Chapter 7 Project Design

7.1 Alignment

The basic policy for the horizontal alignment design is as follows;

- In the eastern access to the 4th bridge, it is advantageous to put the alignment as far from the runway as possible considering the aerial limitations of Marcos A. Gelabert Airport; the horizontal alignment of the monorail is basically set on the east side of the access road to the 4th bridge and parallel to it.
- On the 4th bridge, the alignment runs on the south side of the bridge.
- In the western access to the 4th bridge,
  a) Before the crossing point with the Autopista;

  The alignment runs on the north side of the Panamericana since the road has no median and there are various buried pipelines on the south side of Panamericana from a fuel tank farm located at 9k500~11k000.

  b) After the crossing point with the Autopista;

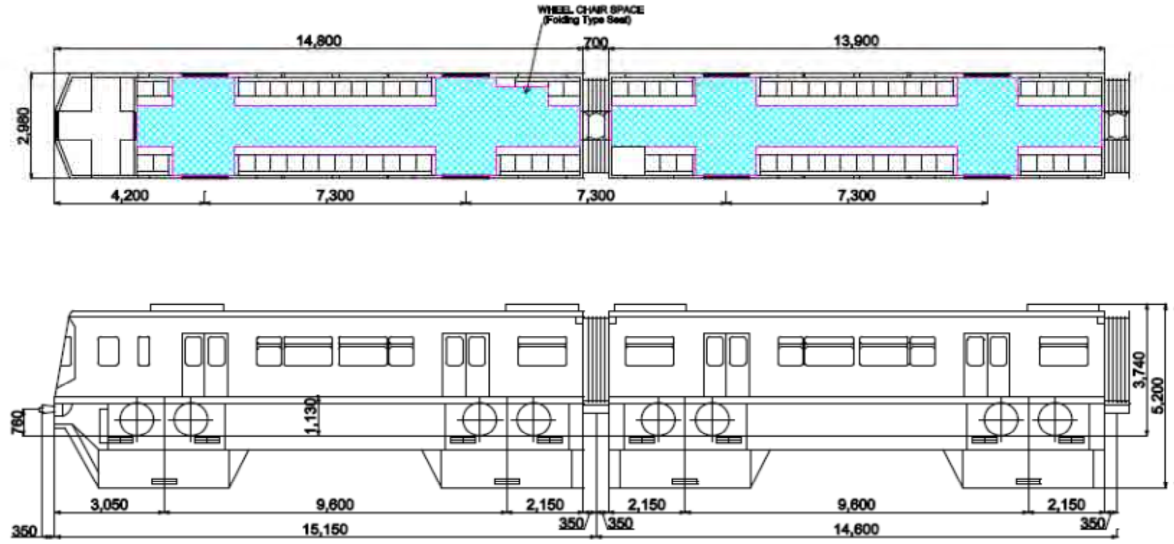
  The monorail alignment runs in the center of the Panamericana since there is a 2~3m wide median in this section of the Panamericana.

7.2 Rolling Stock

7.2.1 Transportation Capacity

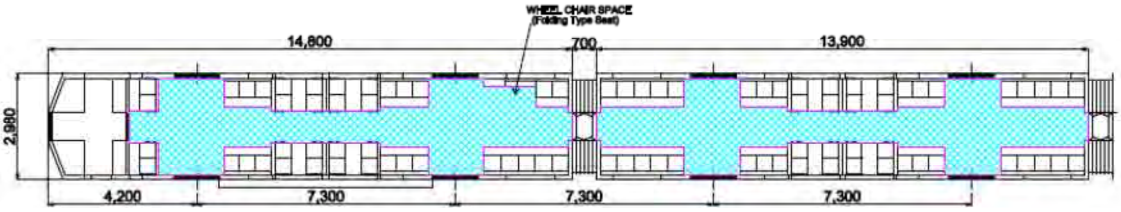
The train composition of Line-3 will be 6-cars from the commencement of the operation to the future.

Figure 7.1 and Figure 7.2 illustrate examples of the car dimensions and the seat arrangement of a large-size straddle monorail. Figure 7.1 shows the Long Seat Type Car which is composed of longitudinal seats only, with 246 seats in a train-set. Meanwhile, Figure 7.2 is an example of the Semi-cross Seat Type Car which has both longitudinal seats and traverse seats, with 270 seats in a train-set. Since Line-3 is characterized as a suburban transportation system due to its long distance between stations, the Study Team recommends that the Semi-cross Seat Type, which has more seats, be selected.



Source：JICA Study Team

Figure 7.1 Car Dimensions and Seat arrangement of "Long Seat Type"



Source：JICA Study Team

Figure 7.2 Seat arrangement of "Semi-cross Seat Type"

7.2.2 Specifications of Rolling Stock

The specifications of rolling stock for Line 3 are described in Table 7.1. These specifications are formulated with reference to the existing straddle monorail systems in Japan.

Numerical values related to vehicle performance are set tentatively, and can be changed in the detailed design phase.

Table 7.1 Principal Specifications

Item	Specifications		
Car type	Tc	M	Train
Train Formation	6-car fixed formation: Tc-M-M-M-M-Tc		
Dimensions			
Car length	15.5 m	14.6 m	89.4 m
Car body length	14.8 m	13.9 m	-
Car width	2,980 mm	2,980 mm	2,980 mm
Car height (Max)	5,200 mm	5,200 mm	5,200 mm
Height above track surface	3,740 mm		
Floor height above track surface	1,130 mm		
Tare weight	27.0 t	26.5 t	160 t
Passengers capacity			
Numbers of seats	39 (35)	48 (44)	270 (246)
3 standees/m2	98 (97)	108 (107)	628 (622)
4 standees/m2	117 (117)	129 (129)	750 (750)
6 standees/m2	157 (159)	169 (171)	990 (1002)
Operation	Automatic Train Operation (ATO) with a train operator		
Performance	Maximum operation speed: 80 km/h		
	Acceleration: 3.5 km/h/s (0.97 m/s^2) at ATO mode		
	Deceleration: 3.5 km/h/s (0.97 m/s^2) at ATO mode		
	Maximum service deceleration: 4.0 km/h/s (1.11 m/s^2)		
	Maximum emergency deceleration: 4.5 km/h/s (1.25 m/s^2)		
	Maximum jerk rate: 0.75 m/s^3		
Minimum curve radius	Horizontal: 100 m at main line, 50 m at depot, Vertical: 1000 m		
Maximum gradient	60 ‰		
Car structure	Light alloy welding, fire-resistant		
Seat arrangement	Semi-cross seat type (or Long seat type)		
Door for passengers	2 doors / one side / car Opening width: 1300 mm, Opening height: 1850 mm		
Emergency door	1 door at center of cabin end		
Bogie	Biaxial, bolster-less, welded steel construction		
	Hydraulically driven disc brake		
	Running wheel: Tubeless rubber tire with Nitrogen gas		
	Guiding wheel and Stabilizing wheel: Rubber tire		
Traction power	DC 1500V		
Traction motor	Three phase squirrel-cage induction motor 110kW		
Traction control	VVVF inverter control (with regenerative brake) 2 traction motors / 1 controller		
Auxiliary power supply	Static Inverter 120 kVA		
Brake	Electric command electro-pneumatic brake with regenerative brake		
	Interlocked with ATP/ATO device, load compensating device		
Air condition Unit	Roof-Mounted type, 18.6 kW (16,000 kcal/ hour) x 2 / car		

Note: The data indicated in ( ) (brackets) are for Long seat type while data indicated without brackets are for Semi-cross seat type.
Source: JICA Study team

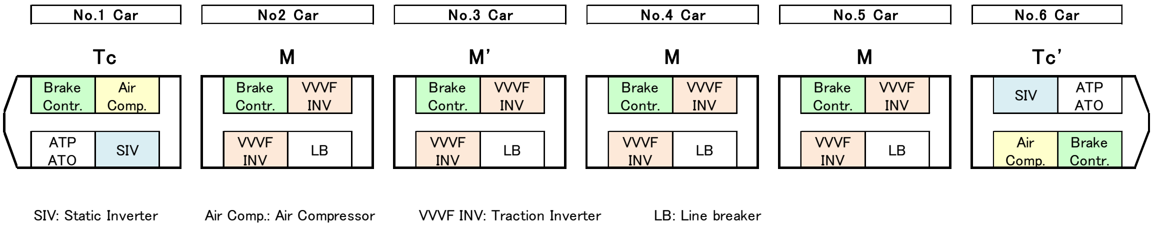
7.2.3 RAMS

(1) Standards and Criteria

Vehicles shall be designed and manufactured in accordance with international standards (IEC, EN, BS and JIS). Some provisions of these standards can be also used as guidelines for universal design.

(2) Redundant System Design

As shown in Figure 7.3, there are four intermediate motor cars. The main traction circuit is configured in a manner so that each car shall be controlled independently. One VVVF inverter controls two induction motors. If one inverter system is disabled, "High Acceleration Mode" is selected so that output from the active traction systems compensates the disabled traction capability as much as possible. The train is then driven at a higher traction capability than normal by the remaining traction system in order to minimize train delay.



Source：JICA Study Team

Figure 7.3 Arrangement of Major Equipment

Under "High Acceleration Mode", a train can also be used to push or pull a disabled train to the nearest station even in the steepest section, which will prevent disabled trains from being stationary for a long time in the section between stations.

(3) Evacuation Methods in Emergency

In case that a monorail becomes immovable due to certain causes, another monorail nearby will rescue the passengers. If monorails near the stopped monorail are full with passengers, a monorail unloads passengers at the nearest station and goes to rescue the stopped monorail. An emergency door is installed at the front of the head car to enable passenger transfer to a rescue train.

(4) Anti-fire Measurements

Incombustible material or flame retardant material shall be used for the parts, equipment and facilities of the cars, even for textile material, in order to resist burning and prevent a fire from spreading.

In case a fire occurs, the method of train operation shall depend on the distance to the nearest station. If a fire is detected when a train is about to leave a station, it must be stopped immediately. If the fire is detected while a train running between stations, the train shall keep running and stop at the next station.

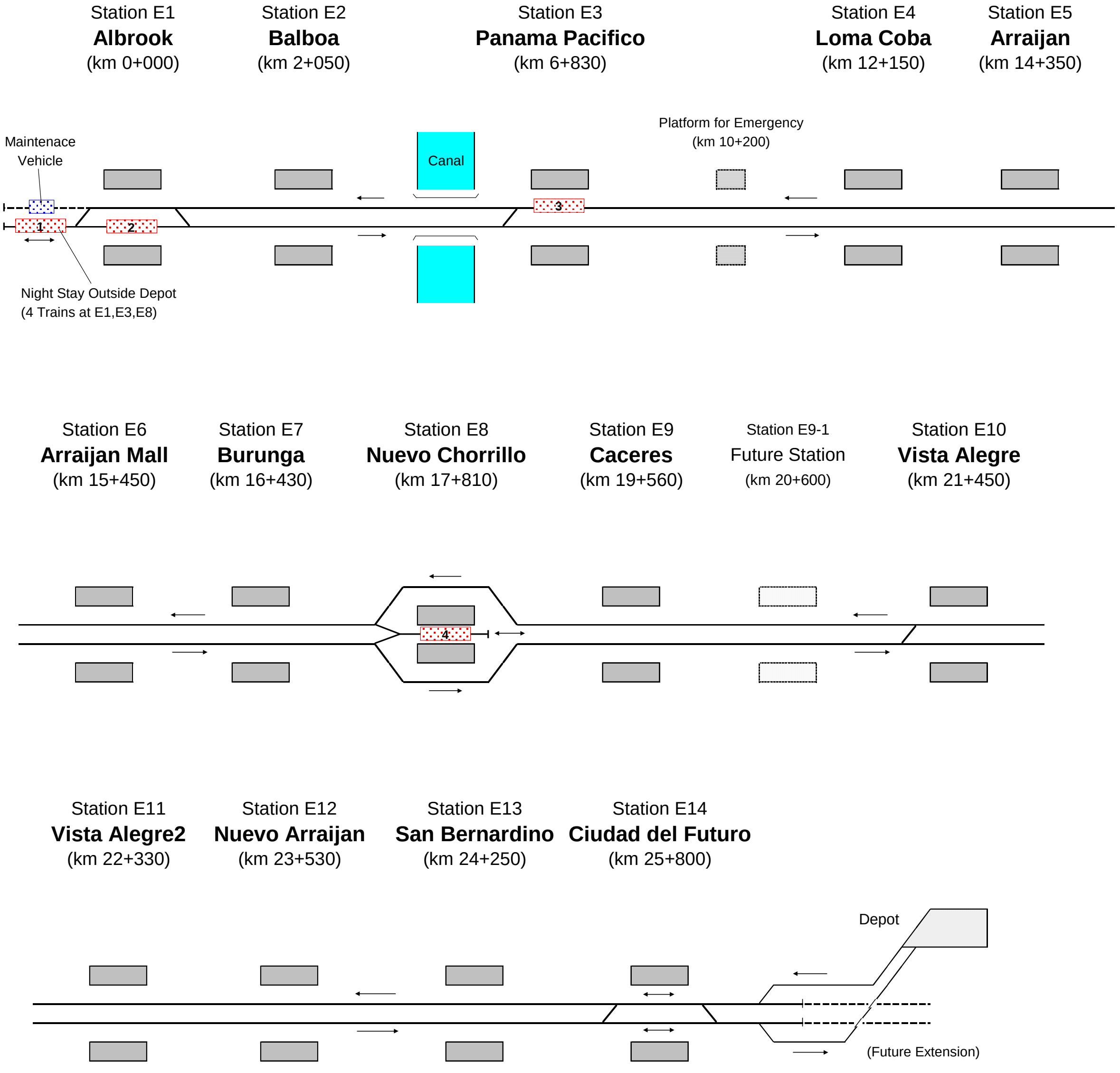
Although some railway systems are equipped with pass-through doors to prevent fire spread, pass-through doors will not be used for Line-3 because it is rather better to enable easy movement to other cars if the anti-fire measurement mentioned above is applied.

7.3 Train Operation Plan

7.3.1 Preconditions of Examination

(1) Track Layout Plan at Stations

Figure 7.4 illustrates the schematic track layout for the Phase 1 section of Line 3. The line is planned to be approx. 25.8km in length with 14 stations (one additional station in the future). Although the average distance between stations is approx. 2.0km, there is a significant difference between the east and west sections with Arraijan (E5) as the boundary. The average distance between stations is approx. 3.6 km in the east section (Albrook side) and approx. 1.3 km in the west section (Ciudad del Futuro side).



Source: JICA Study Team

Figure 7.4 Track Layout Plan at Stations of Line 3 (Phase 1)

(2) Train Configuration and Operation Performance

In case that the target transport volume is 25,000 passengers per hour per direction (full development case), the average number of passengers per square will be 4.04 with 33 trains per hour by applying 6-car composition.

(3) Required Train Operation Time and Commercial Speed

The required train running time for the whole route is 39 minutes 50 seconds including dwell time at the intermediate stations (30 seconds as a standard), 25 minutes 20 seconds in the east section (Albrook - Nuevo Chorrillo), and 14 minutes 30 seconds in the west section (Nuevo Chorrillo - Ciudad del Futuro).

The commercial speed is 38.9 km/h for the whole route, 42.2km/h in the east section, and 33.1km/h in the west section. The speed in the east section is approx. 9km/h faster than the speed in the west section due to the longer distance between stations.

Table 7.2 Required Train Operation Time and Commercial Speed (After 2025)

		Section Length (km)	Average Distance between Stations (km)	Train Operation Time (min:sec)			Commercial Speed (km/h)
				Running Time	Dwell Time	Total	
Whole Route (E1-E14)		25.80	2.0	33:50	6:00	39:50	38.9
	East Section (E1-E8)	17.81	2.5	21:50	3:30	25:20	42.2
	West Section (E8-E14)	7.99	1.3	12:00	2:30	14:30	33.1

Note:
1. The travel time for each interval between stations is rounded up to 5 seconds from simulation results.
2. Dwell time is set at 30 seconds as a standard, but it is set at 50 seconds at E1 where many passengers alight at the morning peak hour with reference to examples of Japanese subway. (Dwell time at E1 is excluded from the calculation of commercial speed because Albrook station is the final stop.)
3. Station No. E1 is Albrook, E8 is Nuevo Chorrillo, and E14 is Ciudad del Futuro.
Source: JICA Study Team

7.3.2 Train Operation Plan

(1) Train Operation Pattern

The demand forecast shows that the PHPDT increases station by station in the shape of stairs and that there is a comparatively large difference in passengers at the section between Nuevo Chorrillo (E8) and Arraijan Mall (E6). Therefore, to appropriately cope with this tendency and implement efficient train operation, this study recommends that a part of the fleet departing from Albrook station turn back at Nuevo Chorrillo station. The reason for setting Nuevo Chorrillo as a turn back station is that there are residences concentrated around this station making it suitable as a turn back station.

(2) Train Operation Plan at Peak Hour

Train frequency at peak hour is calculated by dividing the PHPDT by the train capacity (990 passengers/train). Train capacity can be obtained from train configuration (6-car train) and the average number of standees (6 standees/m^2 as a standard and 4 standees/m^2 in the less congested west section).

The train frequency (trains per hour) in east section is calculated at 18 (3.33 minutes headway) in 2020, and 22 (2.73 minutes headway) in 2050, which that in the west section is

11 (5.45 minutes headway) in 2020 and 12 (5 minutes headway) in 2050.

Table 7.3 Calculation of Train Operation Plan at Peak Hour (East and West Section)

Section	Item	Unit	Year / Formula	2020	2025	2030	2035	2040	2050	Remarks
East Section (E1-E8)	Peak Demand per Hour	Persons/Hour･Direction	a1	17,763	18,757	19,440	20,060	20,604	21,766	Between E4 and E3 (Eastbound Train)
	Train Composition *1	Cars/Train	b1	6	6	6	6	6	6	
	Target Standees/m2	Persons/m2	c1	6	6	6	6	6	6	
	Train Capacity *1	Persons/Train	d1	990	990	990	990	990	990	
	Required Train Operation Frequency	Trains/Hour･Direction	e1=a1/d1	18	19	20	21	21	22	
	Set Train Operation Frequency	Trains/Hour･Direction	f1	18	19	20	21	21	22	
	Train Operation Headway	min.	g1=60/f1	3.33	3.16	3.00	2.86	2.86	2.73	
	Calculated Standees/m2	Persons/m2	h1	5.95	5.95	5.82	5.69	5.90	5.97	Between E5 and E1 higher than 5.0
West Section (E8-E14)	Peak Demand per Hour	Persons/Hour･Direction	a2	10,136	10,631	10,789	10,957	11,069	11,423	Between E9 and E8 (Eastbound Train)
	Train Composition *1	Cars/Train	b2=b1	6	6	6	6	6	6	
	Target Standees/m2	Persons/m2	c2=c1	6	6	6	6	6	6	
	Train Capacity *1	Persons/Train	d2=d1	990	990	990	990	990	990	
	Required Train Operation Frequency	Trains/Hour･Direction	e2=a2/d2	11	11	11	12	12	12	
	Set Train Operation Frequency	Trains/Hour･Direction	f2	11	11	11	12	12	12	
	Train Operation Headway	min.	g2=60/f2	5.45	5.45	5.45	5.00	5.00	5.00	
	Calculated Standees/m2	Persons/m2	h2	5.41	5.78	5.90	5.34	5.41	5.66	Between E10 and E8 higher than 4.0

Notice(*1): 6car-Train=Tc-M-M-M-M-Tc
Car Capacity (persons Tc/M) 4 Standees/m2=117/129, 5 Standees/m2=137/149, 6 Standees/m2=157/169

Source: JICA Study Team

(3) Calculation of the required Number of Train-sets/Cars

The required number of cars is calculated from the round-trip time at peak hour. The required number of train-sets and cars is 26 train-sets (156 cars) in 2020 (not commenced E6, E9 and E13), 29 train-sets (174 cars) in 2025 (commenced all 14 stations), and 32 train-sets (192 cars) in 2050, as shown in Table 7.4. Because transport demand is high in year 2020, a relatively large number of cars is necessary from the commencement of train services.

Table 7.4 Calculation Result of the required Number of Train-sets/Cars

Operation Pattern	Item	Unit	Year / Formula	2020	2025	2030	2035	2040	2050
Whole Route Operation (E1-E14) (25.80km)	Operation Length (1 Direction)	km/Direction	a1	25.80	25.80	25.80	25.80	25.80	25.80
	Train Operation Frequency	Trains/Hour･Direction	b1	11	11	11	12	12	12
	Train Operation Headway	min.	c1=60/b1	5.45	5.45	5.45	5.00	5.00	5.00
	Roundtrip Time	min.	d1	84.5	89.7	89.7	89.7	89.7	89.7
	Number of Trains for Operation	Trains	e1=d1/c1	16	17	17	18	18	18
Eastern Part Operation (E1-E8) (17.81km)	Operation Length (1 Direction)	km/Direction	a2	17.81	17.81	17.81	17.81	17.81	17.81
	Train Operation Frequency	Trains/Hour･Direction	b2	7	8	9	9	9	10
	Train Operation Headway	min.	c2=60/b2	8.57	7.50	6.67	6.67	6.67	6.00
	Roundtrip Time	min.	d2	59.2	60.7	60.7	60.7	60.7	60.7
	Number of Trains for Operation	Trains	e2=d2/c2	7	9	10	10	10	11
Total Number of Trains/Cars	for Operation	Trains	e=e1+e2	23	26	27	28	28	29
	for Spare	Trains	f	3	3	3	3	3	3
	Total Number (Trains)	Trains	g=e+f	26	29	30	31	31	32
	Train Composition	Cars/Train	h	6	6	6	6	6	6
	Total Number (Cars)	Cars	i=g*h	156	174	180	186	186	192

Note: 1.Number of Spare Train-sets are set to 3, each 1 Train-set for sudden breakdown, monthly inspection, and overhoul or renewal.
2.Stations E6, E9 and E13 will be commenced in 2025. Train running time (including dwell time) before 2024 will be shorter than after 2025 by 2min35sec for whole route and 45sec for eastern part.

Source: JICA Study Team

(4) Train Operation Frequency for the Whole Day

Train operation frequency for the whole day is computed in Table 7.5 considering train frequency at the morning peak hour (6:00-7:00) and operation of cars. Commercial operating hours are from 5 a.m. to 24 p.m. (19 hours), and the total train-trips of the two operation patterns for the whole day per direction is 211 trains in 2020, and 244 trains in 2050.

Table 7.5 Train Operation Frequency/Headway of a Whole Day (2020-2050)

Year	2020				2025				2030				2035				2040				2050			
Item	Train Operation Frequency (trains/hour/direction)			Total Headway (min)	Train Operation Frequency (trains/hour/direction)			Total Headway (min)	Train Operation Frequency (trains/hour/direction)			Total Headway (min)	Train Operation Frequency (trains/hour/direction)			Total Headway (min)	Train Operation Frequency (trains/hour/direction)			Total Headway (min)	Train Operation Frequency (trains/hour/direction)			Total Headway (min)
Hour	Whole Route (E1-E14)	Eastern Part (E1-E8)	Total		Whole Route (E1-E14)	Eastern Part (E1-E8)	Total		Whole Route (E1-E14)	Eastern Part (E1-E8)	Total		Whole Route (E1-E14)	Eastern Part (E1-E8)	Total		Whole Route (E1-E14)	Eastern Part (E1-E8)	Total		Whole Route (E1-E14)	Eastern Part (E1-E8)	Total	
5-6	9	5	14	4.29	9	5	14	4.29	9	6	15	4.00	9	6	15	4.00	9	6	15	4.00	10	6	16	3.75
6-7	11	7	18	3.33	11	8	19	3.16	11	9	20	3.00	12	9	21	2.86	12	9	21	2.86	12	10	22	2.73
7-8	9	5	14	4.29	9	5	14	4.29	9	6	15	4.00	9	6	15	4.00	9	6	15	4.00	10	6	16	3.75
8-9	9	5	14	4.29	9	5	14	4.29	9	6	15	4.00	9	6	15	4.00	9	6	15	4.00	10	6	16	3.75
9-10	6	3	9	6.67	6	3	9	6.67	6	4	10	6.00	6	4	10	6.00	6	4	10	6.00	6	5	11	5.45
10-11	6	3	9	6.67	6	3	9	6.67	6	4	10	6.00	6	4	10	6.00	6	4	10	6.00	6	5	11	5.45
11-12	6	3	9	6.67	6	3	9	6.67	6	4	10	6.00	6	4	10	6.00	6	4	10	6.00	6	5	11	5.45
12-13	6	3	9	6.67	6	3	9	6.67	6	4	10	6.00	6	4	10	6.00	6	4	10	6.00	6	5	11	5.45
13-14	6	3	9	6.67	6	3	9	6.67	6	4	10	6.00	6	4	10	6.00	6	4	10	6.00	6	5	11	5.45
14-15	6	3	9	6.67	6	3	9	6.67	6	4	10	6.00	6	4	10	6.00	6	4	10	6.00	6	5	11	5.45
15-16	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	5	13	4.62
16-17	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	5	13	4.62
17-18	9	5	14	4.29	9	5	14	4.29	9	6	15	4.00	9	6	15	4.00	9	6	15	4.00	10	6	16	3.75
18-19	9	5	14	4.29	9	5	14	4.29	9	6	15	4.00	9	6	15	4.00	9	6	15	4.00	10	6	16	3.75
19-20	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	5	13	4.62
20-21	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	4	12	5.00	8	5	13	4.62
21-22	6	3	9	6.67	6	3	9	6.67	6	4	10	6.00	6	4	10	6.00	6	4	10	6.00	6	5	11	5.45
22-23	5	2	7	8.57	5	2	7	8.57	5	3	8	7.50	5	3	8	7.50	5	3	8	7.50	5	3	8	7.50
23-24	4	1	5	12.00	4	1	5	12.00	4	1	5	12.00	4	1	5	12.00	4	1	5	12.00	4	1	5	12.00
TOTAL	139	72	211		139	73	212		139	87	226		140	87	227		140	87	227		145	99	244	

Grounds of Basic Design:
5- 6 (Starting/Morning Transition) = Average of Morning Peak and Daytime
6- 7 (Morning Peak) = Transport Peak Demand by Suitable Frequency (within Target Standees/m2)
7- 9 (Morning Transition) = Average of Morning Peak and Daytime
9-15 (Daytime) = Half of Morning Peak
15-17 (Evening Transition) = Average of Daytime and Evening Peak
17-19 (Evening Peak) = Same to Morning Transition
19-21 (Evening Transition) = Average of Daytime and Evening Peak
21-22 (Night Time) = Same to Daytime
22-23 (Late Night) = Average of Night Time and Midnight
23-24 (Midnight) = Indispensable Service Level (Every 10-20 min.)

Notice:
1.In calculation of train operation frequency, headway will be rounded for the purpose of easy understanding for passengers.
2.Train operation frequency in each service hour may increase depending on actual rostering requirements.

Source: JICA Study Team

7.4 Civil Structure

7.4.1 Basic policy

The basic policy for the design of civil structure is follows:

- In general, the design shall be in accordance with ASTM, AASHTO and JIS standards
- Panamanian standards should be taken into account where applicable
- The design shall provide access-friendly stations for all users
- The design shall have an attractive appearance for users and society

7.4.2 Applicable Design Standards

The following design standards will be applied for the design of civil structure.

Geometric Design	• MLIT - Structure design standard for urban monorail
Geo Technical Investigation	• ASTM D1586 - Soil Standard Penetration Test SPT • AASHTO M145 – Soil sampling and classification test method
Earthworks	• AASHTO T 27 - Maximum particle size • AASHTO T 90 - Plasticity Index • AASHTO T 180 - Density Moisture Relationship • AASHTO T 193 - Laboratory CBR • AASHTO T 193 - Penetration test • AASHTO T 191 - Field Moisture Content • AASHTO T 191 - Field Density
Foundation	• ASTM D1143- Piles, Static load • ASTM C-39 Compressive Strength Tests on cylinders • Cements for structural concrete works shall be Portland cements which comply with JIS R 5210, ASTM C 150, AASHTO M 85 or equivalent and Portland Cement Type I which complies with ASTM C150 or equivalent • ASTM D4945 Dynamic load test for piles method
Concrete Structure	• The materials and workmanship used in the manufacture of concrete shall be in accordance with JIS A 1101, ASTM C 143, AASHTO T 119, JIS A 1108, ASTM C 39, ASSHTO T 22, ACI 214, JIS A 1132, ASTM C 31, AASHTO T 23, JIS A 1105, ASTM C 87, AASHTO T 71, ASTM C-150, ASTM C-1077, ASTM -94 C and ASTM C-33 or approved equivalent international standards as appropriate for concrete works, and as modified by this Specification.
Steel Structure	• Steel reinforcement used in structural concrete shall conform with the requirements of JIS G 3112, ASTM A615, AASHTO M 31, and ACI 408.1 R.
Barrier Free Design	• “Decreto Ejecutivo N°88 de 12 de noviembre de 2002”, (Law N°42 of August 27, 1999)

7.5 Guideway Structures

7.5.1 Super Structure

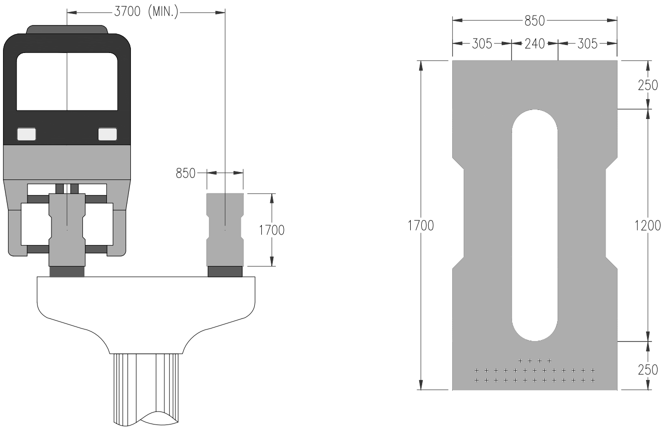
Monorail girders are classified in the following four types, among which the appropriate girder structure is selected based on the span.

1) Short Span (Span length: ~10m): Reinforced concrete girder

2) Standard Span (Span length: 22~30m): Pre-stressed concrete girder

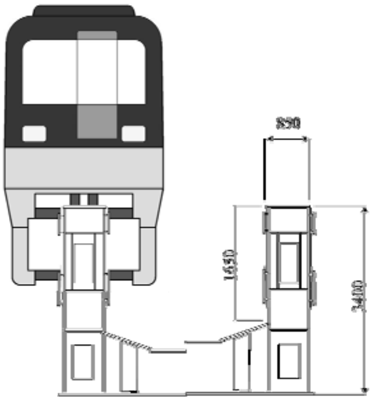
3) Middle Span (Span length: 30m~80m): Steel Girder Bridge

4) Long Span (Span length: 80m~): Steel Arch Bridge and etc.



Source: JICA Study Team

Figure 7.5 Cross Section of pre-stressed concrete girder (L=25m)

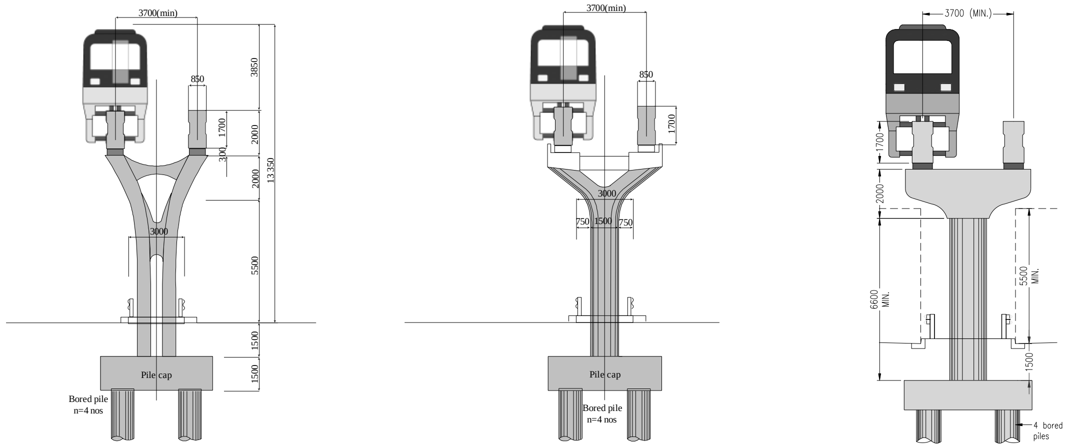


Source: JICA Study Team

Figure 7.6 Cross Section of Steel Girder Bridge (L=50m)

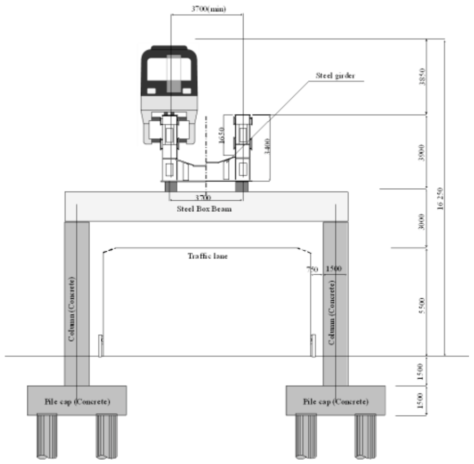
7.5.2 Substructures

The structural requirement of monorail columns, depending on the height, is approximately 1.40m to 2.15m diameter in the case of circular piers, which are easily accommodated in the central median of the road. Typical cross sections of monorail piers are shown in Figure 7.7, Figure 7.8.



Source: JICA Study Team

Figure 7.7 Typical Cross Section of Monorail Piers



Source: JICA Study Team

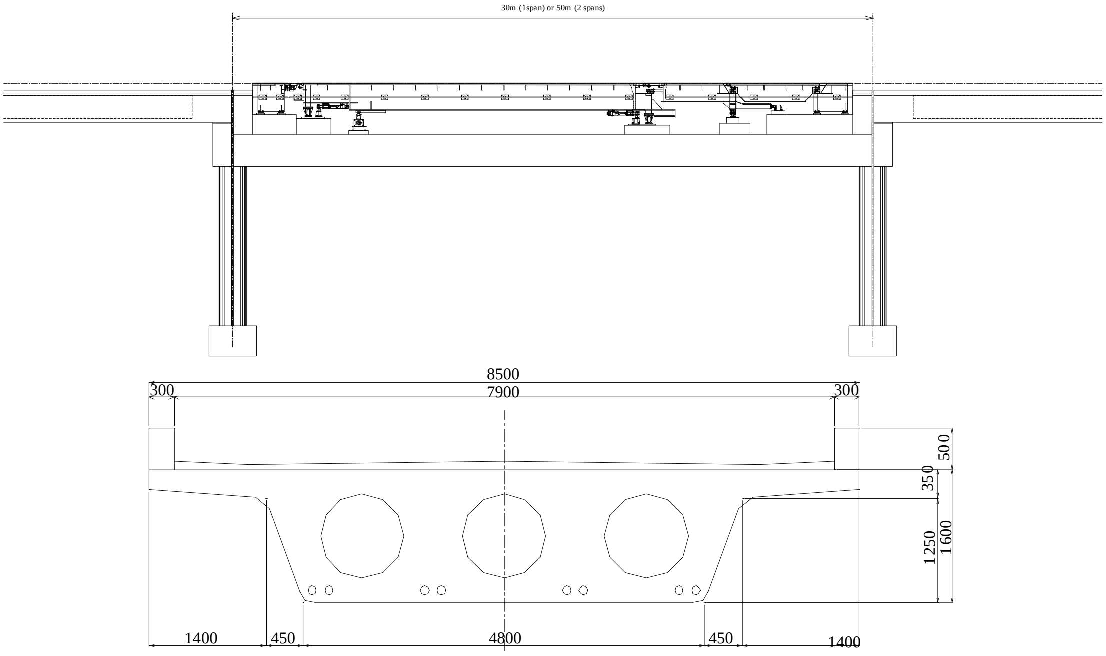
Figure 7.8 Typical Cross Section of a Monorail Viaduct Portal Type Pier

7.5.3 Foundation

To decide on the type of foundation and its depth, a geotechnical survey was carried out along the route alignment. It is expected that all structures will need to be supported by pile foundation. The depth of the bearing layer from the ground level is expected to be from 10m to 30m as shown in Chapter 5. The proposal is to provide 1000/1200/1500 mm dia. bored cast in situ vertical piles. A pile cap approximately 1.4 to 1.8 m thick will be cast over the piles. The pile cap will be kept a minimum of 1500mm below the road level or ground level.

7.5.4 Switch Bridges

Switches and their equipment are installed on the switch bridges. Pre-stressed concrete slab structure shall be applied for the switch bridge.



Source: JICA Study Team

Figure 7.9 Profile and Cross Section of a Monorail switch bridge

7.5.5 Other facilities on the track

(1) Anti-slip surface on the girder

To prevent the tires from slipping on the surface of the steel girder, usage of steel plates with grooves or slip resistance coating will be applied. A steel plate with grooves increases friction between the rubber tire and the surface of the girder by making grooves on the surface, while slip resistance coating increases the friction by coating epoxy resin mortar with silica sand.

(2) Bearing system and expansion joints

The bearing system for the non-continuous track beam will be resistant to vertical, horizontal and torsional reactions. Moreover, it will work smoothly against movement due to temperature differences and angular movement due to live load. The bearing design will be suitable for easy future replacement of track girders and will be adjustable for girder positioning. To provide for a smooth and comfortable ride, steel finger joints will be applied at the ends of the girders.

7.5.6 Design Loads

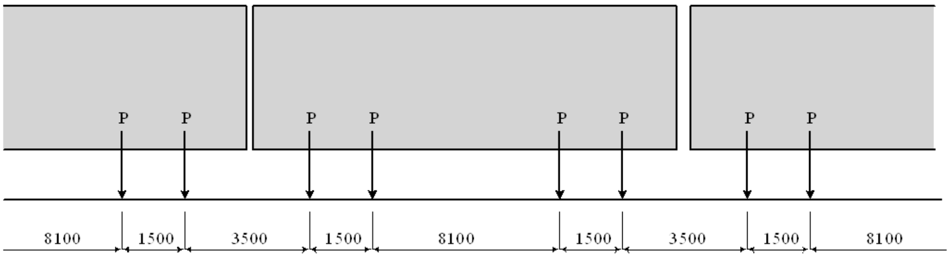
(1) Design Specifications

Specifications for the structural design shall conform to those approved by MOP for the standard design of bridges in Panama. The main design specifications to use for the structural design are presented below:

- American Association of State Highway and Transportation Officials, AASHTO LRFD Bridge Design Specifications, Third Edition, 2004.
- American Concrete Institute, ACI-318.

- American Institute of Steel Construction, AISC.
- Seismic Code for the Republic of Panama, "Reglamento de Diseño Estructural de La República de Panamá" (Regulation of Structural Design of the Republic of Panama).

The axle arrangement and the axle loads to be used for the design are presented on Figure 7.10.



Source: JICA Study Team

Figure 7.10 Axle arrangement

Table 7.6 Axle Loads

Description	P(tons)	Calculation
Crush load	11.0	= 44.0/4
Nominal load	9.0	= 35.2/4
Tare	7.0	= 27.6/4

Source: JICA Study Team

For the calculation of centrifugal and braking forces, the center of gravity of the monorail is taken as 1300 mm measured from the top of the superstructure. The centrifugal and braking forces are horizontal and are taken as a fraction of the vertical live load, as presented in AASHTO LRFD.

(2) Seismic Load

The seismic design will follow the methodology of AASHTO LRFD. The value of the coefficient of ground acceleration, A, will be taken from the seismic code of Panama; this value has a minimum of 0.15g and a maximum of 0.20g. The method of analysis for the calculation of the period of the structure to be used is the Multimode Elastic Method, taken from AASHTO. Depending on the height of the columns periods of 0.90 to 1.80 seconds and seismic coefficients of 0.31 to 0.20 are obtained from preliminary calculations.

7.6 Station

7.6.1 Station equipment

Necessary functions and equipment for a standard station of Line-3 are evaluated as shown in the table below.

Station Equipment	Application Policy to Line-3
1) Ticket window	Tickets are sold at ticket offices by station staff. The size of the ticket window to be constructed will be sufficient to accommodate an automatic ticket vending machine in the future.
2) Ticket gate	Ticket gates are installed. A fare adjustment office is not required since a flat rate fare structure is to be applied. Ticket gates will have a width of 90cm in order to allow passengers in wheelchairs or with large bags to pass through easily.
3) Station office and ticket room	A station office is installed near the entrance for station staff to work, take a rest or for standby personnel. Next to the station office is a ticket room containing both the ticket window and passenger information displays. However, at small stations a minimum sized ticket room will be installed only for the purpose of selling tickets and providing passenger information.
4) Electric and mechanical (E&M) room and signaling and telecommunication equipment (S&C) room	An electric and mechanical (E&M) room and signaling and telecommunication equipment (S&C) room are installed at the concourse level. The E&M room contains electrical equipment to distribute electric power to station facilities and lighting. The S&C room contains signaling and telecommunication equipment. A minimum sized room is installed next to the ticket room to house minimum E&M equipment.
5) Rest room	Although rest rooms are not installed in Line-1's stations, rest rooms shall be installed in major stations only in case of Line-3.
6) Ascending facilities (Elevator and Escalator)	In addition to stairs, elevators and escalators shall be installed on all types of platform.
7) Platform screen door	Platform screen doors with a height of 1.20m or more will need to be installed at the edge of the platform in order to prevent passenger falls.
8) Air conditioner and Ventilation	Not installed for the platforms
9) Substation facilities	Substations will be installed at some of the stations at the concourse level

7.6.2 Station Geometry

The dimensions of the stations for the monorail system will be determined by train length and passenger volume, and the dimensions will be arranged to take into consideration passenger convenience.

The design policy of the stations is as follows:

(1) For passenger convenience, barrier free design and universal design shall be applied;

(2) A simple structure shall be applied emphasizing the monorail’s characteristics and utilizing natural air ventilation; and

(3) Land acquisition shall be minimized by placing the monorail, as much as possible, in the central part of the existing road.

The required spaces for the stations are as follows.

(1) The minimum length of a platform will need to include the train length plus 10 meters of margin. For Line-3 a 6-car train with a length of 90m is used, thus the minimum platform length would be 100m;

(2) The effective width of a platform will be estimated on the basis of the expected passenger volume from the transport demand forecast. A minimum width of 3 m should be secured for passenger circulation; and

(3) A 6 m distance is required from the outside of a station building to allow for firefighting activity in the vicinity of the station. It is desirable to allow a gap of 10 m or more between the outside wall of the stations and the nearest buildings in order to avoid the feeling of oppression from the presence of the station building over a road in the densely urbanized sections.

7.6.3 Barrier free and universal design

The JICA Study Team recommends that some items from the Japanese standards be referred to in order to improve the accessibility of the monorail stations.

7.6.4 Structure of the stations

For the elevated stations of urban transport systems, generally a three-story building is proposed, with a platform level, concourse level and ground level (road level).

A roof is installed and fences for safety are equipped on the platform. At the platform level, passengers wait for and board trains. Also, passengers alight from trains to the platform and move to the concourse level.

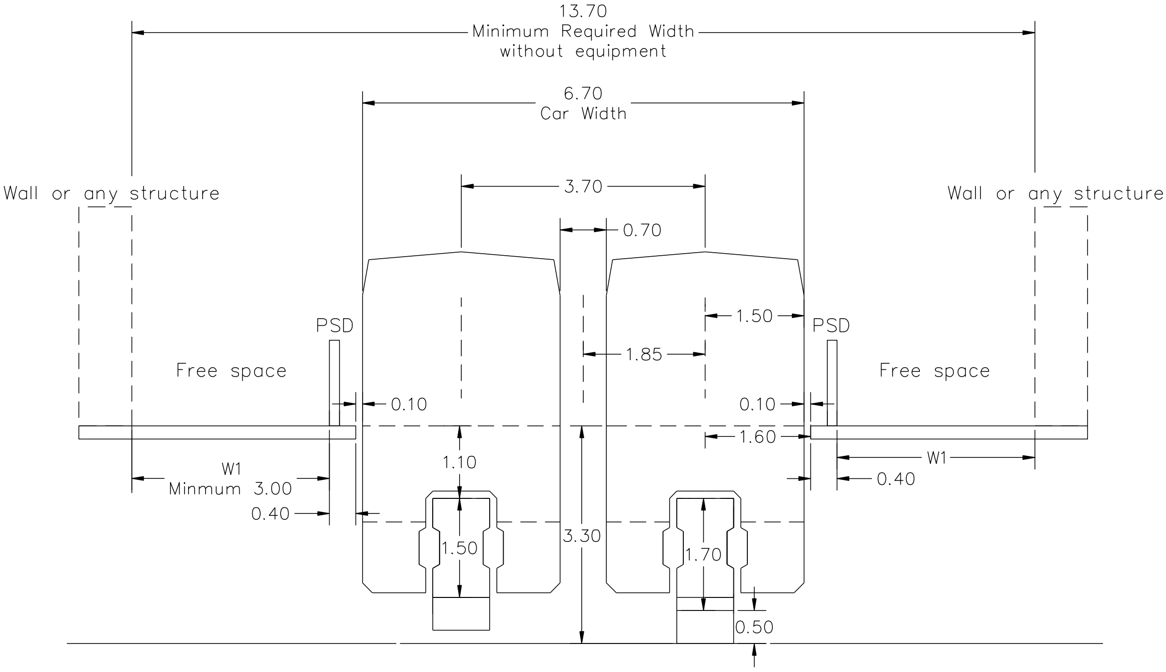
At the concourse level, passengers who will board trains buy tickets and pass through the ticket gates. If passengers need some information regarding train operation, the staff in the station office located on the concourse level will assist them.

Since all the monorail stations are elevated and most are located over a road, stairs and other means of access are provided from the ground level to the concourse. Since the station access connects both sides of the road via the concourse, it can also function as a pedestrian bridge for the general public to cross the road.

The stations are open to the air without air condition except for staff rooms.

7.6.5 Platform

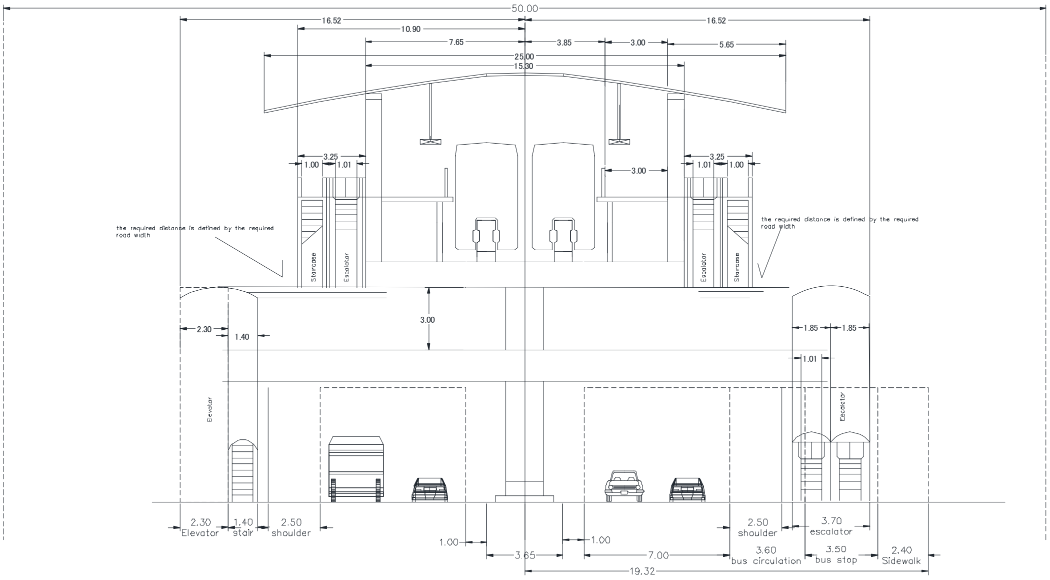
Figure below shows the cross section of the platform level of a standard station.



Source: JICA Study Team

Figure 7.11 Cross section of Station (Platform)

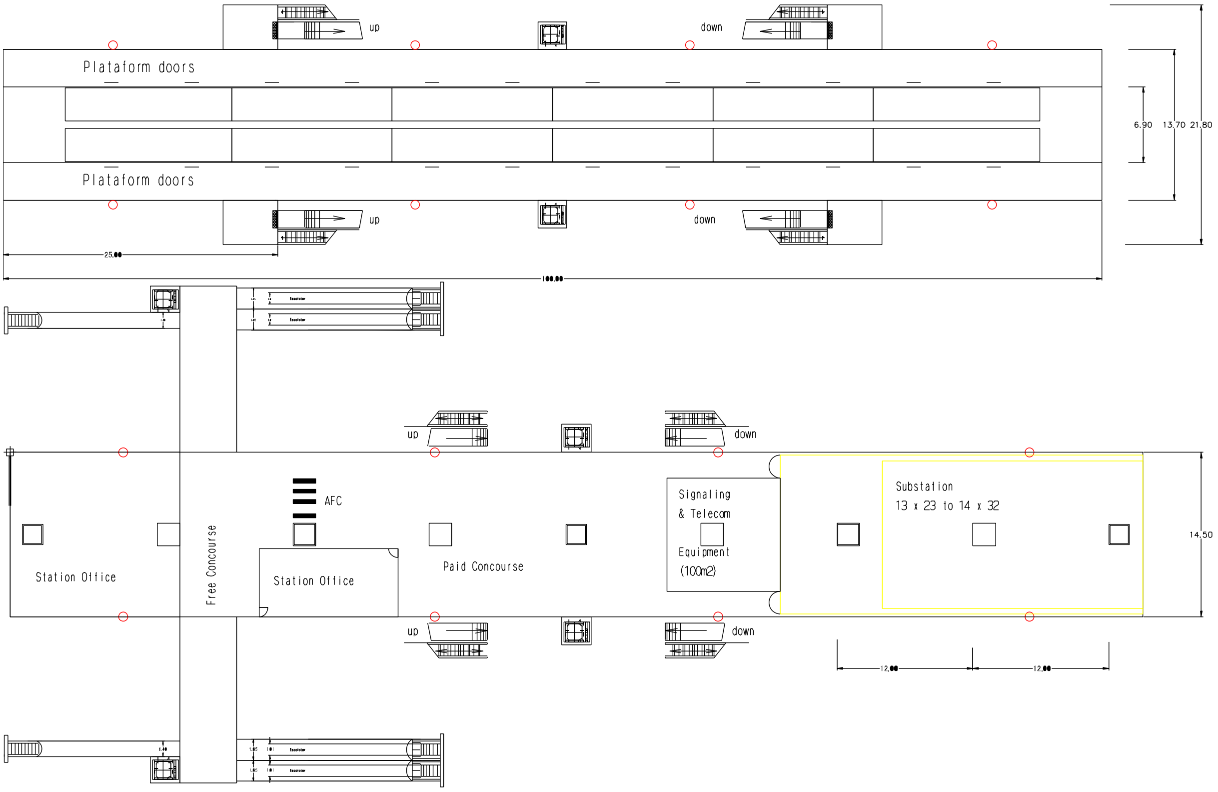
In the typical stations (all stations except Albrook and Nuevo Chorillo), w=38.64m is required in total. The total width includes width for bus stop and sidewalks. The required width for platform is w=15.3 m including column for roof, and 21.8 m in total including elevators, escalators and staircases which are attached out of platform. The stations can be constructed within the ROW of Pan American Road which has w=50 m of ROW. Figure 7.12 shows planned road cross section at station location.



Source: JICA Study Team

Figure 7.12 Road Cross Section at Station

Plan layout of stations is shown in Figure 7.13. Escalators and staircases are installed at 25 m from the edges of platform and the elevator in the middle. This layout complies with NFPA130 which is used as safety standard in Panama. Ticket window, ticket date, E&M room, signaling and telecommunication equipment room and substations are located in the concourse level. Figure 7.13 shows an example of layout with substation.



Source: JICA Study Team

Figure 7.13 Station Layout

7.6.6 Platform Screen Door (PSD)

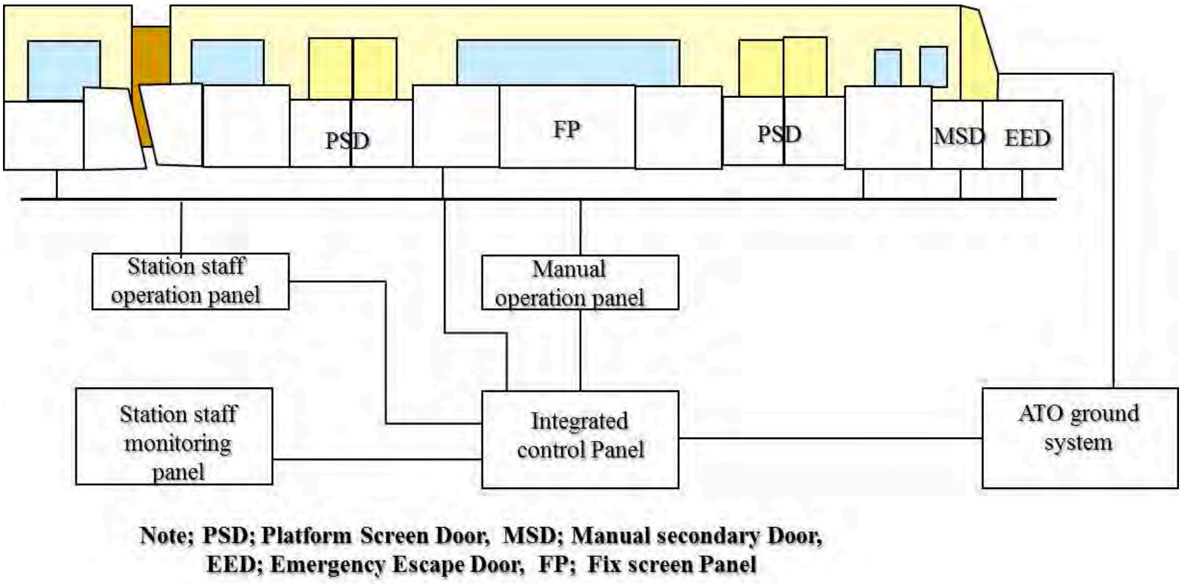
Platform screen door (PSD) systems are introduced in many urban transport systems for the following purposes:

a) To ensure passenger safety

b) To reduce unauthorized access to the trackside

c) To prevent accidental falls of passengers

d) To save station monitoring staff load



Source: JICA Study Team

Figure 7.14 Platform Screen Door System

7.6.7 Automatic Fare Collection

Line 3 system will handle a large number of passengers. Ticketing and fare collection play a vital role in the efficient and proper operation of the system enabling the correct collection of fares and preventing fare evasion. To achieve this, an Automatic Fare Collection system and a Contactless IC card system will be introduced.

For the contactless IC card system, Type-A, which is already used for Metrobus and Line-1, would be appropriate for Line-3, although the introduction of Type-C, which can be used for electric money, could be considered.

An example of the Retractable flap type Control Gates is shown by Figure 7.15.

Source: JICA Study Team

Figure 7.15 Entry/Exit Gates

The necessary number of AFC equipment at each station is calculated as shown in Table 7.7.

Table 7.7 Installation of AFC gates

Station	Board			Alight			Total No. of Gates
	To West	To East	No. of Gates	From West	From East	No. of Gates	
Albrook	2,472		1	20,582		8	10 (R)
Balboa	113	205	1	290	179	1	2
Panama Pacifico	534	392	1	309	0	1	2
Loma Coba	1	1,079	1	16	48	1	2
Arraijan	193	2,577	2	159	196	1	4
Arraijan Mall	6	1,266	1	10	77	1	2
Burunga	4	3,186	2	41	182	1	4
Nuevo Chorrilo	0	1,753	1	10	523	1	2
Caceres	0	711	1	0	180	1	2
Vista Aregre	0	3,517	2	0	345	1	4
Vista Aregre 2	0	1,367	1	0	224	1	2
Nuevo Arraijan	0	1,260	1	0	273	1	2
San Bernardino	0	2,092	1	0	402	1	2
Ciudad del Futuro		2,012	1		694	1	2

Source: JICA Study Team

7.7 Intermodal Facilities

7.7.1 Statioin Type

In order to achieve the permanent use of a monorail system, it is important to provide not only monorail service, but also adequate intermodal transfer facilities.

The following 3 types of stations are provided according to demand and the characteristics of the region.

Station Category	Characteristics
Major Interchange Station	In addition to the intermodal function, access to the business and commercial area around the station is considered.
Exchange Station	Feeder transit lines connect to the station for intermodal transfer between the monorail and the feeder transit lines.
Park & Ride Station	The station has a parking facility for Park & Ride demand.

7.7.2 Universal Design in the Intermodal Facility area

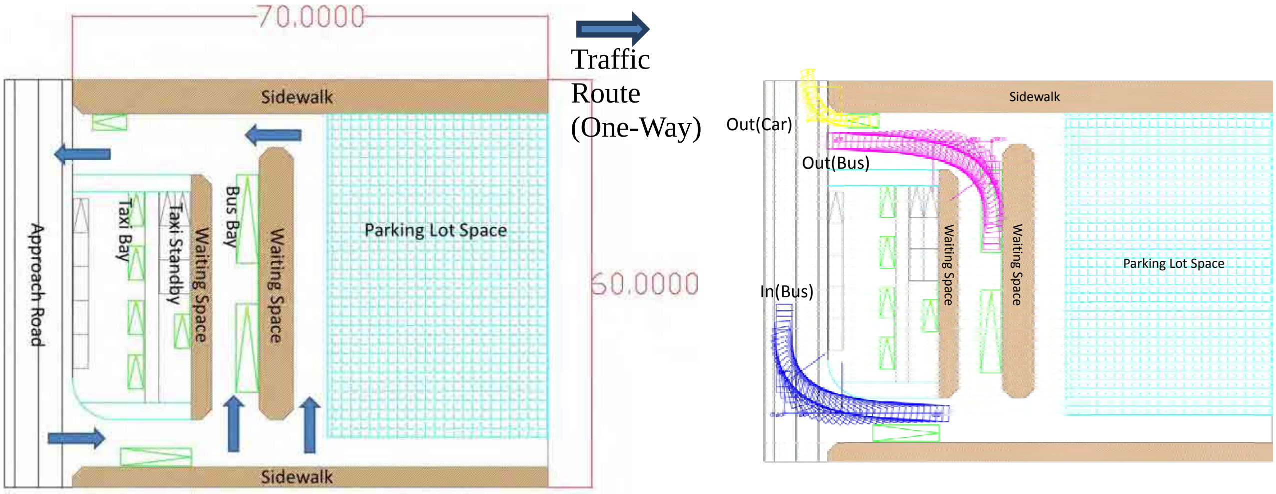
It is necessary to install not only an accessible public transportation service, but also a universal design that everyone can use. Universal design needs to be applied to not only the station's structural design, but also to the area surrounding the station. If the environment around the station gives free access to disabled people, smooth transfer from the monorail to other transportation modes can be provided in a real sense.

7.7.3 Development Approach for Intermodal Facility

(1) Example of a Major Interchange Station

As a large scale intermodal transfer point, a traffic plaza and parking are developed. The figure shows its image.

Conceptual Image



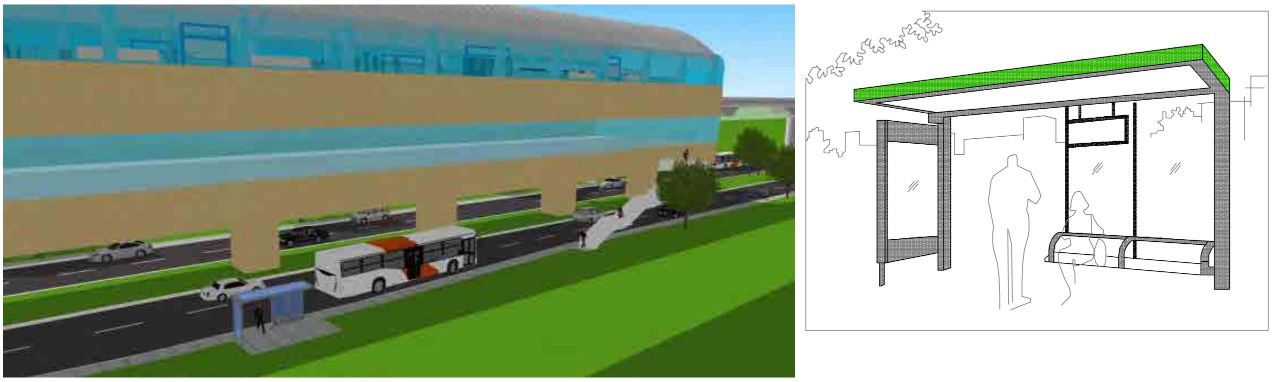
Facility Layout / Travelling Route Vehicle maneuver

Source: JICA Study Team

Figure 7.16 Representative example of Major Interchange Station

(2) Example of Exchange Station

Intermodal facilities for transferring feeder transport to monorail. Figure below shows the image.



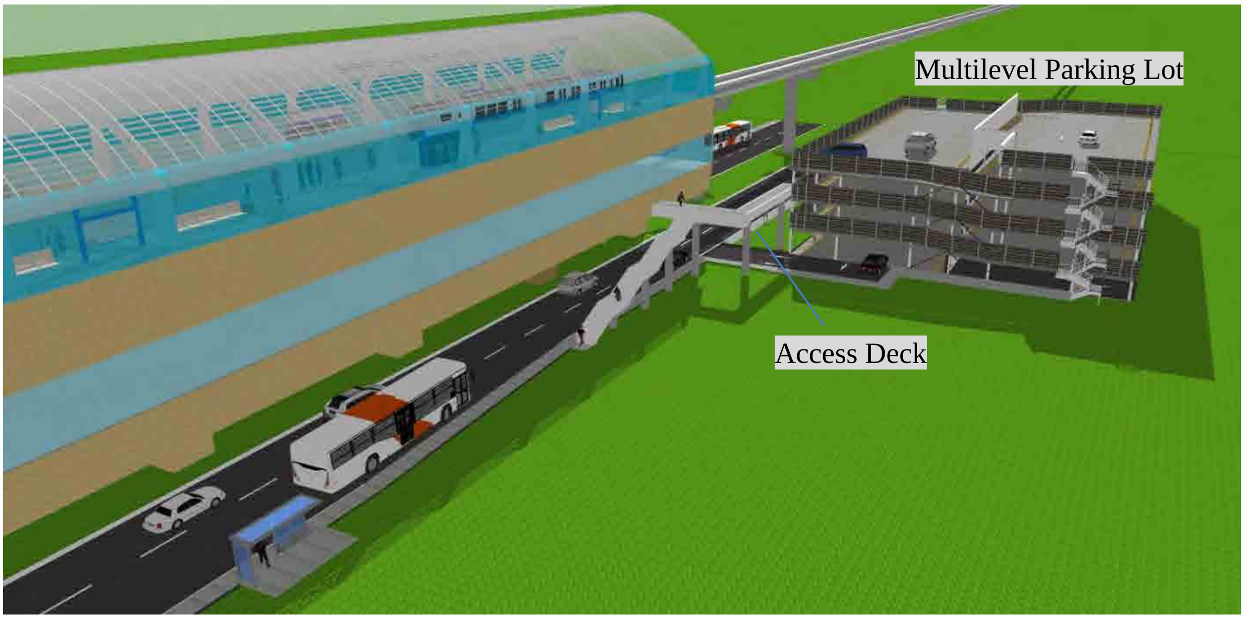
Birds-Eye View Design for Bus Stop

Source: JICA Study Team

Figure 7.17 Representative example of Exchange Station

(3) Representative example of Park and Ride Station

A large scale parking facility is provided adjoining to the station for transfer from private cars to the monorail. The image of the development is shown below.



Source: JICA Study Team

Figure 7.18 Representative example of a Park and Ride Station

(4) Land Acquisition for Intermodal Facilities

The land acquisition for the intermodal facility will only be required at the Nuevo Chorrillo Station and the Vista Alegre Station. The location of intermodal facilities at both stations is shown below.

Nuevo Chorrillo Station (3,720m^2) Vista Alegre Station (4,200m^2+Access Road)

Source: Illustrated by JICA Study Team based on Satellite Image

Figure 7.19 Target Area for Land Acquisition

The station type is set for each station. In addition, the services that are integrated in the station and the facility scale are summarized below.

Table 7.8 Proposed Plan for Intermodal Facility for each Station

Station Name	Connect to	Integration Service	Facility Scale for Intermodal
1. Albrook (0+000km) （Major Interchange Station）	➢ Integrate with MRT Line-1 and AGNT ➢ Access to Albrook Shopping Mall	● Connecting to MRT Line-1, AGNT and Shopping Mall	● Access deck to other facility
2. Balboa (2+050km) （Exchange Station）	➢ Internal Bus Traffic in Balboa area	● Normal Bus Bay	● Bus Bay (2)
3. Panama Pacific (6+650km) （Major Interchange Station）	➢ Internal Bus Traffic in Panama Pacifico and Veracurz area ➢ Taxi Service	● Bus Terminal ● Taxi Stop	● Bus Bay (3) ● Minibus Bay (2) ● Taxi Stop (8) ● Taxi Standby (58) ● Pirata Stop (3) ● Short-time Parking (8)
4. Loma Coba (12+400km) （Exchange Station）	➢ Internal Bus Traffic in Arraijan Area	● Normal Bus Bay	● Bus Bay (3)
5. Arrajian (14+350km) （Exchange Station）	➢ Access to Commercial Area(Super X-tra) ➢ Internal Bus Traffic in Burunga and Arraijan Area ➢ Taxi Service	● Normal Bus Bay ● Taxi Stop *(Sharing with Arrajian Mall)* ● Connecting Deck to commercial area	● Bus Bay (5) ● Taxi Stop (13) ● Taxi Standby (11)
6. Arrajian Mall (15+500km) （Major Interchange Station） （Park & Ride Station）	➢ Access to newly constructed shopping mall ➢ Bus Terminal ➢ Taxi Service ➢ Park & Ride	● Huge Sized Intermodal Facility ● Connecting Deck or pedestrian to commercial zone	● Bus Bay (2) ● Taxi Stop (1) ● Taxi Standby (4) ● Short-time Parking (3) ● Multilevel Parking (870)* (* Shared Use with Commercial use)
7. Burunga (16+400km) （Exchange Station）	➢ Internal Bus Traffic in Burunga Area	● Normal Bus Bay	● Bus Bay (3)
8. Nuevo Chorrillo (17+850km) （Park & Ride Station）	➢ Internal Bus Traffic in Neuvo Chorrillo ➢ Taxi Service ➢ Park & Ride	● Normal Bus Bay（Internal Bus Traffic in Nuevo Chorrillo Area） ● Park & Ride Space included Taxi Stop	● Bus Bay (2) ● Taxi Stop (7) ● Taxi Standby (12) ● Short-time Parking (3) ● Multilevel Parking (430)
9. Cáceres (19+600km) （Exchange Station）	➢ Internal Bus Traffic	● Normal Bus Bay	● Bus Bay (2)
10. Vista Alegre (21+450km) （Major Interchange Station） （Park & Ride Station）	➢ Arterious Bus Traffic from Vacamonte ➢ Taxi Service ➢ Park & Ride	● Huge Sized Intermodal Facility	● Bus Bay (2) ● Minibus Bay (1) ● Taxi Stop (13) ● Taxi Standby (8) ● Pirata Stop (3) ● Short-time Parking (3) ● Multilevel Parking (670)
11. Vista Alegre 2 (22+350km) （Exchange Station）	➢ Access to Commercial Area (Super Rey) ➢ Access to West Land Mall ➢ Internal Bus Traffic in Nuevo Arraijan Area ➢ Taxi Service	● Normal Bus Bay ● Taxi Stop ● Connecting Deck to commercial zone	● Bus Bay (2) ● Taxi Stop/Standby (5)
12. Nuevo Arrajian (23+550km) （Exchange Station）	➢ Internal Bus Traffic in Nuevo Arraijan Area ➢ Taxi Service	● Normal Bus Bay ● Taxi Stop	● Bus Bay (4) ● Taxi Stop/Standby (7)
13. San Bernardino (24+300km) （Exchange Station）	➢ Internal Bus Traffic in Nuevo Arraijan Area ➢ Taxi Service	● Normal Bus Bay ● Taxi Stop	● Bus Bay (4) ● Taxi Stop/Standby (12)
14. Ciudad del Futuro (26+100km) （Major Interchange Station） （Park & Ride Station）	➢ Internal Bus Traffic in La Chorrea ➢ Park & Ride ➢ Taxi Service	● Huge Sized Intermodal Facility	● Bus Bay (3) ● Minibus Bay (3) ● Taxi Stop (11) ● Taxi Standby (16) ● Pirata Stop (3) ● Short-time Parking (4) ● Parking (620)

Source: JICA Study Team

7.8 Depot

7.8.1 Depot Size and Location

(1) Depot Size

The depot consists of stabling tracks, maintenance workshops, car washing facilities, tire exchange facilities, etc. for stabling and maintenance of the monorail cars, an administration building housing the OCC (operation control center) for the entire Line-3, a substation, warehouse and other facilities.

The number of train sets required, based on the demand forecast up to 2050, is 26 sets in 2022 (first year of operation). Subsequently, when opening of there future station is taken into account, the number of train-sets becomes 32.. The train sets are all 6-car sets. Of these, 2 train sets will stable at Albrook Station at night, 1 train set at Panama Pacifico Station and 1 train set at Nuevo Chorrillo Station. Further, in preparation for future line extension, space will be secured in the depot for stabling tracks for an additional 10 train sets. Taking into account the space for other required facilities and equipment, the size of the land for the depot will be approximately 10 hectares.

(2) Depot Candidate Sites

The location of depot was studied among the four alternative sites as shown below and the candidate site-4 was selected as the best location. The candidate site-4 is located on the hill along Pan-American Highway to the west of Neuvo Arraijan. Although a large scale preparation of land is necessary, the site has the largest area among the alternatives.

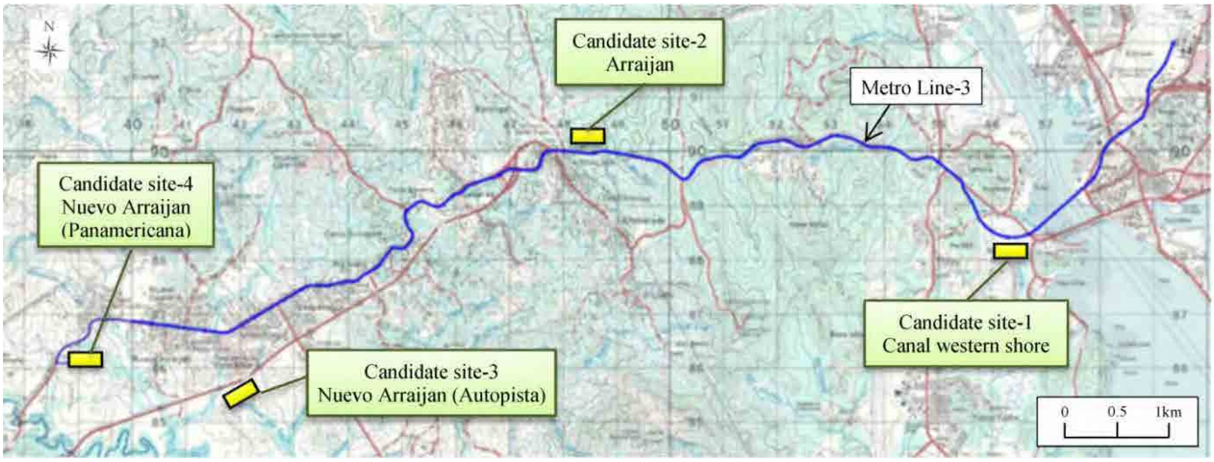
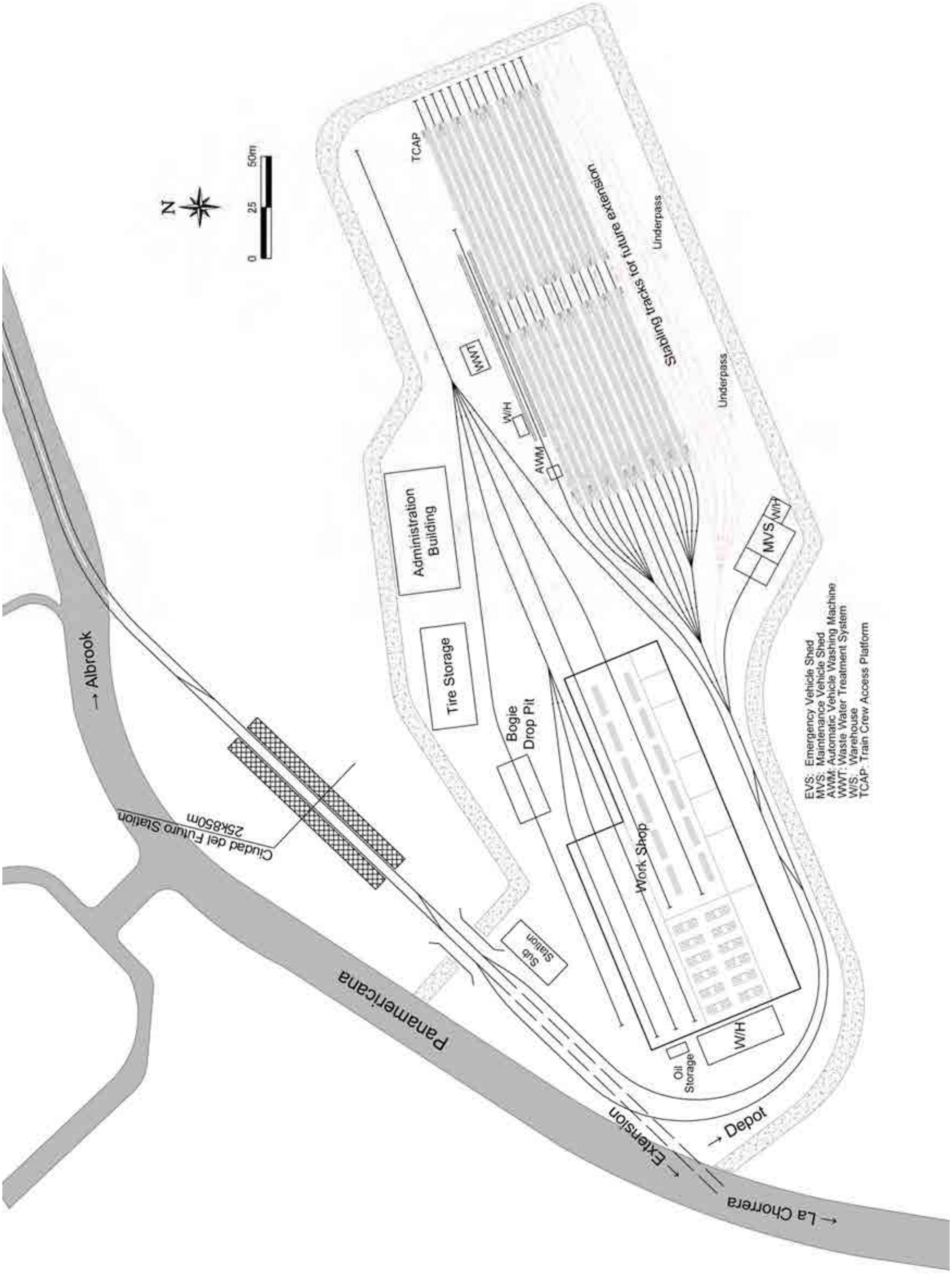


Figure 7.20 Depot Candidate Sites

7.8.2 Depot and Workshop

(1) Depot Layout

The depot layout is shown in Figure 7.21



Source: JICA Study Team

Figure 7.21 Depot Layout

(2) Workshop

Workshop layout is shown in Figure 7.22.

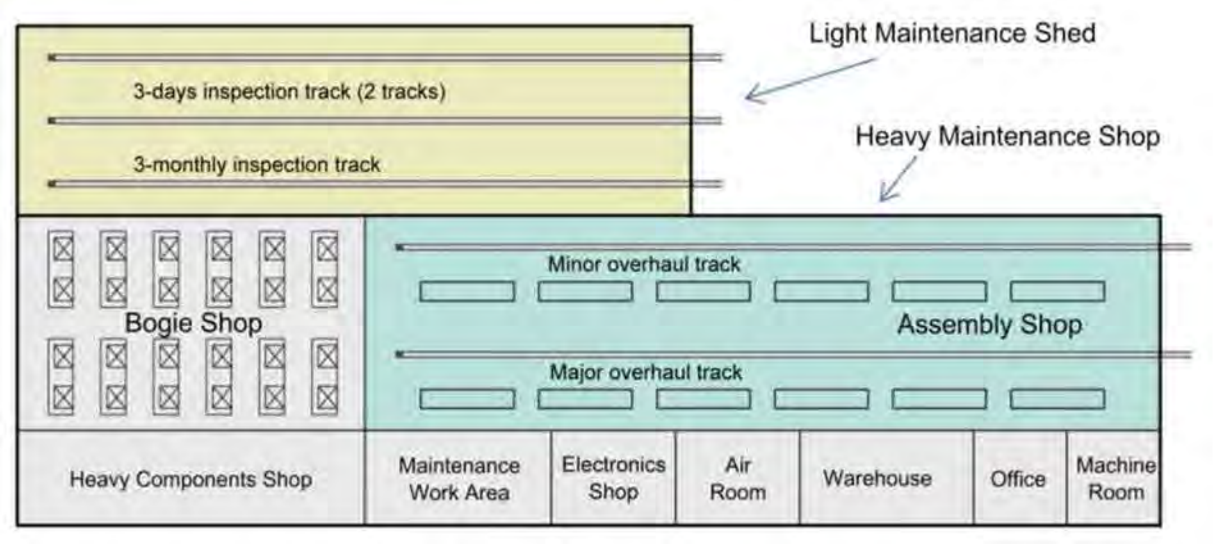


Figure 7.22 Workshop Layout

7.9 Power Supply

7.9.1 Power Supply System in Panama

(1) Present Power Supply condition in Panama

Electric power in Panama is supplied by power generation companies, a transmission system company and distribution companies. Several power generation companies generate electricity and send it to a power transmission company named "EMPRESA DE TRANSMISSION ELECTRICA, SA (ETESA)" and this company controls the nationwide transmission line system in Panama.

Power supply to public consumers is performed by two distribution companies: "ELECTRA NORTE S.A." in the eastern area of Panama City, and "GAS NATURAL FENOSA (Gas Fenosa)" in the west.

The power supply for Metro Line-3 will be done by Gas Fenosa for the whole section.

(2) Power Supply Plan for Metro Line-3

Gas Fenosa has a plan to develop a new substation in Burunga and is preparing land acquisition for the project, according to the information given in the meeting. The new substation will be directly connected to ETESA's 230kV transmission line system for 34.5kV and 13.8kV. The necessary voltage and capacity can be incorporated into the new substation. Since the construction is scheduled for 2014-2015, the substation can supply the power to Line-3 from its commissioning stage.

The reliability of the power source will be high because it is directly branched from the 230kV transmission line. Power reception has four power sources with two directions (substation) and doubled lines, and the substation will be equipped with new reliable devices to provide sufficient reliability. The electric power for Metro Line-3 will be supplied by exclusive lines from this substation.

7.9.2 Transmission Line System

The Project requires large electric power. It is estimated that the power demand is 25MVA (traction power 34 MVA, utility power 6MVA) in 2020 and 30MVA (traction power 23MVA, utility power 6MVA) in 2050. The target power is set at 50MVA. Considering the power load of the Project, 34.5kV would be preferable.

The proposed transmission line structure is receiving 34.5kV at the middle point (Burunga) with two standby lines.

7.9.3 Traction Power Feeding System Plan

Power feeding to the rolling stock is performed by DC 1500V system, and the voltage range is 1900V maximum voltage and 1000V minimum voltage following the IEC limit. For the arrangement of substations, the separate system will be applied for the Project instead of the centralized system. In view of maintenance and security, all substations will be placed inside station buildings.

The selected feeding system diagram is shown in the Figure 7.24

7.9.4 Contact Line System

The feature of the contact line system is summarized below.

Sectioning devices	Connection points in front of substations, the branch point to the depot, and the point to the 4th Bridge where sectioning devices are necessary for operation
Voltage	1500V (max=1900V, min=1100V)
Contact line type	Independent, ridged, two contact line, side friction type T-shaped trestle (section area = 2200mm^2) Trolley wire (section area = 170mm^2, resistance=0.027Ω)
Maximum current	1-hour average maximum = 2700A Instantaneous maximum = 6700A
P-side contact line protective board	Install at front of platform, turnout support, and the places where the height from the ground is not sufficient
Car body earthing plate	Install over the N-side conductor of the track beam and platform
Lighting arrester	Install at draw out points of substations, the branching point, and contact lines 4 sets (2-sets each for P and N contact lines) in an earthed case Ratings: 1500V for the P-side and 600V for the N side 500m interval along the main line

7.9.5 Utility Power supply

Utility power is supplied to each station and the depot with 13.8kV AC from the secondary line's side of the distribution transformers that are installed in the traction substations.

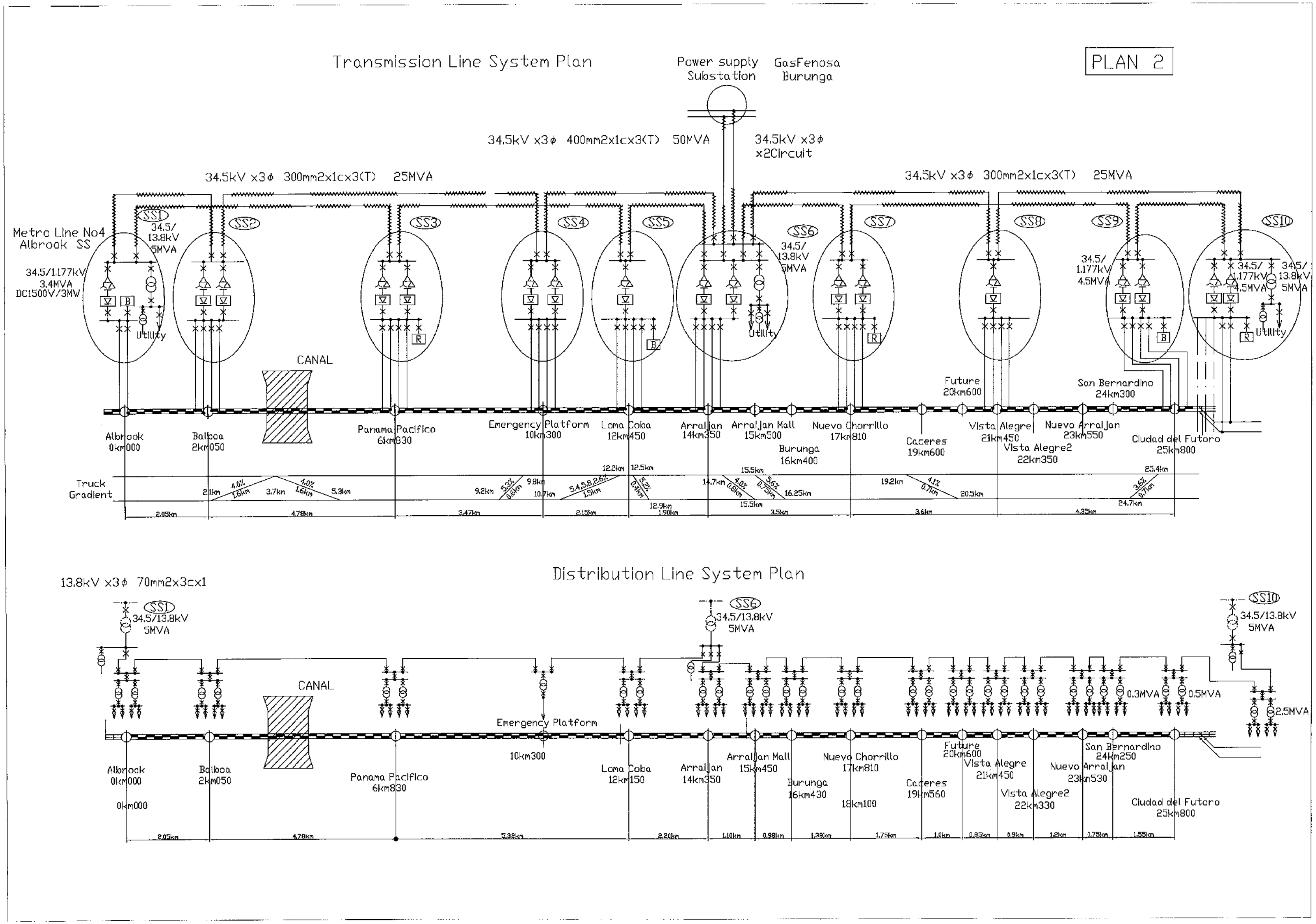
Distribution transformers area placed at both sides and the middle (SS5) of the main line, totaling three distribution transformers. (See Figure 7.23, the lower half of the transmission line system plan.)

As a countermeasure for the utility power stoppage, all the necessary systems have their own back-up supply system such as UPS (unstoppable power source).

The important utility power supply equipment installed in the station shall be supervised and controlled from the OCC through the P-SCADA system.

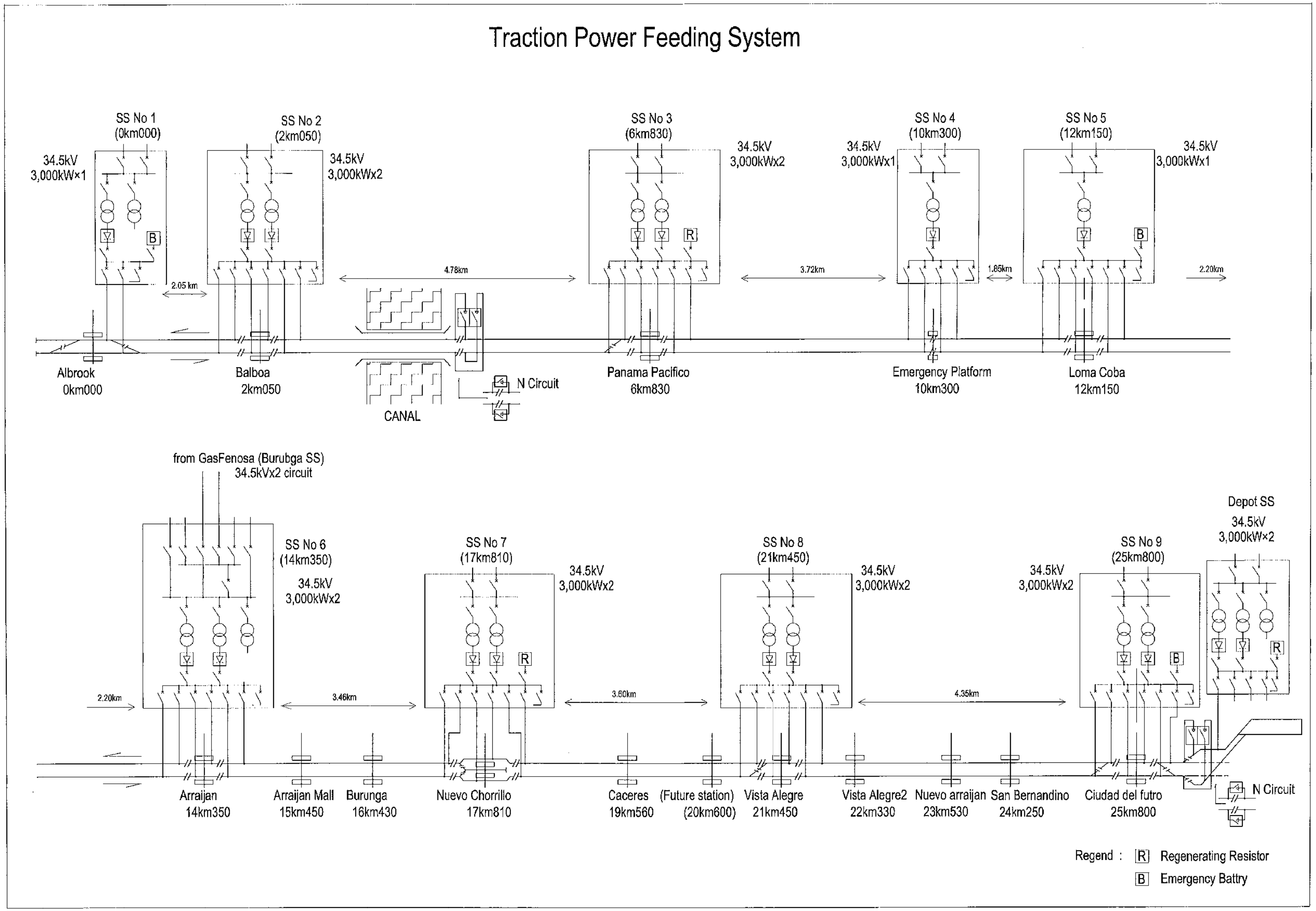
Regarding the installation route for the distribution line cable, a cable trench under one side of the track beam will be used.

For the 15kV line, the XLPE-T 95mm^2 power cable shall be applied



Source : JICA Study Team

Figure 7.23 Transmission Line System Plan



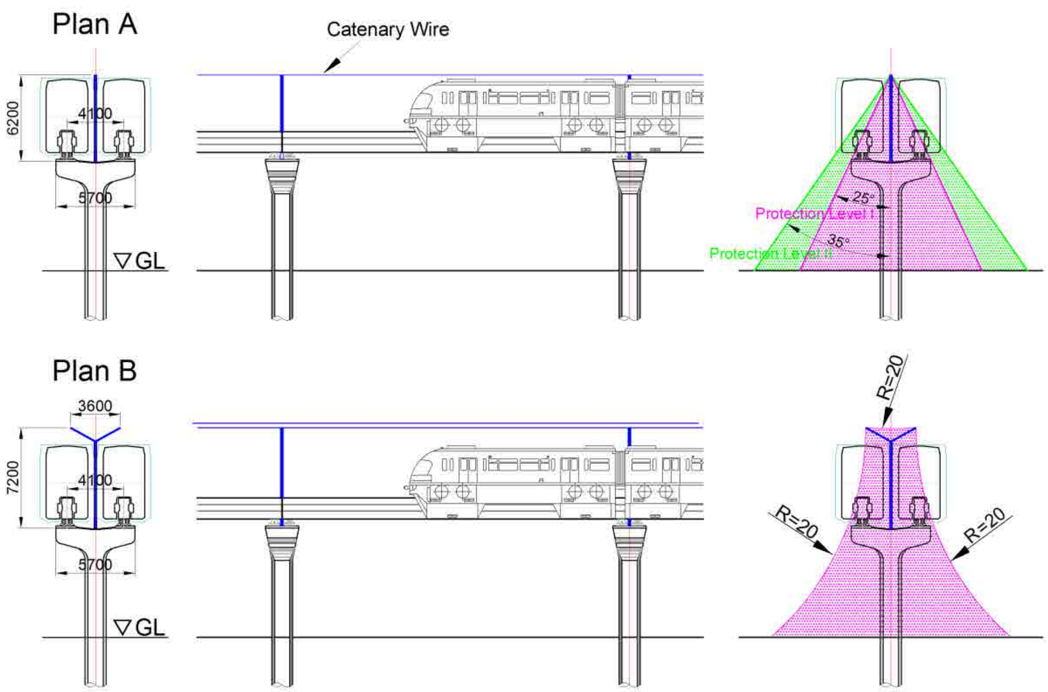
Source: JICA Study Team

Figure 7.24 Feeding System Diagram

7.9.6 Lightning Protection

The objects to be protected from lightning are monorail's track girders, feeding lines and cables around the girders. Catenary wires (overhead ground wires) will be used for the air-termination systems in the external lightning protection system of the monorail, and the overhead ground wires will be installed above the track girder in such a way that the protection area can cover the girder as shown figure below.

Plan-A was employed in the Project taking into account of cost performance and landscape. Using rods (lightning rods) with overhead ground wire or applying Plan-B should be considered where higher protection level is required.



Source: JICA Study Team

Figure 7.25 Alternative Plans of Overhead Ground Wire and Protection Area

7.10 Signaling System

Table 7.9 shows a summary of the signaling system for the Project. A detailed analysis is described in the following sections.

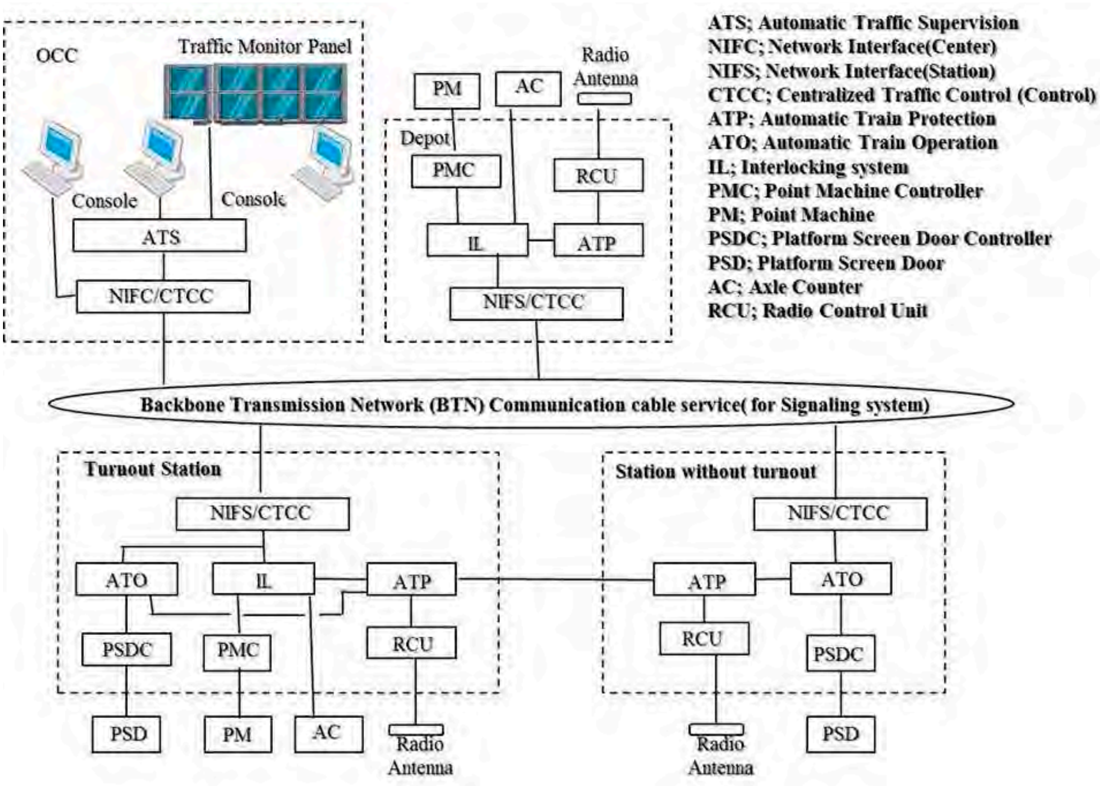
Table 7.9 Summary of the Basic Concepts of the Project's Signaling System

Item		Basic Concept
Standard	Main Standard	a) IEC 62278: Railway Applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) b) IEEE1474.1, 2,3: Standard for Communication-Based Train Control (CBTC)
	Safety Design	Safety design of SIL4 (Safety Integrity Level 4) is required for: a) ATP b) TD c) IL d) Common components of ATP and ATO
Signal System	ATP	Compared with Fixed block system, Moving block system that is achieved by CBTC (Communication Based Train Control) is recommended.
	TD	As ATP adopts CBTC, TD using CBTC is recommended. Using axle counter is recommended as the secondary TD equipment.
	IL	There is a Collective control system and an Individual control system in IL system configurations. The Individual IL system is located at every station that has a turnout and controls its own turnout, while the Collective IL system is located at main stations and remotely controls the turnouts of other smaller stations. Collective IL system is recommended because it can reduce the number of IL systems.
	ATO	One driver operation with ATO
	ATS	Operation monitoring in OCC and automatic route control according to the train diagram.
Depot System	Stabling yard	Stabling yard: Manual operation by the driver, with a speed limit of 15km/h or less by an on board ATP, also with a wayside signal that is controlled by the Depot interlocking system. CBTC and ATO are not used in the stabling yard.
	Maintenance yard	Manual operation by the driver with wayside signal
Backup System in case of System Failure	CBTC	Fixed block system between stations with wayside signal and axle counters for train detection
	ATS	Manual remote route control by a backup console in OCC
	OCC	Manual point machine (PM) control by IL terminal at stations
	IL	Manual point machine (PM) control by wayside PM control panel or Manual control handle

Source：JICA Study Team

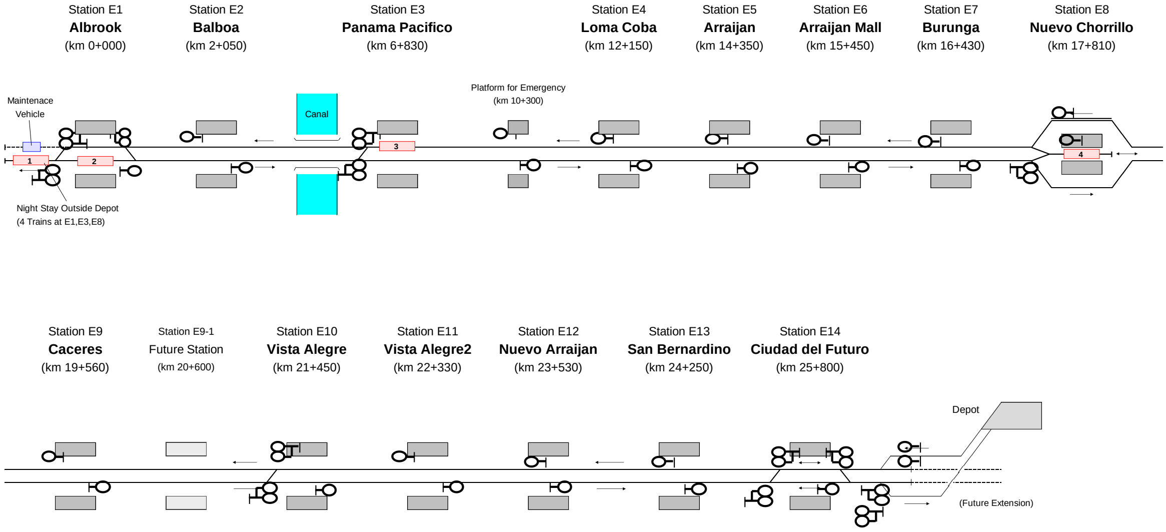
Figure 7.26 shows a schematic diagram of the Signaling system. Figure 7.27 shows the

Outline of Track layout for Metro Line-3.



Source：JICA Study Team

Figure 7.26 Schematic Diagram of Signaling System



Source：JICA Study Team

Figure 7.27 Outline of Track Layout for Metro Line-3

7.11 Telecommunication

Design standard, function, and performance employed for telecommunication system is shown the table below.

Table 7.10 Design standards

System	Design Standards
Train radio communication	Digital radio system with standard antenna or LCX antenna (at Track) and standard antenna (at Depot). Radio frequency: 400MHz or 800MHz band. The radio communication system shall bear both Voice and data.
Telephone exchange	PABX with minimum 100 ports is to be provided at all stations, an exchange with minimum 256 ports to be provided at terminal stations. Minimum 500 port exchange at OCC.
Dispatching Telephone System	Concentrated telephone system with selective calling function should be adopted. Minimum requirements are as follows: • Individual calls. • Group calls • Broadcast calls. • Hands free communication function via speakers and microphones.
Closed Circuit Television System	Fixed and PTZ type cameras shall be provided with station and OCC level monitoring capability. LCD monitors shall be provided for operators to view door closure.
Clock System	Centralized Clock system should be used. Accurate display of time through a synchronization system of slave clocks driven by a master clock at the OCC and sub–master clock in station/depots. This shall also be used for the synchronization of other systems.
Public Addressing System	Public Addressing System covering all platform and concourse areas with local as well as central announcement capability.
Passenger Information Display System	LED/LCD based boards with adequate visibility to be installed at convenient locations in all stations to provide visual indication of the status of the running trains, and also special messages in case of emergencies.
Backbone Transmission Network System	SDH or Gbps/Mbps Ethernet.
Interface	Common and international interface shall be applied as much as possible.
System redundancy (Major system)	Full duplex system for both Mobile Radio base and master station equipment. Path Redundancy provided for Optical Fiber Cable in ring configuration.

Source：JICA Study Team

Chapter 8 Project Implementation Plan

8.1 Engineering Service

SMP has enough experiences in urban transportation projects, because it has undertaken the Line-2 project in addition to the operation of Line-1 which has already been opened. However, there are big differences between MRT and monorail systems in the components of track structure and rolling stock. Since SMP has no experience in constructing a monorail system, support from well-experienced consultants will be required for system design, selection of contractor, construction supervision, operation and maintenance as shown below.

Before Construction	1) Preparation of Tender Document 2) Assistance in Tender Process 3) Assistance in Tender Evaluation
During Construction	1) Supervision of Construction 2) Preparation of Operation and Maintenance Manuals for various subsystems, facilities and equipment 3) Preparation of Staff Training Schedule and Support for Domestic and Overseas Training
After Construction	1) Technical Services after the Commencement of Operation

8.2 Land Acquisition

The land acquisition area is summarized in the table below:

Table 8.1 Land Acquisition Summary

Item	Station Name	Required Area(m^2)
For Intermodal Facilities (Park & Ride)		
P&R1	Nuevo Chorrillo	3,720
P&R2	Vista Alegre	4,200
For Depot		120,000
Total Required Area for Land Acquisition		127,920

Source: JICA Study Team

8.3 Project Cost Estimate

8.3.1 Cost Estimate Conditions

The project costs for Line-3 are estimated with a local currency (LC) portion and a foreign currency (FC) portion under headings of “Construction Costs”, “Consultant Fees” and “Land Acquisition Costs”. Inflation, contingency funds and administrative costs are accounted for in these costs. In addition, based on the experience of Line-1, consumption tax (ITBMS: Impuesto a las Transferencias de Bienes Corporales Muebles y la Prestacion de Servicios) and import duties are exempted.

All prices for exchange rate, inflation, contingency and consultant fees are the prices as of the time of the survey.

Table 8.2 Cost estimate conditions

Item	Remarks
Base year for cost estimation	October 2013
Exchange rate	US Dollar (USD) / Japanese Yen (JPY) USD 1.00 = JPY 99.7
Inflation rate	Foreign currency (FC): 1.3% Local currency (LC): 3.1%
Contingency funds	Construction costs: 5% Consultant fees: 5%
Administration costs	3%

Source: JICA Study Team

Note that the project costs for Line-3 includes the construction cost of girders on the 4th Bridge while the construction costs of superstructure and its lower structure of the 4th Bridge is included in the project costs of the 4th Bridge.

8.3.2 Cost Estimate Results

(1) Initial investment costs

The costs of the Line-3 project are shown in Table 8.3. The construction costs of three future stations (Arraijan Mall, Caceres, and San Bernardo stations) are not included. The number of rolling stock is 168 cars corresponding to the passenger demand until 2030.

(2) Additional investment costs

The required cost for opening three future stations and additional rolling stock cost which will be required on and after 2030 are estimated as JPY 4.7 billion and JPY 5.5 billion, respectively, totaling JPY 10.2 billion. The number of additional cars by 2050 in Phase-1 section was estimated at 24.

(3) Comparison with METI Study

A study for Panama was carried out on November 2012 financed by the Ministry of Economy, Trade and Industry (METI) of Japan. Comparing with the METI Study, the project cost estimated in this report is increased considerably. The main reasons of the increase are many revisions of the project scope based on SMP’s requests and the revisions of unit prices reflecting the latest data from Line 1 project.

Table 8.3 Construction Costs

Annual Fund Requirement

Base Year for Cost Estimation:	Oct, 2013			FC & Total:	million JPY
Exchange Rates	PAB = Yen		99.7	LC :	million PAB
Price Escalation:	FC:	1.3%	LC: 3.1%		
Physical Contingency	5%				
Physical Contingency for Consultant	5%				

Item		Total			2015			2016			2017			2018			2019			2020			2021		
		FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. ELIGIBLE PORTION																									
Ⅰ)	Procurement / Construction	90,852	994	190,001	0	0	0	0	0	0	7,335	202	27,471	25,544	228	48,325	24,579	245	48,969	24,969	225	47,403	8,426	94	17,834
	Mobilization	0	53	5,312	0	0	0	0	0	0	0	53	5,312	0	0	0	0	0	0	0	0	0	0	0	0
	Public Utility Relocation	0	20	1,994	0	0	0	0	0	0	0	20	1,994	0	0	0	0	0	0	0	0	0	0	0	0
	Detailed Design	5,312	0	5,312	0	0	0	0	0	0	2,656	0	2,656	2,656	0	2,656	0	0	0	0	0	0	0	0	0
	Civil Works	5,964	395	45,338	0	0	0	0	0	0	1,032	68	7,847	1,376	91	10,463	1,376	91	10,463	1,376	91	10,463	803	53	6,103
	Switch Work	3,275	0	3,275	0	0	0	0	0	0	0	0	0	1,156	0	1,156	1,156	0	1,156	963	0	963	0	0	0
	Station Building	7,290	195	26,778	0	0	0	0	0	0	394	11	1,447	2,364	63	8,685	2,364	63	8,685	2,167	58	7,961	0	0	0
	Depot & Workshop Construction	224	60	6,246	0	0	0	0	0	0	61	16	1,688	73	20	2,026	73	20	2,026	18	5	506	0	0	0
	Depot Facilities	895	5	1,395	0	0	0	0	0	0	0	0	0	224	1	349	448	3	697	224	1	349	0	0	0
	Rolling Stock	37,031	3	37,367	0	0	0	0	0	0	1,852	0	1,868	11,109	1	11,210	11,109	1	11,210	11,109	1	11,210	1,852	0	1,868
	Power Supply System	10,237	15	11,737	0	0	0	0	0	0	640	1	734	2,559	4	2,934	2,559	4	2,934	2,559	4	2,934	1,919	3	2,201
	Signalling & Telecommunication System	8,378	39	12,223	0	0	0	0	0	0	0	0	0	1,289	6	1,881	2,578	12	3,761	2,578	12	3,761	1,933	9	2,821
	AFC System	1,459	1	1,519	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	729	0	759	729	0	759
	P&R Facility	0	4	431	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	431
	Environmental Mitigation and Monitoring	0	3	347	0	0	0	0	0	0	0	1	60	0	1	72	0	1	72	0	1	72	0	1	72
	Base cost for JICA financing	80,064	794	159,275	0	0	0	0	0	0	6,634	170	23,607	22,806	187	41,431	21,663	194	41,004	21,724	173	38,979	7,237	70	14,255
	Price escalation	6,462	153	21,679	0	0	0	0	0	0	352	22	2,556	1,521	31	4,593	1,746	39	5,634	2,056	41	6,167	788	19	2,729
	Physical contingency	4,326	47	9,048	0	0	0	0	0	0	349	10	1,308	1,216	11	2,301	1,170	12	2,332	1,189	11	2,257	401	4	849
Ⅱ)	Consulting services	3,989	49	8,839	278	4	629	325	4	735	648	9	1,577	754	10	1,782	698	8	1,448	670	7	1,358	617	7	1,311
	Base cost	3,542	39	7,478	258	3	572	298	4	654	586	8	1,369	673	8	1,513	615	6	1,210	583	5	1,112	530	5	1,048
	Price escalation	257	7	940	7	0	27	12	0	46	31	1	133	45	1	183	50	1	169	55	1	181	58	1	201
	Physical contingency	190	2	421	13	0	30	15	0	35	31	0	75	36	0	85	33	0	69	32	0	65	29	0	62
Total (Ⅰ + Ⅱ)		94,841	1,043	198,840	278	4	629	325	4	735	7,983	211	29,048	26,298	239	50,106	25,276	252	50,418	25,639	232	48,760	9,042	101	19,145
B. NON ELIGIBLE PORTION																									
a	Procurement / Construction	0	3	342	0	0	24	0	0	49	0	1	51	0	1	52	0	1	54	0	1	55	0	1	57
	Environmental Mitigation and Compensation	0	3	277	0	0	21	0	0	43	0	0	43	0	0	43	0	0	43	0	0	43	0	0	43
	Base cost for JICA financing	0	3	277	0	0	21	0	0	43	0	0	43	0	0	43	0	0	43	0	0	43	0	0	43
	Price escalation	0	0	49	0	0	1	0	0	4	0	0	6	0	0	7	0	0	9	0	0	10	0	0	12
	Physical contingency	0	0	16	0	0	1	0	0	2	0	0	2	0	0	2	0	0	3	0	0	3	0	0	3
b	Land Acquisition	0	27	2,693	0	0	0	0	21	2,141	0	6	552	0	0	0	0	0	0	0	0	0	0	0	0
	Base cost	0	23	2,326	0	0	0	0	19	1,861	0	5	465	0	0	0	0	0	0	0	0	0	0	0	0
	Price escalation	0	2	239	0	0	0	0	2	178	0	1	60	0	0	0	0	0	0	0	0	0	0	0	0
	Physical contingency	0	1	128	0	0	0	0	1	102	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0
c	Administration cost	0	101	10,094	0	0	33	0	1	146	0	15	1,483	0	25	2,508	0	25	2,524	0	24	2,441	0	10	960
d	VAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
e	Import Tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (a+b+c+d+e)		0	132	13,129	0	1	56	0	23	2,336	0	21	2,085	0	26	2,560	0	26	2,577	0	25	2,496	0	10	1,017
TOTAL (A+B)		94,841	1,175	211,969	278	4	685	325	28	3,071	7,983	232	31,133	26,298	264	52,666	25,276	278	52,995	25,639	257	51,257	9,042	112	20,162
C. Interest during Construction		7,930	0	7,930	0	0	0	0	0	0	369	0	369	1,018	0	1,018	1,676	0	1,676	2,313	0	2,313	2,553	0	2,553
	Interest during Construction(Const.)	7,928	0	7,928	0	0	0	0	0	0	369	0	369	1,018	0	1,018	1,676	0	1,676	2,313	0	2,313	2,552	0	2,552
	Interest during Construction (Consul.)	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
D. Front End Fee		398	0	398	398	0	398	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GRAND TOTAL (A+B+C+D)		103,169	1,175	220,296	676	4	1,083	325	28	3,071	8,352	232	31,502	27,317	264	53,685	26,952	278	54,671	27,952	257	53,570	11,595	112	22,715

Note: Interest during construction is calculated based on the assumption that the loan amount by Japanese ODA loan for 70% of the total cost, while the rest is financed as equity.

Source: JICA Study Team

8.4 Construction Plan

The piers of the main line are pre-stressed concrete beams (PC beams). The PC beams will be manufactured at the yard, transported to the construction site by trailer and erected by crane, etc. Additionally, the monorail contact lines will be installed along the side of the track beams, and the communications and signal system cables and electric power cables will be installed in the cable ladder under the track beams or in the cable tray under the evacuation passageway.

The following projects which affect the Line-3 construction project shall be coordinated as follows.

1) Implementation schedule of the lane widening work for the Panamericana between Panama Pacifico and Arraijan by MOP is unclear. For secure implementation of monorail construction, this project will not wait a construction of widening of a road, and will carry out the land reclamation from the existing road edge to the monorail ROW including the space which widens a road.
2) The construction schedule for the 4th bridge should allow the laying of the track beams for Line-3 up to the bridge and approach road up to 6 months before the completion of the bridge.
3) The expansion amount of the 4th bridge shall be an amount which does not affect the monorail track beam to avoid hindering the running of monorail.

8.4.1 Substructure

The substructure of a monorail is the same as the supporting structure for a general structure and no special forms or construction methods are required. Cast-in-place piles, which have low vibration and noise, are used for the foundation. Traffic management appropriate for each construction site will be implemented as construction equipment will occupy an approximate area of 8.0m width during construction.

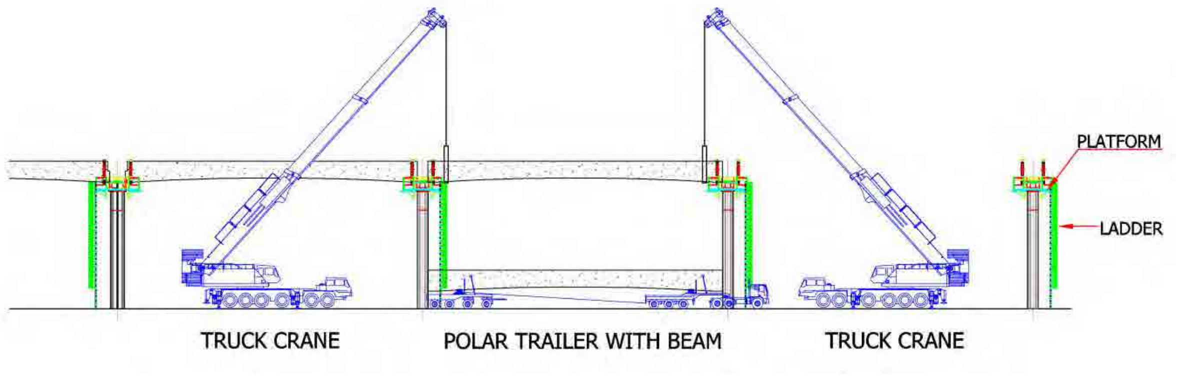
8.4.2 Superstructure

(1) PC beam fabrication

Beams are manufactured in a dedicated yard equipped with a mold device, which is a specialized frame supporting the various beam shapes, in order to ensure that the beams are manufactured uniformly and with high precision. The PC beam fabrication yard will include facilities for beam manufacture and a beam storage space, which will require an area of 3ha or more. Additionally, the PC beam fabrication yard should be located along a wide road to allow for the beams to be transported by large trailers.

(2) PC beam erection

PC beams for general sections will be transported from the PC beam fabrication yard to the construction site via large trailers and then set above the piers by crane. After being set, the continuous girder is rigidly-coupled between beams and between beam and pier with stitching concrete and PC wire and tensioned.



Source: JICA Study Team

Figure 8.1 PC beam erection

(3) PC beam erection on the 4th bridge

The construction of Line-3 will begin in a section other than 4th bridge, and the 4th bridge section construction will be carried out during a short period from when it becomes possible to install the beams on the bridge until the completion of the bridge. In order to construct the 4th bridge section within a short period, beam installation will be conducted both day and night. The beams will be carried in at night and stored temporarily. If it is difficult to use cranes because of the surrounding components of the 4th bridge, a beam transport and erection machine may be used in their place.

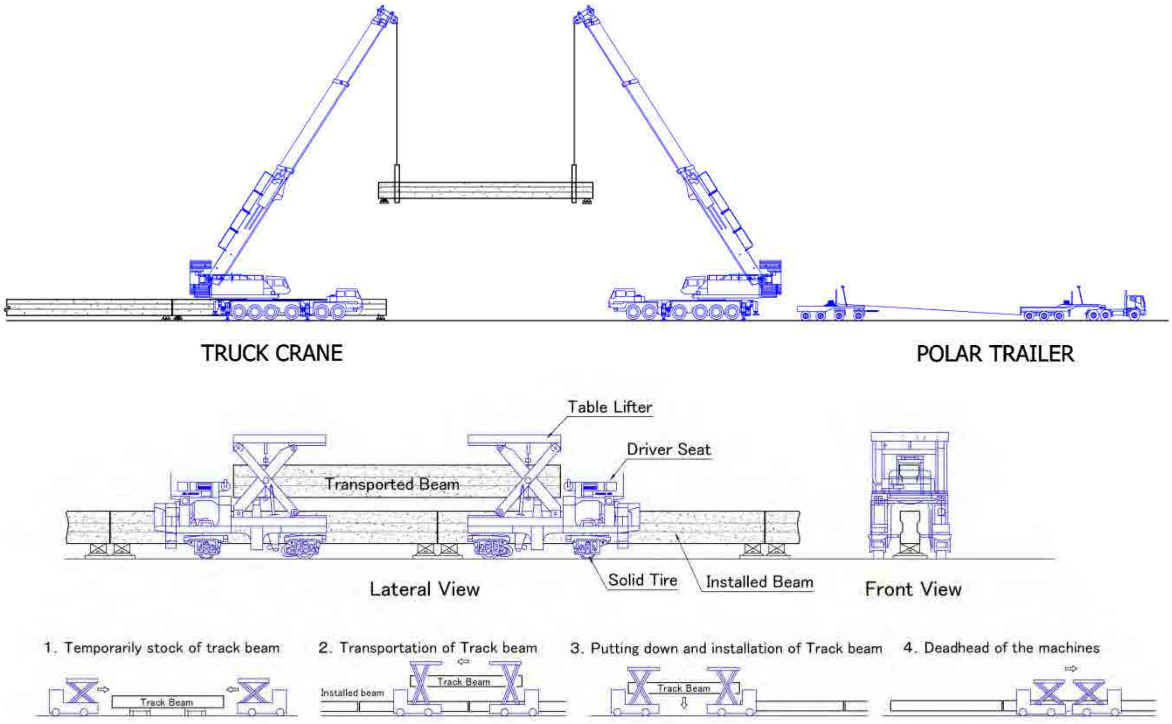


Figure 8.2 Beam transport by cranes and by beam transport and erection machine

(4) Installation of beams in the depot

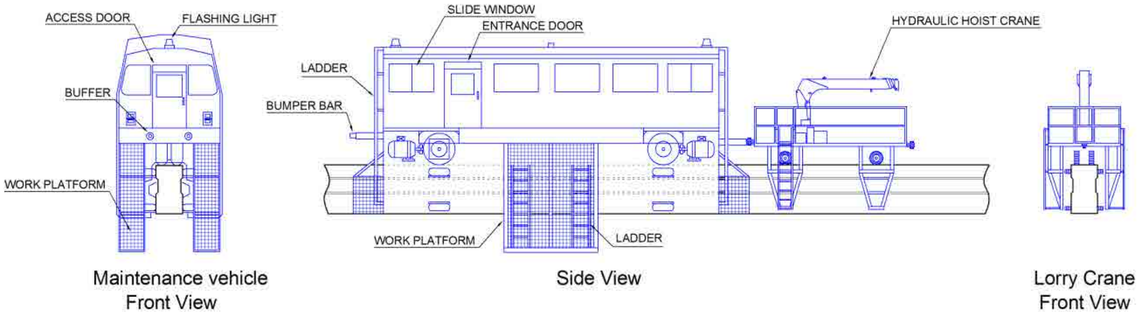
The depot will be established on level ground and the beams in the depot will be installed at ground level. PC beams or RC beams will be used inside the depot. RC beams can be manufactured with a small curve radius, which is difficult to achieve with PC beams.

(5) Other civil construction works

A specialized switch machine for straddle type monorails will be installed at the turnout points. The beam for the turnout point is part of the switch machine. In the elevated stations, the PC beams will be installed after completing the station's civil and structural works, but before beginning the construction of the building, such as the exterior walls, in order to facilitate the transport of the beams.

8.4.3 Installation of Electric Power, Signal and Communications Systems

Monorail contact lines are installed on both sides of the beam. Electric power cables and light electrical cables for signal and communication systems are installed in the cable ladder under the track beams or in the cable tray under the evacuation passageway beside the beams. Since the installation of electric power, signal and communication systems is carried out at high elevations, dedicated self-propelled maintenance vehicles will be used rather than scaffolding from the ground.



Source: JICA Study Team

Figure 8.3 Maintenance vehicle

8.4.4 Traffic Management Plans and Safety Management Plans during Construction

(1) Traffic management plan

A construction area needs to be secured by closing traffic lanes for the construction of substructures. The beams need to be transported at low-speed from the beam fabrication yard to the construction site via large trailers, and the necessary lanes will need to be closed in order to setup the cranes to erect the beams.

Some of the traffic management measures that can be considered for this project are the use of the Centennial Bridge as a detour for the Pan-American Road and coordination of construction hours, including night work.

In the section from the canal to Arriaijan on Pan-American Road, carrying out the land reclamation from the existing road edge to monorail ROW including the space which widens a road will widen the space area available for the construction of the monorail and will minimize the impact on road traffic.

8.4.5 Procurement of Materials and Equipment

(1) Construction materials and equipment

Based on the experience of Line-1, for the construction materials and equipment to be used for Line-3, cement, coarse aggregate and polyvinyl chloride pipe will all be domestic products and other materials will be imported.

(2) Construction machinery

Excavators, truck cranes, concrete pumping trucks, etc. were used for the construction of the elevated sections in Line-1. It has been confirmed that it will be easy to procure this construction machinery for Line-3 as well.

(3) Civil construction labor

Based on the experience of the Line-1 construction, it is assumed that it will be possible to secure engineers, foremen, skilled workers and common workers. However, monorails are a new transportation system for Central America, and the support of professional engineers from overseas with the requisite knowledge and experience will be necessary for providing instruction in the fabrication of high-precision PC beams, instruction in system construction using self-propelled maintenance vehicles, and in the comprehensive testing and commissioning of the monorail.

8.4.6 Consulting Services

Consultants with specialized knowledge and experience will be assigned to the client in order to construct a safe and highly reliable urban monorail transport system. The main activities of the consultants are shown in the table below

Table 8.4 Consulting services

Preparation stage	Construction stage
1) Preparation of basic design 2) Preparation of construction plan and construction schedule outline 3) Estimation of construction costs 4) Preparation of bid and contract documents 5) Bidding procedures 6) Evaluation of bidding documents 7) Providing recommendations to the client	1) Verification and approval of detail designs and specifications by the contractor 2) Verification and approval of construction plan, construction schedule, etc. by the contractor 3) Construction schedule management 4) Quality management 5) Safety management 6) Observation and verification of construction performance 7) Evaluation of changing site conditions and modifications of schedule and costs requested by the client 8) Implementation or verification of site testing, functional testing and commissioning 9) Preparation of construction progress reports

Source: JICA Study Team

8.4.7 Construction Schedule

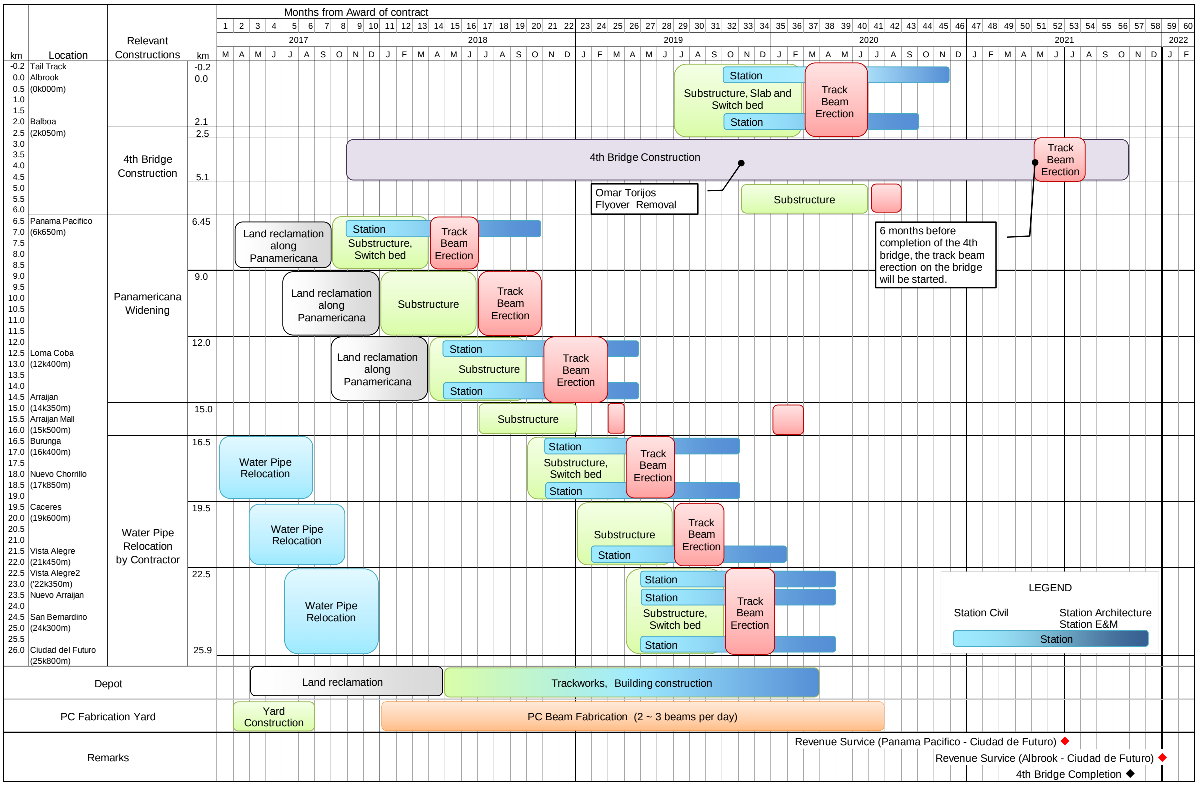
(1) Preconditions

The SMP intends for Line-3 and the 4th bridge to be opened during the same period. The 4th bridge is scheduled to begin construction in November 2017 and complete in October 2021. Erecting of beams for Line-3 will begin up to 6 months before the completion of the bridge, and Line-3 will open in January 2022 after the commissioning test. According to reverse calculations from the opening period and construction period, the beginning of construction of the Line-3 will be July 2017.

(2) Related construction

Relocation work is required for the buried water pipe in the median strip between Burunga and Ciudad del Futuro on the Panamericana, where the monorail piers are to be constructed. In addition, road widening is planned by MOP between Panama Pacifico and Arraijan. The erection of beams for the 4th bridge will begin after the construction of the 4th bridge has progressed and erection permission is obtained. The proposed process for civil works in Line-3, taking into consideration the condition of these related constructions, is shown in the following table.

Table 8.5 Proposed process for civil works



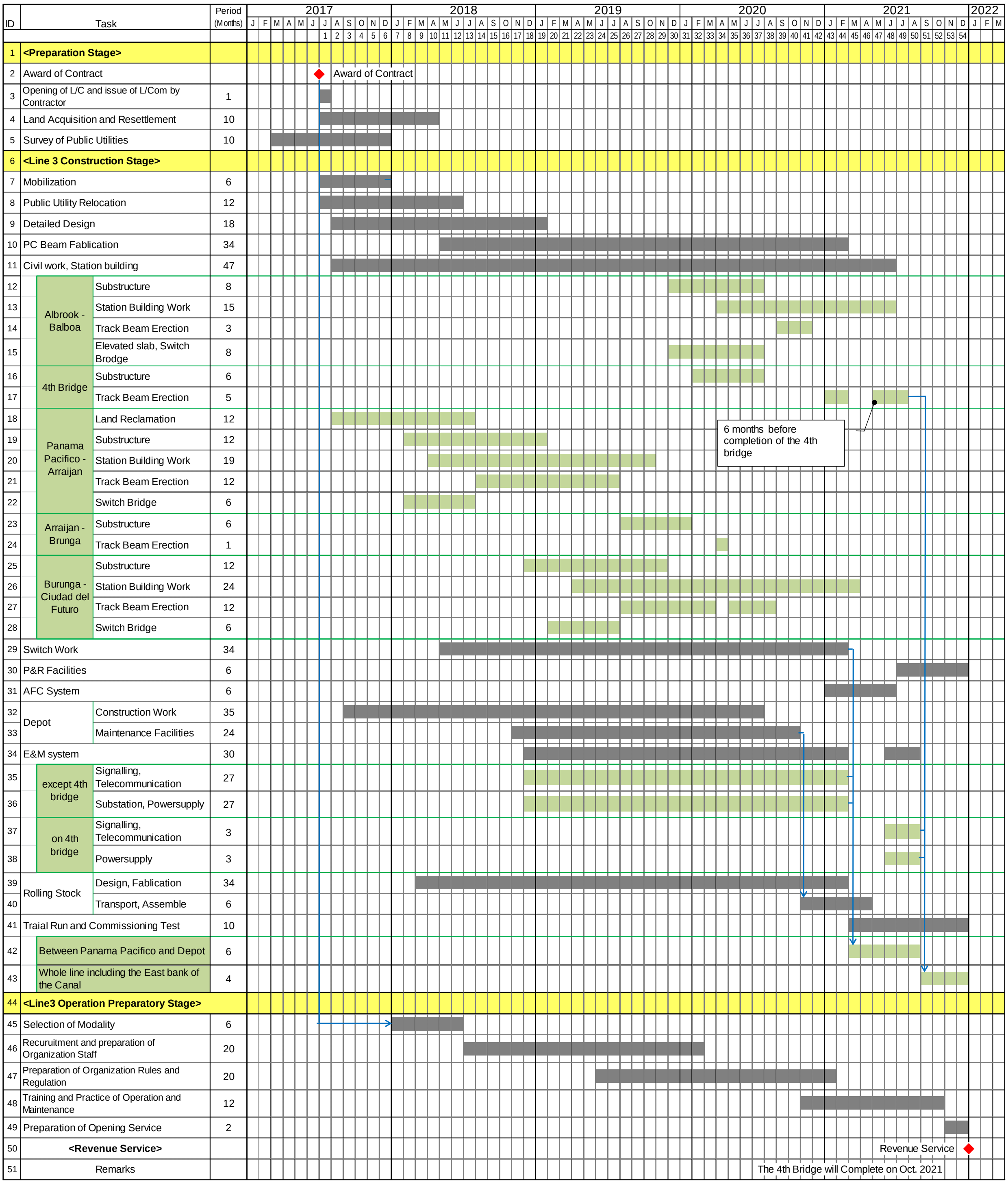
Source: JICA Study Team

(3) Construction Schedule

The estimated construction period for Line-3 is from July 2017 to December 2021, and operation is estimated to begin in January 2022.

The preconditions required for the preparation stage and construction stage are shown in the tables below. The starting procedures for the project, fund-raising, bid contract arrangement with the contractor, and so on will be carried out in the preparation stage.

Table 8.6 Construction schedule



ID	Task		Period (Months)
1	**<Preparation Stage>**		
2	Award of Contract		
3	Opening of L/C and issue of L/Com by Contractor		1
4	Land Acquisition and Resettlement		10
5	Survey of Public Utilities		10
6	**<Line 3 Construction Stage>**		
7	Mobilization		6
8	Public Utility Relocation		12
9	Detailed Design		18
10	PC Beam Fablication		34
11	Civil work, Station building		47
12	Albrook - Balboa	Substructure	8
13		Station Building Work	15
14		Track Beam Erection	3
15		Elevated slab, Switch Brodge	8
16	4th Bridge	Substructure	6
17		Track Beam Erection	5
18	Panama Pacifico - Arraijan	Land Reclamation	12
19		Substructure	12
20		Station Building Work	19
21		Track Beam Erection	12
22		Switch Bridge	6
23	Arraijan - Brunga	Substructure	6
24		Track Beam Erection	1
25	Burunga - Ciudad del Futuro	Substructure	12
26		Station Building Work	24
27		Track Beam Erection	12
28		Switch Bridge	6
29	Switch Work		34
30	P&R Facilities		6
31	AFC System		6
32	Depot	Construction Work	35
33		Maintenance Facilities	24
34	E&M system		30
35	except 4th bridge	Signalling, Telecommunication	27
36		Substation, Powersupply	27
37	on 4th bridge	Signalling, Telecommunication	3
38		Powersupply	3
39	Rolling Stock	Design, Fablication	34
40		Transport, Assemble	6
41	Traial Run and Commissioning Test		10
42	Between Panama Pacifico and Depot		6
43	Whole line including the East bank of the Canal		4
44	**<Line3 Operation Preparatory Stage>**		
45	Selection of Modality		6
46	Recuruitment and preparation of Organization Staff		20
47	Preparation of Organization Rules and Regulation		20
48	Training and Practice of Operation and Maintenance		12
49	Preparation of Opening Service		2
50	**<Revenue Service>**		
51	Remarks		

Source: JICA Study Team

8.5 Procurement Package

Project cost, schedule, operation and maintenance, etc. will be affected by the type of contract. The followings are outline, merits and demerits of various types of contracts.

	Advantage	Disadvantage
Contract for Construction	The Employer can specify desired materials and design in detail.	In case of monorail, preparation of the detailed design will give advantages to a specific manufacturer.
Contract for Design – Build	The Contractor can be selected through a competitive tender without giving advantages to a manufacturer.	As the other side of the advantage, it is difficult to identify the detailed specification of the final product.
EPC/ Turnkey	Since the Contractor handovers the finished-product, the burden on the Employer about the management of design and construction is not heavy.	The construction price tends to become high because the Contractor takes various risks. The burden on the Contractor would be heavy because a complex coordination among stakeholders is required for civil works, utility relocations, and the construction of the 4th Bridge.

Among the above contracts, the contract for design and build is recommended. In case that the construction package is divided into civil and E&M, the tender for the civil package need to be done in the beginning and the tender for the civil package cannot be undertaken unless the design of E&M is confirmed. Therefore, the package consisting of civil and E&M is recommended.

8.6 Public-Private Partnership

Private participation in infrastructure projects has not been regulated by PPP-specific legislation in Panama. A new comprehensive PPP law (Bill 349 of 2011) was sent to the National Assembly in late 2011, but it was withdrawn due to the strong opposition from public-sector workers. PPPs have been implemented based on generally applicable laws and project-specific laws, regulations and/or contract laws, rather than PPP-specific legislation. Hence the regulatory and institutional framework that has been applied varies sector by sector.

However, most recently, it is understood that Law 5 of 1988 as amended in 2010, or the Administrative Concession Law, may serve as the legal basis for new concessions of public infrastructure projects in general, according to the Ministry of Economy and Finance (MEF).

Based on the project's features and the international experience in PPP's in urban rail transit, probable project scheme alternatives for the Line-3 project are listed below.

- Public Investment and Operation
- Concession Scheme (Initial Investment by Government)
- BOT/BTO Scheme (Initial Investment by the Private)
- Vertical Separation (BOT/BTO for Rolling Stock and M&E)
- Public Operation with Private Investment

Table 8.7 below describes the comparison of project scheme alternatives in particular aspects. Followings can be pointed out based on the PPP schemes.

- Any stakeholders have not expressed their intention to implement the Line-3 project in PPP. The public investment and operation with ODA loan finance is the primary setup for the project implementation.
- The project is financially not feasible and requires significant amount of government subsidy (See Section 18.5, Chapter 18 for details). Even with certain operational efficiency assumed in the PPP schemes, it is not very probable to achieve Value for Money compared to the public investment and operation scheme especially for the scheme alternatives involving initial investment by the private sector.
- Among PPP scheme alternatives, the Annuity-based Concession Scheme (Alternative 2-2) with public initial investment has less private efficiency requirement and would be a viable option for the government to achieve VFM through PPP.
- Current absence of predetermined fare setting regulation is a risk for the private partner's revenue source and is not suitable to fare-based PPP schemes. Annuity-based schemes are preferable in the current situation. Appropriate fare setting and adjustment regulation should be established by the government to ensure the project's sustainability.
- In case the government determines the PPP for the Line-3 project, the technical compatibility between public and private works and procurement efficiency must be further analyzed through market sounding of potential suppliers and operators as well as in-depth technical survey. Technical and transaction advisory is a must for the government to implement the further survey.
- Besides the debt service for the ODA loan, it is anticipated for the government to bear significant amount of recurrent government subsidy or annuity payments. Making such arrangements to enhance the financial viability for a PPP scheme is considered implicit

debt in addition to the formal borrowings.

Table 8.7 Comparison of Project Scheme Alternatives

Project Scheme Alternative	**Alternative 1** **Public Investment and Operation**	**Alternative 2** **Concession Scheme**		**Alternative 3** **BOT/BTO Scheme** **(Fare-based)**	**Alternative 4** **Vertical Separation**		**Alternative 5** **Public Operation with Private Investment**
		2-1 Fare-based	**2-2 Annuity-based**		**4-1 Fare-based**	**4-2 Annuity-based**	
1. Roles and Responsibilities							
Initial Investment /1	Public: USD 2,126 mn	Public: USD 2,126 mn		Private: USD 2,126 mn	Public: USD 1,297 mn (Civil Works) Private: USD 829 mn (Rolling Srock, etc.)		Private: USD 2,126 mn
Operation	Public	Private		Private	Private		Public
Private Partner's Revenue Source	N/A	Fare revenue	Annuity for service performance	Fare revenue	Fare revenue	Annuity for service performance	Annuity for the system avilability
2. Fiscal Requirement for Government							
Initial Investment	Construction Cost	Construction Cost		None	Construction Cost (only public portion)		None
Donor Finance	ODA Loan	ODA Loan		None	ODA Loan (only public portion)		None
Recurrent Paymant	O&M Cost	None	Annuity Payment USD 78.6 mn	Annual Subsidy USD 218.3 mn	Annual Subsidy USD 77.3 mn	Annuity Payment USD 165.4 mn	Annuity Payment USD 240.0 mn O&M Cost
Recurrent Income	Operational Profit	Concession fee USD 9.33 mn	Operational Profit	None	None	Operational Profit	Operational Profit
Total Life Cycle Cost /3 **Borne by Government**	USD 1,380 mn	USD 1,424 mn	USD 1,409 mn	USD 1,966 mn	USD 1,638 mn	USD 1,606 mn	USD 1,951 mn
VFM Compared to Alternative 1	N/A	-3.2% (USD -44 mn)	-2.1% (USD -29 mn)	-42.5% (USD -586 mn)	-18.7% (USD -259 mn)	-16.4% (USD -227 mn)	-41.4% (USD -571 mn)
3. Investment and Operational Efficiency Required to Achieve Positive VFM							
Cost Reduction	N/A	O&M and Reinvestment -6.4%	O&M and Reinvestment -4.0%	Construction, O&M and Reinvestment -22.6%	Construction, O&M and Reinvestment -18.4%	Construction, O&M and Reinvestment -16.2%	Construction and Reinvestment -28.1%
Revenue Increase	N/A	Revenue +5.7%	N/A	Revenue +78.5%	Revenue +34.7%	N/A	N/A
Combination of Cost Reduction and Revenue Increase	N/A	(Example) Cost: -4% Revenue: +2%	N/A	(Example) Cost: -15% Revenue: +26%	(Example) Cost: -10% Revenue: +16%	N/A	N/A
4. Procurement of Construction and Private Concessionaire							
Packaging	- Construction	- Construction - Operation concession		- BOT/BTO Contract	- Public Construction for Civil Works - BOT/BTO for Rolling Stock, etc.		- Construction concession
Bid Parameter for Private Partner	N/A	Concession fee amount	Annuity Amount	Annual Subsidy Amount	Annual Subsidy Amount	Annuity Amount	Annuity Amount
5. Major Risk Allocation							
Construction Completion Risk	Public: - Budget appropriation and donor finance for construction - Technical and financial capability of EPC contractors should be evaluated upon public teder for the construction works.			Private: - Sponsor's capability - Technical and financial capability of contractors	Public (Civil Works): - Budget appropriation - Technical and financial capability of contractors Private (Rolling Stock, etc.) - Sponsor's capability - Technical and financial capability of contractors		Private: - Sponsor's capability - Technical and financial capability of contractors
Operation Risk	Public: - Budget appropriation for O&M - Technical capacity of Metro de Panama, S.A. or operating company	Private: - Cash flow projection (Chapter 18) has preliminarily estimated required subsidy/annuity amount for the private concessionaire to cover the required O&M and reinvestment costs. - Technical and investment capacity and appetite among potential concessionaires/operators should be further investigated in accordance with specifications of the Line-3 project.					Public: - Budget appropriation for O&M - Technical capacity of Metro de Panama, S.A. or operating company
Utility Risk	Public: Electricity for the Line-3 operation will be provided by Gas Fenosa. Gas Fenosa is responsible to the construction of new substation (230V) in Burunga which will be completed by 2016 (See Section 6.9.1, Chapter 6)						
Subsidiary/ Annuity Payment	Public: Construction and operation subsidy is paid to Metro de Panama, S.A.	N/A (Concession fee paid by the private)	Public: Annual subsidy or annuity payment by the public side to the private accounts for USD 70 to 240 million over the operating period. The payments are primarily sourced by the national budget; for which the budget appropriation process should be closely monitored to secure the payments to the private.				
Demand Risk	Public	Private	Public	Private	Private	Public	Public

Source: JICA Study Team

8.7 Implementation Schedule

Although the construction of the 4th Bridge will be independent from the construction of Line-3, both projects shall be implemented in parallel because Line-3 has been designed to cross the Canal via the 4th Bridge.

As indicated on the following chart, the construction periods of both projects are estimated to be approximately 4 years. If the financial arrangement progresses without delay, both projects can be commenced at the beginning of year 2017 and completed at the end of 2021 or early 2022.

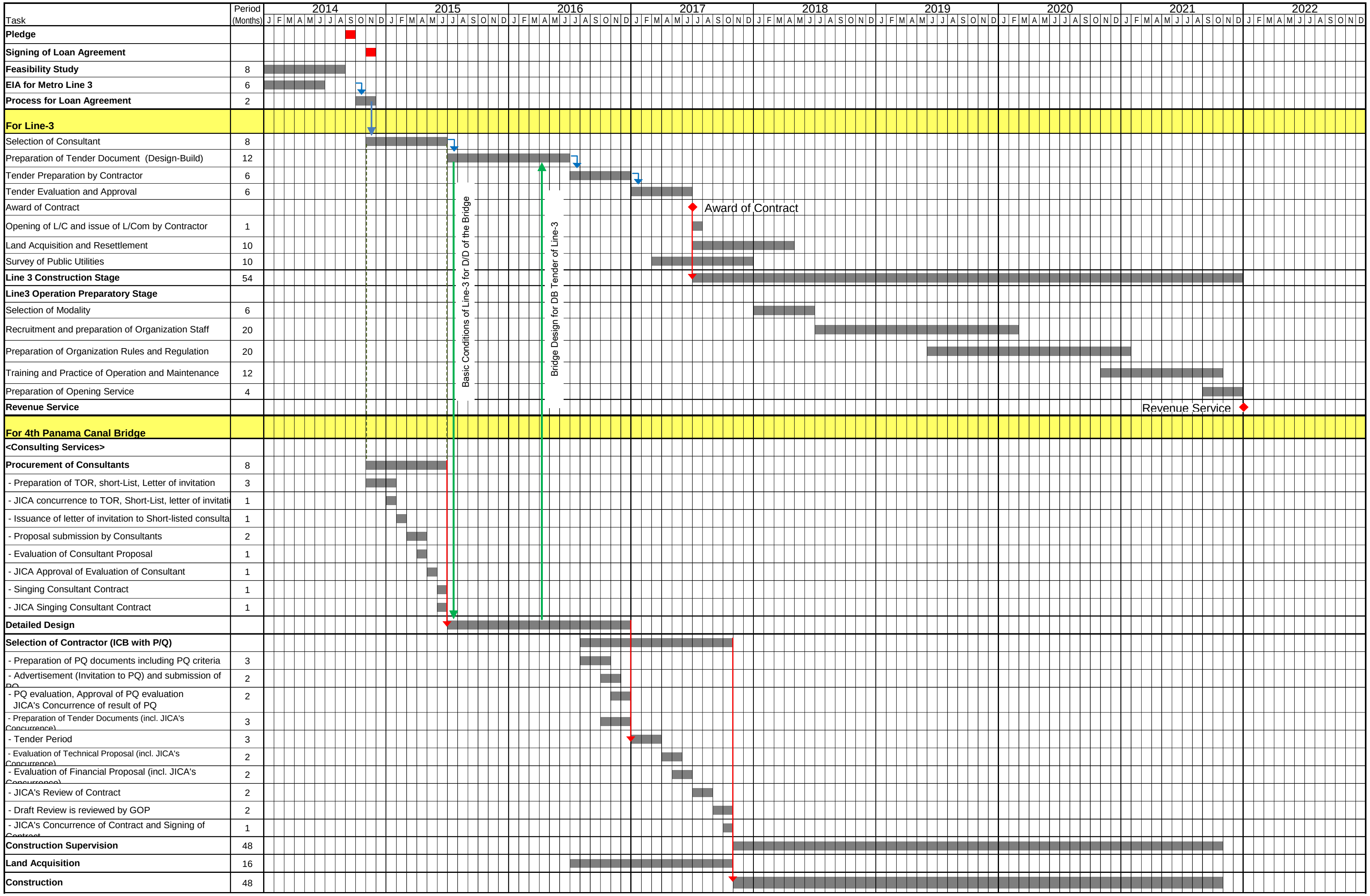


Figure 8.4 Implementation Schedule

Source: JICA Study Team

Chapter 9 Institution and Organization

9.1 Implementation Structure

In the Project, the Line-3 Project will be implemented by SMP as same as Line-1 and Line-2. The 4th Bridge Project will be also implemented by SMP although ACP's cooperation is essential. The overall implementation structure is described in Chapter 17, while this chapter focuses on the implementation of Line-3. The Government of Panama has a plan to transform SMP to Metro de Panamá, S.A. The followings are important points in the Line-3 project.

- The relationship between the Project and Line 1 project, after the function of SMP transferred to the new organization.
- And the window of ODA in Panamanian side.
- The body in Panamanian side for installing the Monorail System.

9.2 Implementation Organization

9.2.1 Implementation Organization for the Project

The implementation organization of the Line-3 project is SMP or its successor.

9.2.2 Finance and Budget Structure

Currently, SMP is an organization under the Presidency, and necessary budget is allocated by the Government of Panama as the implementation organization for Line-1 and 2. It is said that SMP will be reorganized as a metro company, although the policy of the Government has not been clarified.

9.2.3 Technical Level

SMP has enough technical experiences to implement the Line-3 project, taking account of the fact that SMP has implemented the Line-1 project and undertook the Line-2 project.

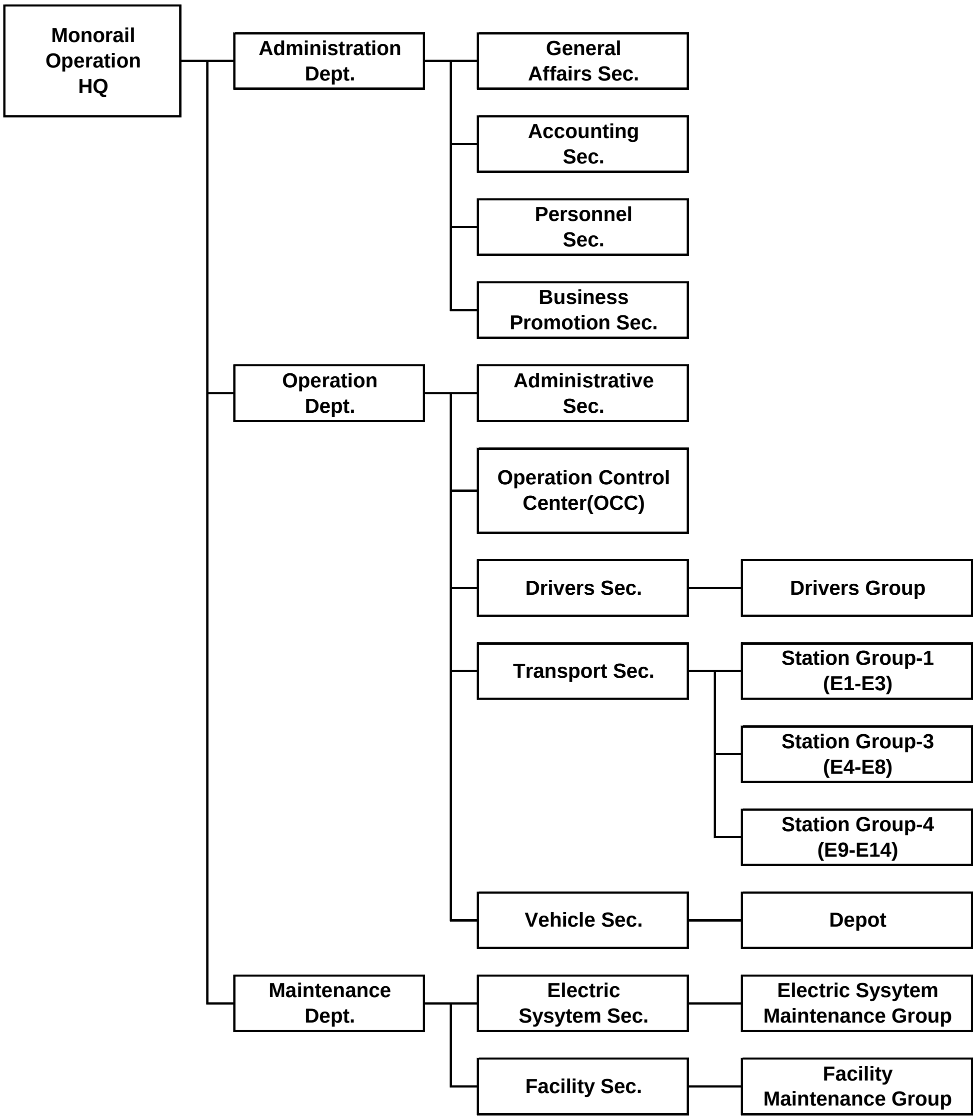
9.3 O&M Organization

9.3.1 Concept of O&M Organization

SMP (or its successor) will be the entity for the operation and maintenance of Line-3. It is recommended that SMP will operate Line-3 directly with integration of Line-1 and Line-2, while the maintenance will be done by outsourcing to a private company.

The organizational structure of O&M for Line-1 is divided into an Operation Division and Maintenance Division and each division is further divided into sections with a specific area of responsibility. For example, Train Operation, Stations, OCC and Rolling Stock sections are under the Operation Division, and Civil, Electromechanical, Signaling and Communication sections are in the Maintenance Division. However, maintenance is subcontracted to the private sector in Line-1.

Based on the above, this study presents a recommendation for the O&M organizational structure for Line-3 as shown in Figure 9.1. This structure is widely popular among Japanese railway operators including monorail operators.



Source: JICA Study Team

Figure 9.1 Organizational Structure of Monorail Operator (Recommendation)

9.4 Operation and Maintenance Plan

9.4.1 Precondition for Operation and Maintenance Plan

(1) Train Operation Method

Train Operation: Automatic operation by ATO (However, one driver with the qualification for manual operation is still required to be on board)

Operation Control: Centralized control by the Operation Control Center (OCC) in the Depot. Because OCC of Line-1 has sufficient space to increase its capacity to control both Line-2 and Line-3 in the future, OCC of Line-3 can be integrated into Line-1 depending on the operation entity.

Signaling System: Moving block by CBTC

(2) Maintenance Work on the 4th Bridge

The Line-3 operator will be responsible for the maintenance work of girders and power feeding facilities of monorail on the 4th Bridge, while other parts of the bridge structure including the superstructure for monorail track will be maintained by the responsible agency of the 4th Bridge.

9.4.2 Organization and Personnel Plan

The number of necessary persons for O&M is estimated as shown in Table 9.1. The number of personnel is 356 persons in the inauguration year 2020. As the train frequency and the number of cars increase, the number grows to 421 persons in 2050, that is approximately a 18% increase from 2020.

Table 9.1 Calculation Results for the Number of Personnel in Line-3 (Phase1)

Item	Profession/Amount	Unit	Formula	2020	2025	2030	2035	2040	2050
Number of Personnel (According to Profession)	Driver	Persons	A=k/a	90	90	95	95	95	102
	Station Staff	Persons	B=b×m	116	147	147	147	147	147
	Other Operation (OCC)	Persons	C=c×n	14	14	14	15	15	15
	Track Maintenace	Persons	D=d×h	19	19	19	19	19	19
	Electric Maintenace	Persons	E=e×h	13	13	13	13	13	13
	Rolling Stock Maintenace	Persons	F=f×j	42	47	49	50	50	52
	Sub-Total	Persons	G=A〜F	294	330	337	339	339	348
	Staff in Headquarter	Persons	H=G×g	62	69	71	71	71	73
	Total	**Persons**	**Q=J+K**	**356**	**399**	**408**	**410**	**410**	**421**
	Total per Line-km	Persons/km	R=Q/k	13.8	15.5	15.8	15.9	15.9	16.3
Unit Number of Personnel	Driver	Ave. Driving-km/Day	a	108.3	108.3	108.3	108.3	108.3	108.3
	Station Staff	Persons/Stations	b	10.5	10.5	10.5	10.5	10.5	10.5
	Other Operation (OCC)	Persons/Ave. Train Frequency	c	0.0352	0.0352	0.0352	0.0352	0.0352	0.0352
	Track Maintenace	Persons/Line-km	d	0.714	0.714	0.714	0.714	0.714	0.714
	Electric Maintenace	Persons/Line-km	e	0.500	0.500	0.500	0.500	0.500	0.500
	Rolling Stock Maintenace	Persons/Cars	f	0.267	0.267	0.267	0.267	0.267	0.267
	Staff in Headquarter	% for Sub-Total	g	20.8%	20.8%	20.8%	20.8%	20.8%	20.8%
Amount Concerning Number of Personnel	Line-km	km	h	25.80	25.80	25.80	25.80	25.80	25.80
	Number of Cars	Cars	j	156	174	180	186	186	192
	Train-km per Day	Train-km/Day	k	9,685	9,719	10,225	10,274	10,274	10,965
	Number of Stations	Stations	m	11	14	14	14	14	14
	Ave. Number of Train Frequency	Train Frequency/Day	n	375.4	376.7	396.3	398.2	398.2	425.0

（Notice）Station E6, E9 and E13 will be commenced in 2025.

Source: JICA Study Team

9.4.3 Maintenance Plan

Considering the nature of monorail systems, troubles should be predicted and coped with in advance based on preventive maintenance, because it takes longer to evacuate passengers from monorails than from normal railways in case trouble arises between stations. For this purpose, the regular maintenance system for monorails in Japan can be referred to, such as the plan for daily inspections, monthly inspections, inspection of important (critical) parts and overhaul. An outline of the regular inspections required for track facilities and electrical equipment is shown in Table 9.2 and Table 9.3.

Table 9.2 Overview of Inspection/Maintenance of Track facilities, Railway structures and Station equipment

Inspection category	Main contents of inspection	Inspection Cycle
Inspection tour of main line	☐Inspection of main line	**Everyday** （combined with inspection of contact line）
Track	☐Track	**1 year**
Track structure	☐Bridge, Tunnel and other track structures	**2 years**
Elevating Machines	☐Elevating machines such as Elevator and Escalator	**6 months to 1 year**
General building structures	☐Station building, Platform ☐Passenger Screen Door	**Properly dealt**
Station Passenger Facility	☐Operation Check and Cleaning of Automatic Vending Machine and Automated Fare Collection Equipment ☐Replacement of wearing parts and Insulation Test etc.	**Properly dealt**
Others	☐Inspection and commissioning upon construction, renovation and restart from operation halt ☐Signage and record of inspection	**Properly dealt**

Source: JICA Study Team (Based on Japanese Regulations)

Table 9.3 Overview of Inspection/Maintenance (Repair) of Electrical Equipment

Inspection category	Main contents of inspection	Inspection Cycle
Power Equipment	☐Catenary (main line）	**Everyday** （combined with track inspection）
	☐Contact Line, Switchgear, ,automatic circuit-breaker, arrestor, protectionsequence machine of substation ☐Critical portions of electrical equipment other than above ☐Other electrical equipment	**1 year** **1 year** **2 years**
Signaling System	☐Safety Equipment such as Signal equipment, Interlocking equipments, switch & lock movement equipment	**1 year**
Communication System	☐Communication equipment	**1 year**
Various Measuring instruments	☐Measuring instruments attached to power equipment, communication equipment and other safety equipment	**1 year**
Disaster Prevention Equipment	☐Fire-alarm box, Sprinkler, Smoke detector, extinguisher etc,	**Six months (visual and functional inspection)** **1 year（overall inspection）**
Other instruments	☐Station monitoring equipment, Signage equipment, lighting equipment etc.	**Properly dealt**
Voluntary Inspection	☐Filter cleaning of Substation, Painting of outside equipment etc.	**Properly dealt**
Others	☐Inspection and commissioning upon construction, renovation and restart from operation halt ☐Signage and record of inspection	**Properly dealt**

Source: JICA Study Team (Based on Japanese Regulations)

9.4.4 Estimation of O&M Cost

The estimated O&M cost and the number of staffs is shown in Table 9.4 and Figure 9.2. Total O&M cost, which is measured in annual term of 2010 price, is estimated at about USD 37 million (JPY 3.6 billion) at the inauguration year 2020. The O&M cost will increase by 17% up to 2030, and will be about USD 43 million (JPY 4.3 billion) during 30 years.

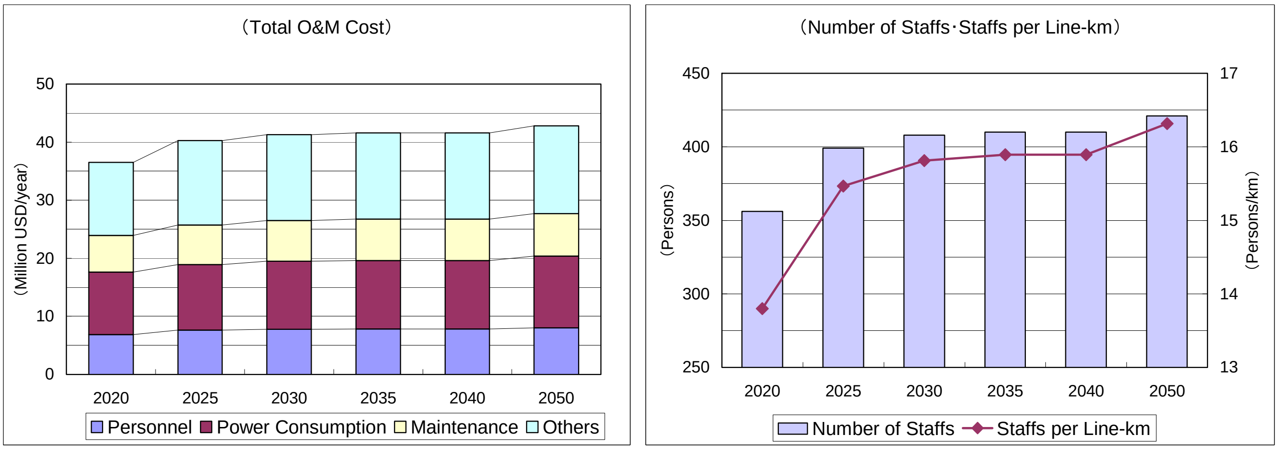
Table 9.4 Summary of Total O&M Cost

Item		Kind of Cost	Details	2020	2025	2030	2035	2040	2050
Cost (USD)	Base Year Price (1000USD/year)	Personnel	Direct, Outsourcing	6,865	7,621	7,786	7,849	7,849	8,043
		Power Consumption	Traction Power, Utility Power	10,729	11,289	11,716	11,757	11,757	12,340
		Maintenance	Track, Electric, Rolling stock	6,357	6,833	6,992	7,151	7,151	7,309
		Others	Train Operation, Station Operation, Administration,	12,558	14,537	14,776	14,834	14,834	15,129
		Total		**36,509**	**40,279**	**41,270**	**41,590**	**41,590**	**42,822**
	Inflated Price (1000USD/year)	Personnel	Direct, Outsourcing	9,316	12,047	14,339	16,837	19,614	27,276
		Power Consumption	Traction Power, Utility Power	14,559	17,845	21,575	25,222	29,381	41,847
		Maintenance	Track, Electric, Rolling stock	7,234	8,294	9,053	9,876	10,535	12,253
		Others	Train Operation, Station Operation, Administration,	14,289	17,644	19,131	20,487	21,854	25,363
		Total		**45,398**	**55,831**	**64,098**	**72,422**	**81,384**	**106,739**
Cost (JPY)	Base Year Price (1000JPY/year)	Personnel	Direct, Outsourcing	684,420	759,780	776,294	782,519	782,519	801,905
		Power Consumption	Traction Power, Utility Power	1,069,656	1,125,491	1,168,091	1,172,201	1,172,201	1,230,319
		Maintenance	Track, Electric, Rolling stock	633,839	681,283	697,098	712,913	712,913	728,728
		Others	Train Operation, Station Operation, Administration,	1,252,038	1,449,311	1,473,145	1,478,924	1,478,924	1,508,401
		Total		**3,639,953**	**4,015,865**	**4,114,628**	**4,146,557**	**4,146,557**	**4,269,352**
	Inflated Price (1000JPY/year)	Personnel	Direct, Outsourcing	928,772	1,201,069	1,429,551	1,678,656	1,955,487	2,719,377
		Power Consumption	Traction Power, Utility Power	1,451,546	1,779,189	2,151,047	2,514,598	2,929,287	4,172,192
		Maintenance	Track, Electric, Rolling stock	721,229	826,931	902,574	984,629	1,050,315	1,221,639
		Others	Train Operation, Station Operation, Administration,	1,424,662	1,759,151	1,907,368	2,042,593	2,178,859	2,528,685
		Total		**4,526,210**	**5,566,341**	**6,390,540**	**7,220,477**	**8,113,949**	**10,641,892**

		2020	2025	2030	2035	2040	2050
Base Year		2010					
Rate of Inflation (Each Year)	Domestic (Applied to Personnel,	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%
	Imported (Applied to Maintenance, Others)	1.3%	1.3%	1.3%	1.3%	1.3%	1.3%
Rate of Inflation (Calculation Year/Base Year)	Domestic (Applied to Personnel,	1.3570	1.5808	1.8415	2.1452	2.4990	3.3911
	Imported (Applied to Maintenance, Others)	1.1379	1.2138	1.2948	1.3811	1.4733	1.6764

(Note) Base year of costs are set to 2010 by adjusting Japanese actual record year.

Source: JICA Study Team



（Note）Each year's price is expressed in base year cost (2010).

Source: JICA Study Team

Figure 9.2 Total O&M Cost and Number of Staffs)

Chapter 10 Comparison Study on Bridge Planning

10.1 Screening of Main Bridge Type for 4th Panama Canal Bridge

10.1.1 Objective

The Pre-F/S on the 4th Panama Canal Bridge Construction Project was conducted by ACP based on the Composite Cable-stayed Bridge; however, a comparison study to select the main bridge type for the 4th Panama Canal Bridge was not conducted in that study.

Therefore, a comparison study was conducted in this Study applying the same bridge planning conditions as in the Pre-F/S to screen the main bridge types for the 4th Panama Canal Bridge. Two alternative main bridge types were selected in this screening and the optimum main bridge type would be selected by final comparison study after completion of preliminary design (see Section 16).

10.1.2 Preconditions

This screening was conducted using the same conditions of bridge planning as in the Pre-F/S (Concept Design Report (January, 2013)).

This screening was conducted for the following 2 cases in accordance with the TOR signed between GOP and GOJ on December 6, 2013.

- Not Use the Channel in Erection Works
- Use the Channel in Erection Works

Preconditions of the bridge plan are shown in Table 10.1.

Table 10.1 Preconditions of Bridge Plan

No.	Item		Preconditions	
			Not Use Channel	Use Channel
1	Road Width	Total Width	49.3m	
2	Navigation	Vertical Clearance	75m	
3	Clearance	Horizontal Clearance	300m	
4	Road Alignment		Follow Pre-F/S	
5	Number of Road Layers		1 Layer	
6	Center Span Length		540m	
7	Side Span Length		110m or 160m (see Section 10.1.3(3))	
8	Erection Condition		Not use channel in erection works	Use channel in erection works

Source: JICA Study Team

10.1.3 Selection of Alternative Main Bridge Type

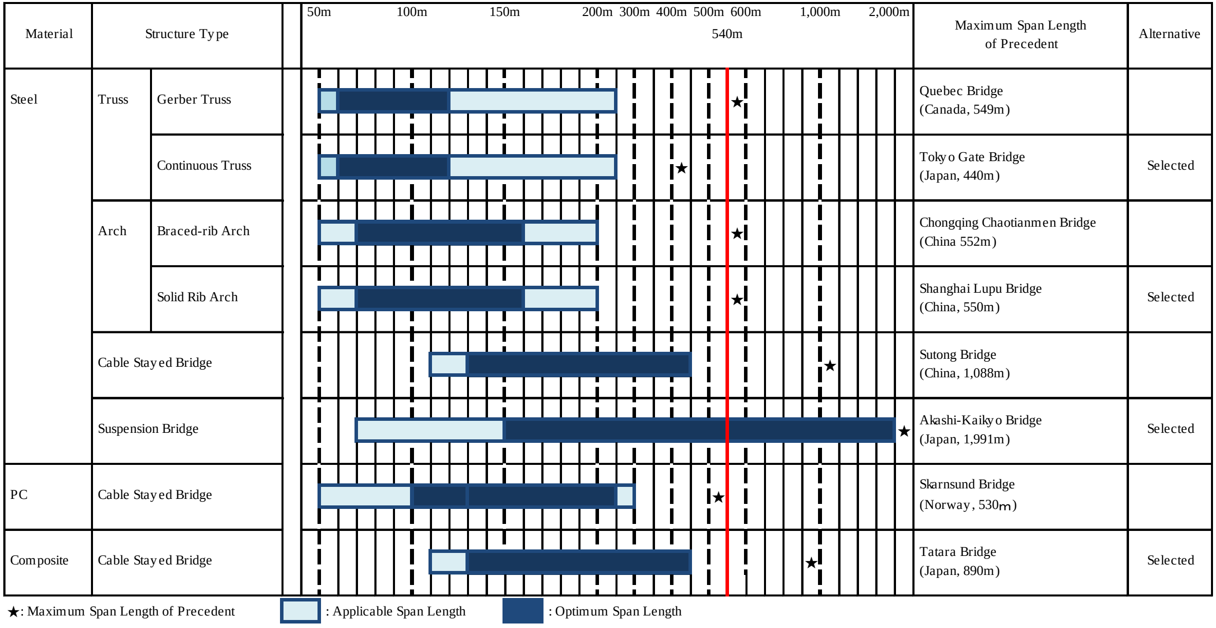
(1) Applicable Span Length

Referring to precedents, the bridge types applicable for a center span length of 540m were selected.

As shown in Table 10.2, the bridge type which is applicable for a center span length of 540m is limited to the suspension bridge. However, bridge types which were applied for center span lengths of more than 500m in the past were also selected as alternatives. In addition, since a composite structure (center span: steel girder, side span: PC girder) was also applied for a center span of more than 500m in the past, this structure was also selected as an alternative type.

Applicable and maximum span lengths for each bridge type are shown in Table 10.2.

Table 10.2 Applicable and Maximum Span Lengths for Each Bridge Type



Material	Structure Type		Maximum Span Length of Precedent	Alternative
Steel	Truss	Gerber Truss	Quebec Bridge (Canada, 549m)	
		Continuous Truss	Tokyo Gate Bridge (Japan, 440m)	Selected
	Arch	Braced-rib Arch	Chongqing Chaotianmen Bridge (China 552m)	
		Solid Rib Arch	Shanghai Lupu Bridge (China, 550m)	Selected
	Cable Stayed Bridge		Sutong Bridge (China, 1,088m)	
	Suspension Bridge		Akashi-Kaikyo Bridge (Japan, 1,991m)	Selected
PC	Cable Stayed Bridge		Skarnsund Bridge (Norway, 530m)	
Composite	Cable Stayed Bridge		Tatara Bridge (Japan, 890m)	Selected

★: Maximum Span Length of Precedent ▢ : Applicable Span Length ■ : Optimum Span Length

Source: Design Data Book'11 (2011, Japan Bridge Association),
PC Highway Bridge Planning Manual (Revised) (2009, Japan Prestressed Concrete Contractors Association)

Note

- Steel Cable-stayed Bridge (Tower: Steel and/or Concrete, Main Girder: Steel, Composite 2 main girders)
- PC Cable-stayed Bridge (Tower: Steel and/or Concrete, Main Girder: PC Box Girder)
- Composite Cable-stayed Bridge (Tower: Steel and/or Concrete, Main Girder: Steel Girder+PC Box Girder)

(2) Selection of Alternative Type

In the previous Section 10.1.3(1), 8 bridge types were selected for the alternative bridge type. Although materials, composition of components and the main structure are different and some bridge types are repeated; the alternative types were further narrowed down based on the following principles:

- Historical progress can be seen.
- Structural weak points are fewer.
- Cost merit is higher.

The selected alternative types and reasons are shown in Table 10.3.

Table 10.3 Selected Alternatives and Reasons

No.	Bridge Type	Selected Alternative	Reason for Selection
1	Truss Bridge	Continuous Truss	There are 2 types of truss bridges such as the Gerber girder type and the continuous truss type. The maximum span length for Gerber girder type in the past is 550m, which is in the same range as the 4th Panama Canal Bridge. However, the Gerber type needs Gerber hinges in the center span and they become structural weak points. On the other hand, the maximum span length of a continuous truss in the past is 440m, which is shorter than the other types. However, designing a continuous truss whose center span is 550m is possible using high tensile strength steel. In addition, unlike the Gerber type, this type does not have structural weak points. Therefore, the continuous truss type was selected as an alternative type.
2	Suspension Bridge		Since the suspension bridge has a span that is within the applicable range, it was selected as an alternative type.
3	Arch Bridge	Solid Rib Arch	There are 2 types of arch bridges such as the braced-rib type and the solid rib type. The arch rib of the braced-rib type is a truss structure like the Bridge of the Americas. The arch rib of the solid rib type is a full web box girder. The maximum span length of both types in the past is 550m, which is in the same range as the 4th Panama Canal Bridge. The braced-rib arch gives the impression of an old style bridge like the Bridge of the Americas. On the other hand, the solid rib type gives the impression of an advanced technology because of its slenderness comparing to the braced-rib type. Therefore, the Solid rib type was selected as an alternative type.
4	Cable-stayed Bridge	Composite	There are 3 types of cable-stayed bridges such as the steel cable-stayed bridge with steel girders for all spans, the PC cable-stayed bridge with PC box girders for all spans, and the composite cable-stayed bridge whose center span is steel girder and side span is PC box girder. The maximum span lengths for all types exceed 500m. Initially, cable-stayed bridges were mainly steel cable-stayed bridges or PC cable-stayed bridges. However, recently, composite cable-stayed bridges are adopted in many cases because of its low cost merit. Since this type was adopted by the Pre-F/S, it was selected as an alternative.

Source: JICA Study Team

(3) Bridge Elements

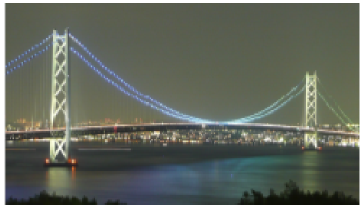
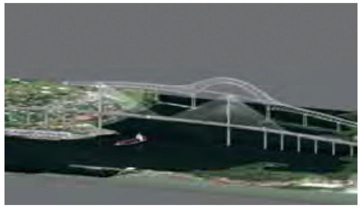
Referring to precedents, the following alternatives were selected based on the applicable span length and the maximum span length.

- Continuous Truss Bridge (Bridge Length: 760m, Span Arrangement: 110m+540m+110m)
- Suspension Bridge (Bridge Length: 860m, Span Arrangement: 160m+540m+160m)
- Solid Rib Arch Bridge (Bridge Length: 760m, Span Arrangement: 110m+540m+110m)
- Composite Cable-stayed Bridge (Original (Pre-F/S)):
  (Bridge Length: 860m*, Span Arrangement: 160m+540m+160m)

*: In the Pre-F/S, the bridge length is 1,040m (250m+540m+250m); however, this selection of span length is optimal for steel cable-stayed, but not optimal for composite cable-stayed bridge. Since the optimum ratio between the side span and the center span stands at 0.3 to 1.0, a side span length of 160m was adopted in this screening.

The bridge elements in the screening are shown in Table 10.4.

Table 10.4 Bridge Elements

No.	Item		Alternative 1	Alternative 2	Alternative 3	Original
Precedent			Tokyo Gate Bridge (Tokyo Metropolitan)  Source: Tokyo Metropolitan	Akashi-Kaikyo Bridge (Hyogo Prefecture)  Source: HSBE	Shin-Kizugawa Bridge (Osaka Prefecture)  Source: Osaka City	4th Panama Canal Bridge (Original (Pre-F/S))  Source: Panama Canal Authority
1	Bridge Type		Truss Bridge (Continuous Truss)	Suspension Bridge	Arch Bridge (Solid Rib)	Cable-stayed Bridge (Composite)
2	Total Width		49.3m			
3	Number of Lanes		Road: 6 lanes (3 lanes/direction), MetroLine-3: 2 lanes (1 lane/direction)			
4	Bridge Length		760m	860m	760m	860m
5	Selection of Span Length		110m+540m+110m	160m+540m+160m	110m+540m+110m	160m+540m+160m
6	Deck Type		Concrete Deck			
7	Superstructure Type		Continuous Truss	Suspension Bridge (Cable, Girder, Tower)	Solid Rib Arch (Arch rib, Girder, Cable)	Cable-stayed Bridge (Stay, Girder, Tower)
8	Substructure Type		Pier	Anchorage	Arch abutment, Pier	Pier
9	Foundation Type		Open Caisson			
10	Main Material	Superstructure	Truss: SBHS Deck: Concrete	Main Cable: PWS Girder: Steel Deck: Concrete Tower: Concrete	Arch Rib: SBHS Girder: Steel Cable: Steel Wire	Girder: Steel, PC Stay: PWS Tower: Concrete
11		Substructure	Concrete	Concrete	Arch Abutment: Concrete Pier: Concrete	Concrete
12		Foundation	Concrete			
13	Erection Method	Not Use Channel in Erection Works	Cantilever method (Traveller Crane)	Main Cable: PWS Erection Girder: Lifting and Swinging from a Barge	Erection by Cable Crane (Use inclined Lifting Jointly)	Stay: Erection by Crane Girder: Lifting and Dragging from a Barge PC Girder: Cantilever Erection
		Use Channel in Erection Work	Cantilever Method (Traveller crane)	Main Cable: PWS Erection Girder: Lifting from a Barge	Side Span: Erection by Crane Bents Center Span: Lifting from a Barge	Stay: Erection by Crane Girder： Lifting from a Barge PC Girder： Cantilever Erection

Source: JICA Study Team

10.1.4 Screening Method

(1) Screening Method

In this screening, a comparative study was conducted under the following conditions.

- The bridge length of each alternative type is different; therefore, the construction cost of each alternative type was estimated and compared for the same total bridge length of 860m which is the longest among all alternative types.
- Construction costs were assessed absolutely and other items were compared relatively based on the established evaluation criteria.

(2) Evaluation Items and Weighting

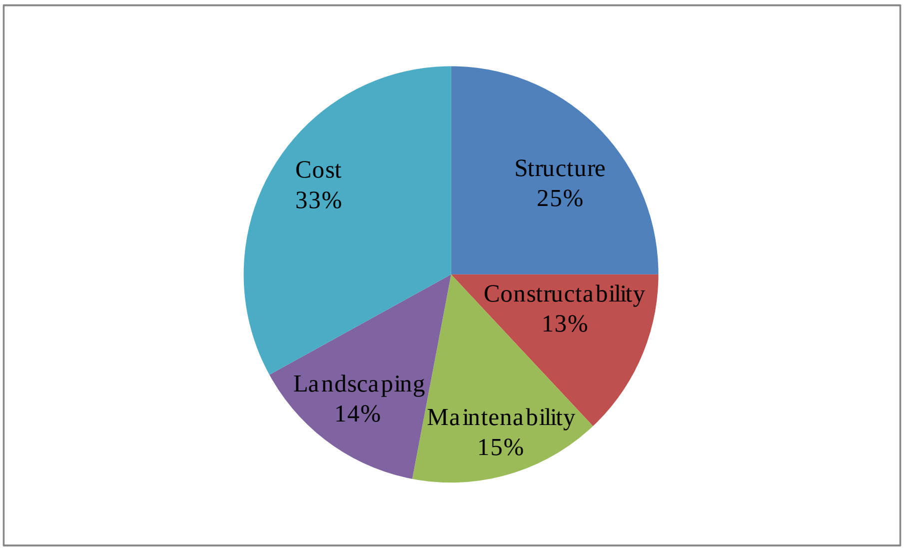
The evaluation items and weighting were decided through discussion with SMP, ACP and JICA and it was evaluated on the basis of 100 points. As for the affection to the environment, it was not included in the evaluation items by reason of no difference among the alternative main bridge types.

Evaluation items and weighting are shown in Table 10.5 and Figure 10.1, respectively.

Table 10.5 Evaluation Items and Weighting

No.	Item	Weight (Points)	Evaluation Method	Evaluation Point
1	Structure	25	Relative Evaluation	Safety for channel and airspace, Stability against storm and earthquake
2	Constructability	13		Safety risk at construction, Construction duration, Availability of local materials, Construction yard required
3	Maintainability	15		Work volume, Workability, Availability of procurement for maintenance works
4	Landscaping	14		Harmony with the Bridge of the Americas and surroundings, Landmark, Originality, Architectural stability, View from deck surface
5	Cost	33	Absolute Evaluation	Initial construction cost and maintenance cost (100 years)
Total		100		

Source: JICA Study Team



Source: JICA Study Team

Figure 10.1 Evaluation Items and Weighting

(3) Evaluation Criteria

Evaluation criteria are shown in Table 10.6 on the next page.

Table 10.6 Evaluation Criteria

Item				Weight (Point)		Evaluation Point	Evaluation Criteria				
							★★★★★: x1.0	★★★★: x0.8	★★★: x0.6	★★: x0.4	★: x0.2
Evaluation Item	Structure	Safety for Channel and Airspace (Risk for Aircraft and Ship Collision)		10	25	Prioritize the bridge type whose risk of collapse by aircraft and ship collision is low.	Degree of Redundancy: High Airspace Reservation: Not interfere	Between 5 stars and 1 star (Closer to 5 stars than 1 star)	Middle of 5 stars and 1 star	Between 5 stars and 1 star (Closer to 1 star than 5 stars)	Degree of Redundancy: Low Airspace Reservation: Greatly interferes
		Bridge Structure	Wind Resistance Stability	5		Prioritize the bridge type which can minimize to occur vibration and lateral deformation in storm.	Vibration: Hardly occurs Lateral Deformation: Hardly occurs				Vibration: Easily occurs Lateral Deformation: Largely deformes
			Seismic Adequacy	5		Prioritize the bridge type whose acting position of interia force is low and hardly occurs resonance in earthquake.	Acting Position of Interia Force: Low position Natural Period: Long				Acting Position of Interia Force: High position Natural Period: Short
			Rigidity	5		Prioritize the bridge type which has high rigidity of superstructure.	High rigidity				Low rigidity
	Constructability	Safety Risk		4	13	Prioritize the bridge type which can minimize affection to the channel even if dropped components, do not need temporary structures in high place and possesses structural stability during construction.	Affection to the Channel: Small Temporary Structures in High Place: Not require Structural Stability during Construction: Stable				Affection to the Channel: Serious Temporary Structures in High Place: Requires Structural Stability during Construction: Unstable
		Construction Duration		4		Prioritize the bridge type whose construction duration is short.	Short construction duration				Long construction duration
		Availability of Local Materials		3		Prioritize the bridge type which can utilize local materials in construction works.	All materials available				All materials Not available
		Construction yard required		2		Prioritize the bridge type which can minimize size of construction yards and do not require concrete plant at construction site.	Construction Yards: Small Concrete Plant: Not require				Construction Yards: Large Concrete Plant: Requires
	Maintainability	Work Volume (Kind, Number and Exposed Area of Structural Components, Frequency of Maintenance Works)		5	15	Prioritize the bridge type which can minimize nos. of component and frequency subject to inspections and re-painting area.	Components to Inspection: Few Frequency of Inspection: Low Re-painting Area: Small				Components to Inspection: Many Frequency of Inspection: High Re-painting Area: Large
		Workability (Working Space and Accessibility for Maintenance Works)		5		Prioritize the bridge type which can shorten inspection ways in total and ensure enough working spaces.	Inspection Ways: Short Working Spaces: Enough at all places				Inspection Ways: Long Working Spaces: Narrow at all places
		Availability of Procurement for Maintenance Works		5		Prioritize the bridge type which can maintain by local contractors during the operation phase.	Possible all maintenance works				Not possible all maintenance works
	Landscaping	Harmony with the Bridge of the Americas and Surroundings		5	14	Prioritize the bridge type which harmonizes with shape of the Bridge of the Americas and characteristics of surrounding landscape (components of natural landscape).	w/ the Bridge of the Americas: Similar (Shape) w/ Surroundings: Excellent	w/ the Bridge of the Americas: Partially similar (Shape) w/ Surroundings: Good	w/ the Bridge of the Americas: Partially similar (Component) w/ Surroundings: Good	w/ the Bridge of the Americas: Partially similar (Component) w/ Surroundigs: Not harmonize	w/ the Bridge of the Americas: Not similar w/ Surroundings: Not harmonize
		Architectural Features	Landmark	2		Prioritize the bridge type which is different bridge type from other bridges on the Panama Canal and creates peculiar symbolic landscaping around the planned location.	Symbolism: Excellent Peculiar Landscaping: Excellent	Symbolism: Good Peculiar Landscaping: Good	Symbolism: Good Peculiar Landscaping: Slightly Good	Similar bridge type to the other bridges on the Panama Canal	Same bridge type to the other bridges on the Panama Canal
			Originality	3		Prioritize the bridge type which can express the remarkable worldwide design originality with structural rationality by state of the art technologies.	By Structure: Easy By Shape: Easy	By Structure: Easy By Shape: Possible (Inferior to 5 stars)	By Structure: Possible By Shape: Limited	By Structure: Limited By Shape: Limited	By Structure: Not possible By Shape: Not possible
			Architectural Stability	2		Prioritize the bridge type which gives visual sense of stability to horizontal force.	Visual Center of Gravity: Low (Splayed tapered shape)	Visual Center of Gravity: Middle	Visual Center of Gravity: Slightly high	Visual Center of Gravity: High	Visual Center of Gravity: High (Massive in side view)
		View from Deck Surface		2		Prioritize the bridge type whose components do not interfer visibility to the outside of bridge from drivers and monorail users.	Not interfere	From Monorail: Interferes (by thin cables) From Driver: Not interfare	From Monorail: Interferes (by thick cables) From Driver: Not interfare	Interferes both of monorail and driver (by cables)	Interferes both of monorail and driver (by thick components)
	Cost	Construction Cost		25	33	=Weight-2*Weight*(Ratio-1.0)					
		Maintenance Cost (100 years (Present Value))		8							
Total					100						

Source: JICA Study Team

10.1.5 Evaluation Results and Conclusion

(1) Evaluation Results

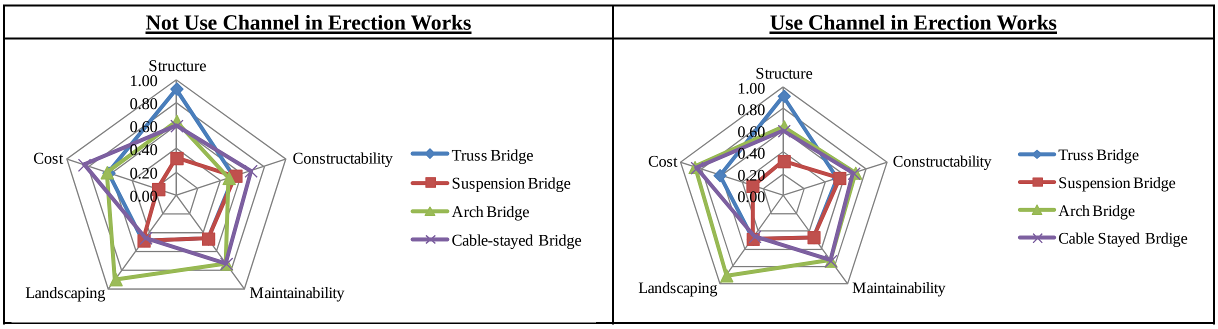
In case the channel is not used in erection works, the total score of the cable-stayed bridge (69.08 points) exceeded that of the arch bridge (66.80 points) by a narrow margin. Compared to the arch bridge, the cable-stayed bridge is disadvantageous in landscaping; however, it has advantages in constructability and cost. Therefore, in the case of not using the channel in erection works, the cable-stayed bridge is evaluated to be the optimum bridge type.

In case of using the channel in erection works, the constructability and cost of the arch bridge are improved and surpass those of the cable-stayed bridge. Furthermore, since the arch bridge does not have towers, the degree of airspace interference is lower. In addition, the arch bridge harmonizes with the exterior view of the existing Bridge of the Americas. This feature improves the landscaping of the arch bridge. Therefore, in the case using the channel in erection works, the arch bridge is the optimum bridge type.

Table 10.7 Evaluation Results

No.	Evaluation Item	Weight (Points)	Not Use Channel in Erection Works				Use Channel in Erection Works			
			Truss Bridge	Suspension Bridge	Arch Bridge	Cable-stayed Bridge	Truss Bridge	Suspension Bridge	Arch Bridge	Cable-stayed Bridge
			Continuous Truss		Solid Rib	Composite	Continuous Truss		Solid Rib	Composite
1	Structure	25	23.00	8.00	16.00	15.00	23.00	8.00	16.00	15.00
2	Constructability	13	6.80	7.00	6.20	8.80	6.80	7.00	9.00	8.80
3	Maintainability	15	7.00	7.00	11.00	11.00	7.00	7.00	11.00	11.00
4	Landscaping	14	6.80	6.80	12.60	6.40	6.80	6.80	12.60	6.40
5	Cost	33	20.50	5.50	21.00	27.88	20.50	10.00	28.50	27.88
Total		**100**	**64.10**	**34.30**	**66.80**	**69.08**	**64.10**	**38.80**	**77.10**	**69.08**
Ranking			**3rd**	**4th**	**2nd**	**1st**	**3rd**	**4th**	**1st**	**2nd**

Source: JICA Study Team



Source: JICA Study Team

Figure 10.2 Radar Chart (Evaluation Results)

(2) Conclusion

The arch bridge and cable-stayed bridge were selected as the appropriate main bridge types in this screening. In the next step, a detailed comparison study will be conducted based on the preliminary design results of the arch bridge and the cable-stayed bridge and the optimum main bridge type will be selected. The preliminary design of the cable-stayed bridge was conducted in the Pre-F/S; therefore, the preliminary design of the arch bridge will be conducted in this JICA Study.

10.2 Study of Platform Plan for 4th Panama Canal Bridge

(1) Objective

In accordance with the study results of Section 10.1 Screening of Main Bridge Type of 4th Panama Canal Bridge, the preliminary design of the arch bridge will be conducted in the JICA Study. However, the 4th Panama Canal Bridge will have 6 lanes of roadway and 2 lanes of Metro Line-3 and the bridge width of more than 50m is required.

Therefore, the optimum platform plan of arch bridge was studied.

(2) Study Items

Single and double-deck plans were selected as alternative platform plans in consideration of the following gradient requirements for the approach sections (see Section 11.4.2(1)2)).

- Road: 4%
- Metro Line-3: Max. 6%

The evaluation items were established as follows:

- Road Serviceability
- Structure
- Cost
- Maintainability

(3) Study Results

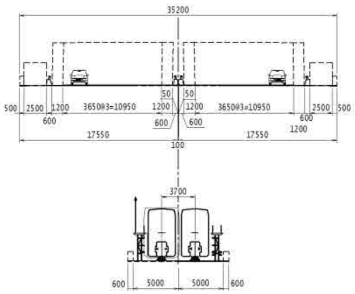
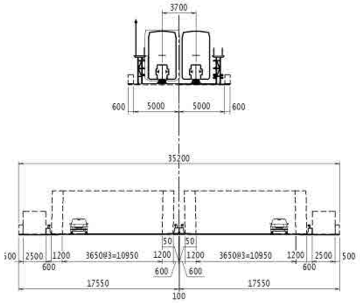
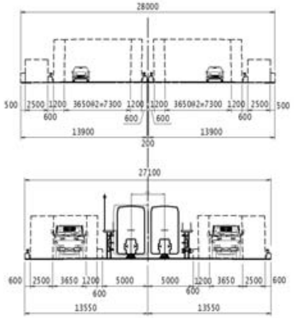
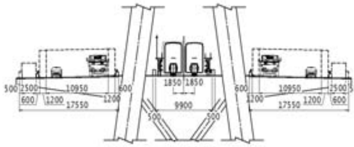
A summary of the study results of platform plan is shown in Table 10.8.

(4) Conclusion

Alternative D (single deck plan) was selected as the optimum platform plan and was applied in the preliminary design of the arch bridge in the JICA Study.

In this Study, the location of Metro Line 3 was in the center of the main bridge, however, its location was revised to the south side (Pacific Ocean side) after this Study because of the relocation of Balboa and Panama Pacifico Stations to the south side in the Metro Line-3 Study. However, this has not affected the results of this study; therefore, a new study was not conducted based on the revised location of Metro Line-3 on the main bridge.

Table 10.8 Summary of Study Results of Platform Plan (Main Bridge of 4th Panama Canal Bridge)

Item		Double Deck			Single Deck
		Alternative A	Alternative B	Alternative C	Alternative D
Platform Plan					
Road Serviceability	Metro Profile	★★★★★: Max. 4%	★★★★★: Max. 6%	★★★★★: Max. 4%	★★★★★: Max. 4%
	Road Profile	★★: Max. more than 5%	★★★★★: Max. 4%	★★★★: Max. 4% (Heavy Vehicle) Max. more than 5% (Small Vehicle)	★★★★★: Max. 4%
	Alignment (Approach)	★★★: Alignment: Simple Independent section: Long	★★★: Alignment: Simple Independent section: Long	★★: Alignment: Complexity Independent section: Long	★★★★★: Alignment: Simple Independent section: Short
	Road Configuration	★★★★★: 3 lanes/direction	★★★★★: 3 lanes/direction	★: 2 lanes+1 lane/direction (separate)	★★★★★: 3 lanes/direction
Structure	Configuration (Stiff. Girder)	★★★★: Well balanced by applying inverted trapezoid	★★★: Too much redundant space on upper layer	★★★★★: No redundant space	★★★: No redundant space but cantilever length≥15m
	Girder Spacing	★★★: Approx. 40m	★★★: Approx. 40m	★★★★: Approx. 30m	★★★★★Approx. 15m
	Wind Resistance	Aerodynamic Stability ★★★★★: Excellent Static Stability ★★★: Average	Aerodynamic Stability ★★★★★: Excellent Static Stability ★★★: Average	Aerodynamic Stability ★★★★★: Excellent Static Stability ★★★: Average	Aerodynamic Stability ★★★★: Good By reason of box shape, inferior to truss structure but superior than cable-stayed bridge Static Stability ★★★★: Good
Initial Construction Cost1)		★★: Approx. 45 Bil.JPY (450 Mil.PAB) (Steel Weight: Approx. 47,000tons) (Approach Section: Approx. 800m)	★★: Approx. 45 Bil.JPY (450 Mil.PAB) (Steel Weight: Approx. 47,000tons) (Approach Section: Approx. 800m)	★★★: Approx. 41 Bil.JPY (410 Mil.PAB) (Steel Weight: Approx. 43,000tons) (Approach Section: Approx. 1,600m)	★★★★★: Approx. 36 Bil.JPY (360 Mil.PAB) (Steel Weight: Approx. 38,800tons) (Approach Section: Approx. 800m)
Maintainability		★★★★: Large re-painting area (truss structure)	★★★★ : Large re-painting area (truss structure)	★★★★ : Large re-painting area (truss structure)	★★★★★ : Less painting area (box shape)
Evaluation Results		**Not Acceptable** (Not satisfy the road serviceability) (Max. Gradient (Heavy Vehicle): More than 5%)	**2nd Rank** Satisfy road serviceability but inferior to Alt. D by cost and independent section length	**3rd Rank** Satisfy road serviceability but inferior to Alt. D by cost, alignment, independent section length	**1st Rank** Satisfy road serviceability and superior to other alternatives in cost

1) Estimated by the ratio of steel weight based on the cost data in Section 10.1: Screening of Main Bridge Type of 4th Panama Canal Bridge

Source: JICA Study Team

Chapter 11 Preliminary Road Design

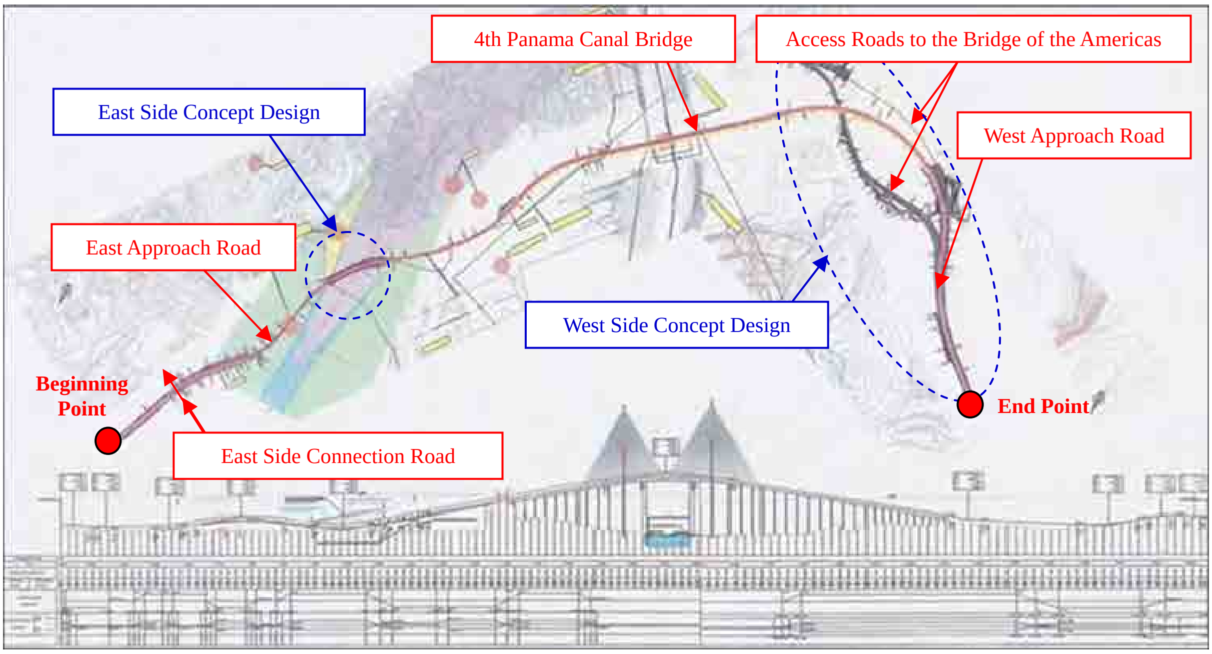
11.1 Objective

The objective of the study is to decide on the scope of the project and to estimate the preliminary project cost based on the preliminary designs of the road and ancillary facilities, the preparation of drawings and the calculation of quantities. In addition, the connectivity between the east and west approach roads and the existing roads needs to be ensured in order to fully achieve the Project's effects; therefore, the design, preparation of drawings and calculation of quantities, at concept design level, were also conducted for the connectivity.

11.2 Study Items

The contents of the road design study are presented below.

A location map of the designed roads is shown in Figure 11.1.



Source: JICA Study Team based on Pre-F/S (Concept Design Report (January 2013)) (ACP)

Figure 11.1 Location Map of the Design Road

(1) Collection and review of existing materials

- Collection and review of the results of the Pre-F/S and related materials

(2) Preliminary Design

- Adjustment with the Panama City Urban Transportation Line-3 Project in its alignment and structure.
- Preliminary design of the East and West Approach Roads (new construction) of the 4th Panama Canal Bridge
- Preliminary design of the Connection Road on the east side (new construction)
- Preliminary design of the Access Roads to the Bridge of the Americas on the west side (reconstruction)

(3) Concept Design

- Connectivity studies for the connecting roads/ramps between the East/West Approach Roads and the existing road
- Evaluations of Service level of the eastside concept design by carrying out a micro simulation of the eastside connectivity.

11.3 General Condition of the Route

11.3.1 General condition of the Route

An Approach Road connects to the Corredor Norte at the beginning point and passes over the Omar Torrijos roundabout, the route then runs along the Roosevelt Ave and connects to the 4th Panama Canal Bridge. On the west side, the route runs westward along the Panamerican Highway, and reaches its end point before the intersection with the access road to Panama Pacifico. The total length of this Arterial Road is 6.7km.

11.3.2 Existing Traffic Condition

There is a flyover connecting Corredor Norte (bound for the Bridge of the Americas) and Roosevelt Ave. Heavy traffic from the center of Panama City, the Bridge of the Americas, and towns along the Canal creates traffic congestion every morning and evening. The traffic volume on the Bridge of the Americas was observed in 2012, and the Annual Average Daily Traffic (AADT) was found to be 49,834 vehicles/day in 2 ways.

11.3.3 Obstacles

(1) Main Obstacles (Results of Site Investigation)

These obstacles are classified as follows with the corresponding measures/considerations to be taken.

Table 11.1 Measures for the obstacles

Properties to be avoided	Properties that require measures/consider
- Roosevelt Ave. - Curundu River box culvert - Sosa hill - Substation building - Chill water Plant	- Existing flyover (To be removed due to decrepitude and interference with the new ramp plan) - Omar Torrijos roundabout (To be improved considering the connectivity with the planned road) - Swamp area on the west side of the bridge (To be measured in the bridge plan)

Source: JICA Study Team

Photos of the main obstacles are shown below.

Photo 1: Flyover

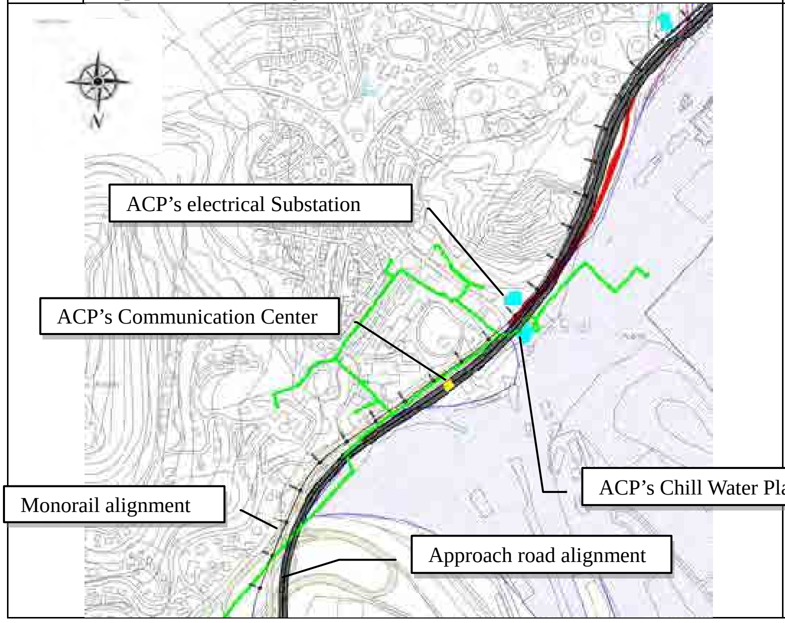
Photo 2: Roosevelt Ave.

(2) Crossing Condition

Since the east side of 4th Panama Canal Bridge is close to ACP's facilities and will cross some existing roads and buried objects, the crossing condition should be considered when selecting the pier locations for the bridge.

The crossing conditions are shown in Table11.2.

Table 11.2 Crossing Condition (East Side of 4th Panama Canal Bridge)

No.	Crossing Condition	Note
🟦	Facility to avoid	ACP 's Electrical Substation ACP's Chill Water Plant
🟨	Facility to avoid if possible (Overpass possible but pier cannot be constructed)	ACP's Communication Center
▨	Area to avoid (inside the blue line) if possible	Panama Port Company
▬	Buried objects to avoid if possible	Chill Water Pipe
▬	Replaceable Existing road	
		ACP's Electrical Substation

Source: JICA Study Team

(3) Navigational Condition

The navigational conditions refer to the future Canal expansion plan of ACP.

The summary of the navigational channel is shown in Table 11.3.

Table 11.3 Summary of the Navigation Channel

No.	Description		Requirement	Ref.
1	Horizontal Clearance	Navigable Width between Prism Lines	300.5m[1)]	Figure 11.6
2		Transition Grade	1:3	-
3	Vertical Clearance	Navigable Height	75m	-
4		Above MLWS (Mean Low Water Spring)	-2.321m	-
5		Water Depth	17.62m	Figure 11.5

Note 1) The navigable width of 300.5m includes the skew angle of the 4th Panama Canal Bridge
Source: ACP

(4) Aviation Condition

As the specific area of the Study includes the road close to the Albrook International Airport and Howard Airport (Ex-Air Force Base), the aviation requirements were confirmed through discussions with the Civil Aviation Authority (AAC Autoridad Autonáutica Civil).

The summary of the civil aviation requirements is shown in Table 11.4.

The horizontal surface does not ensured near the 4th Panama Canal Bridge. However, it does not affect the operation of either airports as confirming by AAC.

Table 11.4 Summary of the Civil Aviation Requirements

No.	Airport	Items	Requirement
1	Albrook International Airport (Marcos A. Gelabert Airport)	Horizontal Surface	54.5m (Radius=4km）
2		Horizontal Upper Face	129.5m
3		Gradient of Heliport Transitional Surface	14.3%
4		Approach Surface	3.3%
5		PAPI System	2.0%
6	Howard Airport	Horizontal Surface	60.8m (Radius=4km）
7		Horizontal Upper Face	135.8m

Source: AAC

11.4 Collection and Review of Existing Material

11.4.1 Collection of Existing Materials

The list of collected materials is shown in Table 11.5.

Table 11.5 List of Collected Materials

No.	Material	Issue	Contents	
1	Pre-F/S Report (Concept Design Report, January 2013)	ACP	Main Report	Chapter 1: Executive Summary (Road Design, Evaluation of Road) Chapter 9: Road Alternatives
			Drawing	Plan, Profile, Typical Cross Section
	Pre-F/S Report (Draft Final Report, November 2013)		Main Report	Chapter 1: Executive Summary (Road Design) Chapter 9: Preliminary Road Design
			Drawing	Plan, Profile, Typical Cross Section
2	Bridge of the Americas	MOP	Drawing	Typical Cross Section
3	Panamerican Highway	MOP	Drawing	Typical Cross Section

Source: JICA Study Team

11.4.2 Proposal of Road Alignment

Based on the verification/evaluation of the validity of the Pre-F/S, the following proposals were adopted.

(1) Proposal to Decrease the Design Speed of the Approach Road

1) Vicinity of the Beginning Point

At the beginning point, the merging and diverging noses are located in short distances. Therefore, the reduction of the design speed from 100km/hr to 80km/hr is proposed in consideration of traffic safety

2) Vicinity of the 4th Panama Canal Bridge

Before and after the 4th Panama Canal Bridge, the horizontal alignment has a 700m radius, a 4% gradient and a 9,500m convex vertical curve, which are values that satisfy the design standard.

The maximum gradient is 5% (urban arterial, flat land) if the design speed would be 120km/hr. The travelling speed of trucks (Power/weight ratio: 10 horsepower/ton) decreases from 80km/hr to 34/km in the case of a 5% gradient, but only to 43km/hr in the case of a 4% gradient.

The summary of running speed and grades is shown in Table 11.6.

Table 11.6 Summary of Running Speed and Grades

Vertical Gradient	Direction	Running Speed	Evaluation
5.0%	From BP to EP	34km/hr	Poor
	From EP to BP	34km/hr	
4.0%	From BP to EP	43km/hr	Good
	From EP to BP	43km/hr	

Source: JICA Study Team

(2) Proposal to Change the Design Value of the Approach Road

The proposed new values corresponding to the Pre-F/S are shown in Table 11.7.

Table 11.7 Proposed Revised Value Corresponding to Pre-F/S

Item	Designed Value (Pre-F/S)	Revised Design Value (This Study)
Superelevation of curve section at BP (Design Speed:80km/hr)	Superelevation 5.03% (R=435m) Superelevation 5.38% (R=500m)	Superelevation 6.4% (R=435m) Superelevation 5.8% (R=500m)
Superelevation of curve section before and after 4th Panama Canal Bridge (Design Speed:100km/hr)	Superelevation 6.11% (R=700m) Superelevation 8% (Minimum Radius)	Superelevation 6.4% (R=700m)
Vertical Curve Radius at EP (Design Speed:100km/hr)	VCR (Convex): 2,343m and 2,396m	VCR (Convex): bigger than 5,200m

Source: JICA Study Team

(3) Proposal on Changing the Number of Lanes and Cross Section Width

The 3.0m width of the outer shoulder is adapted to 1.2m at the retaining wall sections as well as the bridge sections due to the limited space. On the other hand, on the west side of the Canal a return to the 3.0m shoulder width is proposed because of adequate space along the 1.2km section.

A sidewalk was designed for the 4th Panama Canal Bridge section in the Pre-F/S. This Study also follows that basic concept; however, the location was revised. A 4m wide sidewalk is located on the south side (Pacific side) between Pier 30 and Pier 33 to serve as a viewing deck.

The necessity of a sidewalk will be studied again in the D/D stage in consideration of security and economic aspects. In the case of eliminating the sidewalk, the construction cost including the elevators would be reduced by about USD 20 Million.

A detailed discussion of the elevators is made in Chapter 13.

11.5 Preliminary Design

11.5.1 Design Conditions

(1) Geometric Design Standard

The geometric standard for the preliminary design is based on the observations made in Section 11.4 “Collection and Review of Existing Materials”. The target road is ranked as an Urban Arterial Road because it is expected to carry inner-city traffic as well as traffic between urban and rural areas.

The geometric design standard for the preliminary design is shown in Table 11.8.

Table 11.8 Geometric Design Standard (Preliminary Design)

Item	Standard Value		
Beginning/End Point(km)	Beginning Point: (-KM0+020.975) Albrook Station of MetroLine-3, connecting to Corredor Norte End point: (KM6+699.237) Before the Intersection of Howard area, connecting to Panamerican Highway		
Applied Standard	AASHTO, A Policy on the Geometric Design of Highway and Street, 6th Edition 2011		
Road Class	Urban Arterial Road (full access control, toll free operation)		
Design Speed	80km/hr (Section from the beginning point to the connection point with the ramp located on the west side of the roundabout) 100km/hr (Section after the connection point with the ramp located on the west side of the roundabout)		
Stopping Distance	185m (V=100km/hr), 130m (V=80km/hr)		
Number of Lanes	6 lanes (except for the following section) 4 lanes (section from beginning point to the connecting ramp on the west side of the roundabout) Typical Cross Sections are shown in Chapter 11.4.3.		
Geometric Design Standard	Design Speed	100km/hr	80km/hr
	Horizontal Alignment		
	Minimum Curve Radius	R=394m (e=8%)	R=229m (e=8%)
	Minimum Curve Radius with Clothoid	R=592m	R=379m
	Curve Radius without Superelevation	R=3,630m	R=2,440m
	Minimum Clothoid Length	L=56m	L=50m
	Maximum Superelevation	e=8%	e=8%
	Minimum Superelevation	e=2.5%	e=2.5%
	Cross fall	e=2.5%	e=2.5%
	Vertical Alignment		
	Maximum Gradient	i=5%	i=6%
	Minimum Gradient	i=0.3%	i=0.3%
	Minimum Vertical Curve(Convex)	VCR (Convex)=5,200m	VCR (Convex)=2,600m
	Minimum Vertical Curve(Concave)	VCR (Concave)=4,500m	VCR (Concave)=3,000m

Source: JICA Study Team

(2) Pavement Design Standard

The Guide for Design of Pavement Structures 1993 (AASHTO) was applied for the pavement design.

(3) Guard Rail Installation Standard

The Roadside Design Guide 3rd Edition 2006 (AASHTO) was applied for the design of barriers and medians.

11.5.2 Preliminary Design

(1) Alignment Design

1) Approach Road to the 4th Panama Canal Bridge

a) Horizontal Alignment

The horizontal alignment of the approach road is revised based on the results of reviewing the Pre-F/S. It should be noted that the station at the beginning point starts with a minus number due to the fixed station/coordination (KM3+800) at the center of the main bridge.

At the beginning point, the concept design is applied and the alignment is shifted to the south side of the existing road so that the two roads do not interfere with each other (see Section 11.6.1(4)1)).

Along Roosevelt Ave., the alignment is shifted to the north (Balboa Port side) in order to avoid the ACP facilities, make space for the monorail, and minimize the impact on Sosa Hill.

In the section of the 4th Panama Canal Bridge, a straight line was applied for the main span section considering its structural merit.

From the 4th Panama Canal Bridge to the end point, the alignment follows along the Pre-F/S alignment.

The superelevation and superelevation run-off of the curve sections were revised corresponding to the proposed design speed.

b) Vertical Alignment

The vertical alignment of the Approach Road is improved basically to accommodate the horizontal alignment based on the results of the review and the concept design (see Section 11.6 of the Pre-F/S.

At the beginning point, the horizontal alignment is followed, which is based on the result of the concept design (for Omar Torrijos Roundabout) (see Section 11.6.1(4)1)); therefore, the intersection point was shifted to the west (KM1+950) in consideration of the ramp crossing and also to minimize interference with the airspace restrictions, which are located near the beginning point.

The vertical alignment at the 4th Panama Canal Bridge section was matched, 4% to -4% (Intersection Point: km3+800), and the vertical curve radius is the same as that in the Pre-F/S.

The vertical alignment in the vicinity of the end point was revised so that the vertical curve radius satisfied the design speed of 100km/hr.

2) East Side Connection Road

The East Side Connection Road is a ramp (on/off) which connects to the Approach Road at the beginning point, and is the same as in the Pre-F/S.

3) Access Roads to the Bridge of the Americas

The Access Roads to the Bridge of Americas are roads connecting the Bridge of Americas and the Howard intersection, which is located at the end point. A road bound for Panama City starts from the Howard Intersection, and shifts to the west side. It then passes over the swamp area, and reaches the Bridge of Americas. A road bound for Arraijan starts at the Bridge of Americas utilizing the existing road and connects to the West Approach Road.

a) Horizontal Alignment

The horizontal alignment of the Access Roads to the Bridge of the Americas follows the Pre-F/S.

b) Vertical Alignment

The vertical alignment of the Access roads to the Bridge of Americas was not included in the Concept Design of the Pre-F/S. Thus, the vertical alignment for the east-bound road for Panama City was studied based on a topographic map.

(2) Typical Cross Sections

The cross section elements of the Approach Roads are set based on the collection and review of the existing materials.

The cross section elements of the Approach Roads (Preliminary Design) are shown in Table 11.9.

Table 11.9 Cross Section Elements of Approach Roads (Preliminary Design)

Item	Standard Value	
Cross Section Elements	Cross Section Width	
	Lane	W=3.65m
	Median Strip	W=1.2m
	Outer Shoulder	W=1.2m (Bridge, Retaining Wall)
	Inner Shoulder	3.0m (Earth work)
	Sidewalk	W=2.5m (including Drainage Facilities)
	Monorail (including inspection walkway)	W=9.0m
	Road Clearance Limit	h=5.5m
	Panama Canal Navigation limit	h=75m (above MLWS)

Source: JICA Study Team

(3) Earth work Design

The gradient of the slope was decided as follows: Embankment 1:2.0, Cutting Earth 1:1.0, Soft Rock 1:0.5. In the eastern area, reinforced earth will be used due to the limited space between the project road and existing roads.

(4) Soft Ground Treatment

The Access Road to the Bridge of Americas bound for Panama City passes over the swamp area, but a detailed study of this area was not carried out because a soil survey was not available. The road bound for Panama City consists of mostly bridge sections, and does not affect the preliminary cost estimate.

(5) Pavement Design

Regarding the pavement designs at the earth work section, similar to the Corredor Norte and Panamerican Highway, it was decided that the carriageways would have concrete pavement (JCP/Jointed Concrete Pavement) and the shoulders asphalt pavement. As the results of the traffic assignments indicated in Chapter 3.4.4, the ESAL (18kip Equivalent Single Axle Load) is 7.64 million times in 20 years (2021 to 2040), which is less than the 10.96 million times in the Pre-F/S. Therefore, a concrete pavement of t=220mm and a base course of t=250mm (CBR is more than 80%) shall be applied.

(6) Road Facilities Design

1) Drainage Facility

A drainage ditch was planned for the earth work section of the Approach Road, the East Side Connection Road and the Access Roads to the Bridge of the Americas. The ditch (0.5mx0.5m) is installed at the toe of the embankment slope for drainage of surface water.

2) Traffic Safety and Control Facility

a) Barrier

In the Approach Roads, a concrete barrier (New Jersey Type, Testing Level 3, approved by FHWA) was planned for the median strip, and a guardrail was planned for the shoulder. A guardrail was planned for the embankment section of the East Side Connection Road and the Access roads to the Bridge of the Americas.

b) Road Marking

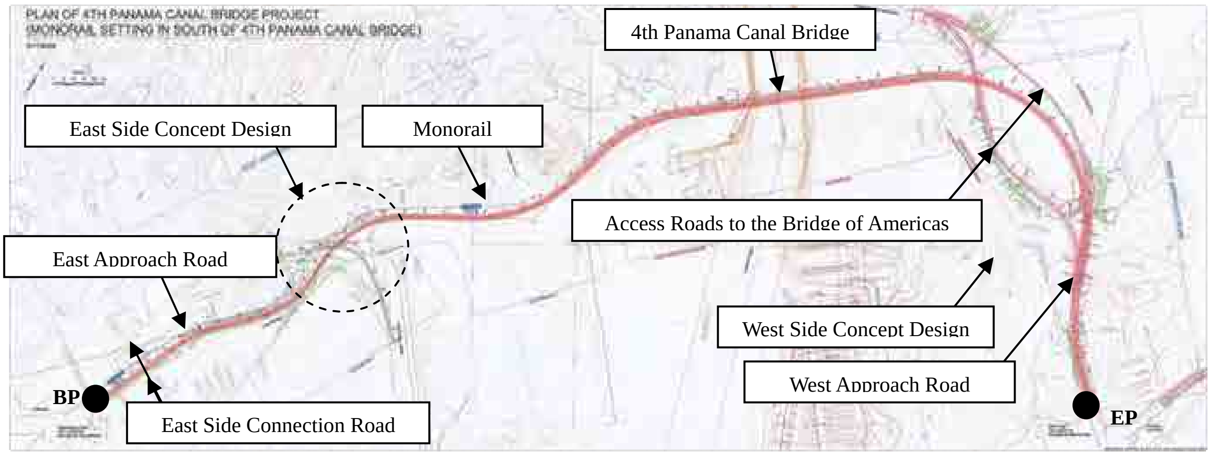
Road markings on the installation road were planned for the traffic lane lines and the lane edge for the whole section. Zebra markings were planned for the ramp terminals of the interchanges. Lane markings (division line and outside line) were planned for the whole section of the East side Connection Road and the Access Roads to the Bridge of the Americas.

c) Traffic Sign

On the Approach Roads, a speed limit sign was planned for indicating the design speed. Guide signs were planned for at the entrance and exit of the interchanges.

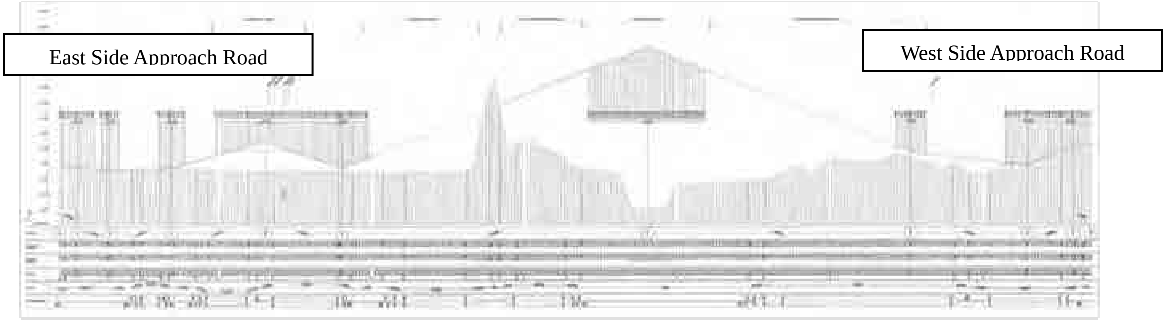
(7) Drawings of Preliminary Design

The plan, profile and typical cross sections are shown in Figures 11.2 to 11.5, respectively.



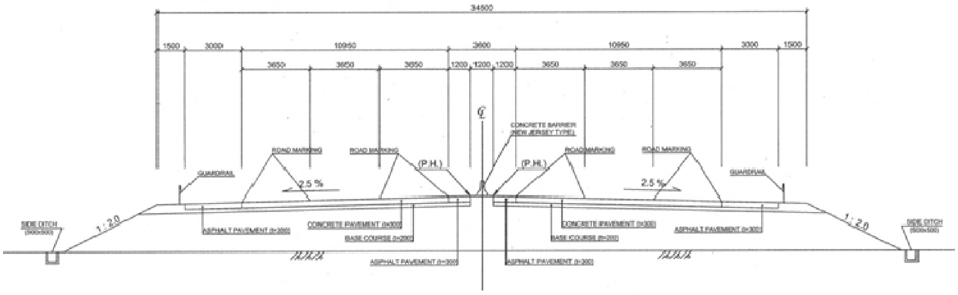
Source: JICA Study Team

Figure 11.2 Project Road Plan (Preliminary Design)



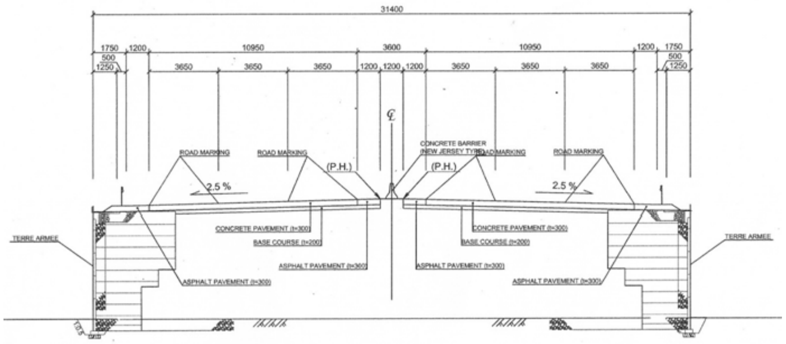
Source: JICA Study Team

Figure 11.3 Project Road Profile (Preliminary Design)



Source: JICA Study Team

Figure 11.4 Typical Cross Section, Earth work (6 lanes) (Preliminary Design)



Source: JICA Study Team

Figure 11.5 Typical Cross Section, Retaining Wall (4 lanes) (Preliminary Design)

11.5.3 Revisions and Proposals based on the Pre-F/S

As a result of the study, the design from the Pre-F/S was improved upon and additional proposals for the design were made as described below.

The design speed of the Access Roads was changed from 120km/hr to 100km/hr because the slowing of trucks (approaching the bridge) will create a greater difference in the traveling speeds between trucks and cars. Also, in the section between the beginning point and the merging/diverging nose at the west side of Omar Torrijos roundabout, the design speed was reduced from 100km/hr to 80km/hr due to the short distance of the merging and diverging nose. Road structures were changed from embankment to retaining wall in the earth work section from the Omar Torrijos roundabout to the merging/diverging nose, because constructions must be carried out in a small/limited space beside the Roosevelt Ave.

The Preliminary design was carried out based on the concept design of the Pre-F/S (January, 2013) due to the delayed submission of the draft final report of the Pre-F/S in December, rather than October 2013, as originally planned. In the Draft Final Report (as of November, 2013) of the Pre-F/S, the design speed of the Approach Road was reduced from 120km/hr to 90km/hr in order to keep the stopping sight distance, while its horizontal and vertical alignments were not changed from the concept design report.

In this preliminary design, the design speed of 100km/hr has been applied to the Approach Road because safety requirements, including the stopping sight distance, can be satisfied with this improved design.

The results of the preliminary design are shown in Table 11.10.

Table 11.10 Summary of the Results of Preliminary Design

	Approach Road	Connection Road at East Side	Access Road to the Bridge of the Americas
Beginning Point/ End Point (Length)	Beginning Point: Albrook Area Connecting to Corredor Norte End Point: before the Howard Intersection connecting to Panamerican Highway (L=6,720.212m)	Beginning Point: Albrook Area End point: Omar Torrijos Roundabout (L= 1,025.190m) (On Ramp: L=400.200m) (Off Ramp: L=624.990m)	Beginning Point: Howard Intersection End point: Bridge of the Americas (L=3,170.400m) (Inbound: L=1,582.400m) (Outbound: L=1,588.000m)
Road Class	Arterial Road (full access controlled, toll-free operation)	Ramp (connecting with Approach road and main urban road)	Rural Road
Number of Lanes	From Beginning Point to merging/diverging nose at the west side of Omar Torrijos roundabout: 2 way, 4-lane From said nose to the End Point: 2 way, 6-lane	1 way, 2 lanes	1 way, 2 lanes
Design Speed	From Beginning Point to merging/diverging nose at the west side of Omar Torrijos roundabout: 80km/hr From said nose to the End Point: 100km/hr	40km/hr	80km/hr
Road Structure	Earth work (including retaining wall) and Bridge	Earth work and Bridge	Earth work and Bridge

Source: JICA Study Team

11.6 Concept Design

11.6.1 Study of the Concept Design

(1) Objective

A concept design study was executed in order to decide on the alignment of the Approach Roads and to improve the vehicular connectivity of the existing roads. The target road links are the existing roads on the east/west side of the 4th Panama Canal Bridge and the Approach Roads on each side.

Especially in eastern area, heavy traffic congestion as well as continued increase in traffic is expected. Therefore, to estimate and evaluate the traffic volume, a micro-simulation of the roundabout was carried out.

For reference, the preliminary construction cost was estimated for this concept design.

(2) Summary of the study

The approach road and existing roads are connected by ramps, and the best formation of the roundabout was determined by considering the location of the existing roads, the terrain and objects in the vicinity. The basic idea for improvement was to provide additional road links to the roundabout without making major changes in the shape of the roundabout.

The existing flyover seems to be almost decrepit and will be removed to allow the elongation of the new ramps.

Furthermore, the micro-simulation of the Omar Torrijos intersection (Concept Design at the east side) was executed. Based on the results of the analysis by micro-simulation, verifications were made of the service level.

The results of the concept design are shown in Table 11.11.

Table 11.11 Summary of the Results of Concept Design

Items	East Side Area		West Side Area
	Underpass	Additional Ramps	Additional Ramps
Beginning Point/ End Point (Length)	Omar Torrijos Ave.: L=1,500m F Ramp (on): L=1,520m G Ramp (off): L=1,500m	A Ramp L=500m B Ramp L=650m C Ramp L=350m D Ramp (off) L=350m E Ramp L=350m H Ramp (off) L=200m I Ramp (on) L=350m	X Ramp (U-turn) L=1130m Ramps to the Existing Roads (Y and a to i Ramps)
Road Class	Urban Road/Ramp	Ramp	Ramp/Rural Road
Number of Lanes	Underpass: 2 ways, 2 lanes On/Off Ramp: 1 way, 2 lanes	1 way, 1 or 2 lanes	1 way, 1 or 2 lanes
Design Speed	60km/hr	40km/hr	40km/hr
Road Structure	Earth work (including retaining wall) and Bridge	Earth work (including retaining wall) and Bridge	Earth work and Bridge

Source: JICA Study Team

(3) Design Condition

The design speed of the ramps was decided to be 40km/hr, and the number of lanes was decided based on the traffic volume.

The design condition of the ramps (concept design) is shown in Table 11.12.

Table 11.12 Design Condition of Ramps (Concept Design)

Item		East Side		West Side
Design Speed of Approach Road		80km/hr		100km/hr
Ramp	Design Speed	40km/hr		40km/hr
	Number of Lanes	1 way, 2 lanes		1 way, 1 lane
	Minimum Curve Radius	40m		40m
	Maximum Gradient	8%		8%
Underpass	Design Speed	60km/hr	40km (Ramp)	-----
	Number of Lane	2 way, 4 lanes	1 way, 1 lane	
	Minimum Curve Radius	150m	40m	
	Maximum Gradient	6%	8%	

Source: JICA Study Team

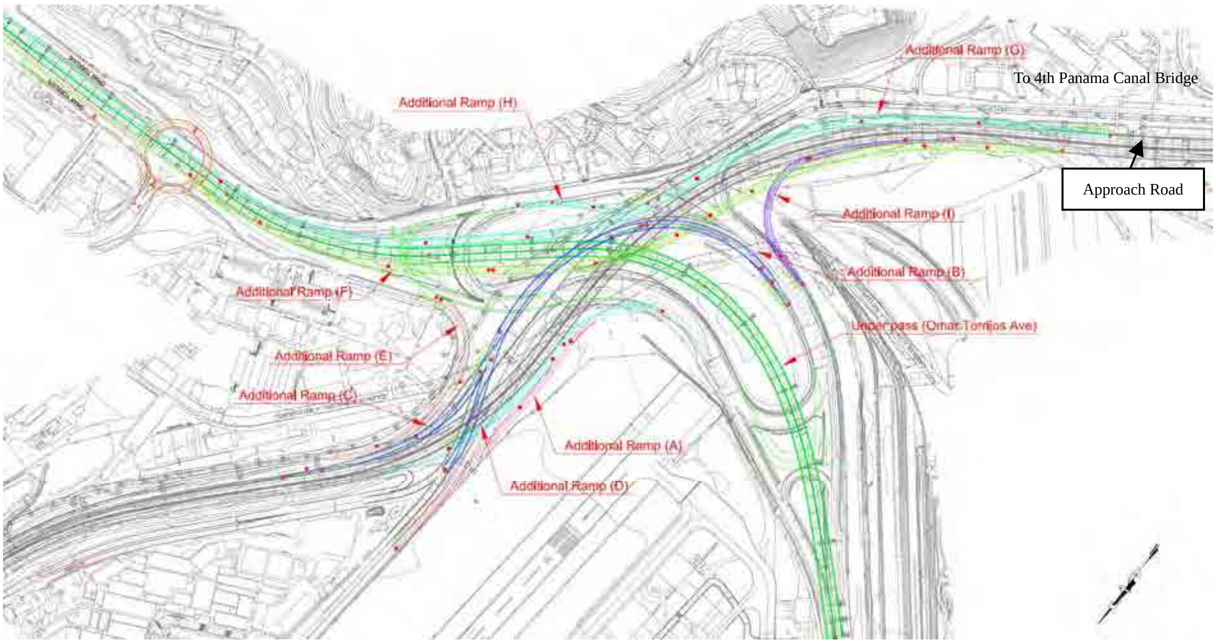
(4) Concept Design

1) East Side

The Approach Road passes over the Omar Torrijos roundabout by means of a flyover. A study was conducted on the connectivity between the Approach Road and the roundabout. The Omar Torrijos roundabout is located in an important area, being surrounded by the National Bus Terminal, Albrook Mall, Balboa Port, Albrook “Marcos A. Gelabert” Airport and ACP facilities; it also connects to the Bridge of Americas, as well as the roads along the Panama Canal.

As the discussion results with SMP, the existing shape of Omar Torrijos Intersection was not changed as can as possible in consideration of limited land use conditions at the site. North-south is the predominant direction of the traffic using the roundabout. Accordingly, this concept design provides an underpass for the north-south traffic so it will no longer enter the roundabout. As a result, it is expected that traffic in the Omar Torrijos roundabout will decrease, and traffic congestion will be eased. The underpass goes under the existing Curundu River box culvert (6m*5m*2) which is underground.

The concept design road links with additional ramps and underpasses, connecting to the approach road or to neighboring roads.



Source: JICA Study Team

Figure 11.6 Layout of the Concept Design (East Side)

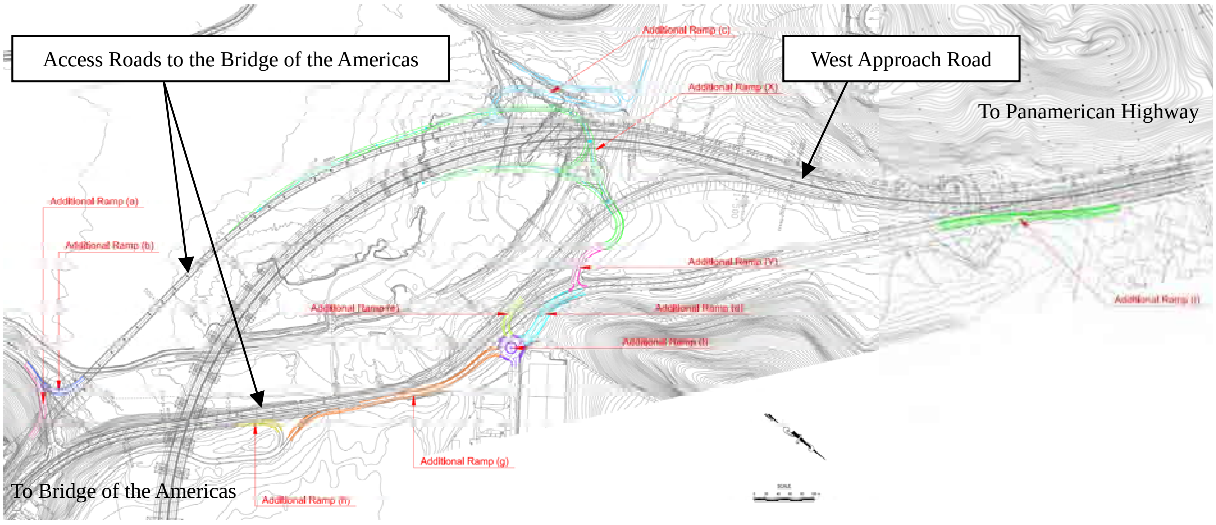
2) West Side

In the Pre-F/S, the traffic between the West Approach Road and the existing road creates difficulties even though the Panamerican Highway (Access Roads to the Bridge of the Americas) was planned to be a 2 way, 4 lane road in order to improve the connectivity to the vicinity.

Therefore, additional/extension ramps were planned for connecting the 4th Panama Canal Bridge, the West Approach Road, and the east-bound and west-bound Access Roads to the Bridge of the Americas through an intersection.

Additional Ramps (a) and (b) are located between the Access Bridge and the Bridge of the Americas, and connecting southern road. Additional Ramps (c) to (h) connect the Access Bridge/Road and the exist roads. Additional Ramps (X) and (Y) are off-ramps from the west approach road. Additional Ramp (i) is an alternative route of the existing road due to interference from the west approach road.

A layout of the west side concept design is shown in Figure 11.7.



Source: JICA Study Team

Figure 11.7 Layout of the Concept Design (West Side)

11.6.2 Micro Simulation

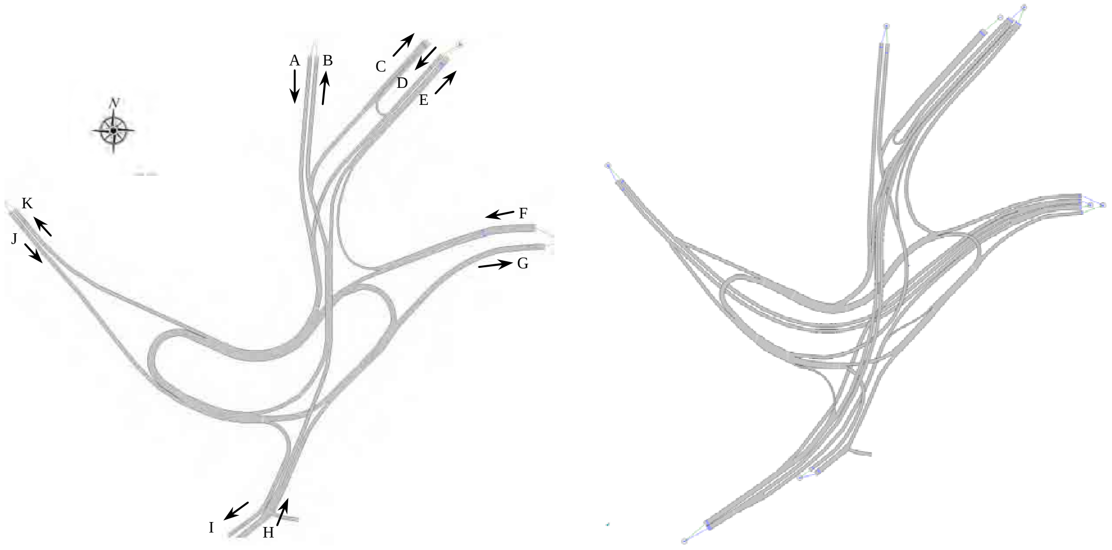
(1) Objective

A micro simulation was conducted to detect the occurrence of traffic congestion in the improved Omar Torrijos intersection, which was proposed in 11.6.1.

(2) Method of Verification

The two cases below were simulated by utilizing the software "Aimsun 6".

Case	Applied Network Model	Applied Traffic Volume
Present Condition	Exiting Network *Figure 11.8	OD Traffic Volume in 2013 Spot Traffic Volume in 2013 (7:00am-8:00am)
Improvement Plan	Future Network (Improvement) *Figure 11.8	OD Traffic Volume in 2050 (7:00am-8:00am)



Existing Network Mode

Future Network Model (Improved)

Source: JICA Study Team

Figure 11.8 Network Models applied to Micro Simulation (Existing and Future)

(3) Result and Evaluation

In general, the definition of traffic congestion varies according to the road types and among the responsible organizations. In this micro simulation, the evaluation was conducted by comparing the design speed and simulated speed in the existing network model and in the future network model.

Table 11.13 Average Simulated Speed of Each Case

		Approach Road	Underpass	Existing Road	Ramp	Roundabout
Existing Network (Year 2013)	Design Speed (km/hr)	-	-	50	40	30
	Average Simulated Speed (km/hr)	-	-	52.8	43.9	31.0
Future Network (Year 2050)	Design Speed (km/hr)	80	60	50	40	30
	Average Simulated Speed (km/hr)	84.1	64.3	51.9	42.5	30.6

Source: JICA Study Team

In both the existing network and the future network (improved plan), the average simulated speed on each type of road is more than the design speed. The simulation also verified that traffic congestion would not occur in the future network.

Chapter 12 Preliminary Bridge Design

12.1 Objective

The objective of the study is to decide on the scope of the project and to estimate the preliminary project cost from the preliminary designs of the bridge structures and ancillary facilities, and the preparation of drawings and the calculation of work quantities.

12.2 Items included in the Preliminary Design

The Preliminary Design includes the following elements.

- Establishment of planning conditions and design criteria
- Establishment of cross sections
- Preliminary designs of bridges, which consist of bridge planning and determination of required structural sections
- Planning and design of bridge ancillary works
- Preparation of drawings
- Calculation of quantities

As a result of Chapter 10.1 Screening of Main Bridge Type for 4th Panama Canal Bridge, the Preliminary Design for the main 4th Panama Canal Bridge assumed two scenarios, using the navigation channel and without using the navigation channel in the bridge construction.

Furthermore, the improvement of the Omar Torrijos roundabout was conducted as a Concept Design in the Study (see Section 11.6); therefore, the bridge planning does not include the improvement of the Omar Torrijos roundabout.

12.3 Results of Preliminary Design

The results of the Preliminary Design are summarized in Table 12.1.

Although the arch bridge can be built by two different erection methods, that is using the navigation channel and without using the navigation channel, the structural elements of the arch bridge were determined for its completed state, which is much more predominant than the construction methods. On the other hand, temporary facilities, construction period and construction costs are related to the construction method, depending on whether or not the navigation channel is used. These discussions are made in Chapter 15.

Table 12.1 Summary of Preliminary Bridge Design Results

No.	Route	Bridge Name		Location (KM)	Bridge Length	Span Arrangement	Width	Bridge Type
1	Project Road	Flyover No. 1		1+050 to 1+320	270m	2@40m+30m+4@40m	22.100m	PC-I
				1+320 to 1+570	250m	50m+2@60m+45m+35m		Steel Box
2		Flyover No. 2		2+000 to 2+260	260m	5@40m+2@30m	29.400m	PC-I
				2+260 to 2+740	480m	60m+4@90m+60m		Steel Box
3		4th Panama Canal Bridge	East Approach	2+847 to 3+380	533m	43m+60m+50m+90m+2@100m+90m	38.400m to 50.235m	Steel Box
4			Main Bridge	3+380 to 4+220	840m	150m+840m+150m	48.742m to 52.494m	Arch
5			West Approach	4+220 to 5+030	810m	90m+3@100m+80m+5@60m	38.400m to 48.742m	Steel Box
				5+030 to 5+390	360m	9@40m	29.400m	PC-I
6	Access Roads to the Bridge of Americas	Connection Bridge to the Bridge of the Americas		0+520 to 1+280	760m	19@40m	10.900m	PC-I

Source: JICA Study Team

12.4 Planning Conditions and Design Criteria

12.4.1 Planning Conditions

The Project road is characterized as follows:

- Crosses over the Panama Canal
- Road construction is close to the Albrook “Marcos A. Gelabert” International Airport and Howard Airport
- It is an intra-city road that carries appurtenances and crosses a considerable number of existing public utilities

The conditions for planning the bridge structures are established taking the above aspects into consideration.

(1) Topographic Condition

The Study utilized the topographic data produced by the Pre-F/S on the basis of ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) - DRM which was developed by NASA and METI (Ministry of Economy, Technology and Industry, Japan). The data obtained from the Pre-F/S was digitalized as follows.

- 10m contour CAD data/ WGS 84/ UTM

The Pre-F/S carried out supplementary surveys by using PTS-GPS to obtain 1m interval contour lines in addition to the above.

(2) Subsoil Condition

The intended area of study is delimited by the lowest point, at -15.0m in the navigation channel, with basalt rock on the eastern bank and siltstone, sandstone and tuff rock on the western bank. According to RQD, There are some cracks in the rock, but it is enough hard as the bearing strata.

Soft clayey soil, which is formed by coastal sediments, covers the shallow depths of the plain area as shown in Figure 12.3. On the eastern bank, an embankment constructed from marl and black soil covers the surface layer.

(3) Erection Conditions

The following two erection methods have been considered in the bridge plan and design.

- Using the navigation channel
- Without using the navigation channel

Detailed discussions are made in the subsequent Chapter 15.1..

(4) Accommodation Position of the Metro Line 3

The 4th Panama Canal Bridge is to be built as a highway cum metro (mass transit) rail bridge. Regarding the Metro line 3 project, three stations are to be within the study area of the 4th Panama Canal Bridge; namely Albrook Station, Balboa Station and Panama Pacifico Station. All three stations are to be located along the southern (Pacific) side of the road alignment of the 4th Panama Canal Bridge.

Accordingly, the position of the Metro Line 3 was decided to be along the southern side of the road alignment of the 4th Panama Canal Bridge.

12.4.2 Design Standards and Criteria

(1) Design Standards

In principle, the design should be made on the basis of the AASHTO LRFD Bridge Design Specifications, 6th Edition, 2012, except for those parameters regarding the natural conditions specified by the design standards of Panama, or by the existing analysis results.

(2) Operational Category

The “Critical Bridge” specified in the AASHTO LRFD Bridge Design Specifications should be adopted in the Study. Accordingly, the return period of seismic horizontal equivalent force and the acceleration response spectrum should be 2,500 years.

(3) Design Life

The design life time should be 100 years.

(4) Design Live Load

The HL-93 specified by AASHTO LRFD Bridge Design Specifications should be used.

(5) Acceleration Response Spectrum

The acceleration response spectrum is based on the AASHTO LRFD Bridge Design Specifications. As for regional characteristics, the parameters referred to those obtained in the Seismic Hazard Assessment of the 2nd Panama Canal Bridge (Centennial Bridge).

The assumption that the natural period of structure in the Project is 1.5 Sec. or more, the design horizontal seismic factor of 0.2 was adopted.

(6) Design Wind Load

As discussed in 4.4.4, the maximum wind velocity around the Study area for the past 10 years was 81.9 km/hr. The wind velocity around the Study area was calculated in the following manner for a 100 year probability.

$V(100) = 81.9/0.874 = 93.7 \text{km/hr}$

On the other hand, the design standards of Panama (REP) stipulate a maximum wind velocity of 115 km/hr. Taking the conservative side, the maximum wind velocity of 115 km/hr was adopted in the Study.

Wind forces can be obtained from the above maximum wind velocity and ASCE7-10.

(7) Design Thermal Load

On the basis of Panama Standards (REP), the loads of thermal effect were calculated as follows:

- Base Temperature: 27C
- Temperature Fall and Rise: ±15C

12.5 Preliminary Designs of Bridge Structures

12.5.1 Main Bridge

(1) 4th Panama Canal Bridge

1) Main Bridge

i. Basis of Planning and Preliminary Design

A summary of the bridge planning and preliminary designs are discussed below.

Floor Deck Slab

Reinforced concrete (RC) slab is employed because Guss asphalt pavement on a steel orthotropic deck is difficult to maintain and is unattainable in Panama.

Splices of Steel Members

Since paint on high tension bolts will likely be worn and corrosion is likely to occur, field welding should be adopted instead of bolt splice so as to improve the future maintenance performance. In the places such as the diaphragms of the arch-rib and the stiffening girder where external environmental effects appear to be low, bolt splicing can be permitted.

Steel Materials

Stress concentration occurs at the corner sections of the conjunction of the arch-rib and stiffening girder, therefore, steel materials of SBHS (Steels for Bridge High Performance Structure) (considerable degree of SBHS500) were employed taking into consideration the advantages of welding workability.

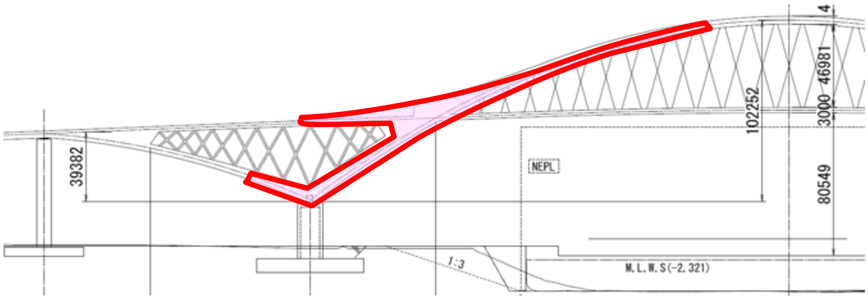
The characteristics of SBHS are as follows (see Section 20.3.1 in details).

- Increase the yield strength (SBHS500: 500N/mm2, SM570: 450N/mm2)
- High-grade workability and weldability, and a reduction of preheat time

Usually, the thickness of the steel used for a bridge is 100mm or less, since the thicker the steel is, the more inferior will be the weldability and the greater the weight. If a greater thickness of steel is designed, then a better grade of steel is adapted.

The main structural element consists of SM490Y. SBHS (considerable degree of SBHS500) is applied because of the reduction in preheat time in case of applying steel more than 40mm thick.

Based on the general design, the application for SBHS500 is as follows.



Source: JICA Study Team

Figure 12.1 Scope of application for SBHS500

The stronger steel material (SBHS700) is not adapted for this bridge because of the normal yield strength and few beneficial achievements.

Form of main structure

We decided that the form of the Solid rib arch is more adaptable than that of the Braced arch. The reasons are as follows.

- The number of steel members: The Braced arch has many steel members and entails greater work days and higher costs.
- The number of joints: It is easy for fluids and dust to accumulate in the joints of the steel members increasing the possibility of corrosion in these joints. The Braced arch is thus inferior in maintenance.

Positioning and Allocation of Vehicle Types on the Deck Slab

The positioning of a sidewalk, 2-track monorail, arch-rib (suspending hanger), 3-lane carriageway, arch-rib (suspending hanger) and 3-lane carriageway are allocated from the southern edge towards the northern edge at every cross section.

The position of the monorail on the southern side is one of the preconditions according to the monorail alignment and 4th Panama Canal Bridge alignment. The cross section is split into three blocks and the arch rib is placed in between the two adjacent blocks. The light load of the pedestrian sidewalk is located at the southern tip.

For seismic stability and wind resistance stability at right angles to the bridge, the main member of the arch is inclined toward the inside. Both arch-ribs are connected at the center of the arch span, so the stiffness out of the arch plane is improved.

Floor framing of Stiffening Girder

The stiffening girder forms a monolith box in order to achieve a higher rigidity of the cantilever decks with the expectation of high wind stability transversally. Also, aiming at improving wind stability, the girder depths decline towards the cantilever tips.

Connection between the Arch-rib and Stiffening Girder (Tension members in the arch span)

The stiffening girder is suspended from the arch-rib via hanger cables (as Tension members) in the main span.

The form of the hanger cables is an X-form, which is stronger than a vertical form.

Connection between the Arch-rib and Stiffening Girder (Compression members in the side spans)

In the side spans and the part outside the main span’s arch-rib, the stiffening girder is supported by the arch-rib via strut members (as Compression members). On these parts, the strut members adapt an X-form for its stiffness.

Bearing Conditions

The bearings at the springing points of the arch are a fixed type taking into consideration the benefit of structural rigidity like low displacement.

<u>Paint (weathering steel)</u>

Paint applied to steel materials should be an anti-corrosive type (see Section 20.3.2) as mentioned above. In addition to the anti-corrosive properties it provides for steel materials, paint should also be applied from the view point of maintenance and aesthetics.

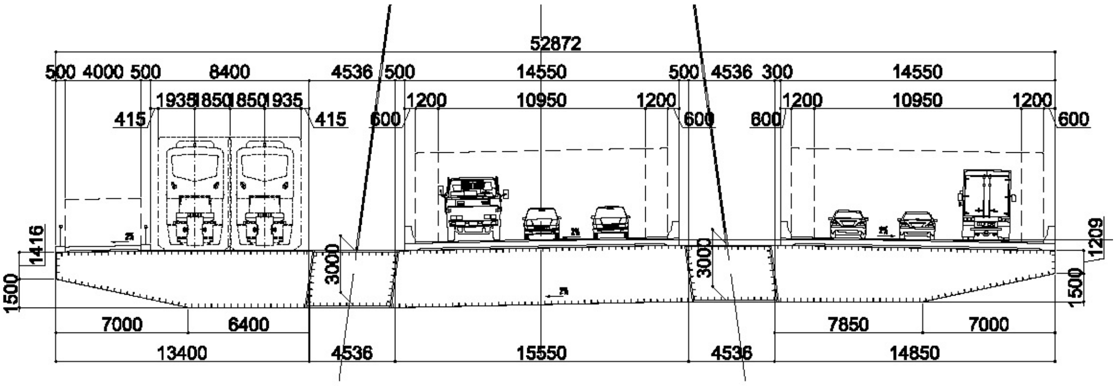
In areas where there are a lot of fragments with salt content, it is difficult for stable rust to form on weathering steel. Therefore, Nickelic high weathering steel was developed for this type of area. It was decided that this type of steel would be adapted for this bridge location.

It should be noted that samples of anti-corrosive type steel have been attached to the steel surface of the Bridge of Americas for checking the degree of weathering in the vicinity of the Project site. It will be necessary to make a study at the stage of execution design.

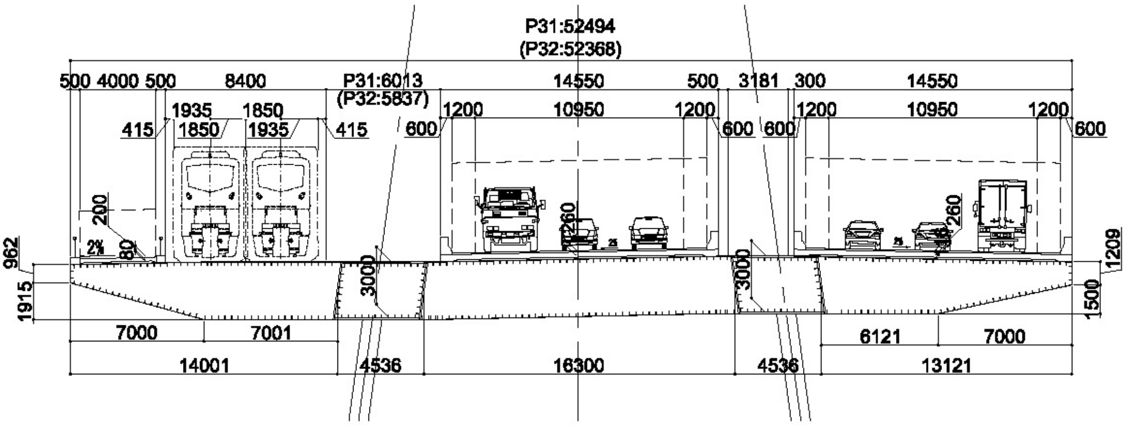
ii. Typical Cross Sections

Figure 12.2 shows the typical cross sections of the main bridge (arch bridge).

<u>Main Span</u>



<u>Side Span</u>



Source: JICA Study Team

Figure 12.2 Typical Cross Sections of Main Bridge (Arch Bridge)

iii. Bridge Length and Span Arrangement

Main Span

The proposed location of the arch bridge piers follows the same location of the cable stayed bridge piers determined by the Pre-F/S. The pier locations had been agreed upon among the concerned organizations through various meetings, so that the pier locations were set back a sufficient distance from the Prism Line. Accordingly, the main span length was decided to be 540m, which is the same as in the Pre-F/S.

Table 12.2 shows the pier locations along with the reasoning for the decision.

Table 12.2 Pier Locations and reasons for the Decision

No.	Pier (Coordinates)	Reasons for the Pier Location	Set-back Distance (from Prism Line to the Pier)
1	Pier on East Bank (X=657613.96 (Coordinate)) (Y=989297.18 (NAD27))	Agreed between ACP and Balboa Port	119.0m
2	Pier on West Bank (X=657205.83 (Coordinate)) (Y=988943.580 (NAD27))	Risk Analysis against Ship Collision	120.5m

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

Side Span

The side span length was decided to be 150m taking into consideration the following:

- Extending to the length where negative reaction does not occur
- Eliminate the transition curve (clothoid) within the arch bridge
- Reducing the horizontal Reaction induced by the arch

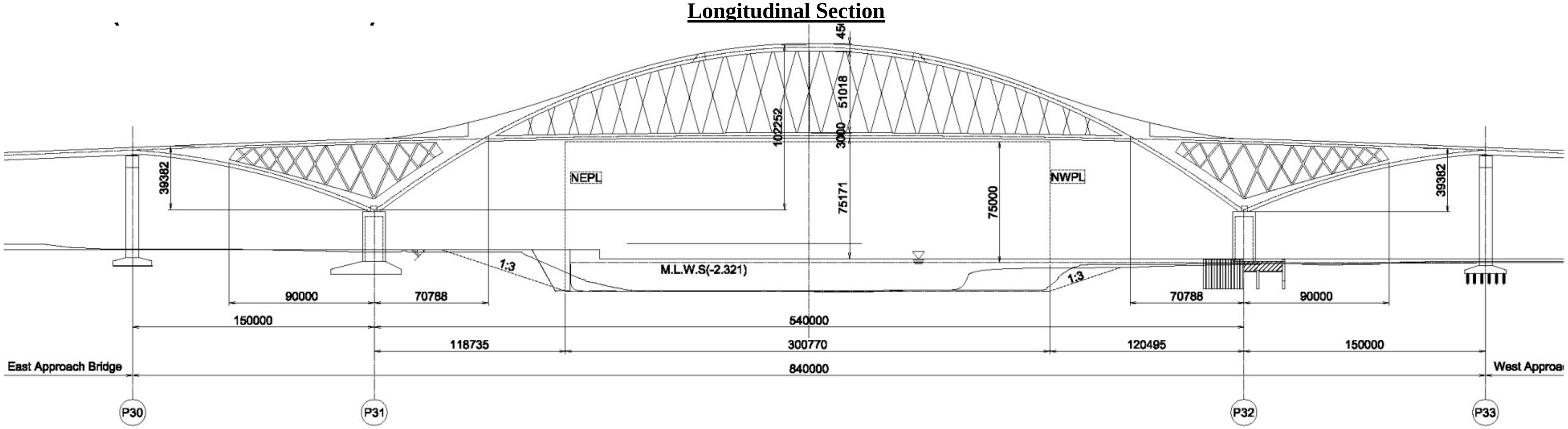
Figure 12.3 shows the span arrangement of the main bridge (arch bridge).

Bridge Length and Span Arrangement

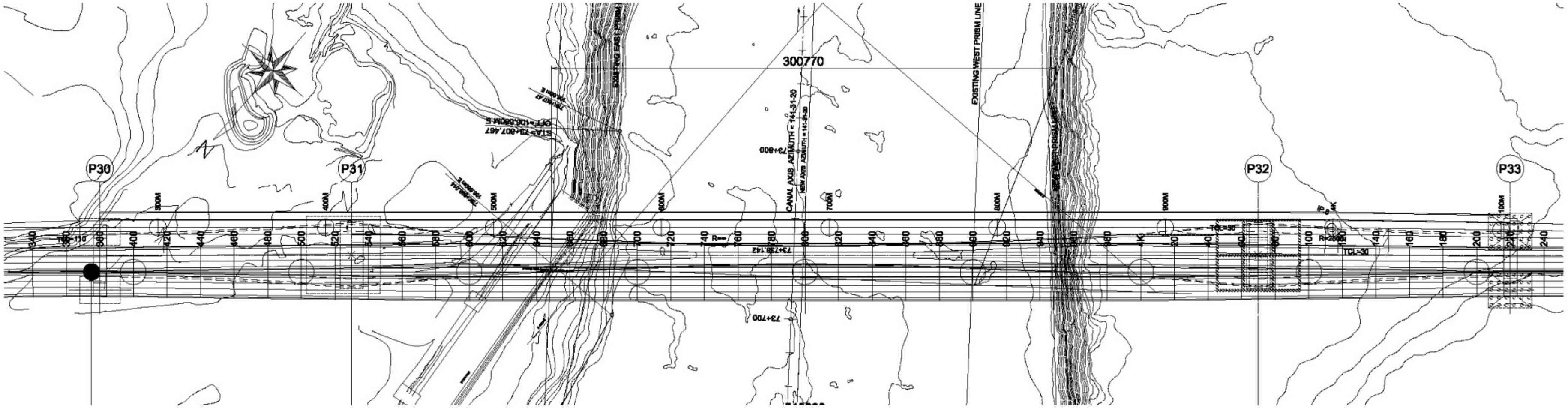
Bridge Length = 840m

Span Arrangement: 150m+540m+150m

Longitudinal Section



Plan



Source: JICA Study Team

Figure 12.3 Span Arrangement of Main Bridge (Arch Bridge)

iv. Structural Analyses and Design of the Superstructure

An outline of the structural analyses is explained below.

Loading Cases

Dead load, live load and seismic force are considered.

Skelton Model of Structural Analyses

A 3D static elastic model was used for the analyses.

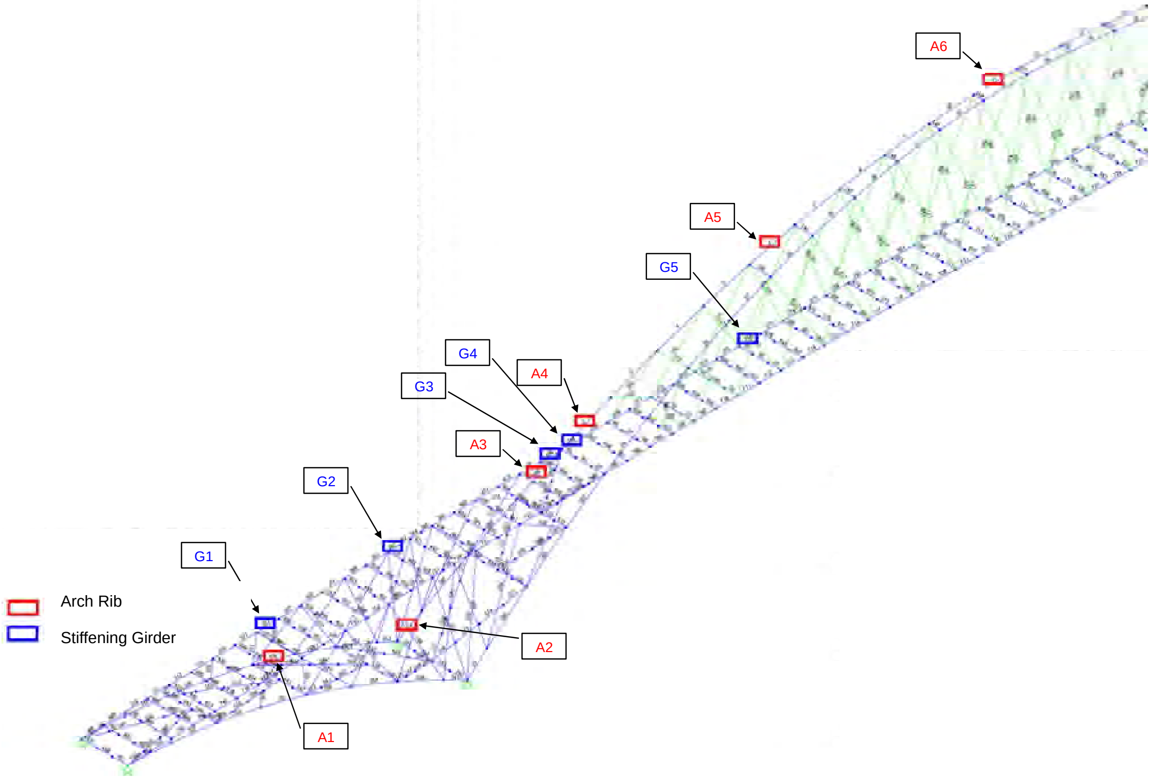
Designated points for Stress Calculation

Table 12.3 explains the designated points for stress calculation, Figure 12.4 shows the designated points and Figure 12.5 shows the designated sections based on the stress calculation, respectively.

Table 12.3 Designated Points for Stress Calculation

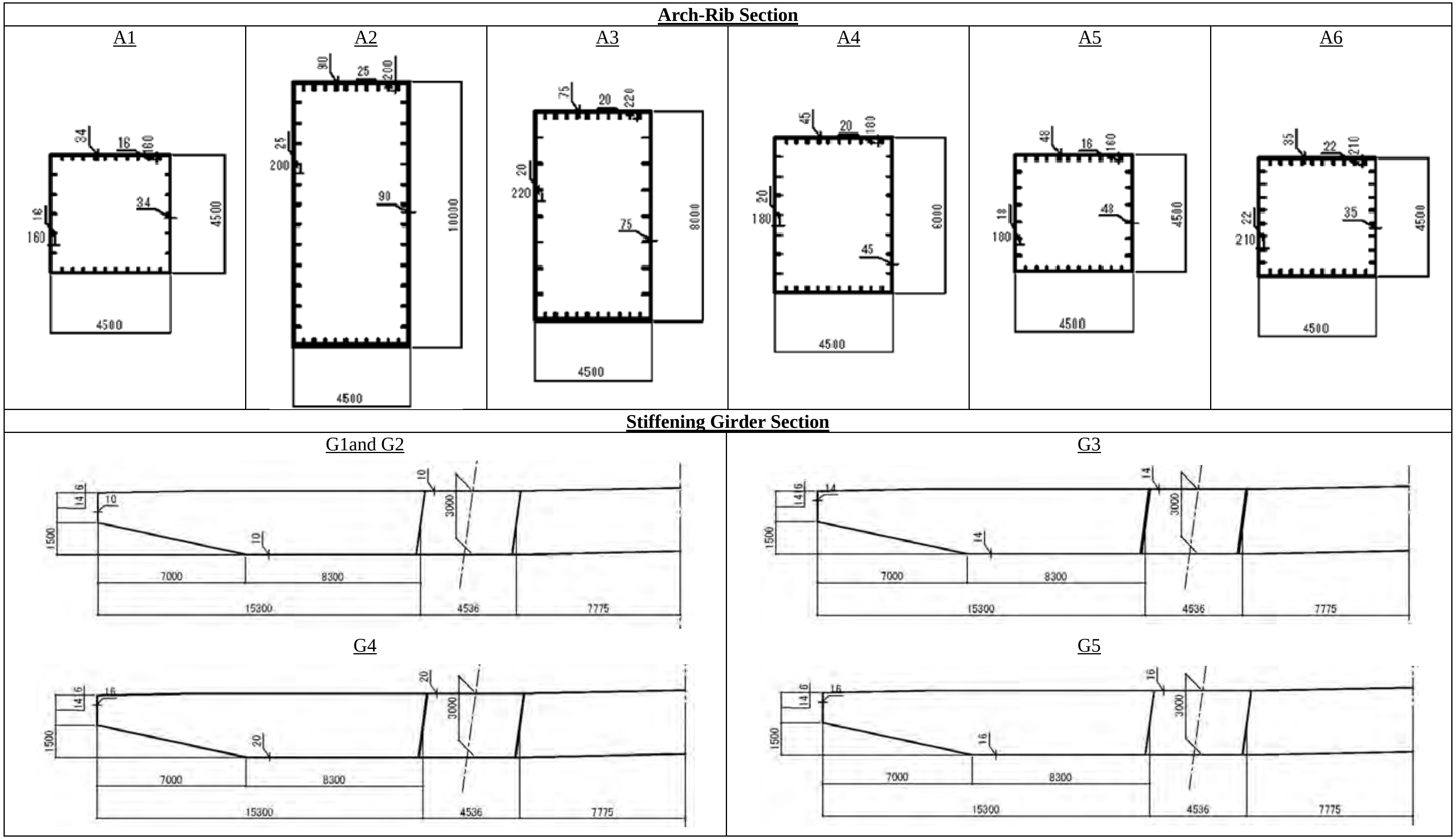
No.	Component	Stress Calculation Point	Remarks
1	Arch-Rib	A1	Typical point representing the side span
2		A2	Arch springing where the maximum main span forces occur - representing the conjunction between arch-rib and stiffening girder
3		A3	Lower side section of conjunction
4		A4	Upper side section of conjunction
5		A5	Quarter point of arch-rib span
6		A6	Highest point of arch-rib
7	Stiffening Girder	G1	Section corresponding to A1of arch-rib
8		G2	Section corresponding to A2of arch-rib
9		G3	Section corresponding to A3of arch-rib
10		G4	Section corresponding to A4 of arch-rib
11		G5	Point representing the suspended span of the stiffening girder

Source: JICA Study Team



Source: JICA Study Team

Figure 12.4 Designated Points for Stress Calculation



Source: JICA Study Team

Figure 12.5 Designed Sections based on the Stress Calculation

v. Design of Substructure and Foundation

Design Policy

Piers and Foundations Supporting the Arch Springing

The piers should be a reinforced concrete structure to support the external forces such as horizontal forces and bending moment transmitted from the arch structural system.

As for the foundation, a spread foundation is used where the bearing strata appear at shallow depth, and a well foundation with steel pipe sheet piles (SPSP) is used where the bearing strata are deep.

Piers Supporting the End Bearings

Piers should support both the end span bearings of the arch bridge (main bridge) and the approach viaducts. As the piers are of a high-rise structure and likely to receive large seismic force in the transverse direction, the piers should be a reinforced concrete structure, but not a fully concrete-filled monolith to reduce its own weight.

The beam of the pier consists of steel for the reduction of moment on the bottom of the pier in the case of an earthquake.

Foundations supporting Arch Springing and End Bearing (East side)

The East pier of the Arch-rib or the East pier of the end bearing is on the ground. The bearing ground (rock) lies 14m under the surface of the earth. The spread foundation is adapted for this point for the purpose of cost benefit.

Foundations supporting Arch Springing (West side)

The West foundation of the Arch-rib is under water. The bearing ground lies about 15m under the riverbed. The caisson foundation or the steel pipe sheet pile (see Section 20.3.3) is adaptable for this location, the reason being that a reinforced concrete cast-in-place pile foundation would not be applicable.

Regarding the caisson foundation, it would be unrealistic for this point because of the area of construction. For this reason, the steel pipe sheet pile is applied, which is effective in reducing the foundation installation.

Foundations supporting the End Bearings (West side)

A reinforced concrete cast-in-place pile foundation, which is widely used in Panama, shall be employed.

Design Principle

Materials to be used

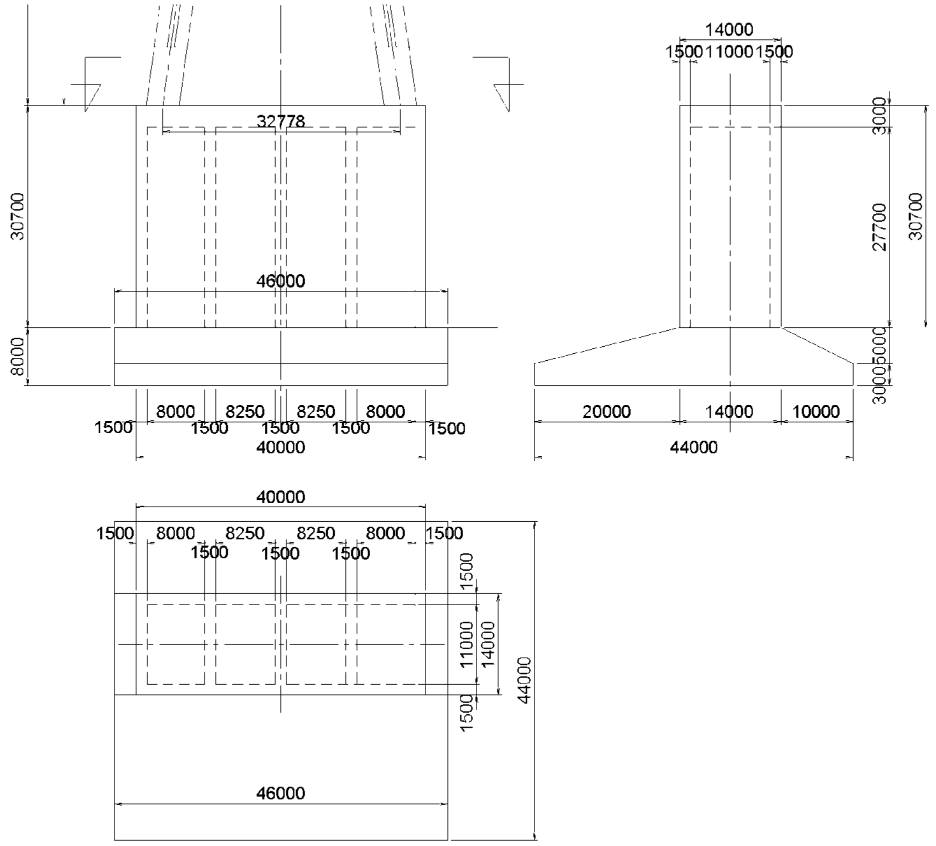
Concrete Strength: 30MPa

Re-bars: SD 345

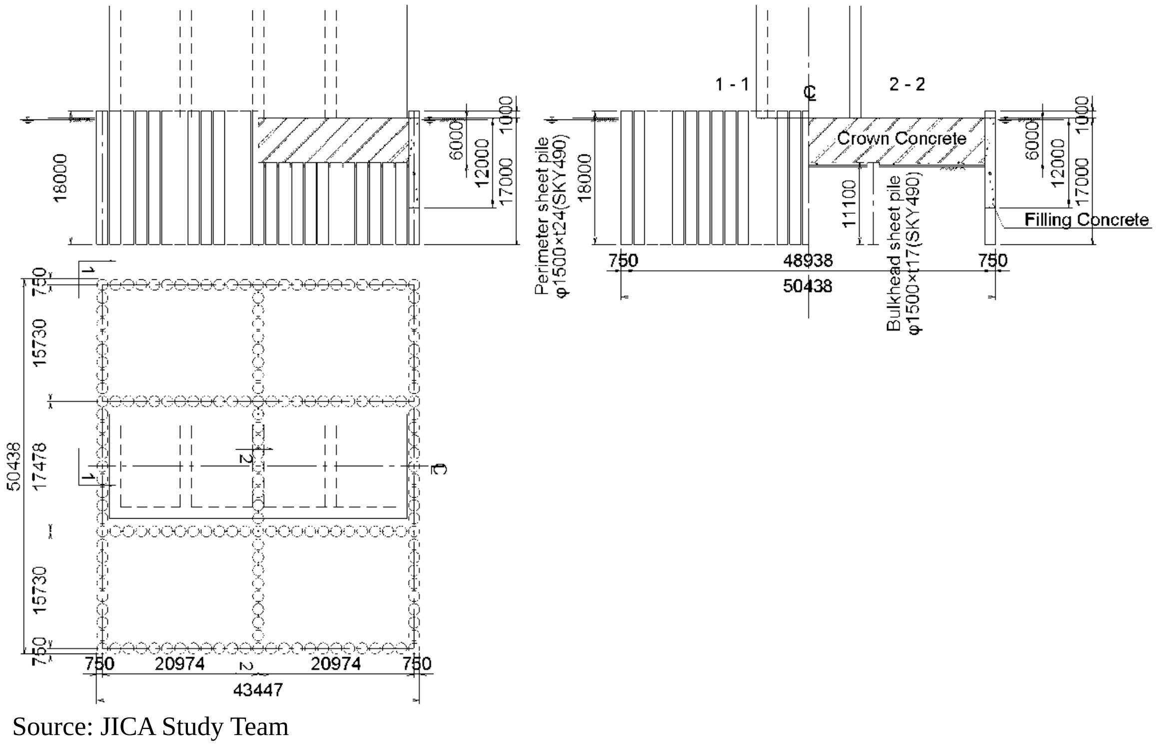
Design Outcomes

Figures 12.6 show the design outcomes for the substructure and foundation.

Pier and Foundation at the P31 Pier (Spread Foundation)



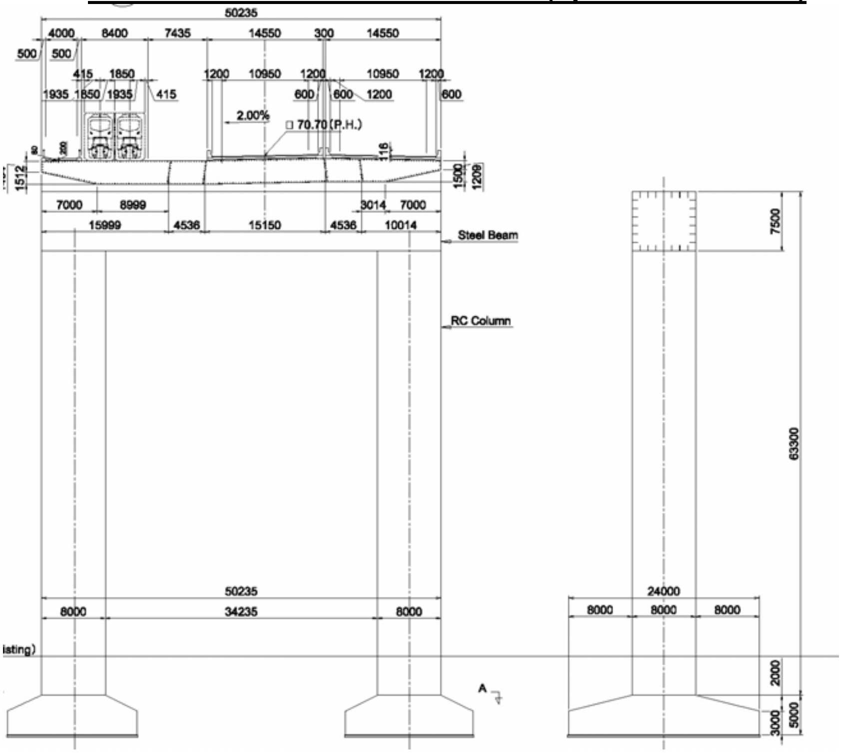
Well Foundation with Steel Pipe Sheet Piles at the P32 Pier (SPSP)



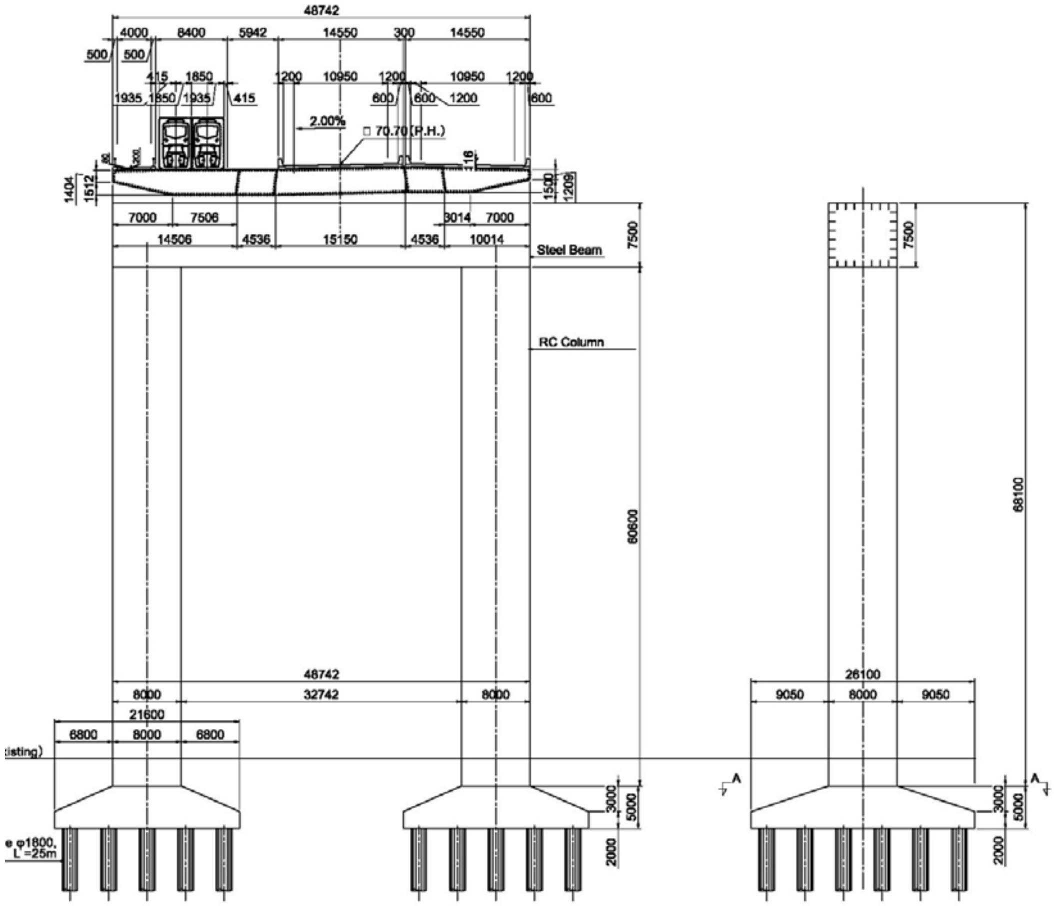
Source: JICA Study Team

Figure 12.6 Outcomes of the Substructure and Foundation Designs (1/2)

Pier and Foundation at the P30 Pier (Spread Foundation)



Pier and Foundation at the P33 Pier (Cast in Place Pile Foundation)



Source: JICA Study Team

Figure12.6 Outcomes of the Substructure and Foundation Designs (2/2)

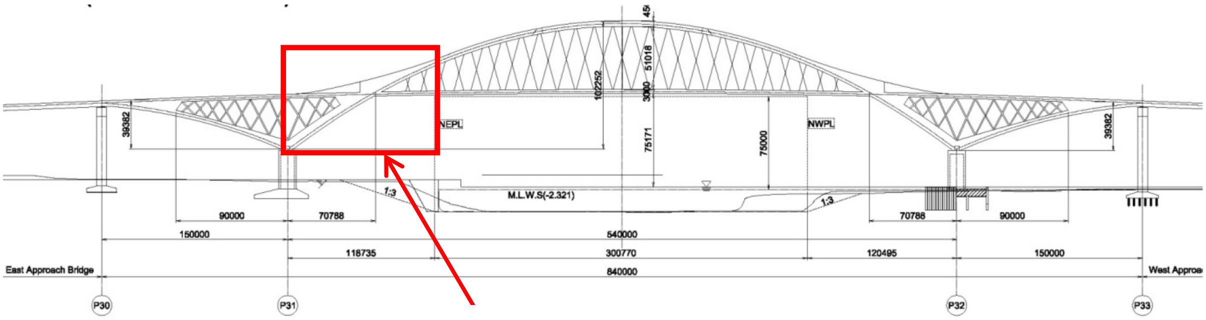
vi. Detail Analysis of the main structure

The connections between the arch-rib and the stiffening girder are carried out with FEM analysis.

Abstract of the FEM analysis

The stress transferring mechanism of the connection between the arch-rib and the stiffening girder is complicated. There are the axial force of the dead load and the moment of seismic load for out-of-plane at the rigid connection. This connection is carried out with the 3D FEM analysis. The properties of stress transferring and stress concentration are verified.

Cross point between arch-rib and stiffening girder



3D shell elements model

Source: JICA Study Team

Figure 12.7 Modeling of cross point between the arch-rib and the stiffening girder

Analysis Conditions

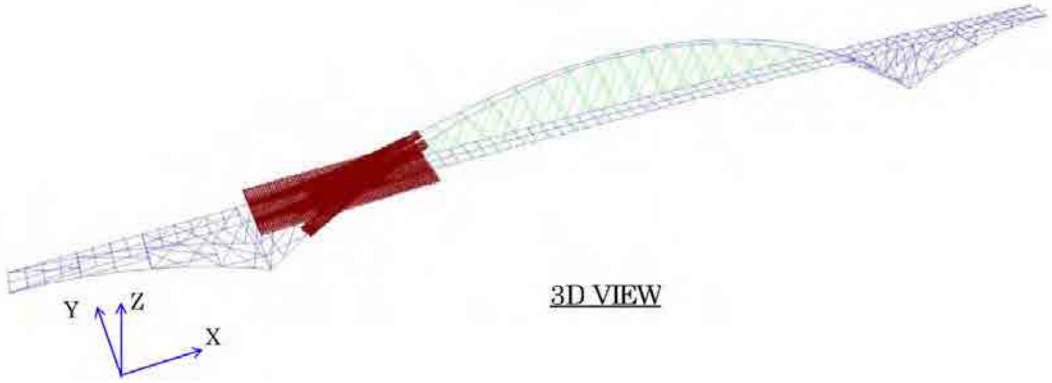
Table 12.4 shows the analysis conditions.

Table 12.4 Analysis Conditions

Item	Content	
Element Type	3D shell element、3D line element	
Material	Elastic material, E module 2.0×10^{5}N/mm2、Poisson ratio 0.3	
Modeling Scope	Total bridge (3D shell element、about 110m from P37 to arch span)	
Load	Same Load as the superstructure analysis	
Boundary condition	Rigid element between 3D shell elements and 3D line element	
Restricted condition	Fixed points at the bottom of arch-rib	
Case	CASE 1	Dead Load
	CASE 2	Seismic Load (direction Y)
	CASE 3	Dead Load+ Seismic Load (direction Y)

Source: JICA Study Team

Analysis Model



Source: JICA Study Team

Figure 12.8 Analysis Model

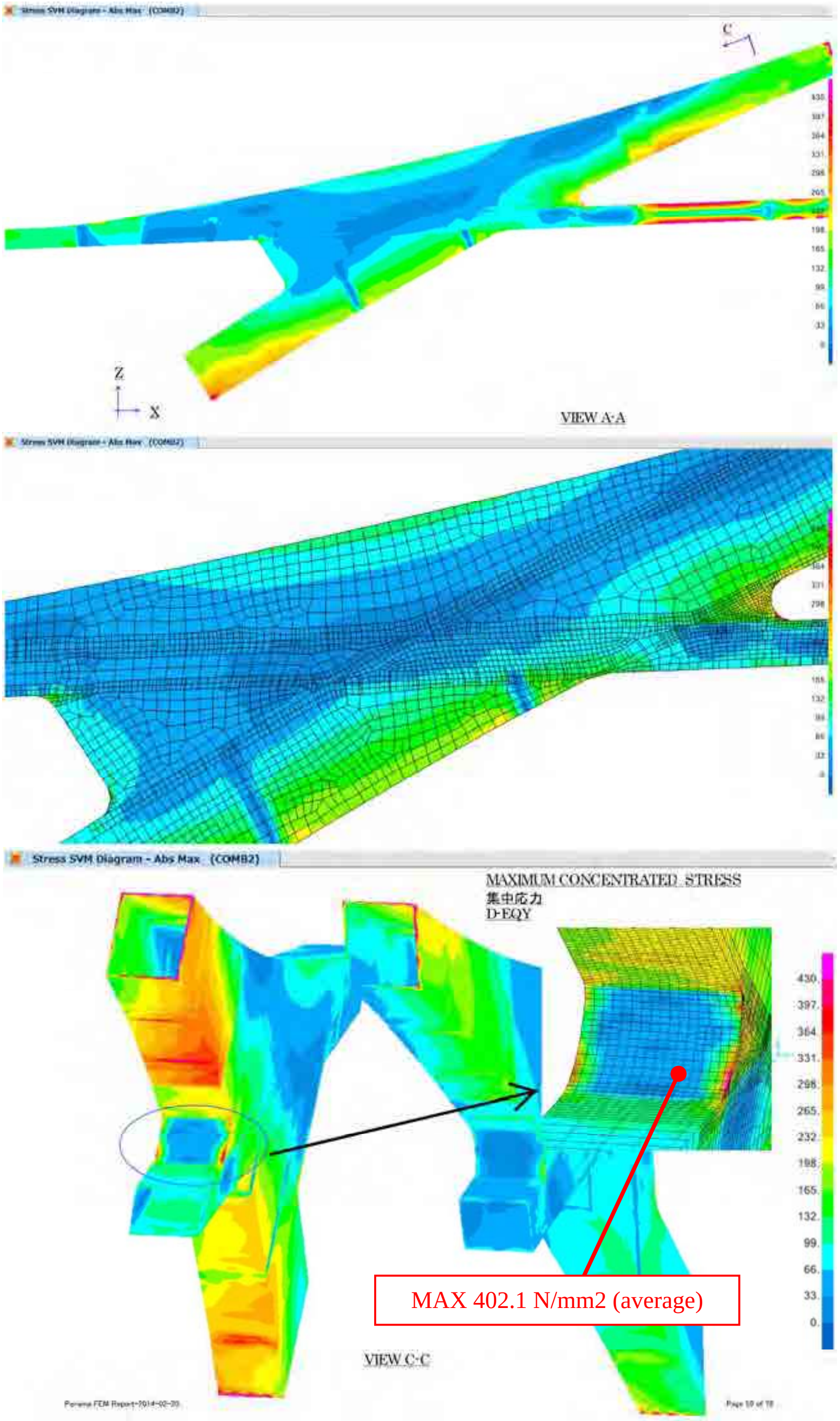
<u>Results of FEM analysis</u>

The results of the FEM analysis are calculated with Von Mises stress. As a result, the fillet at the corner of the connection between the arch-rib and the stiffening girder has the stress concentration.

The maximum value of stress concentration (CASE 3: Dead Load + Seismic Load) is

402.1 N/mm2 (average of element's value) < 500 N/mm2 (the yield point of SBHS500)

Figure 12.9 shows the results of the FEM analysis (CASE 3).



Source: JICA Study Team

Figure 12.9 Results of the FEM analysis CASE3

2) Approach Viaduct

i. Design Principles of Planning and Design

Superstructure

The types of superstructure have been selected by the span lengths as shown in Table 12.5 taking into consideration the structural aspect and economic aspect. In the case of 40m lengths or less, the PC-I girder was chosen because it is often applied in Panama. For span lengths greater than 40m the PC box girder and the steel box girder were compared. As a result of the comparison, the construction cost of the PC box girder was found to be 1.34 times greater than that of the steel box girder. Therefore, the steel box girder is economically advantageous.

Table 12.5 Structure Types by Span Lengths

No.	Span Length	Structure Type
1	40m or less	PC-I Girder
2	Over 40m	Steel Box Girder

Source: JICA Study Team

Substructures

Inverted T type abutments were selected taking into consideration the structural aspect and economic aspect. As for the piers, their structural types differ depending on whether the pier is independently carrying only the road viaduct or is a combined structure carrying both the Metro Line 3 and the road viaduct as per Table 12.6.

Table 12.6 Pier Types

No.	Independent or Combined Structure	Structure Type
1	Independent	Cantilever Pier
2	Combined	Portal Rigid Frame Pier

Source: JICA Study Team

Foundations

The type of foundation was selected based on the results of the geological survey.

Flyover No.1 and No.2: Since the depth of the support layer is about 15m, the Cast-in-place pile (φ1500) was selected, which is common in Panama. East Bank Approach Bridge: Since the depth of the support layer is less than 10m, the Spread footing foundation was selected. West Bank Approach Bridge and Access bridges to the Bridge of the Americas: Since the depth of the support layer is more than 20m, the Cast-in-place pile (φ1800) was selected.

Conjunction between the Approach Viaduct and Metro Line 3

The Metro Line 3 Project has planned to locate the Balboa Station before the 4th Panama Canal Bridge and the Panama Pacifico Station after the bridge. The conjunctions with Metro Line 3 were studied taking into consideration the longitudinal profile of Metro Line 3 and the planned deck level of the 4th Panama Canal Bridge. Table 12.7 shows the conjunction points between Metro Line 3 and the 4th Panama Canal Bridge. On the other hand, the maximum span length used in Metro line-3 is 50m in this study. Therefore in the case of the steel box girder and the arch bridge the combined pier structure will be used. The PC-I girder structure will used for the individual pier structures.

Table 12.7 Conjunction Points with Metro Line 3

No.	Location	Chainage (KM)
1	East Bank Side	2+717
2	West Bank Side	5+065

Source: JICA Study Team

ii. Bridge Length and Span Arrangement

Locations of Abutments

The locations of the abutments were determined to be where the abutment height is 10m.

Table 12.8 shows the chainage of the abutment locations.

Table 12.8 Locations of Viaduct Abutments

No.	Viaduct Name	Abutment ID	Chainage (KM)
1	East Bank Approach Viaduct	Abutment A5	KM2+847
2	West Bank Approach Viaduct	Abutment A6	KM5+390

Source: JICA Study Team

Bridge Length and Span Arrangement

The span arrangements were determined based on the following:

- Avoid crossing existing structures
- Adjust the span length based on the economic aspect

Table 12.9 shows the most favorable span lengths by pier heights and types of approach viaducts to the 4th Panama Canal Bridge, and Table 12.10 shows the bridge lengths and span arrangements.

Table 12.9 Most Favorable Span Length by Pier Heights

No.	Pier Height	Most Favorable Span Lengths (Viaduct Types)
1	30m or less	40m (PC-I Girder)
2	Over 30m to 50m	60m (Steel Box Girder)
3	Over 50m	100m (Steel Box Girder)

Source: JICA Study Team

Table 12.10 Bridge Lengths and Span Arrangements

No.	Viaduct Name	Chainage (KM)	Bridge Length	Span Arrangement
1	East Bank Approach	2+847~3+380	533m	43m+60m+50m+90m+2@100m+90m
2	West Bank Approach	4+220~5+390	1,170m	90m+3@100m+80m+5@60m+40m+9@40m

Source: JICA Study Team

iii. Superstructure Design

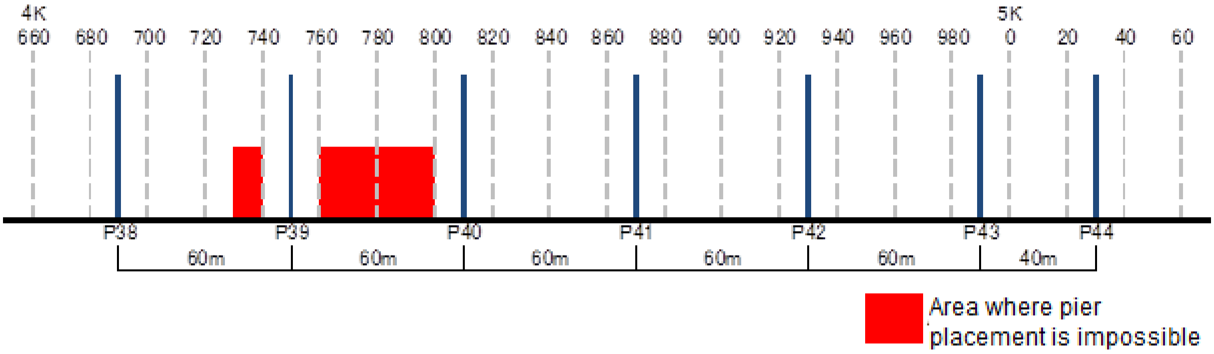
Since the total width of the superstructure is great, the superstructure was divided into three parts, from the view point of economic benefit; namely, a 3-lane road carriageway towards the city center, a 3-lane road carriageway toward Arraijan, and a 2-track monorail with a 4m sidewalk.

Figure 12.11 shows the typical cross section of Approach Viaduct.

In the East Bank Approach Bridge, the piers up to 30m in height carry steel box girder with a maximum span length of 60m. Piers higher than 30m have steel box girder with a maximum span length of 90m. For the substructure the portal rigid frame pier is used.

West Bank Approach Bridge No.1; for piers 40m or higher, the steel box girder is selected for the superstructure, which has a maximum span length of 100m. West Bank Approach Bridge No.2; the pier height varies from 10m to 40m,this section is integrated with the monorail with some crossing structure. Therefore, the steel box girder superstructure is selected with a maximum span length of 60m. West Bank Approach Bridge No.3; since the pier height is less than 10m, with no crossing structure, the PC-I girder superstructure is selected.

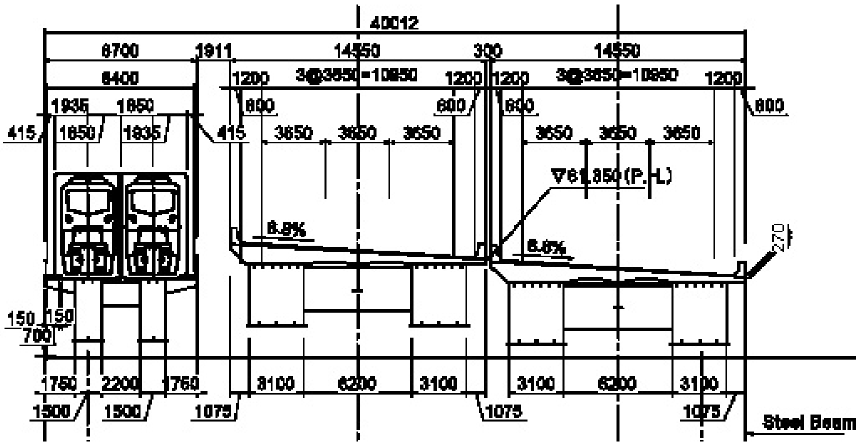
Figure 12.10 shows the span arrangement of the West Bank Approach Bridge No.2 with the crossing structure.



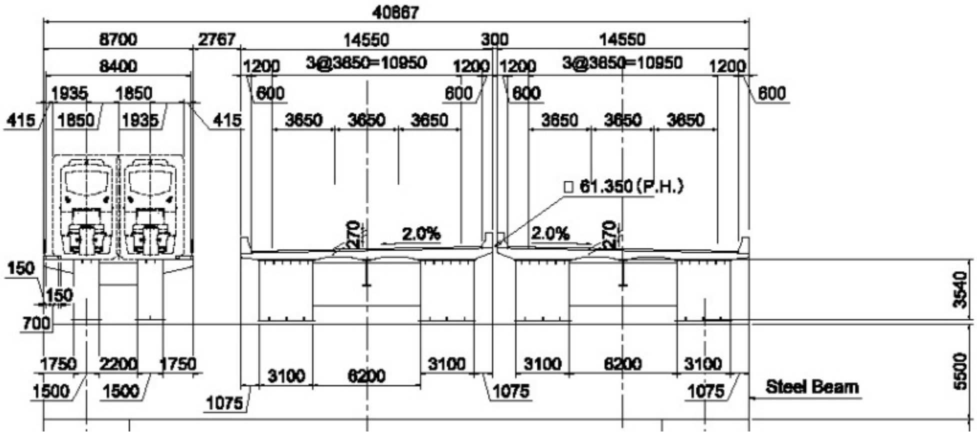
Source: JICA Study Team

Figure 12.10 Span arrangement of the West Bank Approach Viaduct No.2

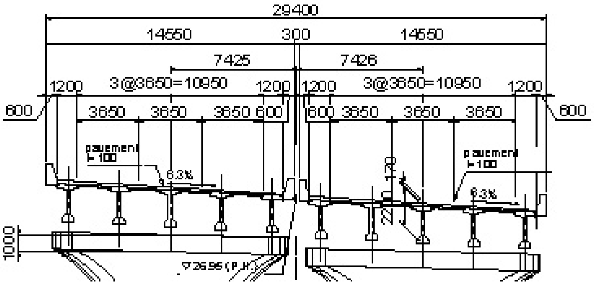
Superstructure: Steel Box Girder



Superstructure: Steel Box Girder



Superstructure: PC-I Girder



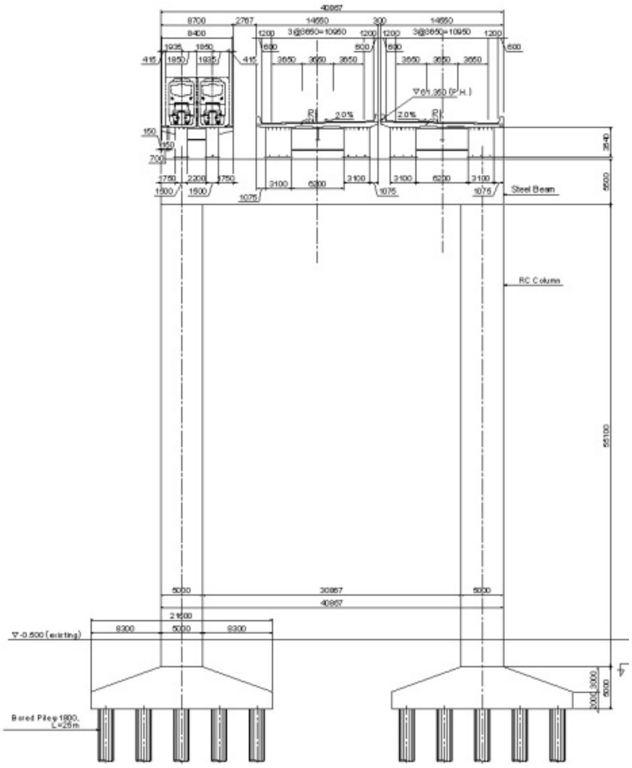
Source: JICA Study Team

Figure 12.11 Typical Cross Section of Approach Viaduct

iv. Substructure and Foundation Design

Combined Section of Metro Line 3 and Approach Viaduct

A portal rigid frame was employed in the section where the Metro Line 3 and the approach viaduct are combined as per Figure 12.12.



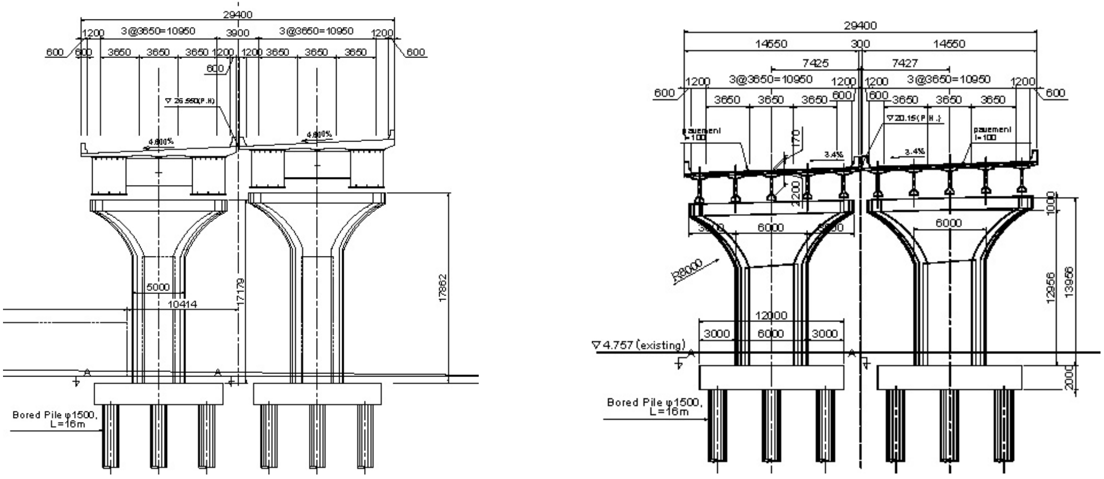
Source: JICA Study Team

Figure 12.12 Portal Rigid Frame for the Combined Section of Metro Line 3 and Approach Viaduct

Independent (Separate) Section

In the section where the structures of Metro Line 3 and the approach viaducts to the 4th Panama Canal Bridge are built independently, cantilever type piers were employed as per Figure 12.13.

Superstructure: Steel Box Girder **Superstructure: PC-I Girder**



Source: JICA Study Team

Figure 12.13 Cantilever type Piers at the Independent (Separate) Section

(2) Flyover

1) Principles for Planning and Design

As with the approach viaduct discussed in 12.5.1(1)2)i, flyovers were also planned and designed.

2) Bridge Length and Span Arrangement

Abutment Locations

As with the approach viaduct, the places where the abutment height is 10m were selected for the abutment locations.

Table 12.11 shows the abutment locations.

Table 12.11 Abutment Locations (Flyover)

No.	Flyover Name	Abutment ID	Chainage
1	Flyover No.1	Abutment A1(Inbound)	KM1+070
2		Abutment A1(Outbound)	KM1+050
3		Abutment A2	KM1+570
4	Flyover No.2	Abutment A3	KM2+000
5		Abutment A4	KM2+740

Source: JICA Study Team

Bridge Length and Span Arrangement

Table 12.12 shows the bridge lengths and span arrangements of the flyovers.

Table 12.12 Bridge Length and Span Arrangements of Flyovers

No.	Flyover Name	Bridge Length	Span Arrangement
1	Flyover No.1(Inbound)	500m	6@40m+2@50m+60m+2@50m
2	Flyover No.1(Outbound)	520m	2@40m+30m+4@40m+50m+2@60m+45m+35m
3	Flyover No.2	740m	5@40m+2@30m+60m+4@90m+60m

Source: JICA Study Team

3) Superstructure

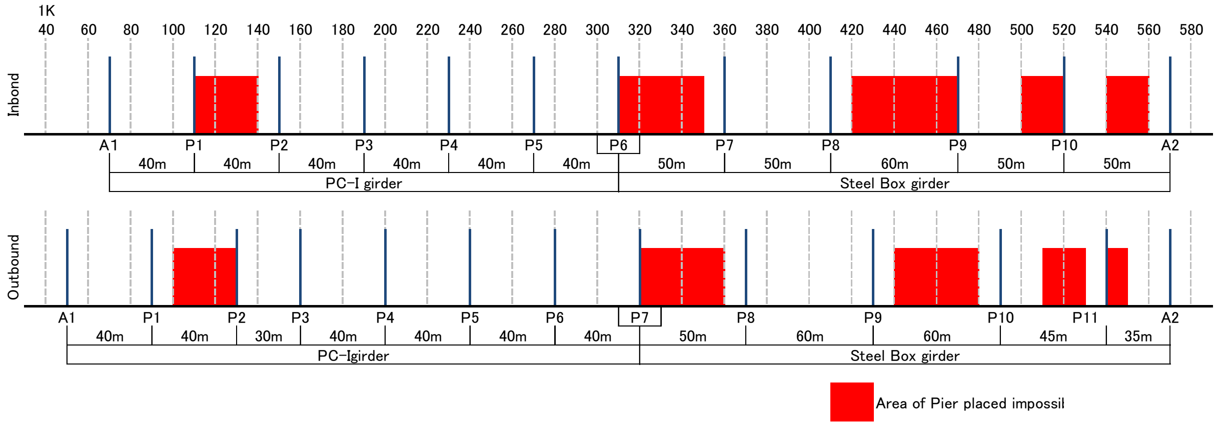
The typical cross sections of the flyovers are shown in Figure 12.17.

The pier heights in Flyover No.1 are less than 10m., however it has many cross structures.

Therefore the Bridge plan is as follows.

- A separate span arrangement is applied to each outbound and inbound line.
- From the A1 abutment to 1K +320, the number of cross-structures is less and the distances where piers cannot be placed are less than 40m. Therefore in this range the PC-I girder with a 40m span is applied.
- From 1K+320 to the A2 abutment, the number of cross-structures is greater and the distance where it is impossible to place piers is 60m. Therefore in this range the Steel box girder with a 60m span is applied.

Figure 12.14 shows the span arrangement of Flyover No.1 with the cross structures.



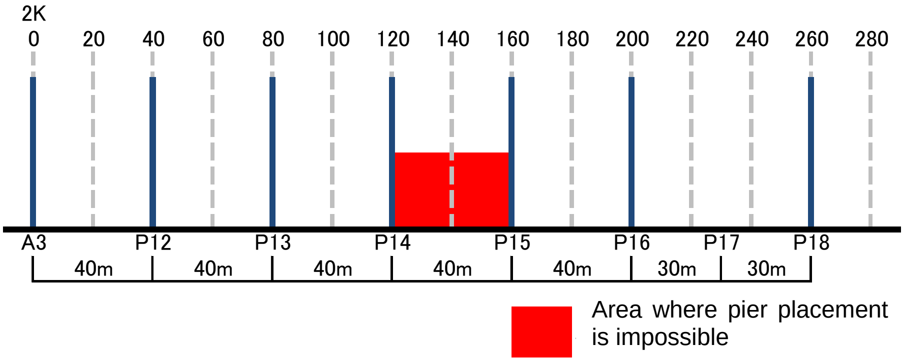
Source: JICA Study Team

Figure 12.14 Span Arrangement of Flyover No.1

Flyover No.2 is divided into two depending on the conditions of the cross-structures.

Figure 12.15 shows the span arrangement of Flyover No.2-1.

Flyover No.2-1 is a PC-I girder bridge with a span length of 40m. The span arrangement also avoids the ACP communication facility.

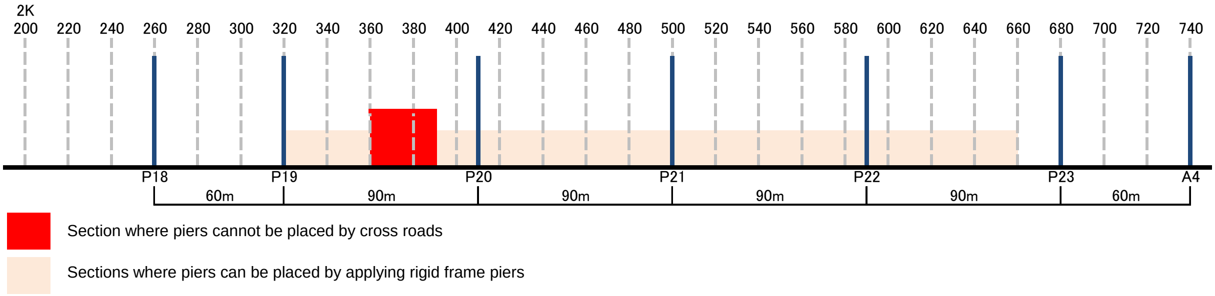


Source: JICA Study Team

Figure 12.15 Span Arrangement of Flyover No.2-1

Figure 12.16 shows the span arrangement of Flyover No.2-2.

Because the angle of intersection of the crossing street is shallow, a portal rigid frame pier will be used if a pier is needed in this range. Since the extension for the rigid frame piers is 320m, steel box girders with a 90m span length will be applied. A portal rigid frame pier will be used from P20 to P22.

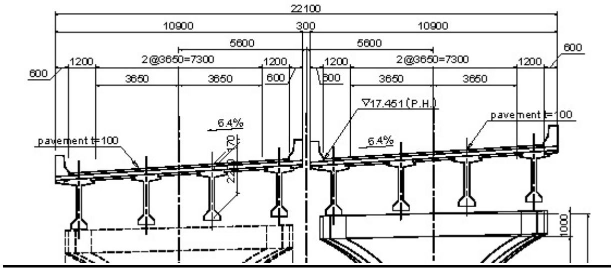


Source: JICA Study Team

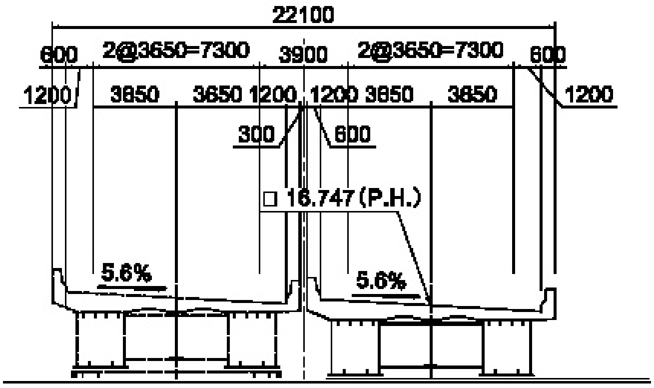
Figure 12.16 Span Arrangement of Flyover No.2-2

Flyover No.1

Superstructure: PC-I Girder

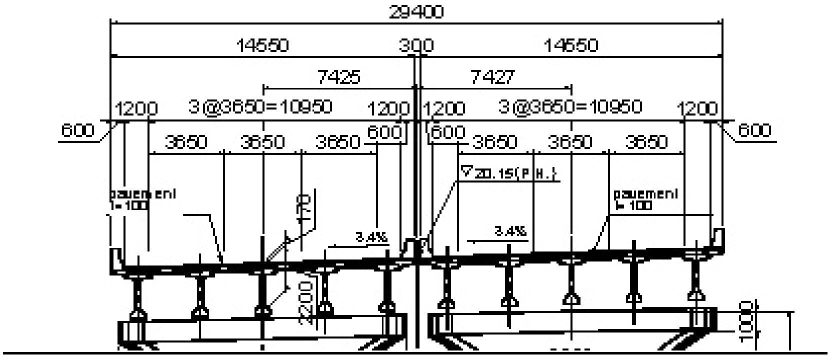


Superstructure: Steel Box Girder

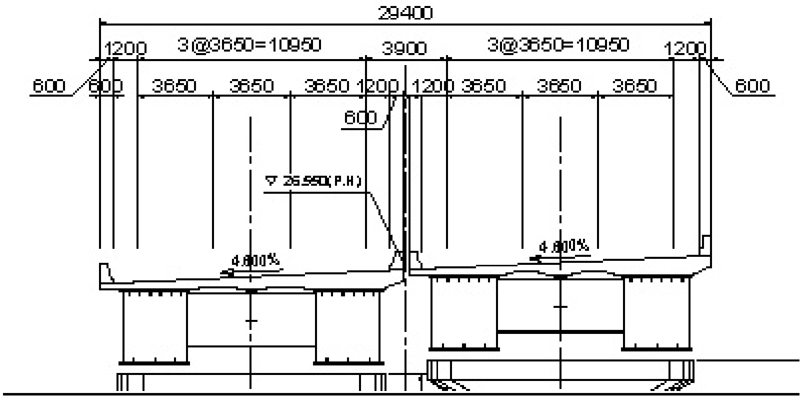


Flyovers No.2

Superstructure: PC-I Girder



Superstructure: Steel Box Girder



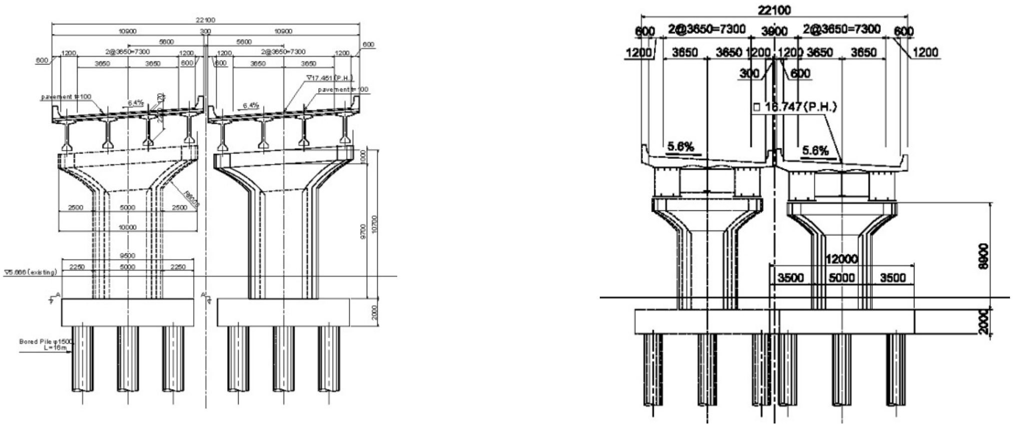
Source: JICA Study Team

Figure 12.17 Typical Cross Sections of Flyovers

4) Substructures and Foundations

Figure 12.18 shows the cantilever type piers for supporting the flyover superstructures.

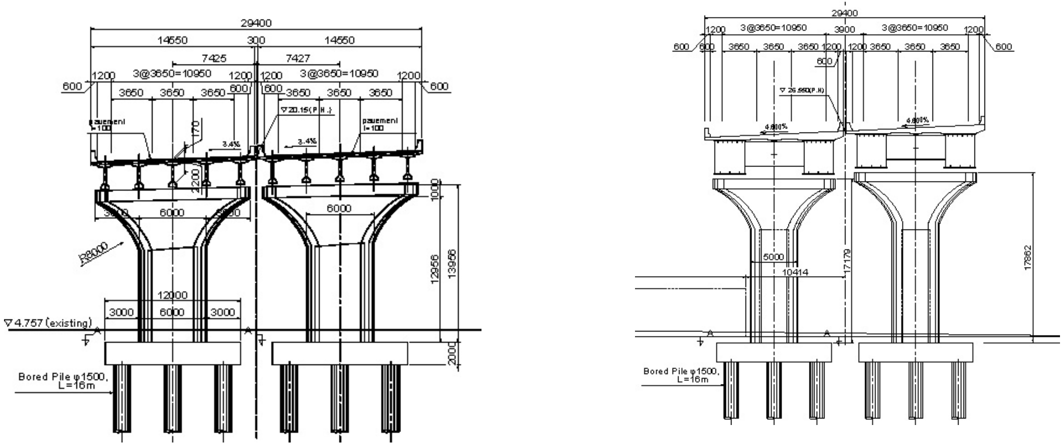
Flyover No.1



Superstructure: PC-I Girder (Individual)

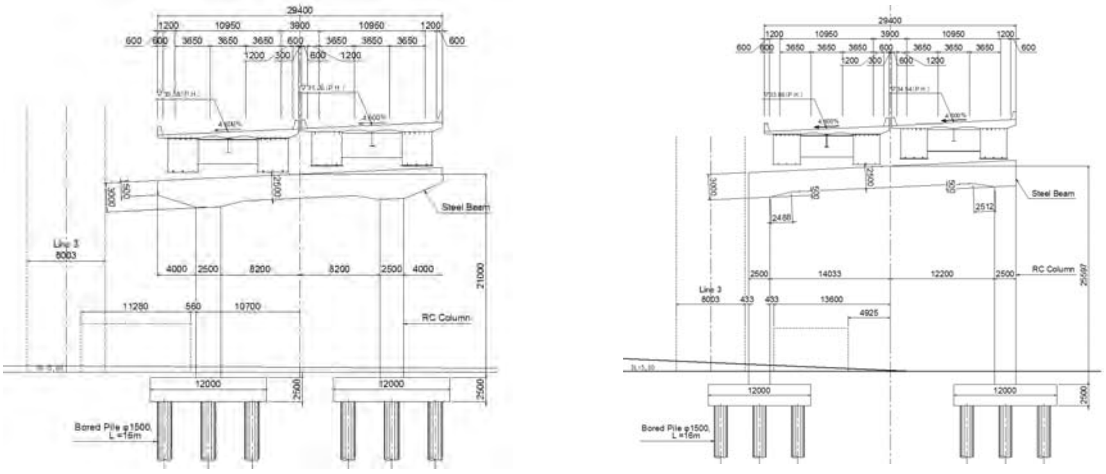
Superstructure: Steel Box Girder (Individual)

Flyover No.2



Superstructure: PC- Girder (Individual)

Superstructure: Steel Box Girder (Individual)



Superstructure: Steel Box Girder (Portal Rigid Frame P20)

Superstructure: Steel Box Girder (Portal Rigid Frame P21)

Source: JICA Study Team

Figure 12.18 Cross Sections of Cantilever Type Piers for Flyovers

12.5.2 Access Bridges to the Bridge of the Americas

(1) Principles in Planning and Design

As with the approach viaducts discussed in 12.5.1(1)2)i, the same principles were also considered here.

(2) Span Arrangement

Abutment Location

As with the approach viaduct, the places where the abutment height is 10m were selected for the abutment locations.

Table 12.13 shows the abutment locations.

Table 12.13 Abutment Locations

No.	Bridge Name	Abutment ID	Chainage
1	Access Bridge to the Bridge of the Americas	Abutment A1	KM0+520
2		Abutment A2	KM1+280

Source: JICA Study Team

Bridge Length and Span Arrangement

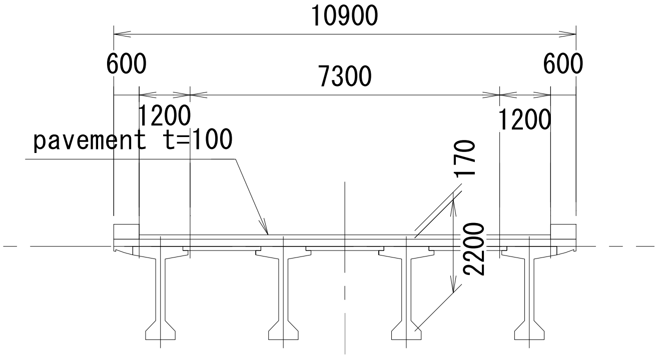
As with the approach viaducts discussed in 12.5.1(1)2) ii, the PC-I girder was selected as the superstructure type for the access road bridges to the Bridge of the Americas. The total number of spans is 19, which are divided into 2 continuous structures consisting of 9 spans and 10 spans in order to eliminate the adverse effect of concrete creeps.

Bridge Length: 760m

Span Arrangement: 9@40m + 10@40m

(3) Superstructure

Figure 12.19 shows the typical cross section of the access bridges to the Bridge of the Americas.

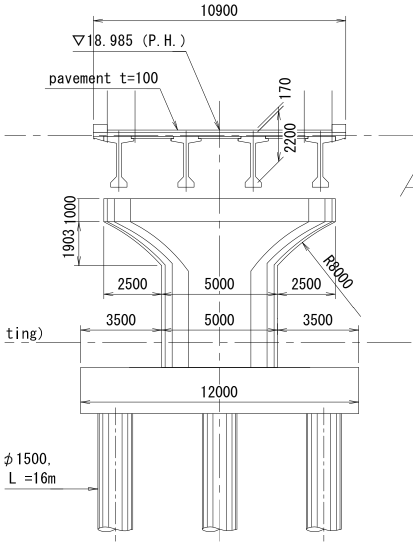


Source: JICA Study Team

Figure 12.19 Typical Cross Section of Access Bridges to the Bridge of the Americas

(4) Substructure and Foundation

Figure 12.20 shows the pier cross section of the access bridges to the Bridge of the Americas.



Source: JICA Study Team

Figure 12.20 Typical Pier Section of Access Bridges to the Bridge of the Americas

12.6 Bridge Ancillary Works

12.6.1 Expansion Joint

The types of expansion joints were determined according to the horizontal displacement and the bridge type. Since all the bridge types in the Project have horizontal displacements of 30mm or more, the finger type load support joints were selected.

Table 12.14 shows the expansion joints

Table 12.14 Summary Table of Expansion Joints

No.	Route	Bridge Name		Type	Chainage (KM)	Displacement (mm)
1	4th Panama Canal Bridge	Flyover No.1	Inbound	Steel Finger Type Joint	A1 : 1+070 P6 : 1+310 A2 : 1+570	-30 to +84 -30 to +84 -30 to +84
			Outbound		A1 : 1+050 P7 : 1+320 A2 : 1+570	-30 to +84 -30 to +84 -30 to+84
2		Flyover No.2			A3 : 2+000 P18 : 2+260 A4 : 2+740	-16 to +45 -24 to+67 -24 to+67
3		4th Panama Canal Bridge	East Bank Approach		A5 : 2+847 P26 : 3+000	-8 to +22 -8 to +22
4			Main Bridge		P30 : 3+380 P33 : 4+220	-189 to +189 -189 to +189
5			West Bank Approach		P38 : 4+690 A6 : 5+390	-35 to +98 -18 to +50
6	Access Roads to the Bridge of the Americas	Access Bridges to the Bridge of the Americas			A1 : 0+520 P9 : 0+880 A2 : 1+280	-18 to +50 -38 to +106 -20 to +56

Source: JICA Study Team

12.6.2 Bearings

The types of bearings were determined taking into consideration the bridge types and constructability.

Table 12.15 shows a summary of the bearings.

Table 12.15 Summary of Bearings

No.	Superstructure Type	Bearing	Reasons for Selection
1	PC-I Girder	Elastomeric Rubber	Install simply rubber bearings at the girder ends Elastomeric rubber bearing is generally used.
2	Steel Box Girder	Elastomeric Rubber	Elastomeric rubber bearing is generally used.
3	Arch	Iron Fixed Bearing Elastomeric Rubber	Fixed at Arch Springing At arch end bearing

Source: JICA Study Team

12.6.3 Sidewalk

A sidewalk is accommodated along the southern edge of the bridge deck in the area from P30 to P33 as a panoramic viewing facility. Connection between the ground level roads and the bridge sidewalk is achieved by way of elevators to be installed at the P30.

The necessity of a bridge deck will be studied again in the D/D stage in consideration of security and economic aspects. In case the bridge deck is eliminated, the construction cost including the elevators will be reduced by about USD 20 Million.

A detailed discussion of the elevators is made in Chapter 13.

12.6.4 Maintenance Walkways

- There is no maintenance walkway for PC-I girders that at a low level. Instead, they can be accessed from the ground level.
- There are maintenance walkways in the stiffening girders of the main bridge.
- There are also maintenance walkways under the floor boards of the steel Box girders. It is possible to perform maintenance inside a Box girder, but maintenance cannot be done on the outer surface of the floor board. Therefore, maintenance walkways including manholes at the cross girders are planned for.

12.6.5 Paint (weathering steel)

Paint applied to steel materials should be an anti-corrosive type as mentioned above. In addition to the anti-corrosive properties it provides for steel materials, paint should also be applied from the view point of maintenance and aesthetics.

In areas where there are a lot of fragments with salt content, it is difficult for stable rust to form on weathering steel. Therefore, Nickelic high weathering steel was developed for this type of area. It was decided that this type of steel would be adapted for this bridge location.

It should be noted that samples of anti-corrosive type steel have been attached to the steel surface of the Bridge of Americas for checking the degree of weathering in the vicinity of the Project site. It will be necessary to make a study at the stage of execution design.

12.7 Drawings and Work Quantities of Preliminary Design

The drawings of the preliminary design are shown in Appendix 5-1-3 of Main Report.

The preliminary quantities of the bridge works were taken off from the preliminary drawings and it is shown in Appendix 7 of main Report.

12.8 Pending Studies for the D/D

The studies that need to be conducted for the detailed design are as follows.

- Geological survey: A survey under the piers is necessary. If the width of foundation is large, several points under each pier need to be surveyed.
- Survey (including a bathymetry)
- Wind tunnel test: 2D model of the stiffening girder or 3D model of the cantilever erection.
- Simulation of vessel collision: investigation of the impact of ship collision on the main frame.
- Survey of tide levels and tidal stream: for the navigation plan of the barges used in construction.
- Road alignment: the positions of the bearings are high and the slope of pier’s beams is sharp at the some points in this plan. The road alignment needs to be reviewed with its sharply-sloping superelevations in each direction.

Chapter 13 Preliminary Electrical and Mechanical Design

13.1 Objective

In this study, the preliminary designs of the electrical and mechanical equipment for the bridge, including the preparation of design drawings and the calculation of estimated work quantities, are prepared in order to estimate the project cost and to determine the project scope.

13.2 Study Items

In the preliminary designs, the following items are considered:

- Selection criteria of the equipment necessary for the Project
- Coordination with the Metro Line-3 Project
- Equipment installation plan
- Development of preliminary designs for equipment
  (only for the necessary equipment, for estimating the work quantities)
- Plan for attaching public utility facilities to the 4th Panama Canal Bridge
  (out of the scope of the Project)
- Plan for relocating existing public utility facilities
- Preparation of drawings for the preliminary designs
- Calculation of the estimated work quantities

Furthermore, the improvement of the Omar Torrijos roundabout was conducted as a Concept Design in the Study (see Section 11.6); therefore, the electrical and mechanical design does not include the improvement of the Omar Torrijos roundabout.

13.3 Study Results

13.3.1 Selection of Necessary Equipment for the Project

In this study, discussions with the relevant authorities of Panama were held and the following criteria are proposed for selecting the necessary equipment for the Project:

- The minimum equipment necessary for the management of the road and bridge as a general road will be installed.
- Since the road and the Metro Line-3 will be established in parallel, some of the equipment could be shared by both. However, it was proposed that the equipment for the road and Metro Line-3 NOT be shared in consideration of their different operation, maintenance and management systems.
- In Panama, the Land Transit and Transportation Authority (Autoridad del Tránsito y Transporte Terrestre, ATTT) is responsible for the management and maintenance of equipment for general roads. In the Project as well, ATTT is in charge of the management and maintenance of the equipment, and no additional, independent control center for the Project will be established. The equipment to be operated and maintained by ATTT will be the meteorological observation equipment and CCTV cameras. Their installation is proposed within the scope of the project.
- Since no additional and independent control center will be established in the Project, any equipment that ATTT is not managing and monitoring by remote control will not be installed.

13.3.2 Coordination with the Metro Line-3 Project

In this study, it is proposed that no equipment will be shared with Metro Line-3.

Since the pipes/lines of the meteorological observation equipment, Variable Message Sign (VMS) boards and CCTV cameras to be installed on the road will require a relatively small area, they will use the cable rack for the Metro Line-3in consideration of its maintainability. Table 13.1 shows a comparison between the equipment of the Project and that of Metro Line-3, and Table 13.2 describes the reasons for not sharing equipment with Metro Line-3.

Table 13.1 Comparison with the Equipment for Metro Line-3

Category		Function	This Project	Metro Line-3
Lighting Equipment		Provide illumination of the road at night	Included	Included
Power Supply Equipment		Supply power	Included	Included
Electric Room		Location for installing power supply equipment		Included
Signal		Warn users of danger		Included
Lightning Protection Equipment		Protect equipment from lightning damage	Included	Included
Meteorological Observation Equipment	Anemometer	Observe meteorological conditions for traffic regulation	Included	Included
	Rain gauge		Included	
	Precipitation detector		Included	
	Visibility meter		Included	
	Thermometer		Included	
	Seismometer			
Variable Message Sign (VMS)		Provide users with information	Included	
CCTV Camera		Remotely monitor any accidents and fallen objects	Included	Included
Emergency Communication System		Radio equipment for when general telephones cannot be used due to power outage or other reasons		Included
Elevator		Used for movement between the ground level and the bridge	Included	
Remote Control and Monitoring (Control Center)		Location for remote control and monitoring		Included

Source: JICA Study Team

Table 13.2 Reasons for Not Sharing Equipment with the Metro Line-3

Equipment	Reason for not sharing
Lighting Equipment	The luminance levels required for the road and Metro Line-3 are different.
Power Supply Equipment	Since maintenance and management will be carried out by different companies, it is difficult to clarify the demarcation of the O&M works between the companies and to properly allocate the electricity costs and equipment replacement costs to each company.
Lightning Protection Equipment	Lightning protection will be provided for each road equipment , and along the entire track for Metro Line-3. Therefore, the equipment cannot be shared.
Meteorological Observation equipment	While only the anemometers could be shared, the maintenance and management company are not the same.
CCTV Camera	Although the cameras could be shared, they will not be due to different administrators in charge of monitoring and control.

Source: JICA Study Team

13.3.3 Equipment Plan

The Pre-F/S assumed that the equipment would be managed from a control center with full-time managers, and remote control and monitoring equipment were identified as necessary. This study proposes, however, not to set up a control center with full-time managers, but rather to install only the minimum equipment necessary for general roads as agreed upon in the discussions held with relevant authorities. Furthermore, the installation of outdoor cubicles is also proposed for the necessary power supply instead of constructing an electric room.

Table13.3 shows a list of the necessary equipment.

Table 13.3 List of Necessary Equipment

No.	Category	Equipment		Function	Location of Installation
1	Electrical Equipment	Lighting Equipment	Bridge Lighting	Provide sufficient illumination of the bridge at night	Entire bridge
2			Road Lighting	Provide sufficient illumination of the road at night	Entire road
3		Warning Lights	Airplane Warning Light	Signal the location of the bridge for airplanes	Top of 4th Panama Canal Bridge
4			Marine Warning Light	Signal the location of the bridge for marine vessels	Bridge piers of 4th Panama Canal Bridge
5		Illumination		Illuminate the bridge for aesthetic purposes	4th Panama Canal Bridge
6		Power Supply Equipment		Supply power	3 locations on the land sections
7		Protection from Lightning Damage	Lightning Protection Equipment	Protect equipment from lightning damage	Each equipment location
8	Communication Equipment	Meteorological Observation Equipment	Anemometer	Measure the wind speed on the bridge	Central part of 4th Panama Canal Bridge
9			Rain Gauge	Measure rainfall on the bridge	Ditto
10			Precipitation Detector	Detect the start and end of precipitation on the bridge	Ditto
11			Visibility Meter	Measure fog density on the bridge	Ditto
12			Thermometer	Measure the temperature on the bridge	Ditto
13		CCTV Camera		Monitor the road condition	Top of the road; entrances to the 4th Panama Canal Bridge
14	Mechanical Equipment	Elevator		Used for movement between the ground level and the bridge.	Entrances to the 4th Panama Canal Bridge sidewalk

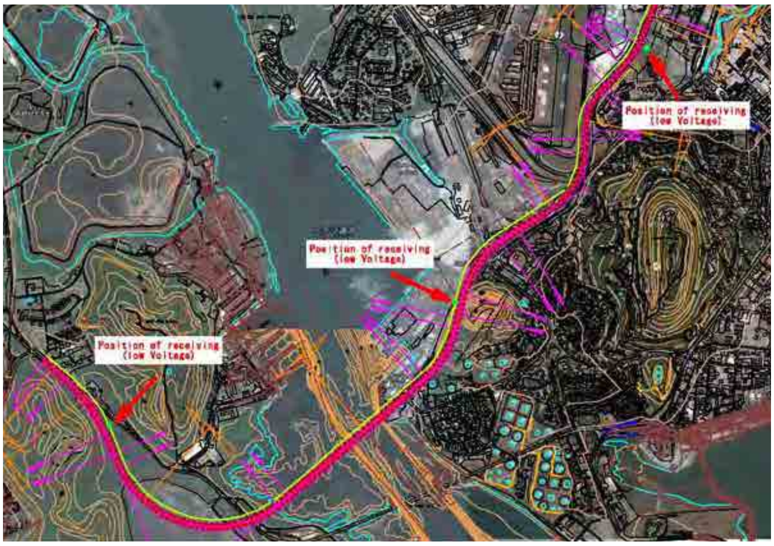
Source: JICA Study Team

13.3.4 Preliminary Designs

In this study, the preliminary designs of lighting equipment and meteorological observation equipment are carried out in order to estimate the work quantities. Since the lighting equipment is required for providing an adequate level of luminance along the bridge and road, appropriate arrangements of lighting equipment were determined in consideration of the structure of the civil engineering facilities. Furthermore, in light of Panama’s tropical climate, meteorological observation equipment that warns drivers of weather conditions were also selected.

(1) Lighting Equipment

In this study, continuous lighting was planned for along the entire length of the road of this Project. For lighting equipment, CIE 132-1999: “Design Methods for Lighting of Roads” was applied as the design standard to determine the number of lighting devices based on lighting calculation. The light source was planned to employ LED lamps in consideration of low power consumption and maintenance cost. Furthermore, the power receiving equipment was planned to install 3 outdoor cubicles as shown in Figure 13.1.



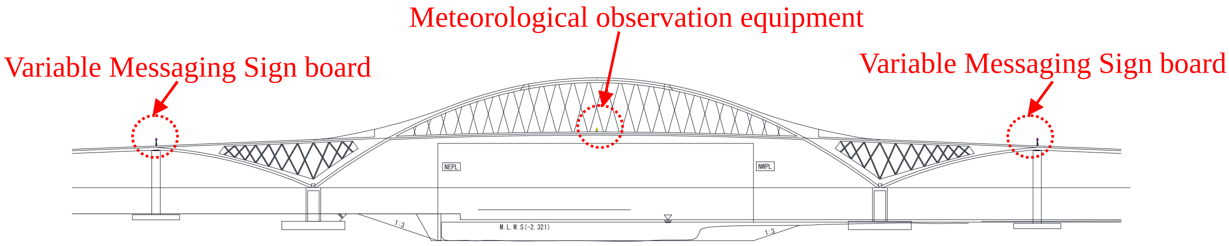
Source: JICA Study Team

Figure 13.1 Positions to Install Power Receiving Equipment

(2) Meteorological Observation Equipment

Meteorological observation equipment measures the weather conditions of the site where it is installed. The data is used for disaster prevention and forecasting future conditions. In the Project, the equipment will measure weather conditions on the bridge and warn traffic of dangers, such as foggy conditions, heavy rain and gales. Upon consulting with relevant authorities, it was decided that meteorological observation equipment and VMS boards would be installed to inform drivers of the weather conditions on the bridge.

Figure 13.2 shows the locations for installing meteorological observation equipment.



Source: JICA Study Team

Figure 13.2 Locations for Installing Meteorological Observation Equipment

13.3.5 Utility Installation Plan (Out of the Scope of the Project)

The installation plan of installing water pipelines, high-voltage lines and communication lines was studied. As the utility service providers are in charge of installing the respective utilities (including pipes/lines), the Project only covers the provision of the space and the installation of the supporting frames.

Table 13.4 shows a list of the utilities to be installed.

Table 13.4 List of the Utilities to Be Installed

Type	Use	Quantity	Total size in inches (centimeter)	Piping Class
Water Supply Pipe	Drinking water	1	18 (45.72)	PVC
High Voltage Line	General power supply	24	6 (15.24)	HDPE
Communication Line	Telephone, Internet	6	4 (10.16)	HDPE

Source: JICA Study Team

13.3.6 Plan for Relocating Existing Utilities

The existing utilities located in the area covered by the Project were identified through inquiries with the relevant authorities.

Table 13.5 shows a list of the existing utilities in the Project area.

Table 13.5 List of Existing Utilities in the Project Area

No.	Facility	Location (within the project targeted land or not)	Management company
Existing Utilities (above ground)			
1	Telecommunication Building	Yes	ACP
2	Chill water Plant	No	ACP
3	Substation	No	ACP
4	High-voltage Transmission Tower	Yes	ACP
5	Marine Traffic Control Building	No	ACP
6	Mechanical Maintenance Plant	Yes	ACP
7	Oil tank	No	ACP
Existing Utilities (underground)			
8	Power line	Yes (only APC owned lines)	ACP, Gas Natural fenosa,
9	Water pipeline	Yes (only APC owned pipes)	ACP, IDAAN
10	Drainage pipe	Yes (only APC owned pipes)	ACP, IDAAN
11	Communication line	Yes (only APC owned lines)	ACP, Cable Onda, Cable and Wireless
12	Water pipe (Chill water plant)	Yes (only APC owned pipes)	ACP
13	Gas line	No	ACP
14	Oil line	No	ACP

Source: Respective Service Providers

13.3.7 Drawings of Preliminary Designs and Estimated Work Quantities

In the Study, the drawings of the preliminary design for the equipment listed below have been prepared in order to estimate the work quantities.

- Lighting equipment
- Meteorological observation equipment

The preliminary design drawings for the equipment, the estimated work quantities for electrical and mechanical facilities are shown in Appendices 5-1-4 and 7 in the Main Report, respectively.

13.4 Conclusion

Plans and preliminary designs were developed for all of the electrical and mechanical equipment necessary for the Project. Specific plans for the following facilities should be reviewed in the detailed design.

- Adoption of low-position lighting
- Method for connecting the weather observation equipment and CCTV cameras with ATTT's central system with
- Adoption of illumination
- Introduction of elevator facility

Regarding the improvement of the Omar Torrijos roundabout, the study was conducted only at the level of a concept design; therefore, a relocation plan was not prepared. The relocation plan will be studied with the preliminary design by GOP.

Chapter 14 Preliminary Operation and Maintenance Plan

14.1 Objective

In order to calculate the estimated operation and maintenance costs, the preliminary operation and maintenance plan, to be implemented after project completion, was examined.

14.2 Study Items

In the study, the following items were considered:

- Examination of the outline of the operation, maintenance and management plan.
- Examination of the operation, maintenance and management system.
- Development of an outline for the maintenance and management plan.

As the Project involves the development of a bridge for road and railway, the preliminary operation and maintenance plan was studied in order to support the efficiency of the different operation and maintenance service providers.

14.3 Survey Results

14.3.1 Summary of Survey Results

The road to be developed by the Project is a general road so tolls will not be collected under this plan. It was also decided that the operation, maintenance and management services in the road Project would be separated from those of Metro Line-3 because of the different service providers. Under this plan, the maintenance and management entity for the civil engineering facilities constructed by the Project is the MOP (Ministry of Public Works of Panama), while ATTT (Land Transit and Transportation Authority) is responsibility for traffic management and equipment maintenance.

Table 14.1 shows the relevant service providers and their respective areas of responsibility, and Table 14.2 indicates the entities in charge of the operation, maintenance and management of the equipment installed by the Project.

Table 14.1 Relevant Service Providers and their Respective Areas of Responsibility

No.	Category	Service Required	Operator/Service Provider
1	4th Panama Canal Bridge	Bridge management	Ministry of Public Works (MOP)
2		Management of the Metro Line-3	Panama Metro Secretariat (SMP)
3		Road traffic management	Land Transit and Transportation Authority (ATTT)
4	Other Roads[1]	Road traffic management	Land Transit and Transportation Authority (ATTT)
5	Panama Canal	Navigation channel	Panama Canal Authority (ACP)
6	Albrook Airport	Airport management	Civil Aviation Authority (AAC)
7	Overall Facilities	Response to accidents and disasters	Police, fire department, emergency service
8	Elevator	Response to emergency contacts	Elevator maintenance company

1) East Side Connection Road, Access Roads to the Bridge of the Americas, Omar Torrijos roundabout, West Side Connection Roads
Source: Respective Service Providers

Table 14.2 Operation and Maintenance of the Equipment

No.	Category	Equipment	Administrator
1	Electrical Equipment	Bridge lighting	Gas Natural Fenosa
2		Road lighting	Gas Natural Fenosa
3		Airplane warning lights	MOP
4		Marine warning lights	ACP
5		Illumination	MOP
6		Power supply equipment	Gas Natural Fenosa
7	Communication Equipment	Anemometer	ATTT
8		Rain gauge	
9		Precipitation detector	
10		Visibility meter	
11		Thermometer	
12		CCTV camera	
13	Mechanical Equipment	Elevators	MOP

Source: JICA Study Team

14.3.2 Preliminary Operation and Maintenance Plan

(1) Development Plan

The Project consists of the following roads:

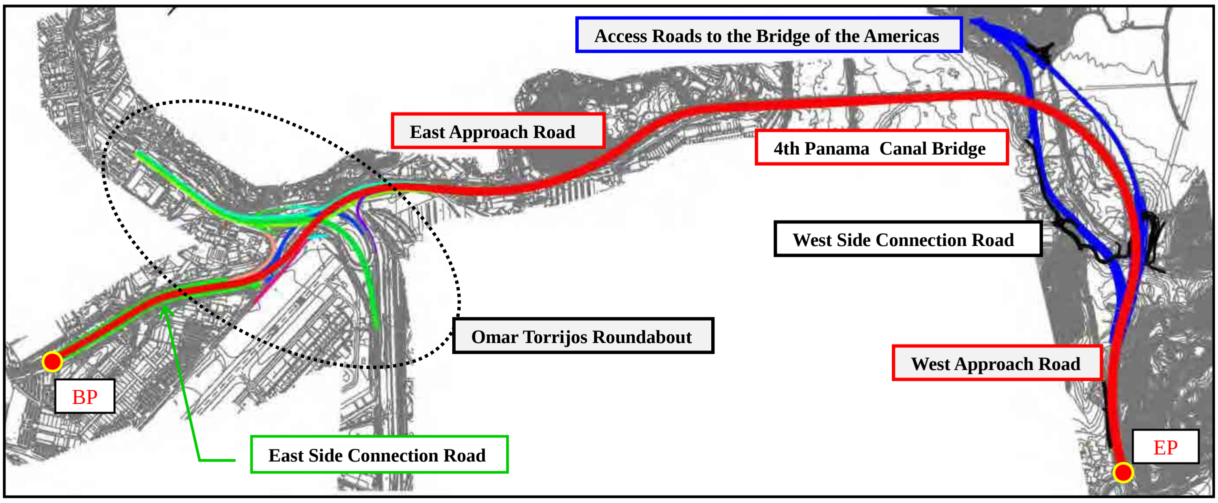
- 4th Panama Canal Bridge (including East and West Approach Roads)
- East Side Connection Roads
- Access Road to the Bridge of the Americas (West Side)
- Omar Torrijos Roundabout
- West Side Connection Roads (excluding Additional Ramp X (future))

Table 14.3 shows the features of the project (scope of construction works) and Figure 14.1 presents a map illustrating the project location.

Table 14.3 Project Features (Scope of Construction Works)

No.	Route	Segment		Item	Description
1	4th Panama Canal Bridge (Construction)	Whole segment			Road Length: 6,720.212m (-KM0+020.975 to KM6+699.237) No. of Lanes: 6 lanes (2*3 lanes) (BP～Omar Torrijos Roundabout: 4 lanes (2*2 lanes))
		Break-down	Civil	East Approach Road	Road Length: 2,867.975m
				4th Panama Canal Bridge	Road Length: 2,543m
				West Approach Road	Road Length: 1,309.237m
			Utilities	Whole Section	Electrical, communication and mechanical facilities
2	East Side Connection Road (Construction)	Whole segment			Road Length: 1,025.19m, No. of Lanes: 2 lanes
		Break-down	Civil	Additional Ramps	On Ramp, Off Ramp
			Utilities	Whole Section	Electrical facilities (road lighting)
3	Access Roads to the Bridge of the Americas (Reconstruction)	Whole			Road Length: 3,170.4m, No. of Lanes: 4 lanes (2*2 lanes)
		Break-down	Civil	East, to Panama City West, to Arraijan	Reconstruction of east-bound to Panama City. and west-bound, to Arraijan
			Utilities	Whole Section	Electrical Facilities (road lighting)
4	Omar Torrijos Roundabout (Improvement)	Whole segment			Road Length: 5,690m No. of Lanes: Ramps - 1way, 1or 2 lanes Underpass: 4 lanes (2x2 lanes)
		Break-down	Civil	Additional Ramps	Additional ramps, Flyover[1)], Underpass
				Existing Roundabout	Widening of existing roundabout
			Utilities	Whole Section	Electrical facilities (road lighting)
				Underpass Section.	Mechanical facilities (drainage pumps)
5	West Side Additional Ramps (Reconstruction)	Whole segment			Road Length: 1,130m, No. of Lanes: 1way, 2 lanes
		Break-down	Civil	Additional Ramps	Additional Ramp Y and ramps a to i
			Utilities	Whole Section	Electrical facilities (road lighting)

1) Assumption, 2) Except Additional Ramp X (For the future)
Source: JICA Study Team



Source: JICA Study Team

Figure 14.1 Project Location Map

(2) Division of the Operation and Maintenance Services

As the road to be developed in the Project will require a wide range of services, including the management of the road, the Metro Line-3 and utilities (water supply, electricity and communication), the plan will distribute the operation and maintenance services among the different service providers.

(3) Operation and Maintenance Entity

As the road to be developed is a general road, the operation, maintenance and management entity is the Ministry of Public Works (Ministerio de Obras Publicas, MOP). Nonetheless, as in the case of other general roads, the use of other service providers and the outsourcing of services will also be considered.

To ensure the long-term operation of the equipment, standards and other documents should be developed describing the work procedures for the Project facilities. In the case of outsourcing, this would also help the external service providers in understanding their duties.

(4) Operation Method

1) Toll

Since the road is categorized as an urban arterial road, tolls will not be collected.

2) Traffic Management

The traffic on the road to be developed in the Project will be managed as a general road. While the Ministry of Public Works is the entity responsible for the operation, maintenance and management of the general roads, ATTT is solely responsible for traffic management on the general roads.

In Panama there is generally no traffic management even under adverse weather conditions (wind, rain, fog). Accordingly, the types of traffic regulations to be implemented on the Project's road, and their standard values need to be established.

Furthermore, the implementation of regulation on vehicles and for road works is also necessary to confirm.

3) Facility Management

a) Civil Facilities and Equipment

Facility maintenance and management in general involves the patrol service, maintenance, inspection, repair, administrative work and consultation services.

While all of the maintenance and management services mentioned above are required in the Project, they will be outsourced because the Ministry of Public Works has no technical section dedicated to repairs, which requires specialized skills.

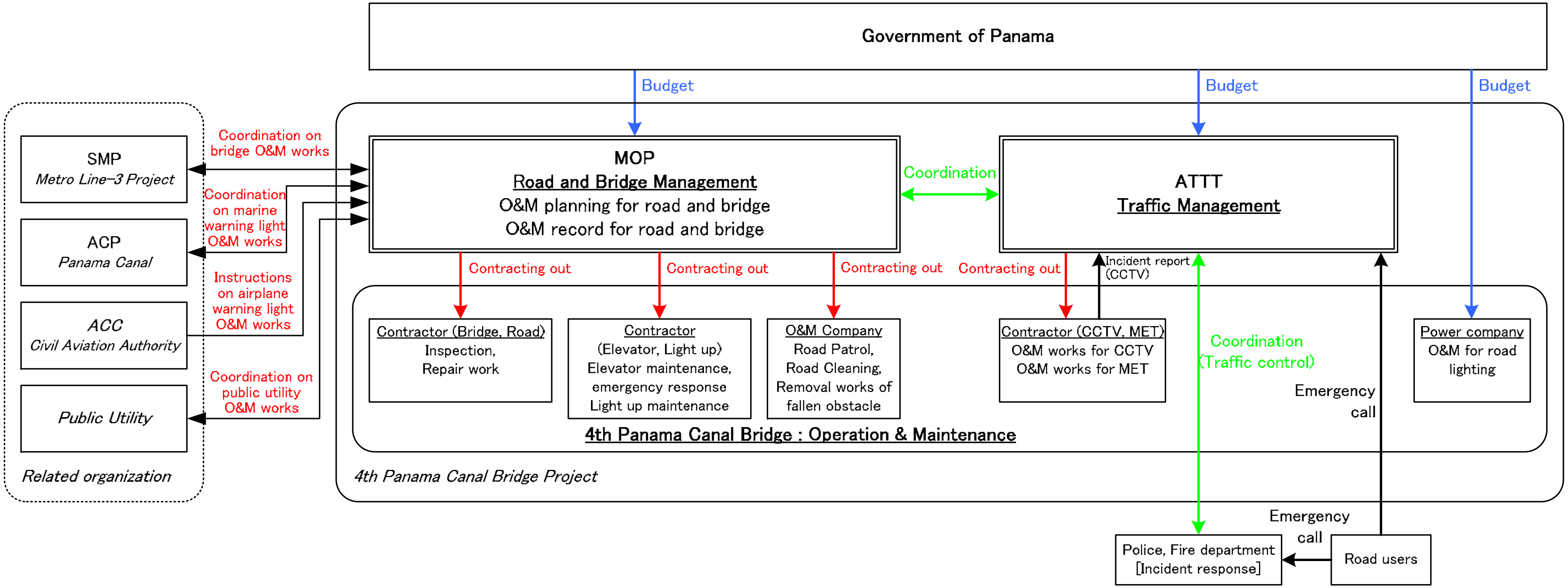
The functioning of the equipment needs to be maintained above a certain level through regular inspections as well as emergency repairs if necessary. A replacement schedule should also be developed.

b) Utilities

While utilities such as water supply pipelines, high-voltage lines and communication lines need to be installed in the Project, operation and maintenance services for the utilities will be performed by the respective service providers.

14.3.3 Outline of the Operation, Maintenance and Management System

Figures 14.2 illustrate the organizational chart of the operation and maintenance system for the completed Project and a schematic diagram of the system.



Source: JICA Study Team

Figure 14.2 Organizational Chart of the Operation and Maintenance System

14.3.4 Preliminary Maintenance Plan

A preliminary maintenance plan was developed for the Project based on the results of the civil engineering and equipment designs in this study in order to estimate the operation and maintenance costs as explained below.

(1) Civil Structures

Table 14.4 shows the preliminary maintenance plan in the Project (civil structures).

Table 14.4 Preliminary Maintenance Plan in the Project (Civil Structures)

Category		Structures	Specifications	Maintenance Method	Frequency (Year)
Common		Road markings	White color	Repaint	10
		Road signs	F-type, Single pole type	Replace	10
Road		Pavement (Vehicle way)	Concrete	Replace, Overlay	30
		Pavement (Shoulder)	Surface course: dense-grade asphalt	Remove old surface, overlay	10
		Retaining wall	Reinforced earth	Replace surface panel	50
		Cut slope protection	Mortar spraying	Re-spray	20
		Embankment slope treatment	Seeding	Trim a slope, Re-seeding	20
		Side ditch, catch pit	Concrete	Replace	15
		Guardrails	Flexible guard fence	Partially replace	10
Bridge	Common	Wall Barrier	Concrete	Replace	100
		Pavement (Surface course)	Dense-grade asphalt	Remove old one surface, overlay	10
		Pavement (Binder course , waterproofing)	Dense-grade asphalt	Remove old layer, overlay	30
		Pavement (Sidewalk)	Asphalt	Remove old pavement, overlay	30
		Catch pit	Steel	Replace	50
		Accessories (partial)	—	Cleaning, patching, repair	5
	Arch	Painting	Equivalent to Class C-5	Scraping, re-painting	40
		Painting (partial)	Equivalent to Classes C-5/D-5	Scraping, re-painting	15
		Scaffolding for re-painting	—	—	40
		Cable strands	PWS	Replace	100
		Deck slab	RC deck slab	Replace	100
		Deck slab (partial)	RC deck slab	Repair the section	15
		Bearings	Rubber type	Replace	100
		Expansion joint	Steel	Replace	40
		Substructure (partial)	RC	Repair the section	10
	Steel Box Girder	Painting	Equivalent to Class C-5	Scraping, re-painting	40
		Painting (partial)	Equivalent to Classes C-5/D-5	Scraping, re-painting	15
		Scaffolding for re-painting	—	—	40
		Deck slab	RC deck slab	Replace	100
		Deck slab (partial)	RC deck slab,	Repair the section	15
		Bearings	Rubber type	Replace	100
		Expansion joint	Steel	Replace	40
		Substructure (partial)	RC	Repair the section	10
	PC-I Girder	Main girder (partial)	PC	Repair the section	15
		Bearings	Rubber type	Replace	100
		Expansion joint	Steel	Replace	40
		Substructure (partial)	RC	Repair the section	10

Source: JICA Study Team

(2) Electrical and Mechanical Equipment

The functions and level of reliability required for similar electrical & mechanical equipment may differ according to the objectives, conditions and locations. The equipment that is to be installed needs to be appropriate to the objectives, and proper and necessary maintenance needs to be carried out to ensure that the equipment can fulfill the required functions.

Basic maintenance services for electrical & mechanical equipment include periodical inspection to check and analyze the condition of the various electrical and communication devices that are installed and operated, in order to extend their service through steady improvement measures.

Inspections made in a planned manner help to determine the proper timing for replacing the equipment, maintain its functions, performance and reliability, and reduce the lifecycle cost.

Table 14.5 shows the preliminary maintenance plan in the Project (for electrical and mechanical equipment).

Table 14.5 Preliminary Maintenance Plan in the Project (Electrical and Mechanical Equipment)

Item		Inspection item	Inspection Frequency	Replacement Frequency
Lighting Facilities	Pole Lighting	- Deterioration of poles - Power consumption - Cleaning	Twice a year	Pole: every 30 years LED lamp: every 15 years
	Road Lighting (Underpass)	- Deterioration of lighting fixture - Power consumption - Deterioration of cable and conduit - Cleaning	Twice a year	Lighting fixture: every 30 years LED lamp: every 15 years
	Airplane Warning Light	- Deterioration of control parts - Deterioration of solar cell	Twice a year	Solar cell: every 10 years Control panel: every 15 years
	Marine Warning Light	- Deterioration of control parts - Deterioration of solar cell	Twice a year	Solar cell: every 10 years Control panel: every 15 years
Power Supply Facilities	Illumination	- Deterioration of fixtures * Lamps are replaced in case of failure	Twice a year	Fixture: every 30 years LED lamp: every 15 years
	Outdoor Switchboard	- Voltage measurement - Deterioration of internal devices - Deterioration of piping/wiring	Once a year	Every 30 years
Communication Facilities	Meteorological observation equipment	- Function of measurement parts - Deterioration of display devices - Deterioration of piping/wiring	Twice a year	Meteorological observation equipment: every 20 years Pole: every 30 years Measurement device: every 15 years
	Variable Massaging Sigh Board	- Function of measurement parts - Deterioration of display devices - Deterioration of piping/wiring	Twice a year	Information board: every 15 years Pole: every 30 years
	CCTV Camera	- Function of measurement parts - Deterioration of display devices - Deterioration of piping/wiring	Twice a year	CCTV camera: every 10 years Pole: every 30 years Optical cable: every 20 years
Mechanical Facilities	Elevator Equipment	- Function of elevators - Function of emergency power generators - Deterioration of wires - Emergency communication system - Blinking of display devices	Twice a year	Elevator apparatus: every 20 years Shaft: every 50 years Driving system: every 15 years
	Drain pump	- Function of pump - Pump tank - Function of control equipment - Cleaning	Once a year	Every 30 years

Source: JICA Study Team

(3) Environmental Monitoring

Environmental monitoring should carry out the monitoring on air quality, noise, vibration, water quality, soil quality, and waste water during the first three years of the operation stage.

The detail of environmental monitoring plan was described in Section 19.

14.4 Conclusion

The preliminary operation and maintenance plan was studied.

Most of the operation and maintenance services for the equipment installed by the Project will be provided by ATTT. The administrative system for the equipment has to be determined after confirming with ATTT on how it operates other general roads.

While electricity charges account for a large proportion of the equipment operation and maintenance cost, the lighting cost for general roads is borne by the power company. Therefore the lighting bill for the bridge and other public roads of this Project will be paid by the power company. Information on the electricity charges for road lighting in this project is based on the electricity tariff list obtained from the power company in this Study.

Chapter 15 Preliminary Construction Planning and Project Cost Estimate

15.1 Preliminary Construction Planning

15.1.1 Summary

Contract packaging, procurement of materials and machinery, construction method, temporary facilities and construction schedule were studied in the preliminary construction planning taking into account the construction quantities, scale and characteristics of structures and site conditions to formulate a realizable and optimum preliminary construction plan. As for the erection method of the main bridge of the 4th Panama Canal Bridge, two cases of using/without using the navigation channel in the erection works were studied. The preliminary construction plan of the concept design section for the Omar Torrijos Roundabout and the western additional ramps is not included (see Section 11.2).

15.1.2 Related Regulation and Standards

According to the survey results, there are no exact regulations and standards system for road construction works in Panama. As for the regulation of construction safety, this is described in Section 15.1.8 of this Draft Final Report.

15.1.3 Contract Packaging

(1) Project Facilities and Approximate Construction Quantities

The main facilities of the Project are the 4th Panama Canal Bridge including the approach roads and access roads to the Bridge of the Americas. The main construction works are road and bridge construction including temporary facilities and the demolition of the existing flyover at the Omar Torrijos Roundabout. The facilities and equipment related to the Metro Line-3 and Omar Torrijos Roundabout were excluded from this preliminary construction planning.

(2) Construction Sections

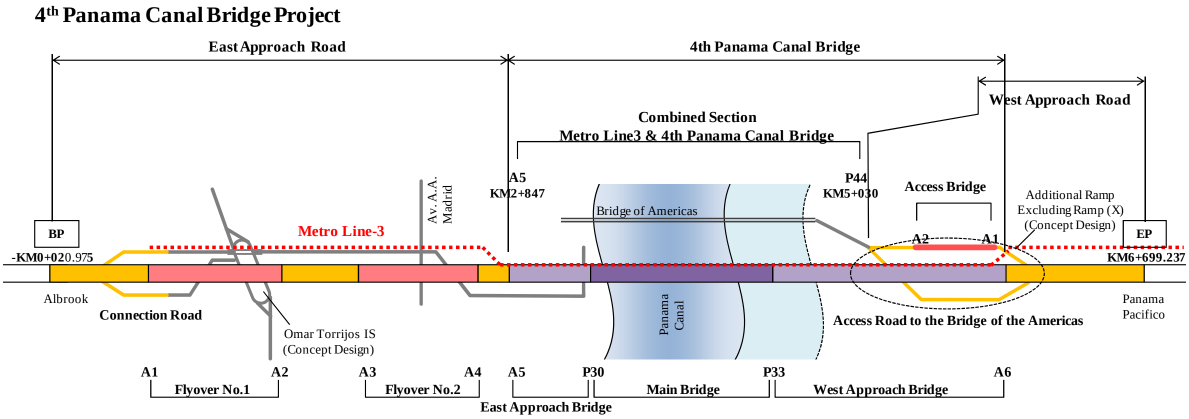
The geographical conditions of the Project are divided into the eastern and western sides of the Panama Canal, with the eastern side being located in an urban area including intersections and existing roads. Since the only existing transportation network that connects the eastern and western sides in the vicinity of the Project is the Bridge of the Americas, a separate transportation route is needed for construction on the eastern and western sides.

Furthermore, the main construction works are road and bridge works that include various types of structures and the construction of these structures needs to be done in parallel in a limited work space. Therefore, the construction yards and work schedule shall be adjusted each other to avoid the interference. By these reasons, one construction contract package was assumed for this Study, since this would allow a joint schedule management for the control and implementation of a unified project.

In addition, for the purpose of calculating design and construction quantities, the Project was divided into the following 3 sections in consideration of the total length of the construction section (6.7 km) as shown in Figure 15.1.

- East Approach Road
- 4th Panama Canal Bridge
- West Approach Road

The Omar Torrijos Roundabout was included in another construction section, and the western additional ramps (excluding ramp X) were included in the West Approach Road.



Source: JICA Study Team

Figure 15.1 Construction Sections

15.1.4 Procurement of Labor, Material and Equipment

(1) Labor

Based on the experience of the Metro Line-1 Construction Project, it was assumed that it will be possible to secure engineers, foremen, skilled and common labours. However, support of foreign engineers with technological skills and experience are necessary for assisting in the construction of a long-span arch bridge erected in water, steel pipe sheet pile foundation, high piers, and high-elevation girders, since these skilled labours are not in Panama.

(2) Construction Material and Equipment

Regarding the construction material and equipment to be used in the Project, embankment material, crushed stone, asphalt, cement, and aggregate will use domestic products, while the other materials will be imported products, based on the experience of Metro Line-1 Construction Project. Steel girders will be fabricated in a foreign country and the high yield point steel materials will also be supplied by a foreign country.

(3) Construction Machinery

Excavators, truck cranes, concrete pumping trucks, etc. were used for the construction of the elevated sections in the Metro Line-1 Construction Project. In the 4th Panama Canal Bridge Construction Project, since special construction machinery such as heavy cranes, gantry, and equipment for erecting over the Canal cannot be supplied domestically, special machinery will be obtained from foreign countries. The main bridge arch rib is assembled on a barge; a large barge with temporary support beams should be also procured from a foreign country. Supplying the machinery for the approach road section will be comparatively easy. However, it is assumed that provision from foreign countries will also be necessary because parallel works need to be carried out in a short period.

15.1.5 Construction Method

(1) 4th Panama Canal Bridge (Main Bridge)

1) Superstructure

The method for erecting the superstructure of the main bridge for the 4th Panama Canal Bridge was studied for the following two cases:

- Using the Navigation Channel
- Without Using the Navigation Channel

The superstructure (main bridge of 4th Panama Canal Bridge) erection methods are shown in Table 15.1.

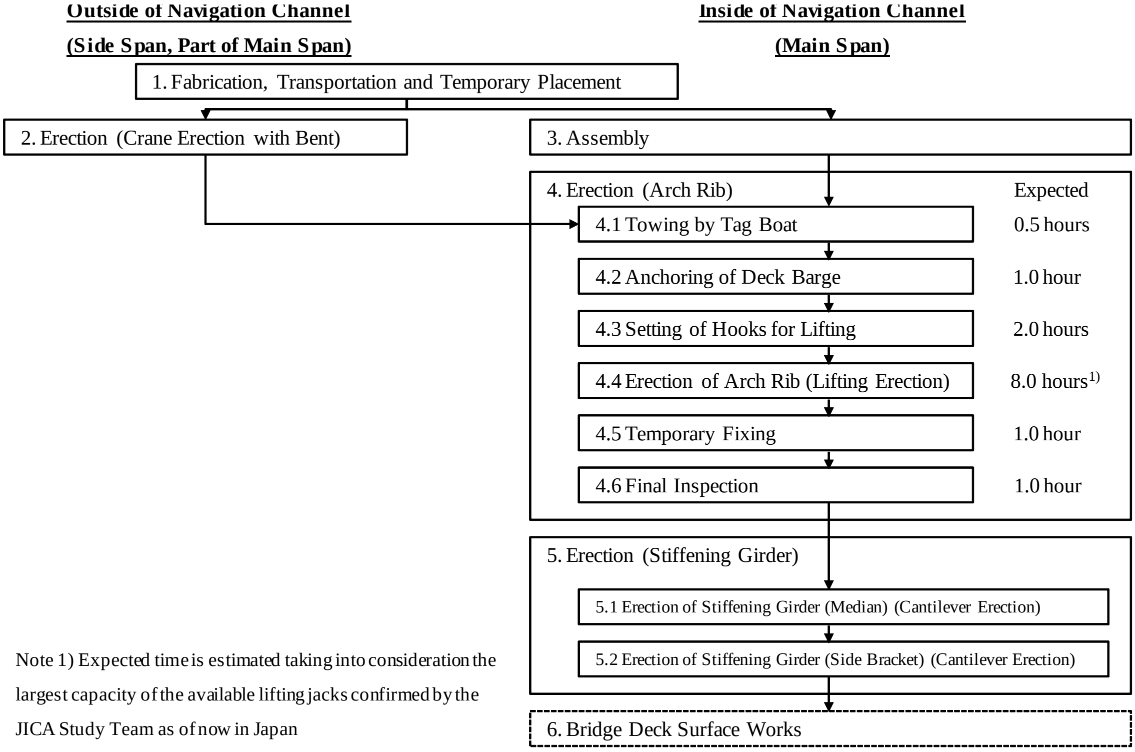
Table 15.1 Superstructure Erection Methods (Main Bridge of 4th Panama Canal Bridge)

No.	Erection Segment of Superstructure			Erection Methods	
				Using Navigation Channel	Without Using Navigation Channel
1	Outside of Canal (Side Span, Part of Main Span)			Crane Erection with Bent	
2	Inside of Canal	Arch Rib		Lifting Erection from Deck Barge	Cable Erection with Oblique Hang
3	(Main Span)	Stiffening	Median	Cantilever Erection (Slewing Jib-crane)	
4		Girder	Side Bracket	Cantilever Erection (Gantry)	

Source: JICA Study Team

a) Using the Navigation Channel

The procedure for erecting the main bridge of the 4th Panama Canal Bridge using the navigation channel in the erection works is shown in Figure 15.2 and explained in the subsequent sections.



Note 1) Expected time is estimated taking into consideration the largest capacity of the available lifting jacks confirmed by the JICA Study Team as of now in Japan

Source: JICA Study Team

Figure 15.2 Erection Procedure of Main Bridge of 4th Panama Canal Bridge using Navigation Channel

1. Fabrication, Transportation and Temporary Placement

The arch rib and stiffening girders (arch rib: 4.5m*10m, stiffening girder: 14.55m*3m) are fabricated in a foreign country, transported by sea and are to be placed in a temporary yard along the Panama Canal.

2. Erection (Crane Erection with Bent)

The side span and part of the main span (outside the navigation channel) are constructed by the crane erection method. A temporary peninsula is constructed by embankment inside the canal (but outside the navigation channel) on the west side.

3. Assembly

The arch rib and stiffening girders for the main span are assembled in the following locations during the erection of the side span and part of the main span (outside the navigation channel).

- Arch Rib: On a deck barge (alongside the temporary yard)
- Stiffening Girders : In the temporary yard

4. Erection (Arch Rib)

4.1 Towing by Tug Boat

After completing the erection works (outside the navigation channel) and assembling the arch rib segment (on a barge inside the canal, but outside the navigation channel), the arch rib segment is towed to the erection site by a tug boat. The time for the towing is expected to be about 0.5 hours, according to past construction experiences.

4.2 Anchoring of Deck Barge

After arriving at the erection site, the deck barge is anchored precisely utilizing the GPS system. The time for anchoring is expected to be about 1.0 hour, according to past experiences.

4.3 Setting of Hooks for Lifting

After anchoring of deck barge, the wire strands are hooked onto the arch rib for lifting. The time for anchoring is expected to be about 2.0 hours, according to past experiences.

4.4 Erection of Arch Rib (Lifting Erection)

After anchoring the deck barge, the pre-installed wire strands are attached to the arch rib and the arch rib is erected utilizing the lifting method. Temporary cross beams are installed at the lifting points in order to ensure the balance of arch rib during the lifting operation. The time for the lifting operation is expected to be about 8.0 hours, according to the capacity of the hydraulic pumps of the lifting jacks.

The erection plan of the arch rib using the lifting method is shown in Figure 15.3.

4.5 Temporary Attachment

After the lifting operation is completed, the arch rib is temporarily attached to the main span by temporary shear pins. The time for the temporary attachment of the arch rib is expected to be about 1.0 hour, according to past experiences.

4.6 Final Inspection

After attaching the arch rib segment, a final inspection is conducted before restoring the operation of the Panama Canal. The time for the final inspection is expected to be about 1.0 hour, according to past experiences.

5. Erection of Stiffening Girders

5.1 Erection of Stiffening Girders (for Median) (Cantilever Erection)

After completing the erection of the arch rib structure, stiffening girders for the median are constructed by cantilever erection (slewing jib-crane) in order to reduce the horizontal force at the piers.

The stiffening girders are lifted at the piers and transported on the bridge deck; therefore, the erection of the stiffening girders does not use the navigation channel.

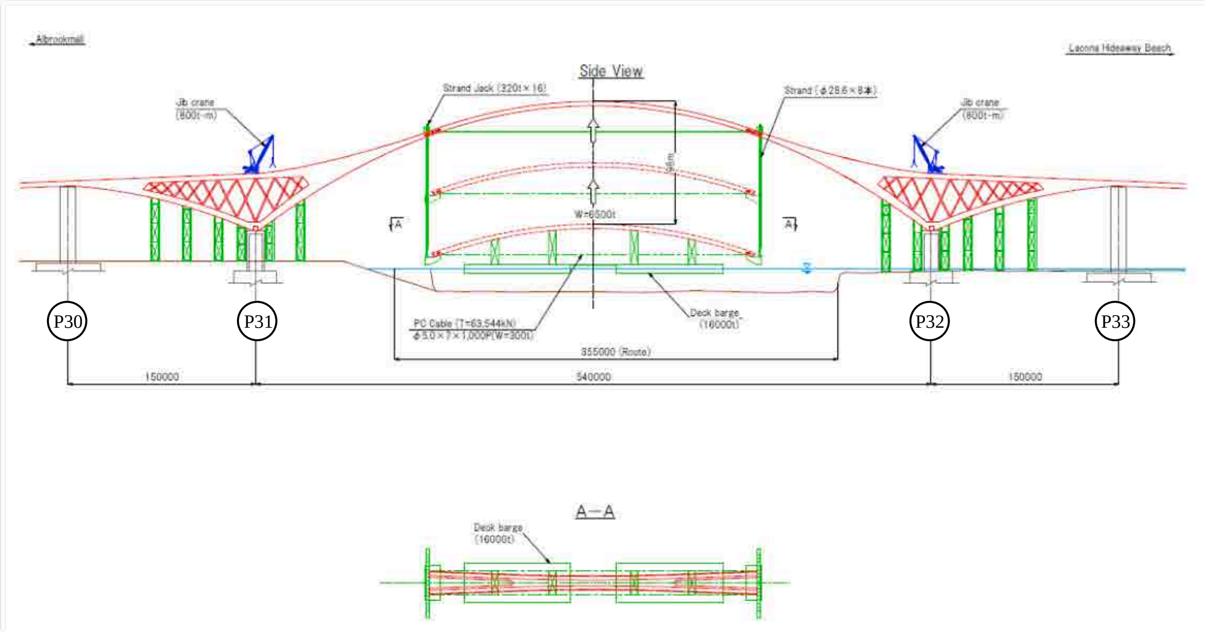
The erection plan of the (median) stiffening girders (cantilever erection) is shown in Figure 15.4.

5.2 Erection of Stiffening Girders (for Side Bracket) (Cantilever Erection)

After completing the construction of the stiffening girders for the median, the stiffening girders for the side brackets are constructed by cantilever erection (gantry).

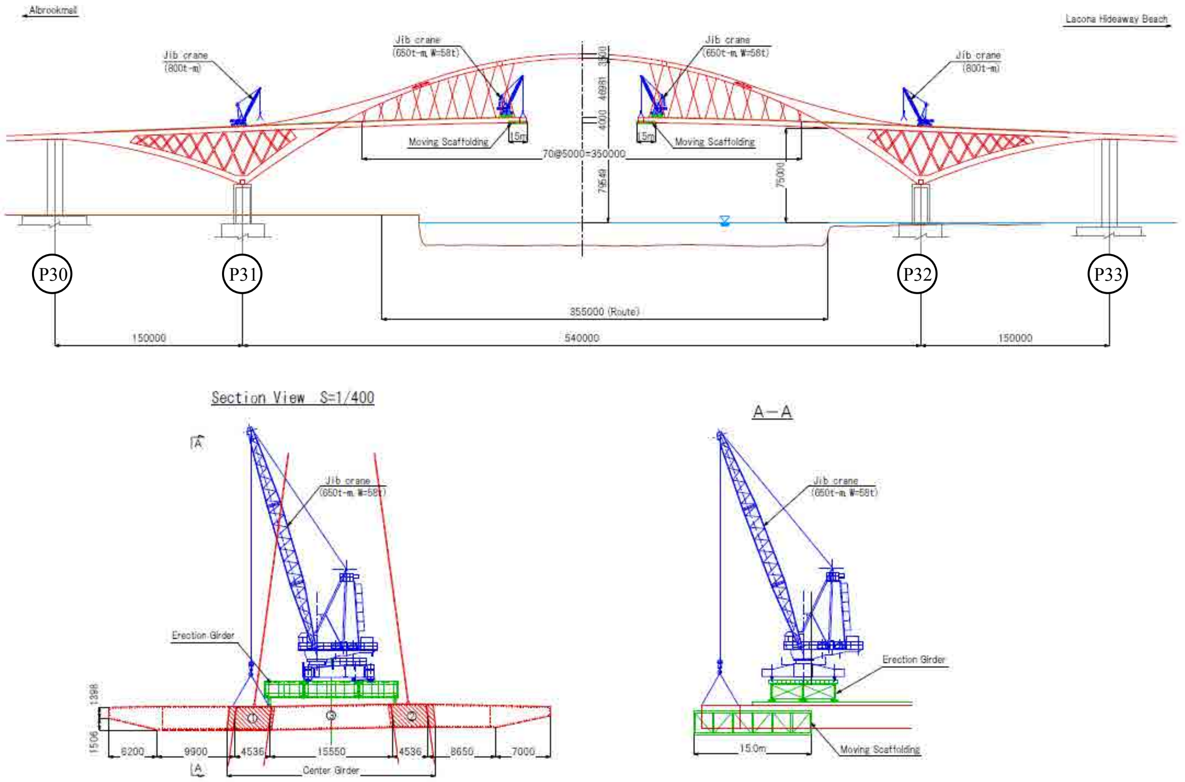
This erection work also does not use the navigation channel.

The erection plan for the (side bracket) stiffening girders (cantilever erection) is shown in Figure 15.5.



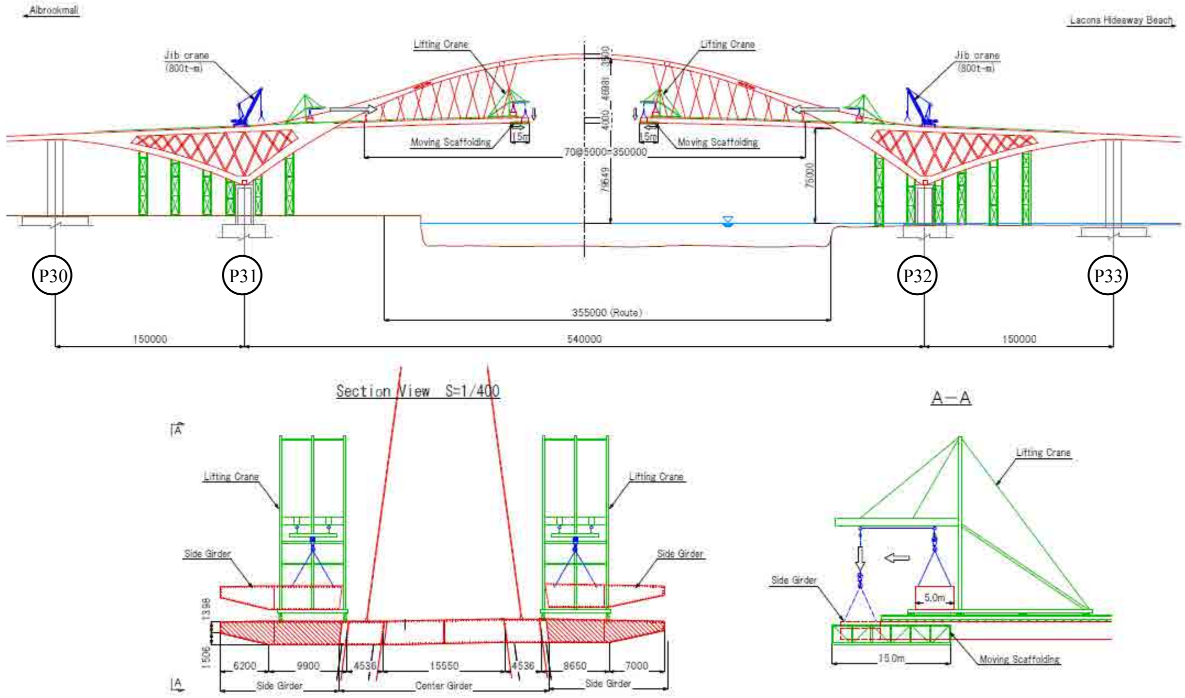
Source: JICA Study Team

Figure 15.3 Erection Plan of Arch Rib (Lifting Method)
(With Using the Navigation Channel)



Source: JICA Study Team

Figure 15.4 Erection Plan of Stiffening Girders for Median (Cantilever Erection)



Source: JICA Study Team

Figure 15.5 Erection Plan of Stiffening Girders for Side Brackets (Cantilever Erection)

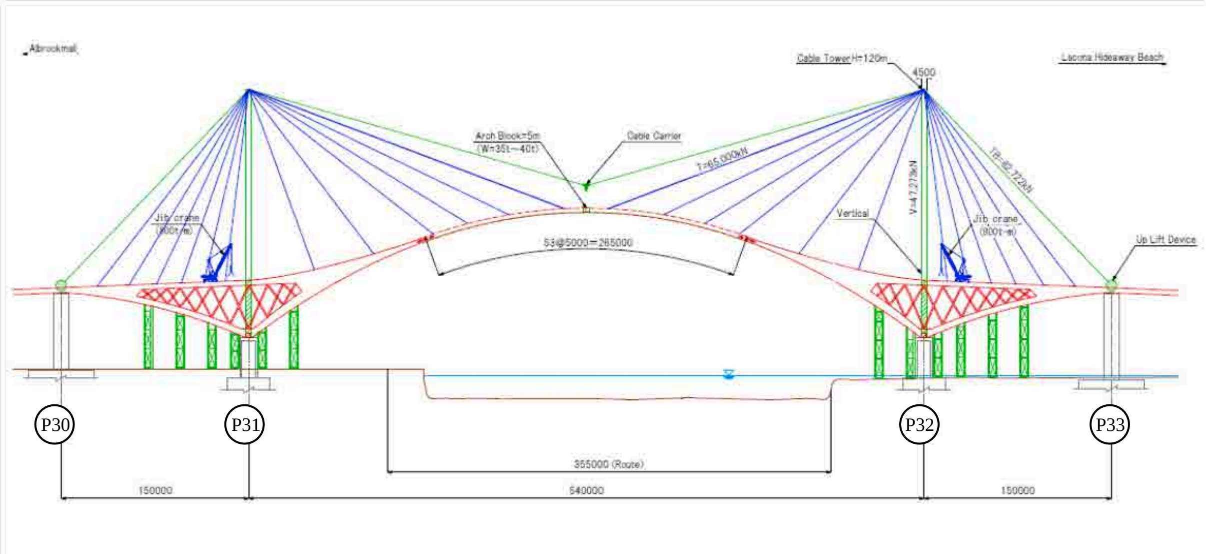
b) Without Using the Navigation Channel

In the case of not using the navigation channel, the followings points are different from the erection procedure shown in Figure 15.2:

- 2. Assembly: Assembled at the temporary yard (Length of each arch rib block: 5m only).
- 4. Erection of Arch Rib: Constructed by cable erection with oblique hang.

The other erection procedures and methods are the same as those in Figures 15.4 and 15.5.

The erection plan of the arch rib (using cable cranes with oblique hang) is shown in Figure 15.6.



Source: JICA Study Team

Figure 15.6 Erection Plan of Arch Rib (using Cable Cranes with Oblique Hang) (Without Using the Navigation Channel)

c) Technical Risk Analysis

The technical risks involved in erecting the superstructure for the 4th Panama Canal Bridge are concentrated in the erection of the arch rib.

A technical risk analysis of the superstructure (arch rib) erection (for the main bridge of the 4th Panama Canal Bridge) is shown in Table 15.2.

Table 15.2 Technical Risk Analysis of the Superstructure (Arch Rib) Erection (Main Bridge of 4th Panama Canal Bridge)

No.	Erection Conditions	Risk Item	Risk and Mitigation Measure	Remaining Risk
1	Using the Navigation Channel	Inclement Weather	In the case of inclement weather (strong wind, heavy rain), the lifting operation can not be carried due to safety considerations. The change of weather after commencing the erection works can be avoided by monitoring the weather forecast in advance of the erection works. On the other hand, if the erection works are cancelled in accordance with the weather forecast, the use of the navigation channel needs to be recoordinated among the stakeholders.	Delay of work by inclement weather
2		Lifting Jack (Failure)	In case of failure of the lifting jacks due to their insufficient capacity, the arch rib stops in the navigation space. The failure of lifting jacks has not occurred in past experiences; however, a 2.0 safety factor is applied to the lifting jack capacity to ensure adequate lifting capacity and avoid the above problem. Futhermore, expert mechanics are on standby at the site to minimize the time for replacing a failed lifting jack. (Replacement time of a lifting jack: 1.0 hour)	Mostly mitigated
3		Lifting Jack (Slipping off of Wire Strands)	In case wire strands slip off from the lifting jack, the strands may brake from insufficient lifting capacity. The slipping off of strands can be avoided by using lifting jacks with the multiple safety devices.	Mostly mitigated
4		Wire Strands (Breakage)	In case of losing balance during the lifting operation, the wire strands may brake from unbalanced loads. Unbalanced load conditions can be avoided by using the established computer control system. Furthermore, a 4.0 safety factor is applied to the wire strand capacity to avoid the breaking of wire stands even if unbalanced load conditions occur.	Mostly mitigated
5	Without Using the Navigation Channel	Instability of Structure	The structure is not stable during the cable erection works by reason of the oblique hanging conditions. By applying a large-scale temporary structure, the unstable conditions can be improved partially; however, it is costly and the unstable conditions still remain under strong wind and earthquakes. Some bridges have collapsed in past experiences.	Risk of collapse by improper tension control and inclement weather
6		Hanging Cable (Tension Control/Capacity)	Tension control is difficult by reason of the enormous tension force and the critical hanging cables that vary at each step. Regarding the unbalanced loading conditions ocurring cable by cable, the capacity of the existing hanging cables might not withstand the loading conditions. Regarding the application of the hanging cables, it cannot be denied that they could collapse due to improper control of tension force.	Risk of collapse by improper tension control and inclement weather

Source: JICA Study Team

d) Risk Analysis by Panamanian Side

The risk analysis for the arch rib erection (using the navigation channel in the erection works) was conducted by the Panamanian side (see above Section 15.1.5(1)1) a. to c.).

The risk analysis report for the main bridge of the 4th Panama Canal Bridge is shown in Appendix 10 of Main Report.

A summary of the risk analysis results and the additional study results made by the JICA Study Team are described below.

1. Pre-conditions of the Risk Analysis

a. Timing of the Arch Rib Erection Works

The timing of the arch rib erection works in the risk analysis was assumed to be in June, 2019 according to the work schedule prepared by the JICA Study Team (see Section 15.1.7).

b. Expected Time for Using the Navigation Channel in the Erection Works

The expected time needed for erecting the arch rib was estimated to be about 13.5 hours by the JICA Study Team (see 15.1.5(1)1)a.). Based on this standard time, the maximum time was set at 24 hours by the Panamanian side in the risk analysis.

2. Summary of Risk Analysis Results

a. Maximum Duration of Channel Closure

In case of the arch rib falling into the canal water, a longer channel closure will be required than the maximum time for the arch rib erection works (expected to be 24 hours). As a result of Canal operational simulation by ACP, the maximum acceptable backlog of ships is 100 vessels in consideration of revenue and increased work volume to reduce the backlog. In accordance with this requirement, the maximum duration of channel closure in case of such an accident was determined to be 3 days in the risk analysis by the Panamanian side.

b. Risk Items and Countermeasures

The risk items and countermeasures of the risk analysis are shown in Table 15.3.

Table 15.3 Risk Items and Countermeasures

No.	Risk Items		Countermeasures
1	Closure of Pacific Approach Channel and Special Prevention Measures	Compensation to neighbouring businesses (revenue, incremental works)	Direct Compensation Cost
2		Standby equipment, test simulation cost	Construction Cost
3	Short Notice Postponement of Pacific Approach Channel Closure Date	Compensation to neighbouring businesses (revenue, incremental works)	Risk Contingency1)
4	Falling of Rib Arch Segment	Compensation to neighbouring businesses (revenue, incremental works)2)	CGL Insurance
5		Compensation of additional project cost and delayed start-up in Metro Line 3 due to the extension of the construction period	ALOP Insurance
6		Cost for removal of arch rib and additional project cost in 4th Panama Canal Bridge Project due to the extension of the construction period	CEAR Insurance

Source: JICA Study Team

Red: Studied by the JICA Study Team in accordance with the request by the Panamanian side

CGL : Comprehensive General Liability

ALOP : Delayed Start-Up

CEAR : Construction/Erection All Risks

1) Project Cost: 100%, Comparison of Main Bridge Type: 50%

2) Limit of Indemnity: Assumed 100 Mil.USD (practice in the 3rd Panama Canal Bridge) according to the discussion results on the Draft Final Report

3. Additional Study Results of Erection Works by the JICA Study Team

In accordance with the request by the Panamanian side, the following additional study related to the erection works was conducted by the JICA Study team.

The results of this study were reflected in the risk cost estimate.

a. Expected Extension of the Construction Period due to the Arch Rib Falling

In case of the falling of the arch rib, the JICA Study Team estimated that the extension of the construction period would be about 9 months for the re-fabrication and erection works. In the risk cost estimate, the extension of the construction period was considered to be 1 year.

b. Lifting Test (Simulation) of Arch Rib

The following lifting test (simulation) was planned by the JICA Study Team.

- Structural analysis and simulation by 3D frame program
- Test lifting at the assembling yard

c Removal of Arch Rib

In case of the arch rib falling into the canal water, it will be removed to the edge of the canal by towboats and pusher boats. The removal works was planned to be completed within the maximum duration of channel closure (3 days).

2) Substructure and Foundation

The following construction method is assumed for the substructures and foundations of the main bridge of the 4th Panama Canal Bridge.

East Side (on land): Spread Foundation (P30,P31)

The standard method for the substructures on land is a spread footing, which carries out intrusion without auxiliary method to the rock formation in this area. Construction procedures for the substructures consist of earth retention by steel sheet-pile, excavation, and the construction of the structure.

West Side (in the Canal): Steel-pipe-sheet-pile Foundation(P32) and Cast in Place Pile(P33)

There are many experiences in the construction of a bridge foundation in water, which are applicable to the substructures for an arch bridge in a canal. High construction safety can be expected from the use of the steel-pipe-sheet-pile construction method, without a cofferdam.

(2) Construction Method of the Approach Road

1) Substructure

The approach road section is constructed on land and can be transported from existing roads. The foundation type is the cast-in-place pile which has few construction impacts (noise and vibration) for the scale of the structure. The substructure in the low-elevation approach sections is the commonly used reinforced concrete, and does not require a special construction method. In the section near the main bridge, lifting type falsework is recommended for piers over 30m high. In the eastern section, when constructing piles and lifting materials, the construction methods should take into full consideration the obstacle limitation surfaces of the nearby airport. Parallel to the construction of the approach road, improvements will be made to the Omar Torrijios roundabout. Schedule management, such as traffic detours and construction procedures, should be coordinated between both construction areas.

2) Superstructure (PC-I Girder)

For the fabrication of the PC-I Girders, the precast segmental method at a construction yard is adopted. The segments are divided and fabricated in consideration of the transportable size. The fabrication procedure is to carry the segments to the assembly base at the erection point, where they are unified by gluing and pre-stressing.

For raising the girders, the truck-crane erection method is adopted. A truck crane is set on the ground at the erection point, and a unified PC girder is lifted and installed. Coordinated lifting by two cranes is assumed as the PC girder’s length is 40 m and weighs about 100t.

In the eastern approach road, the crane work for flyovers No.1 and No.2 should take into consideration the airspace restrictions near the airport. The construction procedure for the PC I-girders is as follows:

1. Carry segments to the erection point
2. Join segments on the assembly table
3. Main girder erection by coordinated lifting by two cranes
4. Installation of falsework
5. Construction of cross beams, floor slab, and bridge surface, and
6. Proceed to next span

3) Superstructure (Steel Box Girder)

For the Steel Box-girder Bridge, the truck-crane erection method and the large block erection method with winches are adopted. The procedure orf the large block erection method is to carry the girder component blocks to the erection point, and the girder for one span is assembled on the ground. Winches are installed on top of a pier or constructed girder, and the assembled girder for one span is placed by tandem lifting. For the floor slab, the precast RC floor slab is adopted. Slab blocks are installed on the constructed girder, and then unified.

1. Assembling of lifting machine and winches
2. Carrying and assembling of girder at erection point
3. Girder erection
4. Removal of lifting machine and winches (to next span), and
5. Carrying and installation of precast floor slab

15.1.6 Temporary Facilities

(1) Construction Yard Area

When constructing the 4th Panama Canal Bridge, a construction yard is necessary for girder/floor-slab fabrication, holding of stock, a concrete manufacturing plant, handling of material, temporary placement of excavated earth, and an office and worker camp. Since the eastern side does not have enough space, the construction yard there will be minimal. Therefore, the yard for girder / floor-slab fabrication / stock will be located on the western side. According to the result of estimating the necessary yard area based on similar constructions from actual experience, about 270,000 square meters will be required.

The construction yard area is as shown in Table 15.4.

Table 15.4 Construction Yard Area

Item	East side	West side
Girder/floor-slab fabrication and stock	18,000m2	22,000m2
Reinforcement work, formwork fabrication, stock, and temporary placement of false work	---	50,000m2
Temporary placement of machinery, office, parking, worker camp	13,000m2	17,000m2
Main bridge and approach bridge; temporary placement and arch assembling	---	134,000m2
Temporary placement of excavation earth	8,000m2	8,000m2
Subtotal	30,000m2	231,000m2
Total	270,000m2	

Source: JICA Study Team

(2) Candidate Locations of Construction Yard

The candidate locations of the construction yard are selected based on a survey of land use and interviews with related authorities. The concrete location should be confirmed in the future.

(3) Construction Work Road and Temporary Pier

In order to construct a large-scale structure in a short period, many works should be carried out in parallel. A road for construction work should be secured on both sides of the canal to insure the smooth transporting of material and equipment to each work point.

Regarding the transporting of material between the east and west sides, the use of the Pan-American Highway would impact work efficiency and traffic, as such, waterborne transportation by barge is recommended. Therefore, on the west bank, a peninsula will be constructed by embankment for the substructure work and girder erection, and a temporary jetty will be erected to serve as a dock for barge transport across the canal.

15.1.7 Construction Schedule

The construction schedule is planned in consideration of the construction methods, procedures, site characteristics, workload, and related constructions based on the designed quantities. The construction schedule is divided into 3 construction sections. For the erection of the main bridge, assessment was made for two cases: using/without using the navigation channel of the Panama Canal, with a construction period of 48 months and 60 months, respectively.

The construction schedule is divided into 3 sections and it is assumed that each work is carried out in parallel. It is also assumed that the improvement of the Omar Torrijos roundabout will be implemented at once. Traffic diversion at the roundabout should be adjusted with the project during flyover removal and construction. The installation of Line-3 rail girders shall be commenced after completion of slab works in the 4th Panama Canal Bridge.

15.1.8 Traffic Management and Safety Management during Construction Period

(1) Traffic Management Plan

The 4th Panama Canal Bridge and approach roads are constructed in locations that avoid the existing roads. Although impact on current traffic is comparatively small, the route has crossovers over existing intersections and roads. Traffic should be managed by providing detours and lane closure during the foundation and footing work, and also during the installation of cranes for girder erection.. As for the removal of the existing flyover at the Omar Torrijos roundabout, the schedule for the new construction and roundabout improvement should be adjusted according to the flyover removal.

Lane closure during construction and other aspects of the traffic management plan should comply with Panamanian law (Law 34 of the Land Transport and Transit Authority, ATTT). Permission is required from ATTT if the construction will affect road traffic, regardless of the scale of the construction.

(2) Safety Management Plan

Regulations related to construction safety management are indicated below. The 4th Panama Canal Bridge construction will conform to these regulations.

Safety, health, and hygiene during construction are secured in accordance with the "Executive Decree No.2 (of February 15, 2008) Whereby Safety, Health, and Hygiene of the Construction Industry are regulated" (*DECRETO EJECUTIVO No. 2 (de 15 de febrero de 2008) Por el cual se reglamenta la Seguridad, Salud e Higiene en la Industria de la Construcción*) under MITRADEL (Ministry of Work and Labor Development). Regarding street safety regulations for road construction, the "Manual for the Control of Traffic during the execution of Construction and Maintenance Works in Streets and Roads" (*Manual para el Control de Transito durante la ejecution de Trabajos de Construccion y Mantenimiento en Calles y Carreteras)* under MOP, is being enforced. In addition, in the construction of Line-1, SMP applied the OSG Act regulations established by OSHA (Occupational Safety & Health Administration), which is an organization under the U.S. Department of Labor.

Regarding safety management for constructions on water, deliberations were held in a workshop with entities concerned. These deliberations should also be continued in the future.

15.1.9 Conclusion

The section for design quantities is divided into 3 taking into account the construction scale, structural characteristics, and on-site conditions. Regarding the construction contract, one construction contract package was assumed for this Study, since this would allow a joint schedule management for the control and implementation of a unified project. For the main bridge erection, the large block erection method using the navigation channel is proposed by reason of shorten construction period in the result of a comparison study. For the other bridges, suitable construction methods are proposed in consideration of the structural characteristics and site situation. A large construction yard is needed for girder and floor-slab fabrication, and the temporary placement of girder components and materials. Although candidate temporary yard locations are proposed, a concrete location should be selected in the future. For the construction schedule, the main bridge construction will take the longest, and it is assumed that the construction period is 4 years using the canal. Schedule management should be adjusted with Metro Line-3 construction project and Omar Torrijos intersection improvement.

15.2 Preliminary Project Cost Estimate

15.2.1 Objective

The preliminary project cost for the 4th Panama Canal Bridge is estimated based on the results of the preliminary design and preliminary construction planning.

15.2.2 Study Items

The preliminary cost estimate is carried out by considering the condition, methodology, and unit costs, assuming that the 4th Panama Canal Bridge project is implemented as a Japanese yen loan project. The costs for the Omar Torrijos Roundabout and the western additional ramps, which are included in the Concept Design Section, are estimated by using the costs of a similar scale project.

15.2.3 Related Laws and Regulations

There are no systematic laws and regulations for project cost estimating in Panama, the construction cost is estimated based on unit-prices from historical and market information.

15.2.4 Conditions of the Cost Estimate

The conditions of the cost estimate are as shown in Table 15.5.

However, the exchange rate, price escalation rate and contingency are values from the JICA study. The conditions of the cost estimate will be presented by JICA at the appraisal.

Table 15.5 Conditions of Cost Estimate

Item	Remarks
Project Finance	Japanese yen loan
Base year of cost estimate	October 2013
Construction package	1 package
Currency	Foreign currency (FC): Japanese Yen (JPY) Local currency (LC): US Dollar (USD)
Exchange rate	USD 1.00 =JPY 99.7
Price escalation	FC : 1.3% LC : 3.1%
Physical contingency	Construction cost : 5% Consultant fee: 5%
Rate of interest during construction	Construction cost : 1.80% Consultant fee: 0.01%
Rate of front end fee	0.2%
Rate of tax	0.0%
Rate of administration cost	5.0%

Source: JICA Study Team

15.2.5 Methodology of Cost Estimate

(1) Cost Structure

The preliminary cost estimate of the 4th Panama Canal Bridge is divided into an eligible portion and a non-eligible portion.

The eligible portion consists of the construction costs for civil works, utilities, utilities relocation, environmental mitigation and monitoring and risk cost, and consultant fee. The non-eligible portion consists of environmental compensation cost, and land acquisition and resettlement costs.

Moreover, the preliminary project cost estimate is divided to a foreign currency portion and a local currency portion.

(2) Methodology

Costs for construction works and utilities are estimated based on the quantities calculated from the preliminary design and unit costs in the Panamanian market. Temporary works are considered in the construction cost estimate.

Consultant fees for the detailed design stage, contractor selection stage, and construction stage for a Japanese yen loan project are estimated based on inputs from the necessary specialists. The consultant's role is described in Chapter 17.

Public utilities relocation cost is estimated based on the quantities from the preliminary design and unit costs.

Costs for environmental mitigation and compensation are estimated based on the necessary actions that will be taken during the construction stage.

Land acquisition and resettlement costs are estimated based on the Panamanian market cost.

The construction costs for the Omar Torrijos Roundabout and the western additional ramp, which are included in the Concept Design Section, are estimated by using the costs of a similar scale project.

15.2.6 Unit Costs

The unit costs for construction works and utilities relocation are determined from historical construction data and quotation. Detailed unit costs are shown in Appendix 7 of Main Report. The rental fee for the temporary construction yard is set at 100 USD/m2/year.

The following monthly fees for consultant services are applied; 2,730 thousand JPY for international consultant (Professional A), 18,750USD for local consultant (Professional B), and 3,000USD for supporting staff.

The unit costs for environmental mitigation and compensation and the unit costs for land acquisition and resettlement are investigated in this study.

15.2.7 Preliminary Project Cost

The preliminary project cost and annual disbursement for the 4th Panama Canal Bridge are estimated for two cases, one using the canal in the main bridge construction, and the other not using the canal in the main bridge construction.

The preliminary project cost and annual disbursement are estimated according to the project implementation schedule as described in Chapter 17.

Because the project scale is extremely large, the project cost should be carefully determined through a more detailed survey and design, and discussion with the related organizations.

The preliminary project cost and annual disbursement are as shown in Table 15.6 in the case of using the canal and Table 15.7 in the case of not using the canal.

Table 15.6 Preliminary Project Cost and Annual Disbursement (Using the Navigation Channel)

Annual Fund Requirement (Main Bridge : Arch-rib Lifting Method)

Base Year for Cost Estimation: Oct, 2013 FC & Total : million JPY
Exchange Rates USD = Yen 99.7 LC : million USD
Price Escalation: FC: 1.3% LC: 3.1%
Physical Contingency 5.0%
Physical Contingency for Consultant 5.0%

Item		Total			2015			2016			2017			2018			2019			2020			2021			2022		
		FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. ELIGIBLE PORTION																												
Ⅰ)	Procurement / Construction	68,435	935	161,666	0	0	0	0	6	622	1,382	30	4,326	16,797	219	38,674	17,015	226	39,570	17,236	233	40,491	16,005	220	37,983	0	0	0
	1)Temporary Works	2,383	93	11,691	0	0	0	0	0	0	50	2	244	596	23	2,923	596	23	2,923	596	23	2,923	546	21	2,679	0	0	0
	2)East Approach Road	7,715	102	17,876	0	0	0	0	0	0	161	2	372	1,929	25	4,469	1,929	25	4,469	1,929	25	4,469	1,768	23	4,097	0	0	0
	3)4th Panama Canal Bridge (A5 - A6 section)	39,480	318	71,153	0	0	0	0	0	0	823	7	1,482	9,870	79	17,788	9,870	79	17,788	9,870	79	17,788	9,048	73	16,306	0	0	0
	4)West Approach Road (including Additional Ramp)	2,120	56	7,742	0	0	0	0	0	0	44	1	161	530	14	1,936	530	14	1,936	530	14	1,936	486	13	1,774	0	0	0
	5)Omar Torrijos Intersection	5,889	138	19,631	0	0	0	0	0	0	123	3	409	1,472	34	4,908	1,472	34	4,908	1,472	34	4,908	1,350	32	4,499	0	0	0
	6)Utilities	1,014	8	1,850	0	0	0	0	0	0	21	0	39	253	2	462	253	2	462	253	2	462	232	2	424	0	0	0
	7)Public Utilities Relocation	0	15	1,532	0	0	0	0	5	541	0	10	992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8)Environmental Mitigation and Monitoring	0	2	202	0	0	0	0	0	0	0	0	4	0	1	50	0	1	50	0	1	50	0	0	46	0	0	0
	9)Risk Cost	1,384	0	1,384	0	0	0	0	0	0	29	0	29	346	0	346	346	0	346	346	0	346	317	0	317	0	0	0
	Base cost for JICA financing	59,985	733	133,061	0	0	0	0	5	541	1,250	25	3,732	14,996	179	32,882	14,996	179	32,882	14,996	179	32,882	13,747	164	30,142	0	0	0
	Price escalation	5,191	158	20,907	0	0	0	0	1	52	66	3	389	1,000	30	3,950	1,208	36	4,804	1,419	43	5,680	1,496	45	6,032	0	0	0
	Physical contingency	3,259	45	7,698	0	0	0	0	0	30	66	1	206	800	10	1,842	810	11	1,884	821	11	1,928	762	10	1,809	0	0	0
Ⅱ)	Consulting services	6,434	52	11,651	556	3	876	1,003	6	1,605	202	2	381	1,231	10	2,242	1,214	11	2,292	1,147	11	2,199	1,061	10	2,014	21	0	43
	1)Consulting services A	4,498	34	7,867	406	2	638	723	4	1,145	144	1	265	866	7	1,532	842	7	1,532	786	7	1,438	717	6	1,291	14	0	27
	2)Consulting services B for Concept Design Section	1,214	8	2,024	110	1	165	195	1	297	39	0	68	234	2	394	227	2	393	212	2	369	194	1	331	4	0	7
	Base cost	5,713	42	9,891	516	3	803	919	5	1,442	183	2	333	1,099	8	1,925	1,070	9	1,925	998	8	1,807	911	7	1,622	18	0	34
	Price escalation	415	8	1,205	13	0	32	36	1	86	10	0	29	73	1	210	86	2	258	94	2	287	99	2	296	2	0	7
	Physical contingency	306	2	555	26	0	42	48	0	76	10	0	18	59	0	107	58	1	109	55	1	105	51	0	96	1	0	2
Total (Ⅰ + Ⅱ)		74,869	987	173,318	556	3	876	1,003	12	2,227	1,584	31	4,707	18,028	230	40,915	18,229	237	41,862	18,383	244	42,689	17,066	230	39,997	21	0	43
B. NON ELIGIBLE PORTION																												
a	Procurement / Construction	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1)Environmental Compensation	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Base cost	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Price escalation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Physical contingency	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b	Land Acquisition and Resettlement	0	6	620	0	0	0	0	2	215	0	4	406	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Base cost	0	5	529	0	0	0	0	2	187	0	3	342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Price escalation	0	1	62	0	0	0	0	0	18	0	0	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Physical contingency	0	0	30	0	0	0	0	0	10	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c	Administration cost	0	87	8,697	0	0	44	0	1	122	0	3	256	0	21	2,046	0	21	2,093	0	21	2,134	0	20	2,000	0	0	2
d	VAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
e	Import Tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (a+b+c+d+e)		0	93	9,319	0	0	44	0	3	337	0	7	662	0	21	2,046	0	21	2,093	0	21	2,134	0	20	2,000	0	0	2
TOTAL (A+B)		74,869	1,081	182,636	556	4	920	1,003	16	2,564	1,584	38	5,370	18,028	250	42,961	18,229	258	43,955	18,383	265	44,824	17,066	250	41,997	21	0	45
C. Interest during Construction		7,697	0	7,697	0	0	0	8	0	8	66	0	66	580	0	580	1,105	0	1,105	1,643	0	1,643	2,147	0	2,147	2,147	0	2,147
	Interest during Construction(Const.)	7,693	0	7,693	0	0	0	8	0	8	65.7	0	65.7	579.2	0	579.2	1,104.6	0	1,104.6	1,642.2	0	1,642.2	2,146.5	0	2,146.5	2,147	0	2,147
	Interest during Construction (Consul.)	4	0	4	0	0	0	0.18	0	0.18	0.21	0	0.21	0.38	0	0.38	0.55	0	0.55	0.71	0	0.71	0.86	0	0.86	1	0	1
D. Front End Fee		693	0	693	347	0	347	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GRAND TOTAL (A+B+C+D)		83,259	1,081	191,026	902	4	1,267	1,011	16	2,573	1,650	38	5,436	18,607	250	43,541	19,334	258	45,061	20,026	265	46,467	19,213	250	44,144	2,168	0	2,193

Note: Interest during construction is calculated based on the assumption that the loan amount by Japanese ODA loan for 70% of the total cost, while the rest is financed as equity.

Source: JICA Study Team

Table 15.7 Preliminary Project Cost and Annual Disbursement (Without Using the Navigation Channel)

Annual Fund Requirement (Main Bridge : Cable Erection Method)

Base Year for Cost Estimation:	Oct, 2013			FC & Total : million JPY	
Exchange Rates	USD = Yen		99.7	LC	: million USD
Price Escalation:	FC:	1.3%	LC:	3.1%	
Physical Contingency	5.0%				
Physical Contingency for Consultant	5.0%				

Item	Total			2015			2016			2017			2018			2019			2020			2021			2022			2023		
	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total	FC	LC	Total
A. ELIGIBLE PORTION																														
Ⅰ) Procurement / Construction	71,570	965	167,733	0	0	0	0	6	622	1,149	26	3,762	13,961	178	31,745	14,143	184	32,477	14,327	190	33,230	14,513	195	34,002	13,477	185	31,895	0	0	0
1)Temporary Works	2,571	101	12,628	0	0	0	0	0	0	43	2	210	514	20	2,526	514	20	2,526	514	20	2,526	514	20	2,526	471	18	2,315	0	0	0
2)East Approach Road	7,715	102	17,876	0	0	0	0	0	0	129	2	298	1,543	20	3,575	1,543	20	3,575	1,543	20	3,575	1,543	20	3,575	1,414	19	3,277	0	0	0
3)4th Panama Canal Bridge (A5 - A6 section)	42,337	321	74,383	0	0	0	0	0	0	706	5	1,240	8,467	64	14,877	8,467	64	14,877	8,467	64	14,877	8,467	64	14,877	7,762	59	13,637	0	0	0
4)West Approach Road (including Additional Ramp)	2,120	56	7,742	0	0	0	0	0	0	35	1	129	424	11	1,548	424	11	1,548	424	11	1,548	424	11	1,548	389	10	1,419	0	0	0
5)Omar Torrijos Intersection	5,889	138	19,631	0	0	0	0	0	0	98	2	327	1,178	28	3,926	1,178	28	3,926	1,178	28	3,926	1,178	28	3,926	1,080	25	3,599	0	0	0
6)Utilities	1,014	8	1,850	0	0	0	0	0	0	17	0	31	203	2	370	203	2	370	203	2	370	203	2	370	186	2	339	0	0	0
7)Public Utilities Relocation	0	15	1,532	0	0	0	0	5	541	0	10	992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8)Environmental Mitigation and Monitoring	0	2	230	0	0	0	0	0	0	0	0	4	0	0	46	0	0	46	0	0	46	0	0	46	0	0	42	0	0	0
9)Risk Cost	679	0	679	0	0	0	0	0	0	11	0	11	136	0	136	136	0	136	136	0	136	136	0	136	125	0	125	0	0	0
Base cost for JICA financing	62,325	744	136,551	0	0	0	0	5	541	1,039	22	3,242	12,465	146	27,004	12,465	146	27,004	12,465	146	27,004	12,465	146	27,004	11,426	134	24,753	0	0	0
Price escalation	5,836	174	23,195	0	0	0	0	1	52	55	3	341	832	24	3,229	1,004	29	3,927	1,180	35	4,643	1,357	40	5,379	1,409	42	5,623	0	0	0
Physical contingency	3,408	46	7,987	0	0	0	0	0	30	55	1	179	665	8	1,512	673	9	1,547	682	9	1,582	691	9	1,619	642	9	1,519	0	0	0
Ⅱ) Consulting services	7,199	57	12,908	534	3	850	964	6	1,557	195	2	370	1,160	9	2,082	1,136	10	2,085	1,116	9	2,044	1,075	10	2,023	999	9	1,854	20	0	43
1)Consulting services A	5,136	37	8,834	401	2	633	714	4	1,137	142	1	264	838	6	1,456	810	6	1,427	785	6	1,371	747	6	1,327	685	5	1,193	14	0	27
2)Consulting services B for Concept Design Section	1,214	8	2,024	95	1	146	169	1	261	34	0	60	198	1	333	191	1	327	186	1	314	177	1	304	162	1	273	3	0	6
Base cost	6,350	45	10,858	496	3	779	883	5	1,399	176	1	324	1,036	8	1,789	1,001	8	1,754	971	7	1,684	924	7	1,630	847	6	1,466	17	0	33
Price escalation	506	9	1,435	13	0	31	35	0	84	9	0	29	69	1	193	81	2	232	92	2	262	101	2	296	104	2	300	2	0	8
Physical contingency	343	3	615	25	0	40	46	0	74	9	0	18	55	0	99	54	0	99	53	0	97	51	0	96	48	0	88	1	0	2
Total (Ⅰ + Ⅱ)	78,769	1,022	180,641	534	3	850	964	12	2,180	1,343	28	4,133	15,122	188	33,826	15,279	193	34,562	15,442	199	35,273	15,589	205	36,024	14,476	193	33,749	20	0	43
B. NON ELIGIBLE PORTION																														
a Procurement / Construction	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1)Environmental Compensation	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Base cost	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Price escalation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physical contingency	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b Land Acquisition and Resettlement	0	6	620	0	0	0	0	2	215	0	4	406	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Base cost	0	5	529	0	0	0	0	2	187	0	3	342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Price escalation	0	1	62	0	0	0	0	0	18	0	0	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physical contingency	0	0	30	0	0	0	0	0	10	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c Administration cost	0	91	9,063	0	0	43	0	1	120	0	2	227	0	17	1,691	0	17	1,728	0	18	1,764	0	18	1,801	0	17	1,687	0	0	2
d VAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
e Import Tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (a+b+c+d+e)	0	97	9,685	0	0	43	0	3	335	0	6	634	0	17	1,691	0	17	1,728	0	18	1,764	0	18	1,801	0	17	1,687	0	0	2
TOTAL (A+B)	78,769	1,119	190,326	534	4	893	964	16	2,515	1,343	34	4,766	15,122	205	35,518	15,279	211	36,290	15,442	217	37,037	15,589	223	37,826	14,476	210	35,436	20	0	45
C. Interest during Construction	7,746	0	7,746	0	0	0	8	0	8	58	0	58	480	0	480	911	0	911	1,353	0	1,353	1,363	0	1,363	1,786	0	1,786	1,786	0	1,786
Interest during Construction(Const.)	7,742	0	7,742	0	0	0	8	0	8	58.2	0	58.2	479.6	0	479.6	910.8	0	910.8	1,351.9	0	1,351.9	1,362.2	0	1,362.2	1,785.6	0	1,785.6	1,786	0	1,786
Interest during Construction (Consul.)	4	0	4	0	0	0	0.18	0	0.18	0.20	0	0.20	0.36	0	0.36	0.51	0	0.51	0.66	0	0.66	0.66	0	0.66	0.80	0	0.80	1	0	1
D. Front End Fee	723	0	723	361	0	361	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GRAND TOTAL (A+B+C+D)	87,238	1,119	198,795	896	4	1,254	972	16	2,523	1,401	34	4,825	15,602	205	35,998	16,190	211	37,202	16,795	217	38,390	16,951	223	39,189	16,262	210	37,223	1,806	0	1,832

Note: Interest during construction is calculated based on the assumption that the loan amount by Japanese ODA loan for 70% of the total cost, while the rest is financed as equity.

Source: JICA Study Team

15.2.8 Conclusion

The preliminary project cost of the 4th Panama Canal Bridge Project is as shown in Table 15.8.

The preliminary cost of the 4th Panama Canal Bridge Project is estimated to be approximately 191 billion yen (1,916million USD) in case the main bridge is constructed by using the canal, and approximately 199 billion yen (1,994 million USD) in case the main bridge is constructed without using the canal.

Because the project scale is extremely large, the project cost should be carefully determined through a more detailed survey and design, and discussion with the related organizations.

Table 15.8 Preliminary Project Cost

Condition for Main Bridge Construction	Preliminary Project Cost		
	FC (mil.JPY)	LC (mil.USD)	Total (mil.JPY)
Using Navigation Channel (Construction Period: 4 years)	83,259	1,081	191,026
Without Using Navigation Channel (Construction Period: 5 years)	87,238	1,119	198,795

Source: JICA Study Team

15.3 Preliminary Operation and Maintenance Cost

15.3.1 Objective

The preliminary operation and maintenance costs for 100 years after the opening of the 4th Panama Canal Bridge are estimated based on operation and maintenance planning.

15.3.2 Preliminary Operation and Maintenance Cost

Table 15.9 shows the preliminary operation and maintenance cost. Details are as shown in Appendix 8 of Main Report.

Table 15.9 Preliminary Operation and Maintenance Cost

Item	Preliminary Operation and Maintenance Cost(mil.JPY)
Civil works	33,451
Utility	7,453
Concept Design Section (Omar Torrijos Intersection and West Side Additional Ramp)	11,663
Total	52,567

Source: JICA Study Team

15.3.3 Environmental Monitoring Cost

SMP should carry out the monitoring on air quality, noise, vibration, water quality, soil quality, and waste water during the first three years of the operation stage. The monitoring cost during the operation stage is estimated at US$ 225,900 according to the EIA.

15.3.4 Conclusion

The preliminary operation and maintenance costs for 100 years after the opening of the 4th Panama Canal Bridge are estimated to be 52.6 billion JPY (527 million USD).

During the first three years of the operation stage, environmental monitoring will be required.

Chapter 16 Comparison Study between the Pre-F/S Option and the JICA Study Option

16.1 Objective

As described in Section 10.1, a screening of the main bridge type for the 4th Panama Canal Bridge was conducted at the beginning of the JICA Study (November, 2013). In the screening, the cable-stayed bridge and the arch bridge were selected as the alternative bridge types and it was decided that these two alternatives would be compared again to select the optimum bridge type in accordance with the preliminary design results. In the Pre-F/S, the preliminary design was made for the cable-stayed option; therefore, the preliminary design of the arch bridge was conducted in the JICA Study.

The objective of this chapter is to make a comparison study between the Pre-F/S option and the JICA Study option in accordance with the preliminary design results and to recommend the optimum bridge type for the main bridge of the 4th Panama Canal Bridge.

16.2 Summary of Preliminary Design Results

16.2.1 JICA Study Option

The following 2 cases in the preliminary design of the arch bridge were examined in the JICA Study:

- With the use of the navigation channel in the erection works of the main span
- Without using the navigation channel in the erection works of the main span

A summary of the preliminary design results of the arch bridge is shown in Table 16.1.

The “With” case was selected as the JICA Study option for the following reasons:

Construction Duration

In the “With” case, the navigation channel needs to be used one time only (expected period: 13.5 hours) in the erection works of the arch rib; however, as a result the entire construction duration can be shortened by 1 year in comparison to the “Without” case.

Initial Construction Cost

The initial construction cost of the “With” case can be reduced by about 3.2Bil.JPY (32Mil.USD) in comparison to the “Without” case due to the shorter construction period and the smaller scale of temporary structures used in the erection works of the arch rib.

Technical Risks (Erection Works)

In the “With” case, it is important to ensure safety in the erection works of the arch rib; however, the technical risks are expected to be minimized by applying adequate mitigation measures (see Section 15.1.5(1)1)c.).

16.2.2 Pre-F/S Option

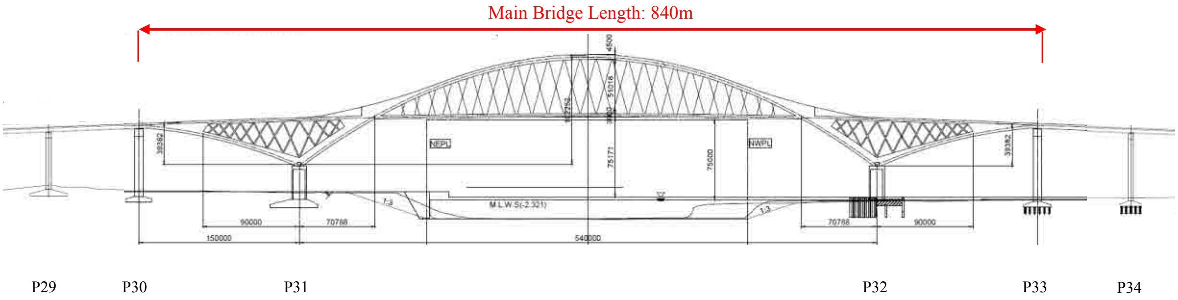
The preliminary design of the cable-stayed bridge was conducted in the Pre-F/S and its results are described in the Draft Final Report of the Pre-F/S (November, 2013).

A summary of the preliminary design results of the cable-stayed bridge is shown in Table 16.2.

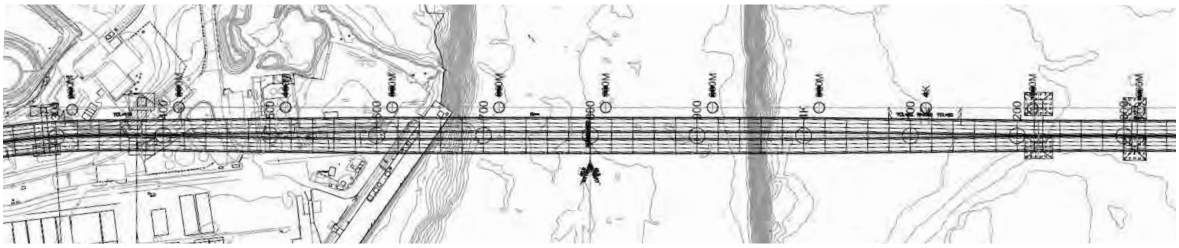
Table 16.1 Summary of Preliminary Design Results of Arch Bridge (JICA Study)

No.	Item		Preliminary Design Results	
			With Use of Navigation Channel (Option selected by the JICA Study)	Without Using Navigation Channel
1	Bridge Length		840m	
2	Span Arrangement		150m+540m+150m	
3	Total Bridge Width		48.742m~52.872m	
4	Metro Line 3		Monorail (Width: 8.4m)	
5	Erection Method (Main Span)	Arch Rib	Lifting from Deck Barge	Cable Erection with Oblique Hang
		Stiffening Girder	Cantilever Erection (Slewing Jib-crane, Gantry)	
		Using Navigation Channel	1 time (expected 13.5 hours)	Not used
		Technical Risks	Refer to 15.1.5(1)1)c)	
6	Construction Duration		4 years	5 years
7	Initial Construction Cost		36.2 Bil.JPY (363 Mil.USD) (Civil Works (Bridge) only)	39.4 Bil.JPY (396 Mil.USD) (Civil Works (Bridge) only)
8	Maintenance Cost (100 Years)		8.8 Bil.JPY (88 Mil.USD) (Discount Rate: 0%)	

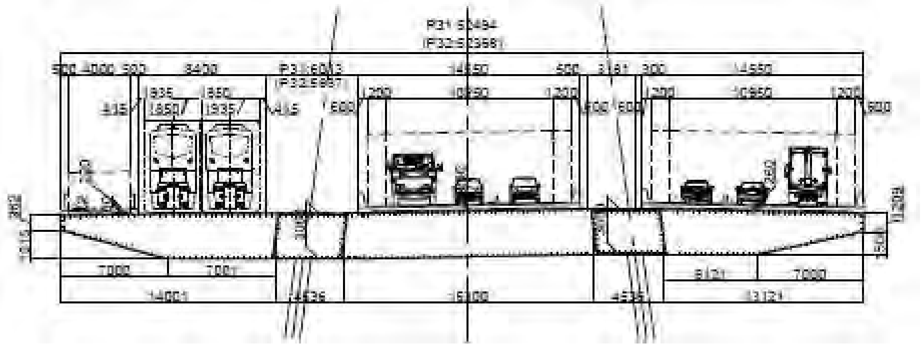
Side View



Plan



Cross Section (At Piers P31 and P32)

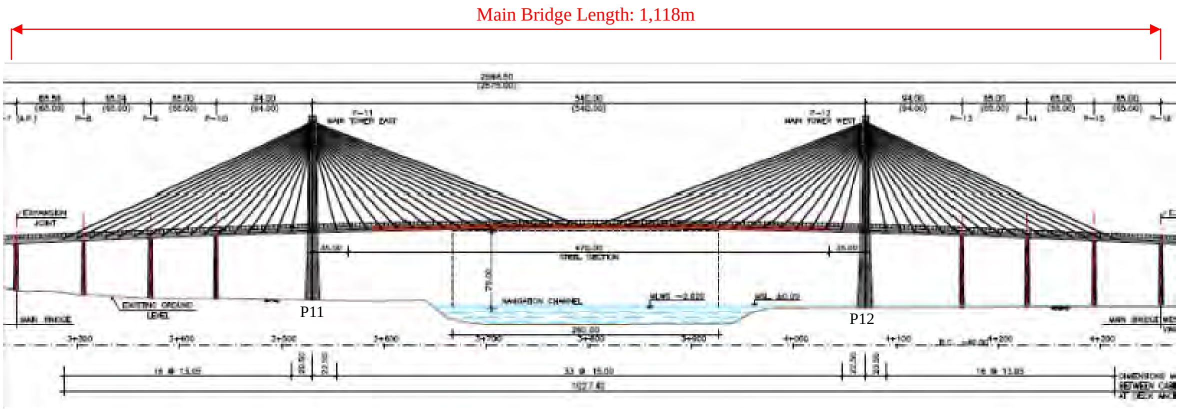


Source: JICA Study Team

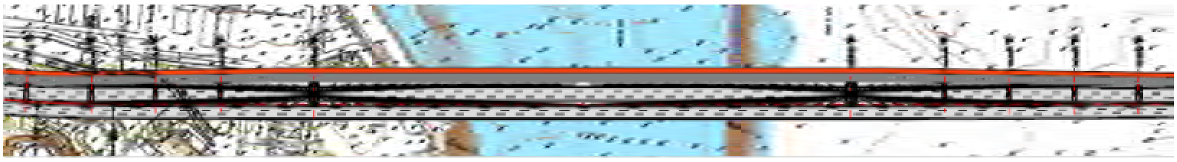
Table 16.2 Summary of Preliminary Design Results of Cable-stayed Bridge (Pre-F/S)

No.	Item		Preliminary Design Results
1	Bridge Length		1,118m
2	Span Arrangement		3@65m+94m+540m+94m+3@65m
3	Total Bridge Width		51.9m
4	Metro Line 3		Linear Metro (Width: 9m)
5	Erection Method (Main Span)	Erection Method	Cantilever Erection
		Using Navigation Channel	Not used
6	Construction Duration		4 years
7	Initial Construction Cost		426 Mil.USD (42.5 Bil.JPY) (Civil/E&M Works (Bridge), Track Beam/E&M Works (Metro Line 3)
8	Maintenance Cost (100 Years)		146 Mil.USD (14.6 Bil.JPY) (Discount Rate: 0%) (Civil/E&M Works (Bridge), Track Beam/E&M Works (Metro Line 3)

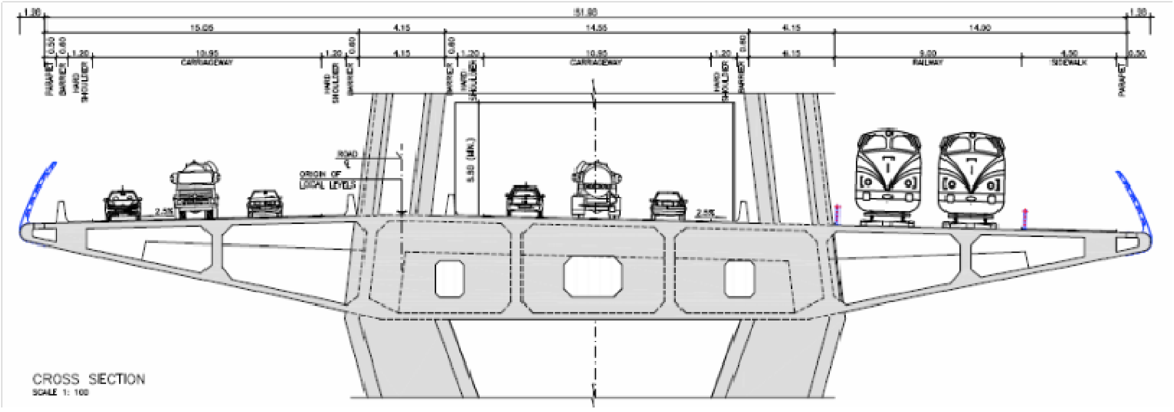
Side View



Plan



Cross Sections (At Pylons P11 and P12)



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

16.3 Comparison Study between the Pre-F/S Option and the JICA Study Option

16.3.1 Study Method

Based on the screening result of the main bridge type for the 4th Panama Canal Bridge (see Section 10.1), a comparison study was made between the Pre-F/S option and the JICA study option in the following manner:

- The evaluation results, other than the cost items, were no different from those of the screening results and the preliminary designs; therefore, only the cost evaluation was updated.
- The cost evaluation was updated in accordance with the preliminary design results.
- The cost included the risk cost for the construction of the main bridge in accordance with the risk analysis results conducted by Panamanian side.
- The cost was evaluated by life-cycle cost (discount rate: 4% (JICA's policy)).

(1) Adjustment of Comparison Conditions

The Draft Final Report of the Pre-F/S (Nov. 2013) was reviewed and some differences in the planning and design conditions between the two Options were identified (see Appendix 9).

Therefore, the following items were adjusted to make a fair comparison under the same conditions:

<u>JICA Study Option: Bridge Length</u>

The main bridge lengths between the two Options are different; therefore, the bridge length of the longer Option (Pre-F/S: 1,118m) was used for both Options in the comparison study. Thus, the initial construction and maintenance cost for the JICA Study Option considered not only the main bridge (840m), but also the approach bridges (278m) in the comparison study.

Initial Const. Cost : 36.2 Bil.JPY (Main) + 4.3 Bil.JPY (Approach: 278m) = 40.5 Bil.JPY

Maintenance Cost : 8.8 Bil.JPY (Main) + 1.8 Bil.JPY (Approach: 278m) = 10.6 Bil.JPY

<u>Pre-F/S Option: Items in the Initial Construction Cost</u>

The initial construction cost (426 Mil.USD) of the Pre-F/S Option included not only civil works (bridge), but also E&M works (bridge) and items related to the Metro Line 3; thus, the E&M planning and design conditions and the Metro Line 3 works are different between the two Options. Therefore, the cost items in the comparison study were limited to the civil works (bridge) only and the E&M and Metro Line 3 works were deducted from the initial construction cost of the Pre-F/S Option.

Initial Const. Cost : 426 Mil.USD - 20 Mil.USD (E&M/Metro Line 3 Works) = 406 Mil.USD

<u>Pre-F/S Option: Effective Width</u>

The effective road width is the same between the two Options; however, the width of Metro Line 3 is different between the two. (Pre-F/S (Linear Metro): 9m, JICA Study (Monorail): 8.4m). The width of 8.4m was applied for Metro Line 3 in the comparison study, therefore, the initial construction cost for the Pre-F/S Option was adjusted by the ratio to the total bridge width (51.9m).

Initial Const. Cost : 406 Mil.USD * (51.9m - 0.6m)/51.9m = 402 Mil.USD

Pre-F/S Option: Maintenance Items and Cost

The maintenance items / frequency are basically the same between the two Options; however, the Pre-F/S Option includes not only civil works (bridge) but also E&M works (bridge) and items related to the Metro Line 3. The maintenance cost items in the comparison study were limited to the civil works (bridge), therefore, the other items were deducted from the maintenance cost in the Pre-F/S Option. Furthermore, the Pre-F/S Option did not include the reconstruction of the binder course and waterproofing; therefore, this maintenance cost was added to the Pre-F/S Option based on the unit cost and frequency of the JICA Study Option.

Maintenance Cost : 146 Mil.USD - 3 Mil.USD (E&M/Metro Line 3 Works)
+ 80 USD/m2 * 33,100m2 * 3 times/100years = 150 Mil.USD

(2) Risk Cost

A risk analysis was conducted by the Panamanian side based on the erection plan of the arch rib (main bridge of 4th Panama Canal Bridge) prepared by the JICA Study (see 15.1.5(1)1)d)).

The risk cost estimated in the risk analysis was included in this comparison study.

The risk cost (main bridge of 4th Panama Canal Bridge) is shown in Table 16.3.

Table 16.3 Risk Cost (Main Bridge of 4th Panama Canal Bridge)

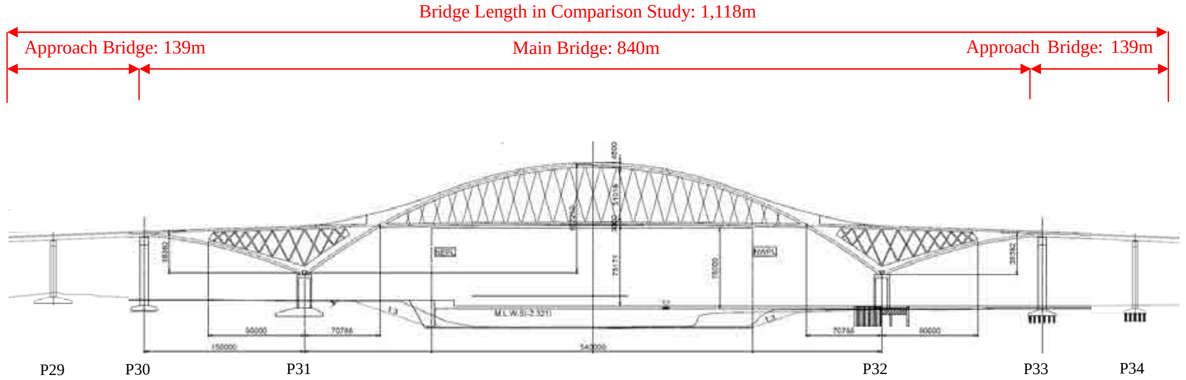
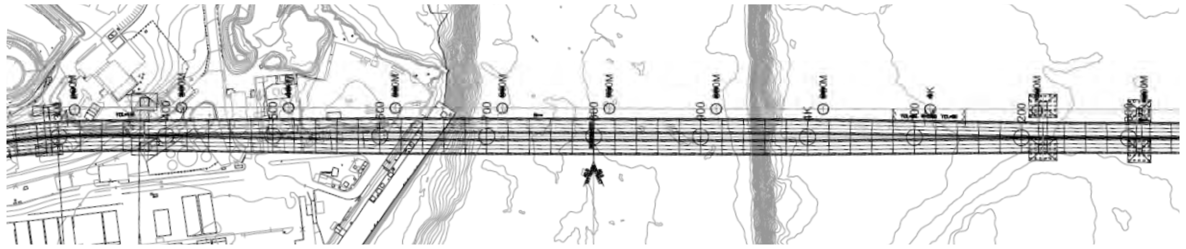
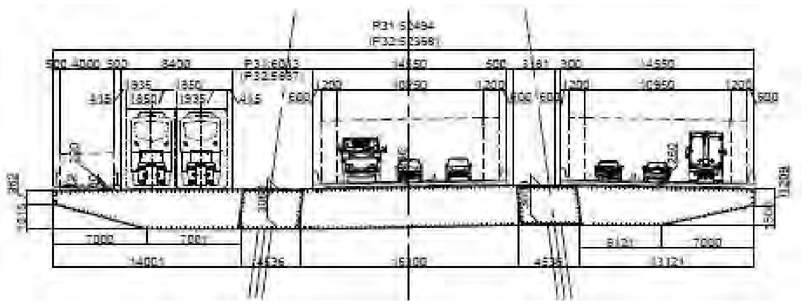
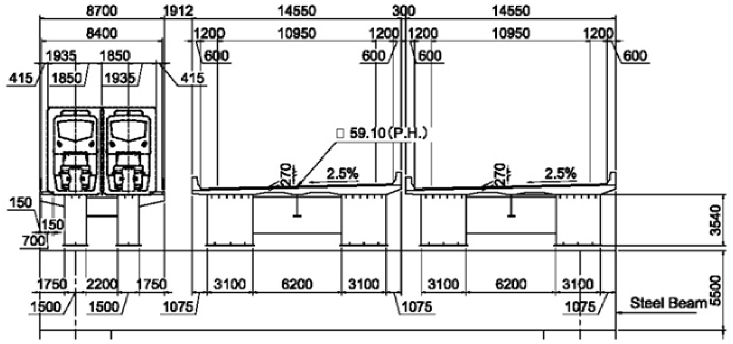
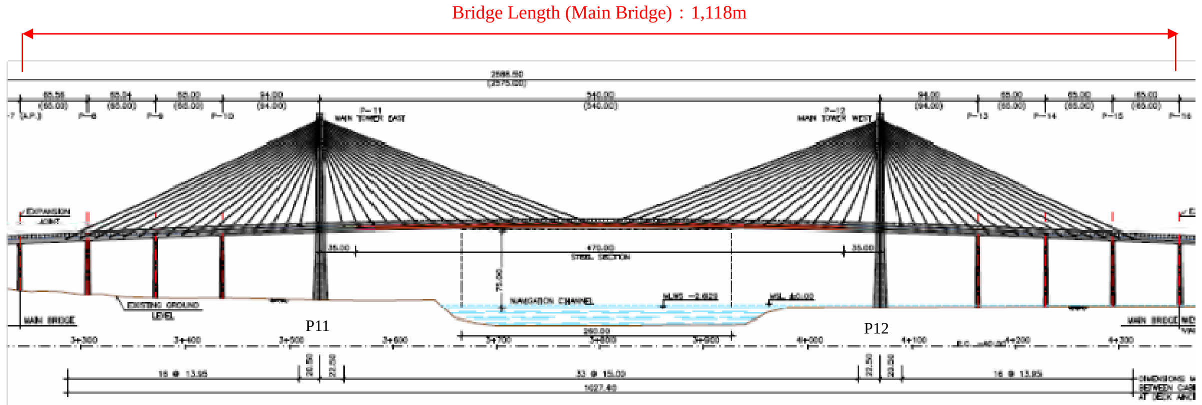
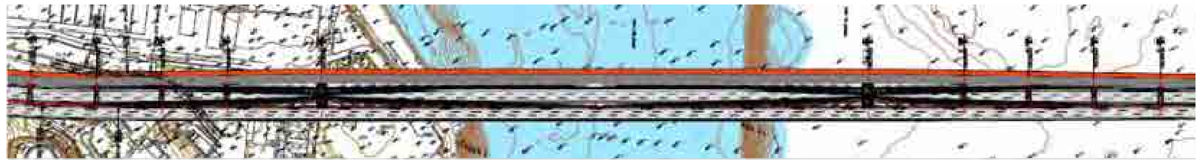
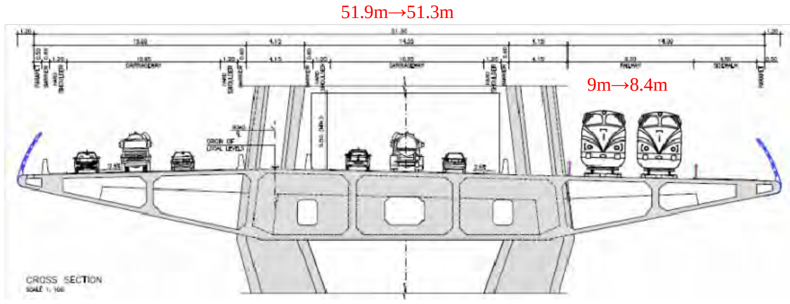
No.	Item		Risk Cost	
			Option of the Pre-F/S (Cable-stayed Bridge)	Option of the JICA Study (Arch Bridge) (Using Navigation Channel in Erection Works)
1	Cost for Closure of Pacific Approach Channel and Special Prevention Measures	Direct Compensation Cost		1.9 Mil.USD
2		Standby Equipment, Test Simulation Cost		3.6 Mil.USD
3	Risk Contingency for Short Notice Postponement of Pacific Approach Channel Closure Date[1]			0.4 Mil.USD
4	Insurance Premium for for the Rib Arch Segment Falling	CGL Insurance Premium[2]		0.5 Mil.USD
5		ALOP Premium		0.4 Mil.USD
6		CEAR Insurance Premium	2.0 Mil.USD	2.1 Mil.USD
Total			2.0 Mil.USD	8.9 Mil.USD

Source: JICA Study Team
CGL: Comprehensive General Liability
ALOP: Delayed Start-Up
CEAR: Construction/Erection All Risks
1) Project Cost: 100%, Comparison of Main Bridge Type: 50%
2) Limit of Indemnity: Assumed 100 Mil.USD (practice in the 3rd Panama Canal Bridge) according to the discussion results on the Draft Final Report

(3) Both Options after Adjustment

The two options, after making the adjustments for comparison purpose, are shown in Table 16.4.

Table 16.4 Both Options after Adjustment of Comparison Conditions

Item		Option of the JICA Study: Arch Bridge (Using Navigation Channel in Erection Works)	Option of the Pre-F/S: Cable-stayed Bridge
General View		**Side View**  **Plan**  **Cross Section** Main Bridge (At P31 and P32 Piers)  Approach Bridge (At P29, P30, P33 and P34 Piers) 	**Side View**  **Plan**  **Cross Section** At P11 and P12 Pylons 
Bridge Length in Comparison Study		1,118m	1,118m
Span Arrangement		139m+150m+540m+150m+139m	3@65m+94m+540m+94m+3@65m
Total Bridge Width		Main Bridge: 48.742m~52.872m, Approach Bridge: 29.400m (at A6 Abutment) ~ 50.235m (at P30 Pier)	51.3m
Metro Line 3		Monorail (Width: 8.4m)	Linear Metro (Width: 8.4m)
Erection Method		Arch Rib: Lifting Erection; Stiffening Girder: Cantilever Erection (Slewing Jib-crane, Gantry); Approach Bridge: Large Block Erection	Cantilever Erection
Using Navigation Channel		Arch Rib: 1 Time (Expected 13.5 hours)	Not Used
Construction Duration		4 years	4 years
Initial Construction Cost	Const. Cost	40.5 Bil.JPY (406 Mil.USD)	402 Mil.USD
	Risk Cost	0.89 Bil.JPY (8.9 Mil.USD)	2.0 Mil.USD
	Total	41.4 Bil.JPY (415 Mil.USD)	404 Mil.USD
Maintenance Cost (100 Years)	DR = 0%	10.6 Bil.JPY (106 Mil.USD)	150 Mil.USD
	DR = 4%	1.6 Bil.JPY (16 Mil.USD)	24 Mil.USD
Life-cycle Cost	DR = 0%	52.0 Bil.JPY (521 Mil.USD)	554 Mil.USD
	DR = 4%	43.0 Bil.JPY (431 Mil.USD)	428 Mil.USD

Source: JICA Study Team
Exchange Rate: 1 USD = 99.7 JPY

16.3.2 Study Results

The life-cycle cost (discount rate = 4%) was evaluated by the following formula:

Score of Cost Evaluation = Weight - 2 * Weight * (Ratio- 1.0)

Ratio: Ratio to the Option with the lower life-cycle cost (lower option: 1.0)

The results of the comparison study are shown in Table 16.5.

Table 16.5 Comparison Study Results

No.	Evaluation Item	Weight (Points)	JICA Study Option	Pre-F/S Option
			Arch Bridge (With Use of Navigation Channel)	Cable-stayed Bridge (Without Using Navigation Channel)
1	Structure	25	16.00	15.00
2	Constructability	13	9.00	8.80
3	Maintainability	15	11.00	11.00
4	Landscaping	14	12.60	6.40
5	Cost	33	32.54	33.00
Total		**100**	**81.14**	**74.20**

Source: JICA Study Team

16.4 Conclusion

The following 2 cases in the preliminary design of the arch bridge were examined in the JICA Study:

- With use of the navigation channel in the erection works of the main span
- Without using the navigation channel in the erection works of the main span

The “With” case has an advantage to the “Without” case in the construction duration and initial construction cost. On the other hand, it is important to ensure safety in the erection works of the arch rib; however, the technical risks are expected to be minimized by applying adequate mitigation measures. Therefore, the JICA Study Option selected the “With” case.

Based on the screening result for the main bridge type of the 4th Panama Canal Bridge (see Section 10.1), a comparison study was made between the Pre-F/S Option and the JICA study Option, and the JICA Study Option (81.14 points) exceeded the Pre-F/S Option (74.20 points).

In addition to the screening results, the arch bridge has advantages over the cable-stayed bridge due to its rigid structure and distinctive architectural features; therefore, the JICA Study Team recommends the JICA Study Option as the optimum main bridge type for the 4th Panama Canal Bridge.

The “With” case has not been approved yet by ACP at this time and it shall be necessary to obtain their approval based on this Final Report.

Chapter 17 Implementation Plan

17.1 Project Components

The Project for the 4th Panama Canal Bridge consists of the following components:

- Procurement of the Consultant
- Detailed Design and Construction Supervision
- Land Acquisition and Compensation
- Relocation of Public Utilities and Underground Utilities
- Procurement of the Construction Contractor
- Construction (Except Additional Ramp X in West Area)
- Defects Liability
- Operation and Maintenance

17.1.1 Scope of Construction Works

Table 17.1 shows the scope of the construction works.

Table 17.1 Scope of Construction Works

No.	Route	Segment		Item	Description
1	4th Panama Canal Bridge (Construction)	Whole segment			Road Length: 6,720.212m (-KM0+020.975 to KM6+699.237) No. of Lanes: 6 lanes (2*3 lanes) (BP～Omar Torrijos Roundabout: 4 lanes (2*2 lanes)) Metro Line-3: South Side (Combined Section: 2,183m (KM2+847(A5) to KM5+030(P44)))
		Break-down	Civil	East Approach Road (-0+020.975～2+847)	Road Length: 2,867.975m Flyover No.1: PC-I/Steel Box (L=520m) Flyover No.2: PC-I/Steel Box (L=740m)
				4th Panama Canal Bridge (2+847～5+390)	Road Length: 2,543m East Approach Viaduct: Steel Box (L=533m) Main Bridge: Steel Arch (L=840m) West Approach Viaduct: Steel Box/PC-I (1,170m)
				West Approach Road (5+390～6+699.237)	Road Length: 1,309.237m
			Utilities	Whole Section	Electrical, communication and mechanical facilities
2	East Side Connection Road (Construction)	Whole segment			Road Length: 1,025.19m No. of Lanes: 1 way, 2 lanes
		Break-down	Civil	Additional Ramps	On Ramp: 400.2m Off Ramp: 624.99m
			Utilities	Whole Section	Electrical facilities (road lighting)
3	Access Roads to the Bridge of the Americas (Reconstruction)	Whole segment			Road Length: 3,170.4m Nos of Lanes: 4 lanes (2*2 lanes)
		Break-down	Civil	East, to Panama City	Road Length: 1,582.4m Access bridge to the Bridge of the Americas: PC-I (760m)
				West, to Arraijan	Road Length: 1,588m
			Utilities	Whole Section	Electrical facilities (road lighting)
4	Omar Torrijos Roundabout (Improvement)	Whole segment			Road Length: 5,690m No. of Lanes (Additional Ramp): 1 way, 1 or 2 lanes No. of Lanes (Underpass): 4 lanes (2*2 lanes)
		Break-down	Civil	Additional Ramps	Additional Ramp: Additional ramps A to I, Omar Torrijos Road Flyover: Additional ramps B, C (partial)1) Widening of Flyover No.2: Additional ramps F and G (partial)1) Underpass: Additional ramps F and G, Omar Torrijos Road
				Existing Roundabout	Widening of existing roundabout
			Utilities	Whole Section	Electrical facilities (road lighting)
				Add. Ramps F, G, Omar Torrijos Rd.	Mechanical facilities (drainage pump)
5	West Side Additional Ramps2) (Reconstruction)	Whole segment			Road Length: 1,130m No. of Lanes: 1 way 2 lanes
		Break-down	Civil	Additional Ramps	Additional Ramp: Additional ramp Y and ramps a to i
			Utilities	Whole Section	Electrical facilities (road lighting)

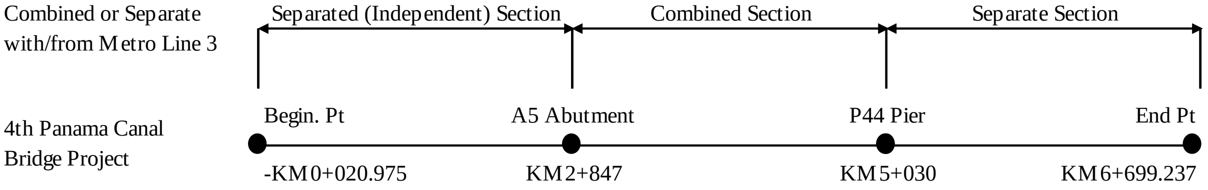
1) Assumption
2) Except Additional Ramp X (For the future)
Source: JICA Study Team

17.1.2 Relocation of Existing Utilities

The relocation of existing utilities is essential and necessary for construction in urban areas, especially on the east side of the 4th Panama Canal Bridge. Accordingly, all relocation works are planned to be completed before the commencement of construction works.

17.2 Demarcation between Metro Line-3 and 4th Panama Canal Bridge

As the alignment of the 4th Panama Canal Bridge runs parallel to that of Metro Line-3, the structures for some stretches of the road will carry both the Line-3 tracks and the carriageway of the 4th Panama Canal Bridge. The following diagram and chart were made to establish a clear demarcation between the two projects.



Civil Works	Independent	4th Panama Canal Bridge Project	Independent
Civil Works (Rail)	Metro Line 3 Project		
Utilities	Independent		
Land Acquisition/ Compensation	4th Panama Canal Bridge Project		
Relocation Works of Existing Utilities	4th Panama Canal Bridge Project		

A5 Abutment and P44 Pier: Included 4th Panama Canal Bridge Project

Source: JICA Study Team

Figure 17.1 Demarcation between the two Projects (Metro Line-3 Project, 4th Panama Canal Bridge Project)

17.3 Fund Procurement Plan

The following fund procurement plan was assumed in this Study:

- Japanese Yen Loan: 70% of Total Project Cost
- Panamanian State Budget: 30% of Total Project Cost

The ceiling of Japanese Yen Loan was assumed 70% of Total Project Cost in the above fund procurement plan and it will be finalized between the Government of Panama and JICA during the appraisal stage.

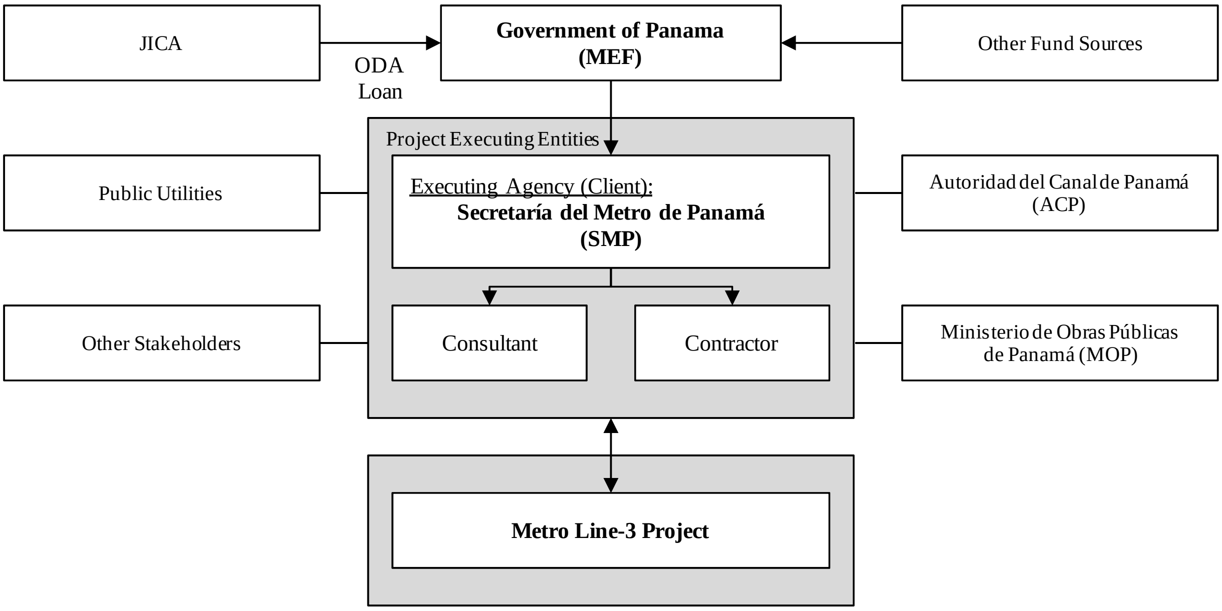
17.4 Project Implementation Structure

17.4.1 Project Implementation Organizations

It was assumed that the executing agency (the Client: SMP) shall procure the consultant for design and construction supervision, and shall procure the construction contractor(s) through a traditional contract where the detailed design is prepared by the Client following the outcomes of the consultation. As explained in previous chapters, ACP will collaborate with SMP to analyze the impacts and risks from using the navigation channel in the implementation stage. In addition, MOP, which prepares the design standards and guidelines in Panama, shall collaborate with SMP during the Project.

In the implementation stage of the Project, stakeholders such as the institutions in charge of the overhead cables and underground utilities, ACP, port companies and transport operators will become involved. Moreover, the implementation of the Metro Line-3 Project needs to progress in parallel with the 4th Panama Canal Bridge Project, as such, close coordination between the two projects will be very important.

The organizational scheme for the implementation of the Project is shown in Figure 17.2.



Source: JICA Study Team

Figure 17.2 Project Implementation Scheme

17.4.2 Financial and Budgetary Status and Technical Level of the Executing Agency

(1) Organizational Structure of SMP

The executing agency of Metro Line-3 Project is SMP, which is also the executing agency of the 4th Panama Canal Bridge Project. SMP, as the Client, along with the consultant and the contractor(s), will have to organize the implementation scheme. It should be noted that in 2014, SMP will be transferred to a limited liability state company, called “Metro de Panama S.A.”.

(2) Financial and Budgetary Status

The Ministry of the Presidency of Panama controls SMP and two other organizations together in its general accounting budget management. The Study Team could not obtain separate data regarding the financial and budgetary status of SMP.

(3) Technical Level

The Bridge of the Americas is built as a braced-rib arch, the 2nd Panama Canal Bridge, the Centenario bridge, is built as a PC cable-stayed girder, and now the construction of the 3rd Panama Canal Bridge is underway by ACP. Accordingly, the technical level of bridge engineering is regarded to be high.

17.4.3 Financial and Budgetary Status and Technical Level of the Maintenance Agency

(1) Organizational Structure of MOP

As with the Bridge of Americas and the 2nd Bridge, or the Centenario Bridge, the Maintenance Department of MOP (Ministry of Public Works of Panama） will be responsible for the future maintenance of the 4th Panama Canal Bridge.

(2) Financial and Budgetary Status

In order to keep the urban road networks as well as intra urban highways in good conditions, the following works are scheduled for the short term:

- A road construction program is scheduled to cover 2,500 miles (4,000km) of the inter-city road network, which represents a USD45 billion investment.
- Maintenance of about 200 miles (320km) of the inter-city road network for a total cost of USD28 million.
- Restoration of the intra-urban roads, where MOP plans to invest USD25 million in surface repaving.
- Maintenance work for cleaning side ditches and drainage systems, clearing roads, maintenance and re-painting of bridges, among other works.

(3) Technical Level of MOP

At present, the Maintenance Department of MOP has 2,000 staff and 1,340 units of light and heavy equipment with which it conducts maintenance on the following structures:

- 7,000km. of Urban Road Network (streets)
- 15,000km. of Inter City Road Network (roads)
- 1,800 Vehicular Bridges
- 214 Pedestrian Bridges

MOP provides construction and maintenance works to the above roads in Panama. These works has been carried out by private company through public tender. The company that constructs the works should carry out their maintenance for a period of two to three years after their completion. Therefore, the technical level of maintenance companies is regarded to be high through the technical transferring by the construction contractors. In addition, MOP's performance in maintaining the Bridge of the Americas and the Centenario Bridge is well and gives it a technical level high enough to maintain the completed 4th Panama Canal Bridge in the future.

17.5 Procurement Plan

17.5.1 Procurement of the Consultant

(1) Procurement Method

Design-build scheme will be applied in the Metro Line-3 Project (see Section 8); therefore, the detailed design works in the 4th Panama Canal Bridge shall be conducted by a consultant in consideration adjustment between two projects.

Although the implementation of the Project will progress in parallel with the Metro Line 3 Project, the bridge deck works of the Project need to be completed before work can begin on the installation of the beams and signal system of Metro Line-3.

The adjustment between two projects is not easy; therefore, the consultant services include both the detailed design and construction supervision. Accordingly, the procurement plan considers a single procurement for the consultant services.

An International Competitive Bidding (ICB) is recommended according to the JICA Procurement Guideline taking into consideration the size and engineering level of the Project.

(2) Scope of Consultant Services

- Detailed Design (Structural Analyses, Design, Preparation of Drawings, Quantity Calculation, Preparation of Technical Specifications, Construction Planning, Cost Estimate), Pre-qualification Document Preparation, Bid Document Preparation: 18 months
- Pre-construction Stage Services including assistance to the Client for Procurement of Construction Contractor(s) (Pre-qualification Assistance, Bid Assistance, Contracting Assistance, etc.): 15 months, 5 months overlap with the above Detailed Design
- Construction Supervision (Inspection and Recording of Quality Assurance/Control, Inspection and Recording of Work Progress, Inspection and Recording of the Completion of Facilities, Checking of Safety): 48 months (Arch-Rib Lifting Method), 60 months (Cable Erection Method)
- Defects Liability Inspection (1 Year): 12 months

17.5.2 Procurement of the Construction Contractor(s)

(1) Procurement Method

Procurement of contractor is recommended to apply an ICB procedure without pre qualification in order to perform efficient procurement procedures. The bidders should be submitted qualification documents, technical bids and financial bids simultaneously.

(2) Scope of the Construction Contractor(s)

- Construction of Facilities based on the Contract Documents, (Quality Assurance/Control, Work Progress Control, Control and Management of Physical and Monetary Progress, Safety Control): 48 months (Arch-Rib Lifting Method), 60 months (Cable Erection Method)
- Defects Liability (1 year): 12 months

17.6 Implementation Schedule of the 4th Panama Canal Bridge Project

Figure 17.3 shows the implementation schedule for the case of “using” the navigation channel for erection (Arch-Rib Lifting Method), and Figure 17.4 shows the case of “without” using the navigation channel for erection (Cable Erection Method).

The case of “using” the navigation channel for erection (Arch-Rib Lifting Method) shown in Figure 17.3 is the implementation schedule as the optimal option (see Section 16). This schedule was adjusted with the Metro Line-3 Project as shown in Figure 8.4.

17.7 Other Items to be Implicated

(1) Ownership and Responsibility of Future Maintenance

Although the Project Costs between Metro Line-3 and 4th Panama Canal Bridge should correspond to the Sub-Section “17.1.1 Scope of the Project” and Section “17.2 Demarcation between Metro Line-3 and 4th Panama Canal Bridge”, ACP will be the owner of the bridge and responsible for its future maintenance, and Metro Line-3 will be entitled to use the bridge infrastructure free-of-charge for its operation.

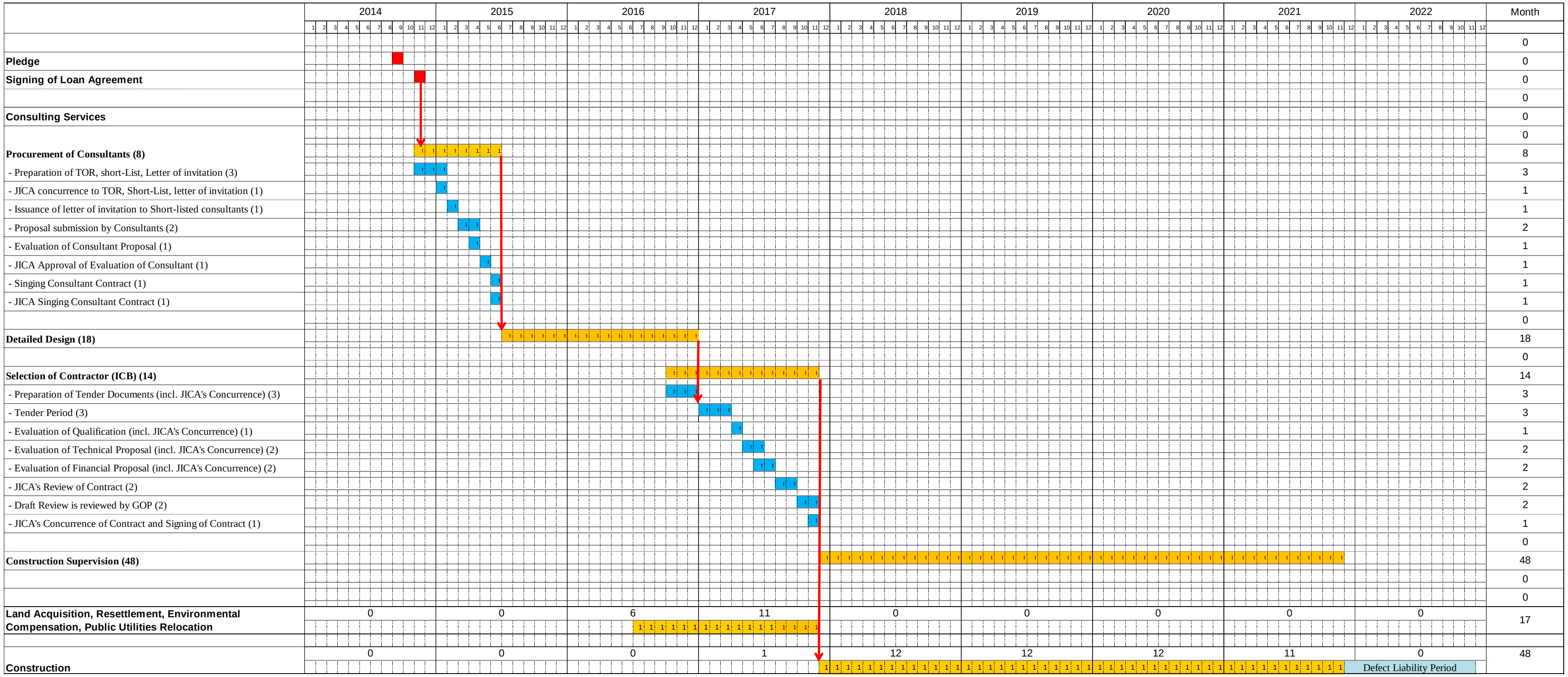
The future maintenance of facilities other than the 4th Panama Canal Bridge should be conducted as already discussed in “Chapter 14: Operation and Maintenance Plan”.

(2) Approval of EIA Report

During this feasibility study, the JICA Study Team supported SMP in carrying out the EIA studies and preparing the draft EIA report, in accordance with the Panamanian legal framework and JICA’s Guidelines for Environmental and Social Considerations (2010).

In the months ahead, ANAM will review the EIA report. It should be noted by all parties that if ANAM requires any additional work, report revisions, or other conditions for approval of the EIA report, the Panamanian Government will be responsible for complying with ANAM and carrying out any additional work.

Implementation Schedule for ICB (4th Panama Canal Bridge Construction Project, Arch-rib Lifting Method)

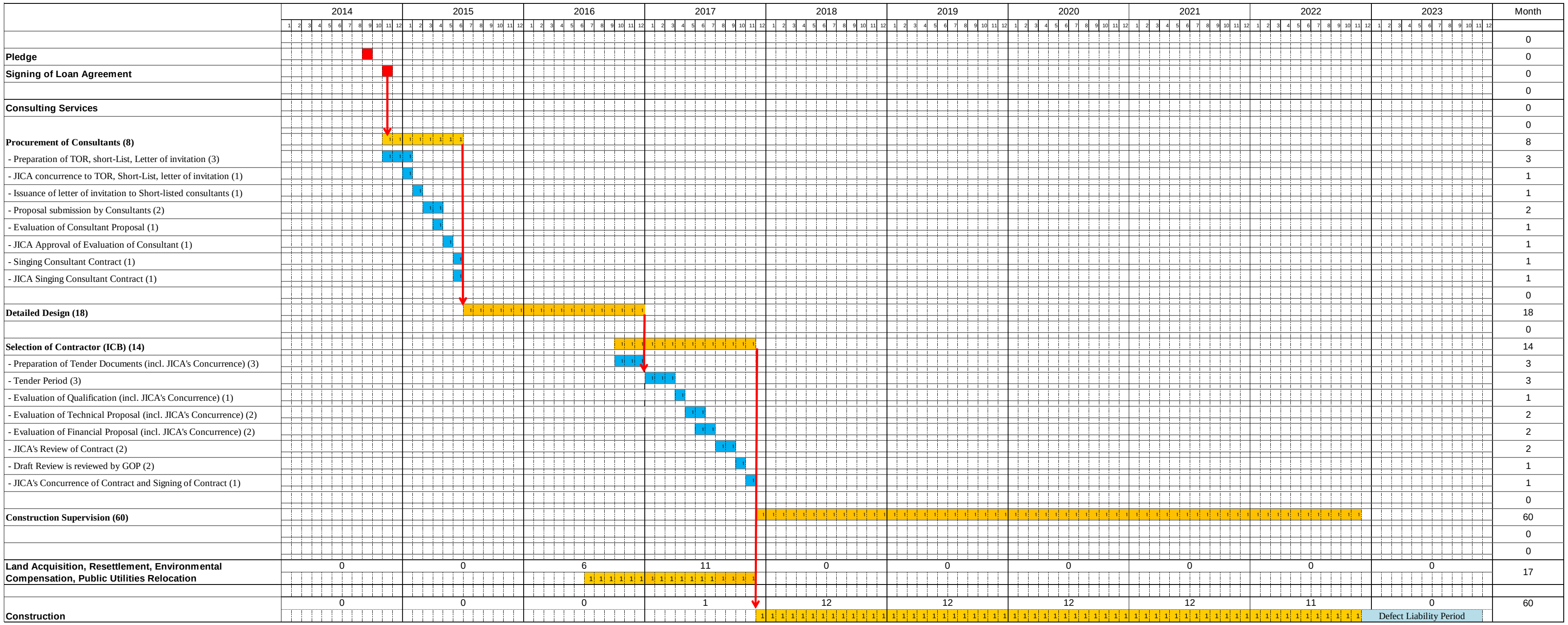


	2014	2015	2016	2017	2018	2019	2020	2021	2022	Month
										0
Pledge										0
Signing of Loan Agreement										0
										0
Consulting Services										0
										0
Procurement of Consultants (8)										8
- Preparation of TOR, short-List, Letter of invitation (3)										3
- JICA concurrence to TOR, Short-List, letter of invitation (1)										1
- Issuance of letter of invitation to Short-listed consultants (1)										1
- Proposal submission by Consultants (2)										2
- Evaluation of Consultant Proposal (1)										1
- JICA Approval of Evaluation of Consultant (1)										1
- Singing Consultant Contract (1)										1
- JICA Singing Consultant Contract (1)										1
										0
Detailed Design (18)										18
										0
Selection of Contractor (ICB) (14)										14
- Preparation of Tender Documents (incl. JICA's Concurrence) (3)										3
- Tender Period (3)										3
- Evaluation of Qualification (incl. JICA's Concurrence) (1)										1
- Evaluation of Technical Proposal (incl. JICA's Concurrence) (2)										2
- Evaluation of Financial Proposal (incl. JICA's Concurrence) (2)										2
- JICA's Review of Contract (2)										2
- Draft Review is reviewed by GOP (2)										2
- JICA's Concurrence of Contract and Signing of Contract (1)										1
										0
Construction Supervision (48)										48
										0
										0
Land Acquisition, Resettlement, Environmental Compensation, Public Utilities Relocation	0	0	6	11	0	0	0	0	0	17
Construction	0	0	0	1	12	12	12	11	0 Defect Liability Period	48

Source: JICA Study Team

Figure 17.3 Project Implementation Schedule for the Case of "Using" the Navigation Channel (Arch-Rib Lifting Method)

Implementation Schedule for ICB (4th Panama Canal Bridge Construction Project, Cable Erection Method)



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Month
											0
Pledge											0
Signing of Loan Agreement											0
											0
Consulting Services											0
											0
Procurement of Consultants (8)											8
- Preparation of TOR, short-List, Letter of invitation (3)											3
- JICA concurrence to TOR, Short-List, letter of invitation (1)											1
- Issuance of letter of invitation to Short-listed consultants (1)											1
- Proposal submission by Consultants (2)											2
- Evaluation of Consultant Proposal (1)											1
- JICA Approval of Evaluation of Consultant (1)											1
- Singing Consultant Contract (1)											1
- JICA Singing Consultant Contract (1)											1
											0
Detailed Design (18)											18
											0
Selection of Contractor (ICB) (14)											14
- Preparation of Tender Documents (incl. JICA's Concurrence) (3)											3
- Tender Period (3)											3
- Evaluation of Qualification (incl. JICA's Concurrence) (1)											1
- Evaluation of Technical Proposal (incl. JICA's Concurrence) (2)											2
- Evaluation of Financial Proposal (incl. JICA's Concurrence) (2)											2
- JICA's Review of Contract (2)											2
- Draft Review is reviewed by GOP (2)											1
- JICA's Concurrence of Contract and Signing of Contract (1)											1
											0
Construction Supervision (60)											60
											0
											0
Land Acquisition, Resettlement, Environmental Compensation, Public Utilities Relocation	0	0	6	11	0	0	0	0	0	0	17
Construction	0	0	0	1	12	12	12	12	11	0 Defect Liability Period	60

Source: JICA Study Team

Figure 17.4 Project Implementation Schedule for the Case of "Without" Using the Navigation Channel (Cable Erection Method)

Chapter 18 Project Impacts

18.1 Greenhouse Gas Emissions Reductions

The Line-3 Project will reduce CO_2 emissions by reducing the number of vehicles used for passenger transport, and will increase CO_2 emissions from power plants by using electricity for the Line-3 operation. Since the former reduction volume is larger than the latter, the Line-3 Project will reduce CO_2 emissions in total.

To estimate the volume of the CO_2 reductions by the Project, JICA Climate Finance Impact Tool for Mitigation (JICA-FIT) was used in the Study.

Reduction in CO_2 emission was calculated as shown in Table 18.1.

Table 18.1 CO_2 Reduction by the Project

Year	2020	2025	2030	2035	2040	2045	2050
t-CO_2/year	23,989	26,510	17,804	19,446	20,798	21,770	21,779

Source: JICA Study Team

18.2 Operation and Effect Indicators

The operation indicator of the 4th Bridge Project is the daily traffic of the bridge. Since the peak hour traffic is used for the decision of the number of lanes and the traffic of heavy vehicles is used for the decision of the depth of the pavement, these data are also employed for operation indicators.

Since the basic operation indicators are passenger transport volume and operation volume of trains, the average number of passengers per day and the average train-kilometers per day were employed, respectively. Rolling stock operating rate was also employed to evaluate whether the rolling stock purchased in the Project is sufficiently used. Because of the importance of transport service for the peak hour commuter demand, the capacity in peak hours is necessary for the operation indicators, and the number of trains in the peak hour was employed for this. Although the average number of train operations per day can be a operation indicator for the density of transport services, it was excluded because it can be calculated by dividing train-kilometers by the route length. The table below shows the operation indicators proposed in the Study.

Table 18.2 Operation Indicators

Project	Purpose of Indicators	Indicator	Target (2025)
Bridge	Traffic	Daily traffic	34,700
	Peak hour traffic	Peak hour traffic for the peak direction	1,800
	Heavy vehicle traffic	Daily traffic of heavy vehicles	1,300
Line-3	Transport Volume	No. of passengers per day	172,200
	Total amount of services provided	Train-km per day	9,719
	Peak hour capacity	No. of train operations in the peak hour	19
	Efficient use of rolling stock	Rolling stock operating rate *1	90%

*1: Cumulative operating days per year per train /361 (average inspection days=4 days/year)
Source: JICA Study Team

18.3 Qualitative Impacts

The following qualitative impacts are expected from the Project.

- Improved image of Panama City

- Development of tourism
- Environmentally friendly transportation system
- More efficient travel
- Urban and industrial development
- Safe access to educational institutions in any weather

18.4 Economic Analysis

The following three economic analyses were carried out in the Study: (a) 4th Bridge and Line-3, (b) 4th Bridge, and (c) Line-3. "With" and "Without" cases of them are as summarized in the table below. Numbers 1)-3) correspond to the number of the network scenario in Chapter 3.

Table 18.3 Targets of Economic Analysis

Targets of Economic Analysis	With Case	Without Case
(a) 4th Bridge and Line-3	3) 4th Bridge & Line-3	1) Present
(b) 4th Bridge	2) 4th Bridge	1) Present
(c) Line-3	3) 4th Bridge & Line-3	2) 4th Bridge

Source: Setting by the JICA Study Team

For the economic analysis of (c) Line-3, the "Without Case" is the case when the 4th Bridge is constructed without Line-3, while the "With Case" is the case when both the 4th Bridge and Line-3 projects are implemented as shown in the above table. The reason is that the Study of Line-3 is based on the assumption that Line-3 will be constructed on the 4th Bridge.

It is assumed that no public transport improvement projects are taken place for the "Without Case" except for the construction of Line-2. "With Case" is the case of "Without Case" plus Line-3 project. However, express bus services are assumed to be operated through the 4th Bridge for both "With" and "Without" cases.

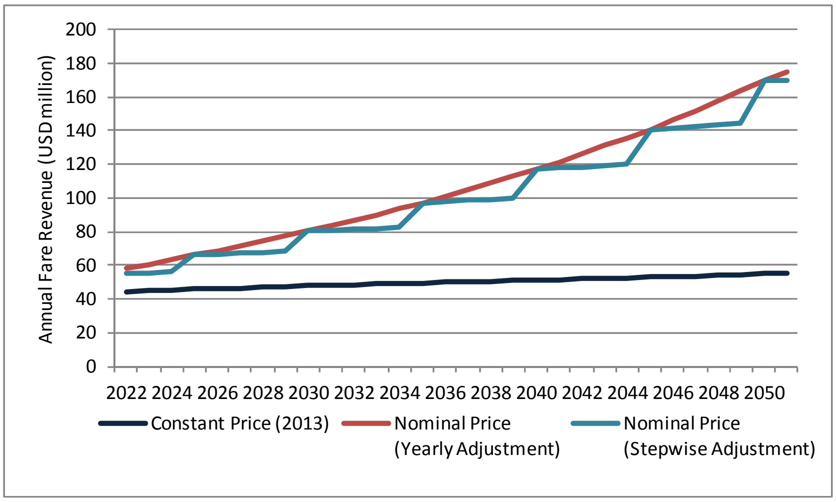
The economic benefit of the Project is composed of travel time reduction and vehicle operating cost (VOC) saving. Travel time reduction is the direct benefit that Line-3 passengers and 4th Bridge users can experience.

The result of the EIRR calculation is shown in the table below. Comparing the result with the Government funding cost in Panama, the Project would be feasible.

Targets of Economic Analysis	EIRR
(a) 4th Bridge and Line-3	6.8%
(b) 4th Bridge	5.6%
(c) Line-3	8.2%

18.5 Financial Analysis

The fare revenue of the Project is estimated as shown in the figure below.



Source: JICA Study Team

Figure 18.1 Fare Revenue Projection

The project FIRR is estimated at minus 7.21% mainly due to high construction cost and affordable passenger fare. The project is deemed financially not viable compared to the WACC of 2.44%.

Currently the government has no predetermined tariff setting and adjustment mechanism for the Metro system to ensure the project’s financial sustainability in the long run. The project will be highly subsidized to maintain sound operation.

The net present value of the project’s life cycle cost (LCC) to be borne by the government is estimated at USD 1,380 million in total which includes construction subsidy, ODA loan debt service and reinvestment subsidy to Metro de Panamá, S.A.

The private sector participation may achieve Value for Money (VFM) to the government only if the private partner can provide significant cost and revenue efficiency to cover its capital cost higher than the government funding. Estimates on efficiency requirement indicate that the private investment for the entire project scope (BOT/BTO Scheme and Public Operation with Private Investment) requires extremely high efficiency and is considered not feasible. The Concession Scheme with government’s initial investment is a more probable option in terms of financial viability

.

Chapter 19 Environmetnal and Social Considerations

Comprehensive EIA and SRAP studies have been carried out for the two projects, exceeding the requirements of both Panamanian law and JICA Guidelines. The studies included significant effort to gather and analyse both existing available data, and new baseline data obtained via field surveys and interviews. Forest inventories were also carried out as part of the baseline studies, in accordance with Panamanian legislation.

The approach to the EIA and SRAP studies was fully participatory, and local communities, civil society, and academia were consulted throughout the project process. Designs and approaches were modified were necessary in accordance with the opinions provided in these public meetings and focus group discussions.

The impact assessments were conducted using a systematic and quantitative methodology, allowing for an accurate prediction of potential positive and negative environmental and social impacts. Following the identification of impacts, a comprehensive outline Environmental Management Plan (EMP) was prepared. The EMP lists the mitigation measures developed by the study team to reduce potential negative impacts to acceptable levels, and to maximise the benefits of positive impacts. The expected costs of implementing the EMP were provided so that sufficient funds will be made available for environmental and social mitigation during preparation of overall cost estimates and tender documents.

The key findings and conclusions of the EIA studies were as follows:

- The alignment of both projects pass through an area which is largely urban, commercial or industrial, and which is highly trafficked and generally disturbed by anthropogenic activities.
- As a result, background noise levels are high, and water and air quality results obtained in the project area reflect the human presence. Likewise, the estuarine environment in the Panama Canal at the location where the 4th Panama Canal Bridge is proposed also shows signs of existing biological and chemical pollution resulting from the very high levels of shipping activity in the Canal, and its proximity to Panama City.
- The project alignments do pass through some natural forested areas, and one area of mangrove, however the baseline studies determined that the habitats to be lost were generally already disturbed, did not host significant diversity or density of flora and fauna species, and were not critical habitat for the threatened species identified.
- The presence and operation of the project will have sustained, highly significant positive impacts on various aspects of the social environment, including alleviation of traffic congestion, increased economic development, and reduction in journey times.
- The presence and operation of the project will also produce localised positive impacts in some areas due to reduction / offset in emissions and noise from buses and other road traffic. At a wider scale, the operation of the project is expected to offset between 16,000-25,000 tonnes of CO_2 per year.
- The majority of expected negative impacts are associated with the construction process, and relate to public disturbance type impacts (which tend to be reversible and short term);
- The construction and operation of both the 4th Panama Canal Bridge Project and the Metro Line 3 Project are not expected to have significant negative impacts on terrestrial or marine flora and fauna. Whilst a number of internationally rare species were identified during the field surveys, no primary forest exists and none of the

areas to be lost were considered as critical habitat for the rare species identified. Rapid regeneration of the small mangrove area to be lost during construction is also predicted.

- Land acquisition (totalling around 130,000 m^2), resettlement (five families), and displacement of economic units (around 41 units) will be required. Throughout the study various alternative analyses and design changes were carried out to minimize such negative impacts, but a certain number is unavoidable. In fact, it is considered that the above numbers are relatively low for projects of this nature and scale.
- A Strategic Resettlement Action Plan was prepared according to World Bank OP 4.12 and JICA Guidelines. SMP will update the SRAP and prepare MINI RAP during the tender document preparation stage.
- All PAPs have been be well informed about the project and will be compensated adequately. Public support for the projects is overwhelmingly positive.
- The classification of most negative impacts during construction were moderate or low and these can be easily mitigated for via the Environmental Management Plan (EMP) using standard mitigation measures that form of part of construction best practice.
- The classification of most negative impacts during operation were “low”. Only four operational negative impacts were classified as “moderate”; noise, vibration, and effect on the local microclimate. It should be highlighted that these moderate impacts will only occur in very restricted localised areas, and will not be widely experienced.
- None of the potential impacts classified as “high” or “very high” were negative; all were positive.
- Reaction to the projects within the community and civil society was generally very positive.

The following recommendations to JICA and the project proponents are provided by the JICA Study Team:

1. Article 49 of Decree 123 states that EIA studies have a validity of two years from approval to the “initiation of project execution”. The wording of this article is somewhat vague, and it is not stated what activities constitute “initiation”. The study team has learned that a condition of EIA approval is likely to be an annual report to ANAM, and that, providing the 1st annual report to ANAM demonstrates some progression with the project (for example design activities or preparation of bidding documents) this is classified as “initiation of project execution”. It is therefore recommended that SMP / JICA ensure that follow-on studies on the projects begin within one year of EIA approval, to avoid the need to repeat the EIA study in the future.
2. Although the projects are generally very well supported by the Panamanian public, it is nevertheless recommended that consultation with PAPs, the local population and civil society is maintained throughout planning, design and construction.
3. Likewise, it will be important to ensure that environmental and social specialists are included in the design and construction supervision teams.
4. To ensure that the eventual Contractor fulfils his contractual obligations with regards to mitigation of potential environmental and social impacts, it is strongly recommended that the mitigation measures be included in the Bill of Quantities where feasible, and should also be linked to payment items in the contract.
5. During this feasibility study, the JICA Study Team supported SMP in carrying out the EIA studies and preparing the draft EIA report, according to the Panamanian legal framework and JICA Guidelines. In the months ahead, ANAM will review the EIA report. It should be noted by all parties that if ANAM requires any additional

work, report revisions, or other conditions for approval of the EIA report, the Panamanian Government will be responsible for complying with ANAM and carrying out any additional work.

Chapter 20 Introduction of Applicable Japanese Technology

20.1 General

In this Chapter, the JICA Study Team introduces the Japanese technologies that are applicable to the Project. The technology covers following two cases:

- Technology that is planned for in this study.
- Technology not planned for, but which needs to be studied or planned for in the detailed design stage.

The following Japanese technology is introduced for Metro Line-3 and the 4th Panama Canal Bridge Projects:

Metro Line-3 Project (See Chapter 20.2)

- Battery Power System (BPS)

4th Panama Canal Bridge Project (See Chapter 20.3)

- Steels for Bridge High Performance Structure (SBHS)
- Advanced Weathering Steel (Nickel Type)
- Steel Pipe Sheet Pile (SPSP)
- Low-position Lighting

20.2 Metro Line-3 Project

20.2.1 Battery Power System (BPS) for Railway

The monorail system proposed in this study is itself a technology developed in Japan. As a part of the power supply system, the Battery Power System (BPS) using high-capacity nickel hydrogen battery called the “GIGACELL^{TM}” is another applicable Japanese technology.

When trains stop for an extended period due to power failure of an outside source, the BPS is able to move all the trains on the main line to the nearest stations.

The BPS has the following functions, which are applicable not only for emergency situations;

- BPS is able to store the excessive electricity generated by the operating trains by charging the GIGACELL. In this way, the regenerated electricity can be fully utilized.
- BPS is able to reduce power demand during the peak hour by discharging its electricity.
- BPS is able to assist optimum train operation by stabilizing line voltage, by feeding power to the accelerating trains and by preventing voltage drop.
- BPS is able to support substation functions by discharging power, which enables the downsizing of the substation facilities.

The application of BPS is also closely related to passenger evacuation methods. During discussions with SMP, the necessity of providing an evacuation walkway (catwalk) for emergency evacuation purposes was considered. However, in the case of monorails, many monorail lines have no evacuation walkway because of the difficulty of passengers transferring from a train to a walkway, and also because the walkway structure spoils the scenery. As a result of the discussions, it was concluded that no evacuation walkway would be required if the BPS is installed. (In case of an emergency, the train would not stop, but would be powered by the BPS to run to the nearest station.)

BPS has been successfully introduced in the Tokyo Monorail, Osaka Subway and Den-en-toshi Line in Japan. In addition, operation tests are currently underway on the Washington D.C. Metro operated by the Washington Metropolitan Area Transit Authority.

20.3 4th Panama Canal Bridge Construction Project

20.3.1 Steels for Bridge High Performance Structure (SBHS)

SBHS will be used in the main bridge of the 4th Panama Canal Bridge for the following reasons.

- The main bridge of the 4th Panama Canal Bridge was planned as a long-span bridge (center span: 540m) and its steel weight greatly affects the construction cost; therefore, SBHS was applied to reduce the thickness (weight).
- The joints of the external components will use site welding (boltless) to improve their maintainability; therefore, SBHS was applied to ensure weldability.

Conventional steel (SM490Y class) was mainly applied to the main structural components of the main bridge of the 4th Panama Canal Bridge; however, where the thickness would exceed 40mm, SBHS500 was applied to reduce thickness and ensure weldability.

SBHS500 was applied at the conjunction and bottom of the arch rib, where there are large internal forces, in order to reduce the thickness and ensure weldability.

The planned SBHS components in the Project are shown in Figure 20.1.

Source: JICA Study Team

Figure 20.1 Components using SBHS in the Project (Main Bridge of the 4th Panama Canal Bridge)

20.3.2 Advanced Weathering Steel (Nickel Type)

The main bridge of the 4th Panama Canal Bridge and part of the approach bridges are to be steel bridges. The box-shaped arch rib was employed to reduce the area that needs to be painted; however, the necessity of repainting work still remains. Therefore, the application of weathering steel was studied to reduce the repainting work.

The Project road was planned as part of an urban road; therefore, the steel bridges will be painted to ensure corrosion protection and improved bridge aesthetics. The type of paint to be applied is the Fluorine resin paint in consideration of its high durability near the Pacific Ocean and a repainting frequency that is expected to be 40 years.

On the other hand, the steel components will be made of weathering steel. In case there is partial peeling of the paint before the time for repainting, maintenance work can be reduced because the steel will be protected by the rust layer.

The weathering steel to be used is the Nickel type in the JICA Study and its exposure test and measurement of precipitation rate of air-born salt is being conducted on the Bridge of the Americas. The suitability of its use will be confirmed in the D/D stage in accordance with the analysis of the test results.

20.3.3 Steel Pipe Sheet Pile (SPSP)

The main bridge of the 4th Panama Canal Bridge is a long-span bridge (center span: 540m) over the Panama Canal; therefore, a large-scale, temporary cofferdam and foundation are required.

SPSP can combine the foundation with the temporary cofferdam, furthermore its bending rigidity is high; therefore, SPSP was selected in the JICA Study.

SPSP will be employed for the west side pier of the main bridge of the 4th Panama Canal Bridge (P32 Pier) in consideration of the large horizontal force and its location in the Panama Canal. On the other hand, SPSP was not employed for the piers of the west approach bridge of the 4th Panama Canal Bridge by reason of the small horizontal force and the possibility of using embanked construction roads.

20.3.4 Low-position Lighting

The application of low-position lighting on the 4th Panama Canal Bridge is considered for the following reasons:

- The foundations of light poles are problematic on the arch rib.
- From the view of aesthetics, different lighting systems are used for the arch rib and for the other areas.
- Maintenance and inspection of low-position lighting can be performed without lane closure because there is no need to use vehicles for working at heights.

Normally a light pole is 12m or 10m high. The mounting position of low-position lighting, at about 1m height, is excellent for construction and maintenance.

The uniformity of low-position lighting and visibility by continuous placement is also very excellent and is superior to induction lighting.

The low-position lighting was proposed in this study; however, there is no precedence for its use in Panama. Luminance of the road surface shall be confirmed by simulation at the detailed design stage to decide on whether to adopt it or not.

Therefore, in this study the pole-type lighting is tentatively planned for.

Chapter 21 Conclusions and Recommendations

21.1 Conclusions

1) The Project (Urban Transportation Line-3 and the 4th Panama Canal Bridge) is to construct a new bridge over the Panama Canal and introduce an urban transport system, aiming at alleviating traffic congestion on the Bridge of Americas and contributing the development of the area to the west of the canal. From the analysis of the benefits and costs of the Project, it was concluded that the Project would be economically feasible. In addition, it was estimated that the Project would reduce 17,000 tons of CO_2 per year in 2035.
2) After the comparison analysis among railway, monorail, AGT, LRT, BRT and other urban transport systems for the urban transportation Line-3, the straddle type monorail, which can perform flexibility for steep slopes and curves, was selected as the best system.
3) In the beginning of the Study, the route was assumed to be along Autopista, although after the comparison analysis with along Pan-American Road, it was concluded that the route should go through Pan-American Road, where the adjoining area had been already urbanized.
4) A monorail train is composed of 6-cars, and the monorail system will carry 20,000 passengers per direction in peak hours in 2035. A total of 156 cars will be introduced at the beginning of the operation and added cars according to the demand increase. The traction power is direct current of 1500 volt, and 4 intermediate cars are motor cars in which induced motors are controlled by VVVF and equipped with electricity regeneration function.
5) The line is constructed as elevated structure except for the section on the 4th Panama Canal Bridge, and runs along the median of roads in principle.
6) The road link of the 4th Panama Canal Bridge along with Approaches is an inner city road of 3 lane dual carriageway (6 lanes) with median strip in Panama City starting at the conjunction with the Corridor Norte at Albrook, then crossing the Panama Canal from Balboa Port on the eastern bank side to Arraijan on the western bank side about 6.72 km in length. The road/monorail combined section of 2.183 km consisting of the 4th Panama Canal Bridge and adjacent viaducts is multi-purpose bridge structures to carry the 6 lane road and the double track Metro Line 3.
7) On the western bank side, there exist Gelabert International Airport which require civil aviation limits for road longitudinal alignment, Omar Torrijos Intersection which is large and complex roundabout, and important buildings and underground utilities along the Av. Roosevelt. The 4th Panama Canal Bridge crosses the Panama Canal in approximately 6.72 km between Balboa Port on the eastern bank side and Arraijan on the western bank side. At the Arraijan ending point, an access road to the First Bridge “Puente de las Américas” is scheduled.
8) As for the bridge type of the 4th Panama Canal Bridge, a preliminary design of the 840m long steel arch bridge was conducted by the Study Team as alternative bridge type of the 1,118m long cable stayed bridge which was examined in the Pre Feasibility Study by ACP. In case of the steel arch bridge, lift-up method of arch rib segment from the barges using the Panama Canal was examined by the Study Team and risk analysis on the lift-up method was conducted by ACP and SMP. The Study Team implicated the results of the risk analysis into the construction cost of the steel arch bridge.
9) Multi-criteria analysis was conducted by the Study Team to evaluate the 1,118m long cable stayed bridge and the 880m long steel arch bridge. As a result, the 840m long bridge was regarded as advantageous from the view points of high rigidity of arch structure, good landscaping of arch bridge with the existing First Bridge “Puente de las

Américas" and life cycle cost including initial investment and 100 year maintenance costs.

10) The Study Team has conducted a concept design on the Improvement of the Omar Torrijos Intersection including new construction of an underpass to augment the traffic capacity for the north-south traffic flows in Panama City. The concept design of the Omar Torrijos Intersection Improvement was followed by micro-simulation analysis to assess the traffic movements in the morning peak hours. The micro simulation revealed that traffics from the 4th Panama Canal Bridge mainly flow toward the Av. Omar Torrijos Herrera in the intersection but volume of traffics toward the Corridor Norte proposed by Pre Feasibility Study as the possible connectivity is extremely low. Accordingly, it is confirmed through the micro-simulation analysis that the Improvement of Omar Torrijos Intersection is very obvious to provide better connectivity of the 4th Panama Canal Bridge Project.
11) During this F/S, an EIA was carried out and Strategic RAP was prepared through various type of community participation activities. Any very significant negative impacts were not foreseen, and an Environmental Management Plan was prepared to manage adequately all negative impact. No resettlement will be required. The compensation will be implemented to the economic displacement and relocation of ACP buildings.
12) Before the construction of the Fourth Bridge Project, the Client, SMP, would have to conduct the detailed design on the 4th Panama Canal Bridge and Approaches. The detailed design requires 18 months. The Study Team recommends that wind-tunnel test be conducted in order to examine the stability of the structure and optimize the shapes, lines and sizes of the stiffening girders of the arch bridge. Since the lift of the arch rib segment has no precedence, the Study Team recommends that a mathematical model test (3D image) be conducted during the detailed design in order to examine a safe construction plan.
13) Implementation of the project for the Omar Torrijos Intersection Improvement is essential in order to obtain better connectivity of the 4th Panama Canal Bridge. It is desired that the completion of the Omar Torrijos Intersection Improvement should be in the same time as the 4th Panama Canal Bridge.
14) The construction of the 4th Panama Canal Bridge and Approaches requires 48 months, of which last 6 months are regarded as overlapped working period for the bridge finishing works and installation works of Metro Line 3 infrastructures such as rails, electrical and mechanical facilities.
15) The Project cost is as shown in Table 21.1.

Table 21.1 Project Cost

Item		**Metro Line-3**		**4th Panama Canal Bridge**		**Total**	
		F/C (Equiv.)	L/C (Equiv.)	F/C (Equiv.)	L/C (Equiv.)	F/C (Equiv.)	L/C (Equiv.)
		(Mil.JPY)	(Mil.USD)	(Mil.JPY)	(Mil.USD)	(Mil.JPY)	(Mil.USD)
A. Eligible Portion							
I	Procurement / Construction	190,001	1,906	161,666	1,622	351,667	3,528
II	Consulting Services	8,839	89	11,651	117	20,490	206
Total (I+II)		**198,840**	**1,994**	**173,318**	**1,738**	**372,158**	**3,732**
B. Non Eligible Portion							
a	Procurement / Construction	342	3	1	0	343	3
b	Land Acquisition	2,693	27	620	6	3,313	33
c	Administration Cost	10,094	101	8,697	87	18,791	188
d	VAT	0	0	0	0	0	0
e	Import Tax	0	0	0	0	0	0
Total (a+b+c+d+e)		**13,129**	**132**	**9,319**	**93**	**22,448**	**225**
Total (A+B)		**211,969**	**2,126**	**182,636**	**1,832**	**394,605**	**3,958**
C	Interest during Construction	7,930	80	7,697	77	15,627	157
D	Front End Fee	398	4	693	7	1,091	11
Grand Total (A+B+C+D)		**220,296**	**2,210**	**191,026**	**1,916**	**411,322**	**4,126**

1 USD = 99.7 JPY
Source: JICA Study Team

21.2 Recommendations on Project Implementation Stage

21.2.1 Urban Transport Line-3

In the project implementation stage, it is necessary to consider the following issues.

- Coordination of design and construction between Line-3 and 4th Panama Canal Bridge
- Land acquisition for the depot area
- Selection of the contractor having technology and experiences
- Confirmation of the new organization of SMP

(1) Coordination of design and construction between Line-3 and 4th Panama Canal Bridge

Since the monorails run on the 4th Panama Canal Bridge, accurate adjustments will be required for the design and construction for sections around the merging points of Line-3 and the approach roads of the 4th Panama Canal Bridge. In addition, it is necessary to match deflections and displacements between Line-3 and the 4th Panama Canal Bridge, and the displacements of monorail's girder in case of earthquakes needs to conform to that of the 4th Panama Canal Bridge. Furthermore, since Line-3 cannot start its operation before the completion of the 4th Panama Canal Bridge construction, a close coordination of the construction schedule is required.

Therefore, the coordination of design and construction between Line-3 and the 4th Panama Canal Bridge is an important issue, and it is recommended that utilizing a project management consultant that coordinates the engineering services of Line-3 and the 4th Panama Canal Bridge, or integration of the engineering services.

(2) Land acquisition for the depot area

Since urban development by private sector is taking place actively around the depot area, the possibility of urban development at the depot area cannot be denied in case that the project delays. Therefore, SMP should start the process of land acquisition for the depot area before undertaking the project.

(3) Selecting contractor having technology and experiences

As described in the section 8.5, it is recommended that Line-3 will be implemented by applying a Design-Build contract in FIDIC Yellow Book. In this case, proper technology and rich experiences for monorail system should be required for the international competitive bidding because the contractor will be responsible for the detailed design. The following points shall be confirmed through pre-qualification process;

- Experiences of monorail system construction in his home country and overseas, at least 3 lines in total. The system quoted shall be under operation having operating length of 10km or more. Considering the basic requirements of public transportation system, the system shall have at least 20 years operation experience.
- The system quoted, at least one line, shall have a hilly terrain section similar to Panama Metro Line 3.
- Considering future renewal of rolling stock and turnouts, the Contractor/manufacturer shall have, at least, 30 years experience on the similar products.
- A proof or evidence of transportation capacity required in the performance specification.

- Technical standards applied in his home and overseas countries.
- Experiences and periods involved, directly or indirectly, in the monorail operation and maintenance services.
- Experiences of accidents and mechanical failures in the system quoted.
- Construction period of the quoted lines.

It is recommended to include the abovementioned items in the pre-qualification questionnaire.

(4) Confirmation of the new organization of SMP

It is necessary to coordinate with ACP for the implementation of the Project, and SMP has the capacity to play the role. On the other hand, as described in 8.6.2, SMP will be reorganized to Metro de Panamá, S.A., a 100% state- owned company. It is desirable that Metro de Panamá, S.A. will have established before the start of the Project, although there has been no particular activity as of July 2014. Since SMP or its successor will be the implementation body of the Project, its transformation should be monitored.

To start the Project in the early stage, the structure of the new organization should be confirmed and the new organization should be established as soon as possible.

21.2.2 4th Panama Canal Crossing Bridge

The Study Team recommends the following points to consider for the execution of the Project by SMP and for the operation and maintenance of facilities after completion of the Project.

- Approval of using navigation channel in erection works
- Detailed Design on the 4th Panama Canal Bridge and Approaches by SMP as a Design-Bid-Build Contract
- Detailed Study on Arch Bridge Erection Method
- Coordination with Metro Line 3 during detailed design and construction
- Improvement of Omar Torrijos Intersection for better connectivity of the 4th Panama Canal Bridge
- Approval of EIA Report
- Consideration of contract packaging
- Qualified firms through Pre-qualification process taking into consideration the high technologies and sufficient experiences

(1) Approval of Using Navigation Channel in Erection Works

The using of navigation channel in erection works is not approved yet by ACP at the time and it is necessary to obtain the approval based on this Draft Final Report.

(2) Detailed Design on the 4th Panama Canal Bridge and Approaches by SMP as a Design-Bid-Build Contract

The Client, SMP, would have to conduct the detailed design on the 4th Panama Canal Bridge and Approaches prior to the construction of the Project. The detailed design requires 18 months. The Study Team recommends that a wind-tunnel test be conducted in order to examine the stability of the structure and optimize the shapes, lines and sizes of the stiffening girders of the arch bridge. Since the lifting of the arch rib segment has no structures.

(3) Detailed Study on Arch Bridge Erection

Without precedence, the Study Team recommends that a mathematical model test (3D image) be conducted during the detailed design and if any weakness be found to strengthen the process to ensure stability in lifting and fixing the arch. Prior to the actual erection of the arch rib rifting works, a Full Size Test should be carried out in the vicinity of the erection site to confirm the function and capacity of the equipment to be used for the arch rib rifting method. Furthermore, the Study Team recommends that an alternative, simpler method be studied for the floating and swinging out of the fallen arch in the approach channel of the Panama Canal.

(4) Coordination with Metro Line 3 during Detailed Design and Construction

The road link of the 4th Panama Canal Bridge along with Approaches is an inner city road of 3 lane dual carriageway (6 lanes) with median strip in Panama City starting at the conjunction with the Corridor Norte at Albrook, then crossing the Panama Canal from Balboa Port on the eastern bank side to Arraijan on the western bank side about 6.72 km in length. The road/monorail combined section of 2.183 km consisting of the 4th Panama Canal Bridge and adjacent viaducts is multi-purpose bridge structures to carry the 6 lane road and the double track Metro Line 3.

The construction of the 4th Panama Canal Bridge and Approaches requires 48 months, of which last 6 months are regarded as overlapped working period for the bridge finishing works and installation works of Metro Line 3 infrastructures such as rails, electrical and mechanical facilities. Accordingly, well coordination between the 4th Panama Canal Bridge and Metro Line 3 Project is very essential.

(5) Improvement of Omar Torrijos Intersection for Better Connectivity of the 4th Panama Canal Bridge

The Study Team has conducted a concept design on the Improvement of the Omar Torrijos Intersection including new construction of an underpass to augment the traffic capacity for the north-south traffic flows in Panama City. The concept design of the Omar Torrijos Intersection Improvement was followed by micro-simulation analysis to assess the traffic movements in the morning peak hours. The micro simulation revealed that traffics from the 4th Panama Canal Bridge mainly flow toward the Av. Omar Torrijos Herrera in the intersection but volume of traffics toward the Corridor Norte is extremely low. Accordingly, it is confirmed through the micro-simulation analysis that the Improvement of Omar Torrijos Intersection is very obvious to provide better connectivity of the 4th Panama Canal Bridge Project.

Implementation of the project for the Omar Torrijos Intersection Improvement is essential in order to obtain better connectivity of the 4th Panama Canal Bridge. It is desired that the completion of the Omar Torrijos Intersection Improvement should be in the same time as the 4th Panama Canal Bridge.

(6) Approval of EIA Report

During this feasibility study, the JICA Study Team supported SMP in carrying out the EIA studies and preparing the draft EIA report, according to the Panamanian legal framework and JICA's Guidelines for Environmental and Social Considerations (2010).

In the months ahead, ANAM will review the EIA report. It should be noted by all parties that if ANAM requires any additional work, report revisions, or other conditions for approval of the EIA report, the Panamanian Government will be responsible for complying with ANAM and carrying out any additional work.

(7) Consideration of Contract Packaging

The geographical conditions are divided into east and west sides of the Panama Canal, and the eastern side is located in an urban area including intersections and existing roads. Since the only existing transportation network that connects the eastern and western sides in the vicinity of the Project is the Bridge of the Americas, a separate transportation route is needed for construction on the eastern and western sides.

Furthermore, the main construction works are road and bridge works, and various types of structures are included in the construction items and the construction of these structures needs to be implemented in parallel in a limited work space. Therefore, the construction yards and work schedule shall be adjusted each other to avoid the interference. By these reasons, one construction contract package was assumed for this Study, since this would allow a joint schedule management for the control and implementation of a unified project.

However, it is necessary to decide it by further hearing from construction companies in consideration of construction volume to ensure enough nos. of applicable bidders.

(8) Qualified firms through Pre-qualification Process taking into consideration the high technologies and sufficient experiences

International Competitive Bidding (ICB) will be adopted for the 4th Panama Canal Bridge and Approaches on the basis of the detailed design under the Owner’s Design Contract (Conventional Contract). Qualified firms through Pre-qualification Process, which have passed the evaluation criteria including the sufficient technologies and experiences, can participate in the ICB process. The following items might be considered in the evaluation criteria:

- Sufficient experience either in domestic or international projects in the similar bridge building projects
- Sufficient experiences to fabricate and construct solid-rib arch bridges
- Sufficient experiences in off-shore construction of bridges by using barge, including at least 3 projects experienced in the arch rib lift method
- Sufficient size and capacity of factories to fabricate the arch bridge elements within the designated time schedule by the Owner SMP, and sufficient staffing and equipment to be mobilized to the site

21.3 Recommendations on Project Operation Stage

21.3.1 Urban Transportation Line-3

The operating body of Line3 will be SMP (or its successor), which is currently operating Line-1. Maintenance work of rolling stock of Line 1 is outsourced to the manufacturer of the rolling stock of Line 1. Since the system of Metro Line 3 is different from Line 1, another maintenance system shall be formed. Considering the availability of the monorail technology, it is recommended to include the maintenance work and technology transfer for a certain period in the construction contract.

If it is difficult to include the maintenance work in the Contract, the maintenance work shall be outsourced in a similar way to Line 1. However, monorail operators in Japan are reluctant to participate in the overseas projects considering various risks. In order to encourage those experienced monorail operators, it will be effective to apply support from "Agency for Business Support for Overseas Transportation and Urban Development" which will be formed in near future. Anticipated risks can be decreased by the involvement of the agency.

There are very limited spaces available for railway related business in Line 1 premises because route length is relatively short (13.7km) and the route runs at busy urban area. On the contrary, route length of Line 3 is 25.8km at the beginning and exceeds 30km in the future. Since Line 3 runs mainly suburban and undeveloped areas, the potential for railway related business is very high. Therefore, it is recommended to have a division for property development in the new company for Metro operation. The followings are the example of railway related business;

- Advertisement within railway station and inside of cars
- Kiosks within stations
- Park & Ride facilities
- Station building development

In Japan, the average income from non-railway business is 10.5% of the total income of major 16 private railway companies.

21.3.2 4th Panama Canal Bridge

As with the First Bridge "Puente de las Américas" and the Second Bridge "El Puente Centenario", the maintenance and management entity for the civil engineering facilities in the Project is the MOP (Ministry of Public Works of Panama) while Land Transit and Transportation Authority (Autoridad del Tránsito y Transporte Terrestre, ATTT) is responsibility for traffic management and equipment maintenance.