The Republic of Panama
Secretaría del Metro de Panamá

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

Final Report (Summary)

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
Vacamonte
Panama
Pacifico
Veracruz
La Chorrera
Puerto Caimito
N
0
2
4km


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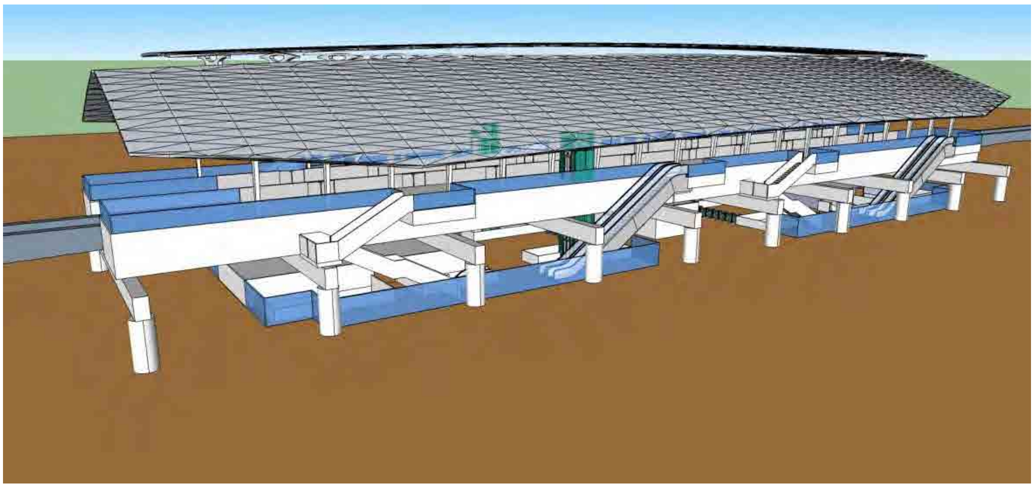
Albrook Station


Standard Station

THE FEASIBILITY STUDY
ON
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FINAL REPORT (SUMMARY)

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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
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 is currently undertaking the Canal expansion project to allow the passage of Post-Panamax ships, and the construction of a 4th bridge across the Canal is in the planning stage. The Panama Canal Authority (ACP) has been conducting the Pre-F/S for the 4th Bridge since 2012. The GOP plans to provide track space on the 4th Bridge for Line-3.

Under the above-mentioned circumstances, the Japan International Cooperation Agency (JICA) and the GOP agreed to conduct a feasibility study for the Line-3 Project in March 2013, and the study started in July 2013. The study on the section of the 4th Bridge was not included in the study scope in the beginning because the 4th Bridge had been studied by ACP as mentioned above[1]. Meanwhile, GOP expressed its interest to fund the 4th Panama Bridge Construction Project - with a Japanese Yen Loan. After this, GOP and Government of Japan (GOP) held a meeting on July 12, 2013 and agreed that GOJ will conduct the study for the 4th Bridge. As a result, the Study for the 4th Panama Bridge Construction Project was commenced under JICA's technical assistance from September, 2013.

1.2 Project Scope

The Project covers the following components of the mass transit system for the section between Nuevo Arraijan and Albrook through the 4th Bridge.

- 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] METI Study also assumed the construction of the 4th Bridge for crossing the Panama Canal

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.

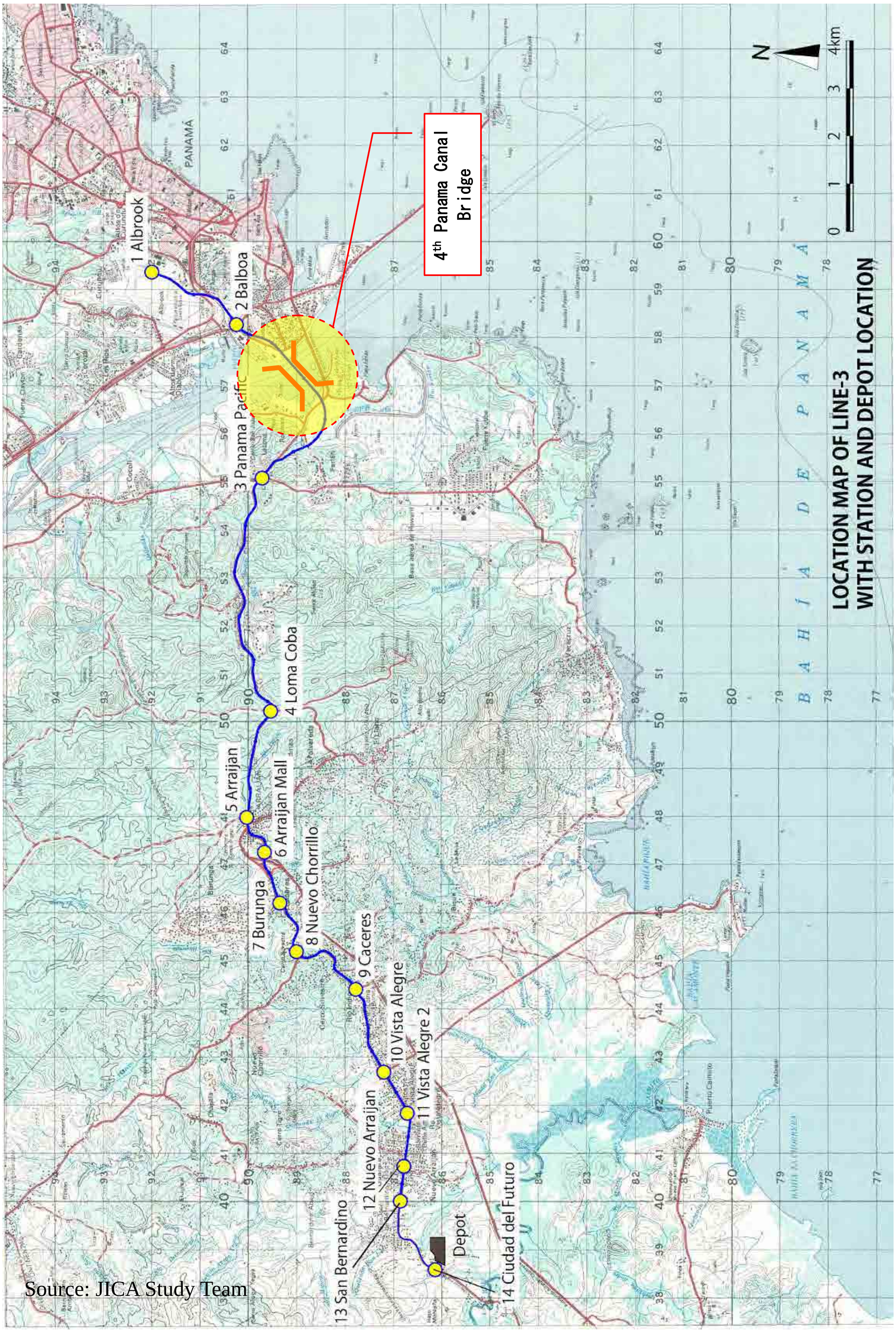


Figure 1.1 Survey area for route study

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.

Chapter 2 Necessity of the Project

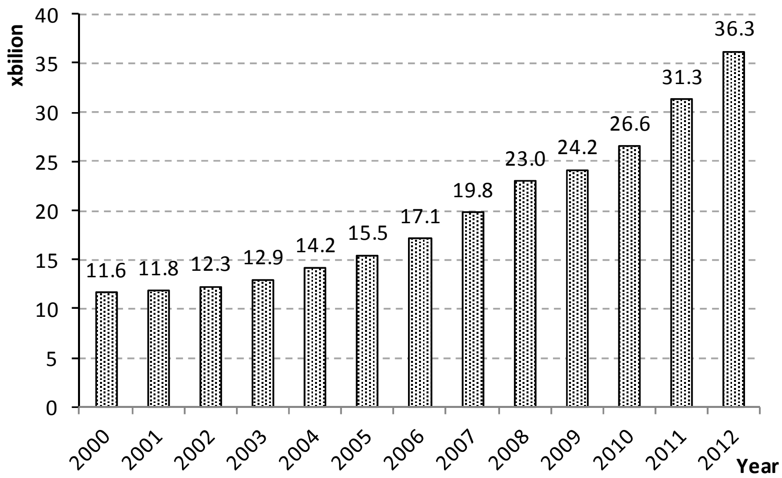
2.1 Current Situation and Issues of Urban Transportation Sector

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 and Colombia to the southeast. The capital is Panama City. The country boasts the world-renown Panama Canal connecting the Pacific Ocean and Atlantic Ocean.

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 metropolitan have multiplied the number of cars resulting in serious traffic congestion.

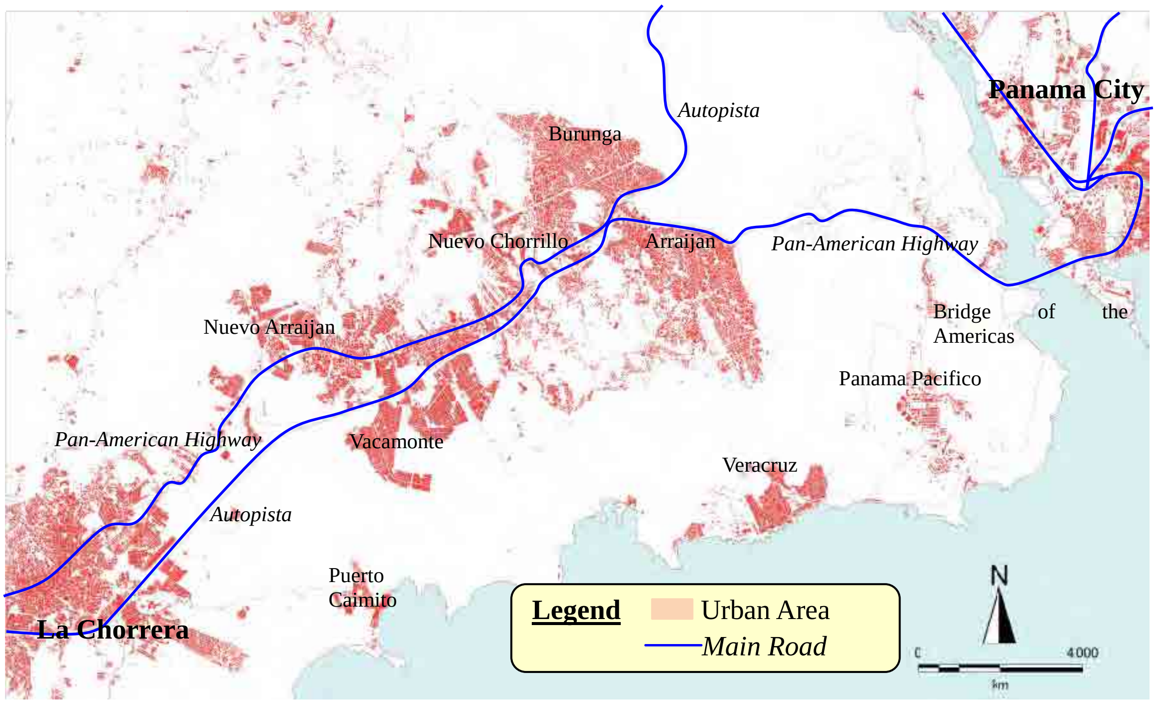
Table 2.1 Population breakdown of Panama

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 of the Arraijan District is fishing, and the main industry of La Chorrera District is agriculture and farming, such as cultivating pineapples and raising pigs. But the main source of employment for the inhabitants of these districts is Panama City highlighting the need for efficient public transportation.

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

Photo: SMP

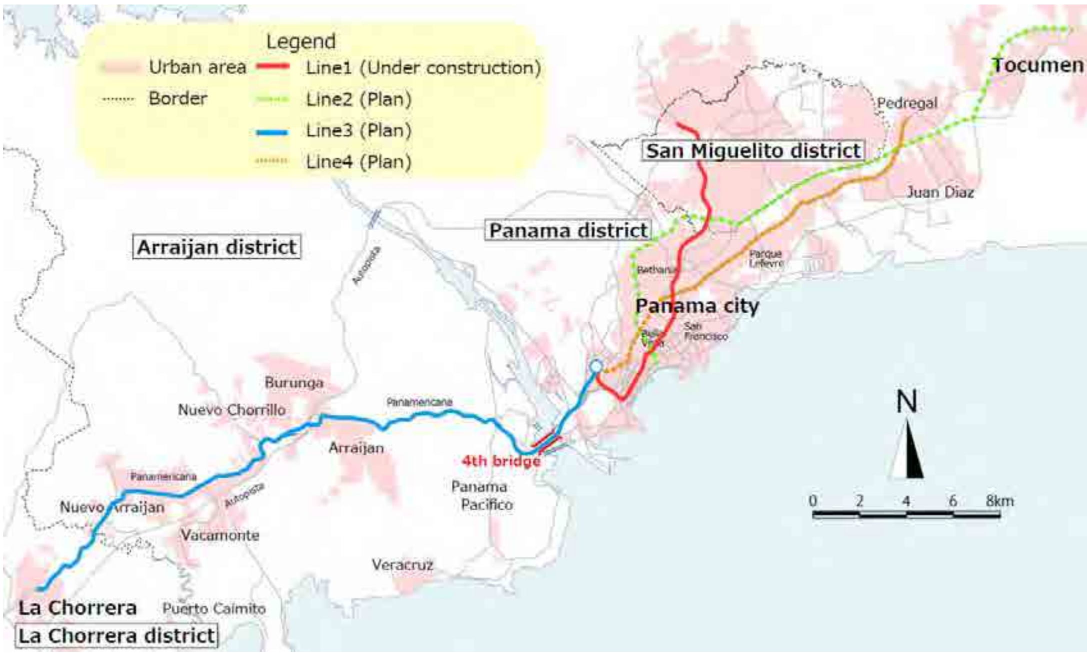
Panama Pacifico, located to the southwest of the Panama Canal, has planned an urban development project for the future. Howard airport is located in the area, but only a few chartered aircrafts use the airport. The area will have 20,000 houses and 40,000 employees according to the master plan.

2.1.2 Transportation Network

There are two bridges over the Panama Canal: the Bridge of Americas (4-lane) located at the entrance of the Panama Canal in the Pacific side and Centennial Bridge located at 15km north of the entrance. The Bridge of Americas forms a part of Pan-American Highway connecting the center of Panama City and the urbanized area in Arraijan and La Chorrera. The Centennial Bridge is a part of an expressway which is called as Autopista, which connect the east and west of the canal making a large diversion route in the north of the city. In the Panama City, there are two expressways such as Corredor Norte and Corredor Sur. Albrook terminal is located at the beginning of Corredor Norte and Albrook Station of Line-1 is located at the opposite side. A complex shaped roundabout is located to the south of Albrook terminal.

2.1.3 Public Transport

Panama has a plan to introduce four metro lines (rail-base urban transport system), and Line-1 with a total length of 13.7km opened in April 2014. In the Study Area, buses (second hand school buses from USA) called "Diablo Rojo" have been operated but modern type buses called Metrobus has been introduced in Panama City since 2010. Metrobus is not introduced in Arraijan and La Chorrera where Diablo Rojo is still operated. Since bus capacity is not enough to cover the demand, taxi and unofficial taxi called as "pirate" are operated.



Source: JICA Study Team based on SMP plan

Figure 2.3 Metro Plan

2.1.4 Current Situation and Problems of Urban Transportation

There is serious traffic congestion in Panama City at all times of the day and on the west side of the Panama Canal at peak hours. The main business and government offices, and schools, are located in Panama City and there is a large number of commuting employees and students. In addition, the construction of Line-1 and road improvement projects has further worsened traffic conditions.

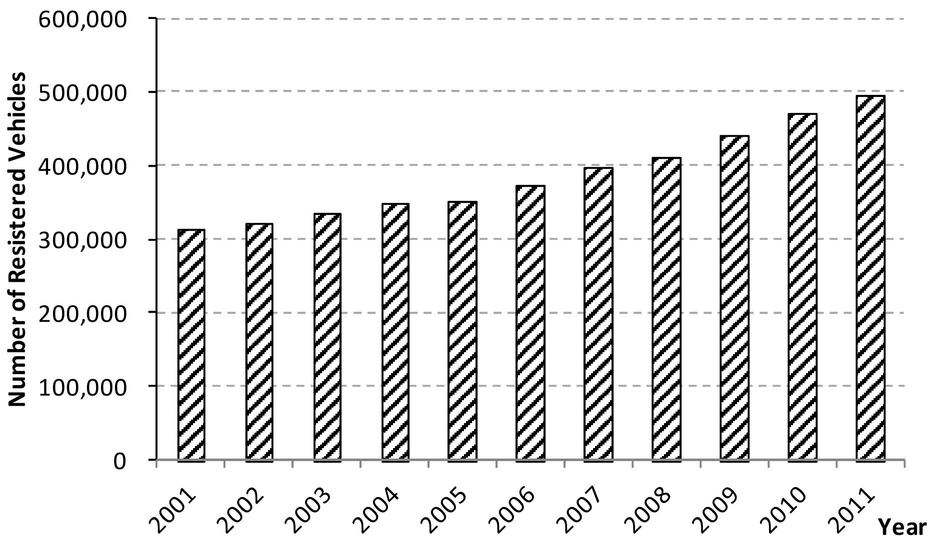
Traffic congestion afflicts not only Panama City, but also the Pan-American Highway, specifically between the Bridge of the Americas and Arraijan, during the morning and evening hours. This section becomes so congested that drivers use the shoulder as a traffic lane during peak hours as shown in Figure 2.4.

Source: JICA Study Team

Figure 2.4 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.

In addition to the above urban transportation problems, the number of cars is increasing year by year in Panama as shown in Figure 2.5, 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 2.5 Number of Registered Vehicles by year

2.2 Policies and Plans for the Urban Transportation Sector

Presently, the following projects are undertaken for transportation sector in Panama.

- Canal Expansion
- Atlantic Bridge (the 3^{rd} Bridge)
- Metro Line-1
- Metro Line-2

2.3 International Assistance in Transportation Sector

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 2.2 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

2.4 Necessity of the Project

2.4.1 Necessity of transport infrastructure crossing the canal

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 in page 2-2. 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 Project

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

2.4.3 Necessity of Urban Transportation Line-3

Urban Transportation Line-3 is necessary because of the following reasons.

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

2.5 Evaluation of Alternatives

To justify the implementation of both the 4th Bridge and Line-3, alternatives were evaluated as shown below.

Alternatives	Evaluation
Without Project	Regional development in the area to the west of the canal will stagnate, and economic loss due to traffic congestion and environmental problem due to CO2 emission will continue.
Line-3 Only	Traffic congestion will be relieved in the short term, although the congestion on the Bridge of Americas will worsen again due to the increase in car traffic.
Tunnel	Although there are some advantages such that the impact on the landscape is less than that of the bridge plan, the disadvantage of high project cost is very large.
Construct Line-3 and 4th Bridge as different projects	Flexibility of carrying out the projects is the advantage but the project cost will be larger.

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 alleviate the traffic congestion on the Bridge of Americas 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 Introduction

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.

3.2 Demand Forecast of ACP's Pre-Feasibility 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 characteristics of the ACP's Study are 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

In addition to a traffic count survey at three places on August 13 (Wednesday), 2013 in the Study, three traffic count surveys were used 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

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.

In addition to the traffic count survey at three points, following surveys were carried out in the Study.

- Passenger OD Survey
- Stated Preference Survey

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

- Travel Time Survey

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. The Study employed the forecast by IMF for the economic growth rates from 2013 to 2018, and 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). 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.

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. 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.

Table 3.1 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%

Source: JICA Study Team

3.4.3 Car ownership

The future number of vehicles was estimated by using the linear function based on the regression analysis as shown in Table 3.2. 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 3.2 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 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 3.3 shows the estimated number of passengers traveling from the west to east of the canal, while Table 3.4 shows that for the east- west direction.

Table 3.3 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

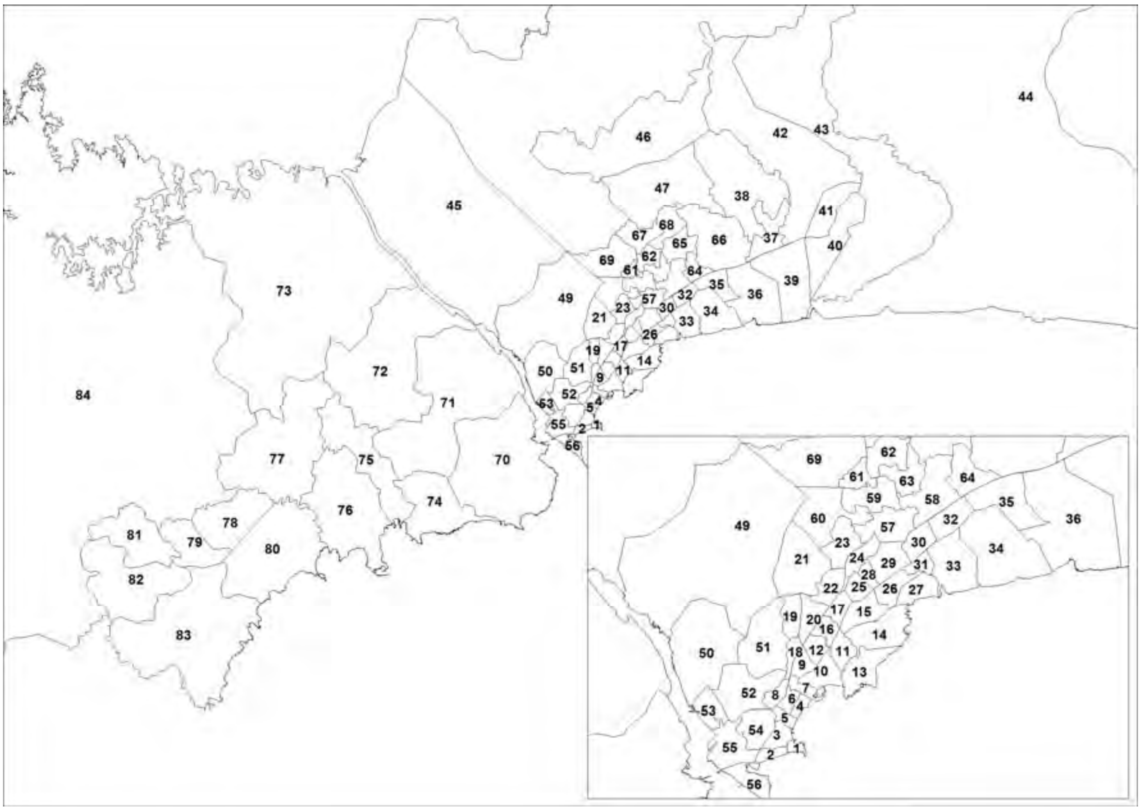
Table 3.4 Estimation of Passenger Volume from East to West

Time	Public					Private	
	Vehicles		Passengers			Car	
	Bus	Taxi	Bus 45/bus	Taxi 2/taxi	Total	Vehicles	Passengers 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

3.5.2 OD Matrices

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". Figure 3.1 shows the zoning system applied in the Study.



Source: JICA Study Team

Figure 3.1 Traffic Zoning System

The process for projecting the future OD matrix is shown in Figure 3.2. The major points of the flowchart are:

1) Replaces the OD that crosses the canal with the estimated OD based on the traffic

survey.

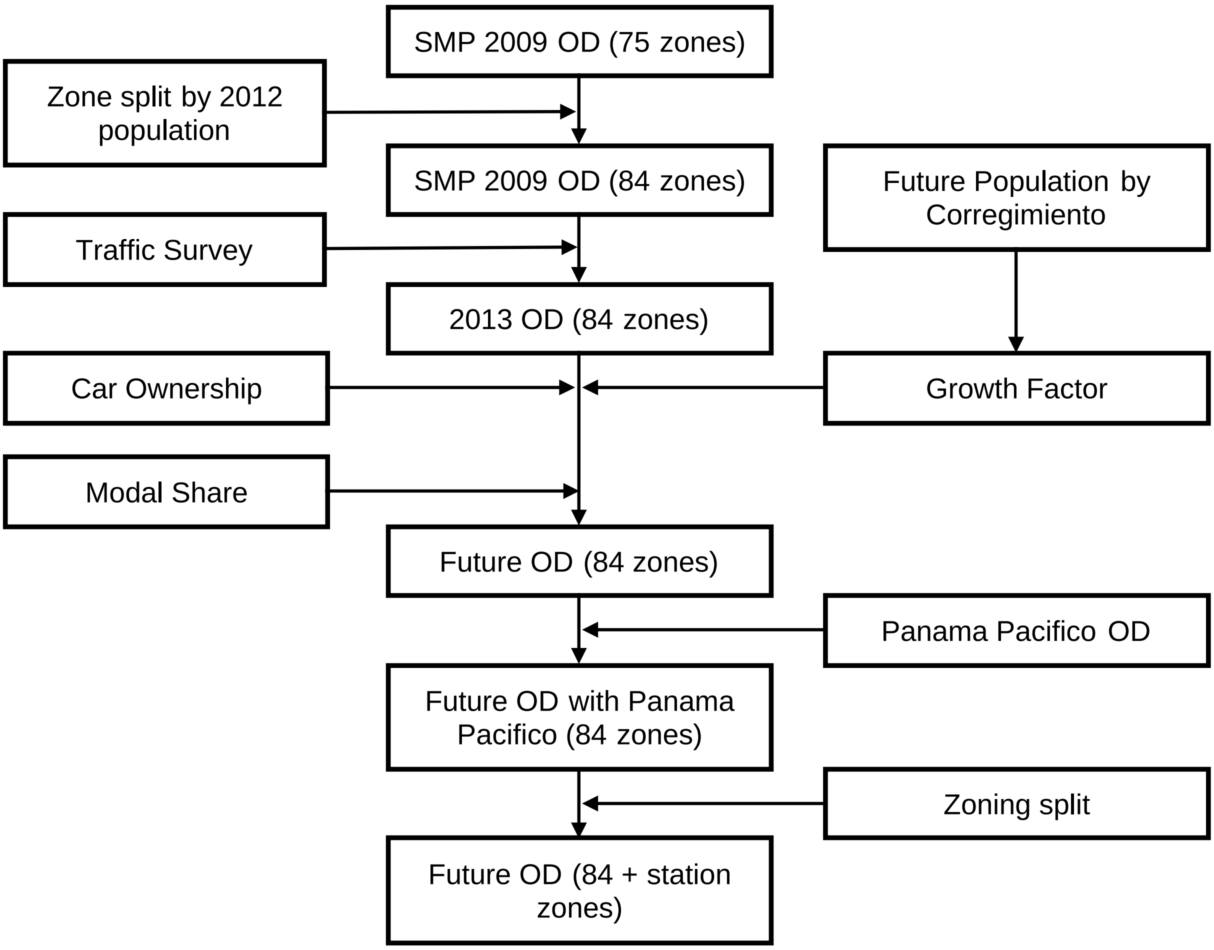
2) Modal shift from public mode to private mode takes into account the increasing number of cars.

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 3.2 Flow for making the OD Matrix

In the Study, since the transport capacity will largely increase after the opening of Line-3, it was assumed that the peak traffic that is presently distributed in the peak 2-hours will concentrate on the peak 1 hour. For the traffic assignment, the 2-hour OD matrix was used as the peak hour OD.

3.5.3 Modal Share

If the destination of a trip is within the walking area of a station, modal shift from car to Line-3 is anticipated by using Park & Ride facilities. It was assumed that the rate of the modal shift to the corresponding OD would be 55% (2020), 60% (2030), and 70% (2050).

3.5.4 Demand of Panama Pacifico

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

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.

Table 3.5 Intermediate Year Forecast of Panama Pacifico Traffic

	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

3.5.5 Transit Assignment

To estimate public transport demand, transit assignments were carried out by using JICA STRADA. Bus speed on general roads was assumed as 10km/h in Panama City and 20km/h in the area to the west of the canal, which the bus speed on expressways is assumed as 40km/h in case of normal buses, and 60km/h in case of express buses. The fare of Line-3 was assumed to be a flat fare of USD 0.65 up to 18km (distance between Albrook and Arraijan) and increase USD 0.042 per kilometer.

3.5.6 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.
- Link is classified into 7 types with the BPR function for link cost functions.
- Time value is assumed as USD 6.57. Fares of toll roads are converted to time by using the time value.

(2) 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. These scenarios are summarized as show in Table 3.6.

Table 3.6 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

(3) Truck Assignment

The number of trucks crossing the canal was estimated as shown in Table 3.7 by using a regression analysis.

Table 3.7 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

3.6 Future Passenger Demand

3.6.1 Peak Hour Passenger Demand

(1) Section Traffic

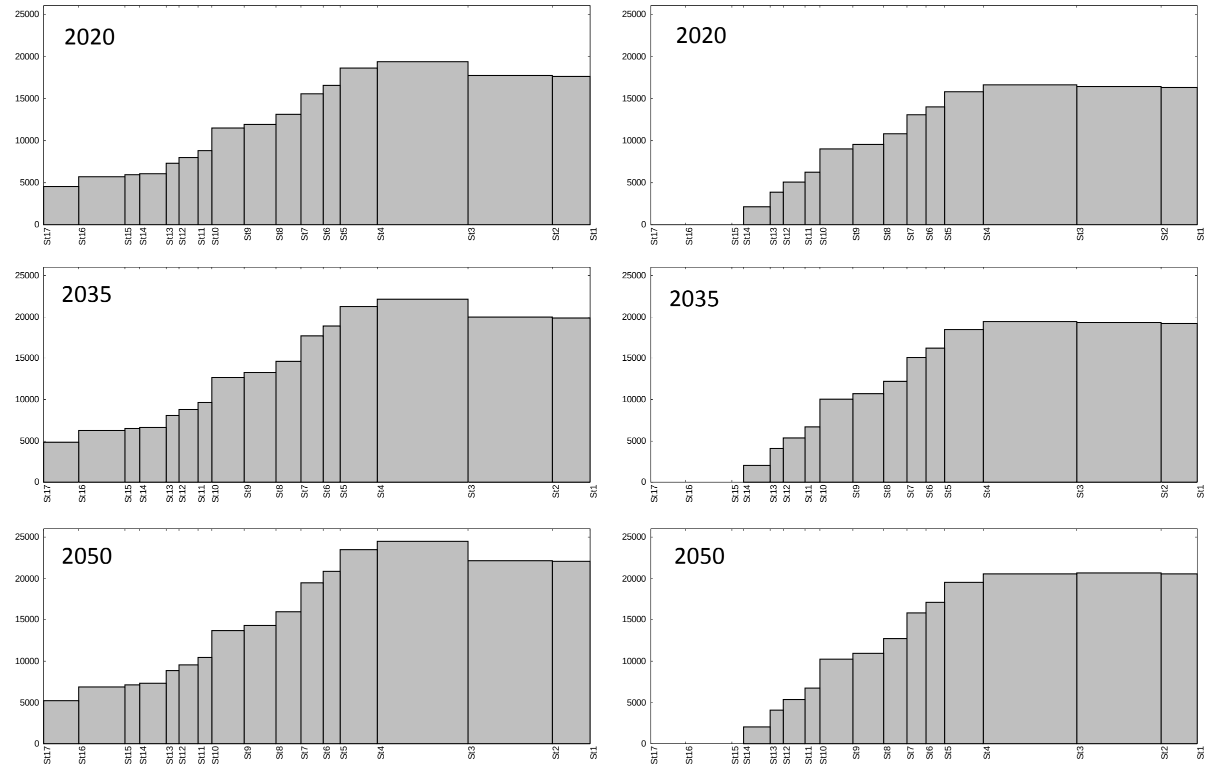
The peak hour traffic in the full development case is estimated at 19,359 in 2020, 22,153 in 2035, and 24,519 in 2050 as shown in Table 3.8. It is estimated that the modal share of public transport will decrease in accordance with the increase in the number of vehicles per inhabitant. However, the modal share of public transport will be higher than that in the without project case.

Table 3.8 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 3.3 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 3.3 Section Traffic for Peak Direction

3.6.2 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 3.9 and Table 3.10.

Table 3.9 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 3.10 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

3.6.3 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 3.11 (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 3.11 (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 3.11 (E).

Table 3.11 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

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 3.12, with the calculation of ESALs. 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 3.12 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

Source: Estimation by the 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.

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.

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.

4.4 Climate

4.4.1 Temperature

Air temperature in Panama is almost stable at around 27C throughout the year.

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.

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.

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.

(2) Wind Velocity

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

(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.

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.

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.

Chapter 5 System Selection

5.1 Route Alternatives

There are two alternatives for the urban transportation Line-3 to the west of Arraijan – Pan American Highway and Autopista. Although Pan-American Highway runs through the urbanized area, conditions of terrain, such as slopes exceeding 6% gradient and curves with radius less than 100m, are hard for introducing an urban transport system. On the other hand, construction is easy along Autopista, although the route is apart from urbanized area because it is on the expressway.

Source: JICA Study Team

Figure 5.1 Route Alternatives

5.1.1 Comparison items

To compare the two alternatives mentioned above, the JICA Study Team and SMP agreed to apply 11 evaluation items, which was categorized into four groups such as (1) demand and service, (2) physical, (3) land availability and resettlement, and (4) environmental.

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 5.1 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.

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.

Based on the result, Pan-American route was selected.

Table 5.2 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 widening	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							
	Environmental / Temporary	(1) Air pollution	Impacts for inhabitants during construction		1	Low density of population	1	Medium density of population	0.6
	Environmental / Temporary	(2) Noise and vibration	ditto		1	ditto	1	ditto	0.6
	Environmental / Temporary	(3) Safety	Impacts on traffic and pedestrians		3	Low risk	2.4	High risk	1.8
	Environmental / Temporary	(4) Traffic	Disturbance for road traffic during construction		3	Low disturbance	2.4	High disturbance	1.8
	Environmental / 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
	Environmental / Long term	(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

5.2 First Screening

The system was selected through a two-step process. In the first screening all the potential urban transport systems were listed and evaluated by four criteria, 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 5.3 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

5.3 Multi-criteria Analysis

5.3.1 System Selection Chart

Six systems were evaluated in the second stage of the comparison. The results of the evaluation are shown in Table 5.4. 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 5.4 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

5.3.2 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

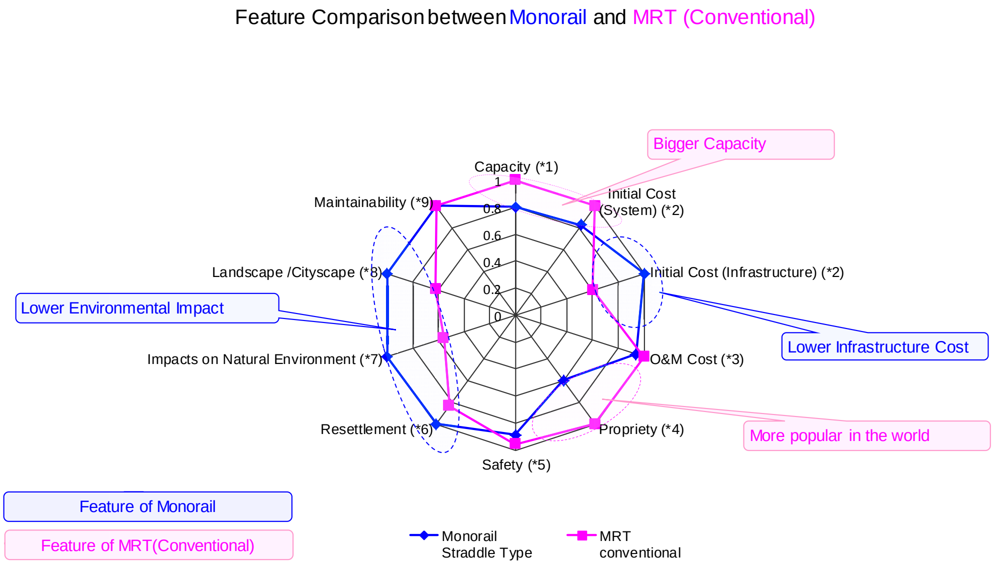
systems;

- 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.

5.3.3 Comparison in a Radar Chart

The top and the second systems, straddle-type monorail and MRT, were compared by using a radar chart as shown in Figure 5.2. 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 5.2 Radar Chart comparison between monorail and MRT

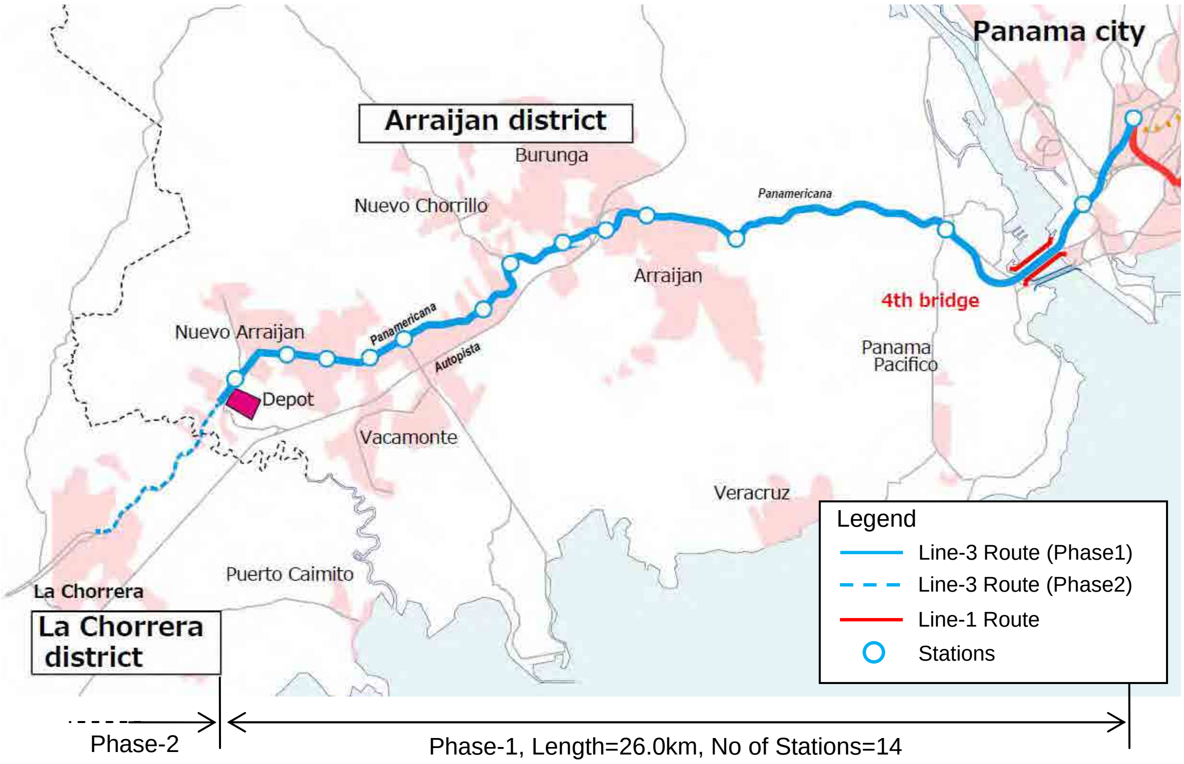
5.4 Conclusion

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 5.4.

Chapter 6 Route Plan

6.1 Route of Line-3

Line-3 is divided into Phase-1 and Phase-2 as shown below. Phase-1 is a 26km section from Albrook station to the depot, which is to be located near Arraijan and La Chorrera boarder, 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.



Source: JICA Study Team

Figure 6.1 Outline of Line-3 Route

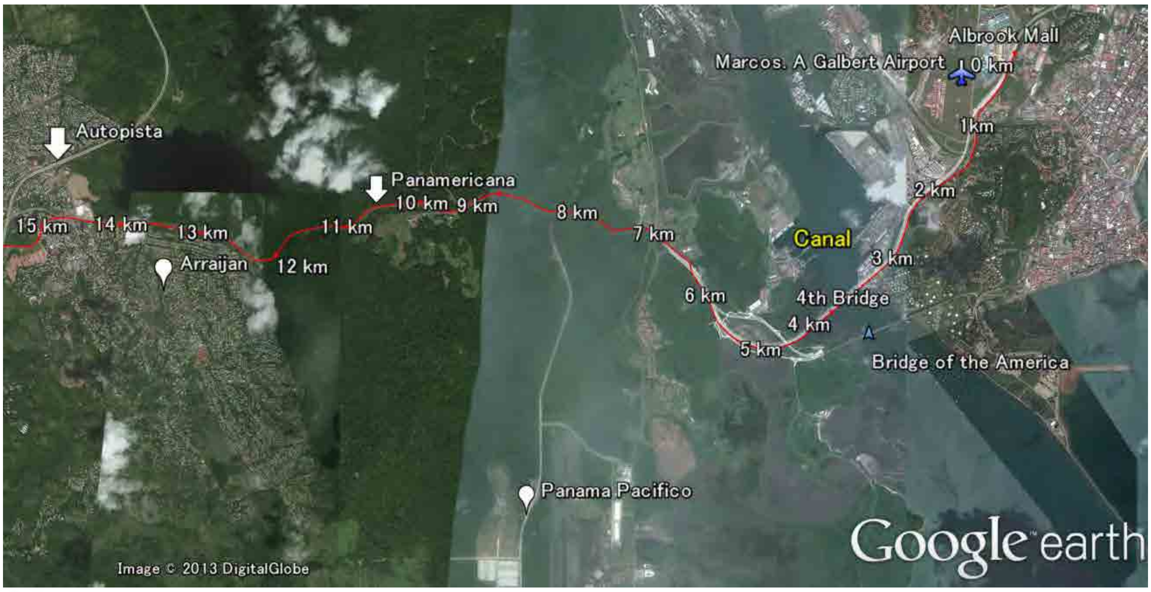
6.2 Route Condition

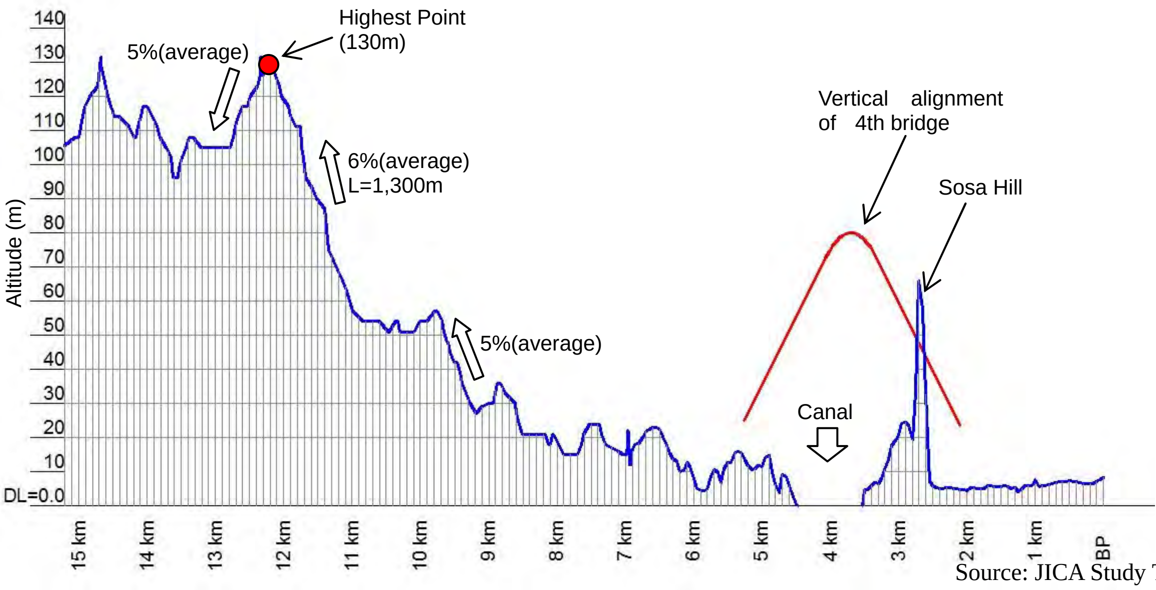
6.2.1 Topographical Conditions

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

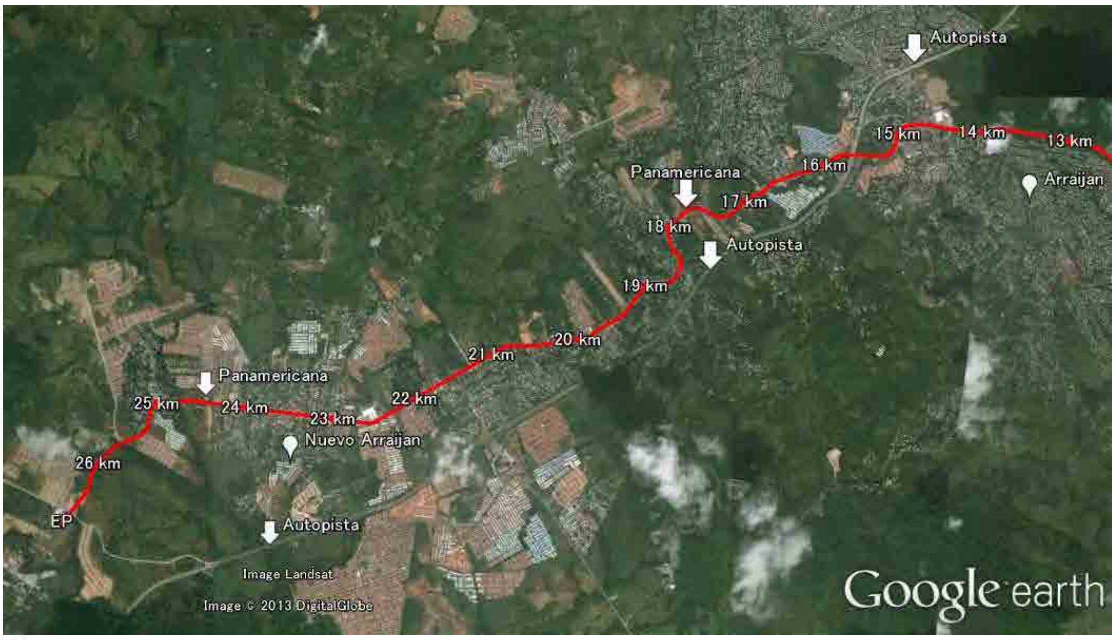
Jungle section with consecutive snaking curves

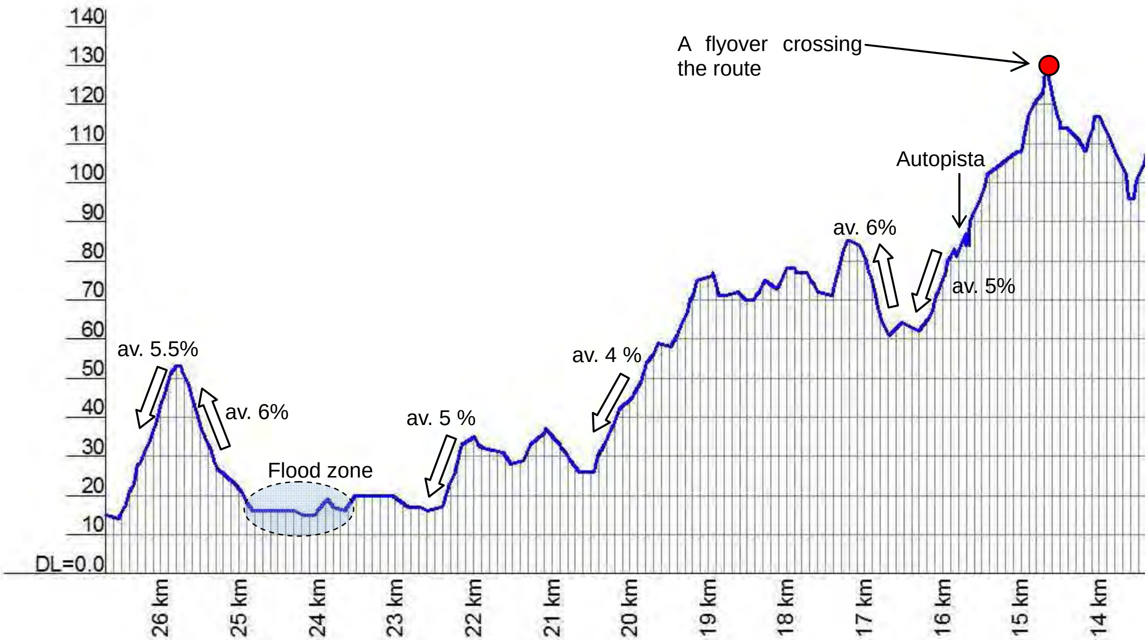
A hill stands in the middle of the route. (Sosa Hill)

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 Panamericana. Since the Panamericana 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 Panamericana.

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

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.

6.2.4 Hydrological Conditions

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.

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.

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.

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).

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 Panamericana 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 6.3 shows the locations of stations and the distances between stations.

Table 6.3 Station Location

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