	0	42	155
ST3	103	7	0	13	62	4	28	24	3	8	3	1	9	114	379
ST4	712	7	0	0	0	0	1	0	0	0	0	0	0	0	720
ST5	1,714	16	15	0	0	1	15	1	0	6	5	5	20	54	1852
ST6	803	8	0	0	0	0	0	0	0	0	0	0	1	1	813
ST7	2,056	20	29	0	0	0	0	0	0	0	0	0	1	1	2107
ST8	1,084	2	5	0	0	0	0	0	0	0	0	0	0	0	1091
ST9	458	4	17	0	3	0	0	0	0	0	0	0	0	0	482
ST10	2,396	23	40	0	22	1	0	0	0	0	0	0	0	0	2482
ST11	1,015	23	19	1	8	1	1	0	0	0	0	0	0	0	1068
ST12	984	22	24	2	13	1	10	1	0	0	0	0	0	0	1057
ST13	1,499	26	45	4	18	2	14	1	0	0	0	0	0	0	1609
ST14	1,808	51	56	1	33	0	0	1	0	0	0	0	0	0	1950
Alighting	14727	332	250	35	200	53	137	309	106	200	133	131	211	496	17320

Y2025

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	134	0	14	37	46	64	317	110	209	133	146	200	290	1700
ST2	122	0	0	4	10	1	5	0	0	2	2	2	2	42	192
ST3	141	7	0	14	89	5	35	32	4	9	5	5	15	146	507
ST4	735	7	0	0	0	0	1	0	0	0	0	0	0	0	743
ST5	1,745	17	15	0	0	1	15	1	0	6	5	4	21	56	1886
ST6	827	9	0	0	0	0	0	0	0	0	0	0	1	1	838
ST7	2,120	22	33	0	0	0	0	0	0	0	0	0	1	1	2177
ST8	1,121	2	5	0	0	0	0	0	0	0	0	0	0	0	1128
ST9	474	4	17	0	3	0	0	0	0	0	0	0	0	0	498
ST10	2,500	24	41	0	23	1	0	0	0	0	0	0	0	0	2589
ST11	1,042	24	19	1	9	1	2	0	0	0	0	0	0	0	1098
ST12	989	24	25	3	15	1	10	1	0	0	0	0	0	0	1068
ST13	1,508	28	44	4	18	3	14	2	0	0	0	0	0	0	1621
ST14	1,782	50	51	1	36	0	0	1	0	0	0	0	0	0	1921
Alighting	15106	352	250	41	240	59	146	354	114	226	145	157	240	536	17966

Y2030

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	141	0	14	40	51	68	346	124	228	150	166	218	303	1849
ST2	138	0	0	4	12	1	5	0	0	3	2	2	2	48	217
ST3	166	7	0	18	98	5	39	34	5	10	7	5	20	157	571
ST4	746	7	0	0	0	0	1	0	0	0	0	0	0	0	754
ST5	1,797	17	14	0	0	1	16	1	0	6	5	6	23	57	1943
ST6	846	9	0	0	1	0	0	0	0	0	0	0	1	1	858
ST7	2,193	24	35	0	0	0	0	0	0	0	0	0	1	1	2254
ST8	1,168	2	7	0	0	0	0	0	0	0	0	0	0	0	1177
ST9	492	5	17	0	3	0	0	0	0	0	0	0	0	0	517
ST10	2,500	25	41	0	23	1	0	0	0	0	0	0	0	0	2590
ST11	1,034	24	18	1	9	1	2	0	0	0	0	0	0	0	1089
ST12	963	24	24	3	16	1	10	1	0	0	0	0	0	0	1042
ST13	1,495	28	44	5	19	3	14	3	0	0	0	0	0	0	1611
ST14	1,732	52	48	1	38	0	0	1	0	0	0	0	0	0	1872
Alighting	15270	365	248	46	259	64	155	386	129	247	164	179	265	567	18344

Y2035

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	150	0	13	43	53	77	371	126	244	156	182	235	308	1958
ST2	163	0	0	4	14	1	5	0	0	4	4	4	5	46	250
ST3	191	7	0	19	98	5	39	35	5	10	7	6	20	158	600
ST4	762	7	0	0	0	0	1	0	0	0	0	0	0	0	770
ST5	1,818	17	14	0	0	1	18	1	0	6	5	5	24	60	1969
ST6	854	10	0	0	0	0	0	0	0	0	0	0	1	1	866
ST7	2,252	25	37	0	0	0	0	0	0	0	0	0	1	1	2316
ST8	1,191	2	7	0	0	0	0	0	0	0	0	0	0	0	1200
ST9	495	5	17	0	3	0	0	0	0	0	0	0	0	0	520
ST10	2,493	25	40	0	24	1	0	0	0	0	0	0	0	0	2583
ST11	1,022	25	15	1	9	1	2	0	0	0	0	0	0	0	1075
ST12	945	24	24	3	16	1	10	1	0	0	0	0	0	0	1024
ST13	1,478	28	41	5	19	4	15	3	0	0	0	0	0	0	1593
ST14	1,700	51	45	1	39	0	0	1	0	0	0	0	0	0	1837
Alighting	15364	376	240	46	265	67	167	412	131	264	172	197	286	574	18561

Y2040

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	156	0	13	46	54	82	396	140	265	173	195	251	320	2091
ST2	176	0	0	5	14	1	5	0	0	6	4	5	5	47	268
ST3	220	7	0	19	98	5	38	35	5	10	7	7	20	160	631
ST4	768	7	0	0	0	0	1	0	0	0	0	0	0	0	776
ST5	1,839	18	14	0	0	1	18	1	0	6	6	5	24	60	1992
ST6	856	10	0	0	0	0	0	0	0	0	0	0	1	1	868
ST7	2,261	26	40	0	0	0	0	0	0	0	0	0	1	1	2329
ST8	1,212	2	8	0	0	0	0	0	0	0	0	0	0	0	1222
ST9	495	4	16	0	3	0	0	0	0	0	0	0	0	0	518
ST10	2,478	25	39	1	24	1	0	0	0	0	0	0	0	0	2568
ST11	992	25	14	1	11	1	2	0	0	0	0	0	0	0	1046
ST12	913	24	24	3	16	1	10	1	0	0	0	0	0	0	992
ST13	1,442	29	34	5	19	4	15	3	0	0	0	0	0	0	1551
ST14	1,633	51	39	1	39	0	0	1	0	0	0	0	0	0	1764
Alighting	15285	384	228	48	270	68	171	437	145	287	190	212	302	589	18616

Y2050

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	167	0	17	49	58	90	438	153	288	175	214	274	336	2259
ST2	189	0	0	5	17	1	6	0	0	6	4	5	6	51	290
ST3	271	6	0	19	99	5	37	36	5	10	7	7	20	161	683
ST4	764	7	0	0	0	0	1	0	0	0	0	0	0	0	772
ST5	1,805	18	14	0	0	1	18	1	0	6	6	5	24	60	1958
ST6	849	9	0	0	0	0	0	0	0	0	0	0	1	1	860
ST7	2,264	25	41	0	0	0	0	0	0	0	0	0	1	1	2332
ST8	1,221	2	5	0	0	0	0	0	0	0	0	0	0	0	1228
ST9	485	4	15	0	3	0	0	0	0	0	0	0	0	0	507
ST10	2,417	24	35	1	24	1	0	0	0	0	0	0	0	0	2502
ST11	926	22	12	1	11	1	2	0	0	0	0	0	0	0	975
ST12	847	24	21	3	16	1	10	1	0	0	0	0	0	0	923
ST13	1,391	29	33	5	20	4	15	3	0	0	0	0	0	0	1500
ST14	1,569	49	35	1	39	0	0	1	0	0	0	0	0	0	1694
Alighting	14998	386	211	52	278	72	179	480	158	310	192	231	326	610	18483

Source: JICA Study Team

Table 3.42 Station-to-Station Matrix (Phase-1 development case: Low Growth)

Y2020

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	119	0	11	30	39	62	277	100	181	120	123	176	274	1512
ST2	94	0	0	3	8	1	5	0	0	1	0	0	0	42	154
ST3	98	7	0	12	61	3	27	22	3	8	3	0	9	112	365
ST4	668	5	0	0	0	0	0	0	0	0	0	0	0	0	673
ST5	1,636	16	15	0	0	1	8	1	0	6	4	4	19	53	1763
ST6	768	8	1	0	0	0	0	0	0	0	0	0	1	1	779
ST7	1,966	19	28	0	0	0	0	0	0	0	0	0	1	1	2015
ST8	1,028	2	5	0	0	0	0	0	0	0	0	0	0	0	1035
ST9	437	2	17	0	3	0	0	0	0	0	0	0	0	0	459
ST10	2,256	21	40	0	21	1	0	0	0	0	0	0	0	0	2339
ST11	952	22	16	1	8	1	1	0	0	0	0	0	0	0	1001
ST12	925	20	24	2	12	1	10	1	0	0	0	0	0	0	995
ST13	1,403	23	42	4	18	2	14	1	0	0	0	0	0	0	1507
ST14	1,702	53	49	0	29	0	0	1	0	0	0	0	0	0	1834
Alighting	13933	317	237	33	190	49	127	303	103	196	127	127	206	483	16431

Y2025

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	126	0	10	37	44	63	305	108	202	124	142	199	289	1649
ST2	109	0	0	4	10	1	5	0	0	1	0	0	0	47	177
ST3	133	7	0	14	80	5	34	32	3	9	5	3	14	143	482
ST4	692	5	0	0	0	0	0	0	0	0	0	0	0	0	697
ST5	1,656	16	15	0	0	1	11	1	0	6	4	5	18	53	1786
ST6	781	8	1	0	0	0	0	0	0	0	0	0	1	1	792
ST7	2,002	21	32	0	0	0	0	0	0	0	0	0	1	1	2057
ST8	1,061	2	5	0	0	0	0	0	0	0	0	0	0	0	1068
ST9	439	4	17	0	3	0	0	0	0	0	0	0	0	0	463
ST10	2,329	23	40	0	22	1	0	0	0	0	0	0	0	0	2415
ST11	979	23	16	1	8	1	2	0	0	0	0	0	0	0	1030
ST12	930	22	23	2	13	1	10	1	0	0	0	0	0	0	1002
ST13	1,418	26	42	4	18	2	14	1	0	0	0	0	0	0	1525
ST14	1,698	49	48	1	31	0	0	1	0	0	0	0	0	0	1828
Alighting	14227	332	239	36	222	56	139	341	111	218	133	150	233	534	16971

Y2030

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	136	0	12	36	46	65	330	115	213	130	156	203	297	1739
ST2	132	0	0	4	11	1	5	0	0	2	2	2	2	45	206
ST3	156	7	0	18	91	5	39	34	4	9	7	4	19	151	544
ST4	714	7	0	0	0	0	1	0	0	0	0	0	0	0	722
ST5	1,696	16	15	0	0	1	15	1	0	6	5	4	21	55	1835
ST6	796	8	0	0	0	0	0	0	0	0	0	0	1	1	806
ST7	2,071	21	34	0	0	0	0	0	0	0	0	0	1	1	2128
ST8	1,098	2	5	0	0	0	0	0	0	0	0	0	0	0	1105
ST9	465	4	16	0	3	0	0	0	0	0	0	0	0	0	488
ST10	2,321	22	40	0	22	1	0	0	0	0	0	0	0	0	2406
ST11	973	24	16	1	9	1	2	0	0	0	0	0	0	0	1026
ST12	914	24	23	3	14	1	10	1	0	0	0	0	0	0	990
ST13	1,417	28	41	4	18	2	14	1	0	0	0	0	0	0	1525
ST14	1,668	47	47	1	35	0	0	1	0	0	0	0	0	0	1799
Alighting	14421	346	237	43	239	58	151	368	119	230	144	166	247	550	17319

Y2035

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	140	0	11	39	50	69	357	121	229	140	170	221	304	1851
ST2	157	0	0	4	12	1	5	0	0	4	4	4	4	43	238
ST3	181	7	0	18	93	5	38	34	4	9	7	5	20	152	573
ST4	721	7	0	0	0	0	1	0	0	0	0	0	0	0	729
ST5	1,729	17	15	0	0	1	15	1	0	6	5	5	23	57	1874
ST6	810	8	0	0	0	0	0	0	0	0	0	0	1	1	820
ST7	2,124	22	36	0	0	0	0	0	0	0	0	0	1	1	2184
ST8	1,125	2	5	0	0	0	0	0	0	0	0	0	0	0	1132
ST9	469	4	16	0	3	0	0	0	0	0	0	0	0	0	492
ST10	2,360	23	39	0	23	1	0	0	0	0	0	0	0	0	2446
ST11	956	22	14	1	9	1	2	0	0	0	0	0	0	0	1005
ST12	901	24	23	3	15	1	10	1	0	0	0	0	0	0	978
ST13	1,404	29	34	4	18	3	14	1	0	0	0	0	0	0	1507
ST14	1,632	49	39	1	36	0	0	1	0	0	0	0	0	0	1758
Alighting	14569	354	221	42	248	63	154	395	125	248	156	184	270	558	17587

Y2040

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	143	0	12	41	52	76	377	127	239	153	173	228	322	1943
ST2	169	0	0	5	14	1	5	0	0	4	4	4	5	46	257
ST3	210	7	0	18	95	5	38	34	5	9	7	5	20	154	607
ST4	738	7	0	0	0	0	1	0	0	0	0	0	0	0	746
ST5	1,771	17	15	0	0	1	15	1	0	6	5	6	23	57	1917
ST6	825	9	0	0	0	0	0	0	0	0	0	0	1	1	836
ST7	2,146	23	39	0	0	0	0	0	0	0	0	0	1	1	2210
ST8	1,153	2	5	0	0	0	0	0	0	0	0	0	0	0	1160
ST9	484	5	15	0	3	0	0	0	0	0	0	0	0	0	507
ST10	2,348	25	38	0	23	1	0	0	0	0	0	0	0	0	2435
ST11	949	24	14	1	9	1	2	0	0	0	0	0	0	0	1000
ST12	877	24	22	3	16	1	10	1	0	0	0	0	0	0	954
ST13	1,396	29	33	4	19	3	14	3	0	0	0	0	0	0	1501
ST14	1,581	49	36	1	38	0	0	1	0	0	0	0	0	0	1706
Alighting	14647	364	217	44	258	65	161	417	132	258	169	188	278	581	17779

Y2050

Line	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10	ST11	ST12	ST13	ST14	Boarding
ST1	0	153	0	15	45	55	82	408	147	270	171	198	263	319	2126
ST2	183	0	0	5	16	1	6	0	0	6	4	5	5	50	281
ST3	266	6	0	19	98	5	37	35	5	10	7	7	20	160	675
ST4	748	7	0	0	0	0	1	0	0	0	0	0	0	0	756
ST5	1,779	17	14	0	0	1	16	1	0	6	6	5	23	60	1928
ST6	838	9	0	0	0	0	0	0	0	0	0	0	1	1	849
ST7	2,209	25	42	0	0	0	0	0	0	0	0	0	1	1	2278
ST8	1,201	2	5	0	0	0	0	0	0	0	0	0	0	0	1208
ST9	478	4	15	0	3	0	0	0	0	0	0	0	0	0	500
ST10	2,356	22	34	0	24	1	0	0	0	0	0	0	0	0	2437
ST11	907	22	12	1	10	1	2	0	0	0	0	0	0	0	955
ST12	821	25	19	3	16	1	10	1	0	0	0	0	0	0	896
ST13	1,364	30	32	5	19	4	15	3	0	0	0	0	0	0	1472
ST14	1,542	47	34	1	39	0	0	1	0	0	0	0	0	0	1664
Alighting	14692	369	207	49	270	69	169	449	152	292	188	215	313	591	18025

Source: JICA Study Team

3.6.3 Daily Traffic

The estimated OD matrices represent the traffic in the morning peak hours, and it is likely that the OD matrix in the afternoon peak hours is the transposed matrix of the morning peaks. It is assumed that the daily OD is calculated from the combined matrix of the morning and afternoon peak hours by multiplying a scalar value.

According to the traffic survey, the bus traffic in the morning peak hours for both directions accounts for 12% of the daily traffic. The rate of the total trips in the morning peaks to that of a day is assumed to be 12%. From this, the number of boarding and alighting passengers in a day was calculated from that of peak hours by multiplying 1/0.12.

The result of the calculation of barding passengers is shown in Table 3.43 and Table 3.44.

Table 3.43 Daily Boarding Passengers by Station (Full Development Case)

Station	2020	2025	2030	2035	2040	2050
1	84,346	88,679	92,813	97,721	101,663	110,854
2	2,779	3,067	3,400	3,604	3,825	4,358
3	8,871	11,250	12,621	12,783	14,175	15,163
4	3,788	4,063	4,350	4,658	4,963	5,392
5	11,004	11,754	12,433	12,983	13,767	15,021
6	4,754	5,088	5,421	5,800	6,179	6,688
7	14,696	15,808	16,979	18,042	18,917	20,692
8	7,363	7,975	8,629	9,183	9,654	10,854
9	2,667	2,854	3,033	3,179	3,300	3,613
10	12,833	13,758	14,233	14,746	15,225	15,783
11	4,125	4,388	4,575	4,733	4,883	5,117
12	3,283	3,488	3,575	3,679	3,742	3,975
13	6,179	6,608	6,879	7,133	7,329	7,917
14	763	863	879	958	1,033	1,167
15	1,413	1,558	1,679	1,808	1,958	2,204
16	5,179	5,988	6,496	6,971	7,563	8,242
17	23,483	24,271	25,046	25,633	26,292	28,479
Total	197,525	211,458	223,042	233,617	244,467	265,517

Source: JICA Study Team

Table 3.44 Daily Boarding and Alighting Passengers by Station (Phase-1 Case)

Station	2020	2025	2030	2035	2040	2050
1	74,496	80,529	84,750	88,913	91,975	96,058
2	2,150	2,438	2,708	2,925	3,079	3,279
3	2,846	3,646	4,083	4,363	4,667	5,146
4	3,483	3,783	4,054	4,267	4,500	4,767
5	9,442	10,321	11,083	11,800	12,308	13,021
6	4,004	4,433	4,779	5,142	5,346	5,663
7	10,300	11,242	12,008	12,871	13,508	14,221
8	6,392	7,021	7,725	8,296	8,771	9,525
9	2,700	2,967	3,150	3,388	3,496	3,713
10	12,504	13,758	14,383	15,075	15,463	16,092
11	5,529	5,954	6,217	6,421	6,542	6,629
12	5,388	5,833	6,071	6,279	6,358	6,388
13	8,292	8,963	9,296	9,663	9,975	10,392
14	10,933	11,313	11,308	11,275	11,379	11,275
Total	158,458	172,200	181,617	190,675	197,367	206,167

Source: JICA Study Team

3.6.4 Results of Traffic Assignment

(1) Peak Hour Traffic

Under the Present scenario, the future peak hour traffic of the Bridge of Americas must be almost the same as the present traffic because the peak hour traffic volume cannot exceed the traffic capacity of the Pan-American Road. After the peak hour traffic on the Centenario Bridge exceeds the capacity, the hourly traffic crossing the canal in the future becomes the same as the present traffic. On the other hand, traffic flow in off-peak hour will continue to increase.

In the demand forecast model, the peak hour traffic is estimated using the peak hour OD matrix although the "peak hour traffic" does not necessarily represent the peak hour traffic, because it should be considered that a part of the traffic would shift to other hours. Table 3.45 (A-C) shows the result of the demand forecast for the peak hour.

(2) Daily Traffic

The peak hour traffic on the Bridge of Americas accounts for 7% of 24 hours of traffic according to the traffic survey conducted in 2013 by the JICA Study Team. The daily traffic was estimated from the peak hour traffic by applying the peak hour rate. Table 3.45 (D) shows the result of the demand forecast of the daily traffic (no. of vehicles). The results of the demand forecast represent the traffic flow in a typical weekday instead of AADT used in the ACP's Study.

To compare the results with the ACP's Study, the results of the demand forecast were converted to AADT (5:00-21:00) using the conversion factors (from a daily to AADT) of 1.0595 and 1.0246 for cars and buses, respectively, which are used in the ACP's Study. The results are shown in Table 3.45 (E).

Table 3.46 and Table 3.47 show the results of the demand forecast of other population scenarios.

Table 3.45 Result of Demand Forecast (Population High Projection)

A: Peak Hour Peak Direction (PCU)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	1,746	3,445	1,379	1,921	1,877	1,157	1,709	1,451	1,264	2,985
2025	2,578	3,871	1,823	2,186	2,425	1,512	2,045	1,841	1,642	3,685
2030	3,282	4,362	2,329	2,425	2,875	1,914	2,222	2,323	2,067	4,319
2035	3,669	5,124	3,133	2,598	3,045	2,287	2,436	2,711	2,607	4,754
2040	4,533	5,522	3,379	2,799	3,953	2,746	2,715	3,118	3,106	5,402
2045	5,131	5,979	4,008	3,123	3,963	3,459	2,754	3,175	3,420	5,897
2050	5,173	6,956	4,083	3,442	4,611	3,391	2,904	3,977	4,208	5,995

B: Peak Hour Off-peak Direction (PCU)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	635	670	609	85	598	604	82	549	605	625
2025	694	713	655	89	648	645	88	588	645	671
2030	751	742	699	86	693	697	84	631	698	710
2035	812	779	766	98	712	759	98	650	760	742
2040	885	820	834	101	752	825	101	684	829	775
2045	922	868	870	106	799	862	104	717	864	814
2050	958	890	928	113	815	896	112	738	897	843

C: Peak Hour Both Directions (PCU)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	2,381	4,115	1,988	2,006	2,475	1,761	1,791	2,000	1,869	3,610
2025	3,272	4,584	2,478	2,275	3,073	2,157	2,133	2,429	2,287	4,356
2030	4,033	5,104	3,028	2,511	3,568	2,611	2,306	2,954	2,765	5,029
2035	4,481	5,903	3,899	2,696	3,757	3,046	2,534	3,361	3,367	5,496
2040	5,418	6,342	4,213	2,900	4,705	3,571	2,816	3,802	3,935	6,177
2045	6,053	6,847	4,878	3,229	4,762	4,321	2,858	3,892	4,284	6,711
2050	6,131	7,846	5,011	3,555	5,426	4,287	3,016	4,715	5,105	6,838

D: Day (24 hours: No. of Vehicles)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	39,280	56,132	33,837	28,269	33,112	30,615	25,905	28,705	32,144	52,560
2025	52,951	62,800	41,794	32,236	41,507	37,222	30,950	34,900	39,072	63,457
2030	64,982	70,495	50,818	35,830	48,616	44,882	33,651	42,566	47,068	73,481
2035	72,418	82,126	64,310	38,663	51,342	52,146	37,113	48,520	56,718	80,505
2040	87,071	89,361	70,021	41,823	65,002	60,857	41,402	55,009	66,050	90,668
2045	97,013	96,226	80,442	46,709	65,867	72,492	42,195	56,424	71,949	98,619
2050	99,138	110,894	83,367	51,608	75,508	73,024	44,665	68,351	84,695	100,808

E: AADT (No. of Vehicles)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	31,525	50,906	26,382	25,615	30,246	23,341	23,361	26,010	25,613	48,988
2025	43,512	56,846	32,976	29,177	37,996	28,661	27,940	31,677	31,427	59,243
2030	53,754	63,668	40,379	32,346	44,488	34,775	30,266	38,690	38,078	68,563
2035	59,775	74,253	52,116	34,821	46,867	40,634	33,334	44,113	46,464	75,005
2040	72,448	80,602	56,350	37,572	59,532	47,700	37,149	50,007	54,377	84,444
2045	80,958	86,753	65,310	42,008	60,177	57,806	37,722	51,169	59,229	91,841
2050	81,996	100,210	67,103	46,436	69,085	57,341	39,859	62,233	70,669	93,577

Source: Estimation by the JICA Study Team

Table 3.46 Result of Demand Forecast (Population Medium Projection)

A: Peak Hour Peak Direction (PCU)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	1,428	3,227	1,194	1,759	1,689	960	1,547	1,291	1,085	2,703
2025	1,916	3,582	1,461	1,972	2,051	1,210	1,832	1,515	1,358	3,190
2030	2,452	3,884	1,753	2,215	2,355	1,476	2,039	1,770	1,634	3,640
2035	2,911	4,158	2,082	2,358	2,617	1,707	2,092	2,124	1,894	4,019
2040	3,332	4,515	2,408	2,489	2,937	1,957	2,302	2,330	2,136	4,444
2045	3,528	4,867	2,750	2,593	3,039	2,115	2,319	2,579	2,353	4,650
2050	3,735	5,196	3,240	2,639	3,039	2,303	2,430	2,781	2,788	4,716

B: Peak Hour Off-peak Direction (PCU)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	610	653	575	82	594	584	78	515	577	624
2025	665	680	631	85	616	620	81	535	617	644
2030	716	711	675	82	658	673	79	565	671	670
2035	762	742	711	89	692	714	85	596	710	710
2040	807	770	758	94	714	757	90	619	752	738
2045	841	793	788	97	737	794	94	632	790	755
2050	870	808	818	99	749	826	94	643	818	771

C: Peak Hour Both Directions (PCU)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	2,038	3,880	1,769	1,841	2,283	1,544	1,625	1,806	1,662	3,327
2025	2,581	4,262	2,092	2,057	2,667	1,830	1,913	2,050	1,975	3,834
2030	3,168	4,595	2,428	2,297	3,013	2,149	2,118	2,335	2,305	4,310
2035	3,673	4,900	2,793	2,447	3,309	2,421	2,177	2,720	2,604	4,729
2040	4,139	5,285	3,166	2,583	3,651	2,714	2,392	2,949	2,888	5,182
2045	4,369	5,660	3,538	2,690	3,776	2,909	2,413	3,211	3,143	5,405
2050	4,605	6,004	4,058	2,738	3,788	3,129	2,524	3,424	3,606	5,487

D: Day (24 hours: No. of Vehicles)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	34,430	53,182	30,751	26,055	30,627	27,573	23,841	26,305	29,223	48,596
2025	43,151	58,843	36,336	29,336	36,129	32,615	28,150	29,907	34,658	56,128
2030	52,718	64,045	42,318	33,044	41,223	38,346	31,330	34,180	40,561	63,388
2035	60,989	68,805	48,596	35,420	45,606	43,282	32,392	39,856	45,882	69,755
2040	68,878	74,832	55,157	37,673	50,709	48,693	35,723	43,337	51,171	76,689
2045	73,085	80,569	61,399	39,424	52,652	52,399	36,217	47,259	55,742	80,240
2050	77,495	85,987	69,867	40,365	53,072	56,574	38,022	50,486	63,388	81,808

E: AADT (No. of Vehicles)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	26,945	48,109	23,468	23,521	27,891	20,467	21,403	23,732	22,761	45,119
2025	34,260	53,090	27,823	26,433	32,906	24,310	25,286	26,951	27,119	52,090
2030	42,175	57,554	32,354	29,708	37,493	28,605	28,063	30,761	31,727	58,713
2035	48,984	61,647	37,282	31,750	41,432	32,266	28,865	35,920	35,889	64,513
2040	55,274	66,871	42,317	33,643	46,018	36,216	31,777	38,975	39,855	70,801
2045	58,369	71,934	47,333	35,118	47,677	38,839	32,067	42,501	43,411	73,903
2050	61,564	76,657	54,358	35,811	47,878	41,812	33,576	45,353	49,873	75,033

Source: Estimation by the JICA Study Team

Table 3.47 Result of Demand Forecast (Population Low Projection)

A: Peak Hour Peak Direction (PCU)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	1,283	3,061	1,081	1,693	1,558	897	1,418	1,233	992	2,546
2025	1,669	3,476	1,349	1,932	1,850	1,106	1,729	1,414	1,240	2,999
2030	2,308	3,676	1,638	2,178	2,155	1,373	1,880	1,716	1,529	3,431
2035	2,689	4,011	1,956	2,262	2,470	1,601	2,106	1,896	1,759	3,834
2040	3,299	4,277	2,298	2,470	2,796	1,882	2,216	2,266	2,049	4,305
2045	3,453	4,662	2,549	2,537	3,018	2,054	2,350	2,389	2,241	4,542
2050	3,689	5,075	3,135	2,624	2,993	2,246	2,410	2,704	2,609	4,742

B: Peak Hour Off-peak Direction (PCU)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	593	634	556	78	580	553	77	507	551	609
2025	635	664	605	83	600	606	76	523	604	625
2030	678	677	640	80	624	635	76	543	630	647
2035	706	690	667	79	639	662	75	554	659	654
2040	747	713	708	84	656	711	80	564	708	670
2045	764	750	722	86	696	723	82	595	719	704
2050	808	767	757	92	716	761	88	611	759	725

C: Peak Hour Both Directions (PCU)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	1,876	3,695	1,637	1,771	2,138	1,450	1,495	1,740	1,543	3,155
2025	2,304	4,140	1,954	2,015	2,450	1,712	1,805	1,937	1,844	3,624
2030	2,986	4,353	2,278	2,258	2,779	2,008	1,956	2,259	2,159	4,078
2035	3,395	4,701	2,623	2,341	3,109	2,263	2,181	2,450	2,418	4,488
2040	4,046	4,990	3,006	2,554	3,452	2,593	2,296	2,830	2,757	4,975
2045	4,217	5,412	3,271	2,623	3,714	2,777	2,432	2,984	2,960	5,246
2050	4,497	5,842	3,892	2,716	3,709	3,007	2,498	3,315	3,368	5,467

D: Day (24 hours: No. of Vehicles)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	32,137	50,753	28,887	25,134	28,691	26,244	22,012	25,384	27,551	46,182
2025	39,222	57,350	34,386	28,814	33,193	30,951	26,636	28,321	32,808	53,200
2030	50,146	60,831	40,196	32,551	38,058	36,346	29,044	33,130	38,489	60,131
2035	57,046	66,219	46,189	33,985	42,927	41,046	32,477	36,042	43,253	66,398
2040	67,578	70,839	52,893	37,323	48,030	46,985	34,373	41,687	49,314	73,825
2045	70,956	77,226	57,606	38,509	51,917	50,542	36,509	44,052	53,156	78,040
2050	75,974	83,816	67,502	40,079	52,051	54,852	37,672	48,965	60,002	81,594

E: AADT (No. of Vehicles)

Scenario	Present		4th Bridge			4th Bridge and Line-3			Without Bridge of Americas	
Year	Centenario	Bridge of Americas	Centenario	Bridge of Americas	4th Bridge	Centenario	Bridge of Americas	4th Bridge	Centenario	4th Bridge
2020	24,780	45,810	21,708	22,648	26,060	19,212	19,676	22,862	21,130	42,762
2025	30,551	51,673	25,982	25,938	30,130	22,739	23,856	25,453	25,313	49,232
2030	39,747	54,513	30,351	29,241	34,501	26,717	25,905	29,769	29,705	55,534
2035	45,262	59,198	35,009	30,393	38,898	30,155	28,945	32,318	33,323	61,236
2040	54,046	63,095	40,180	33,310	43,484	34,604	30,502	37,416	38,043	68,006
2045	56,358	68,772	43,753	34,254	46,978	37,085	32,342	39,473	40,887	71,756
2050	60,127	74,603	52,126	35,540	46,910	40,187	33,245	43,916	46,569	74,824

Source: Estimation by the JICA Study Team

The future traffic volume by vehicle type on the 4th Bridge in the case of the “4th Bridge and Line-3 Scenario” is summarized in Table 3.48, with the calculation of ESALs. There are three demand forecast results based on the population projection scenarios. As explained in 3.2.2, High Population Projection was used for the planning. It was assumed that ESAL of each vehicle type was: Car=0, Bus=1, Small truck=0.018, 2-Axle truck=0.64, and 3 or more axle truck=2.03. These ESALs are the same as those in ACP’ Study except for small truck. The proportion of 2-axle trucks to 3 or more axle trucks was assumed to be 9:1 based on the ACP’s Study.

Table 3.48 Results of Demand Forecast - 4th Bridge (No. of Vehicles per day)

High Population Projection

Year	No. of vehicles						ESAL	
	Car	Bus	Light Truck	2-Axle Truck	3 or more axle truck	Total	Year	Accumlate (million)
2020	26,471	1,050	793	352	39	28,705	451,629	0.45
2025	32,343	1,179	924	409	45	34,900	511,358	2.86
2030	39,700	1,250	1,082	480	53	42,566	555,977	5.53
2035	45,371	1,321	1,224	543	60	48,520	598,375	8.41
2040	51,557	1,379	1,389	616	68	55,009	639,056	11.51
2045	52,729	1,436	1,514	671	75	56,424	674,447	14.79
2050	64,414	1,471	1,651	732	81	68,351	704,486	18.24

Medium Population Projection

Year	No. of vehicles						ESAL	
	Car	Bus	Light Truck	2-Axle Truck	3 or more axle truck	Total	Year	Accumlate (million)
2020	24,443	679	793	352	39	26,305	329,058	0.33
2025	27,771	757	924	409	45	29,907	372,286	2.08
2030	31,771	793	1,082	480	53	34,180	405,120	4.03
2035	37,200	829	1,224	543	60	39,856	435,732	6.13
2040	40,400	864	1,389	616	68	43,337	469,342	8.39
2045	44,129	871	1,514	671	75	47,259	488,232	10.78
2050	47,129	893	1,651	732	81	50,486	513,558	13.29

Low Population Projection

Year	No. of vehicles						ESAL	
	Car	Bus	Light Truck	2-Axle Truck	3 or more axle truck	Total	Year	Accumlate (million)
2020	23,543	657	793	352	39	25,384	321,987	0.32
2025	26,214	729	924	409	45	28,321	362,858	2.03
2030	30,757	757	1,082	480	53	33,130	393,334	3.92
2035	33,429	786	1,224	543	60	36,042	421,589	5.96
2040	38,800	814	1,389	616	68	41,687	452,842	8.15
2045	40,957	836	1,514	671	75	44,052	476,447	10.47
2050	45,643	857	1,651	732	81	48,965	501,772	12.92

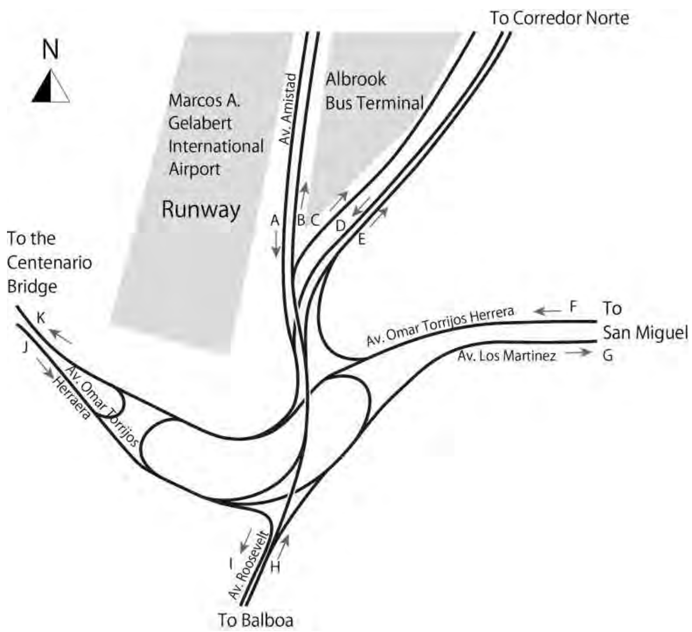
Source: Estimation by the JICA Study Team

3.7 Traffic Simulation at Omar Torrijos Roundabout

3.7.1 Traffic Flow at the Roundabout

The approach road of the 4th Bridge on the east side is to connect directly to the Corredor North as planned in ACP's Study, whereas, in the JICA Study, the approach would connect to a road network before the Corredor North. It is proposed that the approach road would connect to the road network at the Omar Torrijos Roundabout located to the south of the Albrook Airport.

Omar Torrijos Roundabout is basically a 5-way intersection as shown in Figure 3.21. For the traffic simulation of this roundabout, information on traffic flow between each entering leg and exiting leg is necessary. Since there was no such data available, the JICA Study Team conducted a traffic survey at this roundabout on December 5, 2013. In the survey, the license plate numbers were recorded at each leg and the entering and exiting pair was identified for each vehicle.



Source: Illustrated by the JICA Study Team

Figure 3.21 Omar Torrijos Roundabout

The result of the morning peak is shown in Table 3.49. The maximum traffic volume is observed from J to G, followed by the traffic from F to K. Both are traffic in the east-west direction in the above figure.

Table 3.49 Traffic at Omar Torrijos Roundabout (AM 7:00- AM 8:00)

AM 6:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J		102	287	23	135	114	*661*
	H	456		406	42	46	149	*1099*
	F	765	439			143	70	*1417*
	D	301	188	351		28	22	*890*
	A	390	276	160	5		8	*839*
	Total	*1912*	*1005*	*1204*	*70*	*352*	*363*	*4906*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		10	33	2	4	0	*49*
	H	22		20	0	11	8	*61*
	F	62	21			1	2	*86*
	D	27	17	29		0	8	*81*
	A	6	1	4	0		0	*11*
	Total	*117*	*49*	*86*	*2*	*16*	*18*	*288*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		2	1	0	1	8	*12*
	H	0		6	1	0	17	*24*
	F	11	9			76	87	*183*
	D	39	61	92		3	84	*279*
	A	3	2	2	6		2	*15*
	Total	*53*	*74*	*101*	*7*	*80*	*198*	*513*

Small truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		0	12	0	3	0	*15*
	H	2		4	0	2	0	*8*
	F	16	9			8	2	*35*
	D	4	1	3		0	0	*8*
	A	2	0	4	0		0	*6*
	Total	*24*	*10*	*23*	*0*	*13*	*2*	*72*

Large truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		4	0	0	0	0	*4*
	H	0		1	0	3	0	*4*
	F	4	11			2	0	*17*
	D	2	5	1		0	0	*8*
	A	0	0	0	0		0	*0*
	Total	*6*	*20*	*2*	*0*	*5*	*0*	*33*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	118	333	25	143	122	*741*
	H	480	0	437	43	62	174	*1196*
	F	858	489	0	0	230	161	*1738*
	D	373	272	476	0	31	114	*1266*
	A	401	279	170	11	0	10	*871*
	Total	*2112*	*1158*	*1416*	*79*	*466*	*581*	*5812*

AM 7:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	702	1017	75	265	144	*2203*
	H	552	0	301	45	218	182	*1298*
	F	852	276	5	0	148	95	*1376*
	D	466	233	315	0	35	27	*1076*
	A	462	322	257	12	0	32	*1085*
	Total	*2332*	*1533*	*1895*	*132*	*666*	*480*	*7038*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	12	13	0	2	0	*27*
	H	20	0	19	4	14	10	*67*
	F	45	26	0	0	0	1	*72*
	D	16	25	8	0	3	6	*58*
	A	9	3	5	0	0	0	*17*
	Total	*90*	*66*	*45*	*4*	*19*	*17*	*241*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	8	5	0	7	12	*32*
	H	2	0	3	2	3	15	*25*
	F	13	12	0	0	52	43	*120*
	D	13	49	88	0	16	53	*219*
	A	1	3	5	3	0	10	*22*
	Total	*29*	*72*	*101*	*5*	*78*	*133*	*418*

Small truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	15	31	0	2	3	*51*
	H	10	0	12	0	2	0	*24*
	F	27	17	0	0	5	1	*50*
	D	7	4	7	0	1	0	*19*
	A	6	0	3	0	0	0	*9*
	Total	*50*	*36*	*53*	*0*	*10*	*4*	*153*

Large truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	6	2	3	0	0	*11*
	H	5	0	4	5	10	0	*24*
	F	7	9	0	0	2	0	*18*
	D	3	3	1	0	0	0	*7*
	A	0	3	0	0	0	0	*3*
	Total	*15*	*21*	*7*	*8*	*12*	*0*	*63*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	743	1068	78	276	159	*2324*
	H	589	0	339	56	247	207	*1438*
	F	944	340	5	0	207	140	*1636*
	D	505	314	419	0	55	86	*1379*
	A	478	331	270	15	0	42	*1136*
	Total	*2516*	*1728*	*2101*	*149*	*785*	*634*	*7913*

AM 8:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J		595	692	119	138	280	*1824*
	H	523		181	43	423	246	*1416*
	F	776	164			104	34	*1078*
	D	405	228	301		25	48	*1007*
	A	465	435	331	15		75	*1321*
	Total	*2169*	*1422*	*1505*	*177*	*690*	*683*	*6646*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		21	22	3	2	3	*51*
	H	38		16	12	19	41	*126*
	F	29	26			0	1	*56*
	D	12	24	5		1	8	*50*
	A	8	19	12	3		5	*47*
	Total	*87*	*90*	*55*	*18*	*22*	*58*	*330*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		4	2	0	4	5	*15*
	H	2		3	1	3	18	*27*
	F	7	8			31	93	*139*
	D	6	46	81		46	86	*265*
	A	2	3	9	2		25	*41*
	Total	*17*	*61*	*95*	*3*	*84*	*227*	*487*

Small truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		22	51	2	11	5	*91*
	H	9		11	3	2	0	*25*
	F	37	16			7	1	*61*
	D	10	5	10		1	0	*26*
	A	13	0	6	1		0	*20*
	Total	*69*	*43*	*78*	*6*	*21*	*6*	*223*

Large truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		2	1	1	0	0	*4*
	H	2		13	12	6	0	*33*
	F	4	11			2	0	*17*
	D	1	3	2		0	0	*6*
	A	0	6	2	1		0	*9*
	Total	*7*	*22*	*18*	*14*	*8*	*0*	*69*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	644	768	125	155	293	*1985*
	H	574	0	224	71	453	305	*1627*
	F	853	225	0	0	144	129	*1351*
	D	434	306	399	0	73	142	*1354*
	A	488	463	360	22	0	105	*1438*
	Total	*2349*	*1638*	*1751*	*218*	*825*	*974*	*7755*

AM 9:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J		479	590	72	331	43	*1515*
	H	329		376	101	443	247	*1496*
	F	652	115	188		114	139	*1208*
	D	285	98	263		90	78	*814*
	A	298	456	308	21		10	*1093*
	Total	*1564*	*1148*	*1725*	*194*	*978*	*517*	*6126*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		26	23	3	11	0	*63*
	H	18		34	5	21	11	*89*
	F	11	31			0	0	*42*
	D	9	34	7		5	6	*61*
	A	20	8	16	1		1	*46*
	Total	*58*	*99*	*80*	*9*	*37*	*18*	*301*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		1	0	0	0	8	*9*
	H	1		1	3	1	21	*27*
	F	7	9			63	80	*159*
	D	5	38	109		41	118	*311*
	A	2	4	8	3		28	*45*
	Total	*15*	*52*	*118*	*6*	*105*	*255*	*551*

Small truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		20	81	2	11	4	*118*
	H	17		22	4	4	0	*47*
	F	43	24			19	4	*90*
	D	7	4	10		2	0	*23*
	A	16	3	14	0		0	*33*
	Total	*83*	*51*	*127*	*6*	*36*	*8*	*311*

Large truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		12	2	0	0	1	*15*
	H	6		19	8	17	0	*50*
	F	0	15			0	0	*15*
	D	0	4	0		0	0	*4*
	A	1	9	0	4		0	*14*
	Total	*7*	*40*	*21*	*12*	*17*	*1*	*98*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	538	696	77	353	56	*1720*
	H	371	0	452	121	486	279	*1709*
	F	713	194	188	0	196	223	*1514*
	D	306	178	389	0	138	202	*1213*
	A	337	480	346	29	0	39	*1231*
	Total	*1727*	*1390*	*2071*	*227*	*1173*	*799*	*7387*

AM 10:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J	15	397	615	69	428	172	*1696*
	H	400		333	106	599	103	*1541*
	F	650	108	21		208	107	*1094*
	D	188	201	221		41	15	*666*
	A	321	303	278	32	19	31	*984*
	Total	*1574*	*1009*	*1468*	*207*	*1295*	*428*	*5981*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		16	16	2	5	1	*40*
	H	26		25	9	23	12	*95*
	F	13	11			4	2	*30*
	D	9	34	16		5	8	*72*
	A	1	22	8	1		0	*32*
	Total	*49*	*83*	*65*	*12*	*37*	*23*	*269*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		2	11	0	0	5	*18*
	H	1		9	0	8	6	*24*
	F	8	6			15	38	*67*
	D	10	40	89		99	76	*314*
	A	3	5	16	3		10	*37*
	Total	*22*	*53*	*125*	*3*	*122*	*135*	*460*

Small truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		8	44	3	16	3	*74*
	H	17		30	6	15	0	*68*
	F	40	20			29	2	*91*
	D	1	5	14		2	0	*22*
	A	12	29	22	3		0	*66*
	Total	*70*	*62*	*110*	*12*	*62*	*5*	*321*

Large truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		6	2	0	0	0	*8*
	H	4		14	12	12	0	*42*
	F	2	34			2	0	*38*
	D	5	6	7		5	0	*23*
	A	0	10	0	2		0	*12*
	Total	*11*	*56*	*23*	*14*	*19*	*0*	*123*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	15	429	688	74	449	181	*1836*
	H	448	0	411	133	657	121	*1770*
	F	713	179	21	0	258	149	*1320*
	D	213	286	347	0	152	99	*1097*
	A	337	369	324	41	19	41	*1131*
	Total	*1726*	*1263*	*1791*	*248*	*1535*	*591*	*7154*

AM 11:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J		302	780	95	427	206	*1810*
	H	409		342	119	753	134	*1757*
	F	651	108	22		174	130	*1085*
	D	208	385	178		35	10	*816*
	A	374	317	474	57		9	*1231*
	Total	*1642*	*1112*	*1796*	*271*	*1389*	*489*	*6699*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		26	34	2	4	3	*69*
	H	20		25	3	28	19	*95*
	F	26	17			0	2	*45*
	D	12	15	9		3	5	*44*
	A	12	3	8	1		3	*27*
	Total	*70*	*61*	*76*	*6*	*35*	*32*	*280*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		5	5	0	6	9	*25*
	H	1		4	1	3	12	*21*
	F	5	7			42	40	*94*
	D	7	44	117		40	64	*272*
	A	2	6	9	2		17	*36*
	Total	*15*	*62*	*135*	*3*	*91*	*142*	*448*

Small truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		39	98	4	24	3	*168*
	H	27		29	3	5	0	*64*
	F	73	27			24	1	*125*
	D	21	9	19		2	0	*51*
	A	48	5	24	2		0	*79*
	Total	*169*	*80*	*170*	*9*	*55*	*4*	*487*

Large truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		9	5	4	0	0	*18*
	H	4		12	5	14	1	*36*
	F	5	11			1	0	*17*
	D	2	15	6		2	0	*25*
	A	0	3	1	1		0	*5*
	Total	*11*	*38*	*24*	*10*	*17*	*1*	*101*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	381	922	105	461	221	*2090*
	H	461	0	412	131	803	166	*1973*
	F	760	170	22	0	241	173	*1366*
	D	250	468	329	0	82	79	*1208*
	A	436	334	516	63	0	29	*1378*
	Total	*1907*	*1353*	*2201*	*299*	*1587*	*668*	*8015*

PM 2:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J		306	723	163	343	186	*1721*
	H	286		470	121	674	110	*1661*
	F	571	325	83		253	245	*1477*
	D	340	267	195		8	13	*823*
	A	201	455	402	25		76	*1159*
	Total	*1398*	*1353*	*1873*	*309*	*1278*	*630*	*6841*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		25	33	4	7	4	*73*
	H	10		18	5	26	20	*79*
	F	35	24			5	5	*69*
	D	16	33	25		8	14	*96*
	A	15	2	17	2		2	*38*
	Total	*76*	*84*	*93*	*11*	*46*	*45*	*355*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		3	2	4	3	4	*16*
	H	2		4	5	4	23	*38*
	F	11	12	3		59	62	*147*
	D	8	49	133		28	75	*293*
	A	1	4	8	8		10	*31*
	Total	*22*	*68*	*150*	*17*	*94*	*174*	*525*

Small Truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		9	72	8	18	6	*113*
	H	11		32	7	34	3	*87*
	F	47	20			12	7	*86*
	D	28	10	0		0	0	*38*
	A	4	12	15	5		2	*38*
	Total	*90*	*51*	*119*	*20*	*64*	*18*	*362*

Large Truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		8	8	2	2	0	*20*
	H	10		12	9	7	0	*38*
	F	9	17			5	0	*31*
	D	2	12	1		0	0	*15*
	A	3	5	1	2		0	*11*
	Total	*24*	*42*	*22*	*13*	*14*	*0*	*115*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	351	838	181	373	200	*1943*
	H	319	0	536	147	745	156	*1903*
	F	673	398	86	0	334	319	*1810*
	D	394	371	354	0	44	102	*1265*
	A	224	478	443	42	0	90	*1277*
	Total	*1610*	*1598*	*2257*	*370*	*1496*	*867*	*8198*

PM 3:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	403	726	408	525	260	*2322*
	H	297	0	480	284	953	154	*2168*
	F	665	226	47	0	249	343	*1530*
	D	368	289	210	0	8	18	*893*
	A	206	404	450	37	0	105	*1202*
	Total	*1536*	*1322*	*1913*	*729*	*1735*	*880*	*8115*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	14	35	10	25	15	*99*
	H	11	0	22	7	23	18	*81*
	F	43	31	0	0	0	3	*77*
	D	29	30	15	0	9	20	*103*
	A	21	5	9	0	0	0	*35*
	Total	*104*	*80*	*81*	*17*	*57*	*56*	*395*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	3	3	0	1	6	*13*
	H	2	0	5	7	3	20	*37*
	F	8	12	0	0	36	54	*110*
	D	16	62	169	0	25	98	*370*
	A	1	3	6	0	0	12	*22*
	Total	*27*	*80*	*183*	*7*	*65*	*190*	*552*

Small Truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		24	38	10	26	6	*104*
	H	14		17	8	41	5	*85*
	F	32	21			14	6	*73*
	D	14	17	3		0	0	*34*
	A	10	11	4	3		3	*31*
	Total	*70*	*73*	*62*	*21*	*81*	*20*	*327*

Large Truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		2	3	2	1	0	*8*
	H	1		9	10	8	0	*28*
	F	12	15			5	0	*32*
	D	2	8	1		1	0	*12*
	A	3	4	1	3		0	*11*
	Total	*18*	*29*	*14*	*15*	*15*	*0*	*91*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	446	805	430	578	287	*2546*
	H	325	0	533	316	1028	197	*2399*
	F	760	305	47	0	304	406	*1822*
	D	429	406	398	0	43	136	*1412*
	A	241	427	470	43	0	120	*1301*
	Total	*1755*	*1584*	*2253*	*789*	*1953*	*1146*	*9480*

PM 4:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J	15	331	442	503	520	213	*2024*
	H	280		245	350	1079	127	*2081*
	F	502	184	56		308	284	*1334*
	D	298	309	158		19	15	*799*
	A	429	449	214	45		87	*1224*
	Total	*1524*	*1273*	*1115*	*898*	*1926*	*726*	*7462*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		23	21	3	8	7	*62*
	H	9		12	4	19	24	*68*
	F	30	16		0	7	11	*64*
	D	28	34	14		13	30	*119*
	A	15	4	10	2		4	*35*
	Total	*82*	*77*	*57*	*9*	*47*	*76*	*348*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		7	5	3	4	12	*31*
	H	3		7	5	5	42	*62*
	F	7	11		0	32	60	*110*
	D	9	74	133		24	98	*338*
	A	2	6	11	6		20	*45*
	Total	*21*	*98*	*156*	*14*	*65*	*232*	*586*

Small Truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		21	23	8	23	4	*79*
	H	11		9	6	34	3	*63*
	F	24	21		0	12	5	*62*
	D	4	6	0		0	0	*10*
	A	15	19	3	5		2	*44*
	Total	*54*	*67*	*35*	*19*	*69*	*14*	*258*

Large Truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		2	6	2	1	0	*11*
	H	2		18	17	20	0	*57*
	F	7	5		0	4	1	*17*
	D	2	10	1		0	0	*13*
	A	1	1	1	1		0	*4*
	Total	*12*	*18*	*26*	*20*	*25*	*1*	*102*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	15	384	497	519	556	236	*2207*
	H	305	0	291	382	1157	196	*2331*
	F	570	237	56	0	363	361	*1587*
	D	341	433	306	0	56	143	*1279*
	A	462	479	239	59	0	113	*1352*
	Total	*1693*	*1533*	*1389*	*960*	*2132*	*1049*	*8756*

PM 5:00-

Sedan

		Destination						
		K	I	G	E	B	C	Total
Origin	J		273	422	299	444	240	*1678*
	H	316		269	208	1007	143	*1943*
	F	610	241	51		366	318	*1586*
	D	210	216	222		6	16	*670*
	A	260	342	174	27		98	*901*
	Total	*1396*	*1072*	*1138*	*534*	*1823*	*815*	*6778*

Small bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		15	9	2	6	4	*36*
	H	7		10	8	24	27	*76*
	F	15	13			4	6	*38*
	D	9	29	11		7	19	*75*
	A	6	10	8	1		4	*29*
	Total	*37*	*67*	*38*	*11*	*41*	*60*	*254*

Large bus

		Destination						
		K	I	G	E	B	C	Total
Origin	J		2	2	1	2	4	*11*
	H	1		8	5	4	39	*57*
	F	3	12			29	70	*114*
	D	5	63	116		17	83	*284*
	A	1	4	6	4		12	*27*
	Total	*10*	*81*	*132*	*10*	*52*	*208*	*493*

Small Truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		7	9	4	9	1	*30*
	H	5		4	2	16	3	*30*
	F	20	17			10	4	*51*
	D	4	5	2		0	0	*11*
	A	8	7	5	3		2	*25*
	Total	*37*	*36*	*20*	*9*	*35*	*10*	*147*

Large Truck

		Destination						
		K	I	G	E	B	C	Total
Origin	J		0	0	0	0	0	*0*
	H	2		23	14	8	0	*47*
	F	3	2			0	0	*5*
	D	1	8	0		0	0	*9*
	A	3	3	4	3		0	*13*
	Total	*9*	*13*	*27*	*17*	*8*	*0*	*74*

Total

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	297	442	306	461	249	*1755*
	H	331	0	314	237	1059	212	*2153*
	F	651	285	51	0	409	398	*1794*
	D	229	321	351	0	30	118	*1049*
	A	278	366	197	38	0	116	*995*
	Total	*1489*	*1269*	*1355*	*581*	*1959*	*1093*	*7746*

Source: JICA Study Team

3.7.2 Adjustment of the Demand Forecast Model

(1) Comparison of Actual Traffic Flow and the Result of Traffic Assignment

For the traffic demand forecast In the Study, the OD matrix in the SMP's study in 2009 is used, although there is a large difference between the result of the traffic assignment using the OD matrix and the result of the traffic survey mentioned above as shown in Table 3.50. It can be pointed out that one of the reasons of this is that the demand forecast model cannot reproduce internal trips (for example, there two major trip generation and attraction points such as bus terminal and mall in Albrook Area, although they belong to the same zone in the demand forecast model). It can be also identified as one of the reason that the peak hour traffic assignment cannot consider the remaining traffic in the road network in the previous hours. In addition, the OD matrix is not detail enough to reproduce the traffic flow at an intersection.

Table 3.50 Comparison of Actual Traffic and Traffic Assignment at Omar Torrijos Roundabout

Total Traffic in Traffic Survey (7:00-8:00) Unit: PCU

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	729	1052	81	267	147	*2276*
	H	572	0	321	55	240	182	*1370*
	F	893	311	5	0	157	96	*1462*
	D	479	243	324	0	36	27	*1109*
	A	468	328	260	12	0	32	*1100*
	Total	*2412*	*1611*	*1962*	*148*	*700*	*484*	*7317*

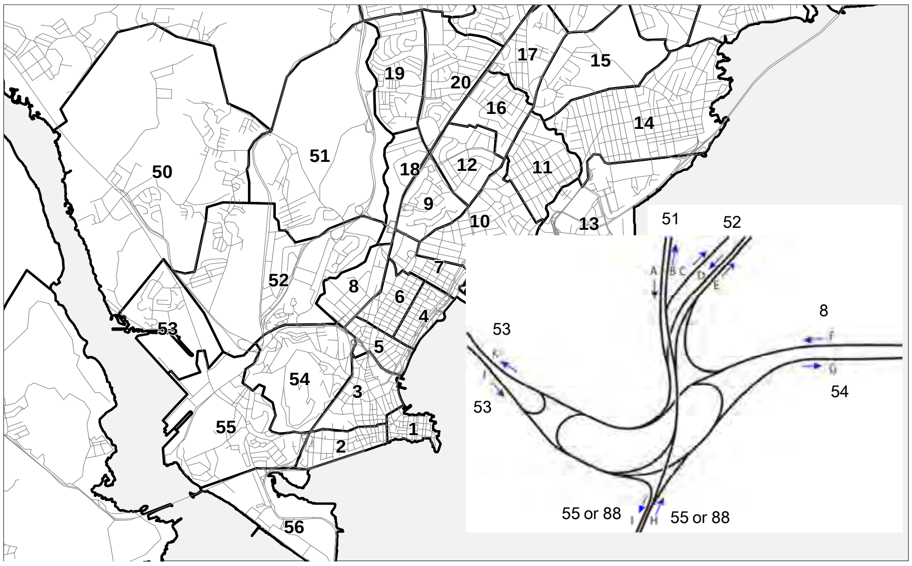
Output of Traffic Assignment with OD before calibration Unit: PCU

		Destination						
		K	I	G	E	B	C	Total
Origin	J	0	2	139	0	1	5	*147*
	H	4	0	90	8	4	40	*146*
	F	183	104	0	22	0	34	*343*
	D	36	78	17	0	0	0	*131*
	A	0	40	0	0	0	0	*40*
	Total	*223*	*224*	*246*	*30*	*5*	*79*	*807*

Source: JICA Study Team

(2) Adjustment of the OD Matrix

The traffic flow by the traffic assignment using the SMP's OD matrix in 2009 is smaller than that of the actual traffic at Omar Torrios Roundabout. Pairs of origin and destination were assigned to the pairs of entering and exiting, and traffic flow was added to the OD matrix so that the traffic flow of each entering and exiting pair can agree the actual traffic. Zoning system around Omar Torrijos Roundabout is shown in Figure 3.22 with a figure in the bottom-right indicating zone numbers that correspond to the pair of entering and exiting legs.



Source: JICA Study Team

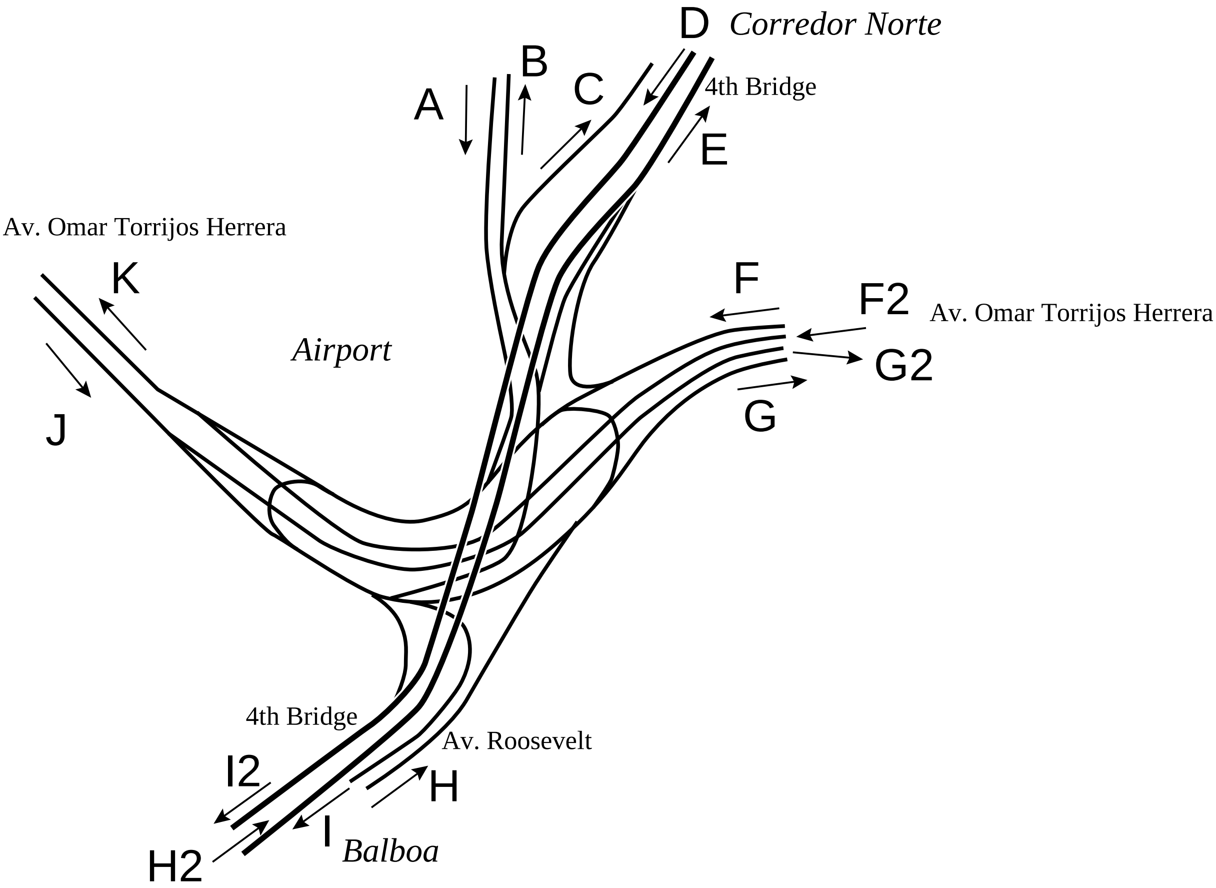
Figure 3.22 Correspond of Entering and Exiting Pair and Zoning

(3) Method of Traffic Forecast by Direction

In the traffic forecast by direction, impact of the improvement of Omar Torrijos Roundabout on the traffic flow in the area could not be ignored. Therefore, it was concluded that the future traffic by direction should not be estimated irrespective of the formation of the intersection. In the Study, the network model was developed for each improvement plan and the future traffic by direction was estimated by the traffic assignment. Therefore, the result of the demand forecast is different by improvement plan. In the traffic assignment, incremental traffic assignment was employed instead of equilibrium assignment in order to sum up the traffic volume for each entering and exiting pair.

3.7.3 Future Traffic

The result of the future traffic of Omar Torrijos Roundabout is shown in Table 3.51. Figure 3.23 shows the location of alphabets used in the table for entering and exiting legs.



Source: JICA Study Team

Figure 3.23 Corresponding Alphabet of Entering and Exiting Legs

Table 3.51 Future Traffic at Omar Torrijos Roundabout

2020

	K	I	G	E	B	C	G2	I2	Total
J	0	820	0	87	302	185	1,270	0	2,664
H	638	0	601	216	276	47	0	0	1,778
F	164	431	208	497	273	118	0	10	1,701
D	565	324	314	0	73	112	0	203	1,591
A	516	366	268	18	0	55	0	26	1,249
F2	887	0	0	0	0	0	0	346	1,233
H2	47	0	140	84	0	82	1,134	0	1,487
Total	2,817	1,941	1,531	902	924	599	2,404	585	11,703

2025

	K	I	G	E	B	C	G2	I2	Total
J	0	841	0	90	310	191	1,334	3	2,769
H	656	0	628	224	283	48	0	0	1,839
F	168	438	216	521	278	120	0	12	1,753
D	585	345	325	0	74	112	0	218	1,659
A	530	384	275	19	0	56	0	32	1,296
F2	909	0	0	0	0	0	0	363	1,272
H2	60	0	230	115	0	103	1,343	0	1,851
Total	2,908	2,008	1,674	969	945	630	2,677	628	12,439

2030

	K	I	G	E	B	C	G2	I2	Total
J	0	866	1	92	318	196	1,390	4	2,867
H	675	0	670	232	290	50	0	0	1,917
F	257	421	224	539	283	121	0	14	1,859
D	593	355	298	0	76	112	0	240	1,674
A	544	398	252	19	0	57	0	34	1,304
F2	845	0	0	0	0	0	0	382	1,227
H2	69	0	570	261	0	110	1,341	0	2,351
Total	2,983	2,040	2,015	1,143	967	646	2,731	674	13,199

2035

	K	I	G	E	B	C	G2	I2	Total
J	0	896	0	95	331	204	1,480	4	3,010
H	698	0	701	241	300	52	0	0	1,992
F	268	422	233	565	289	123	0	15	1,915
D	612	367	311	0	77	112	0	258	1,737
A	563	412	261	20	0	58	0	45	1,359
F2	877	0	0	0	0	0	0	374	1,251
H2	71	0	595	432	0	117	1,538	0	2,753
Total	3,089	2,097	2,101	1,353	997	666	3,018	696	14,017

2040

	K	I	G	E	B	C	G2	I2	Total
J	0	929	1	99	343	211	1,559	5	3,147
H	726	0	716	251	310	54	0	0	2,057
F	188	439	243	572	296	123	0	16	1,877
D	634	384	284	0	79	112	0	270	1,763
A	584	432	238	20	0	60	0	45	1,379
F2	992	0	0	0	0	0	0	394	1,386
H2	79	0	714	826	0	123	1,395	0	3,137
Total	3,203	2,184	2,196	1,768	1,028	683	2,954	730	14,746

2045

	K	I	G	E	B	C	G2	I2	Total
J	0	976	1	104	361	222	1,954	6	3,624
H	761	0	763	269	326	54	0	0	2,173
F	200	455	261	609	306	124	0	17	1,972
D	659	403	314	0	81	112	0	284	1,853
A	614	463	284	21	0	62	0	53	1,497
F2	1,033	0	0	0	0	0	0	408	1,441
H2	72	0	751	745	0	128	1,480	0	3,176
Total	3,339	2,297	2,374	1,748	1,074	702	3,434	768	15,736

2050

	K	I	G	E	B	C	G2	I2	Total
J	0	1,010	7	109	368	227	1,933	6	3,660
H	784	0	803	284	333	55	0	0	2,259
F	207	418	276	626	311	125	0	14	1,977
D	674	411	305	0	82	112	0	298	1,882
A	628	475	255	21	0	63	0	56	1,498
F2	1,049	0	0	0	0	0	0	419	1,468
H2	88	0	805	1,207	0	132	1,595	0	3,827
Total	3,430	2,314	2,451	2,247	1,094	714	3,528	793	16,571

Source: JICA Study Team

Chapter 4 Natural Conditions

4.1 Geography

Panama is located in the Central America region, bordering both the Caribbean Sea in the north and the Pacific Ocean in the south, and between Colombia in the east and Costa Rica in the west. The total land area is 77,082 square kilometers. Panama is located on the narrow isthmus, where the world critical sea lane Panama Canal runs, between the North and South American Continents as per Figure 4.1.

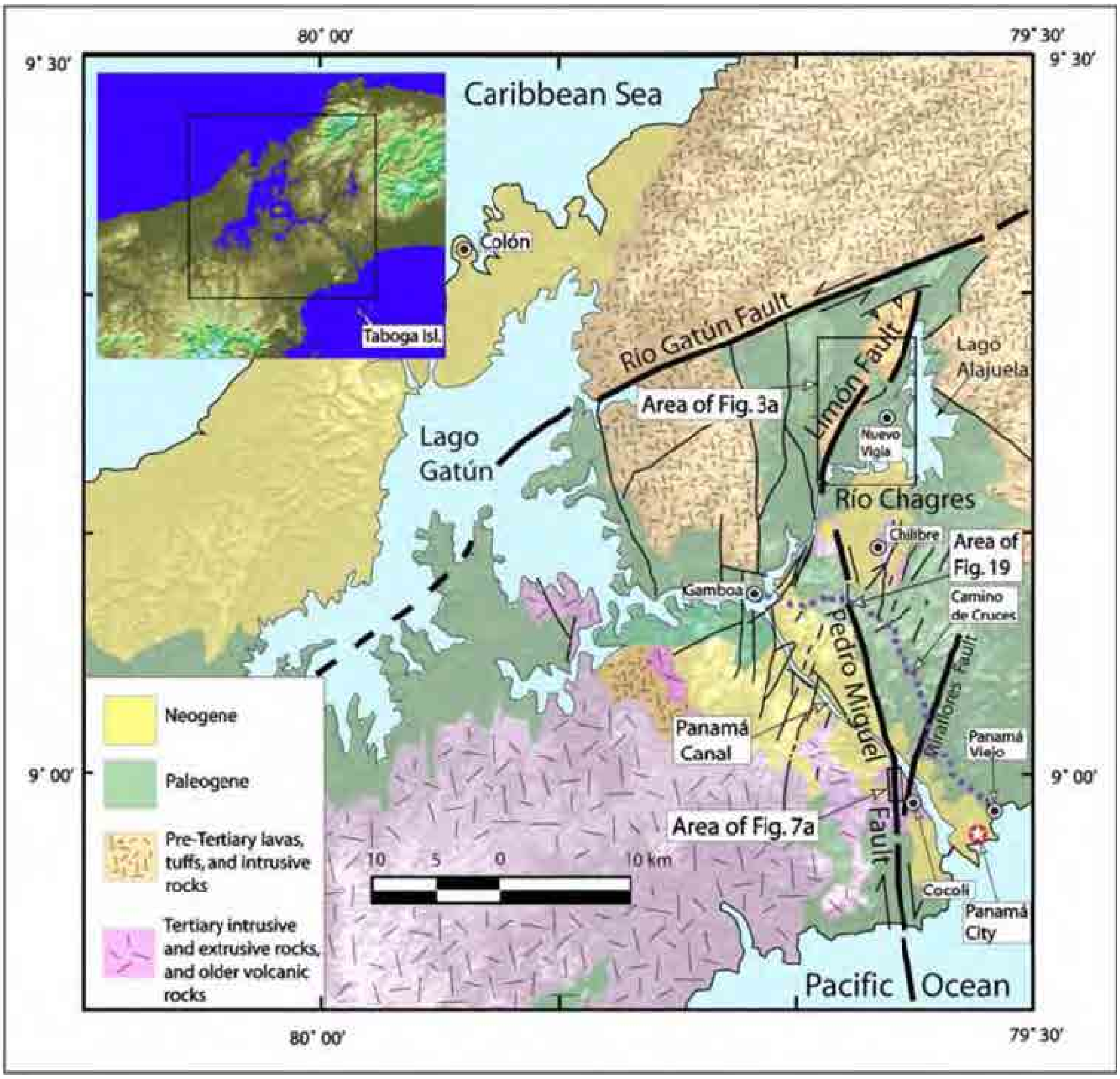
Source: Google Earth

Figure 4.1 Map of Panama Canal Area

4.2 Geography of Project Site

The Republic of Panama sits atop two colliding tectonic plates - Central and South America - and the Project site of the 4th Panama Canal Bridge is located in the Panama Canal Basin. The Pedro Miguel, Limon and related faults comprise a zone that extends from the southern flank of the mountain range in north central Panama southward crossing the Panama Canal between the Miraflores and Pedro Miguel Locks, and extending southwards. The Pedro Miguel fault ruptured in a large earthquake in 1621.

Figure 4.2 shows the geography and active fault distribution of the Study Area.



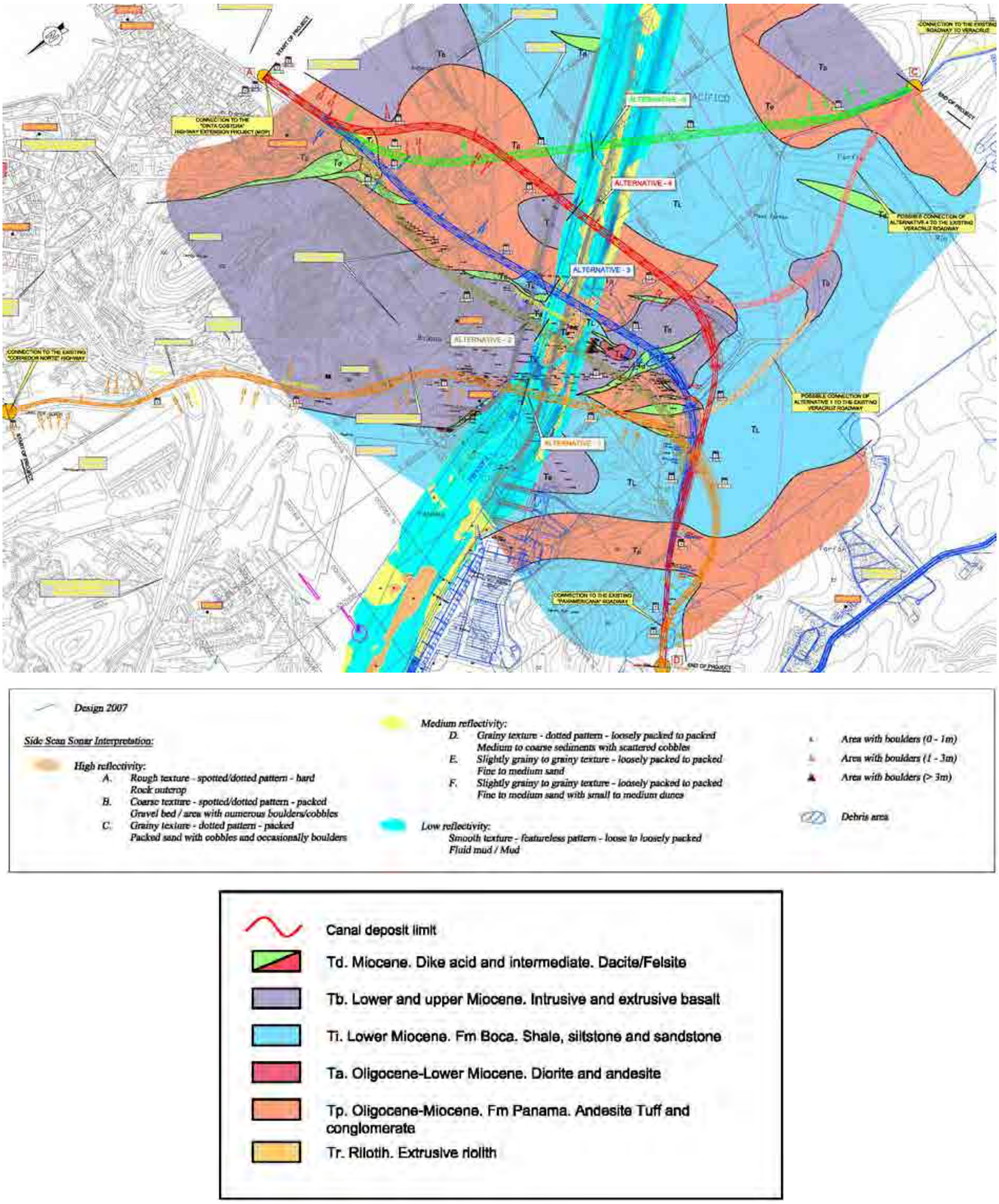
Source: Bulletin of the Seismological Society of America (BSSA)

Figure 4.2 Geography and Active Fault Distribution of the Study Area

4.3 Subsoil Conditions

Basalt rocky mountain extends to the east bank of the Panama Canal, and siltstone and sandstone are found westwards. Low-land swamps containing soft and weak mud sediments cover the Panama Canal area.

Figure 4.3 shows the subsoil conditions of the Study Area.



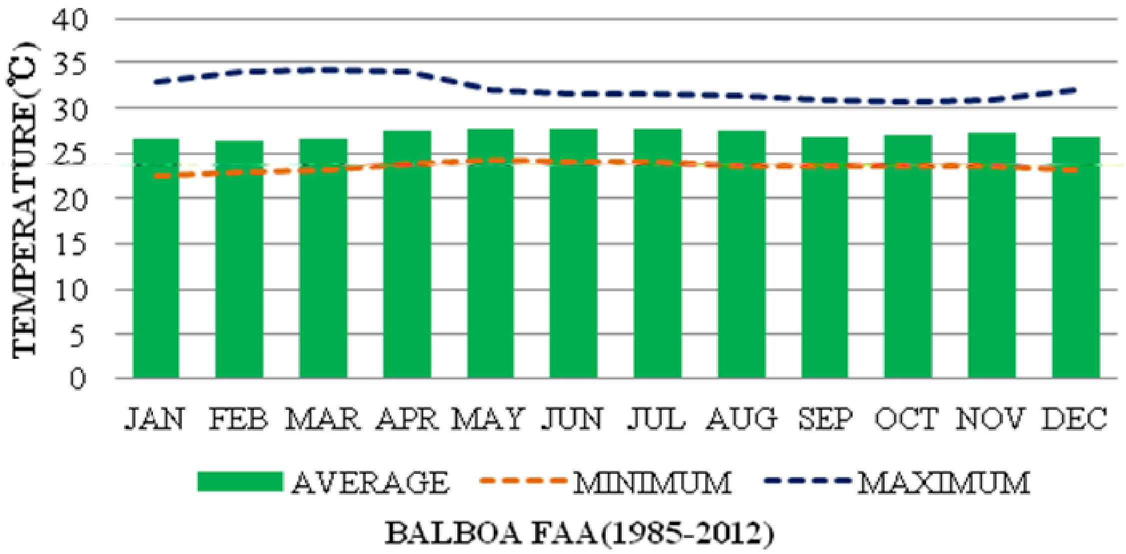
Source: Pre-F/S (Draft Final Report (November 2013)) (ACP)

Figure 4.3 Subsoil Conditions in the Project Site

4.4 Climate

4.4.1 Temperature

Air temperature in Panama is almost stable at around 27C throughout the year. Annual monthly average air temperature in Balboa at the Project site is shown in Figure 4.4.



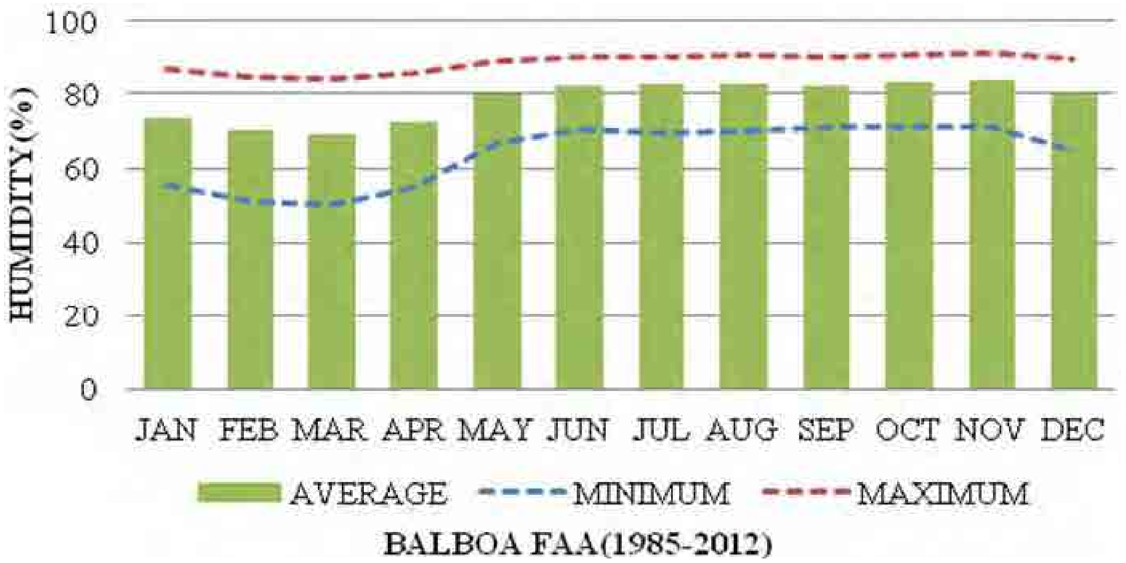
Source: Hydrometeorological Report (ACP)

Figure 4.4 Annual Average Air Temperature, Balboa

4.4.2 Humidity

Relative humidity around the Project site is shown below. According to the records for the years between 1985 and 2012, the monthly relative humidity ranges from 73.7% to 83.7% and is constantly above 80% in the high-humidity season from May to November.

Average relative humidity is shown in Figure 4.5.



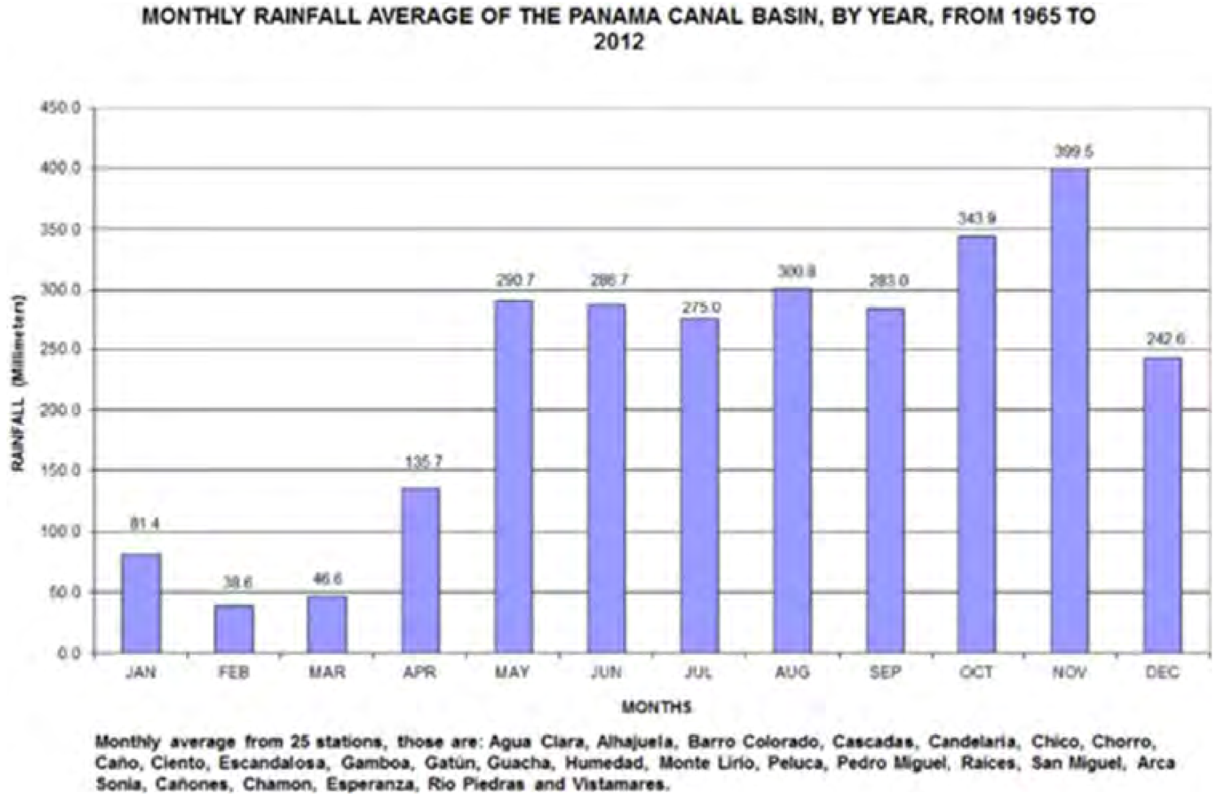
Source: Hydrometeorological Report (ACP)

Figure 4.5 Relative Humidity in the Project Site

4.4.3 Rainfall

Panama has a tropical climate with high humidity and high temperature, and rainy season is from May to November with heaviest rainfall in November.

Figure 4.6 shows the annual monthly average rainfalls of the Panama Canal basin from 1965 to 2012.



Source: Hydrometeorological Report (ACP)

Figure 4.6 Annual Monthly Average Rainfalls, Panama Canal Basin

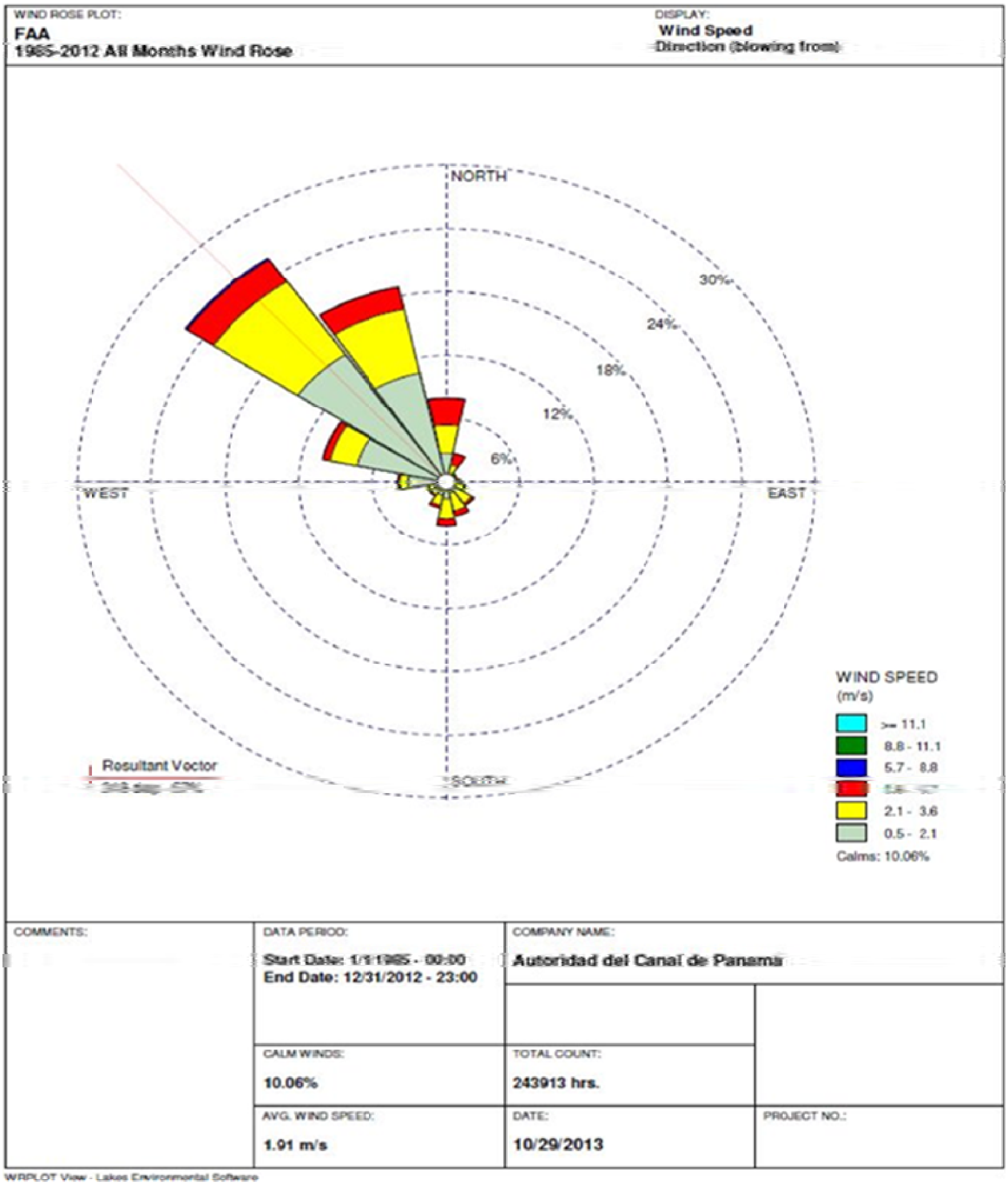
4.4.4 Wind

Wind direction and velocity at the Balboa Observation Station, the nearest location to the 4th Panama Canal Bridge, is discussed below.

(1) Wind Direction

Northwest wind is predominant in the vicinity of the 4th Panama Canal Bridge site.

Figure 4.7 shows wind rose at Balboa in the Project site.



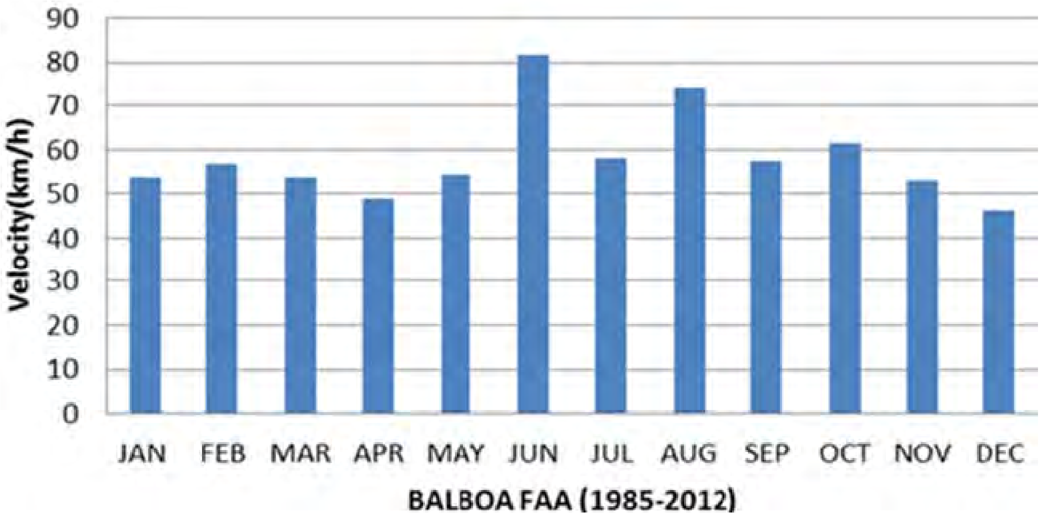
Source: Hydrometeorological Report (ACP)

Figure 4.7 Wind Rose showing Direction and Velocity, Balboa

(2) Wind Velocity

In the Project site, the maximum wind speed of 81.9km/hr (22.7m/sec) was observed in June, 1990.

Figure 4.8 shows the monthly maximum wind speed at Balboa between 1985 and 2012.

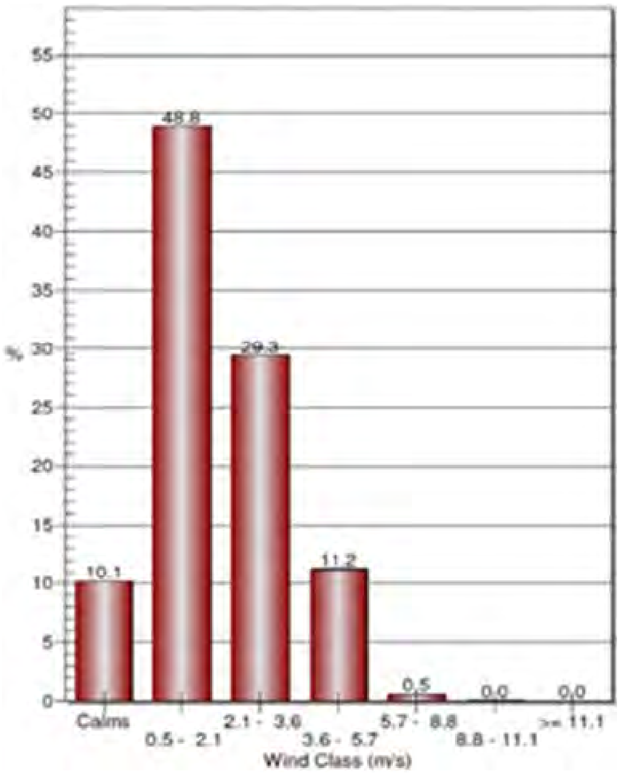


Source: Hydrometeorological Report (ACP)

Figure 4.8 Monthly Maximum Wind Speed between 1985 and 2012, Balboa

(3) Occurrence of Wind Velocity

In the vicinity of the Project site of the 4th Panama Canal Bridge, wind velocity between 0.5 to 2.1 m/sec is predominant sharing 50% of occurrence as per Figure 4.9.



Source: Hydrometeorological Report (ACP)

Figure 4.9 Wind Velocity Occurrence, Balboa

4.5 Hydrology (Including Channel Bed Scouring)

Flow velocity of the Panama Canal is very low and stable at approximately 0.3 m/sec in the vicinity of the Project site. According to the interview survey made to ACP, scouring of the channel bed materials does not occur in the Project site.

Table 4.1 shows the flow velocity in the channel of the Panama Canal.

Table 4.1 Channel Flow Velocity of the Panama Canal near the 4th Panama Canal Bridge Site

	Localización							Velocidad del viento	
Punto	UTM Este Norte	Latitud Longitud	Profun-didad [3], m	Magnitud [3], m/s	Dirección [3],[4], grados (N=0, E=90)	Intervalo del promedio [3], min.	Hora [5]	Magnitud MPH	Dirección [6]
Marea subiendo									
B19	Boya 19	Verde	2	0.25	169	6	11:11	7.4	167
			4	0.27	194				
			6	0.31	213				
B21	Boya 21		2	0.25	170	4	11:58	4.9	114
			6	0.24	179				
			10	0.3	196				
Marea bajando									
B24	Boya 24A	Roja	2	0.31	180	4	16:41	12.3	359
			6	0.29	160				
			10	0.27	177				
B19	Boya 19	Verde	2	0.31	168	3	18:16	9.2	334
			6	0.28	156				
			10	0.31	154				
B21	Boya 21		2	0.34	160	2	18:55	3.4	332
			6	0.33	160				
			10	0.27	170				

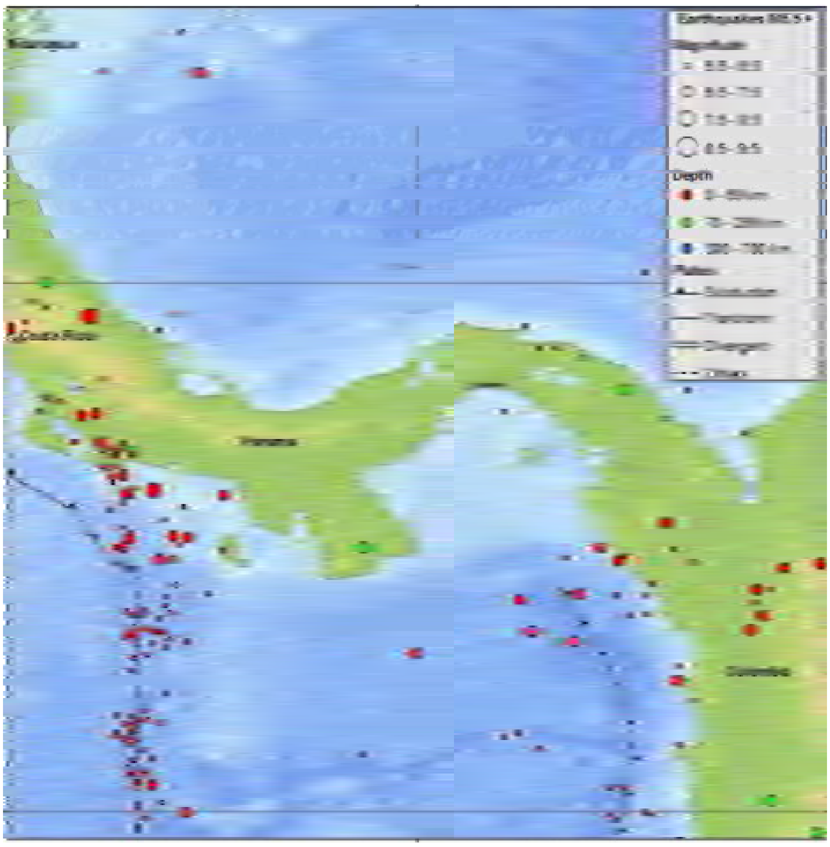
Source: Hydrometeorological Report (ACP)

4.6 Earthquake

Panama is earthquake prone and was damaged by earthquakes in the past. In 1882, earthquakes collapsed many buildings in the Panama City. The Pedro Miguel fault, close to the Project site, was the epicenter of a large earthquake in 1621 which ruptured Panama City in Spanish colonial time.

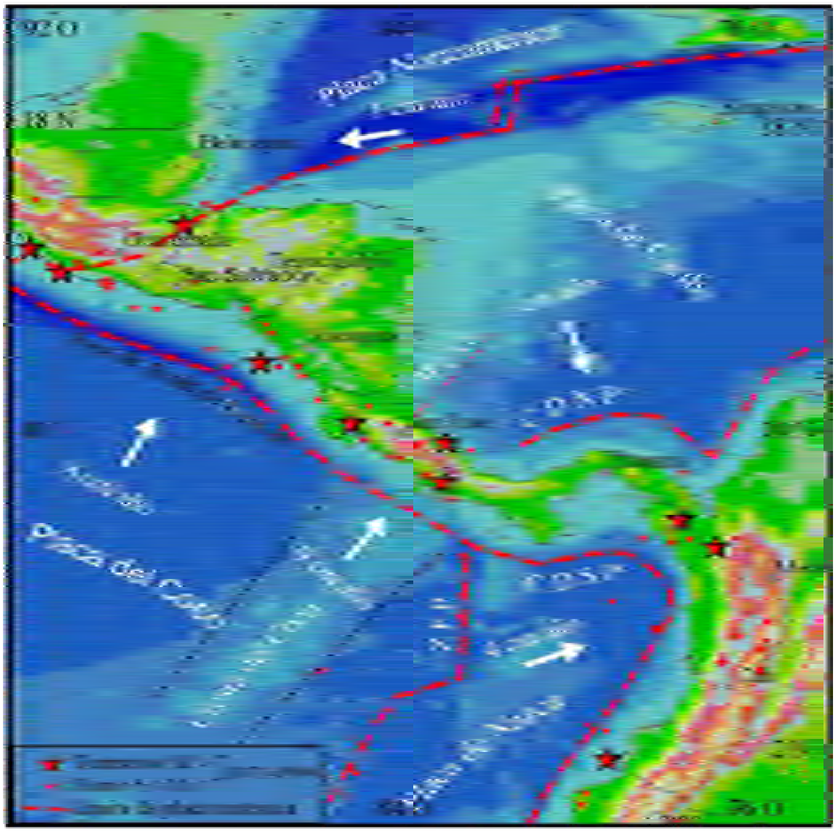
Figure 4.10 shows the epicenter locations since 1997, and the distribution of active faults has been shown in Figure 4.2.

Plate tectonic elements in Central America is shown in Figure 4.11.



Source: USGS Network, Panama Seismicity Map (1900 to March 2012)

Figure 4.10 Distribution of Epicenters of Past Earthquakes since 1997, Panama



Source: Seismic Hazard Assessment of the Second Panama Canal Crossing (Preliminary Report)

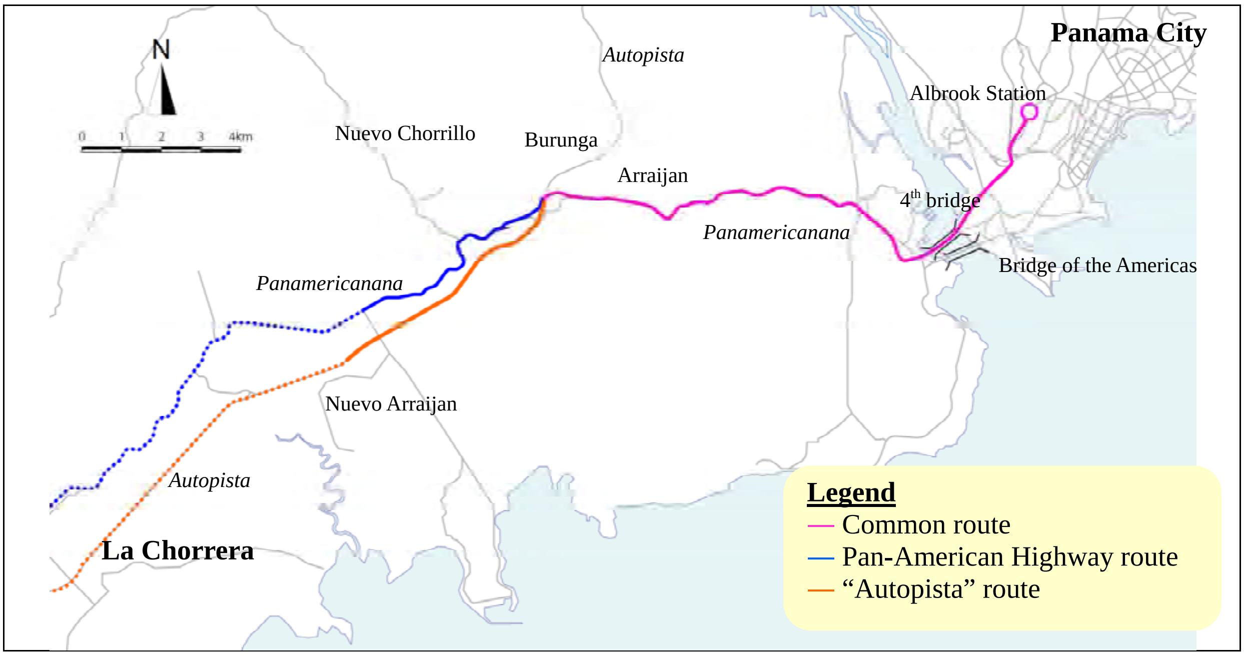
Figure 4.11 Major Tectonic Elements in Central America

Chapter 5 System Selection

5.1 Route Alternatives

The Pan-American Highway is a highway connecting Panama City and La Chorrera to the west. The newly constructed "Autopista" also connects Panama City and La Chorrera, but the section between Panama City and Arraijan forms a long detour to the north connecting the north area of Panama City. Since the detour section is far from the plan route of Line-3, there is no choice other than Pan-American Highway from Panama City to Arraijan.

The METI study proposed that Line-3 be constructed along the existing roads, however from the intersection in Arraijan there are two roads running to the west. Consequently, there are two route alternatives for Line-3, one following only the Pan-American Highway and the other following the Pan-American Highway to Arraijan and from there the "Autopista", as shown below.



Source: JICA Study Team

Figure 5.1 Route Alternatives

The METI Study recommended the "Autopista" route for Line-3 because the route has a wide Right-of-Way and has no steep slopes or sharp curves. On the other hand, the Pan-American route was not selected because of its severe topographic conditions for urban transport system, such as slopes with more than 6% gradient and curve radiuses less than 100m. Alignments having more than 6% slopes are generally not considered as a route for urban transit system when other alternative routes are available.

When this study began, SMP requested the reconsideration of the Pan-American route because of the greater accessibility it would provide to Line-3 and its future demand. As a consequence, the study for route selection was conducted and concluded as described in this report.

5.1.1 Comparison items

In the discussions with SMP, various comparison items were suggested by the JICA Study Team to evaluate the two alternative routes. As a result of several meetings, eleven (11) comparison items were agreed upon, categorized in four (4) sections as follows: (1) Demand and Service, (2) Physical Aspects, (3) Land Availability and Resettlement and (4) Environmental Impacts. In addition, the weights, as shown below, were set through discussions with SMP. The total score of each alternative is calculated as the sum of all comparison items.

Although the project purpose should be fixed between the two alternatives for making a fair comparison, the type of transportation service provided by each alternative would not necessarily be the same because of the difference in land use along the two routes. The service for the Pan-American route should be a more local service because there are local communities along the Pan-American route. The service for the "Autopista" route should focus on rapid commuter service because multiple stations along the "Autopista" would have a negative impact on the highway.

Table 5.1 List of Comparison Items

Categories	Comparison items	Weight allocated
1. Demand and service		50
	(1) Concept of the Route Selection: Type of Service for each route 1) Commuter 2) Commuter and local	
	(2) Potential for generation of demand from current and future development	
	(3) Expected demand considering future extension to La Chorrera	
	(4) Stations	
	(5) Intermodal Facilities (Park & Ride)	
	(6) Feeder bus services	
	(7) Operation speed	
2. Physical Aspects		18
	(1) Total length of Phase 1 and future extension to La Chorrera	
	(2) Alignment between Arraijan - Nuevo Arraijan 1) Steep gradient sections 2) Small curves 3) Impacts on utilities	
3. Land Availability and Resettlement		12
	(1) Depot (2) Stations (3) Intermodal facilities (4) Alignment	
4. Environmental Impact on natural and human environment during construction and operation		20
	(1) Temporary impact 1) Air pollution 2) Noise and vibration 3) Safety 4) Traffic (2) Long term impact 1) Local economy, employment and livelihoods 2) Land use	
	Total	100

Source: JICA Study Team

5.1.2 Comparison method

All the comparison items were evaluated in 6 grades, from Excellent to Not Applicable as shown below. A coefficient is given to each grade, from 1.0 to 0. These coefficients are multiplied by the allocated weight of each category to calculate the scores.

Table 5.2 Evaluation Grades and Coefficients

Evaluation	Coefficient	Evaluation score
(A) Excellent:	1.0	Weight x 1.0
(B) Good:	0.8	Weight x 0.8
(C) Fair:	0.6	Weight x 0.6
(D) Insufficient:	0.4	Weight x 0.4
(E) Poor:	0.2	Weight x 0.2
(F) Not applicable:	0.0	Weight x 0.0

Source: JICA Study Team

5.1.3 Evaluation

The comparison items of "Autopista" and Pan-American routes were analyzed and evaluated in meetings between SMP and JICA Study Team.

(1) Demand and Service

1) Type of Service (Commuter)

Route	Analysis	Evaluation
Autopista	Train operation speed is favorable for commuters because of the moderate topographic conditions, long distance between stations, and the shorter route length than the Pan-American route.	Excellent
Pan-American	Train operation speed is lower than the "Autopista" because of longer route length and more frequent train stops for serving local community, although the speed is satisfactory.	Fair

2) Type of Service (Commuter and Local)

Route	Analysis	Evaluation
Autopista	Demand of local trips along the route is low.	Poor
Pan-American	The route runs through the populated area in the region and passengers making local trips are the beneficiaries of the project. For commuter trips, express train operation can be planned during morning and evening peak hours.	Excellent

3) Potential for Generation of Demand

Route	Analysis	Evaluation
Autopista	The "Autopista" is an intercity highway and development has not been planned along the road. The unplanned residential developments are dispersed and are for middle-income car users. Development toward the south is for middle income housing.	Fair

Pan-American	The urban area between Arraijan and La Chorrera is focused on the Pan-Amrican Highway. Most local businesses and residences (particularly of lower income families) are nearby. The area is a mix of old buildings and new developments. Development toward the north seems to be for low to middle income housing. Demand generation is expected because of the creation of local businesses.	Excellent

4) Expected Demand Considering Future Expansion to La Chorrera

Route	Analysis	Evaluation
Autopista	Although the route can be extended up to the intersection of the Pan-American Highway with the "Autopista" in La Chorrera, the route is located far from the center of La Chorrera.	Fair
Pan-American	Although it is difficult to extend the route to the center of La Chorrera due to the narrow streets, the route can reach the entrance to the city and has good access to the planned bus terminal.	Excellent

5) Station (Accessibility)

Route	Analysis	Evaluation
Autopista	Pedestrian facilities to the stations are poor.	Insufficient
Pan-American	The present pedestrian routes can be used for access by walking.	Excellent

6) Park & Ride (Accessibility)

Route	Analysis	Evaluation
Autopista	Access roads to the Park & Ride facility of the stations need to be developed.	Insufficient
Pan-American	Existing road network provides car access to the stations.	Good

7) Feeder bus services

Route	Analysis	Evaluation
Autopista	Access roads to the stations and intermodal transfer areas need to be developed because feeder bus transfers on the "Autopista" would interrupt the traffic flow of the highway.	Insufficient
Pan-American	Existing road network provides feeder bus access to the stations, although intermodal transfer areas need to be developed.	Good

8) Operation Speed

Route	Analysis	Evaluation
Autopista	The scheduled speed will be 45-50km/h	Excellent
Pan-American	The scheduled speed will be 35-40km/h	Fair

(2) Physical Aspects

1) Total Length

Total project cost will depend on the total length of the line including the future extension to La Chorrera.

Route	Analysis	Evaluation
Autopista	Arraijan - Nuevo Arraijan: 7.42km Nuevo Arraijan - Chorrera: 7.07km Total: 14.49km	Excellent
Pan-American	Arraijan - Nuevo Arraijan: 8.91km Nuevo Arraijan - Chorrera: 7.62km Total: 16.53km	Good

2) Alignment between Arraijan and Nuevo Arraijan (Steep Gradient Section)

Route	Analysis	Evaluation
Autopista	There is no section with gradient higher than 6%.	Excellent
Pan-American	There are three sections where the gradient is higher than 6%. The total length of these sections is 780m.	Poor

3) Alignment between Arraijan and Nuevo Arraijan (Small curves)

Route	Analysis	Evaluation
Autopista	There is no curve with a radius less than 160m.	Excellent
Pan-American	There are 5 curves where the radius is larger than 160m.	Fair

4) Impacts on Utilities

Route	Analysis	Evaluation
Autopista	The number of affected utilities will be small.	Excellent
Pan-American	There are many utilities along the road.	Fair

(3) Land Availability and Resettlement

1) Depot

Route	Analysis	Evaluation
Autopista	Depot can be located adjacent to the “Autopista”.	Excellent
Pan-American	Site for depot can be found to the west of Nuevo Arraijan.	Fair

2) Stations

Route	Analysis	Evaluation
Autopista	Stations will be located at the roadside. ROW at the roadside is sufficient for the stations.	Excellent
Pan-American	Stations will be located in the road median.	Good

3) Intermodal Facilities

Route	Analysis	Evaluation
Autopista	Intermodal facilities cannot be constructed at the roadside because the "Autopista" is a freeway. Intermodal facilities need to be constructed outside the ROW.	Fair
Pan-American	Intermodal facilities can be constructed at the roadside, although they would affect road intersections.	Good

4) Alignment

Route	Analysis	Evaluation
Autopista	ROW can accommodate the alignment.	Excellent
Pan-American	Due to the winding and hilly terrain, it is difficult to keep the alignment within ROW.	Insufficient

(4) Environmental Impact (Temporary)

1) Air pollution and noise & vibration

Route	Analysis	Evaluation
Autopista	Impact is very small because the population density is low.	Excellent
Pan-American	There will be impact on the communities along the road because of medium density population.	Fair

2) Safety

Route	Analysis	Evaluation
Autopista	Risk of traffic accidents during construction is low because pedestrian traffic is low along the construction sites.	Good
Pan-American	Risk of traffic accidents during construction is high because of many pedestrians along the construction sites.	Fair

3) Traffic

	Analysis	Evaluation
Autopista	Impact of traffic disturbance is low because the structures are constructed along the roadside.	Good
Pan-American	Traffic is highly disturbed because the structures are constructed in the middle of the road.	Fair

(5) Environmental Impact (Long term)

1) Local Economy, Employment and Livelihoods

Route	Analysis	Evaluation
Autopista	The project will generate business around the stations in the future.	Fair
Pan-American	The project will contribute to the local economy of existing communities in addition to future business generation.	Excellent

2) Land Use

Route	Analysis	Evaluation
Autopista	New urban developments are expected along the road.	Good
Pan-American	New urban development and densification of urbanized areas are expected.	Excellent

5.1.4 Conclusion

Through a series of discussions held between the JICA Study Team and SMP, an agreement was reached on the route evaluation as shown in the table below. The total points allocated to the Pan-American route were 79.8 against 71.8 for the “Autopista” route, out of 100 points.

Table 5.3 Route Selection Comparison Table

No.			Components	Subjects for Comparison	Weight		Autopista Route	Score	Pan American Route	Score
1	Demand and service		Concept of the Route Selection: Type of Service for each route	Commuter	50	4	Main target users will be commuters to Panama. Due to relatively moderate topographic condition, train operation speed can be higher that that on Pan Americana road and line is shorter.	4	Not only commuters to Panama, but also local passengers within Arraijan - La Chorrera will be the target users. Express train operation can be planned during morning and evening peak hours. Line is longer.	2.4
				Commuter and local		**6**		1.2		6
2			Potential for generation of demand from current and future development	Existing spatial occupation and tendency		12	The Autopista is an intercity highway and development has not been planned along the road. The unplanned developments are mainly detached houses intended for middle-income car users. Development toward the south is for middle income housing.	7.2	The urban area between Arraijan and La Chorrera has the Pan Am road as its focus. Most local business and residences (particularly of lower income families) are nearby. The area is a mix of old buildings and new developments. Development toward the north seems for low to middle income housing.	12
3			Expected demand considering future extension to La Chorrera	Current and future population in the area of influence (walking distance)		8	Limited access for people living along Pan Am road	4.8	High demand can be expected because all housing complexes have access roads to Pan Am road.	8
4			Station	Number and accessibility		5	4 stations, access is difficult and limited	2	5 stations, easy access	5
5			Intermodal Facilities (Park & Ride)	Accessibility		5	Access roads to parking facilities shall be provided	2	Existing road network provide easier access	4
6			Feeder bus services	Accessibility		5	Local access roads to highway are limited and network to feeder facilities has to be constructed	2	Bus bays can be constructed along Pan Am road with some road widenning	4
7			Operation speed	Speed including stop time at stations		5	Schedule speed: 40km/h	5	Schedule speed: 35km/h or less	3
8	Physical		Total length of Phase 1 and future extension to La Chorrera	Length between Arraijan - Nuevo Arraijan - La Chorrera	18	5	Arraijan - N. Arraijan: 7.42km Arraijan - Chorrera: 7.07km Total: 14.49km	5	Arraijan - N. Arraijan: 8.91km Arraijan - Chorrera: 7.62km Total: 16.53km	4
9			Alignment between Arraijan - Nuevo Arraijan							
			(1) Steep gradient sections	Number and length of slope steeper than 6%		5	No slope higher than 6%	5	3 locations. Total length is 780m	2
			(2) Small curves	Number of curves with radius less than R160m		5	No curve less than R=160m	5	5 locations.	3
			(3) Impacts on utilities	Number of affected utilities		3	Affected utilities are limited	3	Many utilities	1.8
10	Land Availability and Resettlement		Land acquisition and resettlement (land availability for)		32					
			(1) Depot	Distance from main line to avoid resettlement		3	Adjacent to Autopista	3	800m from Pan Am road.	1.8
			(2) Stations	Location and space and need for resettlement		3	Road side. There seems to be enought Right-of-Way (ROW).	3	Above the road and may exceed ROW space.	2.4
			(3) Intermodal facilities	Location and space		3	Bus terminal and P&R space are outside of ROW	1.8	Bus terminal is along the road, P&R space is outside of ROW	2.4
			(4) Alignment	Consideration for resettlement		3	Within existing ROW	3	Existing ROW is not enough	1.2
11	Environmental		Impact on natural and human environment during construction and operation							
		Temporary	(1) Air pollution	Impacts for inhabitants during construction		1	Low density of population	1	Medium density of population	0.6
			(2) Noise and vibration	ditto		1	ditto	1	ditto	0.6
			(3) Safety	Impacts on traffic and pedestrians		3	Low risk	2.4	High risk	1.8
			(4) Traffic	Disturbance for road traffic during construction		3	Low disturbance	2.4	High disturbance	1.8
		Long term	(5) Local economy, employment and livelihoods	Business generation and service for existing community		8	May generate business around stations in future	4.8	Much better service for existing community	8
			(6) Land use	Availability of land for future development and potential densification of urban areas		4	Space is available for future development	3.2	Land development and densification of urban development can be expected.	4
			Total			100		71.8		79.8

Source: JICA Study Team

Based on the results of the comparison, the Pan-American route was selected for Line-3.

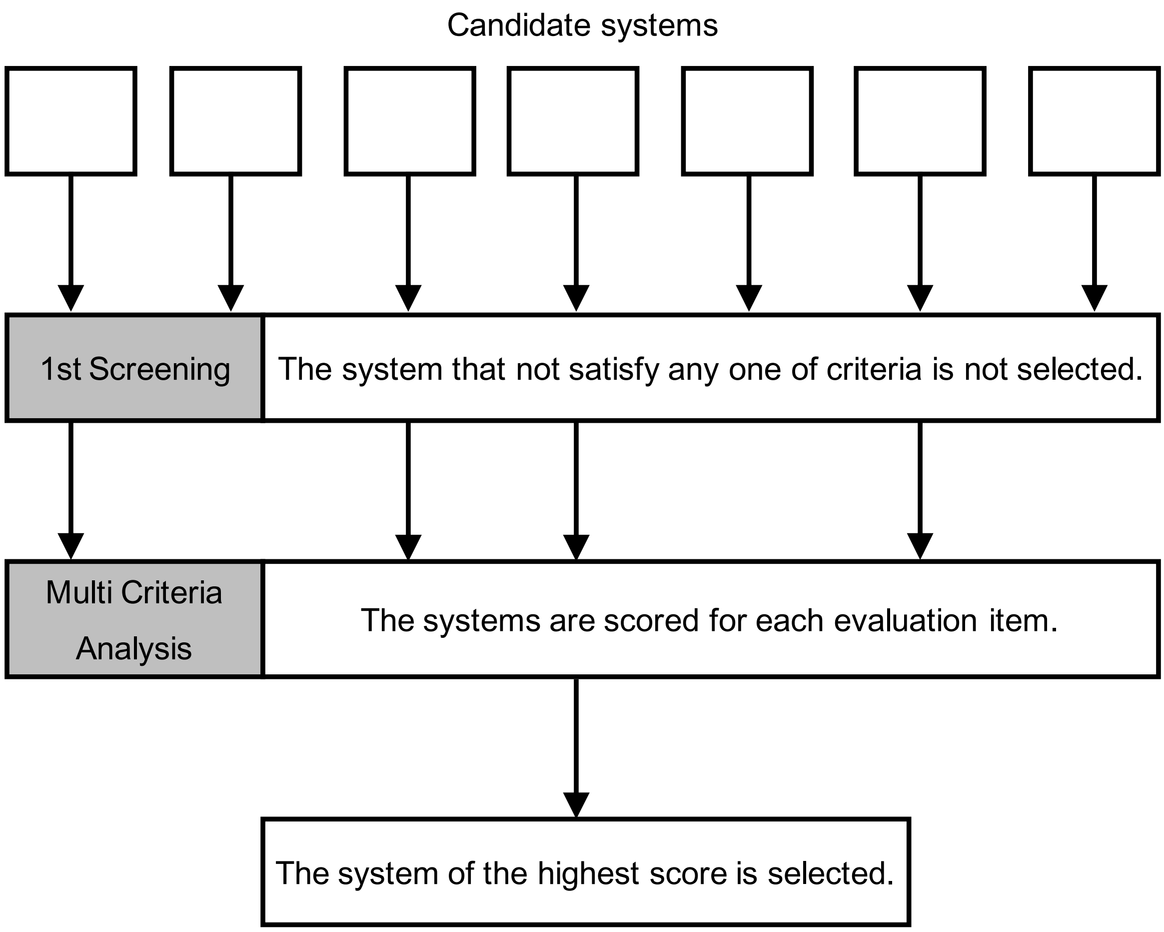
5.2 Candidate Systems and the First Screening

5.2.1 Procedures for System Screening

The suitable transportation system for Line-3 was selected based on two stages: 1st screening and 2nd screening as shown in the table below.

First, all potential urban transportation systems were listed in the 1st screening and each system was evaluated by several criteria. The systems that were NOT screened out would be considered in the second stage of the comparison.

Next, the remaining systems were scored using several sectionalized criteria, such as capacity, maintainability, and cost, in the 2nd stage of the comparison. Finally, the most suitable system would be selected according to the evaluation score.



Source: JICA Study Team

Figure 5.2 System Selection Flow

5.2.2 Candidate Systems

There are various transportation systems all over the world, from which the major systems are listed below.

Table 5.4 Candidate Systems

Candidate systems	Features	Candidate systems	Features
BRT at grade 	Buses run on the same level as the road making for a lower transportation capacity.	Monorail hanging type 	The vehicle is suspended from the track beam constructed on the space above the road and runs with rubber tire.
BRT using dedicated lane 	Buses run in dedicated lanes and have no effect on other traffic conditions.	Monorail straddle type 	The vehicle straddles and runs with rubber tires on the track beam constructed on the space above the road.
LRT at grade 	The track can be installed in the carriageway and/or an exclusive space on the ground. This system can also adapt to viaduct and underground.	Maglev 	The car is levitated by the magnet equipped on the track and bogie. However, only a few cases exist.
LRT using dedicated lane 	The track is installed on a dedicated structure. The car size is smaller and transportation capacity is categorized as medium.	Linear Metro 	The traction power is produced by the linear motor and the reaction plate, which are equipped on the bogie and track, respectively. Steel wheels and rails are used for guide and supporting the load.
AGT 	The vehicle runs on rubber tires on an exclusive track constructed by concrete slabs.	Conventional MRT 	Many cases are seen all over the world; it has high transportation capacity.
		LRT/MRT for steep slope 	The system is applied to steep slopes that conventional MRT cannot climb. However, the train requires many motorized bogies.

Source: JICA Study Team

The JICA Study Team made a comparative analysis of all these candidate systems in the first screening.

5.3 Candidate Systems and the First Screening

In the first screening all the potential urban transport systems were listed and evaluated by four criteria which were agreed between SMP and the JICA Study Team, as listed below.

1) Impact on road traffic;

2) A system in use or in experimental stage;

3) Uses fossil fuel; and

4) Nominal standard capacity greater than 20,000 PHPDT.

BRT (either at grade or in a dedicated lane), surface LRT, hanging type monorail and maglev were filtered out because they do not meet above-mentioned criteria.

As a result, six systems are considered in the second stage of the comparison.

Table 5.5 First System Screening Chart

		ansportation Systems				
		BRT at grade	BRT using dedicated lane	LRT at grade	LRT using dedicated lane	AGT
Subjects for 1st Screening	Impacts to road traffic					
	Experimental stage					
	Using fossil fuel					
	Standard capacity	3,000-5,000	5000-10,000	3,000-8,000	8,000-20,000	8,000-2,2000
	1st Screening					

		Monorail hanging type	Monorail straddle type	Maglev	Linear Metro	MRT conventional	LRT/MRT for steep slope
Subjects for 1st Screening	Impacts to road traffic						
	Experimental stage						
	Using fossil fuel						
	Standard capacity	5,000-10,000	10,000-36,000	5,000-12,000	20,000-50,000	25,000-60,000	15,000-45,000
	1st Screening						

Source: JICA Study Team

5.4 Multi-criteria Analysis

5.4.1 System Selection Chart

Six systems were evaluated in the second stage of the comparison. The results of the evaluation are shown in Table 5.6. Ten criteria were selected from a long list of potential criteria, via brainstorming and discussion sessions held among the SMP and Study Team members. In the evaluation process, the weighted points for each criterion were first established by the SMP and the Study Team. After the weighted distribution was determined, the systems were evaluated by each criterion. Finally, the overall calculation was made by adding the product of the coefficient values (0 ~ 1) multiplied by weighted points for each criterion.

It should be noted that the differences in scores are not absolute but correlated. For example, all the compared systems offer a very safe service. The difference of 1.0 and 0.9 in scoring does not mean that one system is 10% safer than the other or vice versa, but that there is a relative advantage between the evaluated elements.

After a series of discussions and analysis, **it was concluded that a straddle type monorail system is the most appropriate technology for the Line-3**. The comparison table shows that the straddle type monorail has the best score followed by the conventional MRT. The dedicated lane LRT, AGT, linear metro and steep slope MRT were judged as not being appropriate systems for Line-3 because of significant disadvantages compared to the monorail and MRT. There are some notable aspects that reinforce the monorail as the better option for Line-3. Two of which are as follows:

- The initial cost for the monorail is more than USD200 million lower than the MRT for Line-3
- Technical difficulties are observed for some sections of the MRT line where very high piers are required to avoid large scale land acquisition.

Table 5.6 System Comparison Chart

			Urban Transportation Systems					
			LRT using dedicated lane	AGT (Automated Guideway Transit)	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Typical Systems under operation (Country)			Manila LRT Line 1 (Philippine)	Tokyo Yurikamome (Japan)	Tokyo Monorail (Japan) Dubai monorail (Dubai)	Tokyo Metro Oh-edo Line (Japan)	Many cities in the world	Kobe Electric Railway Arima Line (Japan)
								
Evaluating Items		Points allocated						
1)	Capacity (*1)	15	0.8	0.4	0.8	0.7	1.0	0.8
2)	Initial Cost(System) (*2)	10	1.0	0.9	0.8	0.9	1.0	0.9
3)	Initial Cost(Infrastructure) (*2)	20	0.6	0.8	1.0	0.8	0.6	0.8
4)	O&M Cost (*3)	10	1.0	0.8	0.9	0.8	1.0	0.9
5)	Proprietary (*4)	10	0.8	0.6	0.5	0.5	1.0	0.8
6)	Safety (*5)	5	1.0	0.9	0.9	1.0	1.0	0.7
7)	Resettlement (*6)	15	0.8	1.0	1.0	1.0	0.8	0.8
8)	Impacts on Natural Environment (*7)	5	0.8	0.9	1.0	0.8	0.8	0.8
9)	Landscape /Cityscape (*8)	5	0.6	0.6	1.0	0.6	0.6	0.6
10)	Maintainability (*9)	5	1.0	1.0	0.9	1.0	1.0	0.9
Total Points		100	81.2	76.6	88.6	80.4	86.5	82.3

Note:
The total points score is the sum of ten criteria scores calculated from each coefficient multiplied by points allocated (weighting).
*1: Headway is fixed at 3min., and the train composition is 6 coaches for all systems.
*2: Initial costs cover civil work, E&M, and rolling stock costs. Maximum height of pier was set to 20m.
*3: Calculation of the adjusted yearly O&M costs.
*4: International competitive tender is possible.
*5: Evacuation method, possibility of derailment, and rescue methods are evaluated.
*6: Land acquisition and resettlement are evaluated.
*7: Green area that would be removed
*8: Impacts of elevated structure on landscape and cityscape
*9: Ease of maintenance work.
Source: JICA Study Team

5.4.2 Conditions and Method of Comparison

The following preconditions and assumptions were used for the comparison exercise.

- Route length is L=25km via the Pan-American Highway.
- 10 stations are considered for the purpose of comparison.
- Initial demand is set at 20,000 PHPDT and final demand at 35,000 PHPDT;
- 4% slope is used for MRT and LRT whereas 6% slope is used for the monorail and other systems;
- R=100m is used for the minimum horizontal curve for the monorail, AGT and Linear Metro, whereas R=160m was used for MRT and the rest; and
- 4 passengers / m^2 and 3 minute interval were used for the purpose of comparison.

In the discussions between SMP and the JICA Study Team it was pointed out that assessment of a unique condition across the different systems is difficult because each system can be customized to meet the local conditions in different ways. One example of this difficulty is that the capacity of a system was calculated based on the area available for passengers, i.e. length x width of each system's car. The passenger density was set at 4 passengers per square meter and the interval (or headway) of train operation was set at 3 minutes. Under these conditions, the AGT and linear metro are likely to be filtered out for not meeting the target demand of 35,000 PHPDT, and the LRT with dedicated lane and steep slope MRT have to be considered as a conventional MRT to be attractive. The Monorail and MRT seem to be acceptable systems that can service a demand of 35,000 PHPDT.

Another example is the difficulty in evaluating the impact on landscape. The comparison was made based on the area that would be covered by each system's permanent structures, from plan view and lateral view. The score was based on the width of superstructure in the plan view, and width of columns and other superstructure in the lateral view. The result is directly calculated in proportion to the area which obscures the view. The appropriateness of the scoring can be argued widely.

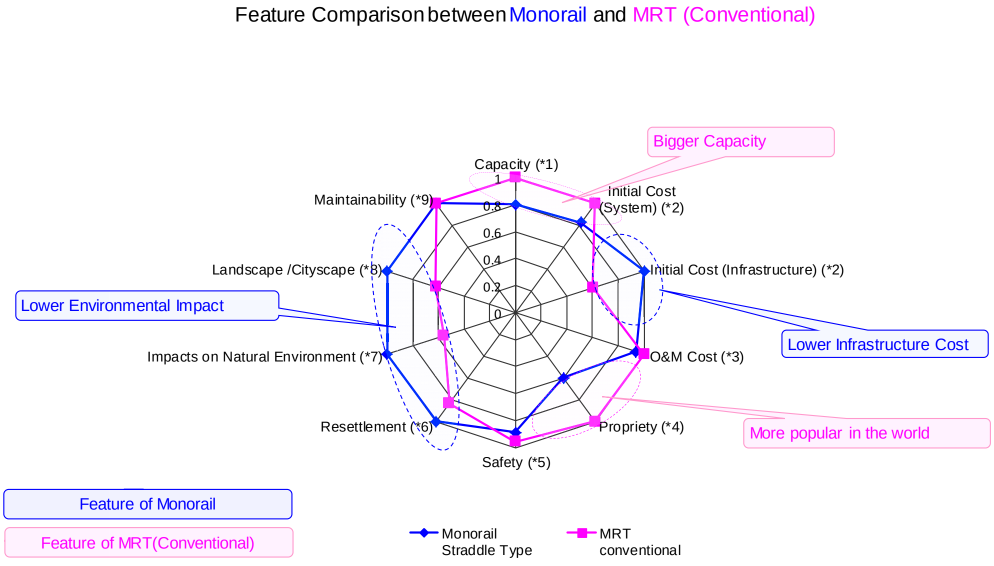
The intention was to only employ elements that can be evaluated objectively. However, in some cases experts' subjective opinions were taken into consideration for the scoring. The criterion "proprietary status" is one such case.

5.4.3 Comparison in a Radar Chart

Despite the above mentioned difficulties, the Consultant believes that a multi-criteria comparison helps to highlight the different characteristics of the available systems, while the scoring result also represents the applicability of the systems to a specific condition, in this case Line-3.

Figure 5.3 shows the result of the comparison made between MRT and monorail; the two systems which obtained the highest scores. A monorail system enjoys a significant advantage in lower initial investment in infrastructure, a better land/cityscape, lower impact on natural environment, and lower impact on land acquisition and resettlement. On the other hand, MRT shows its advantage in its capacity and proprietary aspects.

It should be noted that in order for the MRT system to achieve the aforementioned advantages over the monorail, it would have to be the large type with a car length of 20m; if shorter cars were used the advantages in capacity become insignificant in comparison to the monorail.



Source: JICA Study Team based on multi-criteria comparison

Figure 5.3 Radar Chart comparison between monorail and MRT

5.4.4 Evaluation by Ten Criteria

(1) System Capacity

A density of four passengers/m^2 was used for comparing the capacity of the different systems. The score is essentially determined by the area of each car, calculated from car width and car length. The number of cars per train for this comparison purpose was set at six for all the systems and the train interval (headway) at 3 minutes. The results are an automatic calculation using this formula. AGT has the lowest score due to its small car size. The highest score of MRT with significance difference from other systems is based on the condition that 20m length large-scale cars are used for MRT.

Table 5.7 Comparison of System Capacity

Capacity: Size of car and floor space	LRT using dedicated lane	AGT	Monorail straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Car Width (m)	2.7	2.5	3.0	2.5	2.8	2.7
Car Length (m)	17.0	9.0	15.0	16.0	20.0	17.0
No. of cars	6	6	6	6	6	6
Floor Area:	263.64	128.16	259.26	228.96	322.38	263.64
Train Capacity	1,055	513	1,037	916	1,290	1,055
Car Capacity	176	85	173	153	215	176
Pax/hour/direction	21,091	10,253	20,741	18,317	25,790	21,091
Score 1)	12.27	5.96	12.06	10.65	15.00	12.27
Coefficient for 1)	0.82	0.40	0.80	0.71	1.00	0.82

Note: Coefficient = Each Score / Maximum of Score

Source: JICA Study Team, based on the information obtained from different sources for car size

(2) Initial Cost of the Systems

The score was calculated as a function of the number of cars, the unit price of the cars and the initial E&M cost. The estimated initial demand of 20,000 PHPDT was used to calculate the required number of cars for the initial investment. The total service length of 50km (round trip of 25km line length) and a planned speed of 35km/h were employed. It should be noted that the prices are for comparison purposes only and would require further analysis for feasibility studies. The proportional relationship among the systems is considered acceptable for this criterion.

The result shows that the MRT is the most cost effective in this comparison item, followed by the LRT.

Table 5.8 Comparison of Initial Cost of the Systems

Initial Cost (System)		LRT using dedicated lane	AGT	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Rolling Stock	Cars	186	354	186	210	156	186
	Unit Cost ($ million) approx.	1.8	1.0	2.4	2.0	2.0	2.1
	Total	340	350	450	420	310	390
E&M ($ million)		410	430	430	420	410	410
Total ($ million)		750	780	880	840	720	800
Coefficient for 2)		0.97	0.93	0.82	0.86	1.00	0.91

Note: Coefficient = Minimum of Total / Each Total
Cost of car for Line-1 project is around US$2.7 million/ car which includes training, design, prototype testing, preparation of manuals and so on. The above comparison is net price only.
Source: JICA Study Team, based on the information obtained from different sources for Unit Price

The unit prices of cars were established based on researching the market price and adjusting them to the local conditions. The prices for monorail and AGT were taken from market research. The prices for conventional MRT (L=20m) were based on the market price adjusted to the local conditions of Line-3 where 4% slopes are foreseen. The prices for LRT and other MRT are calculated in proportion to the conventional MRT. The difference in car size is considered, but not in proportion to the size. The increased number of motorized cars is also taken into consideration.

In this comparison, it was noted that the price difference between the monorail and the conventional MRT is larger than the technical rough estimate made initially. It appears that the MRT car market is more mature and this keeps the prices more competitive. It is possible that the price gap will be narrowed when the international monorail market starts to expand. This is likely to happen with the opening of new monorail lines in China, Korea, UAE, and Malaysia, and the construction of monorails in India and Brazil. Furthermore, many cities are currently considering the development of new metro lines using monorail technology.

(3) Initial Cost of Infrastructure

The comparison of the initial cost of infrastructure was made for the main structures only. The number of stations considered for the purpose of comparison was ten stations, including the terminal stations at both ends. The comparison included three elements, namely; 1) cost of elevated structures 2) cost of stations and 3) additional costs due to the difference in the alignment for each system.

The base cost of the elevated structure was calculated from the costs of Line-1, estimated at USD 28 million per kilometer of elevated section. The cost of the stations is calculated from the station length based on the required number of cars plus 5m at each end of the station. The assumed demand is 35,000 PHPDT at the peak hour with 2 minute train intervals. An additional cost is included for LRT and conventional MRT because these systems require higher piers to maintain the maximum 3.5% longitudinal slope. This occurs in the section between the access to Panama Pacifico, after crossing the canal, and Nuevo Arraijan. A comparison of the vertical alignments is summarized below. An additional cost is also included for the difference in the average height of the structures. Conventional MRT and LRT (maximum 3.5% slope) require higher piers on average in comparison to AGT, monorail, linear metro and steep slope MRT (maximum 6% slope).

Table 5.9 Comparison of Vertical Alignment Features

	Conventional MRT and LRT	AGT, monorail, linear metro and steep slope MRT
Vertical alignment maximum slope	3.5%	6.0%
Average pier height:	14.8m	8.5m
Maximum pier height	45.6m	18.6m
Classification by pier height	Less than 20m: 78.9% (14.47km) 20m<h<30m :14.5% (2.66km) 30m<h<40m :3.6% (0.66km) More-than-40m :3.0% (0.54km)	Less than 20m: 100% (18.41km)

Source: JICA Study Team

The results of the comparison are shown in the table below. The monorail system enjoys the first place in this criterion due to its flexible alignment both horizontally and vertically. Other systems such as AGT, linear metro and steep slope MRT share second place because of their ability to manage 6% maximum slope. The difference in cost between the monorail and these 6% slope systems is due to the simple structure used by the monorail.

Table 5.10 Comparison of Initial Cost of Infrastructure

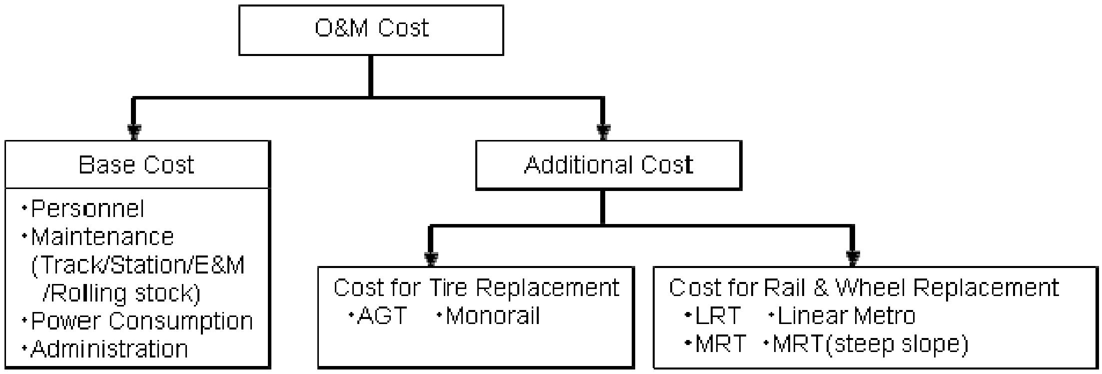
Initial Cost (Infrastructure)	LRT using dedicated lane	AGT	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Station length (m)	130	140	120	140	130	130
Number of cars per train (cars)	7	14	7	8	6	7
Elevated Structure (US$)	640.0	637.2	450.0	625.9	640.0	625.9
Station (10)	157.3	169.4	145.2	157.3	157.3	157.3
Civil work (extra work)	182.7	0.0	0.0	0.0	182.7	0.0
Total	980	807	595	783	980	783
Coefficient for 3)	**0.6**	**0.8**	**1.0**	**0.8**	**0.6**	**0.8**

Note: Coefficient = Minimum of Total / Each Total
1. Extra civil work is included where high piers (over H=20m) are required.
2. 35,000 PHPDT and 30 trains per hour were assumed for the calculation
3. Prices are for reference for comparison purpose only
Source: JICA Study Team based on the cost of Line-1

(4) Operation and Maintenance (O&M) Cost

Through meetings held between SMP and the Consultant, it was decided that O&M costs would be compared in two ways, 1) base cost of required personnel, maintenance, power consumption and administration; 2) additional costs based on the type of technology. In both cases, the same demand was used for the comparison.

The base cost is mainly affected by the number of cars and the running kilometers. The unit costs were taken from the previous METI study and available statistical data. For the additional maintenance costs arising from the different technologies employed, the replacement of rubber tires was assumed for every 150,000km of running distance for the monorail and AGT, and the replacement of rails was assumed for every 20 years for LRT/ MRT and every 10 years for steep slope type systems (linear metro and steep slope MRT). The replacement of steel wheels was assumed for every 1 million km running distance.



Note:
1) Rubber tires are replaced after running 150,000km, price of one tire $1,000 for monorail, $600 for AGT
2) Rails are replaced every 20 years (LRT/MRT), and every 10 years (Linear Metro/MRT(steep slope), replacement of wheels after running 1 million km.
Source: JICA Study Team

Figure 5.4 Structure of O&M Cost Comparison

The results of this comparison were that the conventional MRT ranked first place, closely followed by LRT and monorail.

Table 5.11 Comparison of O&M Cost

O&M Cost	LRT using dedicated lane	AGT	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Regular Operation/Maintenance work	31.8	38.7	31.9	41.9	30.4	37.5
Rubber tire replacement cost	0.0	0.9	1.5	0.0	0.0	0.0
Rail/wheel Replacement cost	0.4	0.0	0.0	0.5	0.4	0.5
Total 4)	32.2	39.6	33.4	42.4	30.8	38.0
Coefficient for 4)	0.97	0.79	0.94	0.73	1.00	0.83

Note: Coefficient = Minimum of Total / Each Total
Source: JICA Study Team

(5) Proprietary

Two comparisons were made for this criterion, namely the comparison at the initial construction stage and at the expansion stage. The expert's opinions were taken into consideration to establish the points for each comparison. For the initial construction stage, MRT enjoys the highest score because of the large market and competition among manufacturers. LRT, AGT, linear metro and monorail received reduced points due to smaller market size or lower number of possible bidders to supply rolling stock. These considerations have less impact at the initial construction stage because, in theory, there is no preference at that time. The 3-point score for the AGT, monorail and linear metro indicate SMP's position against a limited market. In the expansion stage, the difference between conventional MRT and other system becomes larger. This is explained by the fact that a non-standardized system would force SMP to purchase additional rolling stock from the same manufacturer. It is not exactly the same case for purchasing parts. To some extent this phenomenon would apply to conventional MRT also, although not to a degree meriting a lower score. This bias occurs because of manufacturers' efforts to try and keep their clients.

Table 5.12 Comparison of Proprietary

Proprietary	LRT using dedicated lane	AGT	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Monopoly in initial construction stage	5	3	3	3	5	4
Monopoly in expansion stage	3	3	2	2	5	4
Total	8	6	5	5	10	8
Coefficient for 5)	0.8	0.6	0.5	0.5	1.0	0.8

Note: Coefficient = Each Total / Maximum of Total
Source: JICA Study Team

(6) Safety

A comparison of safety was made for the events that could occur in the different technologies. It should be noted that all the compared systems offer a high level of safety in general. The difference in score between 1.0 and 0.9 does not mean that one system is 10% safer than the other or vice versa, but that there is relative advantage between the evaluated elements. The comparative risk score (a higher score means greater exposure to risk) was calculated by multiplying the probability of an event by the severity of an event.

The table below shows the steps taken in the evaluation. The probability and severity of each safety related event were assessed by professionals from SMP and the JICA Study Team. The evaluations are shown in the upper and middle sections of the table. The results of the probability multiplied by severity are shown in the lower section of the table as the overall risk score. The integrated overall score and coefficient scores to be used in the summary comparison are shown at the bottom of the table.

Table 5.13 Comparison of Safety Aspects

PROBABILITY	LRT using dedicated lane	AGT	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Derailment	2	2	1	2	2	3
Fire	2	3	3	2	2	2
Obstacle	3	3	2	3	3	3
Platform fall	2	2	2	2	2	2
Major System/Car Trouble	4	4	4	4	4	5
5: Frequent, 4: Likely, 3:Possible, 2: Unusual, 1: Impossible						
SEVERITY	**LRT using dedicated lane**	**AGT**	**Monorail Straddle Type**	**Linear Metro**	**MRT conventional**	**LRT/MRT for steep slope**
Derailment	4	4	5	4	4	4
Fire	3	4	4	3	3	3
Obstacle	2	2	2	2	2	2
Platform fall	2	2	4	2	3	3
Major System/Car Trouble	2	2	2	2	2	3
5: Fatal, 4: Severe, 3: Moderate, 2: Minor, 1: Negligible						
Overall risk score = probability x severity	**LRT using dedicated lane**	**AGT**	**Monorail Straddle Type**	**Linear Metro**	**MRT conventional**	**LRT/MRT for steep slope**
Derailment	8	8	5	8	8	12
Fire	6	12	12	6	6	6
Obstacle	6	6	4	6	6	6
Platform fall	4	4	8	4	6	6
Major System/Car Trouble	8	8	8	8	8	15
Total Risk Score	32	38	37	32	34	45
Coefficient for 6)	1.00	0.87	0.89	1.00	0.96	0.71

Note: Coefficient = Minimum of Total Risk Score/ Each Total Risk Score
Source: JICA Study Team based on discussions among experts

Some of the relevant considerations that were made for each evaluated event are as follows.

1) Derailment

Monorail systems have a bogie structure that grips the track beam by both stable wheels and guide wheels. Therefore, even if the running speed is high or the alignment includes sharp curves, or even if a strong crosswind is blowing, derailment is extremely unlikely.

As for the LRT/MRT systems for steep slope, the probability of derailment is considered higher than that for the standard slope due to its steep slope operations.

2) Fire

It was assumed that rubber tire systems would have a higher risk of fire than conventional steel wheel systems. There have been some cases of rubber tires catching fire, but it should be noted that there has not been any such event in Japan. Additionally, it was supposed that if a fire occurred the damage sustained in the rubber tire systems could be more severe than the steel wheel systems. This was reflected in the severity scoring.

3) Obstacles

A monorail's track is narrower than that of other systems for which the tracks are built on a slab or on the ground, therefore the probability of obstacles blocking the track is considered to be lower for the monorail than for other systems.

4) Danger of falls from the platform

Monorail systems have a disadvantage due to the greater height from the platform to the floor. This difference is noted in the severity score only, as the probability of falls occurring would be the same for all the systems.

5) Major System/Car Trouble

Major system or car trouble is a situation in which the train cannot move from the point of occurrence. Minor system or car trouble was deleted from the comparison because it was thought that there is no significant difference among the technologies. In the evaluation, LRT/MRT for steep slope was considered to have a disadvantage due to its large number of equipment in the traction system. The same argument could be applied to a linear metro system as it uses more equipment for traction. Conventional MRT would be given the same score when more motorized cars are required.

(7) Land Acquisition and Resettlement

The comparison was made based on the surface area of land acquisition and the extent of resettlement likely to be required for the construction. In some sections of the route, all the systems would need to exit the existing right of way, requiring land acquisition. In other sections, only the LRT/MRT require additional land acquisition due to the application of a larger horizontal curve (R=160m) in contrast to R=100m for the monorail, linear metro and AGT. The likely extent of resettlement is the same for all systems in this comparison. Therefore, the results show that the AGT, monorail and Linear metro enjoy a better score in this criterion.

In this comparative study, higher piers were used for LRT and MRT to comply with the 3.5% maximum slope. This is taken into consideration in the initial cost of infrastructure. Large land acquisitions and resettlements would be necessary if such high piers are not employed.

Land acquisition area and the number of affected houses were weighted as 30% and 70%, respectively. The overall score is calculated based on the factored sum of these two elements. For example the overall score of 0.8 for LRT is obtained as follows: 0.4 x 30% +1.0 x 70%.

Table 5.14 Comparison of Land Acquisition and Resettlement

Impacts on Natural Environment	LRT using dedicated lane	AGT	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Required area for land acquisition (m2)	7,724	3,432	3,432	3,432	7,724	7,724
30%	0.4	1.0	1.0	1.0	0.4	0.4
Number of houses for resettlement	3	3	3	3	3	3
70%	1.0	1.0	1.0	1.0	1.0	1.0
Coefficient for 9)	0.8	1.0	1.0	1.0	0.8	0.8

Source: JICA Study Team

(8) Impacts on Natural Environment

A comparison was made of the surface area from which trees would have to be removed for the construction of each system. This was calculated as the area covered by a permanent structure or the car width in each system from plan view, in the heavily forested stretch from Panama Pacifico to the entrance of Arraijan. The total distance of this section was estimated to be L=7,200 m. The widths used in this comparison were 8.0m car width for Monorail, 10.0m slab width for MRT, LRT, linear metro and LRT/MRT for steep slope, and 9.0m slab width for AGT. The results show that the monorail has a lower impact on the natural environment compared to the other systems.

Table 5.15 Comparison of Impacts on Natural Environment

Impacts on Natural Environment	LRT using dedicated lane	AGT	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Green area to be deforested by construction (m^2) Only in the section from Panama Pacifico to Arraijan	72,000	64,800	57,600	72,000	72,000	72,000
Coefficient for 9)	0.8	0.9	1.0	0.8	0.8	0.8

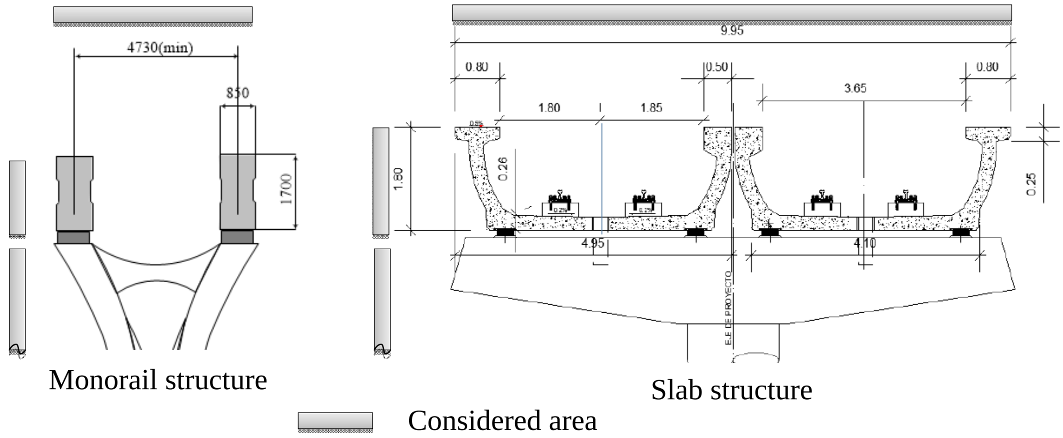
Source: JICA Study Team

Noise impact was discussed as a criterion but was finally dismissed. Even though rubber tire systems such as the monorail and AGT have an advantage of being much quieter than steel based systems, steel system noises can be mitigated by improved technology (i.e.: U-shape slabs used in Line-1) and longer rails.

Several other environmental impacts were considered in the systems comparison (i.e.: the amount of dewatering required, energy consumption and construction period), but the engineering and environment teams determined that the differences in these elements between the systems were minimal, and thus were not included in the scored analysis.

(9) Landscape/ Cityscape

A comparison was made of the area that would be covered by a permanent structure in each system from plan view and lateral view. Scores were calculated based on the width of superstructure from plan view and width of column from lateral view. The results were directly calculated in proportion to the area that obstructs the landscape view.



Source: JICA Study Team based on Line-1 and JICA Study for Sao Paulo Urban Transit

Figure 5.5 Comparison of Impact on Landscape (Area shaded by Structure)

The results show a large advantage for the monorail in this criterion. This is one of the well-known strong selling points of the monorail arising from its simple superstructure. The results here reflect this as well.

Table 5.16 Comparison of Impact on Landscape / Cityscape

Landscape/Cityscape	LRT using dedicated lane	AGT	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Area that would be covered (shaded) by the elevated structure (m^2)	323,750	323,750	207,000	323,750	331,250	323,750
Coefficient for 9)	0.6	0.6	1.0	0.6	0.6	0.6

Source: JICA Study Team

(10) Maintainability

Maintainability was evaluated by examining how difficult / easy maintenance works are for each system. The cost of maintenance is not a factor in this part of the evaluation as it was considered in the O&M cost. The elements that are considered to have different levels of difficulty in maintenance are listed in the comparison table below. In this comparison the overall difference in maintainability is insignificant between the systems. The table, however, helps to provide an understanding of the different characteristics of each system.

Table 5.17 Comparison of Maintainability

Maintainability	LRT using dedicated lane	AGT	Monorail Straddle Type	Linear Metro	MRT conventional	LRT/MRT for steep slope
Track structure	4	5	5	3	4	3
Electric facilities (on track)	5	4	3	5	5	5
Rolling stock	4	5	5	5	5	4
Wheel reprofiling	4	5	5	4	4	4
Tire replacement	5	3	3	5	5	5
Total	22	22	21	22	23	21
Coefficient for 10)	0.96	0.96	0.91	0.96	1	0.91

Source: JICA Study Team based on the discussions among experts

Some of the relevant considerations that were made for each evaluated element are as follows.

1) Track structure

The track structure for AGT and monorail (rubber tire systems) are almost maintenance free, whereas the track structure for linear metro and MRT/LRT for steep slope are harder to maintain due to its steeper profile. In addition, the linear metro has a unique structure with the reaction plate.

2) Electric facilities (on the track)

AGT and monorail have a multiple rigid contact line, whereas LRT, linear metro, conventional MRT and MRT/LRT for steep slope (steel wheel systems) have a simple overhead catenary. The monorail has to use a special maintenance vehicle inspecting the contact line.

3) Rolling stock

All the vehicles for the MRT/LRT for steep slope are configured with motorized cars; therefore they have more electric facilities to maintain.

4) Wheel reprofiling/Tire replacement

AGT and Monorail (rubber tire systems) have to have their rubber tires replaced more frequently than the steel wheels of LRT, linear metro, conventional MRT and MRT/LRT for steep slope (steel wheel systems).

Steel wheel systems have to have their steel wheels reprofiled several times before replacement. The frequency increases for alignments with small horizontal curves, which is the case for Line-3.

5.5 Conclusion

The total point of scores is calculated from the coefficient of each evaluation item for candidate systems by multiplying the coefficient by the weight as shown in Table 5.6.

A multi-criteria comparison was carried out to determine the characteristics of each system taking the route conditions of Line-3 into consideration. Through the analysis described in this chapter, it was confirmed that the monorail is the most appropriate system for Line-3, followed by the conventional MRT. The difference between the two systems is not significant in terms of scores, but there are decisive factors which make the monorail system the most appropriate for Line-3 as shown below.

- The initial cost of the monorail is more than USD200 million lower than the conventional MRT for Line-3
- Technical difficulties are observed for some sections of the MRT line where very high piers (over 40m) would be required to avoid large scale land acquisition needed for softening the vertical profile of the railway infrastructure.

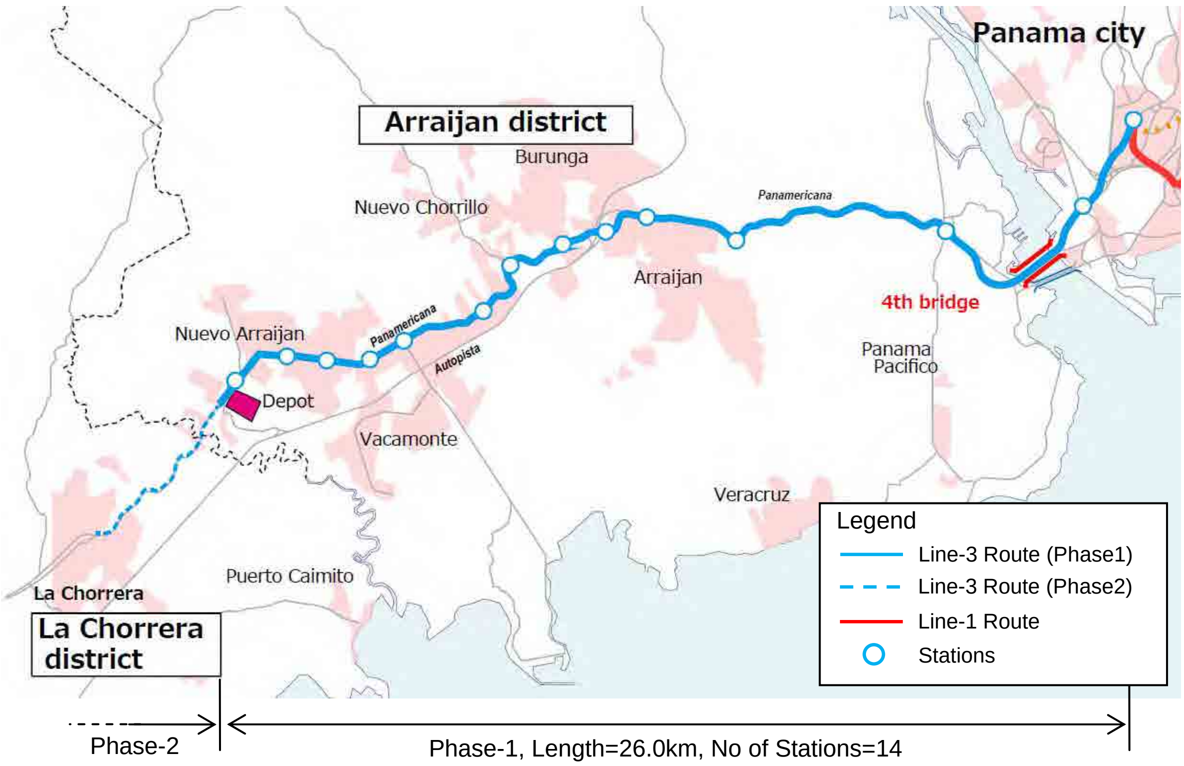
Considering the above results, this report concludes that the monorail is the most appropriate system for Line-3.

Chapter 6 Route Plan

6.1 Route of Line-3

The route of Line-3 is as same as that of Pan-American Road. Lying east and west and linking three districts of Panama Province: Panama District, Arraijan District and La Chorrera District, Line-3 reaches a total length of more than 30km. Line-3 is divided into two stages: Phase-1 is a 26km section from Albrook station to the Depot, which is to be located near Arraijan and La Chorrera bourder, and Phase 2 is an extension of the line toward La Chorrera, although the route and the location of the terminal station have not yet been determined for Phase 2.

Line-3 starts from Albrook station, which is also the beginning point of Line-1, and extends to the southwest parallel to the road leading to the future 4th bridge over the canal. The route crosses the canal via the 4th bridge, and from the west bank of the canal it enters rough terrain zigzagging over the rugged hills along the Pan-American road until reaching Arraijan. Here it crosses over the Autopista highway and continues westward along the Pan-American road ending at the Depot, which is located about 3km west of Nuevo Arraijan.



Source: JICA Study Team

Figure 6.1 Outline of Line-3 Route

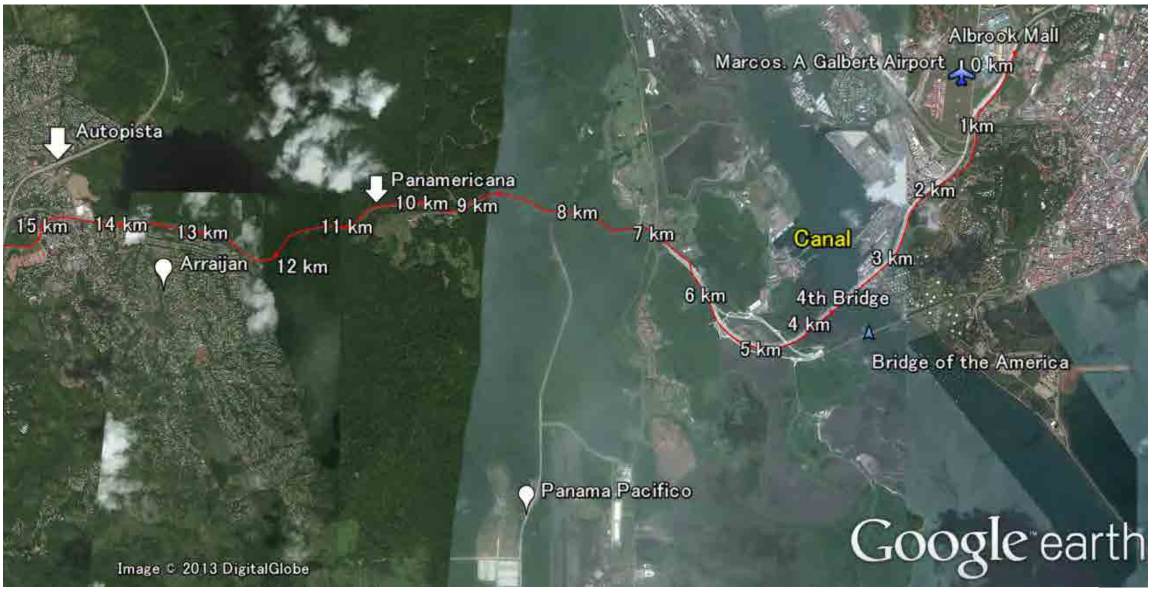
6.2 Route Condition

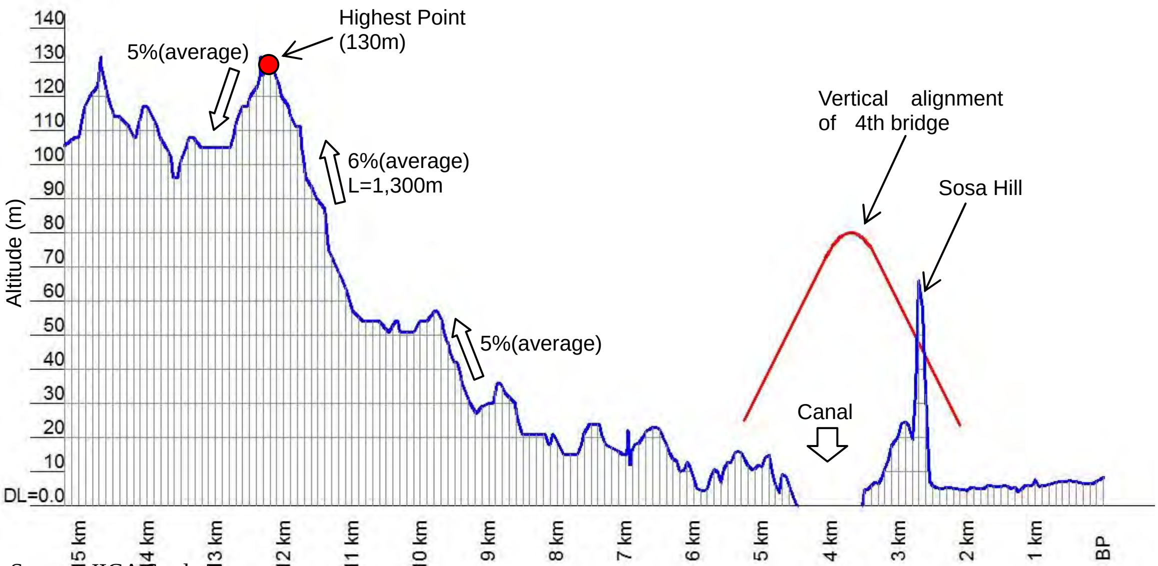
6.2.1 Topographical Conditions

The topographical conditions to the west and east of the canal differ widely. On the east side of the canal the terrain is almost flat although there is a hill in the middle of the route, with a height of approximately 80m, which will require some earth moving works. The route will touch this hill and connect to the 4th Bridge.

To the west of the Canal the terrain is hilly and no flat area can be observed in this area. The elevation gradually increases from the end of the 4th bridge on the west bank of the canal (approx. altitude 10m) and reaches an altitude of 130m at the highest point just before Arraijan. In the section between Panama Pacifico and Arraijan, jungles spread out on both sides of the road and the road has consecutive sharp curves and steep slopes. There is a section of steep slope for a distance of 1,300m just before Arraijan; the average gradient of this long slope is 6%.

Figure 6.2 shows a satellite image with the horizontal alignment, the vertical alignment, and photos of the first half of the route.





Source: JICA Study Team

Highest point (130m altitude) just before Arraijan

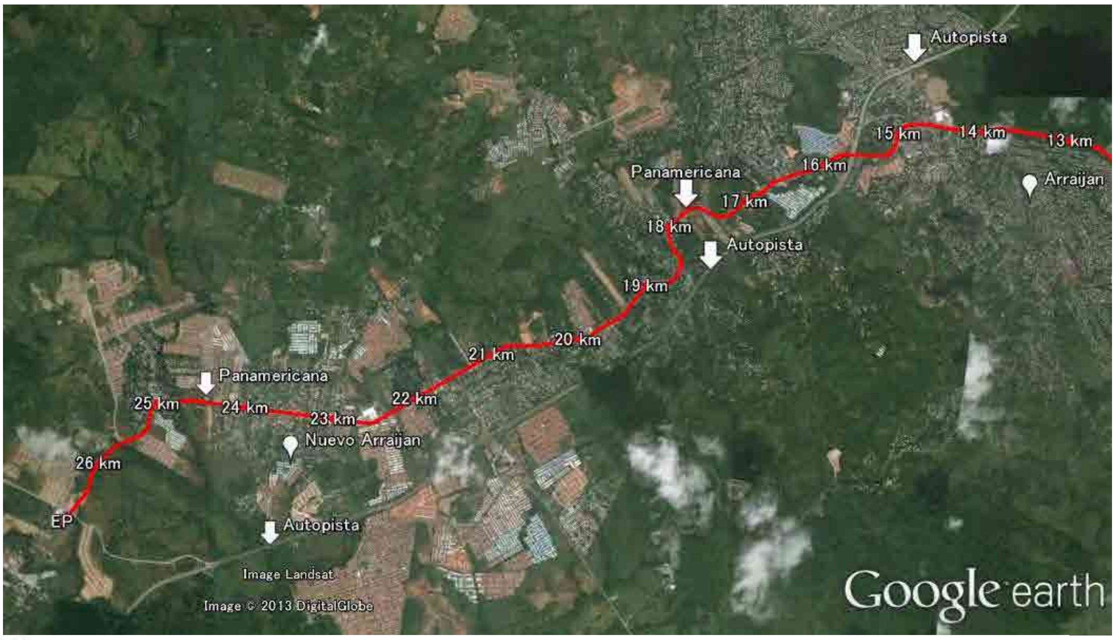
Jungle section with consecutive snaking curves

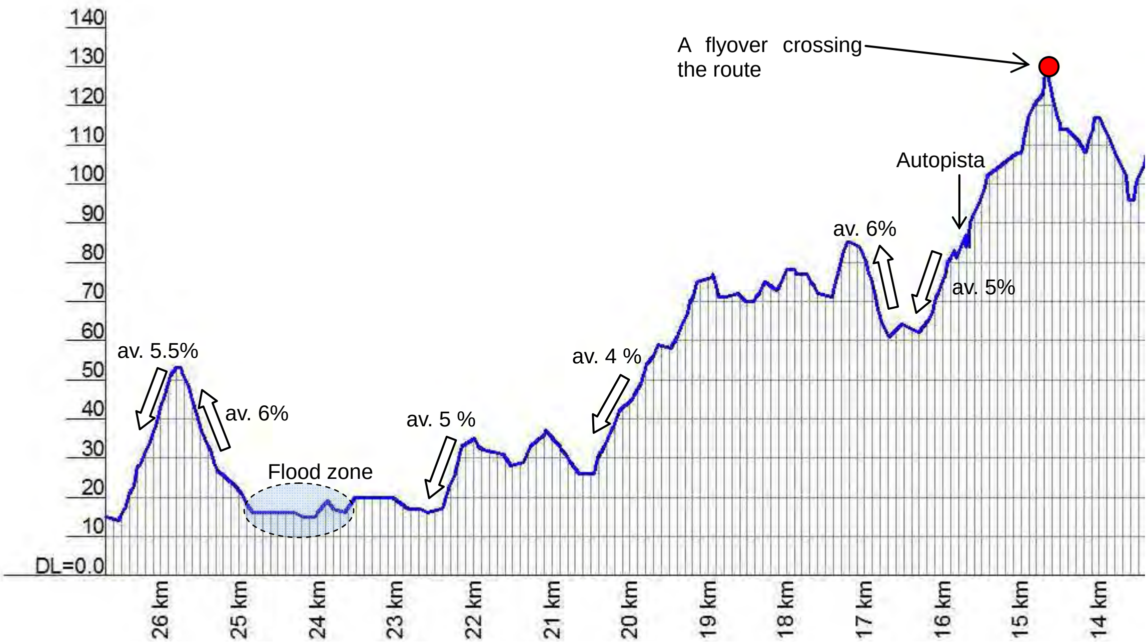
A hill stands in the middle of the route. (Sosa Hill)

Figure 6.2 Satellite image, profile outline and photos along the first half of the project route

After passing Arraijan, houses and stores can be seen intermittently along the Pan-American Road. Since the Pan-American Road was constructed on the surface of hilly terrain, the selected route has consecutive sharp curves and steep slopes although the surrounding area has developed to some extent. By comparison, the Autopista, which runs parallel to the Line-3 route, has less curves and slopes since it is a highway that was constructed with considerable earth works. The elevation decreases toward Nuevo Arraijan in last half of the route. There is a flat area in Nuevo Arraijan with an elevation of around 10m. This flat area experienced extensive flooding in 2012.

Figure 6.3 shows a satellite image with the horizontal alignment, the vertical alignment, and photos of the last half of the route.





Source: JICA Study Team

The area which experienced a flood in 2012. (near the end point of the route)

Route along the Pan-American Road.

A flyover crossing the route.

Figure 6.3 Satellite image, profile outline and photos along the last half of the project route

6.2.2 Geographical Conditions

A geotechnical survey was carried out at 51 locations. Based on the result of investigation and the data obtained from ACP on the east bank of the canal, bearing layer depths to be used for this study were determined as shown in Table 6.1.

Table 6.1 Bearing Layer Depths Determined Based on Geotechnical Investigation

Section	Bearing Layer	Notes
B.P ～2+600	20m	Determined based on 1 boring result from this Study and 7 locations provided by ACP
2+600～5+050	---	Monorail is constructed on the structure of the 4th Bridge.
5+050～10+000 (6+900～7+100)	10m (20m)	Determined from 9 borings results (This section shall be 20m depth.)
10+000～19+000	15m	Determined from 19 borings results
19+000～終点 (24+000～25+500)	25m (30m)	Determined from 18 borings results (This section shall be 30m depth.)

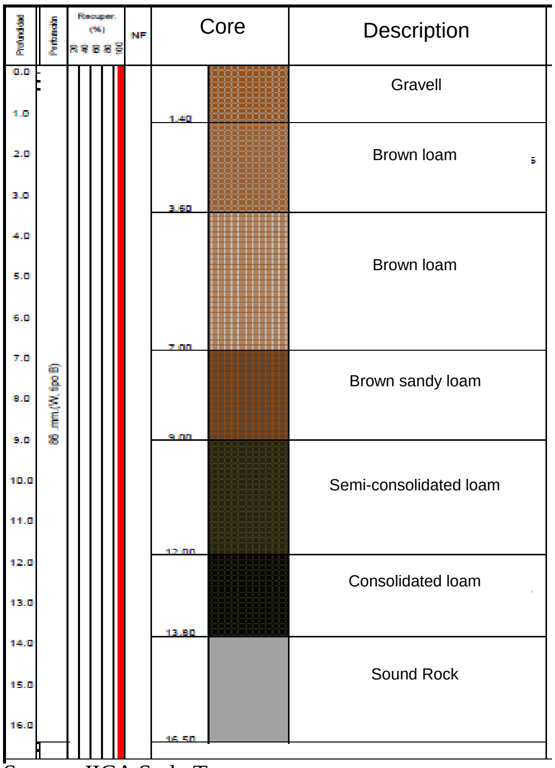
Source: Result of Geotechnical Investigation

(1) Geological Outline from Fourth Bridge to Arraijan

In this section, the geological strata mainly consist of loam with different consolidation levels by depth. Un-consolidated loam lies at the top stratum; followed by semi-consolidated loam. Underneath this layer lies consolidated loam up to an average depth of 9m. The surface is covered by a thin layer of gravel or vegetation and N-value ranges from 3 to 15, depending on the level of consolidation. Sound rock is observed at an average depth of 10~20 m.

(2) Geotechnical Outline from Arraijan to Nuevo Arraijan

Geological conditions of this section are similar to the above section, with trend of having the bearing layer deeper, as it goes west. The bearing layer at nearby existing rivers reaches as deep as 25 m.



Source: JICA Sudy Team

Figure 6.4 Typical Colum Diagram from the 4th Bridge to Arraijan

6.2.3 Utilities

There are different types of utilities along the project route. Some of the utilities such as fuel pipeline and water main should be considered as design controls to avoid the high cost and social impact of their relocation. Other utility service infrastructures such as minor water pipes, relatively small capacity transmission lines, telecommunication lines and so on should be relocated when they interfere with the project alignment.

The information on utility locations was collected not only through field visits but also through interviews with relevant authorities such as IDAAN for water pipes and the Administrative Unit for Reverted Estate of MEF for fuel pipelines. The data was obtained from these entities as physical copies or in digital formats.

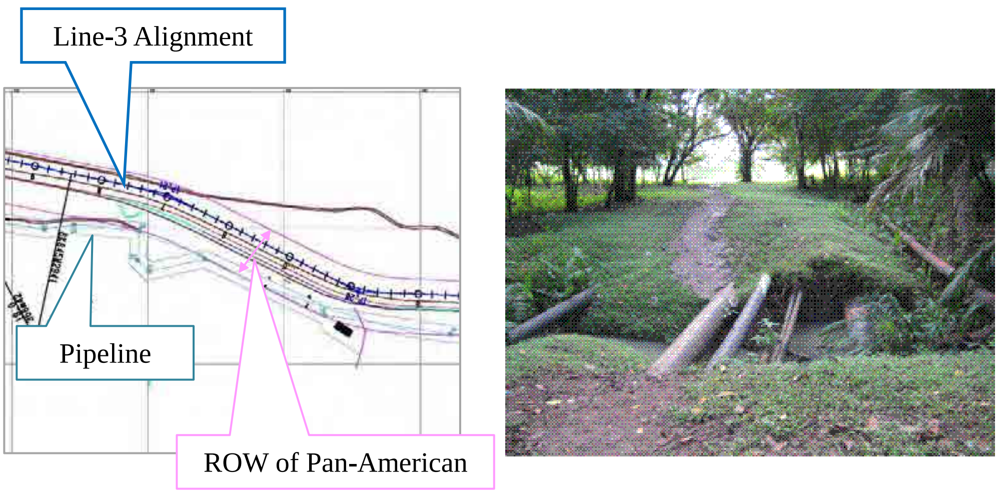
The list of authorities related to public utilities along the project route is shown below.

Table 6.2 The List of Authorities Related to Public Utilities

Type of utility	Name of authority	Description
Fuel pipeline and water pipe in the reverted area	Unidad Administrativa de Bienes Revertidos/ Petroamerica Terminal S.A.	Fuel pipelines from fuel tanks at Finca de Tanque de Arraijan to Vasco Núñez de Balboa navy base should be avoided. Location information was obtained in CAD format.
Water / Sewerage	IDAAN	There are pipes along the project route. The location information was obtained partially in GIS format.
Power supply	ETESA	Line-3 route crossing some transmission lines of medium capacity Network information was obtained in paper
Propane gas supply	Tropigas / Panagas	Gas service is provided in gas cylinders
Telecommunication/Cable	Cable & Wireless / Cable Onda	Major service providers covers the area along the project route

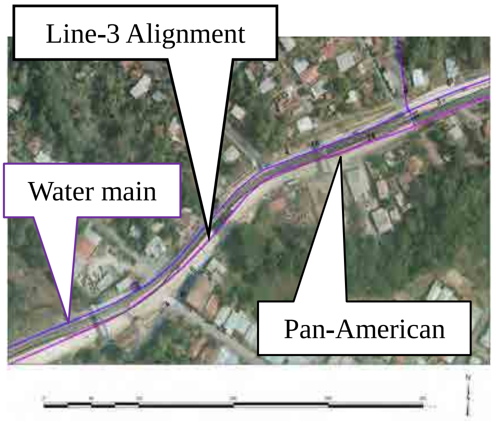
Source: JICA Study Team

The most challenging issue related to the utility service seems to be fuel pipelines and water/sewerage pipes along the project route. Through field visits and interviews with authorities, the important installations were identified. Some examples of the utilities are shown below.



Source: JICA Study Team

Figure 6.5 Location and photo of Fuel Pipelines along the Line-3 Alignment



Source: JICA Study Team

Figure 6.6 Location and photo of IDAAN Water Pipes along the Line-3 Alignment

6.2.4 Hydrological Conditions

(1) Surface Water

The Panama Canal is the body of water with greatest importance in the study area. The estuary formed where the Canal enters the Pacific Ocean is affected by the Pacific tides mixing with the freshwater from the Canal watershed.

Panama City has a number of important watersheds: the Matasnillo River, the Matias Hernandez River, the Cabuya River, the Rio Abajo River, the Tocumen River, the Tapia River, and the Curundu River. These watersheds are formed by secondary rivers, brooks and creeks.

The Line-3 project is located in watershed N°142 (the watershed between the Caimito and Juan Diaz Rivers) and watershed N°140 of Caimito River (see Figure 6.7). Line-3 crosses the following rivers: Caimito; Curundu; Velazquez; Perico; Caceres; Burunga; Aguacate; and Bernardino.

The eastern end of the Line-3 alignment is located in the western watershed of the Curundu River, which includes the Canal, the Marcos A. Gelabert International Airport, and the Balboa area. The small streams in the area were channeled and pass under the existing buildings.

Watershed N°140 is formed by the rivers Aguacate, Caceres, San Bernardino, Potrero and Caimito, the latter being the main river in the watershed.

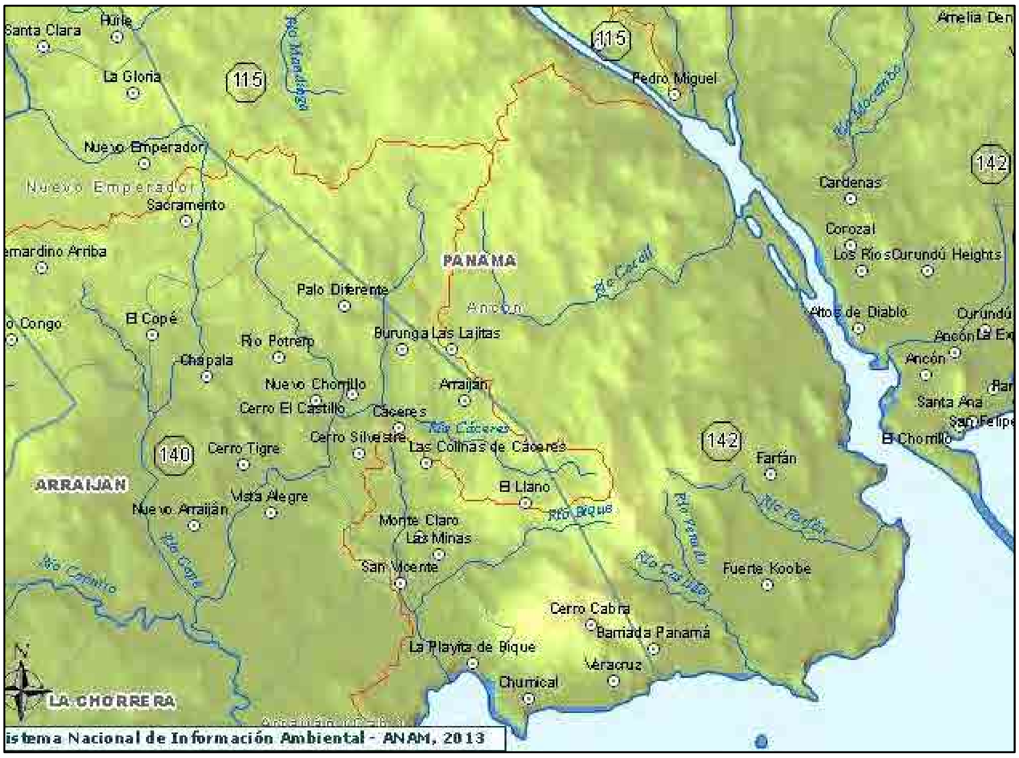
Water use in the watershed is devoted to crop irrigation and domestic use; the watershed is the main source of water for the community of La Chorrera. Near the urban area, the river is under pressure from over-extraction of water, disposal of waste materials and direct discharge of industrial wastes and sewage into the river.

As a result of the pressures on the Caimito River watershed, the quality of the rivers in the watershed has already declined, and it is likely to decline further.

(2) Groundwater

The Hydrogeological Map of ETESA (1999) establishes an aquifer in the study area, within the geological groups of La Boca and Panama Formations. The aquifer is composed of marine deposits, generally of a clastic nature, with occasional sections of biochemical (limestone) origin. The chemical quality of the water is variable.

The water table of the area exhibits significant seasonal variation; during the dry season it can decline to more than five meters below the surface. The water table rises during the rainy season to less than 50 cm from the surface creating problems in surface drainage, and in some cases, welling up onto the surface.

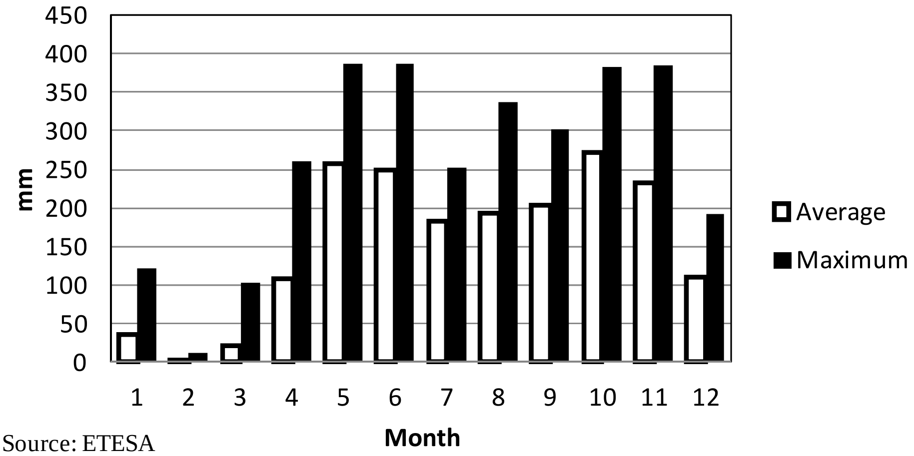


Source: http://mapserver.anam.gob.pa/website/cuencashidrograficas/viewer.htm

Figure 6.7 Watershed distribution - Project Area

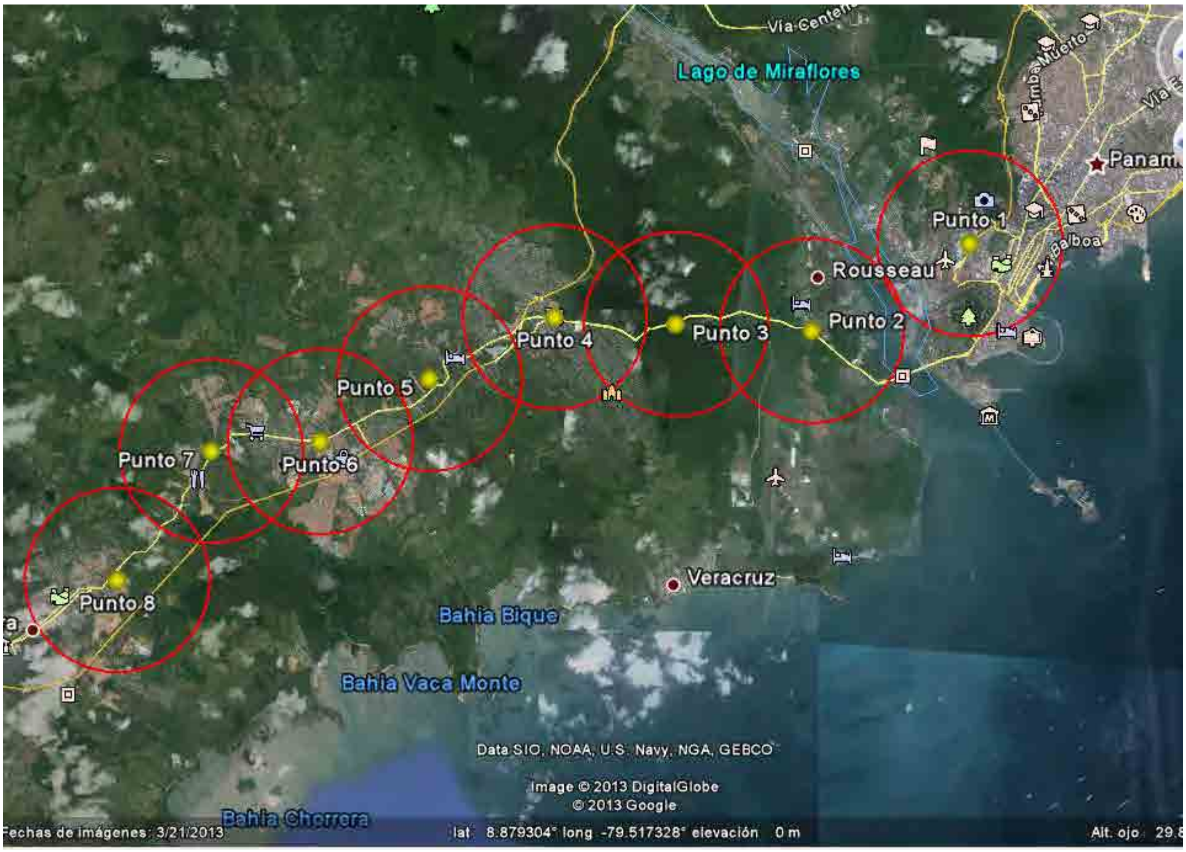
6.2.5 Meteorological Condition

Panama belongs to a tropical climate, having the average temperature of 27 degree through the year with the highest of 39 degree and the lowest of 15 degree. Panama has dry season and wet season, and the rain falls hard with thunders in wet season from May to November. The number of days when thunders are observed is approximately 50 in a year along the study route, and most of them are observed in the wet season (average from 2008 to 2012, ETESA). The number of days of lighting in the area where monorail is operated in Japan is Tokyo-12.9 days, Osaka-16.2 days, Fukuoka-24.7 days, Naha-21.6 days (the average in 30 years from 1981-2010: Japan Meteorological Agency). Since the above isokeraunic level in Panama represents that of very narrow area, the condition about lighting is much more severe than that of Japan. On the other hand, wind is moderate through the year and there is no typhoon and hurricane.



Source: ETESA

Figure 6.8 Monthly Average Rainfall in the Study Area



Source: JICA Study Team

Figure 6.9 Locations of Lighting Statistics

Table 6.3 Yearly Average No. of Days of Lighting (2008-2012)

8	7	6	5	7	3	2	1
43.4	45.6	48.6	50.2	57.2	53.6	53.4	53

Source: ETESA

6.3 Station Location

The stations of Line-3 are located in the central area of each region where there is a high potential for attracting passengers. The locations were decided as described below.

- In a level section of the railway alignment
- Adjacent to existing intermodal facilities such as a bus terminal or bus stop
- Adjacent to intersections of main roads
- Close to existing or developing residential areas
- Close to existing or developing industrial areas

The alignment of Line-3 begins from the Albrook area passing through Balboa and reaches the area where the 4th Bridge is to be constructed in the near feature. After passing over the 4th Bridge to the west side of the canal, the alignment follows the Pan-American Road up to Nuevo Arraijan. The total length of the alignment is approximately 26km from Station No.1 Albrook to Station No.14 Ciudad del Futuro. The longest distance between stations is 5.56km from Station No.3 Panama Pacifico to Station No.4 Loma Coba. An emergency station is planned for the mid point between these stations to provide for evacuation in case of an emergency event.

As mentioned above, Line-3 will have 14 stations and 1 emergency station. The structure of most stations is elevated with the exception of Station No.14 Ciudad del Futuro which is at grade level. Table 6.4 shows the locations of stations and the distances between stations.

Out of 14 planned stations, three stations – E9 (Caceres) and E13 (San Bernardino), which serve newly developed areas and E6 (Arraijan Mall), which is planned at the location where a shopping mall is planned, are projected to have less passengers than other stations and can be supplemented with their neighboring stations. Therefore, these three stations will be considered at the future stations in the implementation plan.

Table 6.4 Station Location

No.	Station	Mileage			Note
		Location (Km)	Distance (Km)		
E1	Albrook	0+000			Integration with Line-1 and AGNT (Albrook bus terminal)
			2.050		
E2	Balboa	2+050			Connection with administrative district
			4.800		
E3	Panama Pacifico	6+850			Connection with industrial area
			3.450	5.560	
	(Emergency Platform)	10+300			
			2.110		
E4	Loma Coba	12+410			Connection with existing residential area
			1.940		
E5	Arraijan	14+350			Intersection with Arraijan and Burunga area
			1.120		
E6	Arraijan Mall (Future Station)	15+470			Connection with future shopping mall
			0.980		
E7	Burunga	16+450			Connection with existing residential area
			1.410		
E8	Nuevo Chorrillo	17+860			Intersection with Nuevo Chorrillo area
			1.290		
E9	Caceres	19+150			Connection with newly-constructed residential area
			1.450	2.300	
E9-1	(Future Station)	20+600			
			0.850		
E10	Vista Alegre	21+450			Intersection of two routes between Panamerica road and Vacamonte area
			0.920		
E11	Vista Alegre 2	22+370			Connection with existing shopping mall
			1.180		
E12	Nuevo Arraijan	23+550			Connection with existing residential area
			0.700		
E13	San Bernardino (Future Station)	24+250			Connection with newly constructed development area
			1.600		
E14	Ciudad del Futuro	25+850			Intersection with La Chorrera area
		Total	25.850		

Source: JICA Study Team

The average distance between stations for the entire line is 1.99km. It would appear that this distance is great, but this situation arises largely from the existence of a protected forest along Line-3. This forest has the function of protecting the canal watershed. There is no large development in the area, nor is there a plan to install a station here.

If the distance of the protected forest is removed, the average distance between stations is 1.34km. This distance is close to the figure for existing urban railways in the world.

The outline of typical stations is shown below.

Table 6.5 Outline of Typical Stations

Station	St.No.1 Albrook	Photos
Structure	• Opposite Platforms and two lines • Switching point for turn-back	
Daily Ridership	Person / Day; 221,708	
Characteristics	The station is located midway between AGNT (Albrook bus terminal) and Line-1, in a key transportation area for Panama. Accessibility needs to be increased between Line-3 and the other mass rapid transit systems. An appropriate platform size is needed to meet the traffic demand of the morning peak hour.	

Station	St.No.4 Panama Pacifico	Photo
Structure	• Opposite Platforms and two lines • Platform length is longer than the normal station's for emergency measures	
Daily Ridership	Person / Day; 30,325	
Characteristics	The station is located at the entrance of the Panama Pacifico industrial area. In the morning peak hour, it has the second largest passenger volume. The platform length is longer than the normal station to accommodate the lead vehicle of another train..	

Station	St.No.6 Arraijan Mall	Photo
Structure	• Opposite Platforms and two lines	
Daily Ridership	Person / Day; 13,375	
Characteristics	The station is located at the planned site for a commercial development. The direct connection between the station and the commercial area increases passenger convenience and use. This area is a transportation hub for local traffic and an Intermodal Facility is also installed in the shopping area to accomodate the traffic.	

Station	St.No.8 Nuevo Chorrillo	Photo
Structure	• Two Platforms and three lines • Switching point for turn-back	
Daily Ridership	Person / Day; 21,708	
Characteristics	The station is located at the mid-point between Albrook Station and the Phase-2 La Chorrera station. A switching point for turn-back is installed. A difference in demand occurs at this station. In addition, a Park & Ride Facility is installed for passengers with cars.	

Station	St.No.10 Vista Alegre	Photo
Structure	• Opposite Platform and two lines	
Daily Ridership	Person / Day; 31,567	
Characteristics	The station is located at the intersection of Pan-American road and the main road to Vacamonte. Vacamonte area is expanding rapidly with the widening of the Autopista. An Intermodal Facility is installed for feeder traffic.	

Station	St.No.14 Ciudad del Futuro	Photo
Structure	• Opposite Platforms and two lines • Switching point for access to Depot / Workshop	
Daily Ridership	Person / Day; 2,333	
Characteristics	This is the last station of Phase-1. In addition, the Depot/Workshop and a large Intermodal Facility will be built in the vicinity of this station. The station has the role of a transportation hub for feeder traffic from La Chorrera.	

Note; Numbers of the daily ridership are based on the demand forecast for Phase-2.
Source: JICA Study Team