ROAD DEVELOPMENT AUTHORITY
MINISTRY OF PORTS AND HIGHWAYS
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

Preparatory Survey on Traffic Improvement Project around New Kelani Bridge

FINAL REPORT

VOLUME 1: MAIN REPORT

DECEMBER 2013

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS CO., LTD.
KATAHIRA & ENGINEERS INTERNATIONAL

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The exchange rates applied in this Study are: USD 1.00 = LKR 132.4 = JPY 99.2 (November, 2013)

*LKR: Sri Lankan rupee

Side View of Main Bridge

View of Main Bridge from Existing Road

View of Approach Bridge of PC Box Girder from Existing Road

View of Approach Bridge of Steel Box Girder from Existing Road

Outline of the Project

1. **Country:** The Democratic Socialist Republic of Sri Lanka
2. **Project Name:** Traffic Improvement Project around New Kelani Bridge
3. **Execution Agency:** Road Development Authority under Ministry of Ports and Highways
4. **Survey Objectives:**

   The objective of this survey is to carry out all the requirements necessary to execute the Project in Japanese ODA Loan, such as defining the project objectives, and preparing project summary, project cost, implementation schedule, implementation method (procurement, construction), implementation plan, operation and maintenance management system, environment and social considerations, and so forth.

5. **Survey Contents:**

   [Stage 1] Review of Existing Conditions and Outline Design
      Fixing the alignment and bridge location
      Determination of the main bridge type
      Determination of the approach bridge type
   [Stage 2] Preliminary Design and Project Evaluation
      Preliminary design for selected alignment and bridge location
      Cost estimates
      Project evaluation
   [Stage 3] Reporting
      Preparation of the final report

6. **Conclusions and Recommendations:**

(1) Conclusions

- The Project is technically and economically feasible and environmentally sound.
- Hence, it is justified to implement the Project for national and people's benefits.
- The Project Road is comprised of the Main Line and the Port Access Road, and two roads are connected by a junction.
- The alignment of the Main Line begins at north of Orugodawatta Intersection and connects to CKE at end point.
- The alignment of the Port Access Road begins at Kelanithissa Junction and connects to existing port access road at end point
- Three types of bridge are constructed in the Project, namely, extra-dozed bridge for main bridge, steel box girder bridge above the existing road and for ramps, and PC box girder bridge along the existing road.

(2) Recommendations

- The master plan study for Colombo metropolitan region and the suburbs (CoMTrans) is going on now, and will be completed in April 2014. Some project will be proposed in Colombo as a result of the master plan. It is recommended that the design of this Project will be modified in the detailed design stage in consideration of the projects proposed by CoMTrans, if necessary.
- Public utilities such as waterworks, telephone line, electricity line, power line, etc. were identified based on the topographic survey and existing documents in the Preparatory Survey. The preliminary design was carried out in consideration of the information. However, it is recommended that detailed survey for the public utilities should be carried out in the detailed design stage, and the design will be reviewed based on the detailed survey result.
- It is recommended that RDA will undertake the tasks for the EIA and RAP during the entire project period in order to implement the Project successfully.
- It is recommended to inform the public of JICA Grievance Mechanism effectively.
- It is recommended that the information such as participants, opinions, etc. in further focus group discussions will be recorded in detail.

Preparatory Survey on Traffic Improvement Project around New Kelani Bridge

EXECUTIVE SUMMARY

1. INTRODUCTION

1.1 Background

The New Kelani Bridge, a 1,160m long, 6 traffic lane bridge located in the northern part of the capital city Colombo, is becoming a key link for transportation as the A01 Road connecting the city center to the 2nd largest city of the country, Kandy, the access road of Colombo Port; and the road connecting to A03 Road which is the access to the Bandaranaike International Airport are all connected to it.

Although three bridges, including the above mentioned bridge, are currently crossing the Kelani River, congestion has increased significantly in the past few years due to the traffic volume growth, affecting severely the economy. In addition, as further traffic congestion is expected from a new expressway connecting the Bandaranaike International Airport to this bridge that is planned to open in 2013, congestion reduction has become an urgent issue. Considering the above issues, the GOSL has requested in June 2012 the support from Japan to build a new bridge to improve traffic situation around New Kelani Bridge.

1.2 Objective of the Survey

Since the GOSL is requesting Japanese ODA Loan for the Traffic Improvement Project around New Kelani Bridge (hereinafter called the Project), the objective of this survey is to carry out all the requirements necessary to execute the Project in Japanese ODA Loan, such as defining the project objectives, and preparing project summary, project cost, implementation schedule, implementation method (procurement, construction), implementation plan, operation and maintenance management system, environment and social considerations, and so forth.

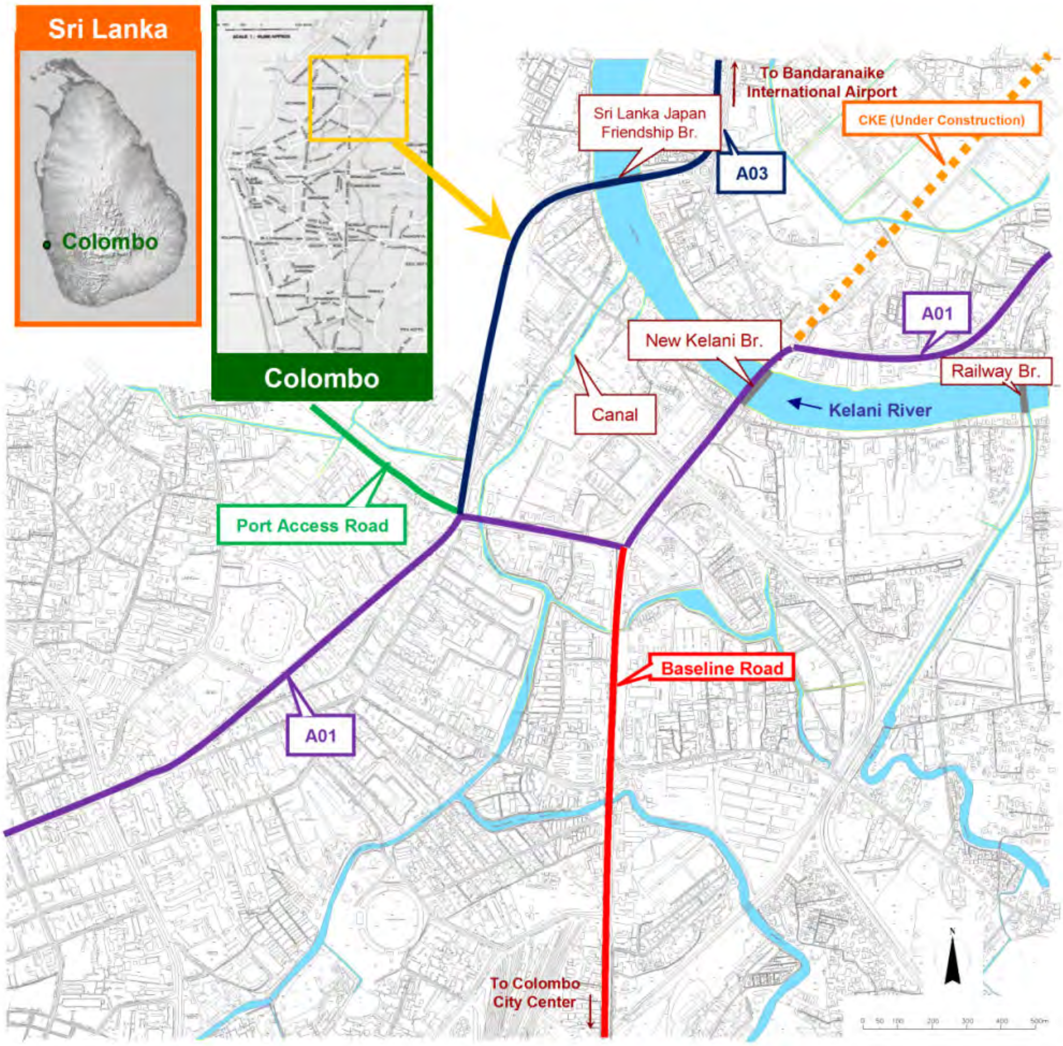
1.3 Survey Area

The location map of the survey area is shown in Figure S 1.3.1.

The survey area is divided into north area and south area by Kelani Rivier. This two areas are connected by two bridges, namely New Kelani Bridge and Sri Lanka Japan Friendship Bridge which is located at approximately 750 m downstream of New Kelani Bridge.

There are three arterial roads, namely A01 Road, A03 Road and Baseline Road, in this area. Therefore large volume of vehicles concentrates in this area at present. In addition, Colombo- Katunayake Expressway (CKE) connecting to New Kelani Bridge will open in 2013.

The area is highly urbanized, and many houses, building, shops, etc. are located along the roads. Large number of resettlements will be required in the Project.



Source: JICA Survey Team

Figure S 1.3.1 Survey Area

2. REVIEW OF THE PROJECT

2.1 Relevant Plan and Programs to New Kelani Bridge

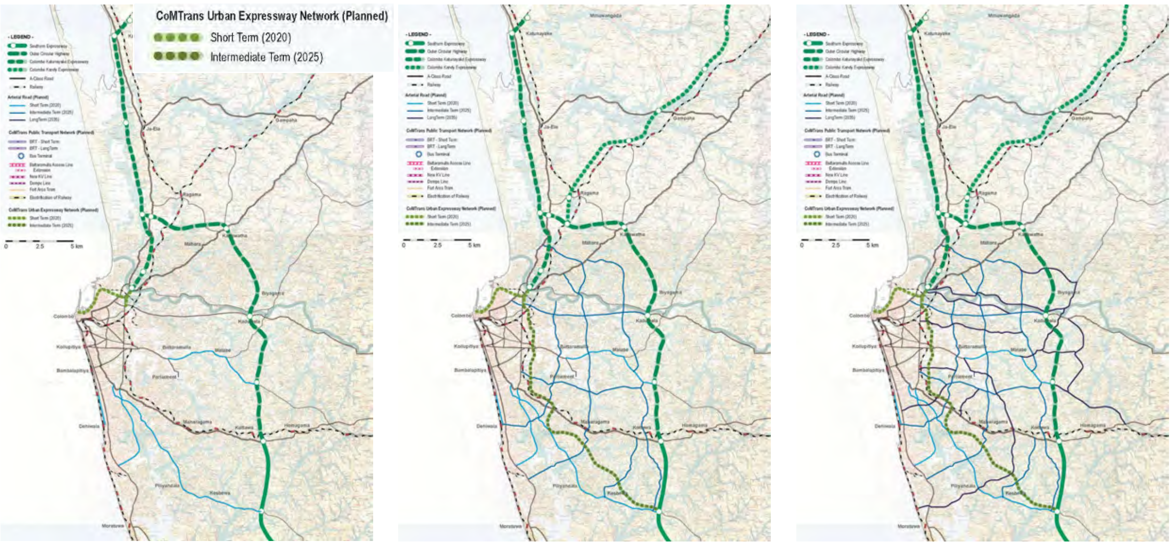
The JICA Survey Team reviewed several relevant plan and programs to New Kelani Bridge, such as, National Development Plan “Mahinda Chinthana”, Urban Transport System Development Project for Colombo Metropolitan region and Suburbs (CoMTrans) and National Road Master Plan (NRMP) 2007-2017 prepared by the Road Development Agency.

The CoMTrans has been conducting from the end of August 2012 by JICA. Since the urban transport master plan includes arterial road network development plan in the metropolitan area, it is important to integrate with the master plan in terms of role and function of roads in the new Kelani Bridge and roads in its surrounding area. The objectives of the CoMTrans are; a) to develop reliable transport database that can be utilised to formulate transport system development plans in a rational manner by conducting a metropolitan area-wide transport survey, b) to formulate an Urban Transport Master Plan for the Colombo Metropolitan area, and c) to conduct a pre-feasibility study on the prioritised project, with the target year of short-term (2020), intermediate-term (2025) and long-term (2035).

The JICA Survey Team reviewed the progress of the study. As of July 2013, the transport demand forecast model with future zone parameters are under developed with the results of Home Visit Survey and other transport surveys. In addition, the Colombo metropolitan area will be indentified based on the volume of commuting trips to the CMC area, and as the target area for providing urban transport system.

Future transport network consisting of not only road network but also public transport network has been prepared based on the analyses on the present transport condition as well as future perspective of the Colombo metropolitan area. It aims to develop well-integrated urban transport network with both roads and public transport mode.

On the Progress Report (1) submitted on May 2013, the CoMTrans Study Team prepared the network development plan for roads and public transport. The Figure S 2.1.1 shows the preliminary CoMTrans road network development plans for short, intermediate and long term.



Short Tem (by 2020) **Intermediate Term (by 2025)** **Long Term (by 2035)**

Source: JICA CoMTrans Study Team, Progress Report (1), May 2013

Figure S 2.1.1 CoMTrans Road Network Development Plan

The urban transport infrastructure, which should meet future incresed urban transport demand and alleviate traffic congestion, require to enough road network provision to ensure smooth accessibility to urban central area and to secure appropriate traffic volume capacity for each road.

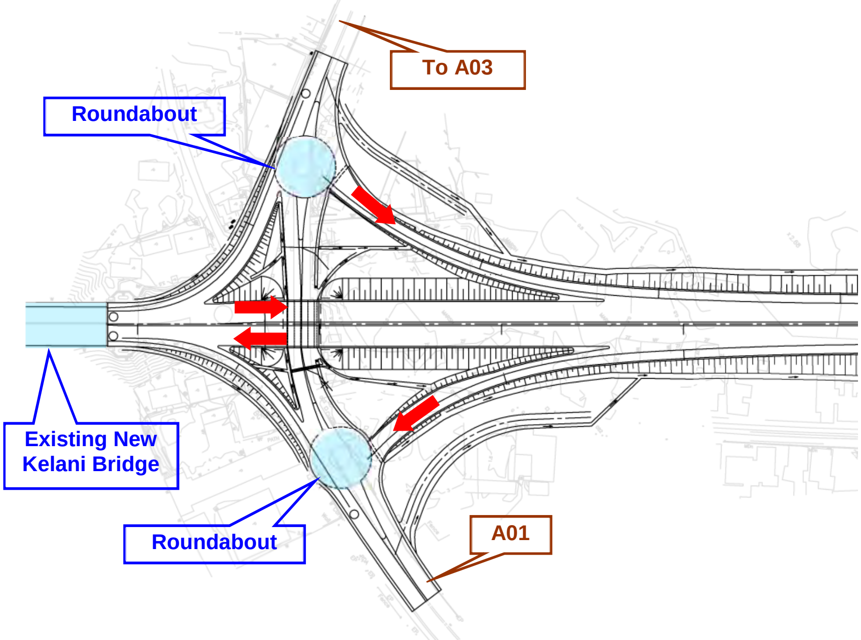
The Project Road, which is located at the end point of Colombo - Katunayake Expressway (CKE) to urban central area and concerned to occur the heavy congestion in the future, should be designed not only for alleviation of traffic congestion at this point but also with good connectibility and scalability to urban arterial road network proposed by CoMTrans.

2.2 Issues of Existing Road Conditions

Major issues of the existing road conditions are as follows.

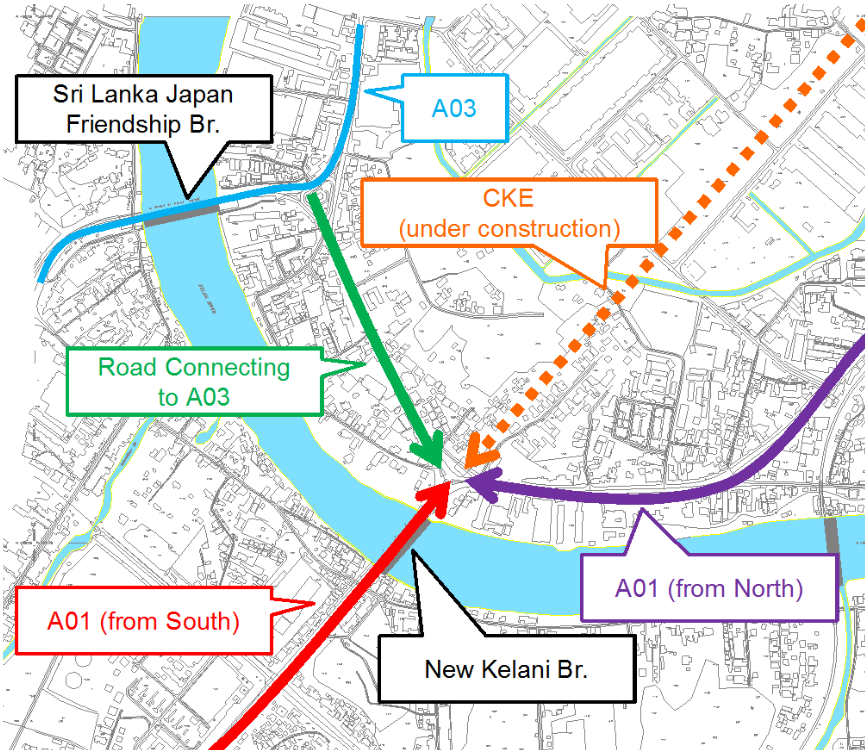
- Three bridges across the Kelani River have been always congested, especially in morning and evening peak hours, due to a high concentration of vehicles on the bridges.
- It is forecasted that traffic volume on the Kelani Bridge will increase and the Bridge will become a traffic bottleneck in this area, since some projects such as Colombo - Katunayake Expressway (CKE) (completed in 2013), Outer Circular Highway (OCH) (completed in 2015) and the expansion of existing Colombo Port (under planning) is under construction or planning.
- CKE is connected to the existing New Kelani Bridge, and ramps are connected to two adjacent roundabouts (see Figure S 2.2.1). Traffic congestion around New Kelani Bridge will be worsened since a large number of vehicles from CKE, A01 Road (from

north), the road connecting to A03 Road and A01 Road (from south) will concentrate in this small area (see Figure S 2.2.2).



Source: CKE Construction Project

Figure S 2.2.1 Area around CKE Endpoint

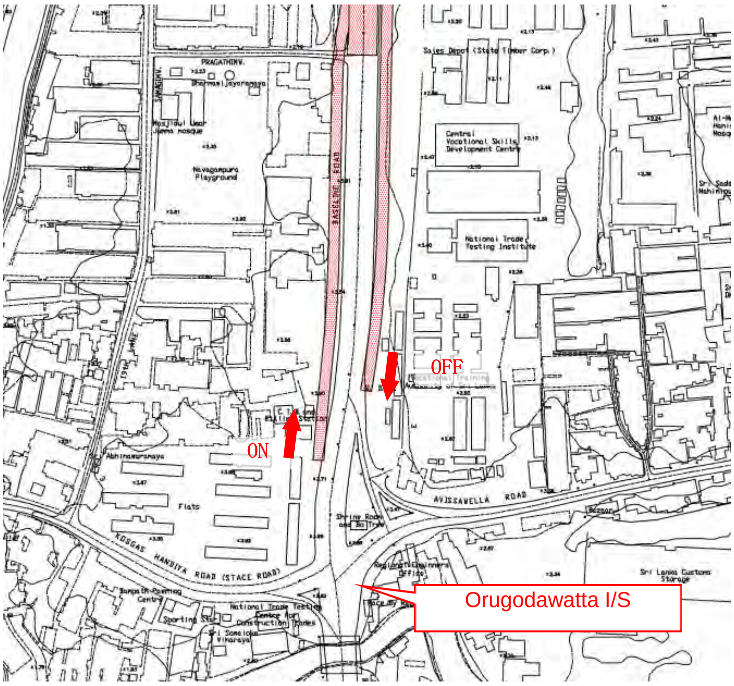


Source: JICA Survey Team

Figure S 2.2.2 High Concentration of Vehicles around New Kelani Bridge

- Traffic volume of the Baseline Road near Orugdawatta Intersection is 95,801 veh/day (89,833 pcu/day) in 2012. The traffic capacity on the Baseline Road, which has 6-lane carriageway, is not enough even in the present condition.

- The construction of the Second New Kelani Bridge and approach road (hereinafter called the Project Road) will be connected to the Baseline Road around the Orugodawatta Intersection through on/off ramps (see Figure S 2.2.3). Large volume of vehicles will flow into the Baseline Road, whose capacity is already overflowed, around the Intersection.



Source: JICA Survey Team

Figure S 2.2.3 On/Off Ramp on Baseline Road

2.3 Purpose of the Project

The purpose of the Project is to improve the traffic situation around New Kelani Bridge.

In order to accomplish the project purpose, the Second New Kelani Bridge and approach road (the Project Road) will be constructed. Traffic situation in this area will be improved by this Project, since the traffic capacity will increase to more than double.

On the other hand, the master plan study (CoMTrans) is being carried out by JICA. Future transport network plan including road, railway and public transportation network for Colombo metropolitan region and suburbs will be presented in this project. In addition, as a part of road network in Colombo metropolitan region, the urban arterial road network is expected to be proposed in the Study.

Alignment of the Project Road as well as the type of interchanges will be determined in consideration of the connectibility to the urban arterial road network and its scalability.

In addition, as stated in “2.6 Issues of Existing Road Conditions”, the traffic congestion in Baseline Road near Orugodawatta Intersection will worsen by the construction of the Project Road. Therefore, improvement of the Intersection will also be implemented in this Project.

3. TRAFFIC DEMAND FORECAST

The JICA Survey Team developed the linear regression model of passenger and freight separately, and forecasted the future traffic demand of the Project roads with future socio-economic framework based on updated observation traffic volume from the survey implemented in target area in 2013.

With the support of JICA, the “Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs (CoMTrans)” has been implementing the home visit survey (HVS) in the Western Province, and is developing the transport model based on the person trip information from HVS. After completion of home cisit survey and established the transport model, this model will be able to forecast the future demands of passenger and assignments to each transport network, including the existing roads, proposed public transport network and the expansion of the road network

Since the CoMTrans schedule is different from the one of this preparatory survey, it will be possible to verify the results of this traffic demands by the CoMTrans model later. Note that, as of the progress of CoMTrans on July 2013, the estimated future traffic demand by this survey is confirmed to be acceptable demand level in accordance with the CoMTrans directions.

Methodology of traffic demand forecast was used as follows;

- The JICA Survey Team collected previous traffic volume and conducted traffic count survey,
- After preparing the Socio-economic framework, simple linier regression model was developed with traffic volume data and socio-economic variables, and
- Based on the vehicle turning volume at each intersection, current OD traffic volume was estimated. The future OD volume was estimated by the linier regression model and applied network assumptions.

The estimated future traffic volume (2035) is as the table below. The traffic volume in the year of 2020 for the start of operation and that in the year of 2022 and other interval years are also estimated based on the traffic forecast in 2035.

Table S 3.1.1 Estimated Traffic Volume (Both Direction)

Unit: vehicle/day (truck and trailer)

Year/project with and without		New Kelani Bridge [Existing]	New Bridge [Elevated]	To Port Access		Baseline Road
				[Existing]	[Elevated]	
Current condition (2013)		92,700 (17,900)	N/A	27,100 (9,300)	N/A	86,400 (15,300)
2020 (start of operation)	With	67,000 (12,000)	51,600 (12,100)	34,100 (13,200)	10,200 (5,400)	107,200 (18,400)
	Without	118,600 (24,100)	N/A	44,300 (18,600)	N/A	107,200 (18,400)
2022 (two years after the operation)	With	67,900 (12,000)	58,100 (13,800)	35,800 (14,200)	11,800 (6,300)	113,400 (19,500)
	Without	126,000 (25,900)	N/A	47,600 (20,500)	N/A	113,400 (19,500)
2025	With	71,900 (13,100)	37,900 (16,100)	39,700 (16,200)	14,000 (7,800)	124,900 (21,400)
	Without	140,000 (29,200)	N/A	53,700 (24,000)	N/A	124,900 (21,400)
2030	With	73,500 (13,200)	83,500 (20,000)	43,700 (18,400)	17,600 (10,000)	139,300 (23,900)
	Without	157,000 (33,200)	N/A	61,300 (28,400)	N/A	139,300 (23,900)
2035	With	73,700 (12,900)	100,500 (24,400)	47,300 (20,500)	21,600 (12,300)	153,700 (26,300)
	Without	174,200 (37,300)	N/A	68,900 (32,800)	N/A	153,700 (26,300)

Source: JICA Survey Team

If the Project road (new bridge and elevated roads) is not implemented, the traffic demand in the direction to existing new Kelani Bridge (vehicle base) will be increased by 1.28 times in 2020 and 1.88 times in 2035, compared to the traffic demand in 2013. (If the Project road is implemented, the traffic volume will be decreased by 0.72 times and 0.79 times respectively.)

In order to examine the required number of lanes in the project road section, the PCU (one side at the peak hour) in 2035 is estimated based on the demand forecast. Table below shows the result of PCU in each section.

Table S 3.1.2 Estimated Future Peak Hour PCU in 2035

	New Kelani Bridge [Existing]	New Bridge [Elevated]	To Port Access		Baseline Road	
			[Existing]	[Elevated]	On/Off	Inflow to Intersection
2035	42,240 [3,800]	54,960 **[4,950]** **3 lane**[1]	35,880 [3,230]	16,850 **[1,520]** **2 lane**[2]	38,410 **[3,460]** **2 lane**	83,520 [7,520]

Source: JICA Survey Team

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[1] Applying the peak hour rate of 9%, the traffic demand in the main section at the peak hour is 4,950 PCU/hour, in the elevated section in the direction to port access is 1,520 PCU/hour and in the section of on/off ramp in direction to the Baseline Road is 3,460 PCU/hour.

[2] The capacity of multi-lane road is 2,000 PCU/hour/lane. The capacity of two lanes road for both directions is only 1,400 PCU/hour/lane.

4. OUTLINE DESIGN AND EVALUATION OF ALTERNATIVE OPTIONS

4.1 Selection of the Route

Four alternative routes were evaluated based on the multi-criteria.

Summary of evaluation is shown in Table S 4.1.1. As a result, “Alternative Route B” was selected as the most appropriate route for the Project Road from the following viewpoints.

- The Project Road is connected directly to CKE.
- Future scalability to the south is ensured.
- Port Access Road as a part of urban arterial road network is provided.
- Reduction of traffic congestion in the project area such as A1, A3 and Baseline Roads is expected.
- Environmental impact of Alternative B is smaller than that of other alternatives.
- Number of the affected structure is smallest among alternatives.

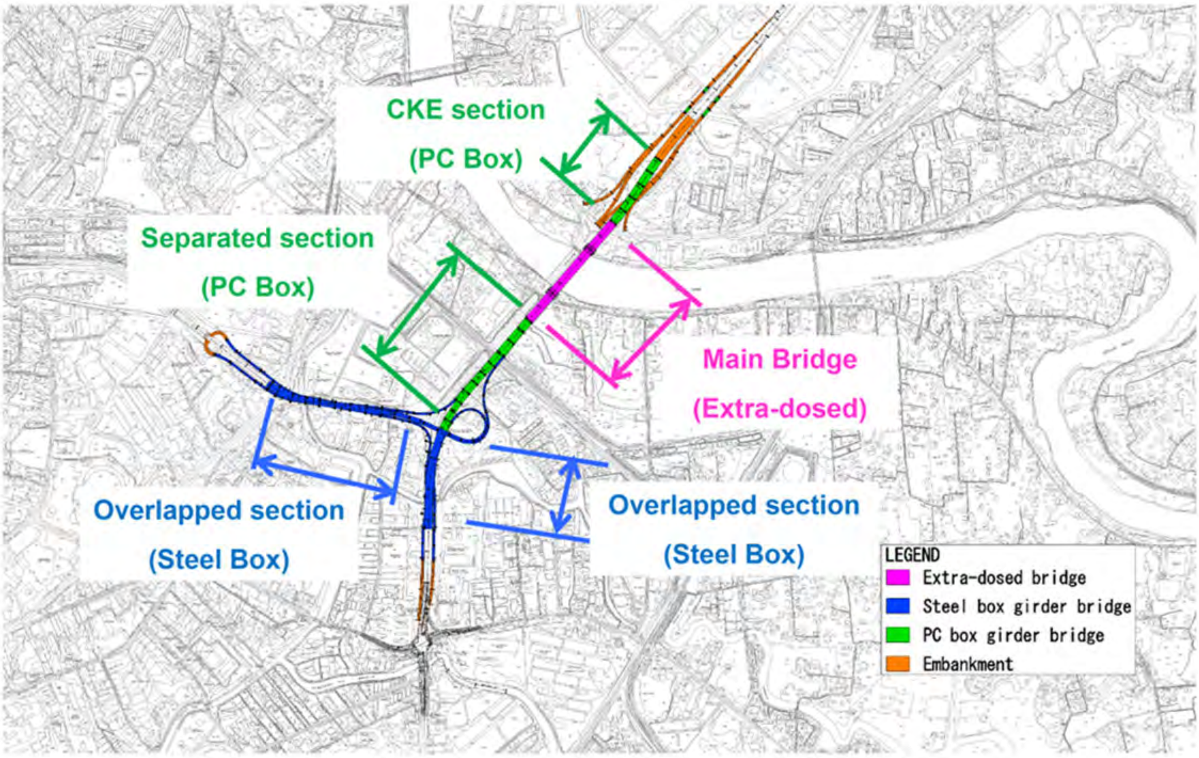
Table S 4.1.1 Evaluation of the Route

	Alternative A	Alternative B	Alternative C	Alternative D
Summary	• Main line: along the existing railway • Junction: Main line - CKE • On/off ramp: from/to Baseline Road	• Main line: along and above the existing road • Port access: above the existing road • Junction: Main line - Port Access Road • On/off ramp: from/to Baseline Road from/to port area	• Main line: above the existing canal • Port access: in the commercial area • Junction: Main line - CKE Main line - Port Access Road • On/off ramp: from/to Baseline Road from/to port area	• Main line: along the existing road and in new area • Port access: above the existing road • Junction: Main line - Port Access Road • On/off ramp: from/to Avissawella Road from/to port area
Plan View				
Length	• Main line: 2.2 km	• Main line: 1.6 km. • New Port Access Road: 0.7 km	• Main line: 2.3 km. • New Port Access Road: 0.5 km	• Main line: 2.0 km. • New Port Access Road: 1.4 km
Urban Arterial Road Network Plan	• The Project Road is connected to CKE by a junction (not directly). • Port Access Road as a part of urban arterial road network is not provided. • Future scalability to the south is ensured, but the distance would be longer (higher cost and increased land acquisition). Poor	• The Project Road is connected directly to CKE. • Port Access Road as a part of urban arterial road network is provided. • Future scalability to the south is ensured. Good	• The Project Road is connected to CKE by a junction (not directly). • Port Access Road as a part of urban arterial road network is provided. • Future scalability to the south is ensured, but the distance would be longer (higher cost and increased land acquisition). Poor	• The Project Road is connected directly to CKE. • Port Access Road as a part of urban arterial road network is provided. • Future scalability to the south is ensured, but the distance would be longer (higher cost and increased land acquisition). Poor
Traffic Congestion on Existing Traffic	• Reduction of traffic congestion in Baseline Road is expected since the vehicles running Baseline Road can easily access to the Project Road. • Reduction of traffic congestion in A01 (existing New Kelani Bridge and Roundabout at the end of CKE) is expected since most vehicles from/to CKE use the Project Road. • Reduction of traffic congestion in A03 road is limited in the project area, since the new road is far from A03 road. Fair	• Reduction of traffic congestion in Baseline Road is expected since the vehicles running Baseline Road can easily access to the Project Road. • Reduction of traffic congestion in A01 (existing New Kelani Bridge and Roundabout at the end of CKE) is expected since most vehicles from/to CKE use the Project Road. Good	• Reduction of traffic congestion in Baseline Road is expected since the vehicles running Baseline Road can easily access to the Project Road. • Reduction of traffic congestion in A01 (existing New Kelani Bridge and Roundabout at the end of CKE) is expected since most vehicles from/to CKE use the Project Road. Good	• Reduction of traffic congestion in Baseline Road is expected since vehicles moving towards the east side could use Project Road instead of Baseline Road. • Reduction of traffic congestion in A01 (existing New Kelani Bridge and Roundabout at the end of CKE) can be expected but is limited since only those moving to the east side would use Project Road. • Traffic congestion in Avissawella Road will worsen. Poor
Construction Cost	• 24,543 million RS • (0.89) Good	• 27,433 million RS • (1.00) Fair	• 30,590 million RS • (1.10) Poor	• 25,009 million RS • (0.91) Good
Construction Period	• 36 months Fair	• 36 months Fair	• 36 months Fair	• 36 months Fair
Constructability	• Traffic control is not required in Baseline Road during construction. Good	• Traffic control is required in Baseline Road during construction. Poor	• Traffic control is not required in Baseline Road during construction. • Construct of the viaduct in the existing canal is required. Fair	• Traffic control is not required in Baseline Road during construction. Good
Environmental Impacts	• Impact on noise and air quality will be increased along the Project Road since the Project Road will be newly constructed in residential and commercial area. Poor	• There is a possibility that impact on noise and air quality will be increased along the Project Road, although the Project Road will be constructed along and above the existing road Fair	• Impact on water quality of the existing canal will be created during construction. • Impact on noise and air quality will be increased along the Project Road since the Project Road will be newly constructed in residential and commercial area. Poor	• Impact on noise and air quality will be increased along the Project Road since the Project Road will be newly constructed in residential and commercial area. Poor
Social Impacts	• 355 structures including 12 large scale structures are affected. • Relocation of Automobile Engineering Training Institute is not required. Fair	• 325 structures including 4 large scale structures are affected. • Relocation of Automobile Engineering Training Institute is required. Fair	• 404 structures including 9 large scale structures are affected. • Relocation of Automobile Engineering Training Institute is not required. Fair	• 394 structures including 3 large scale structures are affected. • Relocation of Automobile Engineering Training Institute is not required. Fair
Evaluation		**Recommended**		

Source: JICA Survey Team

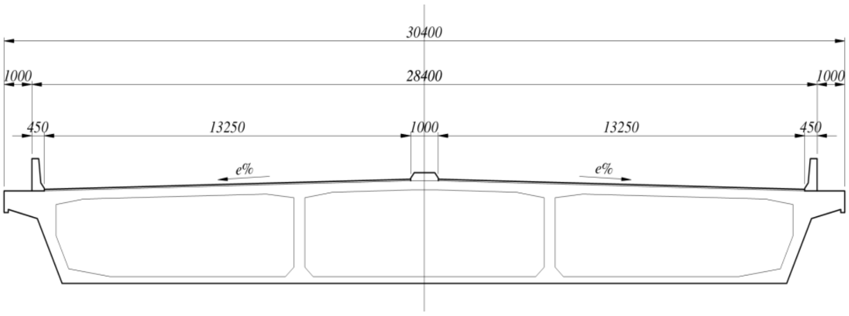
4.2 Selection of the Bridge Type

Bridge type in each section is shown in Figure S 4.2.1. Cross section of each bridge type is shown in Figure S 4.2.2 to 4.2.4.



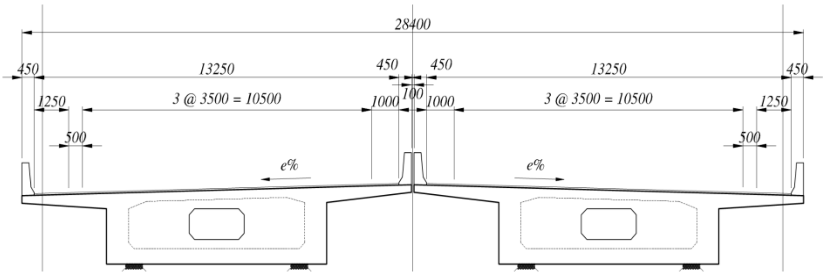
Source: JICA Survey Team

Figure S 4.2.1 Bridge Type in each Section



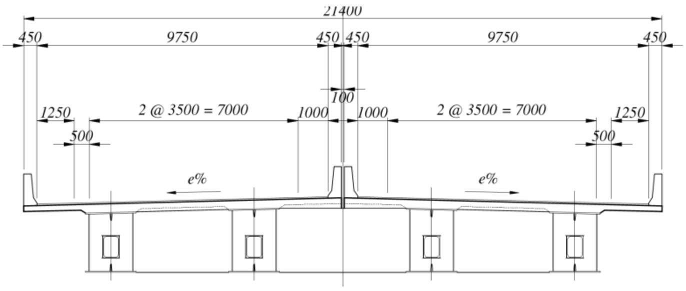
Source: JICA Survey Team

Figure S 4.2.2 Cross Section of Main Bridge (Extra-dosed Bridge, 6-lane)



Source: JICA Survey Team

Figure S 4.2.3 Cross Section of Approach Bridge (PC Box Girder Bridge, 6-lane)



Source: JICA Survey Team

Figure S 4.2.4 Cross Section of Approach Bridge (Steel Box Girder Bridge, 4-lane)

5. PRELIMINARY DESIGN

5.1 Road Design

5.1.1 Horizontal Alignment

Horizontal alignment of the Project Road is determined taking into account the following conditions.

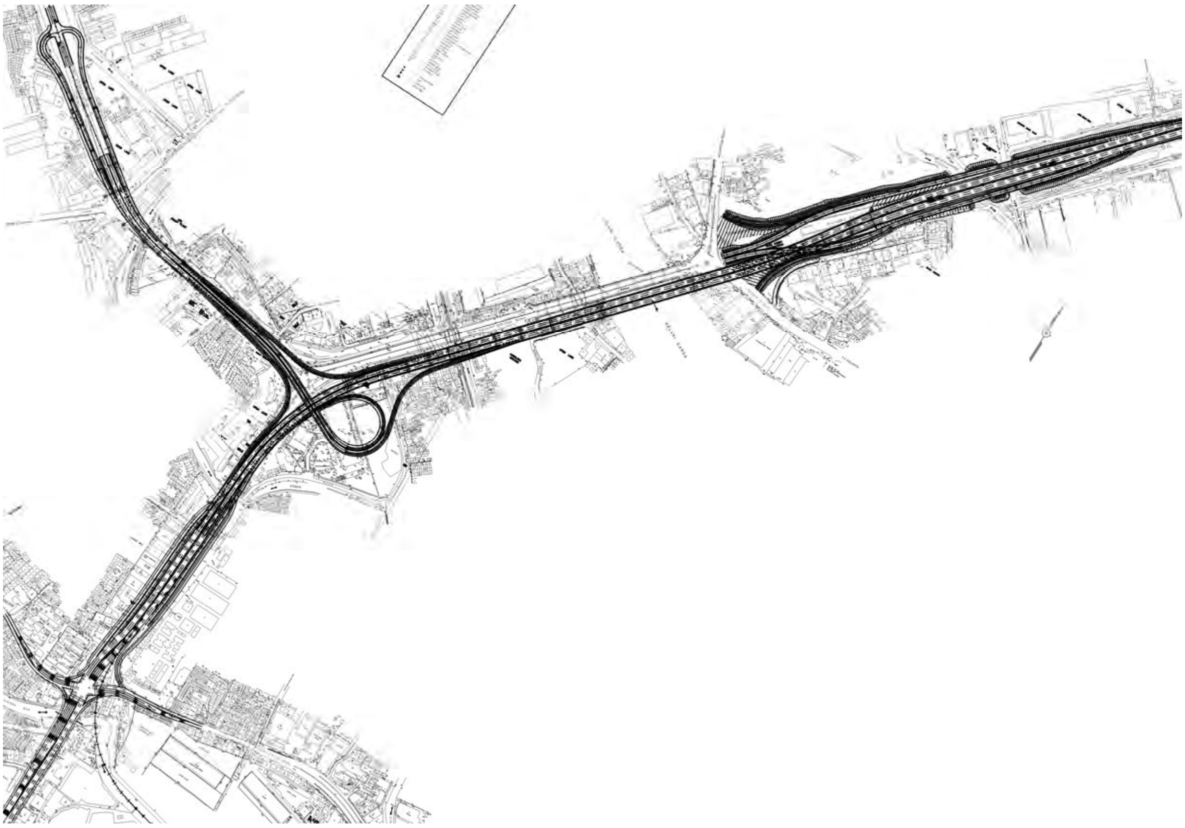
(1) Horizontal Alignment of the Main Line

- From the beginning point to Kelanithissa Junction, there are a large number of large scale buildings along the Baseline Road. Therefore, the alignment is set above the Baseline Road.
- From the Kelanithissa Junction to Kelani River, the alignment is set along the A01 Road to connect to 2nd New Kelani Bridge constructed close to existing New Kelani Bridge.
- 2nd New Kelani Bridge as a part of the Project Road is constructed upstream of the existing New Kelani Bridge closely.
- The end point of the alignment is connected to CKE using S-curve.

(2) Horizontal Alignment of the Port Access Road

- The alignment is set above the A01 Road to reduce the impact to houses, commercial building, power plant, etc. along the A01 Road as much as possible.

Horizontal alignment of the Project Road is shown in Figure S 5.1.1.



Source: JICA Survey Team

Figure S 5.1.1 Horizontal Alignment of the Project Road

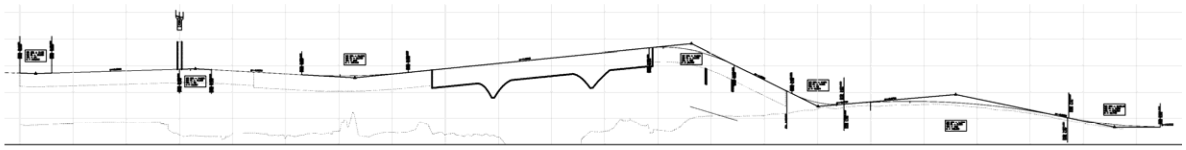
5.1.2 Vertical Alignment

Vertical alignment of the Project Road is determined taking into account the following conditions.

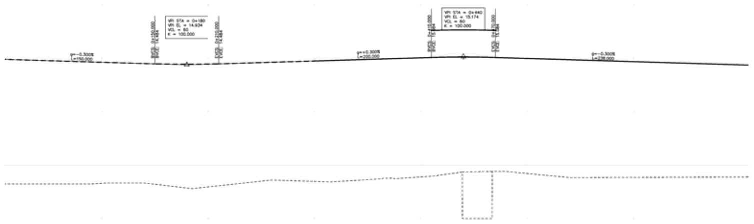
- Vertical clearance of the existing road under the Project Road is 5.1m.
- In addition to 5.1m of clearance, at least 1.0m of additional space under the bridge is provided so that bridge maintenance such as repainting can be carried out without interrupting the existing traffic.

Vertical alignment of the Project Road is shown in Figure S 5.1.2.

(1) Main Line



(2) Port Access Road



Source: JICA Survey Team

Figure S 5.1.2 Vertical Alignment of the Project Road

5.2 Bridge Design

As a result of preliminary design, bridge type and length were summarized as below;

- The Project Road, Main Line
  - Main Bridge (L=380 m): Extra-dozed
  - Approach Bridge (L=625 m): PC Box Girder
  - Approach Bridge (L=425 m): Steel Box Girder

- The Project Road, Port Access Road

  Steel Box Girder (L=390 m)

- Interchange and Junction

  Steel Box Girder (L=1,998 m)

Computer graphics of major bridges are shown below,

Source: The Pre-Preliminary Design (2012)

Figure S 5.2.1 Side View of Main Bridge

Source: The Pre-Preliminary Design (2012)

Figure S 5.2.2 View of Main Bridge from Existing Road

Source: JICA Survey Team

Figure S 5.2.3 View of Approach Bridge of PC Box Girder from Existing Road

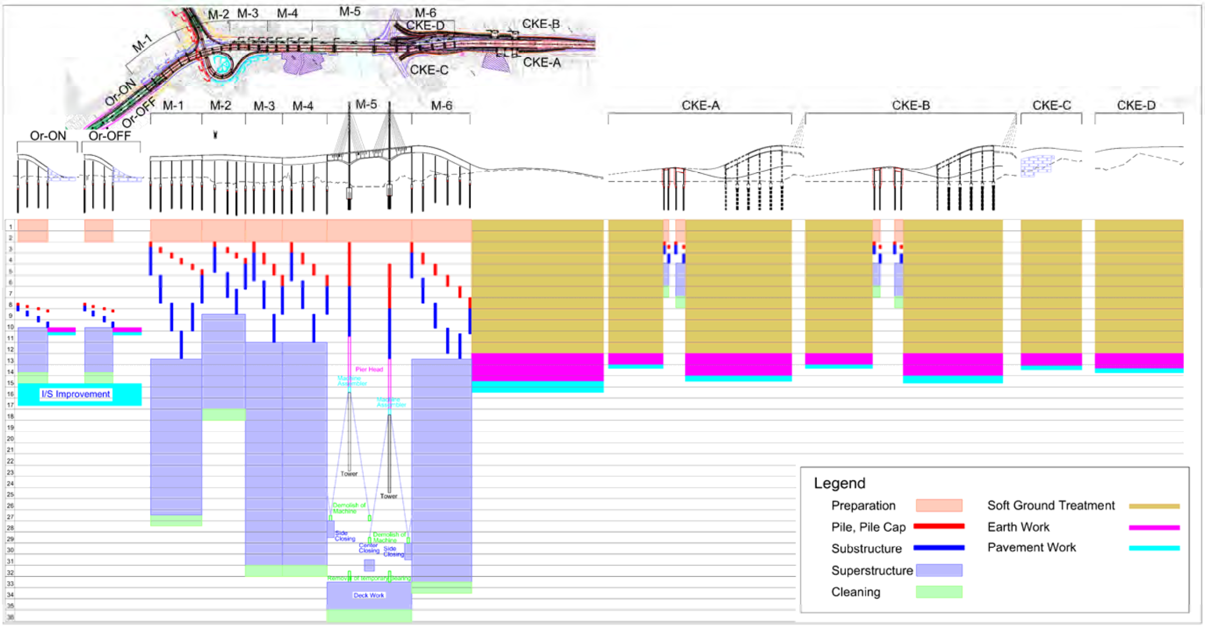
Source: JICA Survey Team

Figure S 5.2.4 View of Approach Bridge of Steel Box Girder from Existing Road

6. CONSTRUCTION PLAN

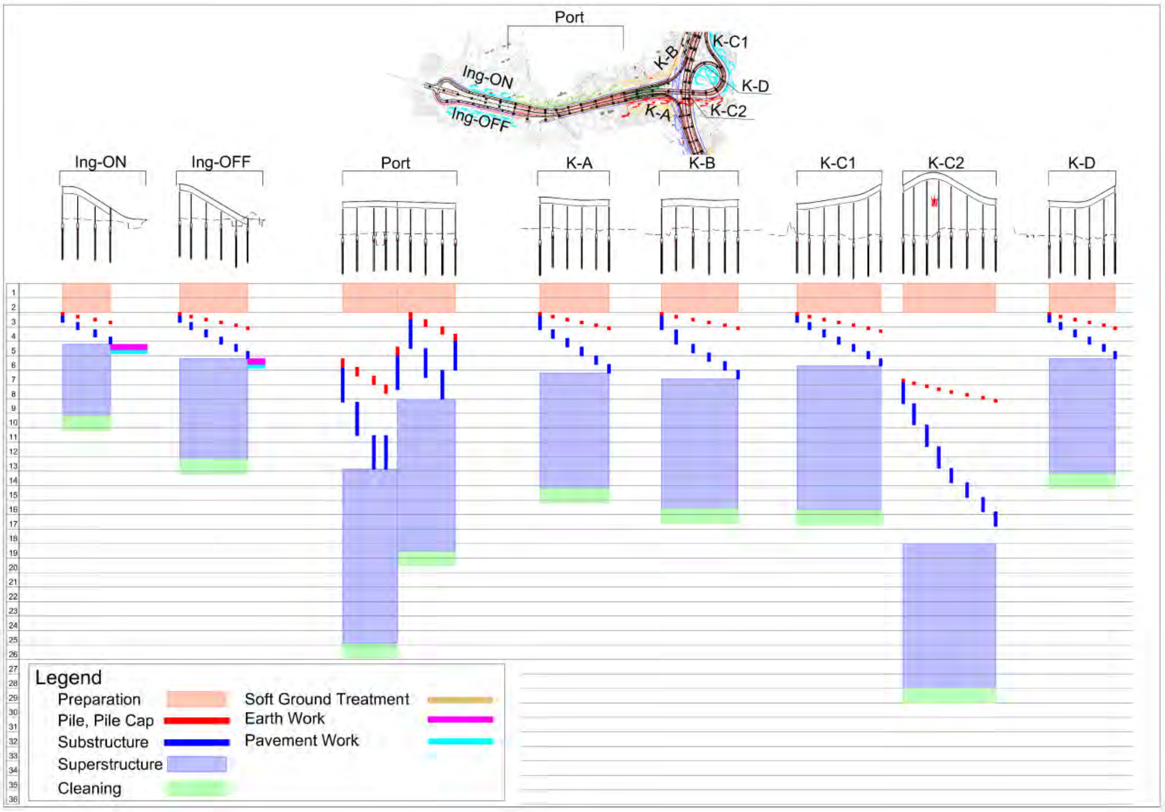
6.1 Construction Schedule

The construction period for the Project is 36 months due to the construction of the Extradosed Bridge. The construction schedule for Main Road, Port Access Road and each Interchange (I/C) Ramp is shown in Figure S 6.1.1 and Figure S 6.1.2 respectively.



Source: JICA Survey Team

Figure S 6.1.1 Construction Schedule for Main Road and Orugodawatta and CKE I/C



Source: JICA Survey Team

Figure S 6.1.2 Construction Schedule for Port Access Road and Kelanitissa I/C

7. OPERAION AND MAINTENANCE PLAN

Following Inspection and Maintenance shall be conducted in order to maintain New Kelani Bridge in sound conditions to sustain smooth and safe traffic flow

◆ Inspection

1) Routine inspection

In order to get to know the current situation of the structures, routine inspection is undertaken visually from road patrol on the shoulder or left-most lane.

2) Periodic inspection

In order to grasp the overall status of the structure, visual inspection from a short distance, prior to initiating inspection works and several field works are undertaken

3) Non periodic inspection (if necessary)

Beyond the daily inspection, sometimes an additional inspection is necessary if any structural damage is suspected to be caused by severe weathering action.

◆ Maintenance

1) Routine maintenance

Routine maintenance includes road cleaning, Localized repairs of pavement, repainting of road markings, repairing and replacing of road signs, lighting and guardrails.

2) Periodic maintenance

Periodical maintenance includes pavement resurfacing, repainting girder, replacement expansion joints, bearing and stay cables.

3) Emergency maintenance

Emergency maintenance should be undertaken when the urgent repair of the road structure damaged by natural disasters or large-scale accidents is required.

8. COST ESTIMATES

8.1 Total Project Cost

The total project cost that includes construction, consulting services, environment monitoring, RAP implementation, physical contingencies, price escalation, VAT and others is estimated at JPY 44,465 million.

Table S 8.1.1 Total Project Cost

Breakdown of Cost	Foreign Currency Portion (million JPY)			Local Currency Portion (million LKR)			Total (million JPY)		
	Total	JICA Portion	Others	Total	JICA Portion	Others	Total	JICA Portion	Others
Civil Works	8,289	8,289	0	24,119	24,119	0	26,355	26,355	0
Price Escalation	413	413	0	1,203	1,203	0	1,314	1,314	0
Physical Contingency	870	870	0	2,532	2,532	0	2,767	2,767	0
Consulting Services	2,456	2,456	0	2,102	2,102	0	4,031	4,031	0
Dispute Board	12	12	0	0	0	0	12	12	0
Land Acquisition	0	0	0	3,576	0	3,576	2,678	0	2,678
Administration Cost	0	0	0	3,969	0	3,969	2,973	0	2,973
Tax	0	0	0	5,522	0	5,522	4,136	0	4,136
Interest during construction	131	131	0	0	0	0	131	131	0
Front-end Fee	69	0	69	0	0	0	69	0	69
Total	12,241	12,172	69	43,023	29,957	13,066	44,465	34,610	9,856

Source: JICA Study Team

8.2 Goods and Services Procured from Japan

This Project is expected to apply STEP scheme. Therefore, the ratio of goods and services procured from Japan is estimated in this Study.

The procurement ratio from Japan is shown in Table S 8.2.1.

Table S 8.2.1 Procurement Ratio from Japan

Construction Cost	26,355 (million JPY)	
Goods and Services Procured from Japan		
PC-Cable for Extradosed Bridge	274	1.04%
Steel Girder	6,556	24.88%
Steel Pier	1,521	5.77%
Composite Slab	1,309	4.97%
Anchor Bolt	62	0.24%
VMS (Variable Messaging Sign)	64	0.24%
General Administrative Overheads	1,903	7.22%
Total	11,688	44.35%

Source: JICA Study Team

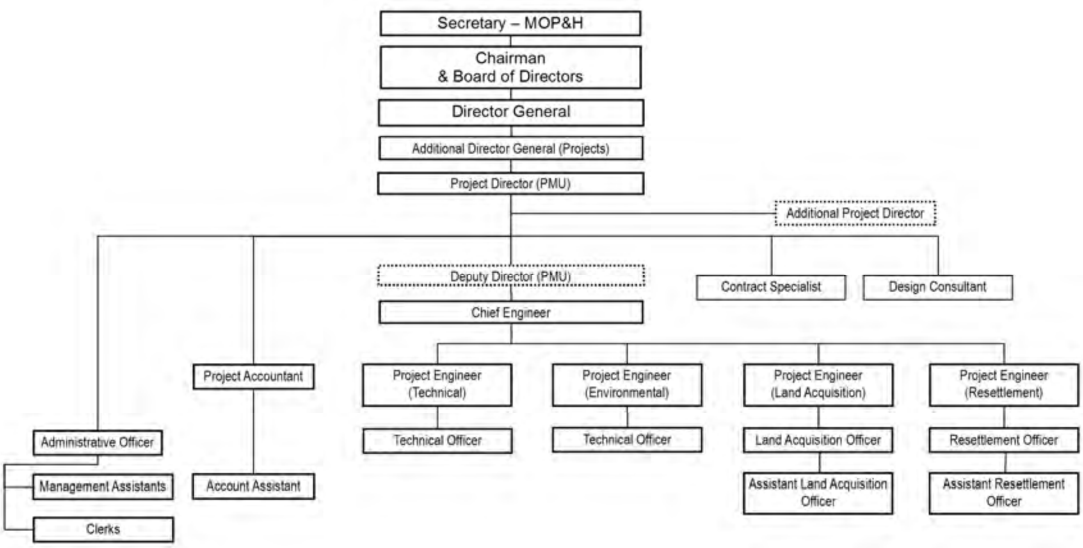
9. IMPLEMENTATION PLAN

9.1 Implementation Organization

The project organization will be organized so that the GOSL can implement the Project smoothly and effectively as well as coordinate with project stakeholders.

It is recommended that the Project Management Unit (PMU) for the Project will be organized under the Ministry of Ports and Highways (MOPH).

The proposed organization of PMU is shown in Figure S 9.1.1.

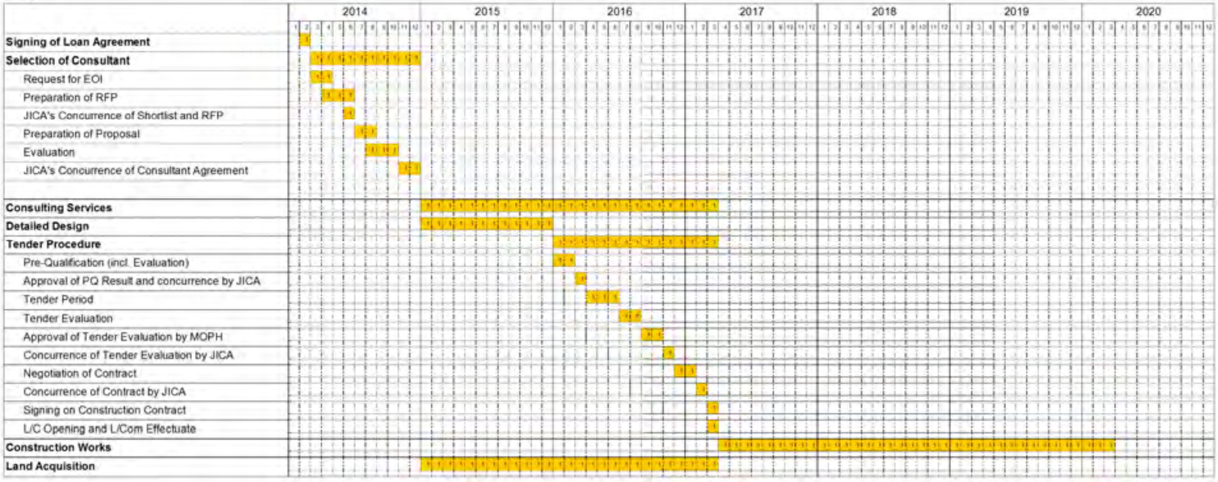


Source: JICA Survey Team

Figure S 9.1.1 Organization of Project Management Unit (PMU)

9.2 Implementation Schedule

It is assumed that International Competitive Bidding (ICB) is applied for procurement of contractor and consultant for the Project. The time required for the procurement is assumed based on the procedures for a financing scheme of Japanese ODA Loan. Implementation schedule for the Project is shown in Figure S 9.2.1.



Source: JICA Survey Team

Figure S 9.2.1 Implementation Schedule

10. PROJECT BENEFITS

In order to understand the project effect of this Project, it is necessary to estimate the effects of improvements at spot area/ road sections quantitatively. Therefore, the JICA Survey Team recognized that a micro-scopic traffic simulation would be appropriate for this purpose because it enable to forecast and examine how the traffic improvement at spot area will be effective or not. This simulation can also evaluate whether the expressway connected to urban area can secure the smooth traffic flow or not with planed connection method and traffic/lane management.

The alignment and traffic/lane management of the current condition was set up based on the results of previous study results, drawings, and the survey results of traffic/lane management and conditions at site. The current traffic volume for every 15 minutes at each intersection is also inputted into the simulator. After the validation of traffic model compared among observed traffic volume and simulated traffic volume, the simulation was conducted for four cases and acquired the results in the table below.

Table S 10.1.1 Simulation Results for each Cases at 8:00 hour's Morning Peak in the Direction towards the City Center

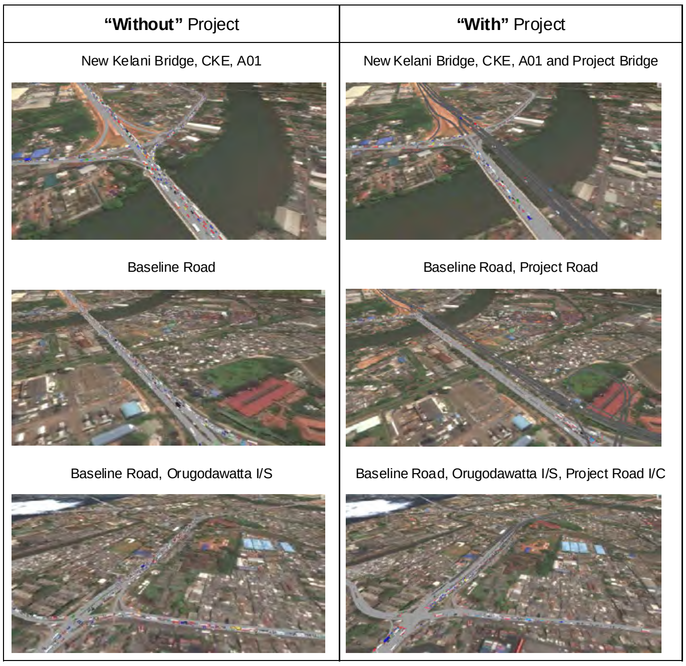
Year With/Without Project		Average Speed (km/h)			Travel Time from 4th mile Post on A01 road to Orugodawatta Intersection (min.),(approx. 2.0 km)
		New Kelani Bridge (Current Bridge)	Project Section [Elevated]	Baseline Road	
Present year of 2013		18.0	N/A	13.6	7.7
2020	With	45.5	42.4	21.3	3.5
	Without	9.4	N/A	5.2	19.1
2035	With	45.5	16.9	17.8	4.1
	Without	3.5	N/A	8.9	44.6

Source: JICA Survey Team

The future traffic conditions around the new Kelani Bridge in the year of 2020 are simulated in the both case of "with the project" and "without the project" and examined by 3D animation. The results of this simulation are summarised as follows;

- In the case of "without the project" in year of 2020, the traffic condition which merges the flow from the CKE and interflow from A01 road is over capacity around the new Kelani Bridge (existing bridge). This causes the traffic congestion at the roundabout and the intersection at Kelanitissa Junction is also over capacity. Especially the future traffic managements at two small roundabouts near the roundabout may cause serious traffic congestion to North bound due to limited traffic capacities.

- In the case of “with the project” in the year of 2020, because there are options to use both existing road and the Project road and reduce the frictions at intersections, the traffic becomes smoothly distributed to Project road and the existing bridge. Therefore, the traffic congestion is not seen at the same point. The figure below shows the comparison of simulated traffic conditions between “without” project and “with” project. Both are simulation results after inputted same number of traffic volume in the whole of network in the peak hour.



Source: JICA Survey Team

The economic benefits to be achieved by implementation of the project are defined as the difference of vehicle operation costs (VOC) and passenger travel time costs (TTC). The annual total benefits are estimated by developed micro-scopic traffic simulator.

Table S 10.1.2 Project Benefits

Unit: Rs million /year (2013 Economic Price)

Benefits Year	Reduction of Travel Time Costs (TTC) (Rs./year)	Reduction of Vehicle Operation Costs (VOC) (Rs./year)	Benefits in total (TTC+VOC) (Rs./year)
2020	2,879.20	982.09	3,861.29
2035	12,965.45	723.32	13,688.78

Source: JICA Survey Team

11. ECONOMIC EVALUATION

11.1 Purpose and Methodology of Economic Evaluation

The main purpose of economic evaluation for the project is to evaluate the economic validity of project implementation. Economic internal rate of return (EIRR), net present value (NPV), and benefit-cost ratio (B/C ratio) will be used to evaluate the economic evaluation results as evaluation indicators.

11.2 Basic Assumption

The following basic assumptions are set up for the economic evaluation

- Project life: 21 years after the start of construction (until the target year of the long-term plan in CoMTrans)
- Implementation schedule: Construction period from 2017 to 2020. Begin operation from 2020.
- Residual value: An undepreciated cost will be earmarked as a negative investment cost in the last year of evaluation 2035.
- Opportunity cost (discount rate): 12%
- Inflation: no consideration in economic evaluation
- Exchange rate: USD1=JPY.99.2, USD1=Rs.132.4, Rs.1 =JPY0.749

11.3 Costs and Benefits

11.3.1 Economic Price

For the economic evaluation, financial costs are converted to economic costs by deducting the tax and subsidies portion, and applying a standard conversion factor (SCF) to the portion of non-trade goods. SCF was estimated 0.972 which was average value from 2008 to 2011, and applied to the local portion of costs in order to adjust the price.

11.3.2 Economic Costs (Construction costs and operation and maintenance costs)

The construction costs of the project and the operation and maintenance costs are shown as follow.

Table S 11.3.1 Construction costs of the Project

(2013 Economic Price)

Breakdown of Cost	Foreign/C JPY	Local/C LKR	Total Financial Cost LKR	Total Economic Cost LKR
Civil Works	8,289	24,119	35,187	34,511
Price Escalation	413	1,203	1,754	552
Physical Contingency	870	2,532	3,694	0
Consulting Services	2,456	2,102	5,381	5,323
Dispute Board	12	0	16	16
Land Acquisition	0	3,576	3,576	3,476
Administration Cost	0	3,969	3,969	3,858
Tax	0	5,522	5,522	0
Interest during construction	131	0	175	175
Front-end Fee	69	0	92	92
Total	12,241	43,023	59,366	48,002

Source: JICA Survey Team

Table S 11.3.2 Operation and Maintenance Cost

Unit: Rs. Million

Items		Interval	Financial Cost	Economic Cost
Routine Maintenance		Every year	1.37	1.34
Highways				
	Periodic Inspection	Every year	0.16	0.15
	Pavement	10	383.39	372.65
Steel Bridge				
	Periodic Inspection	5	0.16	0.15
	Painting	20	43.60	42.38
	Expansion Joint	20	267.86	260.36
PC Bridge				
	Periodic Inspection	5	0.16	0.15
	Expansion Joint	20	236.71	230.09
	Bearing	40	380.88	370.22
Extradosed Bridge				
	Periodic Inspection	5	0.16	0.15
	Expansion Joint	20	86.09	85.12
	Bearing	40	27.60	26.83
	PC Cable	75	1,114.88	1,090.89

Source: JICA Survey Team

11.3.3 Economic Benefits

The estimation of project benefits is described in 10.3.3.

11.4 Cost Benefit Analysis

EIRR shows 13.6% which is over the opportunity cost 12% and NPV is positive. It means that the project implementation is assessed the economic validity from the view point of national economy.

Table S 11.4.1 Summary of Cost Benefit Analysis

Indicator	Result
EIRR	13.6%
B/C (at discount rate of 12%)	1.56
NPV (LKR million, at discount rate of 12%)	15,973

Source: JICA Survey Team

Table S 11.4.2 Cash Flow of Cost Benefit Analysis

Unit: LKR million (2013 Economic Price)

Year	Yrs after ope.	Cash - Out			Cash - In			Net Cash Flow
		Investment	O&M	Total	VOC	TTC	Total	
2013				0			0	0
2014				0			0	0
2015	1	1,534		1,534			0	-1,534
2016	2	1,530		1,530			0	-1,530
2017	3	24,011		24,011			0	-24,011
2018	4	12,913		12,913			0	-12,913
2019	5	5,344		5,344			0	-5,344
2020	6	446	1.5	447	982	3,037	4,019	3,572
2021	7	2,226	1.5	2,227	965	3,847	4,812	2,585
2022	8		1.5	1	947	4,689	5,637	5,635
2023	9		1.5	1	930	5,565	6,495	6,494
2024	10		1.9	2	913	6,476	7,389	7,387
2025	11		1.5	1	896	7,424	8,319	8,318
2026	12		1.5	1	878	8,409	9,287	9,286
2027	13		1.5	1	861	9,433	10,295	10,293
2028	14		1.5	1	844	10,499	11,343	11,342
2029	15		374.6	375	827	11,607	12,434	12,059
2030	16		1.5	1	809	12,760	13,569	13,568
2031	17		1.5	1	792	13,959	14,751	14,749
2032	18		1.5	1	775	15,205	15,980	15,979
2033	19		1.5	1	758	16,502	17,259	17,258
2034	20		1.5	1	740	17,850	18,591	18,589
2035	21	-23,217	1.5	-23,216	723	19,253	19,976	43,191
Total		24,785	397	25,182	13,640	166,517	180,157	154,974
NPV		31,711	189	28,711	8,207	79,993	44,685	15,973
B/C		discount rate 12%						1.56
EIRR								13.6%

Source: JICA Survey Team

11.5 Sensitivity Analysis

Sensitive analysis for a 10% increase in project cost as well as a 10% decrease in estimated benefits is implemented. The case of a 10% decrease in estimated benefits shows the value over the opportunity cost 12.0%

Table S 11.5.1 Results of Sensitive Analysis

	Base	Benefit -10%	Cost +10%	Benefit -10% & Cost +10%
EIRR	13.6%	12.5%	11.9%	11.5%

Source: JICA Survey Team

11.6 Operation and Effect Indicators

11.6.1 General

Operation and effect indicators are used to evaluate the performance of facilities, the effectiveness of the functions of the Project, and the efficiency of operation and maintenance activities after the Project implementation.

11.6.2 Operation and Effect Indicators

The definitions of operation and effect indicators are as follows

1) Operation indicator: An indicator to quantitatively measure the operational status of a project.
2) Effect indicator: An indicator to quantitatively measure the effects generated by a project.

In order to evaluate the achievements of the Project quantitatively, the benchmarks of operation and effect indicators are set up based on the current available data. The target sections for the observed traffic volume (baseline) are selected as the following three main lines. The year of monitoring and evaluation for the Project is 2 years after the operation of the Project in 2022.

A. New Kelani Bridge (Peliyagoda Roundabout JCT – Kelani Thissa Powerstation)
B. Project Section (Elevated)
C. Base Line (Kelani Thissa Powerstation – Orugodawatta I/S)

Table S 11.6.1 Operation and Effect Indicators (Proposal)

Indicator		Section	Current (2013)	2 years after operation (2022)
Operation	Traffic Volume (vehicle/day)	Cross-section at New Kelani Bridge (in total) 2013: New Kelani Bridge Only 2022: New Kelani Bridge and Project Road	92,700	126,000 (67,900+58,100)
Effect	Traffic Volume (vehicle/day)	Cross-section at New Kelani Bridge (in total) 2013: New Kelani Bridge Only 2022: New Kelani Bridge and Project Road	92,700	126,000 (67,900+58,100)
	Traveler's Time at morning peak hour at 8:00 am (minutes)	From Peliyagoda Roundabout JCT – Orugodawatta I/S (approx. 1.3km) *	5.8	2.0
	Average speed at morning peak hour at 8:00am (km/hour)	From Peliyagoda Roundabout JCT – Orugodawatta I/S (approx. 1.3km) **	18.0	New Kelani Bridge 40.0 Project Road 40.0

*: While the route of "Current (2013)" runs on New Kelani Bridge and Baseline road, the route of "2 years after operation (2022)" runs through the CKE direct connection, the Project roads and off-ramp to Baseline.

Source: JICA Survey Team

12. ENVIRONMENTAL IMPACT ASSESSMENT

12.1 General

The EIA report was prepared on the basis of proposed engineering works, field study, stakeholder consultation, primary and secondary data collection, screening of all baseline environmental items, existing environmental quality measurement, and review of the relevant EIA and IEE report in Sri Lanka. The study of taken up during February to June, 2013.

The EIA covers the general environmental profile of the Project area including physical environment, biological environment and socio-cultural environment. The existing environment quality measurement was carried out on the water (surface and ground), air quality, noise, vibration, flora & fauna. The EIA includes an overview of the potential environmental impacts and their assessment, and propose necessary mitigation measures and an environmental management plan for each of the identified impacts. And more, two times of stakeholder meetings were conducted as he part of the EIA.

The EIA report has been prepared based on the Terms of Reference (ToR) issued by the Central Environmental Authority (CEA), 05.03, 2013, while conforming to the JICA Guidelines for Environmental and Social Considerations, April.2010.

12.2 Environmental Impacts

Environmental impact is defined as any change from the existing condition to the condition of "with Project". However, it is defined as the difference of impact between "with Project" and "without Project" for global warning, since it is difficult to measure existing CO2 emission from whole project area, and impact on global warming is generally evaluated by comparing the difference between "with Project" and "without Project". The findings of the assessment are presented according to before construction, during construction and operation stage. The impact will be determined the rating score, positive and negative.

Table S 12.2.1 Environmental Impacts

Impact Theme	**Impact Rating**		**Reasons for attributed impact rating**
	Pre-Construction or Construction	**Operation**	
Socio Economic			
Land acquisition and resettlement	A-	D	**Pre-Construction or Construction** The number of affected dwellings and small business structure within the proposed ROW and service corridor are 449 and demolition/resettlement causes significant negative impacts. **Operation** No operational impact

Impact Theme	Impact Rating		Reasons for attributed impact rating
	Pre-Construction or Construction	Operation	
Livelihood and economic activities	A-	D	**Pre-Construction or Construction** Livelihood of people will be affected once the land is acquired for the project. This will cause significant negative impacts as the livelihood of some community members will be temporarily lost. **Operation** No operational impact
Disruption of Existing Infrastructure facilities(Utilities)	A-	D	**Pre-Construction or Construction** Shifting of the existing high-tension (32kW) power line, Atomic Energy Authority, the Automobile Training Institute will have temporary adverse impacts as shifting may cause inconvenience to the residents and building occupants and public users. （Details are described in “13.2.5”9Existing oil pipeline will get affected by construction machinery etc. It is also considered necessary to relocate electricity power lines, telecommunication lines, water supply lines located within the project area during construction causing temporary adverse impacts such as power outage, water shortages etc. As far as possible constructions near oil pipeline should be done carefully without damaging it resulting in oil leakages. **Operation** No operational impact
Nuisance to neighborhood	C-	D	**Pre-Construction or Construction** Loss of access to residences and to social and administrative institutes could be considered as a nuisance to neighbourhood during construction. This impact is temporary. **Operation** No operational impact
Violation Children's Rights	D	D	**Pre-Construction or Construction** There is no significant impact as child labour is prohibited by laws of Sri Lanka. **Operation** No operational impact
Spreading of HIV/AIDS	C-	D	**Pre-Construction or Construction** There could be some impact from workers coming from outside the project area. But the effects are minimal as they will be commuting rather than living in the project site. There is only one recorded case of HIV among affected people who will be shifted out before commencement of construction. **Operation** No operational impact
Impacts from construction waste and other waste disposal	C-	D	**Pre-Construction or Construction** Loss of retention in marshes , odour emanation, blockage of drainage paths, water stagnation **Operation** No impact
Impacts extraction and transportation of materials	C-	D	**Pre-Construction or Construction** Dust , vibration, public nuisance , drainage congestion, disturbance to landscape **Operation** No impact
Health and safety impairment	C-	C-	**Pre-Construction or Construction** Presence of respiratory diseases because of dust. Spread of communicable diseases because improper solid waste and wastewater disposal. Construction related accidents **Operation** Probable accidents with high vehicular speed

Impact Theme	Impact Rating		Reasons for attributed impact rating
	Pre-Construction or Construction	Operation	
Archaeological sites disturbance	D	D	**Pre-Construction or Construction** Not impact is expected as no archeological sites have been found during the archeological assessment. **Operation** No impacts
Damages to existing New Kelani Bridge	C-	D	**Pre-Construction or Construction** There could be damages to existing New Kelani bridge by construction equipment or piling activities causing vibration **Operation** No impact
Physical Environment			
Change of Existing landscape	B-	C+	**Pre-Construction or Construction** The existing landscape of the proposed construction area will be temporarily altered by construction activities causing fair negative impacts. **Operation** The iconic nature of the proposed bridge will enhance the future landscape
Hydrological			
River flow and canal flow obstruction	C-	D	**Pre-Construction or Construction** There could be temporary negative impacts during construction because of small coffer dams, sheet piles and such obstructions etc. **Operation** There will not be any significant negative impacts as there will not be any piers inside Kelani River or canals for crossings.
Alteration of the local drainage pattern	C-	C-	**Pre-Construction or Construction** Drainage pattern of the area could be temporarily altered by piles of construction materials causing negative impacts. **Operation** There could be blockage of gullies , inlets etc. causing drainage congestion but this impact will not be prominent as there will be regular maintenance
Damages to flood protection scheme	C-	D	**Pre-Construction or Construction** There could be damages to the flood bund from construction equipment **Operation** No impact
Hindrance to flood propagation	C-	D	**Pre-Construction or Construction** There could be hindrances to flood propagation because of material stockpiles, construction yards on the flood plain. This impact is temporary. **Operation** There will not be any significant impact as the structures will be elevated.
Physio-Chemical Environment			
Water quality (Contamination)	B-	D	**Pre-Construction or Construction** There is a possibility that the loose soil, sewage, oil and grease, bentonite or other chemicals etc. may enter water bodies or penetrate to groundwater causing water quality degradation. However Contractor will have to meet the procedures outlined in the Environmental Management Plan to avoid these effects **Operation** Not significant impact is expected

Impact Theme	Impact Rating		Reasons for attributed impact rating
	Pre-Construction or Construction	Operation	
Air quality degradation	C-	C-	**Pre-Construction or Construction** Emission of air pollutant from construction equipment and traffic congestion may cause minor negative impacts temporarily. **Operation** Due to an increase in traffic volume, air quality degradation level will increase slightly but, this does not significantly deviate from current air quality levels.
Noise (Public nuisance)	B-	C+	**Pre-Construction or Construction** During construction, noise in the construction area will be generated by the operation of construction machines causing public nuisance. **Operation** The project may have modest positive impacts since driving speed will increase and noise decay distance is extended.
Vibration (Public nuisance & structure cracks)	C-	C-	**Pre-Construction or Construction** During construction vibration in the construction area will be generated by the operation of construction machines causing public nuisance. Cracks may appear in nearby structures **Operation** Vibration levels could be increased because of enhanced vehicular speed.
Global warming	D	C+	**Pre-Construction or Construction** Construction machines and vehicles generate greenhouse gases, and quantities of generating gases do not give serious impact as quantities are relatively low according to numerical studies carried out. **Operation** After implementation of the project, the amount of CO2 emission will be decreased with some positive contribution to global warming issue.
Soil Contamination	C-	D	**Pre-Construction or Construction** Soil contamination could take place from oil, grease and wastewater from construction area and this might give a minor negative impact. **Operation** Not impact is expected
Ground subsidence	C-	C-	**Pre-Construction or Construction** Ground subsidence not expected as there is no driven piling. Ground subsidence could take place in river and canal banks **Operation** Long term minor settlements within specified tolerance limits could take place
Bottom sediment disturbances	D	D	**Pre-Construction or Construction** No significant impact expected, because pier is not constructed in Kelani river. **Operation** No significant impact expected after river bed stabilisation
Traffic congestion	C-	A+	**Pre-Construction or Construction** Traffic congestion may be strictly temporarily **Operation** Traffic congestion will definitely be reduced when new bridge, access roads are operated
Terrestrial and Aquatic Ecology			
Aquatic habitat destruction	D	D	**Pre-Construction or Construction** There is no significant impact as rare, threatened or endemic aquatic fauna or flora species does not exist. **Operation** Not impact is expected

Impact Theme	**Impact Rating**		**Reasons for attributed impact rating**
	Pre-Construction or Construction	**Operation**	
Terrestrial habitats destruction	C-	D	**Pre-Construction or Construction** Rare threatened or endemic flora species do not exist, however about 260 trees may be removed from the project area. **Operation** No impact is expected

Rating; A;/- : Significant positive/negative
B+/- : Moderate positive/negative
C+/- : Minor positive/negative
D : No impact

12.3 Atomic Energy Authority

It is required to relocate Atomic Energy Authority (AEA) in the Project. The major work of the AEA is to promote peaceful applications of nuclear technology conforming to international standards on radiation safety and security.

The relocation of AEA is discussed in detail in “13. Involuntary Resettlement”.

13. INVOLUNTARY RESETTLEMENT (SUMMARY)

13.1 General

The RAP was prepared since the Project was anticipated large scale involuntary resettlement based on the selected optimal plan of route alternative. The RAP was established based on the sub-contract with local RAP consulting firm under JICA’s financial assistance.

13.2 Summary of the RAP

(1) Project Impact

A total of 449 households (residential and business) consisting of 1915 people will be affected due to the project interventions.

Total area of land surrounding to impact corridor and total land area affected is approximately 620 perch (1 Perch= 25.3 m2) . While, total area of structures within the impact corridor and the total structural area affected is approximately 13,000m2.This includes both residential and commercial structures. In addition, the public utilities such as lamp posts, Name board& sign board and so on as well as trees will be affected by the Project.

(2) Compensation Policy and Cu-off date

The RAP for the Project was prepared based on the National Involuntary Resettlement Policy (NIRP) because NIRP and the WB.OP.4.12 are more or less similar in terms of the approach to land acquisition and payment of compensation.

For this Project, the cut-off date was declared at "DS Level Awareness Creation Meeting" held in the related DS offices from 8th to 10th April before the commencement day of the socioeconomic survey.

(3) Replacement Cost and Project Entitlement Matrix

The compensation cost for land and structures were decided based on the results of the replacement cost survey. The project entitlements were developed and presented in the entitlement matrix corresponding to the potential impacts identified during the field survey. In paying compensation, disturbances and other expenses are also considered based on the provision of the Land acquisition Act 2008 regulations in the entitlement matrix.

(4) Resettlement Measures

Resettlement measures for affected households (AHs) as well as the large scale buildings belong to Government Agencies/Institutes and Centres of Worship were discussed. The compensation package for AHs consists of two options, i.e. (i) self -relocation, (ii) Housing unit from the UDA housing schemes.

(5) Community Participation

The national level stakeholder information sharing meeting held three times and other related meeting including focus group discussions (FGDs) were held.

(6) Grievance Procedures and Monitoring and Evaluation

The Grievance Redress Committee (GRC) with well-defined functions, composition, and a procedure to redress grievances during the implementation of road development projects was proposed based on the existing RDA's experiences. While, the monitoring plan consisting of the internal monitoring by RDA and the external monitoring by an independent party hired by the Consultant was proposed.

(7) Implementation Schedule and Cost and Budget

The implementation schedule for the Project was prepared considering that all resettlement activities will be completed by the end of March 2017. And total cost of land acquisition and resettlement was revealed that approximately LKR 2,599 million equivalent to US$20.5 million (at an exchange rate of LKR 127 for 1US$).

14. CONCLUSION AND RECOMMENDATIONS

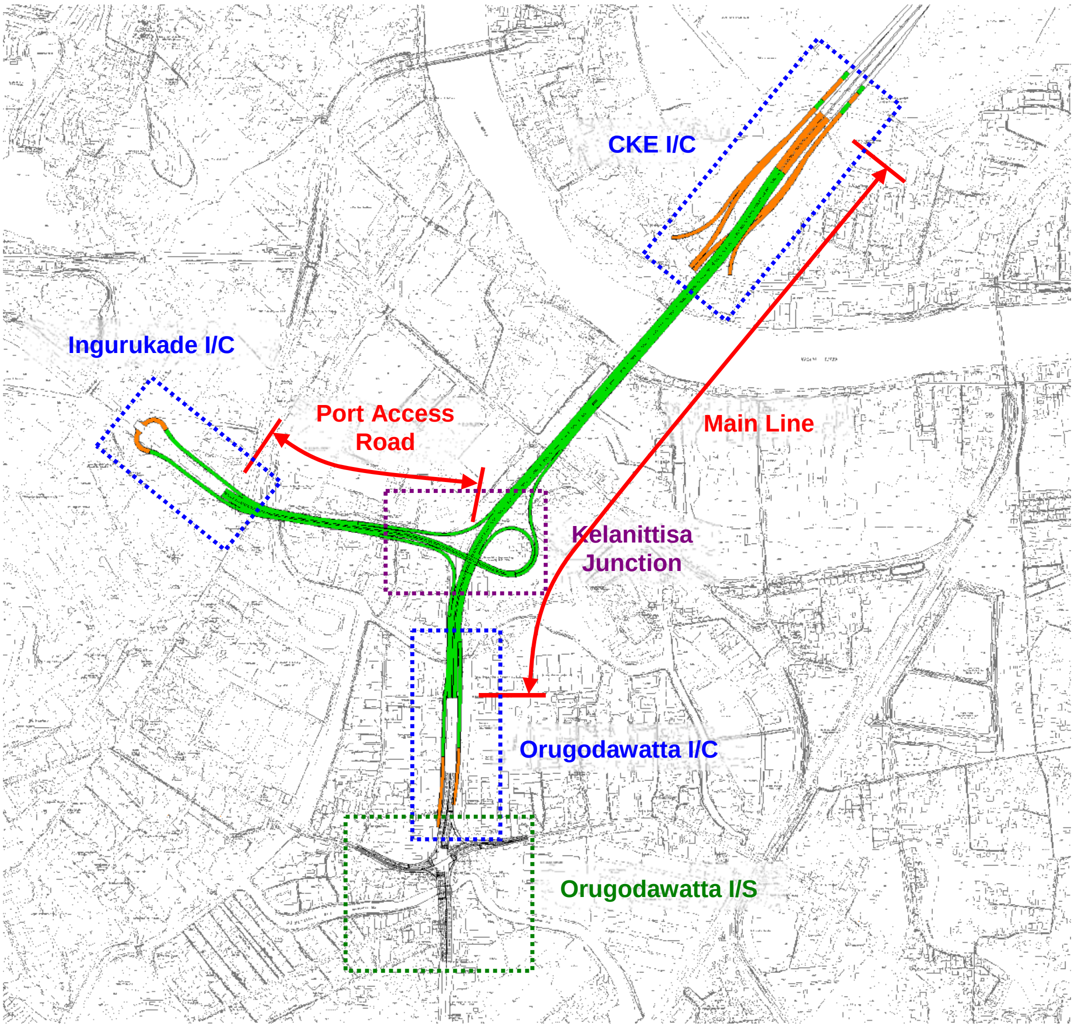
14.1 Conclusion

Summary of the Project is shown in Table S 14.1.1 and Figure S 14.1.1.

Table S 14.1.1 Summary of the Project

Component	Summary
1. Construction of the Project Road, Main Line	• Design Speed: 60 km/h • Road Length: 1,580 m • Cross Section: - Main Bridge (6-lane): 27.5 m - Approach Bridge (6-lane): 27.5 m - Approach Bridge (4-lane): 20.5 m - Earth Work (6-lane): 30.5 m • Bridge Type: - Main Bridge (L=380 m): Extra-dozed - Approach Bridge (L=625 m): PC Box Girder - Approach Bridge (L=425 m): Steel Box Girder • Others - Soft Soil Treatment in Earth Work Section
2. Construction of the Project Road, Port Access Road	• Design Speed: 60 km/h • Road Length: 390 m • Cross Section: 20.5m (4-lane) • Bridge Type: Steel Box Girder (L=390 m)
3. Construction of Interchanges and Junction	• Design Speed: 40 km/h • Ramp Length: - Orugodawatta I/C > Orugodawatta On: 333 m > Orugodawatta Off: 411 m - CKE I/C > CKE A: 820 m > CKE B: 926 m > CKE C: 286 m > CKE D: 345 m - Ingurukade I/C > Ingurukade On: 469 m > Ingurukade Off: 483 m - Kelanithissa JCT > Kelanithissa A: 501 m > Kelanithissa B: 562 m > Kelanithissa C-1: 423 m > Kelanithissa C-2: 324 m > Kelanithissa D: 350 m • Cross Section: - Orugodawatta I/C: 7.0 m (Temporary 2-lane) - CKE I/C: 7.0 m (1-lane), 8.5 m (2-lane) - Ingurukade I/C: 7.0 m (Temporary 2-lane) - Kelanithissa JCT: 7.0 m (1-lane) • Bridge Type: Steel Box Girder (L=1,998 m)
4. Improvement of At-grade Road	• Orugodawatta Intersection - Road Length: > North Bound: 249 m > South Bound: 113 m > East Bound: 191 m > West Bound: 210 m - Cross Section: > North Bound: 8-lane > South Bound: 7-lane > East Bound: 4-lane > West Bound: 5-lane • Kelanithissa Intersection - 1.5 m widening in 100 m

Source: JICA Survey Team



Source: JICA Survey Team

Figure S 14.1.1 Summary of the Project

14.2 Recommendations

Recommendations for further studies and tasks are as follows:

- The master plan study for Colombo metropolitan region and the suburbs (CoMTrans) is going on now, and will be completed in April 2014. Some project will be proposed in Colombo as a result of the master plan. It is recommended that the design of this Project will be modified in the detailed design stage in consideration of the projects proposed by CoMTrans, if necessary.

- Public utilities such as waterworks, telephone line, electricity line, power line, etc. were identified based on the topographic survey and existing documents in the Preparatory Survey. The preliminary design was carried out in consideration of the information. However, it is recommended that detailed survey for the public utilities should be carried out in the detailed design stage, and the design will be reviewed based on the detailed survey result.

- It is recommended that RDA will undertake the tasks for the EIA and RAP during the entire project period in order to implement the Project successfully.
- It is recommended to inform the public of JICA Grievance Mechanism effectively.
- It is recommended that the information such as participants, opinions, etc. in further focus group discussions will be recorded in detail.

Preparatory Survey on Traffic Improvement Project around New Kelani Bridge

VOLUME1: MAIN REPORT

- TABLE OF CONTENTS -

List of Figures

List of Tables

List of Abbreviations

AAGR	Average Annual Growth Rate
AASHTO	American Association of State Highway and Transportation Officials
AEA	Atomic Energy Authority
AHs	Affected Houses
AP	Affected People
B/C Ratio	Benefit-Cost Ratio
BS	British Standard
BSR	Building Schedule of Rates
CBR	California Bearing Ratio
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CEO	Chief Engineering Office
CIF	Cost, Insurance and Freight
CKE	Colombo - Katunayake Expressway
CSC	Construction Supervision Consultant
CoMTrans	Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs
CPI	Consumer Price Index
CPT	Cone Penetrometer Tests
DS	Divisional Secretaries
EA	Environmental Assessment
ECF Strand	Epoxy Coated and Filled Strand Cable
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMoP	Environmental Monitoring Plan
EMP	Environmental Management Plan
EOM&M	Expressway Operation, Maintenance & Management Division
EPS	Expanded Polystyrene
ESD	Environmental and Social Division
FGDs	Focus group Discussions
FOB	Free On Board
FI	Fracture Index
GCP	Gravel Compaction Pile
GDP	Gross Domestic Products
GND	Grama Niladhari Division
GOSL	Government of Sri Lanka
GRC	Grievance Redress Committee
HDPE	High Density Polyethylene

HHs	Households
IAEA	International Atomic Energy Agency
I/C	Interchange
ICB	International Competitive Bidding
ICRP	International Commission on Radiological Protection
IMF	International Monetary Fund
IOL	Inventory of Losses
IRP	Income Restoration Program
JICA	Japan International Cooperation Agency
JST	JICA Survey Team
KEL	Knife Edge Load
L/A	Loan Agreement
LAA	Land Acquisition Act
LAO	Land Acquisition Officer
LD	Land Division
LKR	Sri Lanka Rupee
MGIF	Multi-purpose Gamma Irradiation Facility
MOPH	Ministry of Ports and Highways
MOU	Memorandum of Understanding
NAITA	National Apprentice and Industrial Training Authority
NCNDT	National Center for Non-Destructive Testing
NEA	National Environmental Act
NETIS	New Technology Information System
NIRP	National Policy on Involuntary Resettlement
NDT	Non-Destructive Testing
NPV	Net Present Value
NRMP	National Road Master Plan
NIRP	National Involuntary Resettlement Policy
OCH	Outer Circular Highway
ODA	Official Development Assistance
PAPs	Project Affected Persons
PCU	Passenger Car Unit
PMU	Project Management Unit
RAP	Resettlement Action Plan
RCS	Replacement Cost Survey
RDA	Road Development Authority
ROW	Right of Way
R.P	Radiation Protection
RQD	Rock Quality Designation
RU	Resettlement Unit

SCF	Standard Conversion Factor
STDP	Southern Expressway
SCP	Sand Compaction Pile
SES	Socio Economic Survey
SGT	Soft Ground Treatment
SN	Structural Number
ToR	Terms of Reference
TTC	Travel Time Costs
UDA	Urban Development Authority
UCS	Unconfined Compressive Strength
UDL	Uniformly Distributed Load
VAT	Value Added Tax
V/C	Volume Capacity ratio
VOC	Vehicle Operating Costs
VTA	Vocational Training Authority

1. INTRODUCTION

1.1 Background

Road is an essential transport infrastructure for the Democratic Socialist Republic of Sri Lanka (hereinafter called Sri Lanka), since road accounts for over 90% of freight transport. The president Mahinda Rajapaksa, in the “Mahinda Chintana” for the country development project, has considered transport infrastructure maintenance as one of the major priorities, and has placed road network maintenance on top of the list. For the 4000 bridges that have been built in the whole country as part of the road network, the Government of Sri Lanka (hereinafter called GOSL) has been carrying strengthening or repair works with the support of international agency funds.

The New Kelani Bridge, a 1,160m long, 6 traffic lane bridge located in the northern part of the capital city Colombo, is becoming a key link for transportation as the A01 Road connecting the city center to the 2nd largest city of the country, Kandy, the access road of Colombo Port; and the road connecting to A03 Road which is the access to the Bandaranaike International Airport are all connected to it.

Although three bridges, including the above mentioned bridge, are currently crossing the Kelani River, congestion has increased significantly in the past few years due to the traffic volume growth, severely affecting the economy. In addition, as further traffic congestion is expected from a new expressway connecting the Bandaranaike International Airport to this bridge that is planned to open in 2013, congestion reduction has become an urgent issue. Considering the above issues, the GOSL has requested in June 2012 the support from Japan to build a new bridge to improve traffic situation around New Kelani Bridge.

1.2 Contents of the Request

The contents of the request to Japan are listed below:

- Construction of the Second New Kelani Bridge and approach road
- Detailed design of elevated road between New Kelani Bridge and Colombo Fort

1.3 Objective of the Survey

Since the GOSL is requesting Japanese ODA Loan for the Traffic Improvement Project around New Kelani Bridge (hereinafter called the Project), the objective of this survey is to carry out all the requirements necessary to execute the Project in Japanese ODA Loan, such as defining the project objectives, and preparing project summary, project cost, implementation schedule, implementation method (procurement, construction), implementation plan, operation and maintenance management system, environment and social considerations, and so forth.

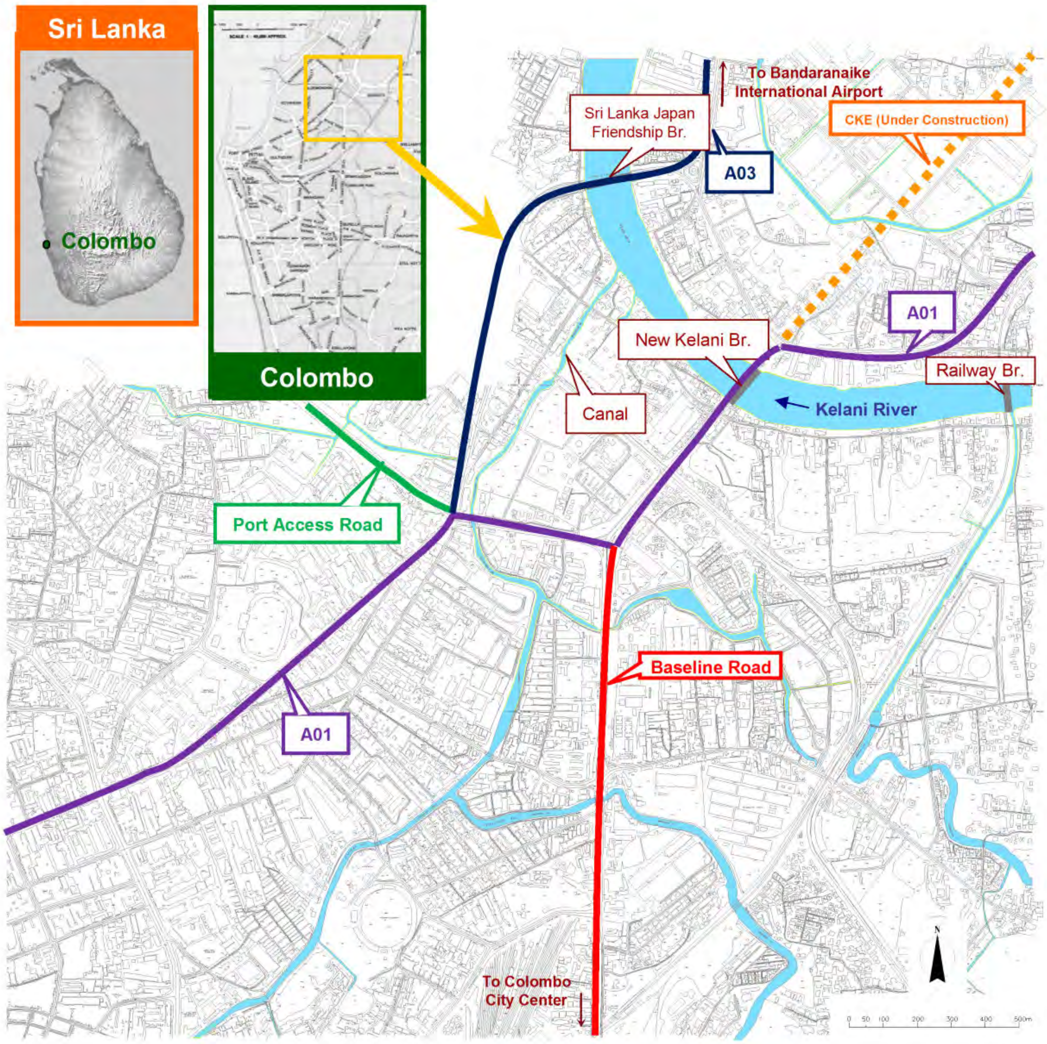
1.4 Survey Area

The location map of the survey area is shown in Figure 1.4.1.

The survey area is divided into north area and south area by Kelani Rivier. This two areas are connected by two bridges, namely New Kelani Bridge and Sri Lanka Japan Friendship Bridge which is located at approximately 750 m downstream of New Kelani Bridge.

There are three arterial roads, namely A01 Road, A03 Road and Baseline Road, in this area. Therefore a large volume of vehicles concentrates in this area at present. In addition, Colombo- Katunayake Expressway (CKE) connecting to New Kelani Bridge will open in 2013.

The area is highly urbanized, and many houses, building, shops, etc. are located along the roads. Large number of resettlements will be required in the Project.



Source: JICA Survey Team

Figure 1.4.1 Survey Area

2. REVIEW OF THE PROJECT

2.1 Relevant Plan and Programs to New Kelani Bridge

2.1.1 National Development Plan Mahinda Chinthana

“Mahinda Chinthana : Vision for a New Sri Lanka”, a ten year national development plan was formulated in 2006 with a target year of 2016. The plan is considered as a national policy framework for economic development aimed at the gross domestic products (GDP) growth rate in over 8 percent. Since the road transport is dominant mode of transport for passenger and freight transport in Sri Lanka, provision of high and quality mobility road is set as a vision of road sector of the “Mahinda Chinthana : Vision for a New Sri Lanka“ (2006-2016). With regard to urban transport, constructions of expressways and flyovers are described as key measures to increase capacity of roads to cater the increasing traffic load of roads. Construction of 16 flyovers and grade separation intersections in the Colombo Metropolitan area is one of the flagship projects of the road sector.

“Mahinda Chintana - Vision for the Future”, a development policy framework of Sri Lanka, was formulated in 2010 to continue the process of “Mahinda Chinthana : Vision for a New Sri Lanka” (2006-2016) at a renewed pace with the policies and measures to be implemented during the next six years and to reposition Sri Lanka in the global arena as a knowledge based strong middle income country with better and improved living standards. The road sector investment is to be accelerated under this policy framework. Introduction of bypass, flyovers and underpasses is highlighted to meet the growing traffic demand in the Colombo metropolitan area. It is expected that funding from foreign donor including Japan will be utilized for the road network development.

The improvement of the New Kelani Bridge and surrounding road network to accommodate the increasing traffic demand in the urbanized area of Colombo is in line with the concept of Mainda Chinthana which aims at improving accessibility of passenger and cargo.

2.1.2 Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs (CoMTrans)

(1) Current Status of the Study

The urban transport master plan study (hereinafter called CoMTrans) has been conducted since the end of August 2012 by JICA. Since the urban transport master plan includes arterial road network development plan in the metropolitan area, it is important to integrate with the master plan in terms of role and function of roads in the new Kelani Bridge and roads in its surrounding area. As of July 2013, the JICA Survey Team reviewed the progress of this study and confirmed that the Progress Report (1) was submitted on May 2013, which includes the current urban transport condition and issues and preliminary concepts for integrated CoMTrans master plan, with the traffic demands and other criteria, will be discussed.

Currently, the transport demand forecast model with future zone parameters are under development from the results of Home Visit Survey and other transport surveys. In addition, the Colombo metropolitan area will be identified based on the volume of commuting trips to the CMC area, and as the target area for providing urban transport system.

(2) Objectives of the CoMTrans

The objectives of the Project are:

- To develop a reliable transport database that can be utilised to formulate transport system development plans in a rational manner by conducting a metropolitan area-wide transport survey.
- To formulate an Urban Transport Master Plan for the Colombo Metropolitan area.
- To conduct a pre-feasibility study on the prioritised project.

The prioritised project is assumed to be a mass transit system development project and the mass transit includes MRT, LRT and BRT.

(3) Target Year for the Urban Transport Master Plan

The target year for the Urban Transport Master Plan is 2035. The master plan includes short-term (2020), intermediate-term (2025) and long-term (2035) transport system development plans.

(4) Study Area and Survey Area

The study area is the Colombo Metropolitan area and it will be identified during the Study. The study area is the planning area for the Urban Transport Master Plan and it should cover the urbanised area in the planning horizon of year 2035. On the other hand, the transport survey area covers the entire Western Province.

(5) Output of the Study

Output of the study includes the followings;

- Urban Transport Master Plan for the Colombo Metropolitan area including a road network development plan and public transport system development plan
- Findings and Recommendation of Pre-Feasibility Study on the Selected Mass Transit System

(6) Transport Surveys

Various kinds of transport surveys were planned in the Study and some of them are being implemented.

Table 2.1.1 Survey Progress

Survey Name	Progress
(1) Home Visit Survey	Filed Survey will be completed soon
(2) Cordon Line Survey	
1) Road side OD Interview Survey	Field Survey Completed
2) Bus Passenger OD Interview Survey	Field Survey Completed
3) Railway Passenger OD Interview Survey	Field Survey Completed
4) Airport Passenger OD Interview Survey	Field Survey Completed
(3) Screen Line Survey	Field Survey Completed
(4) Traffic Count at Intersection Survey	Waiting for the Results of Travel Speed Survey
(5) Truck OD Interview Survey	Field Survey Completed
(6) Land Use Survey	Field Survey Completed
(7) Trip Generation Survey	Field Survey Completed
(8) Travel Speed Survey	Calculation algorism was developed and vehicle tracking data is still collected
(9) Bus Passenger OD Interview Survey	will be conducted after the mode and corridor for pre-feasibility study is determined
(10) Stated Preference Survey	

Source: JICA Survey Team

(7) Preliminary idea of CoMTrans Network (Roads, Public)

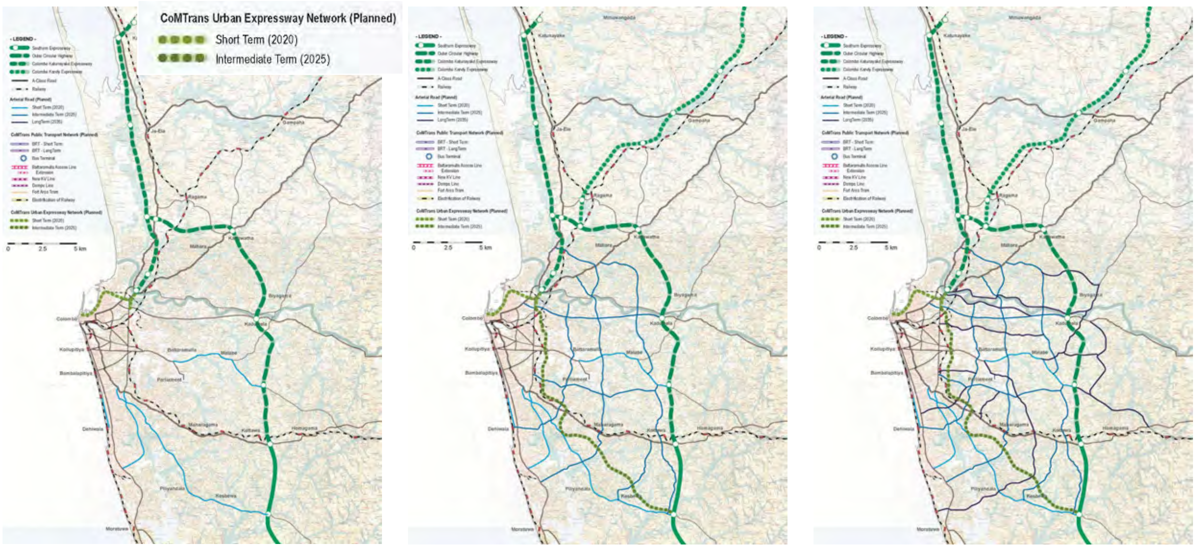
The study prepared the network development plan for roads and public transport on the progress report. Future transport network consisting of road network and public transport network has been prepared based on the analyses on the present transport condition as well as future perspective of the Colombo metropolitan area. Development scenario of both road network and public transport network has been tentatively established for evaluation. This development scenario includes short-term development plan for the year 2020, intermediate term development plan for the year 2025 and the long term development plan for the target year of 2035.

Major considerations for preparing road network and public transport network are;

- integration with urban structure,
- integration of different modes of transport,
- rapid implementation by minimising land acquisition and resettlement, and
- road network to support public transport system development.

Herein under shows the preliminary CoMTrans road network development plans for short, intermediate and long term indicated in the Progress Report (1) submitted in May 2013. It aims to develop well-integrated urban transport network with both roads and public transport mode.

The urban transport infrastructure, which should meet future increased urban transport demand and alleviate traffic congestion, require to enough road network provision to ensure smooth accessibility to urban central area and to secure appropriate traffic volume capacity for each road.



Short Tem (by 2020) **Intermediate Term (by 2025)** **Long Term (by 2035)**

Source: JICA CoMTrans Study Team, Progress Report (1), May 2013

Figure 2.1.1 CoMTrans Road Network Development Plan (Short, Intermediate and Long term)

The Project Road, which is located at the end point of CKE to urban central area and expected to experience heavy congestion in the future, should be designed not only for alleviation of traffic congestion at this point but also with good connectibility and scalability to urban arterial road network proposed by CoMTrans.

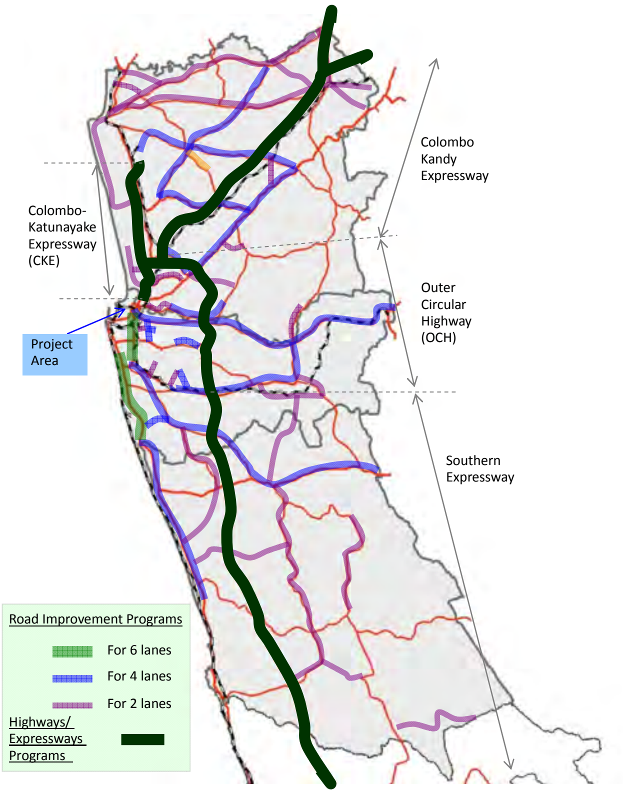
2.1.3 National Road Master Plan (NRMP) 2007-2017

In accordance with the “Mahinda Chintana - Vision for the Future”, the Road Development Agency (hereinafter called RDA) formulated the National Road Master Plan (NRMP) as the long-term road development plan in Sri Lanka started from the year of 2007 to 2017.

The overall objective of the NRMP is to help sustain and enhance general welfare, promote economic growth, eradicate poverty, and strengthen social cohesion. The mission of the NRMP is to provide an adequate and efficient network of national highways, and to ensure mobility and accessibility at an acceptable level of safety and comfort, in an environment-friendly manner for the movement of people and goods in the socio-economic development of the nation.

The NRMP contains 10-year investment program comprising 6 pillars i.e. i) construction of expressways and highways, ii) widening of highways, iii) reduction of traffic congestions by flyovers and junction improvements, signalization and construction of system of ring roads and major bypass, iv) road maintenance and rehabilitation, v) bridge rehabilitation and reconstruction, and vi) land acquisition and resettlement.

Figure 2.1.2 shows the road improvement links in the Western Province identified in the NRMP investment plan, including the Outer Circular Highway (OCH), Southern Expressway, Colombo- Katunayake Expressway (CKE), and Colombo Kandy Expressway as essential highways and expressways.



Source: JICA Survey Team based on the Investment Plan 2007-2017 in NRMP

Figure 2.1.2 Road Improvement Projects in NRMP 2007-2017

According to NRMP, there are less improvement programs around the project area, especially lack of connection with urban arterial road network around the new Kelani Bridge.

2.1.4 Highway Development Plan disseminated by RDA

RDA disseminates the Highway Development Plan in their website, which aims at facilitating greater mobility, shorter travel time and provides easy accessibility with improved safety to the people. The Highway Development Plan mainly consists of two components; i) Rehabilitation of the existing network, ii) Development of a High Mobility Network.

Rehabilitation of existing national roads is required at several length of roads in spite of the substantial increase in traffic demand in the short term. In order to cope with the increased traffic demands in future, RDA considered the following countermeasures to alleviate traffic congestion;

- Planning and provision of high standard trunk road network mainly expressways/ motor ways with high traffic volume capacity to cater to future needs as long term solutions,
- Provision of ring roads to connect CMC and major towns and important urban centres such as Battaramulla and by-pass roads to support the existing truck road, and
- As supplemental countermeasures of above ring road and by-pass roads, major improvements of existing road alignments to ensure smooth traffic flow and to guide and divert to other truck roads.

The project road (new bridge and elevated roads) plays a role of alleviation of traffic congestion, which provides suitable connectivity to urban arterial roads and alternative route.

2.2 Social and Economic Conditions

2.2.1 Population

(1) Historical Population Growth in Sri Lanka and Western Province

After 1950, The Department of Census and Statistics has conducted censuses in Sri Lanka in the year of 1953, 1963, 1971, 1981, 2001, and 2012. Population and Average Annual Growth Rate (AAGR) of Sri Lanka, Colombo District, Gampaha District, Kalutara District, and Western Province of the census years are shown in Table 2.2.1, Figures 2.2.2 and 2.2.3.

The Census of 2012 published the population of the Sri Lanka at 20,263,723 and AAGR at 0.69%, which is lower than the past. The population of the Western Province in 2012 was 5,821,710 and AAGR at 0.72%. Generally the AAGR of Western Province has kept pace with that of the country, but between 2001 and 2012, there was a substantial decrease in the AAGR of the western province. In particular, the AAGR between 2001 and 2012 of Colombo District was much lower than the national level.

Table 2.2.1 Census Population and Average Annual Growth Rate (1953-2012)

Census Population	1953	1963	1971	1981	2001	2012
Sri Lanka	**8,097,800**	**10,582,100**	**12,689,897**	**14,846,750**	**18,797,257**	**20,263,723**
Western Province	**2,232,276**	**2,838,877**	**3,401,779**	**3,919,807**	**5,381,197**	**5,821,710**
Colombo District	1,708,726	2,207,420	1,498,393	1,699,241	2,251,274	2,309,809
Gampaha District*			1,173,872	1,390,862	2,063,684	2,294,641
Kalutara District	523,550	631,457	729,514	829,704	1,066,239	1,217,260
AAGR		**'53-'63**	**'63-71**	**'71-'81**	**'81-'01**	**'01-'12**
Sri Lanka		**2.71%**	**2.30%**	**1.58%**	**1.19%**	**0.69%**
Western Province		**2.43%**	**2.29%**	**1.43%**	**1.60%**	**0.72%**
Colombo District		2.59%	2.42%	1.27%	1.42%	0.23%
Gampaha District				1.71%	1.99%	0.97%
Kalutara District		1.89%	1.45%	1.30%	1.26%	1.21%

Note: * Gampaha district was declared as a new administrative district, separated from Colombo District in 1978.

Source: Department of Census and Statistics

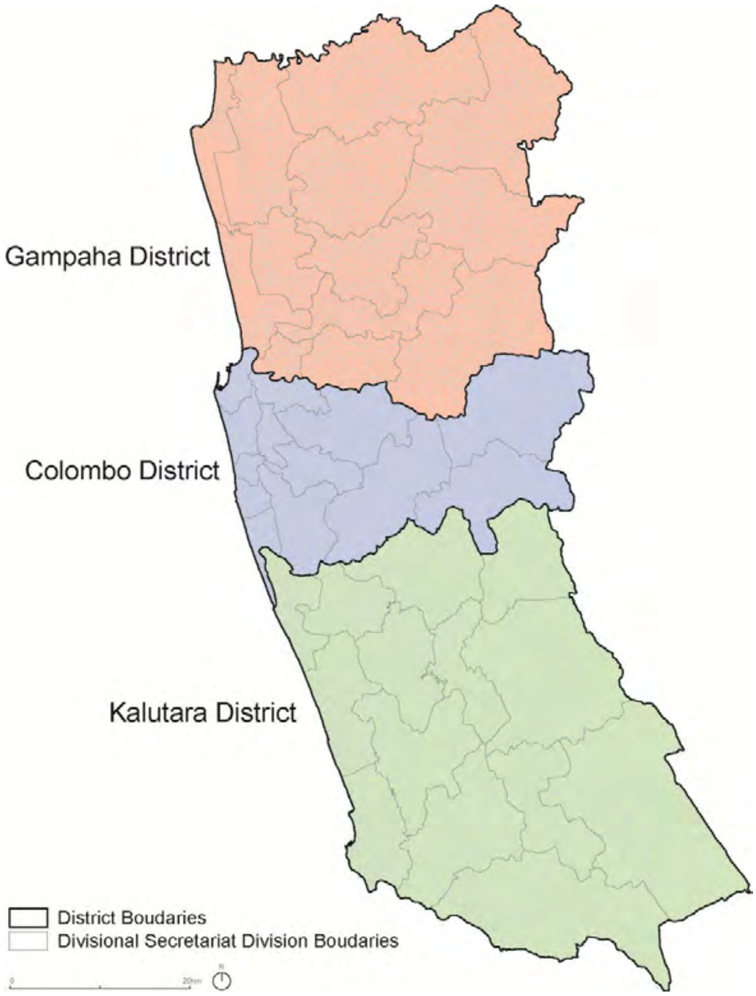
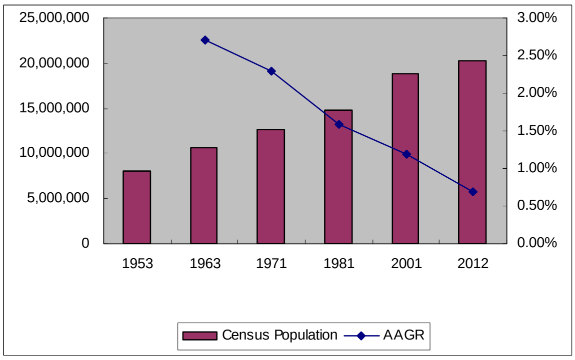
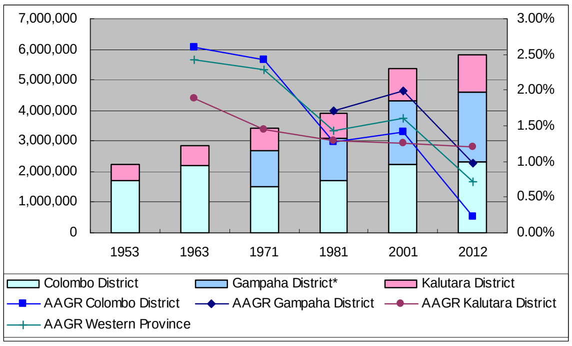


Figure 2.2.1 District Boundaries in Western Provinces



Source: Department of Census and Statistics

Figure 2.2.2 Census Population of Sri Lanka



Source: Department of Census and Statistics

Figure 2.2.3 Census Population in Western Province

Only preliminarily results are available from the latest census in 2012. Populations by sex and 3 age groups, which are: less than 15 years, 15 to 59 years, and 60 years and over, according to Grama Niladhari Division (GND) are published by the Department of Census and Statistics. The population of 2012 for the Districts in the Western Province is shown in Table 2.2.2.

Colombo and Gampaha Districts have approximately 2.3 million population each and 1.5 million are aged 15 to 59 years, which is 64% of the total. Both of the two districts account 80% of the total working-age population in the Western Province..

Table 2.2.2 Population by Sex and Age Group by District in 2012)

2012	Total Population	Sex		Age		
		Male	Female	Less than 15 years	15-59 Years	60 Years and Over
Sri Lanka	**20,263,723**	**9,832,401**	**10,431,322**	**5,228,927**	**12,566,467**	**2,468,329**
Western Province	**5,821,710**	**2,843,244**	**2,978,466**	**1,356,695**	**3,696,417**	**768,598**
Colombo District	2,309,809	1,137,114	1,172,695	516,741	1,484,820	308,248
Gampaha District	2,294,641	1,115,349	1,179,292	536,758	1,467,497	290,386
Kalutara District	1,217,260	590,781	626,479	303,196	744,100	169,964

Source: Census 2012 – Preliminary Result, Department of Census and Statistics

(2) Population by Age Groups

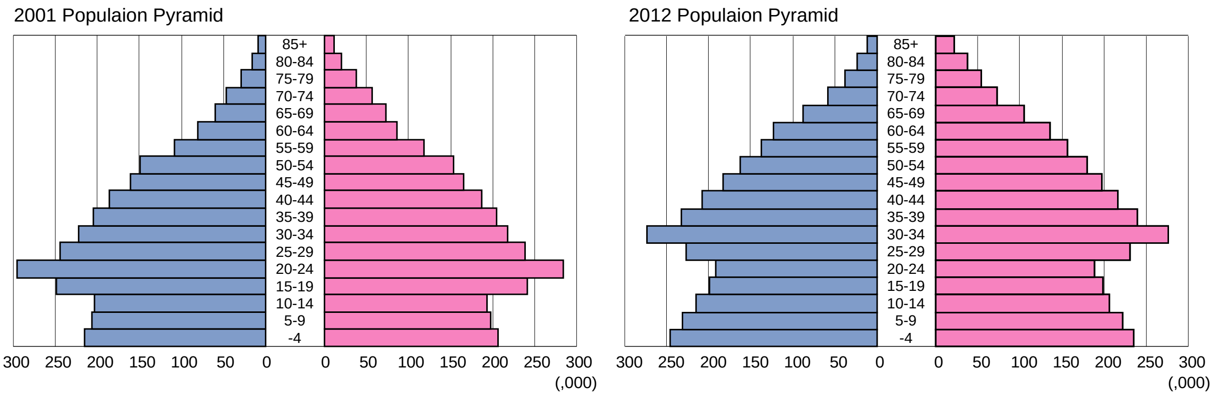
Data from 2001 census gives population by age and sex in 2001. Population by age and sex in 2012 can be estimated from registered number of live birth and death, and preliminary result of 2012 Census, although the detailed results are not available yet. 5-year age group population in 2001 and 2012 are shown in Table 2.2.3, and the Population Pyramids in 2001 and 2012 are shown in Figure 2.2.4.

Table 2.2.3 Population by Sex and 5-year Age Group (2001 and 2012)

Population	2001 Census			2012 Estimation		
Age Group	Male	Female	Total	Male	Female	Total
<4	214,669	205,959	420,628	246,027	235,435	481,462
5-9	206,153	197,097	403,250	231,906	223,027	454,933
10-14	203,570	192,537	396,107	214,386	205,915	420,301
15-19	249,063	240,969	490,032	198,305	198,601	396,906
20-24	296,307	284,486	580,793	191,065	189,242	380,307
25-29	243,825	238,584	482,409	227,127	231,172	458,299
30-34	222,523	218,354	440,877	273,075	277,091	550,166
35-39	204,606	205,221	409,827	232,004	240,385	472,389
40-44	185,462	187,408	372,870	207,224	216,659	423,883
45-49	160,929	164,649	325,578	182,153	197,099	379,252
50-54	148,519	152,883	301,402	162,076	180,019	342,095
55-59	108,798	117,788	226,586	136,980	156,143	293,123
60-64	79,783	86,971	166,754	122,136	136,028	258,164
65-69	60,545	72,803	133,348	87,405	104,846	192,251
70-74	46,404	57,317	103,721	58,267	73,137	131,404
75-79	29,825	38,399	68,224	37,915	54,723	92,638
80-84	16,330	21,053	37,383	23,522	37,617	61,139
85>	9,085	12,323	21,408	11,675	21,328	33,003
Total	**2,686,396**	**2,694,801**	**5,381,197**	**2,843,248**	**2,978,467**	**5,821,715**

Note: Total Population and Population by age group in 2001: Census 2001, by Department of Census and Statistics
Total Population 2012: Preliminary Result of Census 2012, by Department of Census and statistics
Population by age group in 2012: Estimation, by Consultants

Source: Department of Census and Statistics



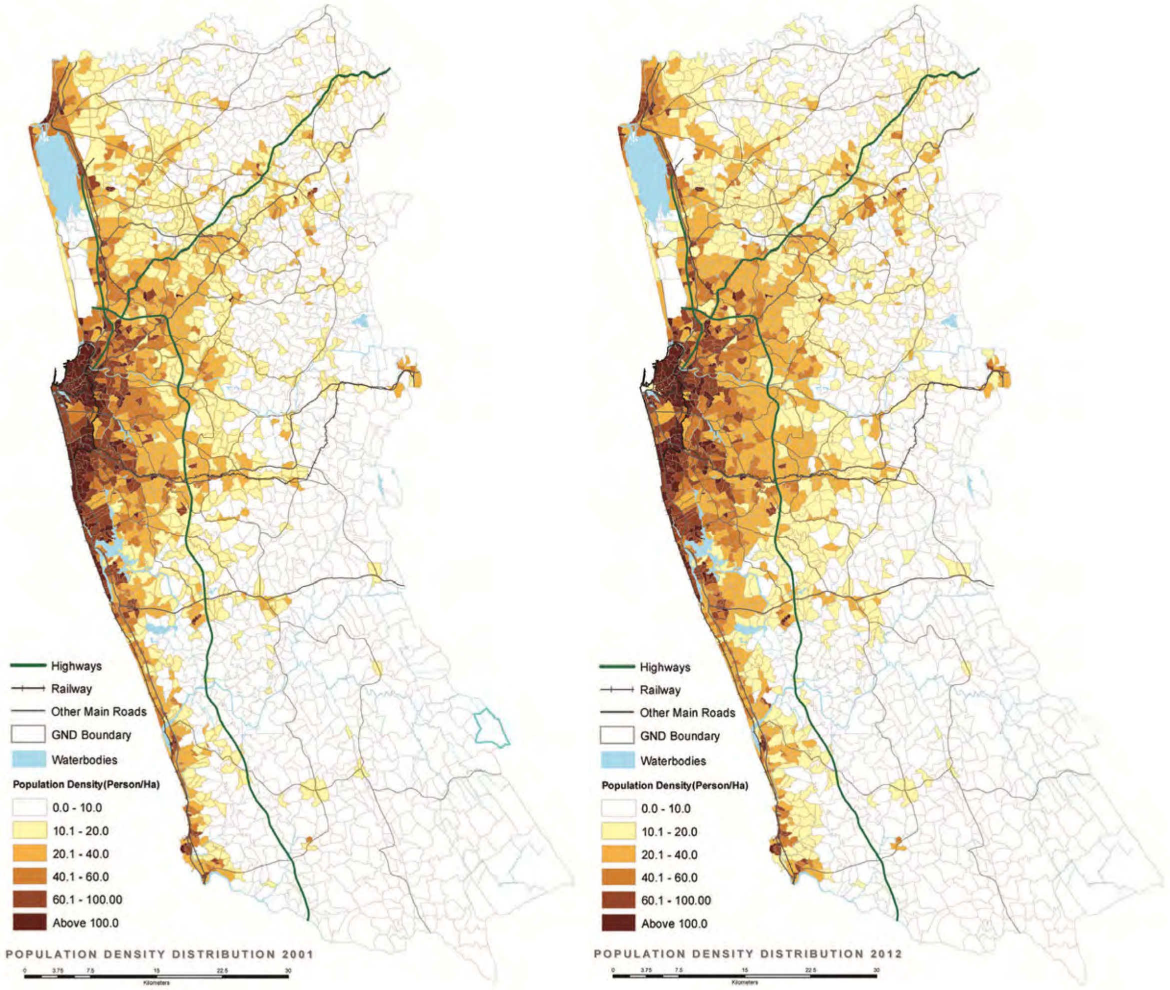
Source: Department of Census and Statistics

Figure 2.2.4 Population Pyramid of Western Province (2001 and 2012)

2.2.2 Spatial Distribution and Growth Trend

(1) Spatial Distribution

Census published the population and population density by GN Division. Figure 2.2.5 shows population density of western province in 2001 and 2012.



Source: Department of Census and Statistics

Figure 2.2.5 Population Density in Western Province (2001 and 2012)

Generally, Populations are concentrated around Colombo, namely areas of Colombo MC, Dehiwala – Mt. Lavinia MC, Sri Jayawardanepura MC, Kollonawa UC, Boralesgamuwa UC, west part of Kaduwela MC, West Part of Maharagama UC in Colombo District, and Peliyagoda UC, Kelaniya PS, Wattala UC in Gampaha District. Coastal Areas have also higher population density as well.

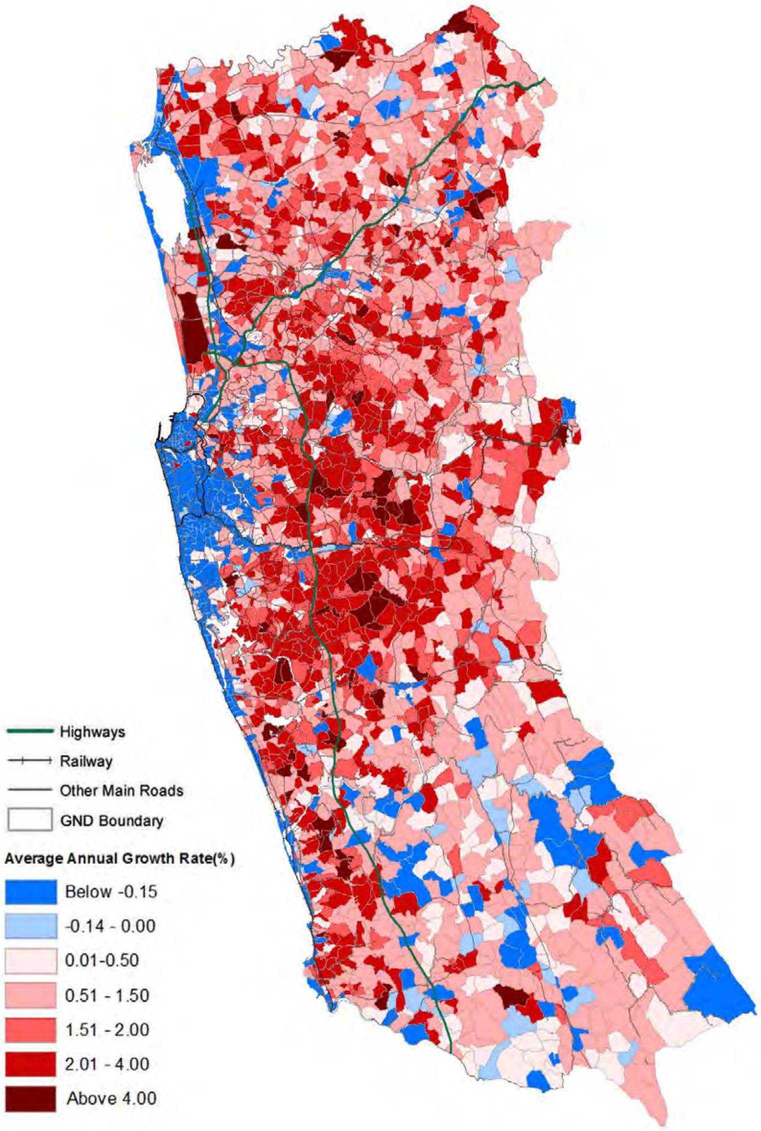
In the suburban Areas, high density areas are concentrated along major roads, such as Kandy Road, High Level Road, Galle Road, Negombo Road, and Horana Road. Around Negombo and Minuwangoda, which are located close l to Bandaranayake International Airport, are also high density area.

From 2001 to 2012, as high density areas expanded towards east, especially around the OCH Corridor, typical population growth in suburban area was observed.

The GND's around the New Kelani Bridge had relatively high population density because of their vicinity to CMC. In 2012, the population density of Sedawatta GND at the Colombo side of the bridge was 107 persons/ha, and that of surrounding GNDs was between 140 and 180 persons/ha. The population density of Peliyagoda Gangabada East GND at the other side was 34 persons/ha. It is low as the land use of the area is mainly industries and warehouses, etc. However, areas surrounding the GND had almost 100 persons/ha. In comparing to 2001, the number of population was almost same at the Colombo side and slightly decreased in the other side.

(2) Growth Trend

Average Annual Growth Rates from 2001 to 2012 are shown in Figure 2.2.6. This gives an idea how urbanization has been occurring in the Western Province. It is clearly shows decreasing population in the centre of Colombo, and increasing population in suburban areas.



Source: Department of Census and Statistics

Figure 2.2.6 Population Change from 2001 to 2012 in Western Province

Population decreasing was occurred in CMC and some surroundings, the coastal strip in southern part of Western Province, and center of Negombo. Population of some rural areas in Kalutara District was also decreased.

Population growth was seen in suburb of Colombo, clearly in Homagama PS, Maharagama UC, Kaduwela MC, and Biyagama PS. Avissawela, west of Negombo, inner costal area of Kalutara district show population increasing, as well.

Major population growth was observed around the planned OCH area. Once highway network is functioned, more population might be attracted in those areas.

On the Colombo side of the New Kelani Bridge, the population kept at same level from 2001 to 2012. On the other hand, the other side of the river, the population decreased at an average annual rate of 0.8%. More residential population might not be expected, since the area would have more commercial uses as the end of the highway network and the entrance of Colombo.

2.2.3 Gross Domestic Products (GDP)

According to the “Economic and Social Statistics of Sri Lanka 2013” by the Central Bank of Sri Lanka, the GDP in Sri Lanka was Rs.3,047,277 million in 2012. Sri Lanka was affected by the global financial crisis in 2009, however the GDP growth has been constantly growing and reached 8.0% in 2010, 8.2% in 2011 and 6.4% in 2012.

The GRDP of west province was Rs. 2,905,159 million in 2011, corresponding to 44% of the total GDP of Sri Lank since the industry, commerce and the governments are concentrated in the Colombo Metropolitan. The service sector accounts for 64 % of GRDP, followed by industry sector with 33%, and agriculture sector with 3 %.

Table 2.2.4 GDP in Sri Lanka

Item	2008	2009	2010	2011	2012*
GDP at Constant (2002) Price (Rs. Mn.)	2,365,501	2,449,214	2,645,542	2,863,854	3,047,277
GDP at Current Market Price (Rs. Mn.)	4,410,682	4,835,293	5,604,104	6,544,009	7,582,376
Real Growth of GDP	6.0%	3.5%	8.0%	8.2%	6.4%
GDP per Capita at Current Market Price (Rs.)	218,167	236,445	271,346	313,576	373,001

Note:*Provisional
Source: Central Bank of Sri Lanka

Table 2.2.5 GRDP at Current Market Prices of Western Province

Item	2007	2008	2009	2010	2011*
GRDP of the Western Province (Rs. Mn.)	1,663,759	2,003,055	2,216,346	2,512,908	2,905,159
Share of the Western Province to Sri Lanka	46.5%	45.4%	45.8%	44.8%	44.4%
GRDP of Agriculture (Rs. Mn.)	48,595	62,076	60,955	75,942	93,308
GRDP of Industry (Rs. Mn.)	531,248	634,274	732,406	802,790	948,994
GRDP of Services (Rs. Mn.)	1,083,915	1,306,706	1,422,985	1,634,176	1,862,858
Share of Agriculture Sector	2.9%	3.1%	2.8%	3.0%	3.2%
Share of Industry Sector	31.9%	31.7%	33.0%	31.9%	32.7%
Share of Service Sector	65.1%	65.2%	64.2%	65.0%	64.1%

Note:*Provisional
Source: Central Bank of Sri Lanka

2.3 Other Projects in the Project Area

2.3.1 Projects by the Support of Japan

The projects for road and bridge sector in Sri Lanka by the support of Japan are shown in Table 2.3.1.

Table 2.3.1 Road and Bridge Sector Projects by the Support of Japan

Project Name	Scheme	Implementation Period	Amount [Billion JPY]
Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs	Study	2012 - 2014	—
The Project for Construction of Manmunai Bridge	Grant Aid	2011 - 2015	1.2
The Project for Reconstruction of 5 Bridges in Eastern Province	Grant Aid	2008 - 2013	1.2
Expressway Administration Project	Technical Cooperation	2008 - 2012	0.3
Greater Colombo Urban Transport Development Project (Phase 2)	Loan	2008 -	5.7（Term1） 31.7（Term2）
Pro-Poor Rural Eastern Infrastructure Development Project	Loan	2006 - 2013	4.5
The study on urban transport development of the Colombo metropolitan region	Study	2006	—
The Project for Construction of New Mannar Bridge and Improvement of Causeway	Grant Aid	2006 - 2010	1.9
The Project for the Construction of a New Highway Bridge at Manampitiya	Grant Aid	2004 - 2007	1.1
Sri Lanka Tsunami Affected Area Recovery and Takeoff Project	Grant Aid	2004 - 2006	8.0
Provincial / Rural Road Development Project	Loan	2002 - 2007	5.8
Southern Highway Construction Project	Loan	2001 - 2012	18.8（Term1） 17.5（Term2）
The Project for Reconstruction of Gampola Bridge and Muwagama Bridge	Grant Aid	2000 - 2003	1.5
Sri Lanka-Japan Friendship Bridge Widening Project	Loan	1993 - 2002	2.2

Source: JICA Survey Team

2.3.2 Projects by the Support of Other Donors

The projects for road at bridge sector in Sri Lanka by the support of other donors are shown in Table 2.3.2.

Table 2.3.2 Road at Bridge Sector Projects by the Support of Other Donors

Project Name	Scheme	Implementation Period	Amount [1000 US$]
Construction and Completion of Thalankudah - Manmunai - Mavadimunmari Road	ADB / Loan	2010 - 2011	2,165
Colombo - Katunayake Expressway Project	China / Loan	2009 - 2013	-
Rehabilitation of Colombo-Ratnapura-Wellawaya-Batticaloa Road from Siyambalanduwa to Akkariapattu	EU・ADB / Grant Aid	2008 - 2010	30,472
Rehabilitation of Trincomalee - Pulmoddai Road	ADB / Loan	2008 – 2010	11,633
Rehabilitation of Bogahawewa - Pulmoddai Road	ADB / Loan	2008 - 2010	4,315
Rehabilitation of Potuvil - Panama Road	ADB / Loan	2008 - 2010	6,117
Rehabilitation of Peradeniya – Badulla - Chenkaladi Road	ADB / Loan	2008 - 2010	3,631
Siyambalanduwa - Thirukkondaiadimadu Road Project	WB / Loan	2007 - 2009	12,832
Siyambalanduwa - Ampara, Ampara - Karativu Highway Project	WB / Loan	2006 - 2010	131

Note: ADB: Asian Development Bank, WB: World Bank
Source: JICA Survey Team

2.4 Review of Existing Road and Bridge Conditions

2.4.1 Purpose of the Investigation

As a part of the Preparatory Survey, it is studied if the existing New Kelani Bridge and its approach road are sound, and confirmed if repair work including reconstruction is not needed in the near future.

In the Preparatory Survey, a series of surveys, inspections and investigations are carried out. However, the survey results do not guarantee the soundness of the existing New Kelani Bridge, since only brief surveys are carried out in the Survey, although the soundness should be concluded based on the detailed surveys.

2.4.2 Survey Items

The existing New Kelani Bridge had repair work including repairing the deck slab cracks in 1993, and no clacks have not been found at the repaired places during 20 years to date. Therefore, it can be said that the Bridge was properly repaired and has properly functioned.

In the Preparatory Survey, only brief surveys, i.e. visual inspections in order to check the physical damage and concrete strength investigation are carried out.

Surveys carried out in the Preparatory Survey are stated bellow.

(1) Obtaining drawings of existing bridge (to grasp the whole picture and structure)

(2) Damages of each part of concrete, cracks, free lime, and rebar exposed

(3) Verification of concrete strength

(4) Extent of damage of bridge bearing

(5) Extent of damage of expansion joint

(6) Extent of damage of road and asphalt

(7) Damage of bridge-attached facilities

(8) Condition of other bridge (Friendship Bridge)

2.4.3 The Findings

(1) Obtaining Drawings of Existing Bridge

Please refer to the Attachment 1 Drawing of New Kelani Bridge (general view and cross section). This drawing is the only one which we received from the RDA.

According to this drawing:

Length of Bridge:	L=266.5m
Width:	W = 24.4 m (Carriage way 18.3m + Footpath 3.05m x 2)
Substructure:	On ground- Concrete driven piles In the river- Cast in place pile
Superstructure:	Reinforced concrete girder bridge, main girders 7nos.
	(Gelber girder at P2-P3, P4-P5, P7-P8)
Number of spans :	10 span,
Span length :	21.35m x 2 +23.315m x 4 +32.635m x 4
Year of Completion:	1959

Significant repair had been made between 1993 to1994. (There are traces of repairing for deck slab cracks, damages of girder concrete and cracks of bulk head concrete.)

From downstream side

From upstream side

From A1 to A2

From A2 to A1

Source: JICA Survey Team

Figure 2.4.1 Bridge Views

(2) Damages of Each Part of Concrete, Cracks, Free Lime, and Rebar Exposed

1) Survey results

P3-P4 span outermost girder of downstream side is damaged. All main rebars fell off due to the effect of over height cargo trucks. However, according to the structure verification, vehicle load has not been supported by these girders. However, these girders support the weight of the sidewalk(Because there is no connection of deck slab concrete and no connection of cross beam, therefore no lateral distribution of vehicle load.)

In other girders, deck slab and cross beam, traces of repairs in the f 1993 to 1994 were found, however, no defects such as new cracks, free lime, exposed rebar and the like could be found on the concrete.

Moreover, it is confirmed that the previous repair was completely functional since the same problems did not occur again to a place where it had been repaired.

2) Reaction on alkaline concrete

It has been already proved that aggregate of Sri Lanka cannot undergo alkali aggregate reactions in the past projects (STDP, OCH projects and so on). Therefore, it is not considered in this survey. In fact, the turtle-shaped crack which is a feature of the alkali-aggregate reaction was not found.

3) Salt damage

It is worried that concrete might be damaged by salt attack, because the New Kelani Bridge is located at 4 km from the sea and may be susceptible to seawater flow back to the bridge at high tide. However, no salt damage is found, since the river at this position has fresh water.

Even though the surface of pile cap concrete has been eroded by sea water and aggregate are exposed, however, the area is few millimeter deep only and no influence to the reinforcement bar. (Please see the photo of strike test.)

 P3-P4 Upstream side No concrete cover and rebar exposed	 P3-P4 Downstream side Concrete has been dropped for about 15 meter long and 10 nos. of rebar with a diameter of 32 mm have been missing. Urgent repairing is necessary.
 Trace of repairing for deck slab	 Traces of repairing girder dated on 20/1/94. No cracks were seen on the same spot.

Source: JICA Survey Team

Figure 2.4.2 Bridge Conditions (1/2)

Soffit of Girder, Trace of repairing.
Epoxycement might be used ?

Trace of deck slab repairing on 17/Aug/93.
No free lime after reairing.

At Gelber.
Before cracks have occred on this location but no cracks can currently be seen.

No cracks can be seen on girder, deck slab and cross beam.

Girder, deck slab and cross beam on the river portion. There are traces of repairing but no new defects can be seen.

Trace of repairing on the cross beam. Condition of deck slab is very good.

Source: JICA Survey Team

Figure 2.4.2 Bridge Conditions (2/2)

(3) Verification of Concrete Strength

1) Shmidt Hammer Concrete Strike Test

To examine the concrete strength of the existing concrete is one of the simple methods to determine the degradation due to aging of concrete bridges.

It was planned to carry out the Schmidt Hammer Test first. If the results are not satisfactory, it is necessary to take core to check more detail, however, if the results are satisfactory, core is not to be taken.

Test was conducted by local Engineering & Laboratory Services (PVT) LTD.

Locations of test are as follows.

Abutments (2 places), piers (9 points, 4 among 9 points on the river)

Girder (on the ground 5 points, 2points on the river)

10 locations were selected from the grid matrix consisting of 16 grids in accordance with Sri Lankan criteria. (Each grid has a spacing of 50mm x 50mm.) These results were recorded.

The design strength of the concrete at construction time was not available. Considering the current design standard that 30N/mm2 for the concrete strength for abutments and piers, and that 35N/mm2 for reinforced concrete girder, these figures can be applied.

Table 2.4.1 The Result of Schmidt Hammer Test

Place	A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	A2	Average (N/mm2)
Pier Concrete	35	35	44	48	52	37	34	44	35	39	32	36.25
Girder Concrete	37	37	39	33	50	46	-	-	-	-	40	40.29

Source: JICA Survey Team

Design strength (assumption)

Substructure (Abutment, Pier) 30N/mm2 < 36.25N/mm2(120%)

Superstructure (Girder) 35N/mm2 < 40.29N/mm2 (115%)

Judging from the results, there are no significant degradation (strength loss), and soundness of concrete is high and durable.

A1 Abutment Shmidt Hammer Test

P1 Pier

Marking 16 grids for shooting

P1-P2 No.3 Girder

P2 Pier

P1-P2 No.2 Girder

Source: JICA Survey Team

Figure 2.4.3   Schmidt Hammer Test (1/3)

P3 Pier

P2- P3 No.2 Girder

P4 Pier

P3-P4 No.2 Girder

P5 Pier

P4-P5 No.5 Girder

Source: JICA Survey Team

Figure 2.4.3 Schmidt Hammer Test (2/3)

 P6 Pier	 P7 Pier
 P8 Pier	 P9 Pier
 A2 Abutment	 P9-A2 No.6 Girder

Source: JICA Survey Team

Figure 2.4.3 Schmidt Hammer Test (3/3)

2) Concrete Strike Test

Strike tests were carried out on the following selected locations/points: unnatural bulge of concrete; rust; concrete whitened by free lime; and, aggregate exposed due to the erosion by water on pile caps in the river.

Special attention was paid to find the defects of concrete at bottom of pier so-called splash zone where the rust of rebar breaks the concrete, however, no defects could be found.

Rebound of hammer shows that all the concrete are well consolidated and no hollows under the concrete.

The appearance of pile cap concrete in the river looked badly damaged; however, very hard rebound shows no problem of soundness.

 Strike Test on Pier	 Pile Cap Concrete Erosion (Other piers are the same)
 Eroded Concrete Surface	 Strike Test (White trace shows it is hard aggregate)

Source: JICA Survey Team

Figure 2.4.4 Strike Test

(4) Extent of Damage of Bridge Bearing

All bridge bearings were encased in concrete during major repair in 1993 to 1994. Therefore no bearings can be seen. It is assumed that rocker bearings were installed at the fixed points and roller bearings were installed for the movable side.

1) Following reasons why steel bearings were encased by concrete are assumed: It was considered that there would be no movement, because deformation of concrete caused by shrinkage and creep was completed 35 years after construction.

2) The difference of range of annual temperature in Sri Lanka is about 10 ℃, and span length is not so long. Therefore movement due to temperature is very small.

3) From the above-mentioned reasons, it was considered that to encase the bearings in concrete was more economical than to replace the new bearings.

Bridge bearing surrounded by concrete

Detail of the Bearing
It seems the bearing is encased in concrete.

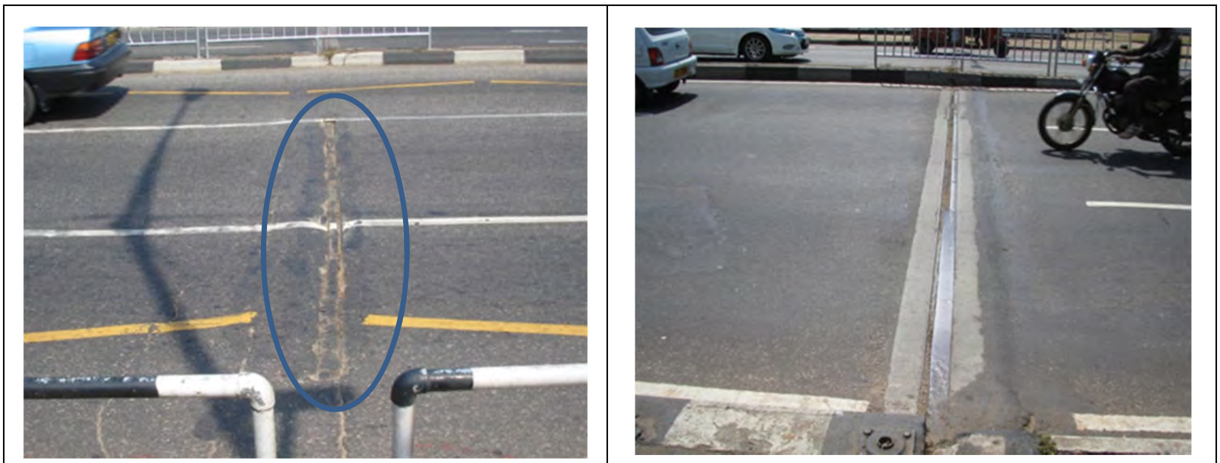
Source: JICA Survey Team

Figure 2.4.5 Extent of Damage of Bridge Bearing

(5) Extent of Damage of Expansion Joint

There are eight expansion joints in New Kelani Bridge. (1 no. each at A1, A2 and 6 nos. at Gelber section.) Shape of expansion joint is very simple type. It is consists of angle shape steel and water proof rubber are in between two angle plates. Estimate movement is approximately 20mm. Almost all expansion joints are covered by asphalt pavement already. It works well because of the small amount of movement as mentioned in the above, however some asphalt cracks can be seen.

However, most of the rubber seals are broken and flow of leakage water has been making the girder concrete dirty.

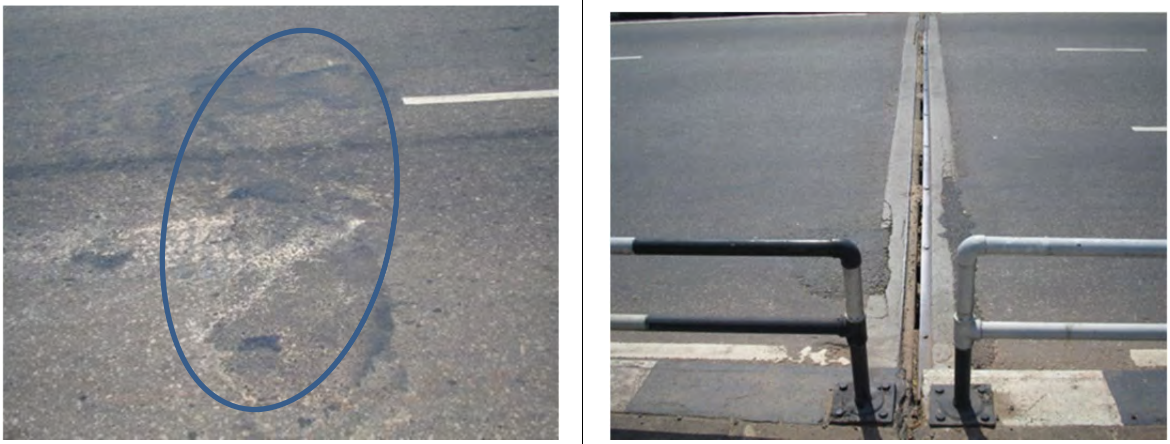


A1 Expansion joint, upstream side
The joint is covered by asphalt, some cracks have appeared but it is still functioning well.

A1 Expansion joint, downstream side
The joint is still in good shape.

Second joint from A1, upstream side
There are some cracks but functioning.

Same as left, downstream side
There are some cracks but in good condition.

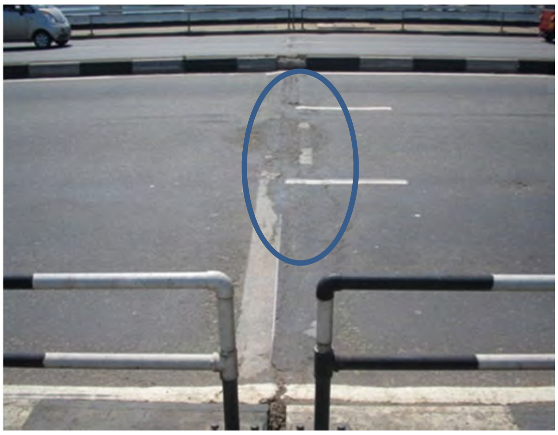


Third joint from A1,upstream,
No cracks but uneven surface.

Same as left, downstream side
Keeping good original shape.

Source: JICA Survey Team

Figure 2.4.6 Extent of Damage of Expansion Joint (1/3)

 The 4th joint, upstream side Covered by asphalt completely.	 The 4th joint, downstream side There are cracks but in good condition.
 The 5 th joint, upstream side There are cracks but functioning.	 The 5th joint, downstream side Keeping good original shape.
 The 6th joint, downstream side There are cracks but good functioning.	 The 7th joint, downstream side There are cracks but functioning.

Source: JICA Survey Team

Figure 2.4.6 Extent of Damage of Expansion Joint (2/3)

A2, upstream
It works good.

A2, downstream
There are cracks along the joint.

Source: JICA Survey Team

Figure 2.4.6 Extent of Damage of Expansion Joint (3/3)

(6) Extent of Damage of Road and Asphalt

No erosion of slope in the land fill area is found because the slope is covered by grasses already. No settlement due to consolidation is found. Consolidation has been completed in 59 years.

Therefore there is no uneven surface due to settlement. Asphalt surface has no pot holes and serious cracks and almost smooth. However there are some cracks just around expansion joints on the bridge.

Conditions of the asphalt at approach roads are as follows:

1) Base line road

There are no significant cracks and pot holes, and some cracks has been repaired already. Surface is smooth and good condition.

2) Road from Weragoda round a bout to west (New Kelani Bridge road)

There are only minor damages such as cracks around expansion joints and pot holes on the pavement surface.

3) Road at Orugodawatta intersection (Stace road, Avissawella road)

Stace road: Surface is very uneven due to heavy loaded trucks and due to the bad paving after trench work. This asphalt pavement must be replaced.

Avissawella road: Condition is good.

Slope at fill area, no erosion
Colombo, upstream side

Asphalt on the bridge
Good condition generally.

Cracks around expansion the joint.

P9-P10 span downstream side,
Asphalt thickness is thin. Deck slab concrete are exposed.

Base line Road near Orugodawatta.There is the trace of asphalt crack repairing.

At Orugodawatta crossing
Asphalt is in the very good condition.

Source: JICA Survey Team

Figure 2.4.7 Extent of Damage of Road and Asphalt (1/2)

 From A2 to Kandy Road Asphalt is in the very good condition.	 At intersection of Waragoda Left lane going to Base Line road is good surface.
 New Kelani Bridge Road No pot holes, cracks and smooth surface.	 Stace road, there are many cracks and uneven surfaces. Must be repaired.
 Avissawella road Good condition.	 Avissawella road, around end of interchange. Good condition.

Source: JICA Survey Team

Figure 2.4.7 Extent of Damage of Road and Asphalt (2/2)

(7) Other Bridge Facilities

1) Bridge Hand Rails

Handrail made by concrete are remained in perfect condition, but there is a damaged place by vehicle collision near A2 abutment.

2) Footpath

Footpath surface is consisted of concrete precast panel. Around the above-mentioned area where the handrail is damaged, the surface is uneven.

3) Guard rail separating footpath from carriage way

There are some damaged places.

4) Bridge lighting

No damages are found.

Above damages on the bridge facilities are not serious but easy to repair. Judging from the point of traffic safety and protecting pedestrian from accident, it is recommended to repair urgently by the maintenance division of RDA.

Bridge handrail
Almost perfect condition.

Damaged place
May be collision of vehicle.

Footpath, surface of concrete panel.

Protection guard rail broken.

Protection guard rail broken.
A1-P1, downstrem

Bridge lighting
In good condition.

Source: JICA Survey Team

Figure 2.4.8 Other Bridge Facilities

(8) Other bridge Condition

Friendship bridge (Victoria Bridge) is located approximately 1km west from New Kelani Bridge.

This Bridge is a Pre-stressed concrete bridge, constructed by Incremental Launching method. Completion date is 1994 and 2000. Therefore, soundness of concrete is very good and condition of road asphalt is also very good.

Victoria bridge, upstream side
No defects were found.

Downstream side

From underside of the bridge
No cracks can be seen.

Bridge Bearing
No damages.

Source: JICA Survey Team

Figure 2.4.9 Other bridge Condition

2.4.4 Conclusions and Recommendations

(1) Conclusions

As an overall conclusion, soundness and durability of the New Kelani Bridge is satisfactory. We can verify that we do not have to take into account early reconstruction of the existing bridge in consideration of Second New Kelani Bridge construction projects, except where necessary repair of P3-P4 span.

Conclusions on the condition of New Kelani Bridge and recommendations are stated as follows.

- Concrete strength for both substructure and superstructure has maintained the original strength. Deterioration of strength due to aging is small.
- The internal degradation by salt and alkali-aggregate reaction has not occurred.
- Exposure of rebar by rust and concrete bulging was found.
- Stress cracks in the concrete subsidence due to live load, settlement of substructure, shrinkage were not found.
- Damages of the bridge bearings were not found.
- Function of expansion joints have not been impaired, it works as the blind joint.
- There are some cracks and uneven surfaces on the asphalt pavements, however, these places can be repaired by minor works. As far as the Stace Road is concerned, the road must be repaired from sub-base layer.
- The partial repairing works for some bridge handrail, footpath, precast panel, protection guard rail, are necessary. It is recommended that these repairi works should be done by local authority from the pedestrian’s safety point of view.
- The damage of girder at P3-P4 span, especially downstream side, must be repaired as soon as possible. This girder is not currently carrying the vehicle live load but main rebars have been. If a big lorry hit one more time, the girder may collapse.It depends on the discussion between two countries if this repairing work shall be included in the scope of work of new project, however, repairing cost is considered not significant, thus, it is recommended that the repairing work be carried out by the local implementing agency from the viewpoint of urgency, too.

(2) Recommendations

1) Recommendation for Repairing P3-P4 Girder

JICA Survey Team would like to propose to use “Steel Plate Bonding Method” as shown in Figure 2.4.10. Steel Plate can work as the part of form work and protection plate for concrete in case lorry hit the girder in future again.

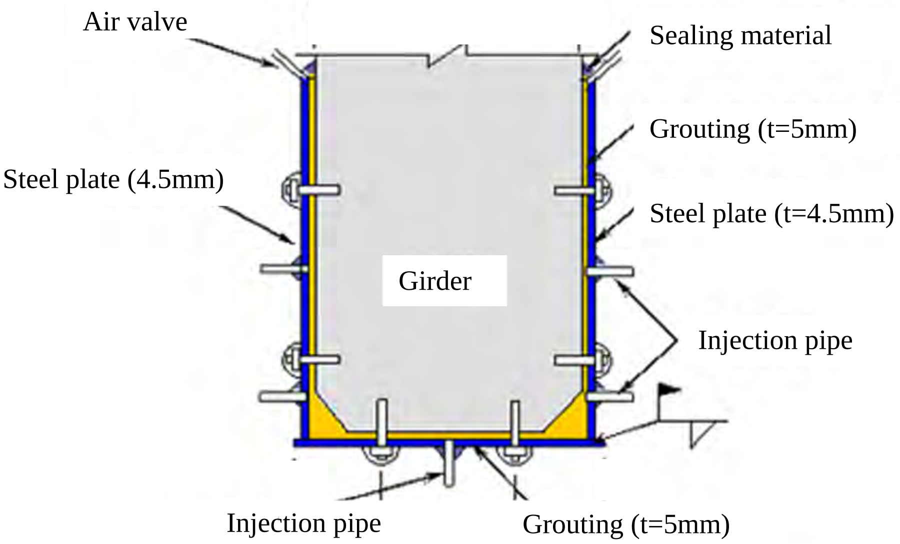


Figure 2.4.10 Detail of Steel Plate Bonding Method

2) Installation of Height Limit Guard Rail

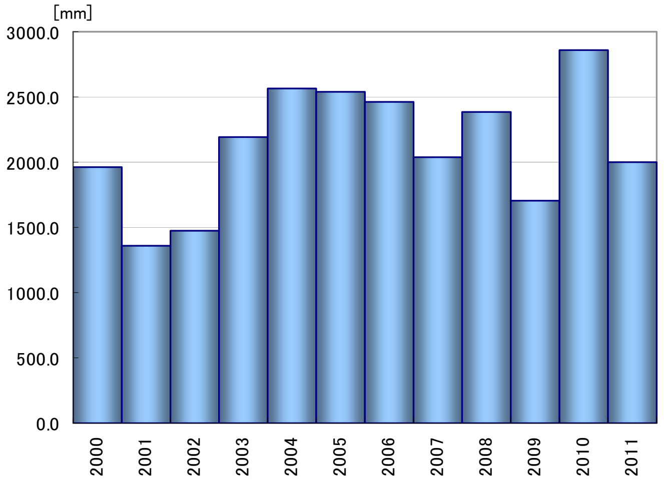
In addition to the above repairing, it is necessary to install ”Height Limit Guard Rail” on both downstream and upstream sides in order to prevent the same incident occurring in future.

Source: JICA Survey Team

Figure 2.4.11 Example for Height Limit Guard Rail (Victoria Bridge)

2.5 Project Site Conditions

2.5.1 Meteorological Condition



Source: JICA Survey Team

Figure 2.5.1 Amount of Rainfall during Rainy Season

Sri Lanka has a tropical climate, which is hot and humid. In this climate, the seasons are divided into two, namely rainy season and dry season. Rainy season sets in May and closes in August from the effect of southwest monsoon. Amount of rainfall increases especially in May, June and August in the rainy season. In November, amount of rainfall also increase due to the northeast monsoon.

As shown in Figure 2.5.1, total amount of rainfall during rainy season varies little during recent years.

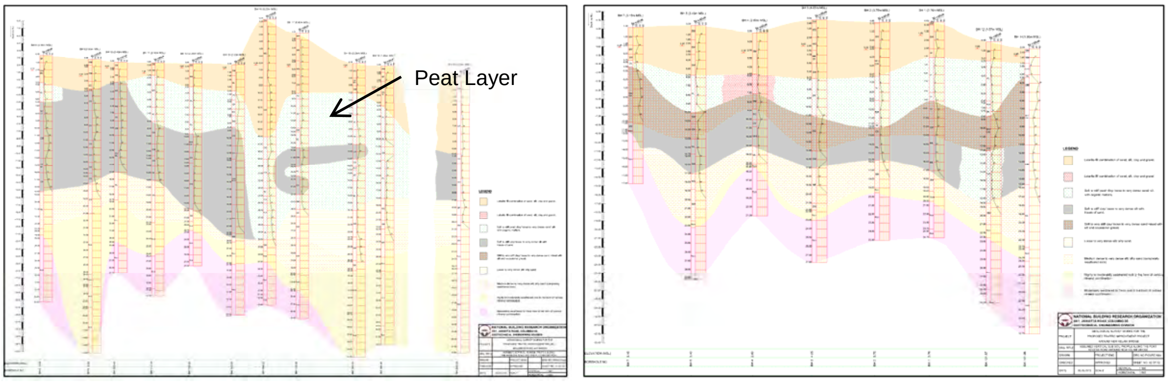
On the other hand, monthly maximum wind speed exceeds 10 m/s in many months at the project site.

These meteorological conditions should be considered in the plan, design and construction stage of the Project.

2.5.2 Topographic and Geological Condition

Project site, around New Kelani Bridge, has suffered from flood damage many times since the topography in the project site is low altitude and flat.

Geological condition in the project site is formed with sediment deposited by the Kelani River, and covered by peat in upper layer. According to the geological survey result, peat layer is laid in the upper layer, and clay layer is laid under the peat layer (see Figure 2.5.2).



(a) Along Baseline Road

(b) Along Port Access Road

Source: JICA Survey Team

Figure 2.5.2 Geological Condition in the Project Site

Soft ground treatment should be considered in the earth work sections and bridge approach sections.

Detailed discussion is stated in “5.2.1 Geological Conditions”.

2.5.3 Utilities

The utilities in the project area, which were identified by JICA Survey Team through the investigation, are shown in Figure 2.5.3 to 2.5.5. Other utilities and their details were found in the topographic survey, which was completed in early April.

As shown in Figure 2.5.5, power lines and pylons are affected by the Project Road. These power lines (132 kV, 220kV) are connected directly to the power station, and the power is provided widely in Colombo. It was agreed with Ceylon Electricity Board (CEB) that the power lines will be relocated before commencement of the construction.

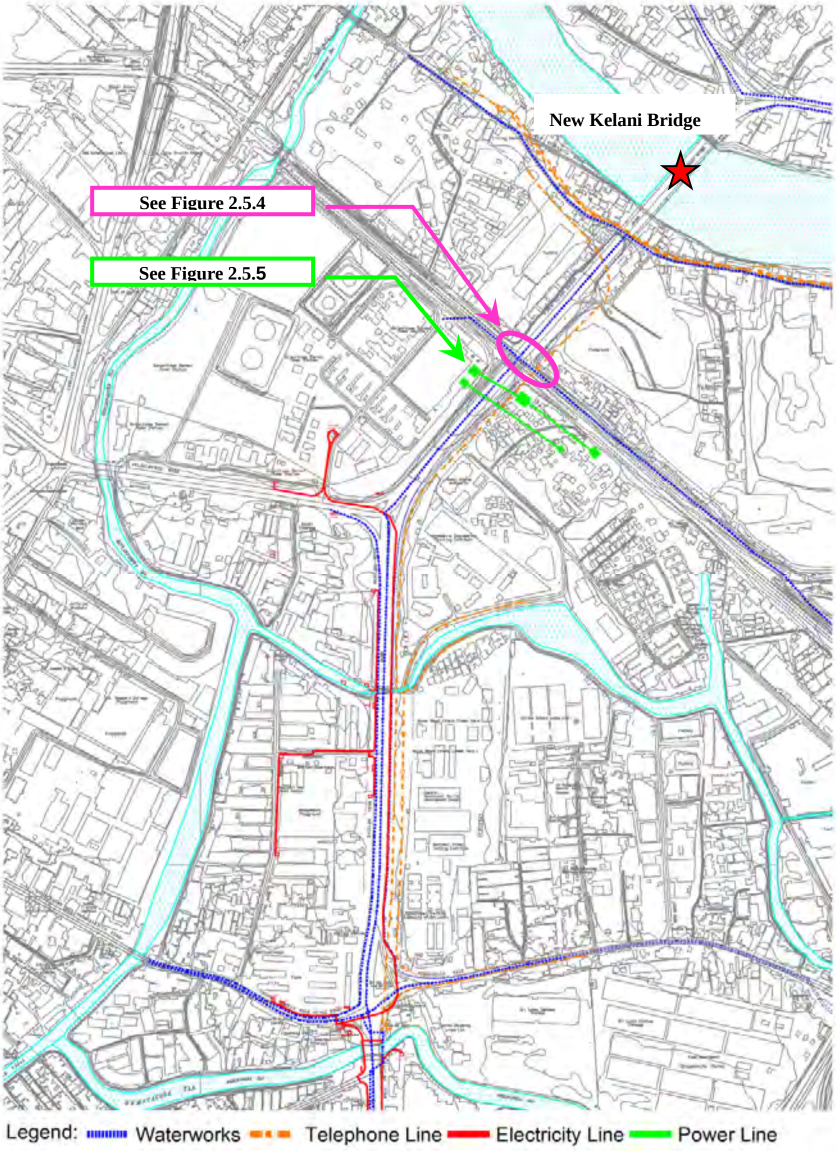
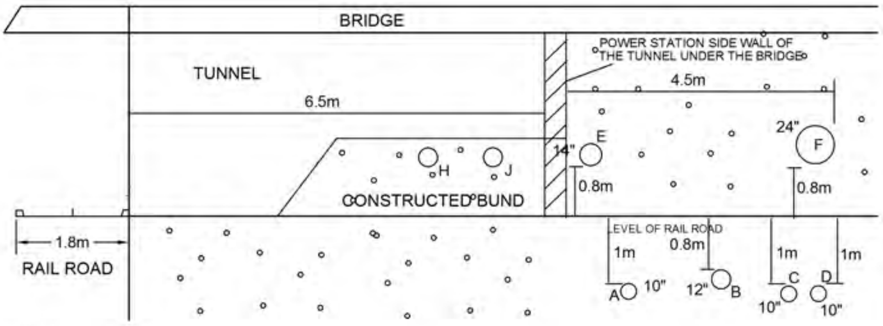


Figure 2.5.3 Location of Utilities in the Project Area



NOTES
THE ABOVE DRAWING IS THE CROSS SECTIONAL VIEW WHEN LOOKING FROM HARBOUR SIDE TOWARDS THE BRIDGE

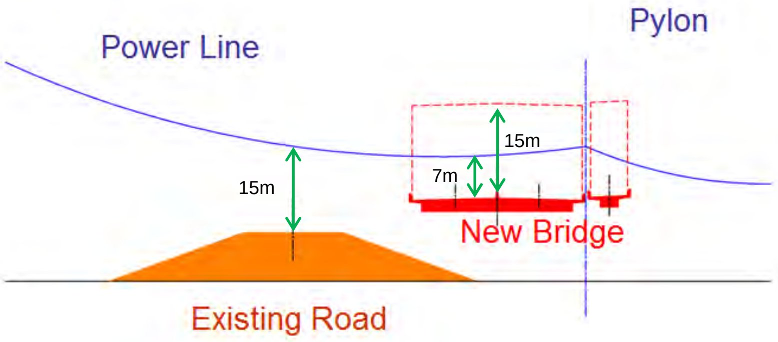
A: DIESELLINE
B: WHITE OIL LINE
C: ABONDONED LINE
D: ABANDONED LINE
E: FUEL OIL LINE
F: CRUDE OIL LINE
H AND J: PIPELINES LAIED WITHIN THE CONSTRUCTED BUND IN SIDE THE TUNNEL UNDER THE BRIDGE TO BYPASS THE LEAKING PIPELINE SECTIONS

IT ASSUMES THAT ELEVATIONS OF ALL THE PIPELINES AND RAIL ROAD WITHIN THE TUNNEL ARE SAME THE ELEVATION AT OUTSIDE OF THE TUNNEL

▨ EARTH FILLED AREAS

Source: Ceylon Petroleum Storage Terminals Limited

Figure 2.5.4 Detail of the Pipelines



Source: Ceylon Electricity Board (CEB)

Figure 2.5.5 Cross Section for Power Line and Pylon

In addition, the affected public utilities shown in Table 2.5.1 were identified through the RAP survey.

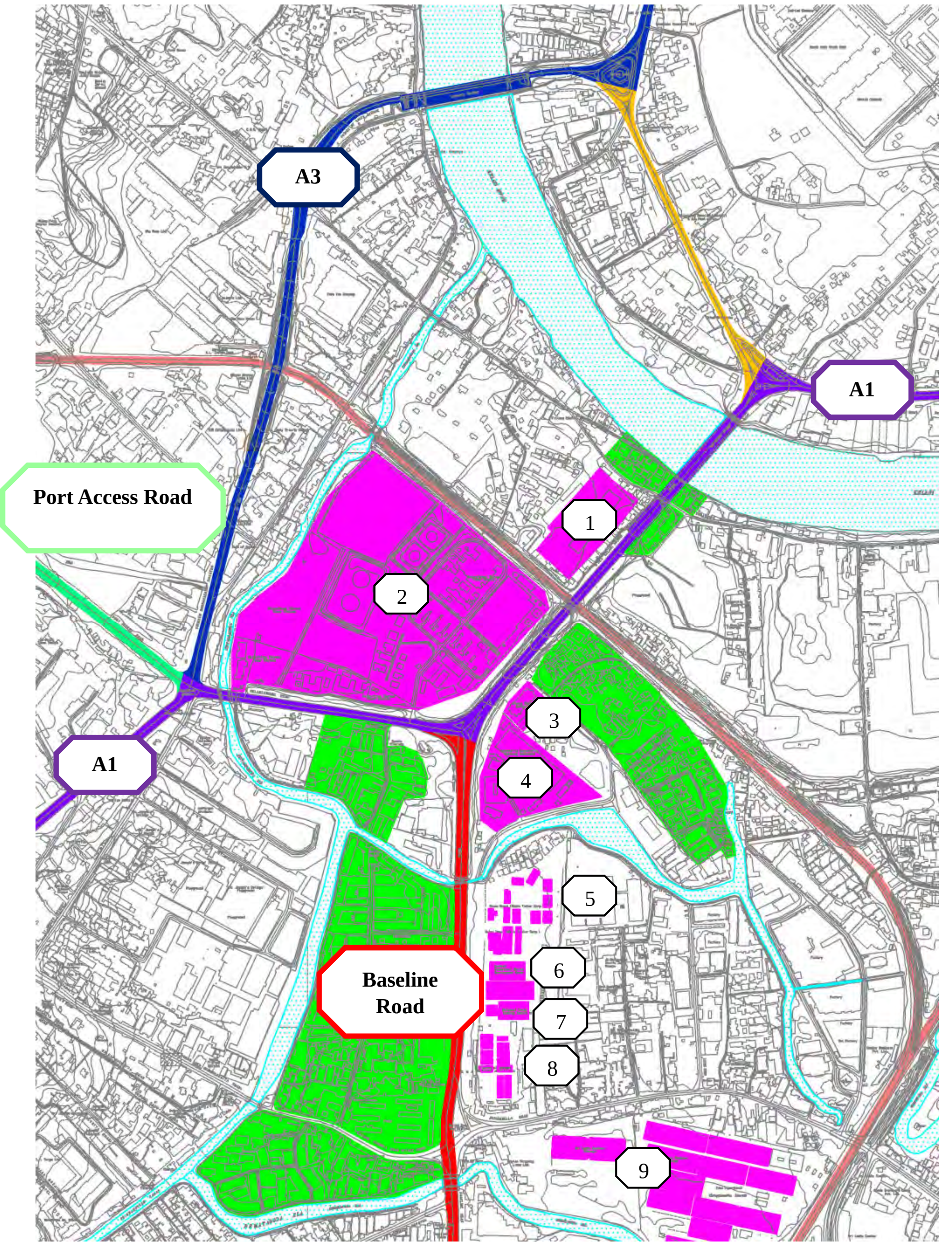
Table 2.5.1 Affected Public Utilities

DS Division	G.N. Division	Type and No. of Public Utilities								
		Telecommunication posts	Electricity Transmission	Lamp posts	Manhole Telecom	Name Board	Sign Board	Manhole Water	Manhole	Telecom Cable Box
Colombo	Bloemendhal	3	0	10	0	2	0	0	3	2
	Nawagampura	11	5	30	13	29	4	7	9	4
	Grandpass	4	0	5	7	2	4	0	10	1
Kolonnawa	Orugodawatta	3	2	1	1	0	0	0	0	0
	Sedawatta	9	7	16	0	0	0	0	0	0
	Wadullawatta	10	22	64	4	13	10	2	4	0
Kelaniya	Peliyagoda Gangabada east	3	4	6	1	2	4	0	0	0
Total		43	40	132	26	48	22	9	26	7

Source: JICA Survey Team

2.5.4 Land Use

Major facilities and areas in the project site are shown in Figure 2.5.6. In the figure, Kelanithissa Thermal Power Station, Atomic Energy Authority and Automobile Engineering Training Institute will be affected by the Project. The buildings for Atomic Energy Authority and Automobile Engineering Training Institute will be able to be relocated. However, it is difficult to relocate Kelanithissa Thermal Power Station. The buildings of the Power Station will be avoided in the alignment study, although a part of the land will be affected.



🟪 Facility Name

1	Factory	6	Central Vocational Skills Development Centre
2	Kelanithissa Thermal Power Station	7	National Trade Testing Institute
3	Atomic Energy Authority	8	Vocational Training Authority of Sri Lanka
4	Automobile Engineering Training Institute	9	Sri Lanka Customs Storage
5	Sales Depot (State Timber Corp.)		

🟩 Residential Area

Source: JICA Survey Team

Figure 2.5.6 Existing Land Use Map

2.6 Issues of Existing Road Conditions

Major issues of the existing road condition are as follows.

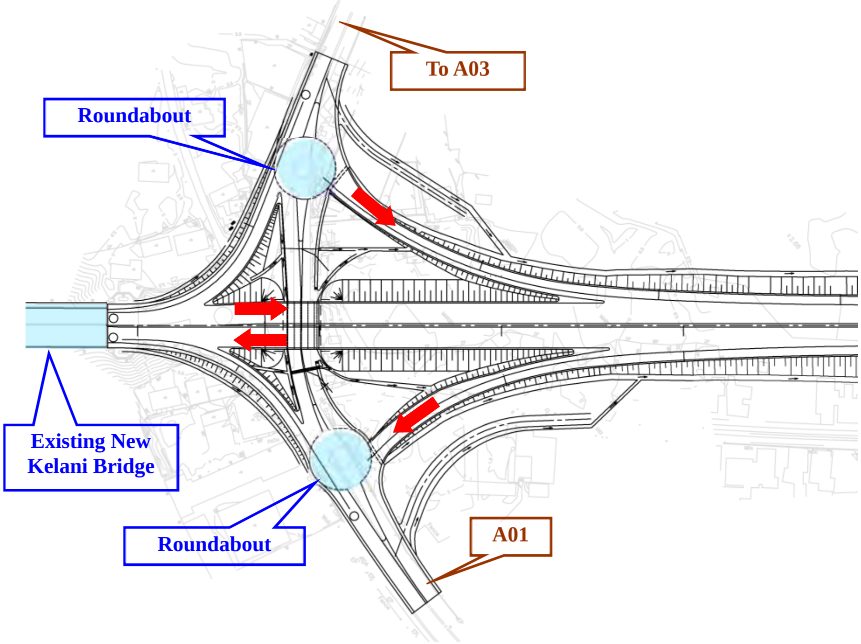
- Three bridges across the Kelani River have been always congested, especially in morning and evening peak hours, due to a high concentration of vehicles on the bridges (see Figure 2.6.1).

Source: JICA Survey Team

Figure 2.6.1 Three Bridges across Kelani River

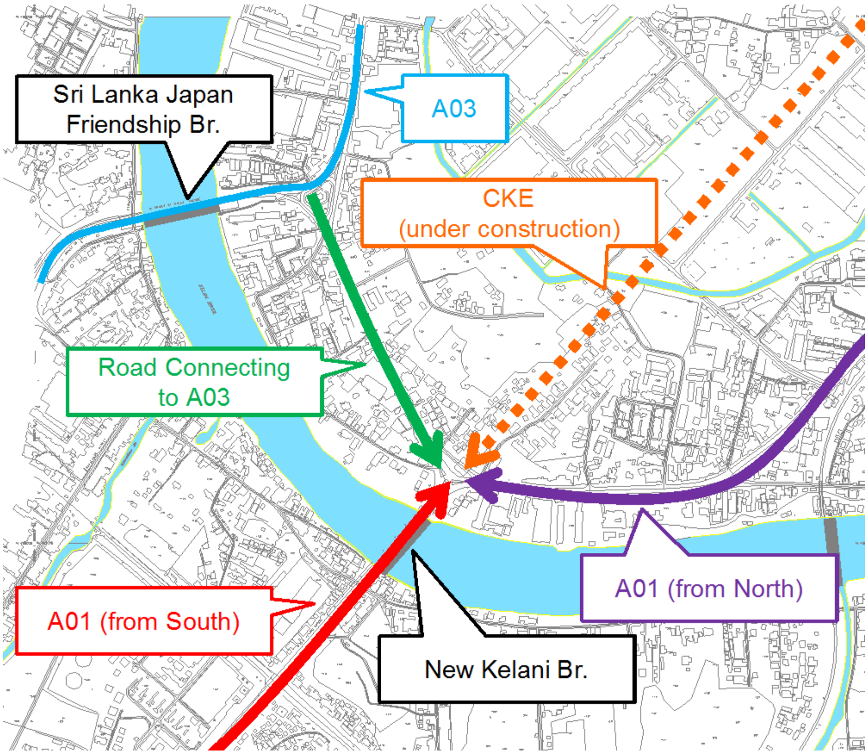
- It is forecasted that traffic volume on the Kelani Bridge will increase and the Bridge will become a traffic bottleneck in this area, since some projects such as Colombo - Katunayake Expressway (CKE) (completed in 2013), Outer Circular Highway (OCH) (completed in 2015) and the expansion of existing Colombo Port (under planning) is under construction or planning.

- CKE is connected to the existing New Kelani Bridge, and ramps are connected to two adjacent roundabouts (see Figure 2.6.2). Traffic congestion around New Kelani Bridge will be worsened since a large number of vehicles from CKE, A01 Road (from north), the road connecting to A03 Road and A01 Road (from south) will concentrate in this small area (see Figure 2.6.3).



Source: CKE Construction Project

Figure 2.6.2 Area around CKE Endpoint

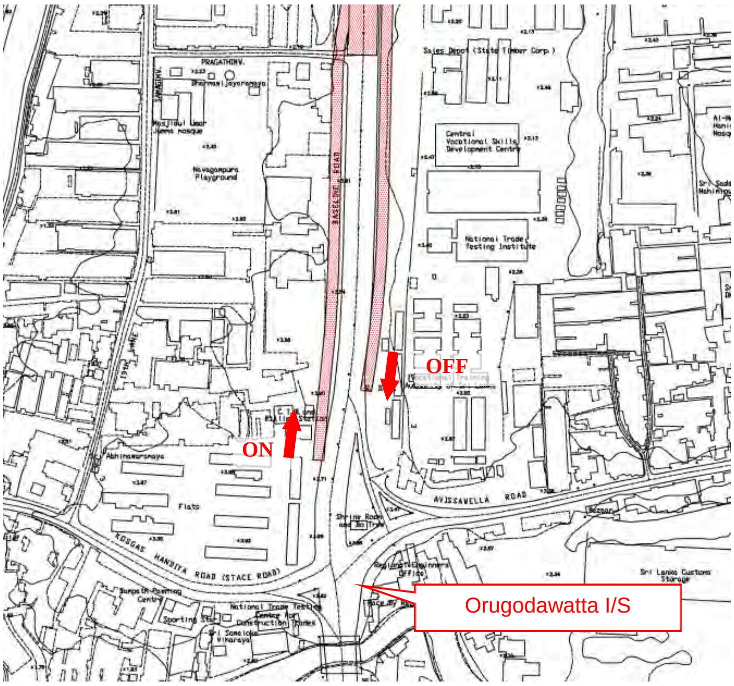


Source: JICA Survey Team

Figure 2.6.3 High Concentration of Vehicles around New Kelani Bridge

- Traffic volume of the Baseline Road near Orugdawatta Intersection is 95,801 veh/day (89,833 pcu/day) in 2012. The traffic capacity on the Baseline Road, which has 6-lane carriageway, is not enough even in the present condition.

- The construction of the Second New Kelani Bridge and approach road (hereinafter called the Project Road) will be connected to the Baseline Road around the Orugodawatta Intersection through on/off ramps (see Figure 2.6.4). Large volume of vehicles will flow into the Baseline Road, whose capacity is already overflowed, around the Intersection.



Source: JICA Survey Team

Figure 2.6.4 On/Off Ramp on Baseline Road

2.7 Purpose of the Project

The purpose of the Project is to improve the traffic situation around New Kelani Bridge.

In order to accomplish the project purpose, the Second New Kelani Bridge and approach road (the Project Road) will be constructed. Traffic situation in this area will be improved by this Project, since the traffic capacity will increase to more than double.

On the other hand, the master plan study (CoMTrans) is being carried out by JICA. Future transport network plan including road, railway and public transportation network for Colombo metropolitan region and suburbs will be presented in this project. In addition, as a part of road network in Colombo metropolitan region, the urban arterial road network is expected to be proposed in the Study.

Alignment of the Project Road as well as the type of interchanges will be determined in consideration of the connectibility to the urban arterial road network and its scalability.

In addition, as stated in “2.6 Issues of Existing Road Conditions”, the traffic congestion in Baseline Road near Orugodawatta Intersection will worsen by the construction of the Project Road. Therefore, improvement of the Intersection will also be implemented in this Project.

3. TRAFFIC DEMAND FORECAST

3.1 Introduction

The survey team developed the linear regression model of passenger and freight separately, and forecasted the future traffic demand of the Project roads with future socio-economic framework based on updated observation traffic volume from the survey implemented in target area in 2013.

With the support of JICA, the “Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs (CoMTrans)” has been implementing the home visit survey in the Western Province, and is developing the model of traffic demand forecast in the wide area based on the person trip from the result of the home visit survey. After completion of home visit survey and establishing the transport model, the model will be able to forecast the future traffic demands and assignments of each transport network, including the existing roads, proposed public transport network and the expansion of the road traffic network at wide area level.

Since the CoMTrans schedule is different from the one of this preparatory survey, it will be possible to verify the results of this traffic demands by the CoMTrans model later. Note that, as of the progress of CoMTrans on July 2013, the estimated future traffic demand by this survey is confirmed to be acceptable demand level in accordance with the CoMTrans directions..

3.2 Methodology for Traffic Demand Forecast

3.2.1 Dataset of Observed Traffic Volume for Traffic Demand Forecast)

Dataset of the observed traffic volume, for use of the linear regression model development is as follows:

- Previous survey on traffic volume for both direction by RDA: the year of 2006, 2010 and 2012
- This survey: the year of 2013

The traffic volume by vehicle type which crossed the point of the new Kelani Bridge and Japan Friendship Bridge were collected, and these areas are targeted for the forecast model.

Targeted vehicle type for forecast was used with six types, such as i) motor cycle, ii) 3-wheeler, iii) car, iv) bus, v) truck and vi) trailer, based on the vehicle type structure in the traffic volume survey at each point.

Average vehicle occupancy was applied the average number from the observation results of CoMTrans. PCU factor was used for the value of RDA Geo Design Standards (1998).

The Table below shows the collected traffic volume data from RDA and the results of the survey by the JICA survey team in 2013.

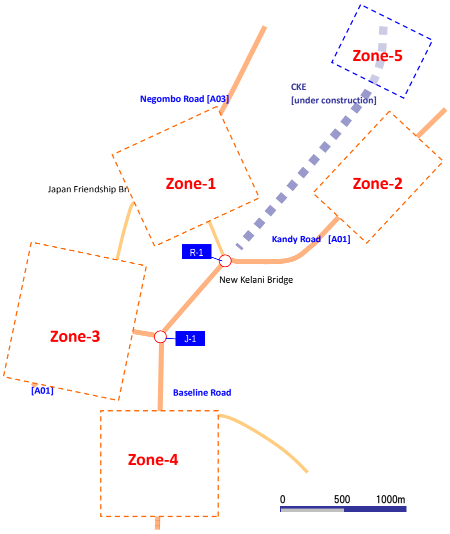
Table 3.2.1 Collected Traffic Volume

Vehicle Type	This Project	MB	Three Wheeler	Car + Van + Pickup	Medium + Large Truck	Container Trailer	Minibus + Large Bus	Total (Vehicle)	Total (PCU)
	RDA	MCL	TWL	CAR + VAN	LGV+R2+HG	AG3+AG4+ AG5+AG6	MBU+LBU		
	2011	Motor Bike	3-Wheeler	Car Jeep/ Pickups, Pax. Van, School Van, Delivery Van	Light Goods, Medium Goods, Heavy Goods	Multi Axle	Route Bus, Non-Route Bus, School Bus		
Daily Traffic Volume (Both Directions)									
New Kelani Bridge A01, Kandy Road	2006	13,753	8,656	36,182	9,270	362	6,179	74,402	77,695
	2010	22,233	17,700	34,104	9,137	1,406	5,905	90,485	90,576
	2012	18,732	17,012	31,270	9,417	1,313	5,983	83,727	85,678
	2013	23,052	18,245	36,608	8,776	1,759	6,307	94,747	95,407
Japan Friendship Bridge A03, Negombo Road	2006	6,978	9,198	16,761	6,354	232	2,831	42,354	44,150
	2010	11,030	10,946	15,664	5,579	969	2,869	47,057	48,173
	2012	11,389	15,897	16,090	5,515	1,189	3,052	53,132	53,822
	2013	11,104	12,952	14,978	4,581	1,293	2,925	47,833	48,824
A001, Kelaniya	2004	12,762	8,546	31,380	7,724	494	6,035	66,941	69,964
A003, Peliyagoda	2004	8,100	7,625	23,353	5,318	1,175	2,626	48,197	51,708

Note: PCU is applied by the factors (MCL=0.5, TWL=0.8, CAR+VAN=1.0, LGV/R2/HG=1.5/1.7/2.8, AG3-6=4.0, MUB/LBU=1.6/1.8, DA Geo Design Standards (1998), Multi-lane, Flat)

Source: RDA (2006, 2010, 2012), JICA Survey Team (2013)

The current OD traffic volume in analyzed target network was estimated to set up the ratio for turning traffic volume of each intersection based on the traffic volume survey for each direction at each intersection conducted during this survey period on March and April, 2013.



Source: JICA Survey Team

Table 3.2.2 Estimated Origin-Destination Matrix in 2013 (Daily)

Upper: Nos. of Vehicle
Middle: Nos. of Large Vehicle (Truck, Bus, Trailer)
Bottom: ***PCU***

O-D	Zone-1	Zone-2	Zone-3	Zone-4	Total
Zone-1	0 (0) **0**	4,544 (691) **4,471**	2,986 (1,089) **4,043**	15,307 (2,684) **15,397**	22,837 (4,464) **23,911**
Zone-2	6,535 (1,565) **7,875**	0 (0) **0**	5,191 (2,051) **6,898**	23,416 (3,645) **22,757**	35,142 (7,261) **37,530**
Zone-3	2,716 (919) **3,508**	6,692 (1,926) **7,373**	0 (0) **0**	4,765 (2,280) **8,151**	14,173 (5,125) **19,031**
Zone-4	10,691 (2,090) **11,551**	25,722 (3,531) **24,128**	4,321 (988) **5,118**	0 (0) **0**	40,734 (6,609) 40,796
Total	19,942 (4,574) **22,933**	36,958 (6,148) **35,972**	12,948 (4,128) **16,059**	43,488 (8,609) **46,305**	112,886 (23,459) **121,269**

Source: JICA Survey Team

3.2.2 Socio-Economic Framework

In terms of socio-economic indicator used for the framework of the future traffic volume, the population was set up for two districts related the Project roads, and GDP growth in Sri Lanka was applied since most of the country's total economic activities are concentrated in Colombo metropolitan region.

Future population was used for the value of future frame, examined in CoMTrans (the estimation by cohort analysis)

The GDP growth rate until 2017 was referred to the forecast by IMF and Central Bank of Sri Lanka (AAGR = 6.5%), and the forecast after 2018 was set up by the survey team (AAGR = 5.5 % from 2017 to 2020 and AAGR = 4.0% from 2020 to 2035).[1]

The Table below shows the previous statistic data and the frame value in 2035

Table 3.2.3 Population, GDP and Future Value

GDP/ Population	Unit	2001	2006	2010	2012	2013	2035 est.
GDP (base year = 2002)	(billion Sri Lanka Rupee)	1,743	2,095	2,639	3,050	3,255	8,854
Population: Colombo District	(million)	2.251	2.277	2,298	2.310	2.326	2.979
Population: Gampaha District	(million)	2.064	2.166	2.251	2.294	2.322	3.178
Population: Western Province	(million)	5.381	5.578	5.740	5.822	5.883	7.940

Source: JICA Survey Team

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[1] I MF evaluated the value of AAGR at 7.763 in 2010, 8.257 in 2011, and estimates around 6.50 to 6.75 during 2012 to 2015 described in the World Economic Outlook Database. On the other hand, Central Bank of Sri Lanka estimates the value of AAGR at 6.5 in 2012, 7.50 in 2013, 8.0 in 2014 and 8.3 in 2015. Therefore, the Survey Team assumed that it would be moderate value, which is 6.50 in near future and become to be reduced to 4.0 because of matured economic activities.

3.2.3 Forecast Models for Passenger/Freight Traffic

Based on the observed traffic volume and socio-economic indicator, the linear regression model was formulated for future passenger and freight traffic volume in the target area.

- Passenger traffic volume model: the regression model was formulated with the total number of passenger (motor cycle, 3-wheleer, car and bus) per day, crossing the new Kelani Bridge and Japan Friendship Bridge as the dependent variable, and district population (Colombo and Gampaha) as the independent variable. The formula developed is expressed as, "Y = 0.154086 * person - 157,171 (R2=0.81) [2]"
- Freight traffic volume model: the regression model was formulated with the total number of the freight PCU per day, crossing the new Kelani Bridge and Japan Friendship Bridge as the dependent variable, and GDP as the independent variable. The formula developed is expressed as, "Y = 5.29 * GDP + 18,832 (R2=0.80) [3] ".

3.2.4 Increments of Future Traffic Demand

Based on the passenger/freight model mentioned in 3.2.3, the traffic demand in 2035 (compared to 2013) was estimated as follows, applying the future socio-economic framework.

- Passenger traffic (number of passenger basis): increased by 40% (1.40 times)
- Freight traffic (PCU basis): increased by 85% (1.85 times)

Passenger traffic volume which crosses the CMC boundary including the new Kelani Bridge and the Japan Friendship Bridge in 2035 is estimated to be increased by approximately double of 2013 according to the result from the preliminary analysis of the CoMTrans.

It can be guessed that 60% of these increased passengers by 2035 are supposed to shift by the railway modernisation, introduction of new transport system, and be diverted to the improvement of wider road network. It is also considered to secure the moving route from Kandy road to inner city especially by the development of terminal station for the new transport system as well as to improve the transport efficiency such as BRT. Based on the above discussion, these demand forecast are assessed to be reasonable one for the Project evaluation.

The freight traffic volume in 2035 is assumed to be increased by approx. 1.85 times volume since GDP per capita in Sri Lanka is increased by approx. 2.11 times. It is also assessed to be valid.

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[2] Details are described in the annex.

[3] Details are described in the annex.

3.2.5 Assumptions for Traffic Volume Estimation for each Vehicle Type

The traffic volume by vehicle type for passenger/freight traffic demand in 2035 was set up as follows.

The passenger traffic of car, motor cycle, 3-wheeler are estimated. The increased volume of passenger demand for car and bus is assumed to be increased, and the volume of motor cycle and 3-wheeler maintains status quo.

The freight traffic is assumed to be increased with same proportional of vehicle type structure.

3.2.6 Assumptions for Traffic Volume Development to/from CKE

For the traffic volume of the CKE after the operation, the traffic volume at the peak hour in 2032 is estimated in the feasibility study of the CKE (the direction of inflow to urban area: 2,566 vehicle/hour (of which large-truck and trailer 593 vehicle/hour)). From the viewpoint of traffic network, the traffic which pass through the same section of the CKE is considered a) shift from A01 (Kandy Road), b) shift from A03 (Negombo Road), and c) induced traffic volume by development of the CKE and the Kandy Expressway. For the survey, the following traffic is assumed that the vehicles, using A01 and A03 will shift to CKE, and the rest are considered the induced traffic volume by the operation of CKE.

- The car, truck and trailer, using A01 are assumed to pass the Project road which connects to the CKE section with free charge. Because of the same length from Kandy road to the Project road by using CKE free section or current A01 road, a half number of buses from Kandy are assumed to use the Project road (for the reference, according to the survey on the bus operation number by route in CoMTrans, the ratio for the number of operation route on A01 and B104[4] is 7:3). The ratio for turning traffic volume at Kelanitissa Interchange (J-1) in Project road is 76% in the direction to port access, and 24% in the direction to the Baseline Road.
- Of which the traffic using A03, the traffic which goes to south, using the Baseline Road will shift to the CKE route.
- The motor cycle and 3-wheeler are assumed not to pass the CKE and the Project road.
- OD traffic volume of induced traffic volume is assumed to follow the origin-destination trip pattern, considering that A01 road as the main destination is the traffic generation/attraction zone.

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[4] B104 is the B-class road which runs from 4th mile post junction to east along the right side of the Kelani river.

3.2.7 Future Traffic Volume

The future traffic volume (2035) is estimated as the table below. The traffic volume in the year of 2020 for the start of operation and that in the year of 2022 and other interval years are also estimated based on the traffic forecast in 2035.

Table 3.2.4 Traffic Volume for Both Direction

Unit: vehicle/day (truck and trailer)

Year/project with and without		New Kelani Bridge 【Existing】	New Bridge 【Elevated】	To Port Access		Base Line
				【Existing】	【Elevated】	
Current condition (2013)		92,700 (17,900)	N/A	27,100 (9,300)	N/A	86,400 (15,300)
2020 (start of operation)	With	67,000 (12,000)	51,600 (12,100)	34,100 (13,200)	10,200 (5,400)	107,200 (18,400)
	Without	118,600 (24,100)	N/A	44,300 (18,600)	N/A	107,200 (18,400)
2022 (two years after the operation)	With	67,900 (12,000)	58,100 (13,800)	35,800 (14,200)	11,800 (6,300)	113,400 (19,500)
	Without	126,000 (25,900)	N/A	47,600 (20,500)	N/A	113,400 (19,500)
2025	With	71,900 (13,100)	37,900 (16,100)	39,700 (16,200)	14,000 (7,800)	124,900 (21,400)
	Without	140,000 (29,200)	N/A	53,700 (24,000)	N/A	124,900 (21,400)
2030	With	73,500 (13,200)	83,500 (20,000)	43,700 (18,400)	17,600 (10,000)	139,300 (23,900)
	Without	157,000 (33,200)	N/A	61,300 (28,400)	N/A	139,300 (23,900)
2035	With	73,700 (12,900)	100,500 (24,400)	47,300 (20,500)	21,600 (12,300)	153,700 (26,300)
	Without	174,200 (37,300)	N/A	68,900 (32,800)	N/A	153,700 (26,300)

Source: JICA Survey Team

If the Project road (new bridge and elevated roads) is not implemented, the traffic demand in the direction to existing new Kelani Bridge (vehicle base) will be increased by 1.28 times in 2020 and 1.88 times in 2035, compared to the traffic demand in 2013. (If the Project road is implemented, the traffic volume will be decreased by 0.72 times and 0.79 times respectively.)

3.3 Required Functions for Lanes for Project Sections

In order to examine the necessary lanes of the project target section, the PCU (one side at the peak hour) in 2035 is estimated based on the demand forecast.

Table 3.3.1 Estimated Future Peak Hour PCU in 2035

	New Kelani Bridge 【Existing】	New Bridge 【Elevated】	To Port Access		Base Line	
			【Existing】	【Elevated】	On/Off	Inflow to Intersection
2035	42,240 [3,800]	54,960 **[4,950]** **3 lane**	35,880 [3,230]	16,850 **[1,520]** **2 lane**	38,410 **[3,460]** **2 lane**	83,520 [7,520]

Source: JICA Survey Team

Future traffic demand of the Project road is approx. 54,960 PCU/day for one side. After multiplying by the rate at peak hour (9%), the traffic demand of main lane at the peak hour is 4,950 PCU/hour, 1,520 PCU/hour for the elevated part in the direction to port access and 3,460 PCU/hour for on/off section in direction to the Baseline Road.

In the case that capacity of multi-lane road per lane is 2,000 PCU/hr./lane, and capacity limitation of the two lanes roads for both directions is 1,400 PCU/hr./lane, six lanes roads for both directions in the section of main lane and four lanes roads for both directions in the section to port access and the on/off section to baseline are necessary to operate.

4. OUTLINE DESIGN AND EVALUATION OF ALTERNATIVE OPTIONS

4.1 Design Standard

4.1.1 Road Design Standard

(1) Geometric Design Criteria for the Main Line and the Port Access Road

The Project Road should be designed in consideration of the connectibility to future urban arterial road network plan as well as the scalability.

Since the urban arterial road is likely to be developed as an expressway, the Project Road is designed in accordance with an expressway design criteria.

Design of the Main Line and the Port Access Road is carried out based on the Shutoko Metropolitan Expressway Standard in Japan, since in Sri Lanka, there is no design standard for expressway in urban area.

60 km/h is applied as the design speed of the Road according to the Shutoko Metropolitan Expressway Standard. Geometric design criteria for the Main Line and the Port Access Road are shown in Table 4.1.1.

Table 4.1.1 Geometric Design Criteria for the Main Line and the Port Access Road

Item	Criteria			Adopted Value	Remark
	Desirable	Standard	Absolute		
Design Speed		60 km/h		60 km/h	
Min. Horizontal Curve Radius (m)	200	150	120	300	
Min. Horizontal Curve length (m)		700/ø	100	110	
Min. Transition Curve Length (m)		50		51	
Min. Radius without Transition Curve (m)		1000	600	1500	
Min. Radius without Superelevation (m)		3000		-	R=V^2/127(I+f) =60^2/127(-0.025 +0.035)≈3000
Max. Grade (%)		4	4-5_500m	5.0_238m	
			5-6_400m		
			6-7_300m		
			7-8_200m		
Min. Vertical Curve Length (m)		50		60	
Min. K value (Crest)		20	14	27	
Min. K value (Sag)		15	10	17	
Max. Superelevation (%)		10.0		6.0	Depending on RDA's recommendation, max. 6.0 %
Superelevation to Horizontal Curve (%)		6.0			R=120-410m
		5.0			R=410-530m
		4.0			R=530-710m
		3.0			R=710-1040m
		2.0			R=1040-1330m
Max. Ratio for Superelevation Development		1/125		1/126	
Stopping Sight Distance (m)		85	75	>85	

Source: Shutoko Metropolitan Expressway Standard

(2) Geometric Design Criteria for Ramp

Ramp design in the Road is also carried out based on the Shutoko Metropolitan Expressway Standard in Japan.

40 km/h is applied as the design speed of the ramp according to the Shutoko Metropolitan Expressway Standard. Geometric design criteria for the ramp are shown in Table 4.1.2.

Table 4.1.2 Geometric Design Criteria for the Ramp

Item		**Criteria**			**Adopted Value**	**Remark**
		Desirable	**Standard**	**Absolute**		
Design Speed			40 km/h		40 km/h	
Main line in IC Section	Min. Horizontal Curve Radius (m)		550	200	450	
	Max. Grade (%)		2.5	5	2.1	
	Min. K value (Crest)		50	25	69	
	Min. K value (Sag)		30	15	83	
Min. Horizontal Curve Radius (m)			50	40	50	
Min. Parameter of Spiral Curve			40		52	
Min. Radius without Transition Curve (m)			500	300	300	
Min. Radius without Superelevation (m)			1300		-	R=V^2/127(I+f) =40^2/127(-0.025 +0.035)≈1300
Max. Grade (%)			7.0	7-8_400m	7.0	
				8-9_300m		
				9-10_200m		
Min. Vertical Curve Length (m)			35		50	
Min. K value (Crest)			4.5		8.1	
Min. K value (Sag)			4.5		8.4	
Max. Superelevation (%)			10.0		6.0	Depending on RDA's recommendation, max. 6.0 %
Superelevation to Horizontal Curve (%)			6.0			R=40-180m
			5.0			R=180-230m
			4.0			R=230-320m
			3.0			R=320-460m
			2.0			R=460-600m
Max. Ratio for Superelevation Development			1/100		1/100	
Stopping Sight Distance (m)			50	40	>50	
Acceleration Length (1-lane) (m)			120		120	
Acceleration Length (2-lane) (m)			180		180	
Deceleration Length (1-lane) (m)			90		90	
Deceleration Length (2-lane) (m)			140		140	
Taper Length (m)			60		60	
Exit Angle			1/15-1/20		1/15	

Source: Shutoko Metropolitan Expressway Standard

(3) Geometric Design Criteria for Local Roads

Local road is improved in some sections according to the Project Road construction.

Local road design is carried out based on the Geometric Design Standards of Roads, Road Development Authority, 1998. Geometric design criteria for the local road are shown in Table 4.1.3.

Table 4.1.3 Geometric Design Criteria for the Local Road

Item	**Criteria**										**Remark**
Road Class	A				B		C	D		E	
Road Type	R0	R1	R2	R3	R2	R3	R4	R4	R5	R5	
Design Speed (km/h)	70	70	70	60	70	60	50	50	40	40	For flat terrain in urban
Cross Fall (%)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	For Asphalt Pavement
Carriageway Width (m)	10.5x2	7.4x2	7.4x2	3.7x2	7.4x2	3.7x2	3.1x2	3.1x2	3.5	3.5	
Shoulder Width (m)	3.0x2	3.0x2	3.0x2	3.0x2	3.0x2	3.0x2	2.4x2	2.4x2	2.4x2	2.4x2	
Drain Width (m)	0.9x2	1.5x2	0.9x2	0.9x2	0.9x2	0.9x2	0.9x2	0.9x2	0.9x2	0.9x2	
Berm (m)		1.0x2	0.6x2		0.6x2		1.2x2	1.2x2			
Stopping Sight Distance (m)	115	115	115	85	115	85	65	65	45	45	
Max. Superelevation (%)	6	6	6	6	6	6	6	6	6	6	For flat terrain
Min. Horizontal Radius (m)	185	185	185	130	185	130	90	90	55	55	
Min. Horizontal Radius without Superelevation (m)	1105	1105	1105	810	1105	810	565	565	360	360	For Open
Max. Vertical Gradient (%)	4	4	4	4	5	5	7	9	9	9	For flat terrain
Min. Vertical Curve Length (m)	60	60	60	50	60	50	50	50	40	40	

Source: Geometric Design Standards of Roads, Road Development Authority

(4) Typical Cross Section

Typical Cross Sections for respective sections in the Project Road are shown in Table 4.1.4 and Figure 4.1.1 to Figure 4.1.9.

Table 4.1.4 Cross Section Component on the Main Line, the Port Access Road and the Ramp

Section	Median or Right Shoulder	Carriageway	Left Shoulder	Total	Note
Main Line, Earth Work (6-lane)	3.5	3.75 x 3	3.0 x 2	32.0	- Follow CKE's cross section.
Main Line, Bridge (6-lane)	3.0	3.5 x 3	1.75 x 2	27.5	- Narrower shoulder for structure.
Port Access Road, Bridge (4-lane)	3.0	3.5 x 2	1.75 x 2	20.5	- Narrower shoulder for structure.
Ramp (1-lane)	1.0	3.5	2.5 x 2	7.0	
Ramp (2-lane)	-	3.5 x 2	0.75 x 2	8.5	- Narrower shoulder for 2-lane.
Ramp (Temporary 2-lane)	-	3.25 x 2	0.25 x 2	7.0	- Same total width as 1-lane. - Depending on RDA's recommendation.

Source: JICA Survey Team

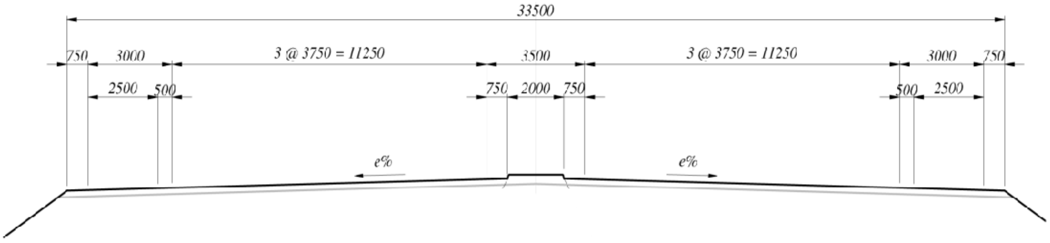


Figure 4.1.1 Typical Cross Section for CKE Earthwork (6-lane)

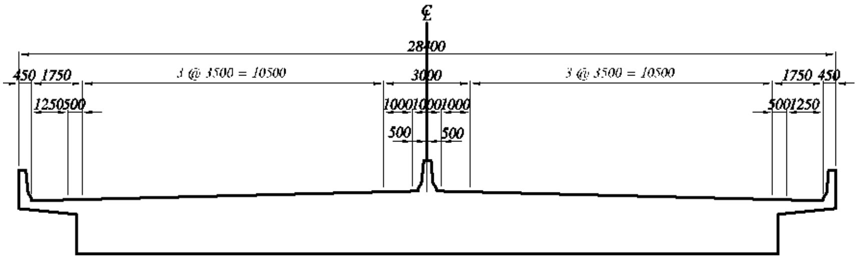


Figure 4.1.2 Typical Cross Section for Main Line Bridge (6-lane)

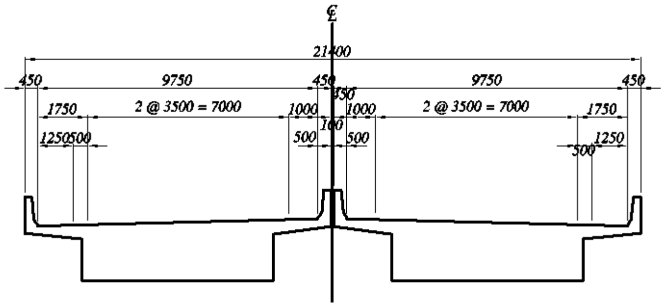


Figure 4.1.3 Typical Cross Section for Port Access Road Bridge (4-lane)

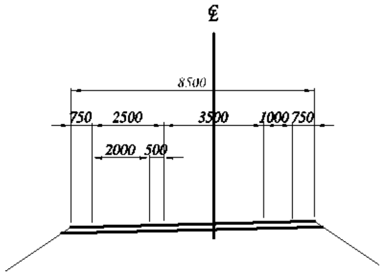


Figure 4.1.4 Typical Cross Section for Ramp (1-lane, Earth Work)

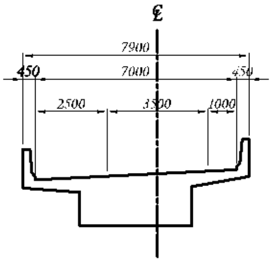


Figure 4.1.5 Typical Cross Section for Ramp (1-lane, Bridge)

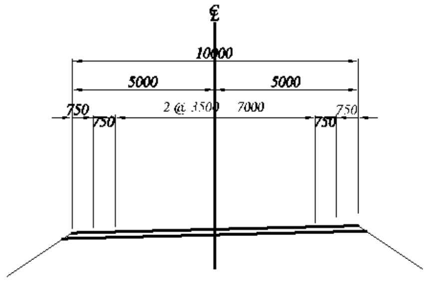


Figure 4.1.6 Typical Cross Section for Ramp (2-lane, Earth Work)

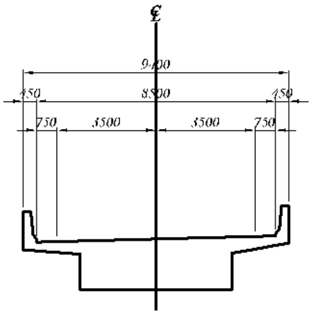


Figure 4.1.7 Typical Cross Section for Ramp (2-lane, Bridge)

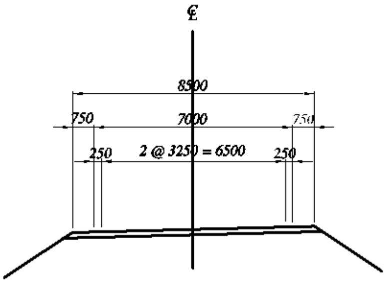


Figure 4.1.8 Typical Cross Section for Ramp (Temporary 2-lane, Earth Work)

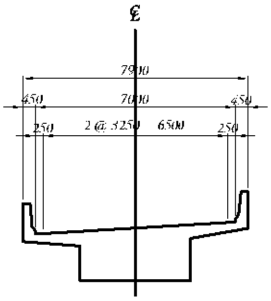


Figure 4.1.9 Typical Cross Section for Ramp (Temporary 2-lane, Bridge)

4.1.2 Bridge Design Standard

Applicable design standards

- Geometric Design Standards of Roads (1998)
- Bridge Design Manual (1997)
- British Standard BS 5400-2 (1978)
- Design Standards of Structures (The Outer Circular Highway to the City of Colombo)

Design loads

Bridges in Sri Lanka do not need to be designed for effects due to earthquakes as Sri Lanka is not in a zone affected by earthquakes. Generally the loading is to conform and applied according to BS 5400 part 2. Bridges should be able to resist the effects of the loads and actions as listed below.

- Dead Load / Superimposed Dead Load
- Earth Pressure
- Live Loads
- Braking & Traction of vehicle
- Water current
- Floating debris & Impact
- Wind
- Temperature
- Shrinkage and Creep

(1) Dead Load/ Superimposed Dead Load

Dead load/ superimposed dead load include self-weight, sidewalks, handrails, etc. The nominal dead load/ superimposed dead load initially assumed shall be accurately checked with the actual weights to be used in construction.

(2) Earth Pressure on retaining structure

The earth pressure acting on the abutment shall be considered by only active earth pressure, not include the resistance by passive earth pressure. Coefficient of earth pressure Ka is calculated as follows:

$Ka = (1 – \sin \theta) / (1 + \sin \theta) =0.333$

Where, θ: friction angle of back fill soil = 30 degree

The effect of live load surcharge shall be considered below:

HA Live Load	10.0 kN/m2
HB Live Load (30 units)	12.5 kN/m2

(3) Live Load

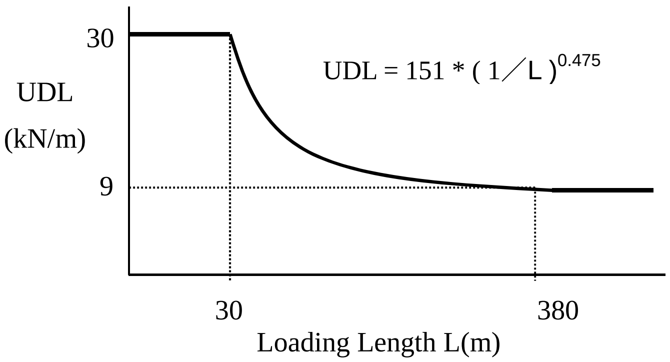
The following loads given in BS5400-2 are used for the bridge design based on Bridge Design Manual, RDA.

- All bridges should be designed to resist the effect of HA loading specified in the relevant code. HA loading is a formula loading – normal traffic, and including impact.

- Bridges should be able to resist the effect of 30 units of HB loading for A & B class of roads. And always the HB vehicle is to straddle two notional lane widths. HB loading is an abnormal vehicle unit loading including impact.

HA Load: Type HA loading consists of three load types.

- Uniformly Distributed Load (UDL) (Figure 4.1.10)
- Knife Edge Load (KEL) : 120 kN / lane
- Single Wheel Load : 100 kN at the most severe position

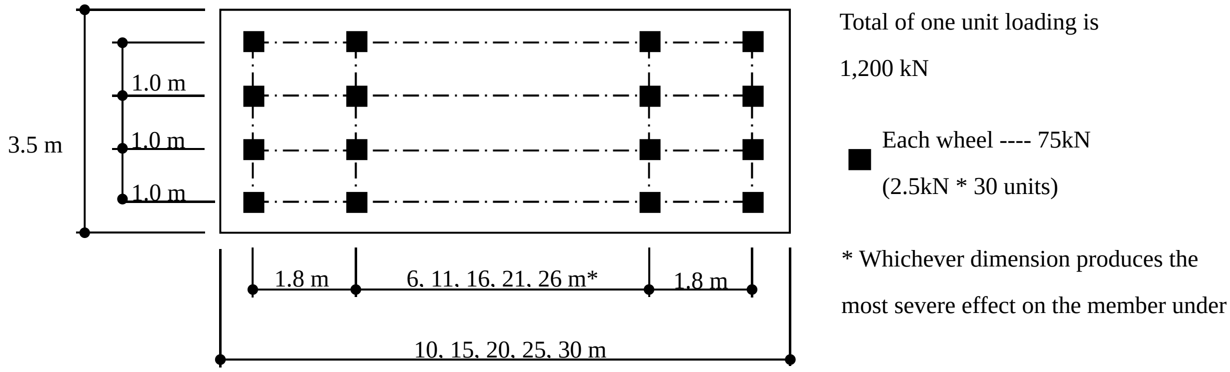


Source: British Standard BS 5400-2 (1978)

Figure 4.1.10 Uniformly Distributed Load

HB Load

30 units of HB loads should be applied in design. Figure 4.1.11 shows the plan and axle arrangement for one unit of nominal HB loading.



Source: British Standard BS 5400-2 (1978)

Figure 4.1.11 HB Load

The overall length of one unit shall be taken as 10, 15, 20, 25, 30 m for inner axle spacings of 6, 11, 16, 21, 26 m respectively, and the effect of the most severe case shall be adopted.

Notional Lanes

For this Project, the following carriageway widths, 13.25m, 9.75m for major bridges or viaducts (dual carriageways) and 7m, 6m for minor bridges (single carriageway) are used. The notional widths are calculated according to BS 5400-2 as below:

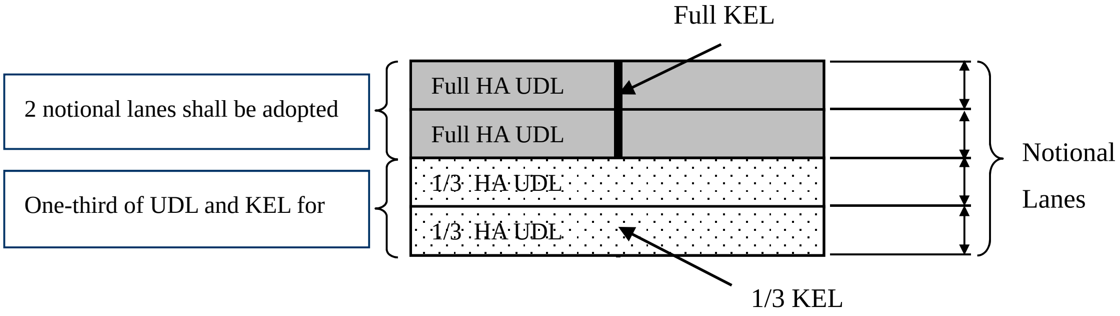
Major Bridges or Viaducts
w = 13.25 m / 4 notional lanes = 3.3125 m
w = 9.75 m / 3 notional lanes = 3.25 m

Minor Bridges
w = 7 m / 2 notional lanes = 3.5 m
w = 6 m / 2 notional lanes = 3 m

Application of Type HA & HB Loading

- Type HA loading

Type HA UDL and KEL loads shall be applied to two notional lanes in the appropriate parts of the influence line for the element or member under consideration and one-third type HA UDL and KEL loads shall be similarly applied to all other notional lanes. The KEL shall be applied at one point only in the loaded length of each notional lane.

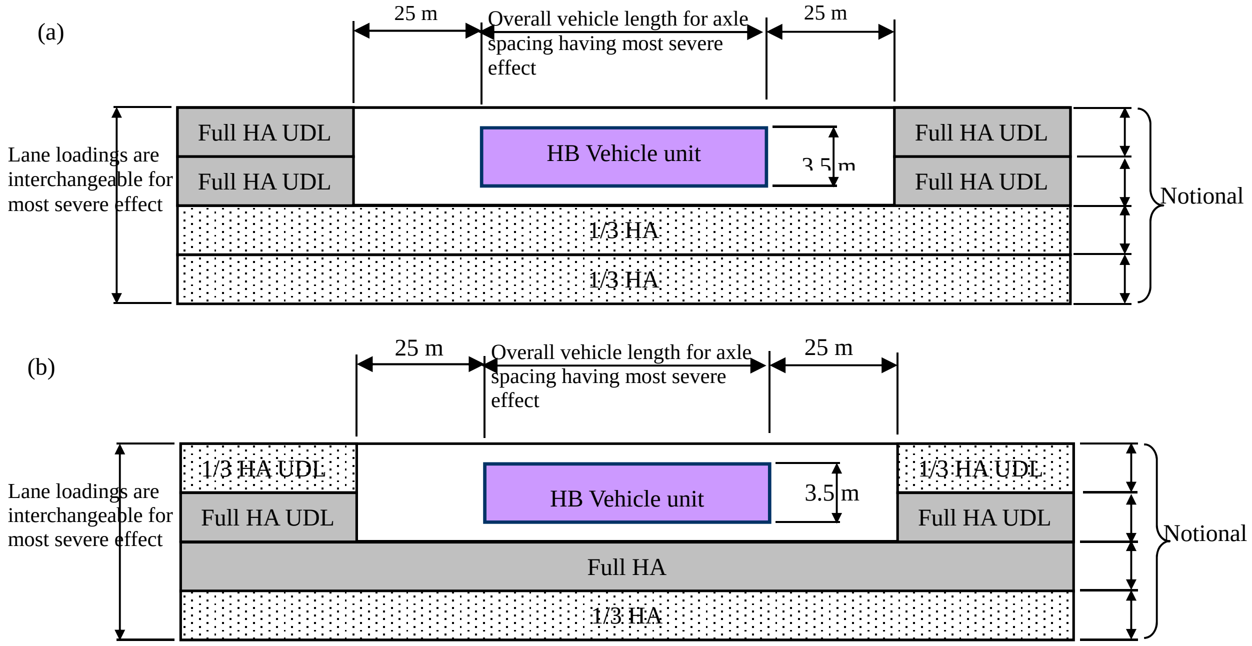


Source: British Standard BS 5400-2 (1978)

Figure 4.1.12 Type HA Loading

- Type HB and HA loading combined

HB vehicle shall be positioned to straddle two notional lanes and no other primary live loading shall be considered for 25 m in front of, to 25 m behind. And HA loading shall be associated.



Source: British Standard BS 5400-2 (1978)

Figure 4.1.13 Type HB and HA combined

(4) Sub Live Load

Centrifugal Load

The nominal centrifugal load Fc and associated vertical load Vc shall be taken for curved bridge and structures.

Fc = 30,000 / (r + 150) kN
Vc = 300 kN, distributed uniformly over the notional lane for a length of 5m
Where, r: the radius of curvature of the lane (m)

Longitudinal Load

The longitudinal force resulting from traction or braking shall be taken.

HAPa = 200 + 8 * L (< 700) kN
HBPb =25% of HB vertical load kN
Where, L: the loading length (m)

Skidding Load

Horizontal load of 250 kN due to skidding shall be taken in design with HA load.

Vehicle Collision Loads

Collision with Parapets:

Four wheels of 25 units of HB loading (250 kN = (2.5 kN x 25 units x 4 wheels)) shall be considered in any position.

Collision with Bridge Supports:

For the vehicle collision load on supports is given as follow:

Table 4.1.5 Collision Loads on Support of Bridges over Highway

	Load Nominal to the Carriageway Below	Load Parallel to the Carriageway Below	Point of Application on Bridge Support
Load Transmitted from Guardrail	150 kN	50 kN	Any one bracket attachment point, or for free standing fences, any one point 0.75 m above carriageway level
Residual Load above Guardrail	100 kN	100 kN	At the most severe point between 1 m and 3 m above carriageway level

Source: British Standard BS 5400-2 (1978)

(5) Horizontal Forces due to Water Current

According to Bridge Design Manual (RDA), on piers parallel to the direction of the water current, the intensity of pressure is given by:

$$P = K * W * V^2 / (2g)$$
$$= 52 * K * V^2$$

Where, P : intensity of pressure due to the water current (N/m^2)
W : unit weight of water (N/m^3)
V : velocity of current at the point where the pressure intensity is being calculated (m/sec)
g : acceleration of gravity (m/sec^2)
K : a constant depending on the shape of pier as follows:

Table 4.1.6 Constant K

Type of Pier	K
Square Ended Pier	1.50
Circular Piers or Semi Circular Cutwaters	0.66
Triangular Cutwaters	0.50 to 0.90
Trestle Type Piers	1.25

Source: British Standard BS 5400-2 (1978)

(6) Floating Debris and log Impact

Floating Debris:

Where debris is likely, allowance shall be made for the force exerted by a minimum depth of 1.2 m debris. The length of the debris applied to any one pier shall be one half of the sum of the adjacent spans with maximum 22.0 m where the deck is not submerged.

For debris the formula for water current shall be used the value of the constant K = 1.0.

Log Impact

Impact force shall be calculated by RDA manual

$P = 0.1 * W * V$

Where, P : collision force (kN)

W : weight of drifting item (kN) ~ assumed 20 kN

V : surface velocity of the water (m/s)

(7) Wind Load

Wind load P shall be given the following formula according to BS 5400 Part-2.

Wind gust speed: The maximum wind gust speed shall be taken as:

$vc = v * K1 * S1 * S2$

where; v : mean hourly wind speed (m/s) = 22.2 m/s ~ “Zone 3”

K1 : wind coefficient related to the return period = 1.00 ~ “120 years”

S1 : funneling factor = 1.0 ~ “General”

S2 : gust factor;

Nominal Transverse Wind Load

The nominal transverse wind load Pt and PL shall be taken as acting at the centroids of the appropriate areas and horizontally unless local conditions change the direction of the wind, and shall be derived from:

$$Pt \text{ or } P_L = q * A * C_D = 0.613 * v_c^2 * A * C_D$$

Where; v_c : maximum wind gust speed (N/s)

A : solid area (m2)

C_D : drag coefficient, ratio b/d

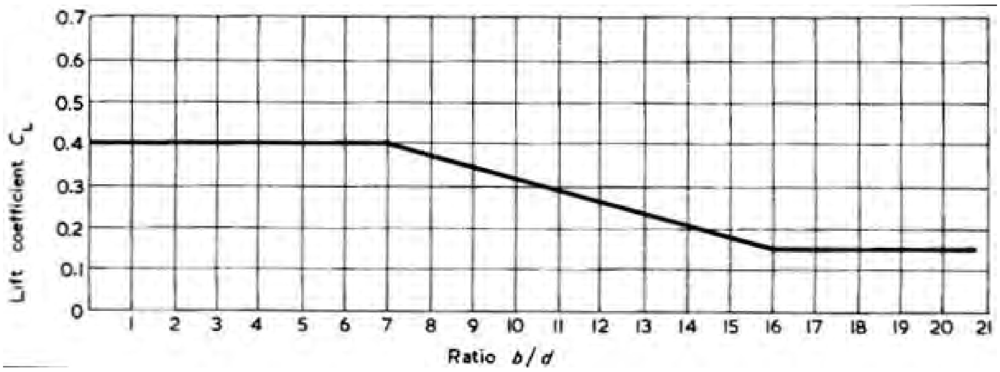
Pt means transverse direction and P_L means longitudinal direction.

Nominal Vertical Wind Load

An upward or downward nominal vertical wind load Pv (N), acting at the centroids of the appropriate areas, for all superstructures shall be derived the following formula;

$$Pt \text{ or } P_L = q * A * C_D = 0.613 * v_c^2 * A * C_D$$

Where; v_c : maximum wind gust speed (N/s)
A : area in plan (m2)
C_D : lift coefficient as derived from Figure 4.1.14 based on superelevation of superstructure



Source: British Standard BS 5400-2 (1978)

Figure 4.1.14 Lift Coefficient

Load Combination

The wind loads Pt, PL and Pv shall be considered the combination of following 4 cases;

- Pt alone
- Pt in combination with +/- Pv
- PL alone
- 0.5*Pt in combination with PL +/- 0.5*Pv

(8) Temperature

Effective Bridge Temperature

According to Bridge Design Manual (RDA), Isotherms map, maximum/minimum shade air temperatures for the bridge design, a 120 years return period shall be considered as

- Maximum shade air temperature 35 degree (^{o}C)
- Minimum shade air temperature 20 degree (^{o}C)
- Mean temperature of 27.5 degree (^{o}C) is applied, and plus/minus (+/-) 7.5 degrees temperature change is considered.

(9) Creep and Shrinkage

Effects of creep and shrinkage shall be conformed with BS 5400: Part 4 Appendix C or BS 8110: Part 2.

Effect of Creep

Creep strain in concrete Δcc is calculated as follows.

$$\Delta_{cc} = (f_c / E_{28}) * \phi$$

Where, f_c: stress due to permanent force (constant stress)

E_{28}: modulus of elasticity of concrete at the age of 28 days

ϕ: creep coefficient of concrete

Effect of Shrinkage

Coefficient of shrinkage for concrete will be taken as 0.0002

Design Standard for Detail Design

It shall be designed by reference to the latest British Standard in Detail Design.

4.2 Selecting Procedure of Alternative Options

The most appropriate option is selected by a two-staged evaluation in the following manner.

(1) First Evaluation

The most appropriate route including main bridge location across the Kelani River is selected in the first evaluation.

Outline design is carried out for the alternative routes using existing 1/2000 topographic maps from Survey Department and satellite images. Multi-criteria including following evaluation items is used for the selection of the route.

- Connectibility to urban arterial road network plan
- Effect on reducing traffic congestion on existing traffic
- Construction cost
- Construction period
- Constructability
- Environmental and social impacts

(2) Second Evaluation

In the second evaluation, the most appropriate bridge type is selected for the selected route in the first evaluation.

Outline design is carried out for the alternative bridge types. Multi-criteria including following evaluation items is used for the selection of the bridge type.

- Aesthetics
- Scouring at bridge piers
- Constructability
- Construction period
- Construction cost
- Others

The most appropriate option for the Project Road is determined based on the result of above two-staged evaluation.

4.3 Selection of the Route

4.3.1 Alternative Routes

Following four alternative routes are prepared. Schematic view for the alternative routes is shown in Figure 4.3.1.

(1) Alternative Route A

- The Project Road is constructed along the existing railway.
- Baseline Road and CKE are connected by the Project Road.
- Future scalability to the south is ensured
- The Project Road is connected to CKE by a new junction.
- New bridge across the Kelani River is constructed along the existing railway bridge.

(2) Alternative Route B

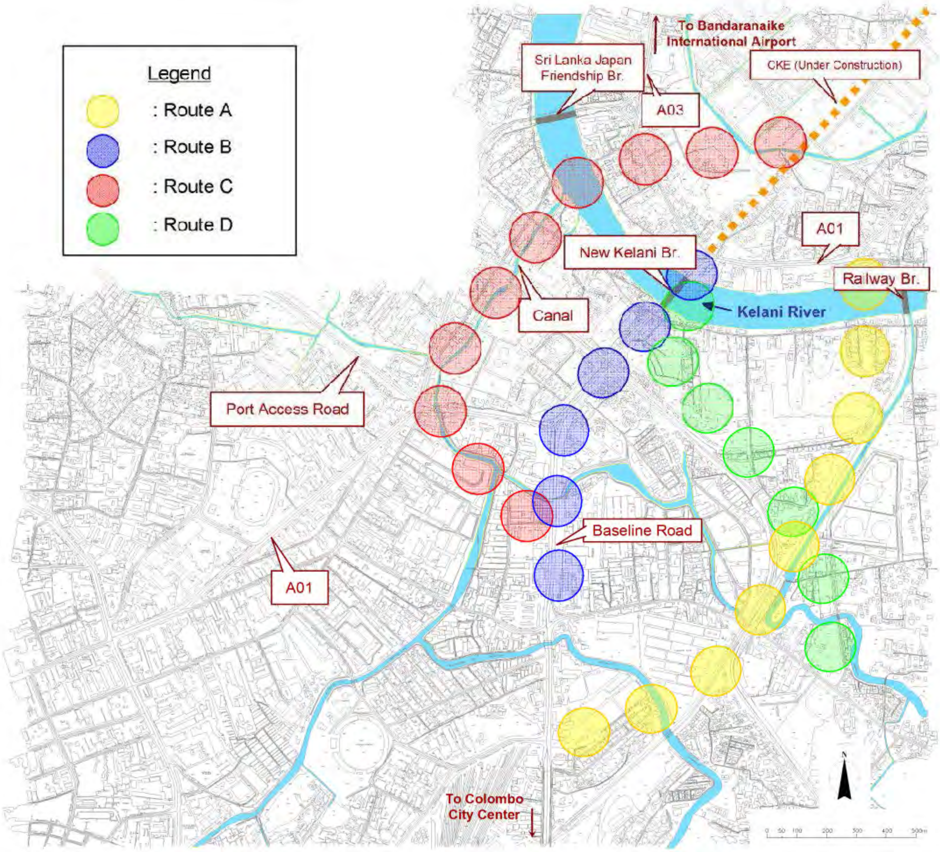
- The Project Road is constructed along and above the Baseline Road.
- Baseline Road and CKE are connected by the Project Road.
- New elevated port access road is constructed as a part of urban arterial road network.
- Future scalability to the south is ensured
- The Project Road is connected to the end point of CKE directly.
- New bridge across the Kelani River is constructed along the existing New Kelani Bridge.

(3) Alternative Route C

- The Project Road is constructed above the existing canal.
- Baseline Road and CKE are connected by the Project Road.
- New elevated port access road is constructed as a part of urban arterial road network.
- Future scalability to the south is ensured
- The Project Road is connected to CKE by a new junction.
- New bridge across the Kelani River is constructed near the existing Friendship Bridge.

(4) Alternative Route D

- This alternative route was proposed by the Road Development Authority (hereinafter called RDA).
- The Project Road is constructed along the Baseline Road and in the residential area.
- Avissawella Road (a crossing road of Baseline Road) and CKE are connected by the Project Road.
- New elevated port access road is constructed as a part of urban arterial road network.
- Future scalability to the south is ensured
- The Project Road is connected to the end point of CKE directly.
- New bridge across the Kelani River is constructed along the existing New Kelani Bridge.

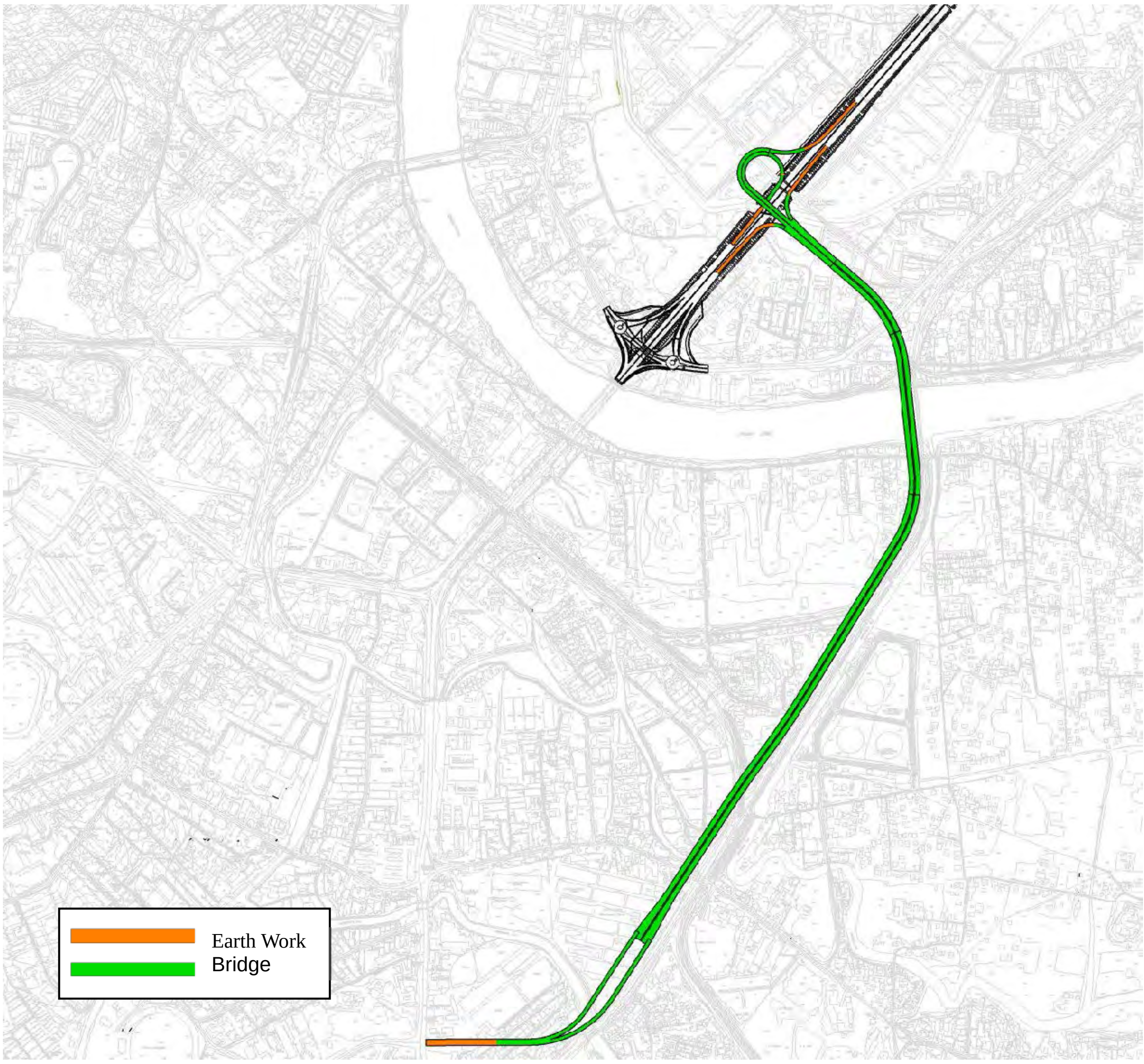


Source: JICA Survey Team

Figure 4.3.1 Schematic View for the Alternative Routes

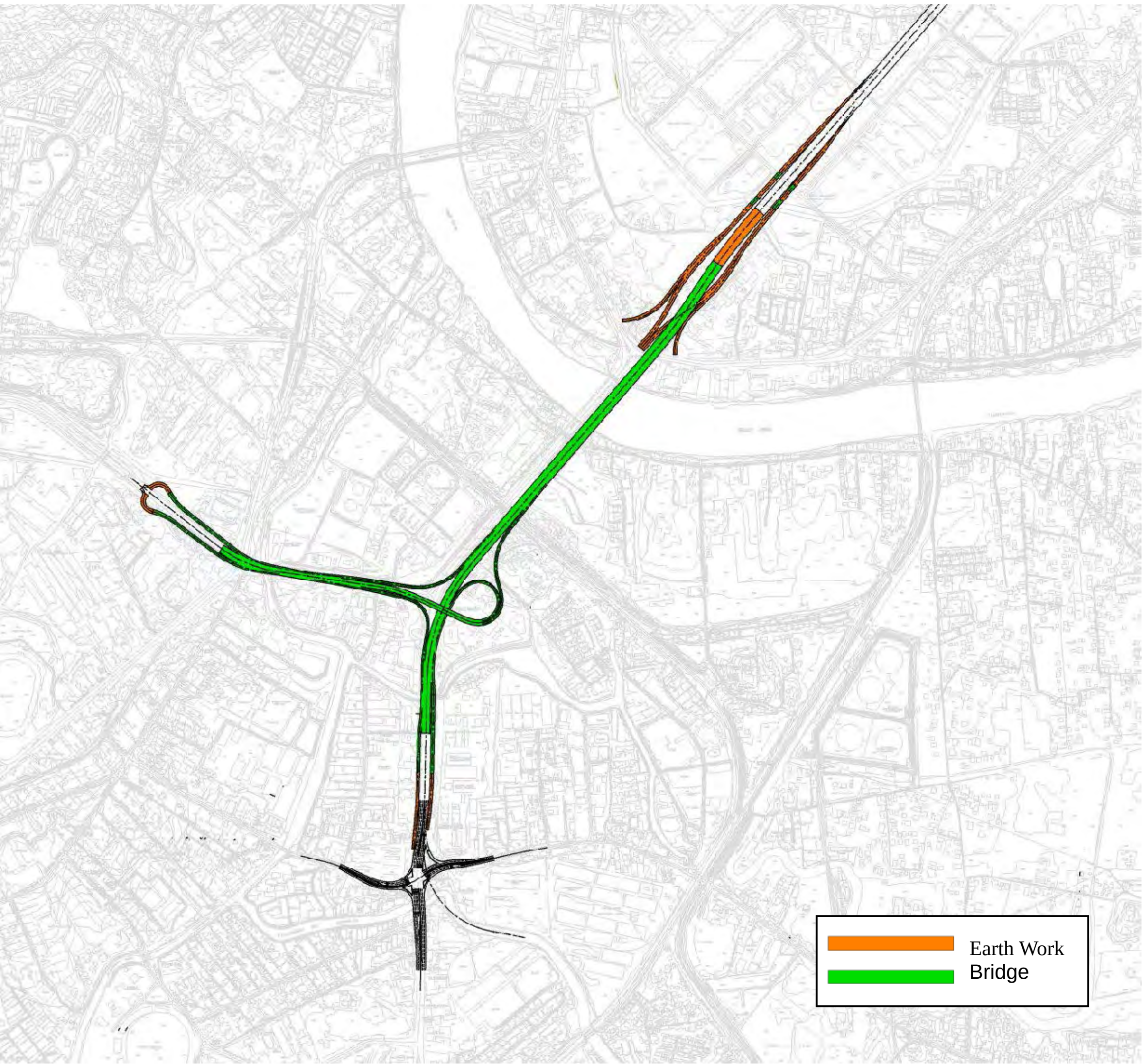
4.3.2 Outline Design of the Routes

Outline design is carried out for four alternative routes based on the 1/2000 topographic map. Plan views of the routes are shown in Figure 4.3.2 to 4.3.5.



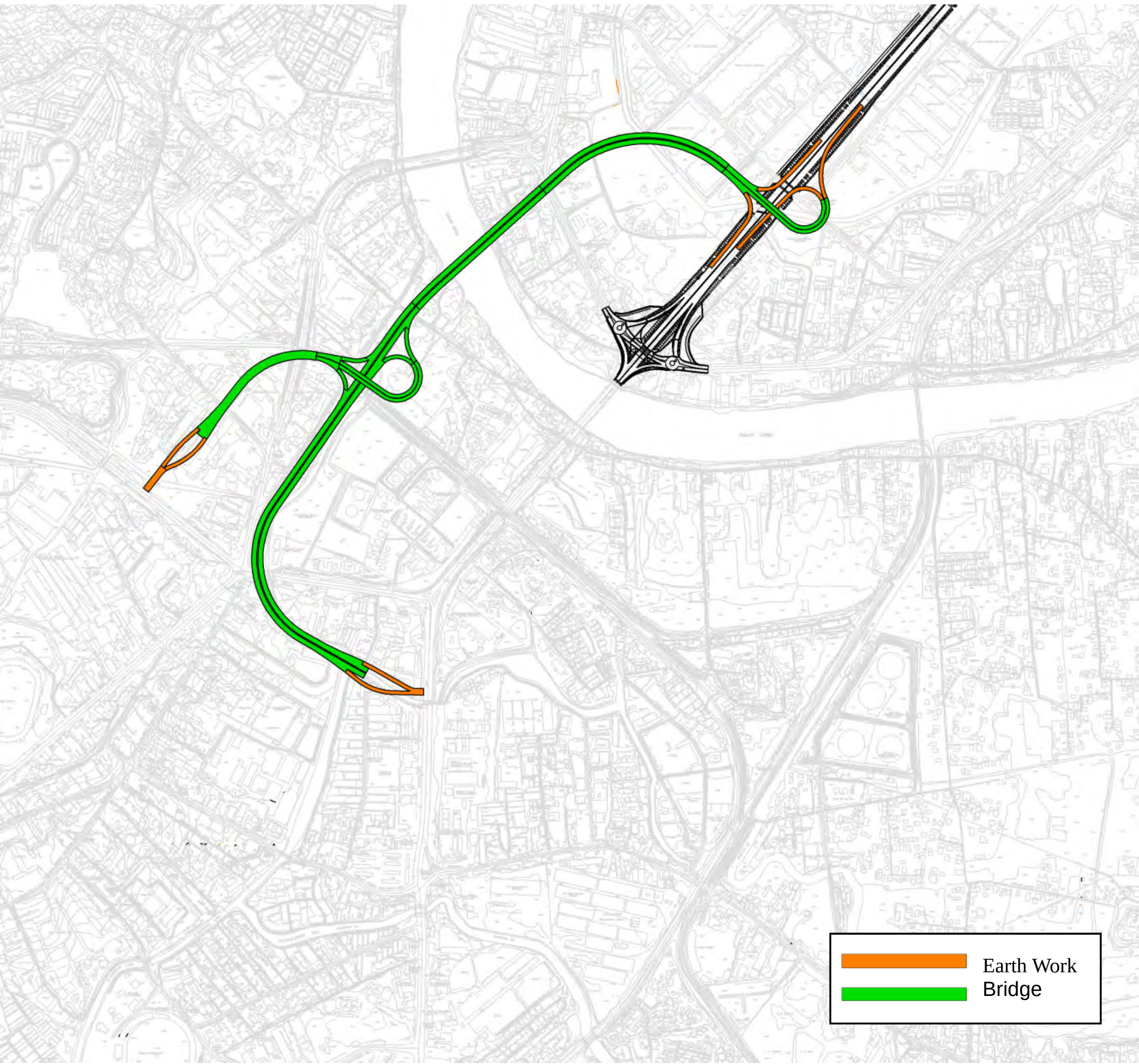
Source: JICA Survey Team

Figure 4.3.2 Plan View for Alternative Route A



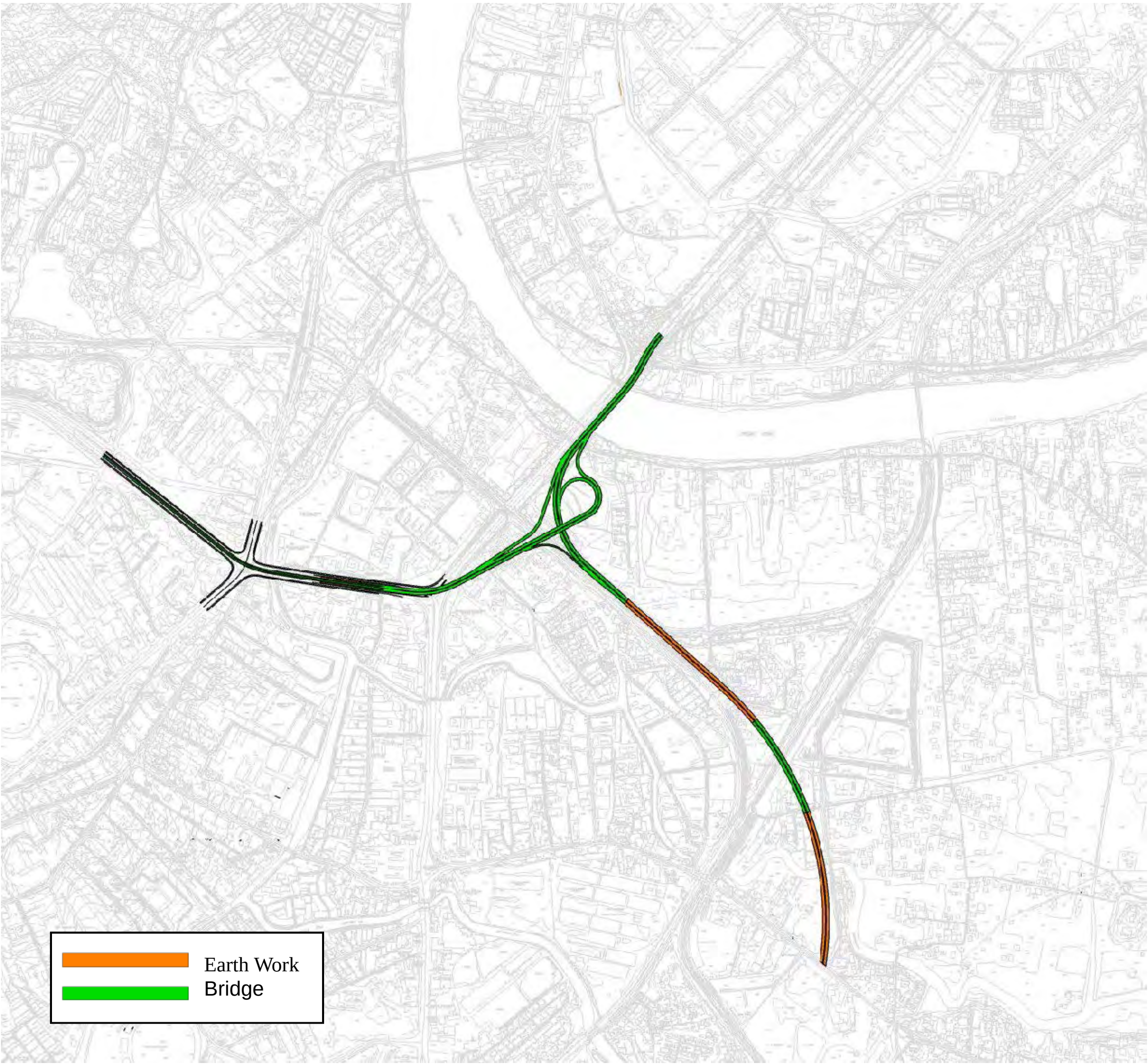
Source: JICA Survey Team

Figure 4.3.3 Plan View for Alternative Route B



Source: JICA Survey Team

Figure 4.3.4 Plan View for Alternative Route C



Source: JICA Survey Team

Figure 4.3.5 Plan View for Alternative Route D

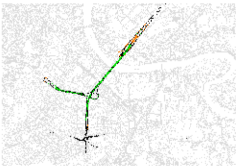
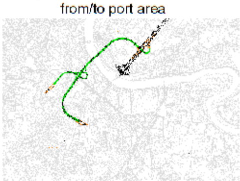
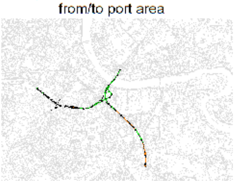
4.3.3 Evaluation of the Routes

Four alternative routes were evaluated based on the multi-criteria.

Summary of evaluation is shown in Table 4.3.1. As a result, “Alternative Route B” was selected as the most appropriate route for the Project Road from the following viewpoints.

- The Project Road is connected directly to CKE.
- Future scalability to the south is ensured.
- Port Access Road as a part of urban arterial road network is provided.
- Reduction of traffic congestion in the project area such as A1, A3 and Baseline Roads is expected.
- Environmental impact of Alternative B is smaller than that of other alternatives.
- Number of the affected structure is smallest among alternatives.

Table 4.3.1 Evaluation of the Route

	Alternative A	Alternative B	Alternative C	Alternative D
Summary	• Main line: along the existing railway • Junction: Main line - CKE • On/off ramp: from/to Baseline Road	• Main line: along and above the existing road • Port access: above the existing road • Junction: Main line - Port Access Road • On/off ramp: from/to Baseline Road from/to port area	• Main line: above the existing canal • Port access: in the commercial area • Junction: Main line - CKE Main line - Port Access Road • On/off ramp: from/to Baseline Road from/to port area	• Main line: along the existing road and in new area • Port access: above the existing road • Junction: Main line - Port Access Road • On/off ramp: from/to Avissawella Road from/to port area
Plan View				
Length	• Main line: 2.2 km	• Main line: 1.6 km. • New Port Access Road: 0.7 km	• Main line: 2.3 km. • New Port Access Road: 0.5 km	• Main line: 2.0 km. • New Port Access Road: 1.4 km
Urban Arterial Road Network Plan	• The Project Road is connected to CKE by a junction (not directly). • Port Access Road as a part of urban arterial road network is not provided. • Future scalability to the south is ensured, but the distance would be longer (higher cost and increased land acquisition). Poor	• The Project Road is connected directly to CKE. • Port Access Road as a part of urban arterial road network is provided. • Future scalability to the south is ensured. Good	• The Project Road is connected to CKE by a junction (not directly). • Port Access Road as a part of urban arterial road network is provided. • Future scalability to the south is ensured, but the distance would be longer (higher cost and increased land acquisition). Poor	• The Project Road is connected directly to CKE. • Port Access Road as a part of urban arterial road network is provided. • Future scalability to the south is ensured, but the distance would be longer (higher cost and increased land acquisition). Poor
Traffic Congestion on Existing Traffic	• Reduction of traffic congestion in Baseline Road is expected since the vehicles running Baseline Road can easily access to the Project Road. • Reduction of traffic congestion in A01 (existing New Kelani Bridge and Roundabout at the end of CKE) is expected since most vehicles from/to CKE use the Project Road. • Reduction of traffic congestion in A03 road is limited in the project area, since the new road is far from A03 road. Fair	• Reduction of traffic congestion in Baseline Road is expected since the vehicles running Baseline Road can easily access to the Project Road. • Reduction of traffic congestion in A01 (existing New Kelani Bridge and Roundabout at the end of CKE) is expected since most vehicles from/to CKE use the Project Road. Good	• Reduction of traffic congestion in Baseline Road is expected since the vehicles running Baseline Road can easily access to the Project Road. • Reduction of traffic congestion in A01 (existing New Kelani Bridge and Roundabout at the end of CKE) is expected since most vehicles from/to CKE use the Project Road. Good	• Reduction of traffic congestion in Baseline Road is expected since vehicles moving towards the east side could use Project Road instead of Baseline Road. • Reduction of traffic congestion in A01 (existing New Kelani Bridge and Roundabout at the end of CKE) can be expected but is limited since only those moving to the east side would use Project Road. • Traffic congestion in Avissawella Road will worsen. Poor
Construction Cost	• 24,543 million RS • (0.89) Good	• 27,433 million RS • (1.00) Fair	• 30,590 million RS • (1.10) Poor	• 25,009 million RS • (0.91) Good
Construction Period	• 36 months Fair	• 36 months Fair	• 36 months Fair	• 36 months Fair
Constructability	• Traffic control is not required in Baseline Road during construction. Good	• Traffic control is required in Baseline Road during construction. Poor	• Traffic control is not required in Baseline Road during construction. • Construct of the viaduct in the existing canal is required. Fair	• Traffic control is not required in Baseline Road during construction. Good
Environmental Impacts	• Impact on noise and air quality will be increased along the Project Road since the Project Road will be newly constructed in residential and commercial area. Poor	• There is a possibility that impact on noise and air quality will be increased along the Project Road, although the Project Road will be constructed along and above the existing road Fair	• Impact on water quality of the existing canal will be created during construction. • Impact on noise and air quality will be increased along the Project Road since the Project Road will be newly constructed in residential and commercial area. Poor	• Impact on noise and air quality will be increased along the Project Road since the Project Road will be newly constructed in residential and commercial area. Poor
Social Impacts	• 355 structures including 12 large scale structures are affected. • Relocation of Automobile Engineering Training Institute is not required. Fair	• 325 structures including 4 large scale structures are affected. • Relocation of Automobile Engineering Training Institute is required. Fair	• 404 structures including 9 large scale structures are affected. • Relocation of Automobile Engineering Training Institute is not required. Fair	• 394 structures including 3 large scale structures are affected. • Relocation of Automobile Engineering Training Institute is not required. Fair
Evaluation		Recommended		

Source: JICA Survey Team

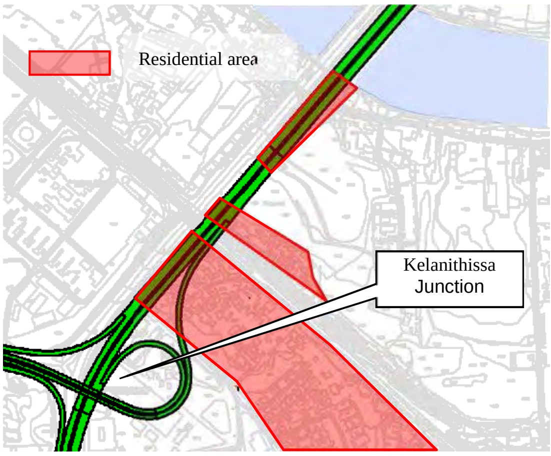
4.4 Optimization of the Selected Route

In addition to selection of the route from four alternatives, namely Route A, B, C and D, the following studies are carried out for the optimization of the route.

- Optimization of the main line alignment
- Optimization of the Orugodawatta Intersection plan
- Optimization of the Ingurukade Interchange type
- Optimization of the Kelanithissa Junction
- Optimization of the CKE Interchange

4.4.1 Main Line Alignment

A large number of houses will be affected by the Project Road, especially in the southern area of the Kelani River along the Baseline Road (see Figure 4.4.1). In order to reduce the number of affected houses, following three alternative routes were prepared, and evaluated based on the multi-criteria.



Source: JICA Survey Team

Figure 4.4.1 Residential Area along the Baseline Road

(1) Alternative Route B-1 (Original)

Approach road (viaduct) is constructed along the Baseline Road between the Kelani River and Kelanithissa Junction (see Figure 4.4.2).

(2) Alternative Route B-2

Approach road (viaduct) is constructed above the Baseline Road by shifting the alignment at the south end of the new bridge (see Figure 4.4.3).

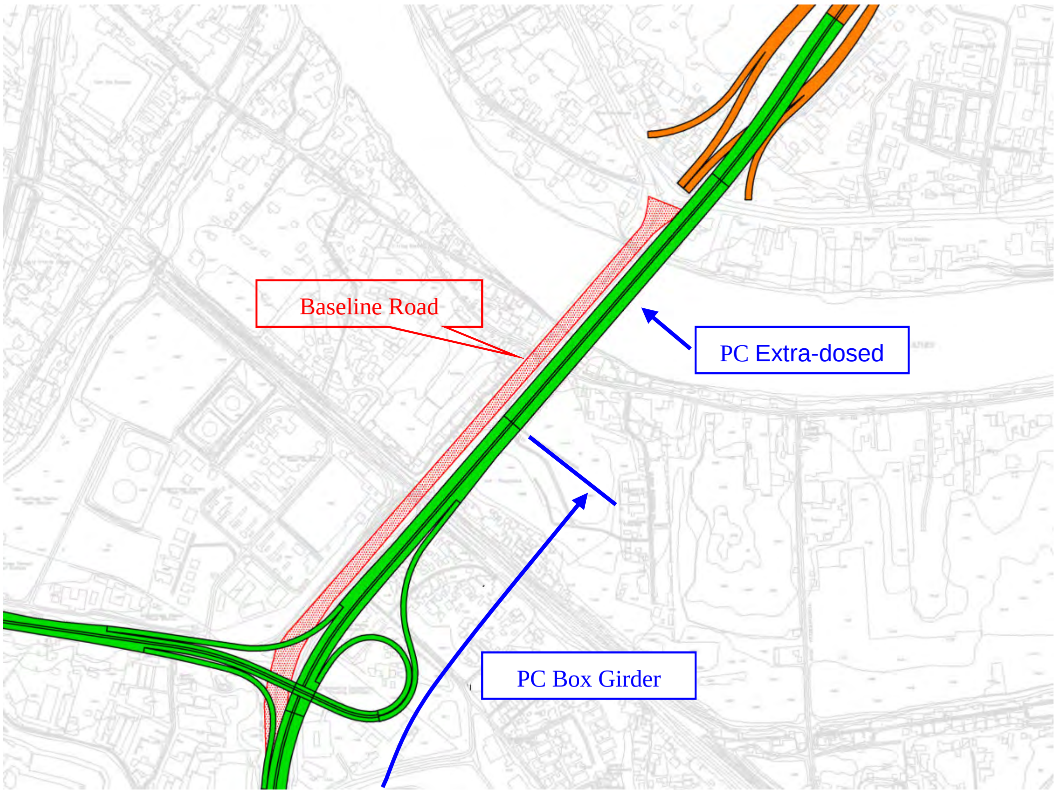
(3) Alternative Route B-3

Approach road (viaduct) is constructed above the Baseline Road including existing New Kelani Bridge section (see Figure 4.4.4).

Summary of evaluation is shown in Table 4.4.1. As a result, “Alternative Route B-1 (Original)” was selected as the most appropriate route from the following viewpoints.

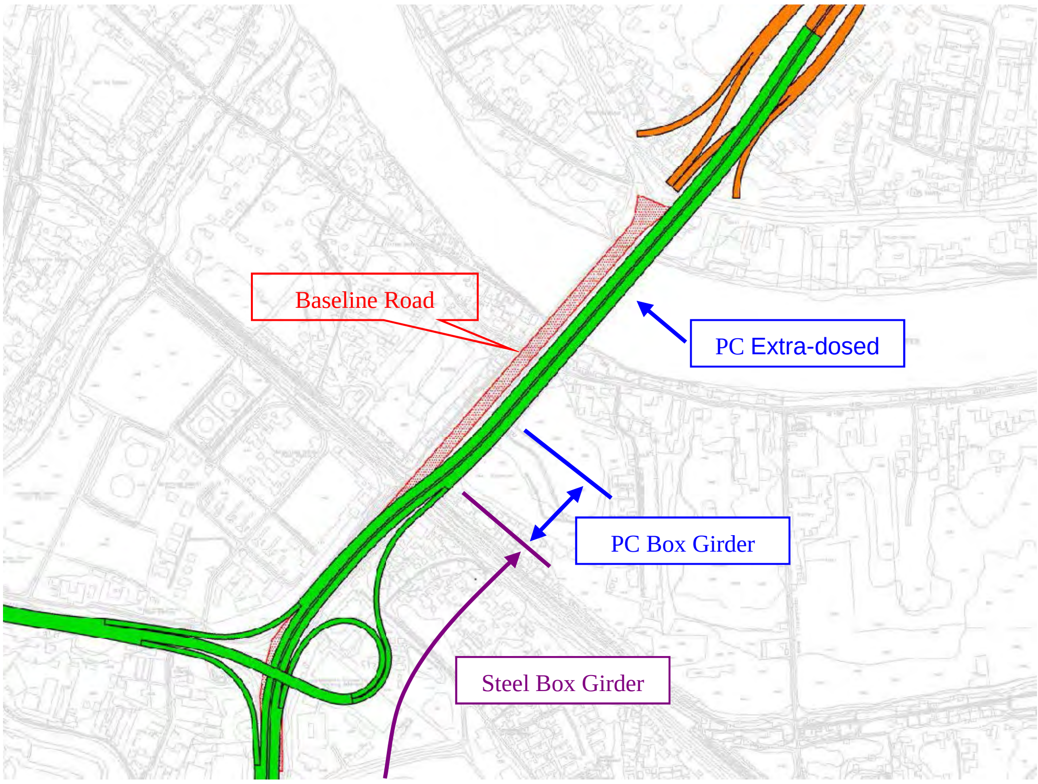
- Construction cost is the cheapest among alternatives.

- It is required to construct the approach bridge (viaduct) with taking care of existing traffic flow in only a small part of the road.
- Although the number of affected houses is large, almost all of the houses in this area are occupied by informal occupiers, and it is planned that they will relocate to new houses which will be provided by the government.



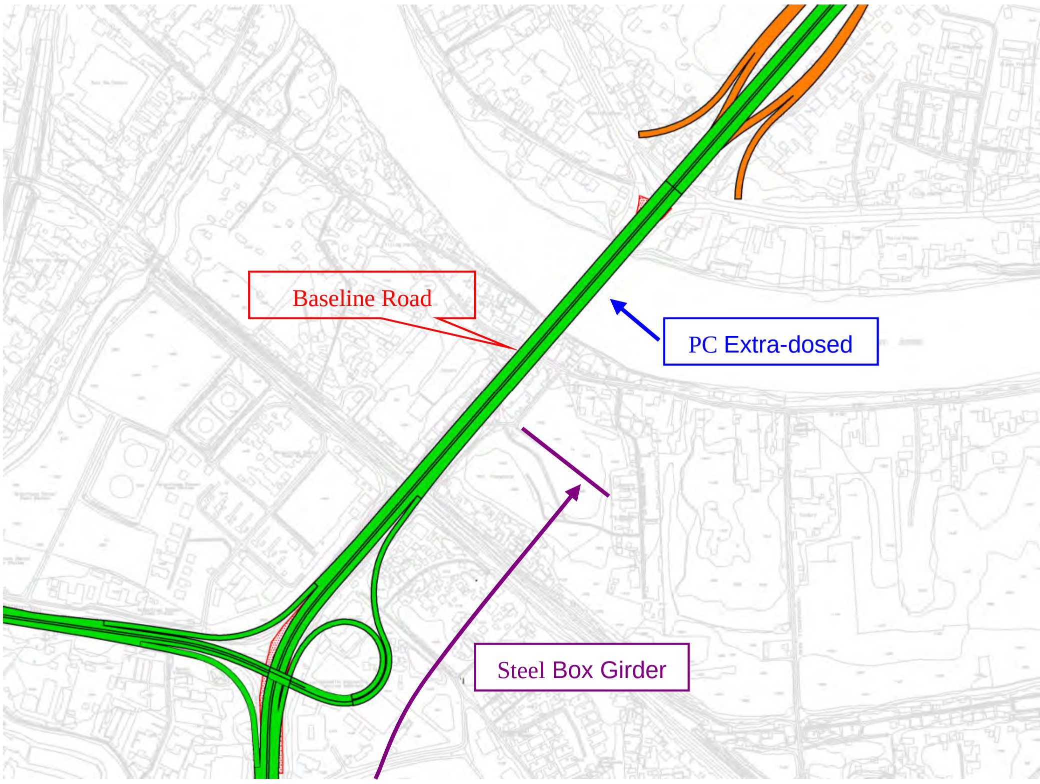
Source: JICA Survey Team

Figure 4.4.2 Plan View for Alternative Route B-1



Source: JICA Survey Team

Figure 4.4.3 Plan View for Alternative Route B-2



Source: JICA Survey Team

Figure 4.4.4 Plan View for Alternative Route B-3

Table 4.4.1 Evaluation of Main Line Alignment

	Alternative B-1 (Original Alternative B)	Alternative B-2	Alternative B-3
Summary	• New bridge (2nd New Kelani Bridge) is constructed along the existing New Kelani Bridge. • Approach road (viaduct) is constructed along the Baseline Road between the Kelani River and Kelanittisa Junction.	• New bridge (2nd New Kelani Bridge) is constructed along the existing New Kelani Bridge. • Approach road (viaduct) is constructed above the Baseline Road by shifting the alignment at the south end of the new bridge.	• New bridge (2nd New Kelani Bridge) is constructed above the existing New Kelani Bridge. • Approach road (viaduct) is constructed above the Baseline Road.
Plan View			
Construction Cost	• 7,304 million RS • (1.00) Good	• 9,046 million RS • (1.24) Poor	• 9,266 million RS • (1.27) Poor
Construction Period	• 36 months Fair	• 36 months Fair	• 36 months Fair
Traffic Safety	• 1 s-curve is required at the end of CKE. Fair	• 2 successive s-curves are required at the end of CKE and near Kelanithissa Junction Poor	• S-curve is not required. Good
Constructability	• It is required to construct the approach bridge (viaduct) with taking care of existing traffic flow in only a small part of the road. Good	• It is required to construct the approach bridge (viaduct) with taking care of existing traffic flow in a large part of the road. Fair	• It is required to construct the approach bridge (viaduct) with taking care of existing traffic flow in whole section. • It is required to construct the new bridge (main bridge) above the existing bridge. Poor
Environmental and Social Impacts	• 569 structures are affected. Fair	• 511 structures are affected. Fair	• 459 structures are affected. Good
Evaluation	**Recommended**		

Source: JICA Survey Team

4.4.2 Orugodawatta Intersection

In the Preliminary Design Study for the 2nd New Kelani Bridge Project, RDA, 2012 (hereinafter called the Pre-preliminary Design (2012)), 4-lane flyover was proposed at Orugodawatta Intersection in order to alleviate the traffic congestion after the Project Road is constructed.

However, a large number of buildings will be affected by the flyover in this area. In order to reduce the number of affected buildings, following three alternatives were prepared, and evaluated based on the multi-criteria.

(1) Alternative 1: 4-lane Flyover

4-lane Flyover is constructed on the crossing road, namely Stace Road and Avissawella Road. In addition, intersection improvement is carried out, since traffic congestion is not solved by the flyover construction only(see Figure 4.4.5).

(2) Alternative 2: 2-lane Flyover

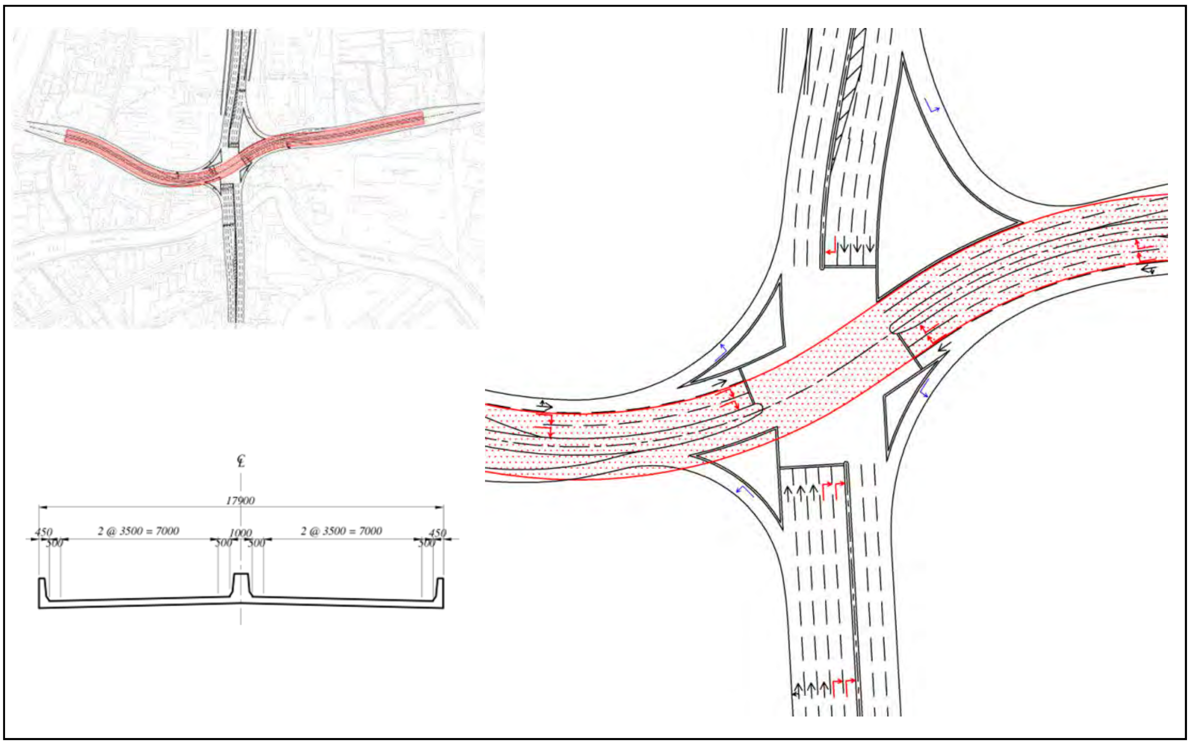
2-lane Flyover is constructed on the crossing road, namely Stace Road and Avissawella Road. In addition, intersection improvement is carried out, since traffic congestion is not solved by the flyover construction only (see Figure 4.4.6).

(3) Alternative 3: Intersection Improvement

Only intersection improvement is carried out without construction of the flyover (see Figure 4.4.7).

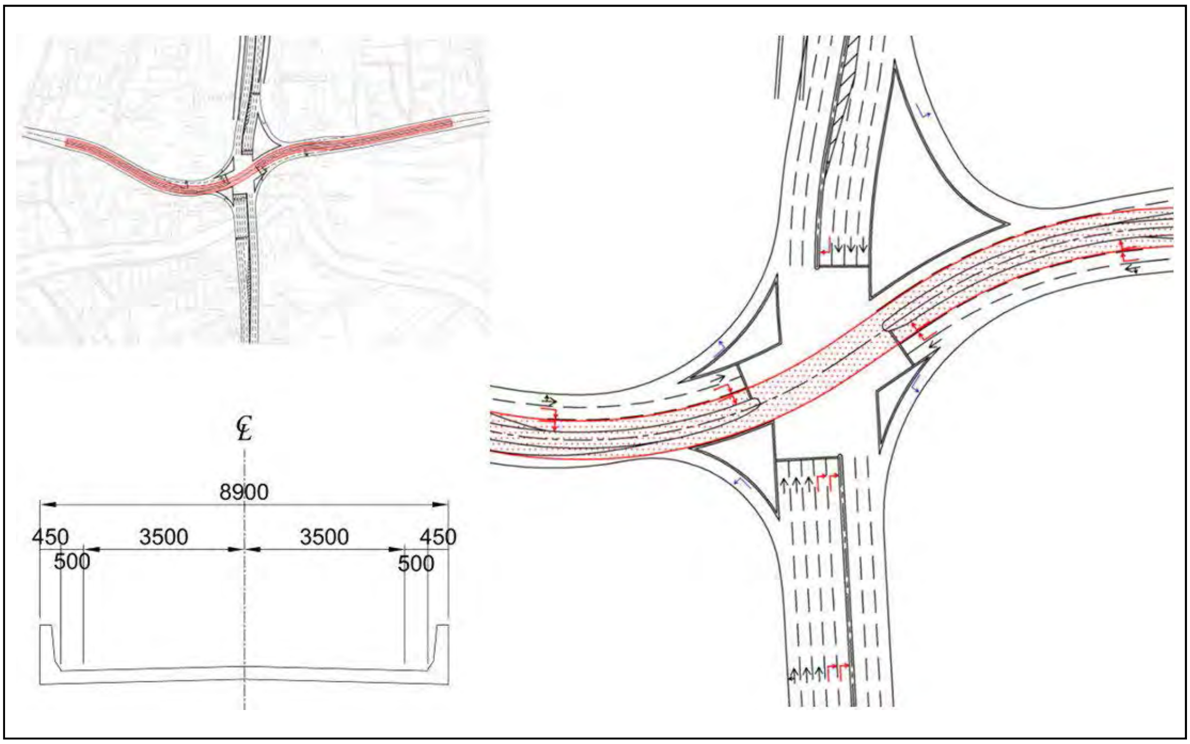
Summary of evaluation is shown in Table 4.4.2. As a result, “Alternative 3: Intersection Improvement” was selected as the most appropriate option from the following viewpoints.

- Construction cost is the cheapest among alternatives.
- Construction in the difficult conditions is not required.
- Number of affected building is the smallest among alternatives.
- Volume capacity ratio (V/C) of at-grade intersection is improved from the existing condition (V/C: 2.0), although V/C will not be less than 1.0.
- V/C of at-grade intersection will not exceed the existing condition until 2030 - 2035.
- Even if the flyover is constructed, volume capacity ratio (V/C) of at-grade intersection will not be less than 1.0 in 2020.



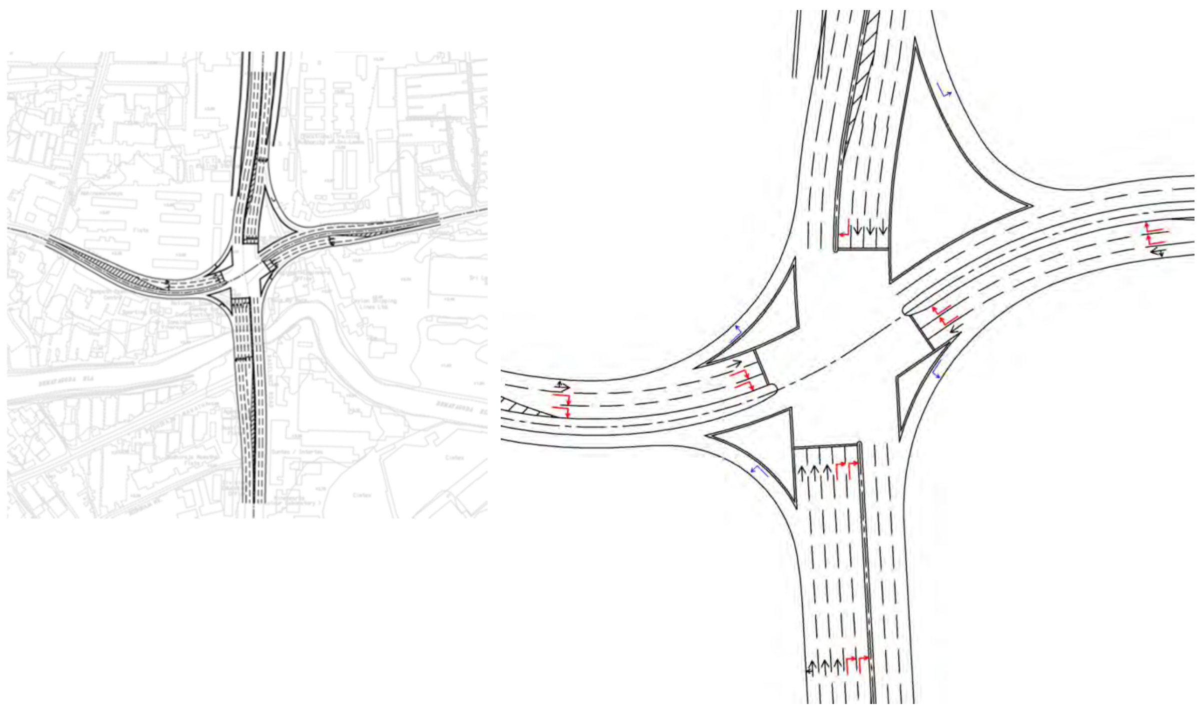
Source: JICA Survey Team

Figure 4.4.5 4-lane Flyover at Orugodawatta Intersection



Source: JICA Survey Team

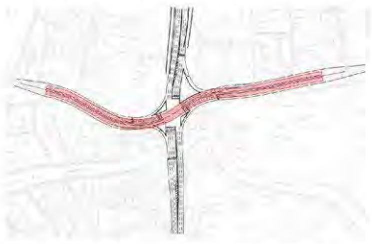
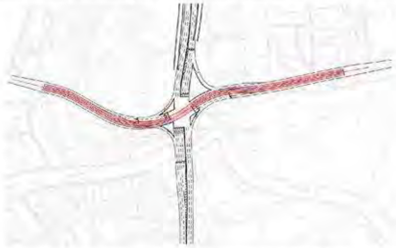
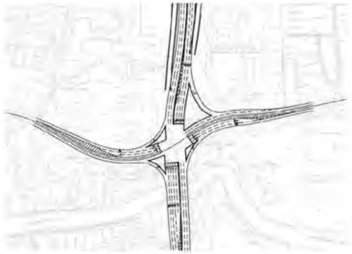
Figure 4.4.6 2-lane Flyover at Orugodawatta Intersection



Source: JICA Survey Team

Figure 4.4.7 Intersection Improvement at Orugodawatta Intersection

Table 4.4.2 Evaluation of Orugodawatta Intersection Improvement

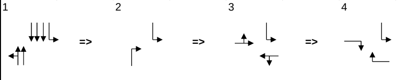
	Alternative 1 **4-lane Flyover**	**Alternative 2** **2-lane Flyover**	**Alternative 3** **Intersection Improvement**
Summary	• 4-lane Flyover is constructed on the crossing road. • Intersection improvement is also carried out.	• 2-lane Flyover is constructed on the crossing road. • Intersection improvement is also carried out.	• Only intersection improvement is carried out without construction of the flyover.
Plan View			
Traffic Flow	• Enough traffic capacity is provided for the flyover. • Volume capacity ratio (V/C) of at-grade intersection is improved. V/C in 2020 is 1.2 although V/C of existing condition (2013) is 2.0. (*) Fair	• Enough traffic capacity is provided for the flyover. • Volume capacity ratio (V/C) of at-grade intersection is improved. V/C in 2020 is 1.2 although V/C of existing condition (2013) is 2.0. (*) Fair	• Volume capacity ratio (V/C) of at-grade intersection is improved. V/C in 2020 is 1.5 although V/C of existing condition (2013) is 2.0. (*) • V/C will not exceed the existing condition until 2030 - 2035 (V/C:1.9 in 2030, V/C: 2.1 in 2035) Fair
Construction Cost	• 2,505 million RS • (1.66) Poor	• 1,509 million RS • (1.00) Fair	• 166 million RS • (0.11) Good
Constructability	• It is required to construct the flyover on the existing road with taking care of existing traffic flow. Poor	• It is required to construct the flyover on the existing road with taking care of existing traffic flow. Poor	• Only earth work is required. Good
Environmental and Social Impacts	• 124 structures are affected. Poor	• 88 structures are affected. Fair	• 33 structures are affected. Good
Evaluation			**Recommended**

(*) V/C calculation is shown in Table 4.3.3.
Source: JICA Survey Team

Table 4.4.3 Intersection Analysis at Orugodawatta Intersection

(1) Existing Condition (2013)

Traffic Volume

	North Bound			East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	193	2,302	415	27	338	210	676	2,585	104	552	486	527
Lane Group		LT+TH	RT		LT+TH	RT	LT	TH	RT		LT+TH	RT
		↰↑	↱		↑→	↴	↳	↓↓↓			←↓	↰
Phase Number		1	2		3	4	1/2/3/4	1			3	4
Phasing												
Flow Rate in Lane Group (v) (pcu/h)		**2,494**	**415**		**365**	**210**	**676**	**2,585**			**1,142**	**527**

Saturation Flow

S_o: Base Sturation Flow		1,900	1,900		1,900	1,900	1,900	1,900			1,900	1,900
N: Number of Lanes		2	1		1	1	1	3			1	1
f_W: Lane Width Adjustment Factor		1.000	1.000		1.000	1.000	1.000	1.000			1.000	1.000
f_{HV}: Heavy-vehicle Adjustment Factor		1.000	1.000		1.000	1.000	1.000	1.000			1.000	1.000
f_G: Grade Adjustment Factor		1.000	1.000		1.000	1.000	1.000	1.000			1.000	1.000
f_P: Parking Adjustment Factor		1.000	1.000		1.000	1.000	1.000	1.000			1.000	1.000
f_{BB}: Bus Blockage Adjustment Factor		1.000	1.000		1.000	1.000	1.000	1.000			1.000	1.000
f_A: Area Type Adjustment Factor		1.000	1.000		1.000	1.000	1.000	1.000			1.000	1.000
f_{LU}: Lane Utilization Adjustment Factor		0.952	1.000		1.000	1.000	1.000	0.908			1.000	1.000
f_{LT}: Left-turn Adjustment Factor		1.000	0.950		1.000	0.950	1.000	1.000			1.000	0.950
f_{RT}: Right-turn Adjustment Factor		0.988	1.000		0.989	1.000	0.850	1.000			0.920	1.000
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor		1.000	1.000		1.000	1.000	1.000	1.000			1.000	1.000
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor		1.000	1.000		1.000	1.000	1.000	1.000			1.000	1.000
Adjusted Saturation Flow (pcu/h)		**3,576**	**1,805**		**1,879**	**1,805**	**1,615**	**5,176**			**1,748**	**1,805**

Capacity Analysis

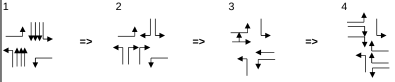
Cycle Length (s)		150	150		150	150	150	150			150	150
Effective Green Time (s)		54	18		49	23	150	54			49	23
Los Time (s)			3			3						3
Green Ratio		0.360	0.120		0.327	0.153	1.000	0.360			0.327	0.153
Lane Group Capacity (c) (pcu/h)		1,287	217		614	277	1,615	1,863			571	277
v/c Ratio for Lane Group		**1.938**	**1.916**		**0.595**	**0.760**	**0.419**	**1.387**			**1.999**	**1.903**

Flow Ratio		0.698	0.230		0.194	0.117	0.419	0.499			0.653	0.292
Critical Lane Group/Phase		*	*								*	*
Sum of Critical Flow Ratios	1.9											
v/c Ratio for Intersection	**2.0**											

Source: JICA Survey Team

(2) 4-lane and 2-lane Flyover (2020)

Traffic Volume

	North Bound			East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	241	2,869	517	34	63	262	835	3,191	128	688	91	657
Lane Group	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
	↰	↑↑↑	↱↱	↗	→	↴↴	↳	↓↓↓	↲	↙	←	↖↖
Phase Number	1/2/3/4	1	2	1/2/3/4	3	4	1/2/3/4	1	2	1/2/3/4	3	4
Phasing												
Flow Rate in Lane Group (v) (pcu/h)	**241**	**2,869**	**517**	**34**	**63**	**262**	**835**	**3,191**	**128**	**688**	**91**	**657**

Saturation Flow

S_o: Base Sturation Flow	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900
N: Number of Lanes	1	3	2	1	1	2	1	3	1	1	1	2
f_W: Lane Width Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{HV}: Heavy-vehicle Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_G: Grade Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_P: Parking Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{BB}: Bus Blockage Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_A: Area Type Adjustment Factor	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
f_{LU}: Lane Utilization Adjustment Factor	1.000	0.908	0.971	1.000	1.000	0.971	1.000	0.908	1.000	1.000	1.000	0.971
f_{LT}: Left-turn Adjustment Factor	1.000	1.000	0.950	1.000	1.000	0.950	1.000	1.000	0.950	1.000	1.000	0.950
f_{RT}: Right-turn Adjustment Factor	0.850	1.000	1.000	0.850	1.000	1.000	0.850	1.000	1.000	0.850	1.000	1.000
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Adjusted Saturation Flow (pcu/h)	**1,454**	**4,658**	**3,155**	**1,454**	**1,710**	**3,155**	**1,454**	**4,658**	**1,625**	**1,454**	**1,710**	**3,155**

Capacity Analysis

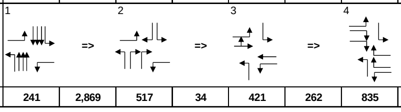
Cycle Length (s)	150	150	150	150	150	150	150	150	150	150	150	150
Effective Green Time (s)	150	87	22	150	7	28	150	87	22	150	7	28
Los Time (s)			3			3			3			3
Green Ratio	1.000	0.580	0.147		0.047	0.187	1.000	0.580	0.147		0.047	0.187
Lane Group Capacity (c) (pcu/h)	1,454	2,702	463		80	589	1,454	2,702	238		80	589
v/c Ratio for Lane Group	**0.165**	**1.062**	**1.118**		**0.791**	**0.445**	**0.575**	**1.181**	**0.538**		**1.139**	**1.115**

Flow Ratio	0.165	0.616	0.164		0.037	0.083	0.575	0.685	0.079		0.053	0.208
Critical Lane Group/Phase			*					*			*	*
Sum of Critical Flow Ratios	1.1											
v/c Ratio for Intersection	**1.2**											

Source: JICA Survey Team

(3) Intersection Improvement (2020)

Traffic Volume

	North Bound			East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	241	2,869	517	34	421	262	835	3,191	128	688	606	657
Lane Group	LT ↰	TH ↑↑↑	RT ↱↱	LT ⬏	TH →	RT ⬎⬎	LT ↳	TH ↓↓↓	RT ↲	LT ⬐	TH ←	RT ⬑⬑
Phase Number	1/2/3/4	1	2	1/2/3/4	3	4	1/2/3/4	1	2	1/2/3/4	3	4
Phasing												
Flow Rate in Lane Group (v) (pcu/h)	**241**	**2,869**	**517**	**34**	**421**	**262**	**835**	**3,191**	**128**	**688**	**606**	**657**

Saturation Flow

S_o: Base Sturation Flow	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900
N: Number of Lanes	1	3	2	1	1	2	1	3	1	1	1	2
f_w: Lane Width Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{HV}: Heavy-vehicle Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_G: Grade Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_P: Parking Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{BB}: Bus Blockage Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_A: Area Type Adjustment Factor	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
f_{LU}: Lane Utilization Adjustment Factor	1.000	0.908	0.971	1.000	1.000	0.971	1.000	0.908	1.000	1.000	1.000	0.971
f_{LT}: Left-turn Adjustment Factor	1.000	1.000	0.950	1.000	1.000	0.950	1.000	1.000	0.950	1.000	1.000	0.950
f_{RT}: Right-turn Adjustment Factor	0.850	1.000	1.000	0.850	1.000	1.000	0.850	1.000	1.000	0.850	1.000	1.000
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Adjusted Saturation Flow (pcu/h)	**1,454**	**4,658**	**3,155**	**1,454**	**1,710**	**3,155**	**1,454**	**4,658**	**1,625**	**1,454**	**1,710**	**3,155**

Capacity Analysis

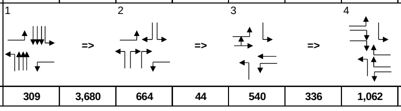
Cycle Length (s)	150	150	150	150	150	150	150	150	150	150	150	150
Effective Green Time (s)	150	69	17	150	37	21	150	69	17	150	37	21
Los Time (s)			3			3			3			3
Green Ratio	1.000	0.460	0.113		0.247	0.140	1.000	0.460	0.113		0.247	0.140
Lane Group Capacity (c) (pcu/h)	1,454	2,143	358		422	442	1,454	2,143	184		422	442
v/c Ratio for Lane Group	**0.165**	**1.339**	**1.447**		**0.998**	**0.594**	**0.575**	**1.489**	**0.696**		**1.437**	**1.487**

Flow Ratio	0.165	0.616	0.164		0.246	0.083	0.575	0.685	0.079		0.354	0.208
Critical Lane Group/Phase			*					*			*	*
Sum of Critical Flow Ratios	1.4											
v/c Ratio for Intersection	**1.5**											

Source: JICA Survey Team

(4) Intersection Improvement (2030)

Traffic Volume

	North Bound			East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	309	3,680	664	44	540	336	1,062	4,057	163	882	777	842
Lane Group	LT ↰	TH ↑↑↑	RT ↱↱	LT ⬏	TH →	RT ⬎⬎	LT ↳	TH ↓↓↓	RT ↲	LT ⬐	TH ←	RT ⬑⬑
Phase Number	1/2/3/4	1	2	1/2/3/4	3	4	1/2/3/4	1	2	1/2/3/4	3	4
Phasing												
Flow Rate in Lane Group (v) (pcu/h)	**309**	**3,680**	**664**	**44**	**540**	**336**	**1,062**	**4,057**	**163**	**882**	**777**	**842**

Saturation Flow

S_o: Base Sturation Flow	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900
N: Number of Lanes	1	3	2	1	1	2	1	3	1	1	1	2
f_w: Lane Width Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{HV}: Heavy-vehicle Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_G: Grade Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_P: Parking Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{BB}: Bus Blockage Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_A: Area Type Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{LU}: Lane Utilization Adjustment Factor	1.000	0.908	0.971	1.000	1.000	0.971	1.000	0.908	1.000	1.000	1.000	0.971
f_{LT}: Left-turn Adjustment Factor	1.000	1.000	0.950	1.000	1.000	0.950	1.000	1.000	0.950	1.000	1.000	0.950
f_{RT}: Right-turn Adjustment Factor	0.850	1.000	1.000	0.850	1.000	1.000	0.850	1.000	1.000	0.850	1.000	1.000
f_{Lpb}: Left-turn Ped/Bike Adjustment Factor	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Adjusted Saturation Flow (pcu/h)	**1,454**	**4,658**	**3,155**	**1,454**	**1,710**	**3,155**	**1,454**	**4,658**	**1,625**	**1,454**	**1,710**	**3,155**

Capacity Analysis

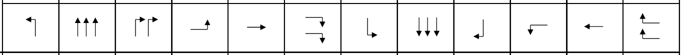
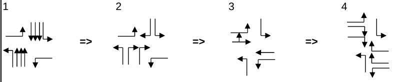
Cycle Length (s)	150	150	150	150	150	150	150	150	150	150	150	150
Effective Green Time (s)	150	70	17	150	36	21	150	70	17	150	36	21
Los Time (s)			3			3			3			3
Green Ratio	1.000	0.467	0.113		0.240	0.140	1.000	0.467	0.113		0.240	0.140
Lane Group Capacity (c) (pcu/h)	1,454	2,174	358		410	442	1,454	2,174	184		410	442
v/c Ratio for Lane Group	**0.212**	**1.693**	**1.856**		**1.315**	**0.761**	**0.731**	**1.867**	**0.886**		**1.894**	**1.907**

Flow Ratio	0.212	0.790	0.210		0.316	0.107	0.731	0.871	0.100		0.455	0.267
Critical Lane Group/Phase			*					*			*	*
Sum of Critical Flow Ratios	1.8											
v/c Ratio for Intersection	**1.9**											

Source: JICA Survey Team

(5) Intersection Improvement (2035)

Traffic Volume

	North Bound			East Bound			South Bound			West Bound		
	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn	Left Turn	Through	Right Turn
Flow Rate (pcu/h)	342	4,085	737	49	599	373	1,175	4,491	180	980	863	935
Lane Group	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
												
Phase Number	1/2/3/4	1	2	1/2/3/4	3	4	1/2/3/4	1	2	1/2/3/4	3	4
Phasing												
Flow Rate in Lane Group (v) (pcu/h)	**342**	**4,085**	**737**	**49**	**599**	**373**	**1,175**	**4,491**	**180**	**980**	**863**	**935**

Saturation Flow

S_o: Base Sturation Flow	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900	1,900
N: Number of Lanes	1	3	2	1	1	2	1	3	1	1	1	2
f_w: Lane Width Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{HV}: Heavy-vehicle Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_G: Grade Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_P: Parking Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{BB}: Bus Blockage Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_A: Area Type Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{LU}: Lane Utilization Adjustment Factor	1.000	0.908	0.971	1.000	1.000	0.971	1.000	0.908	1.000	1.000	1.000	0.971
f_{LT}: Left-turn Adjustment Factor	1.000	1.000	0.950	1.000	1.000	0.950	1.000	1.000	0.950	1.000	1.000	0.950
f_{RT}: Right-turn Adjustment Factor	0.850	1.000	1.000	0.850	1.000	1.000	0.850	1.000	1.000	0.850	1.000	1.000
CBD	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
f_{Rpb}: Right-turn Ped/Bike Adjustment Factor	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Adjusted Saturation Flow (pcu/h)	**1,454**	**4,658**	**3,155**	**1,454**	**1,710**	**3,155**	**1,454**	**4,658**	**1,625**	**1,454**	**1,710**	**3,155**

Capacity Analysis

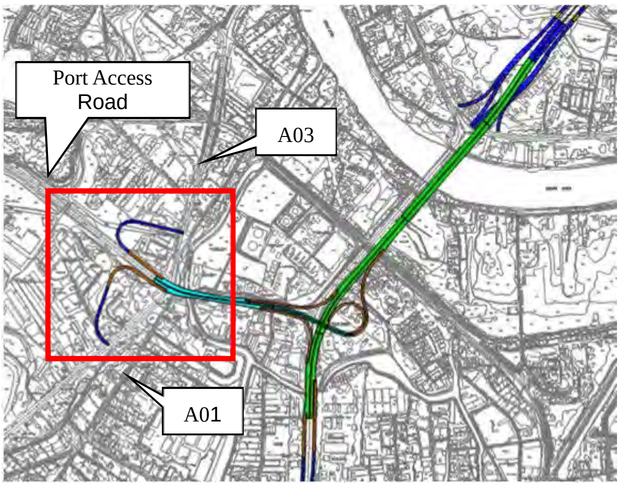
Cycle Length (s)	150	150	150	150	150	150	150	150	150	150	150	150
Effective Green Time (s)	150	70	17	150	36	21	150	70	17	150	36	21
Los Time (s)			3			3			3			3
Green Ratio	1.000	0.467	0.113		0.240	0.140	1.000	0.467	0.113		0.240	0.140
Lane Group Capacity (c) (pcu/h)	1,454	2,174	358		410	442	1,454	2,174	184		410	442
v/c Ratio for Lane Group	**0.236**	**1.879**	**2.061**		**1.460**	**0.845**	**0.809**	**2.066**	**0.980**		**2.102**	**2.117**

Flow Ratio	0.236	0.877	0.234		0.350	0.118	0.809	0.964	0.111		0.505	0.296
Critical Lane Group/Phase			*					*			*	*
Sum of Critical Flow Ratios	2.0											
v/c Ratio for Intersection	**2.1**											

Source: JICA Survey Team

4.4.3 Ingurukade Interchange

In the Pre-preliminary Design (2012), half cloverleaf type interchange was proposed for the Ingurukade Interchange (see Figure 4.4.8). In order to reduce the number of affected buildings, the following two alternative types were prepared, and evaluated based on the multi-criteria.



Source: JICA Survey Team

Figure 4.4.8 Ingurukade Interchange

(1) Alternative 1: Half Cloverleaf Type (Original)

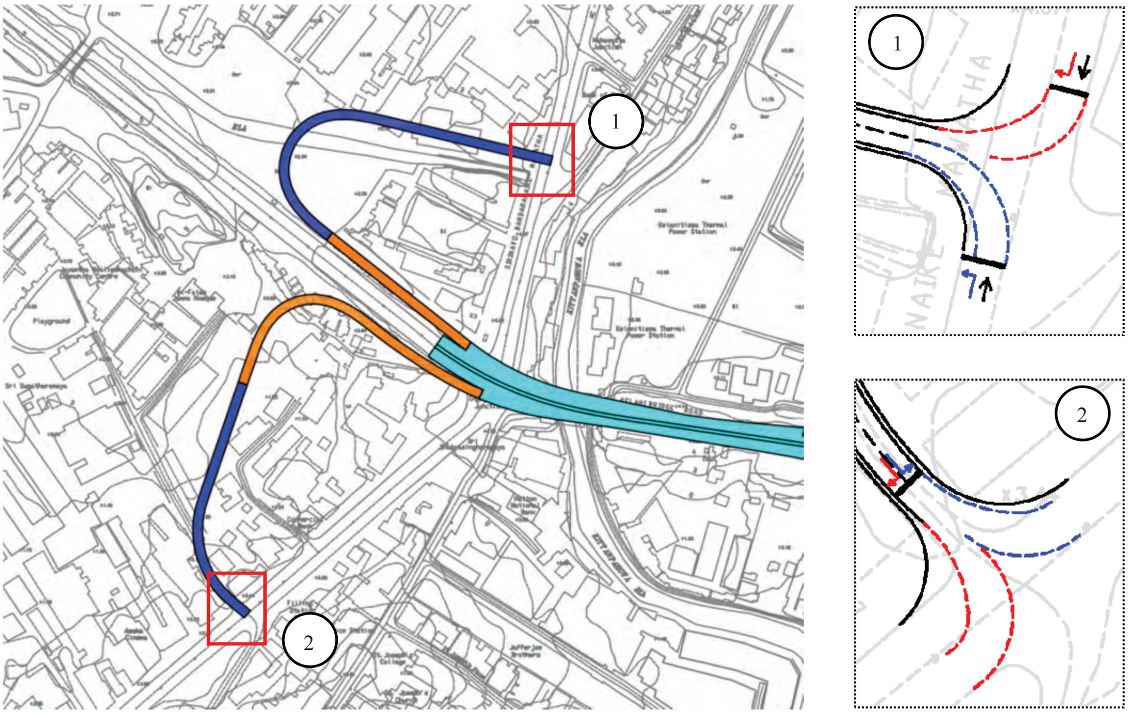
On and off ramps are connected to A03 Road and A01 Road, respectively (see Figure 4.4.9).

(2) Alternative 2: Half Diamond Type

On and off ramps are connected to existing Port Access Road (see Figure 4.4.10).

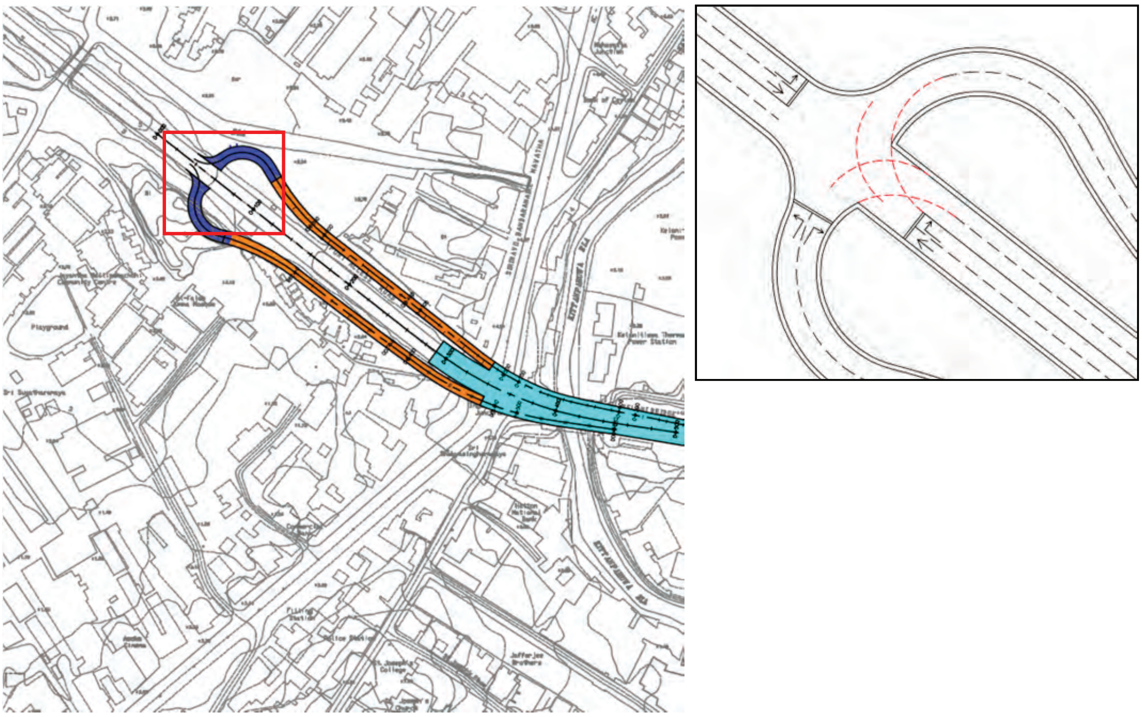
Summary of evaluation is shown in Table 4.4.4. As a result, "Alternative 2: Half Diamond Type" was selected as the most appropriate interchange type for Ingurukade Interchange from the following viewpoints.

- Construction cost is cheaper.
- Number of affected building is smaller.



Source: JICA Survey Team

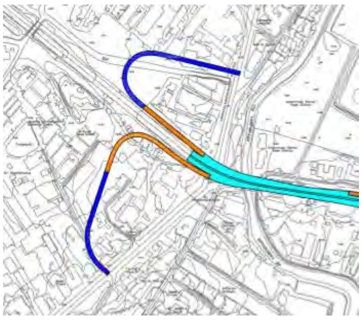
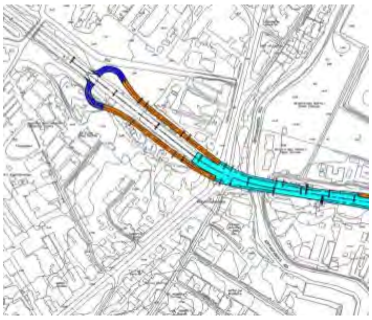
Figure 4.4.9 Half Cloverleaf Type Ingurukade Interchange



Source: JICA Survey Team

Figure 4.4.10 Half Diamond Type Ingurukade Interchange

Table 4.4.4 Evaluation of Ingurukade Interchange Type

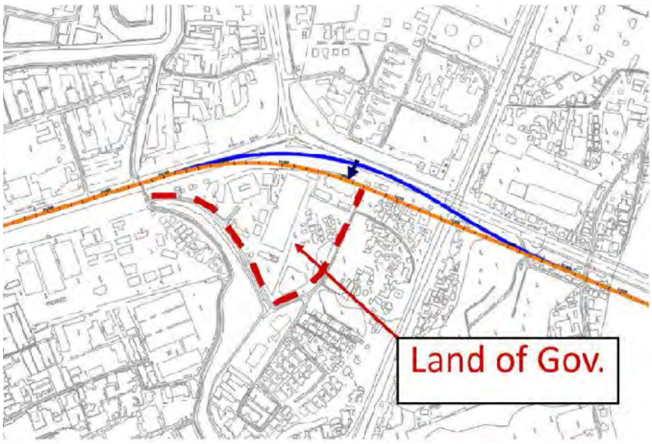
	Alternative 1: Half Cloverleaf Type (Original)		**Alternative 2: Half Diamond Type**	
Summary	- On and off ramps are connected to A03 Road and A01 Road, respectively. - Ramps are constructed avoiding buildings as much as possible.		- On and off ramps are connected to existing Port Access Road. - New intersection is constructed on the existing Port Access Road.	
Plan View				
Traffic Flow	- Vehicles can easily access to the Project Road since the ramps are connected to A01 and A03 directly.	Good	- Vehicles access to the Project Road through two intersections, namely the existing intersection among A01, A03 and Port Access Road and the new intersection on existing Port Access Road.	Fair
Construction Cost	- 1,550 million RS - (1.46)	Poor	- 1,059 million RS - (1.00)	Good
Constructability	- Construction in the difficult conditions is not required.	Fair	- Construction in the difficult conditions is not required.	Fair
Environmental and Social Impacts	- 31 structures are affected.	Poor	- 14 structures are affected.	Good
Evaluation			**Recommended**	

Source: JICA Survey Team

4.4.4 Kelanithissa Junction

In the Pre-preliminary Design (2012), originally, three-layered structure (Y type) was considered for this junction because of the urgent need for handling containers and cargoes from the Bandaranayke Airport to the Port and minimizing land acquisition at the existing Kelanithissa intersection (see Figure 4.4.12).

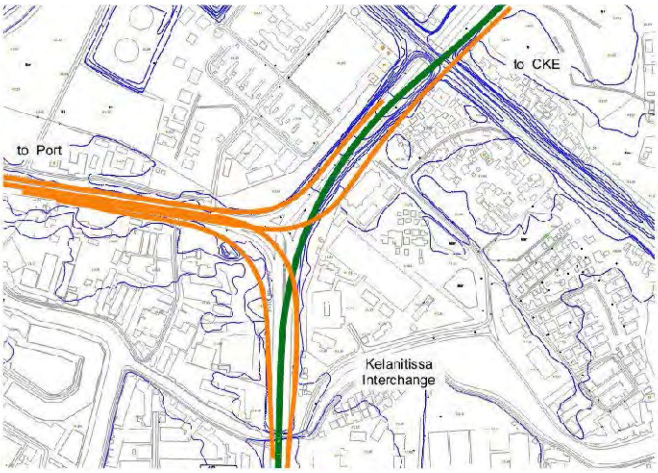
However, after discussions with RDA, it is decided that the government land as shown in Figure 4.4.11 can be used for construction of the junction. Thus, two options (Trumpet A and B types) are added for comparison (see Figure 4.4.13, 4.4.14). Summations for each design are presented below:



Source: JICA Survey Team

Figure 4.4.11 Government Land which can be used for Construction

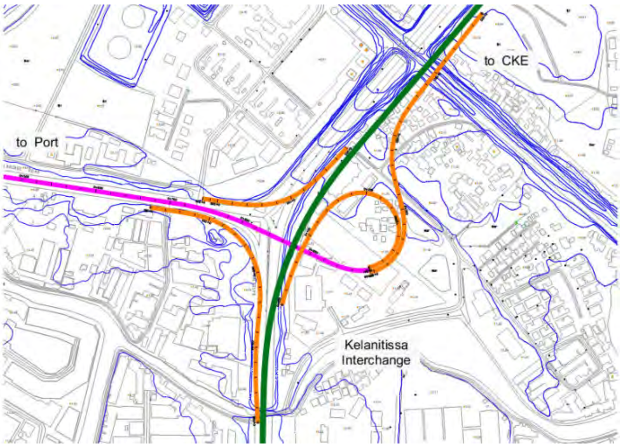
- Y type: Among three options, this design requires the least land acquisition but is at higher elevation (3 layers) over existing road. This means difficulty in construction and expensive construction cost.



Source: JICA Survey Team

Figure 4.4.12 Y Type Junction

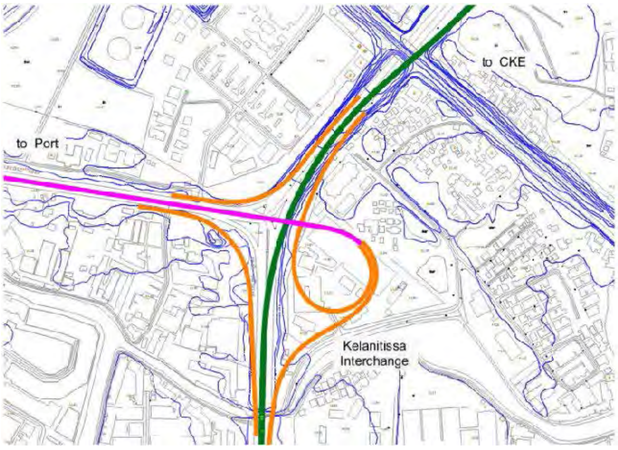
- Trumpet type (A type): utilizing the above mentioned government land for constructing the interchange. This design has a lower elevation (2 layers) than Y type. However, it requires more land acquisition and a resettlement plan shall be taken into consideration.



Source: JICA Survey Team

Figure 4.4.13 Trumpet A Type Interchange

- Trumpet type (B type): this design is similar to A type with better utilization of government land. The difference between two trumpet types is the use of a loop as an entrance ramp to main line (A type) or an exit ramp from the main line (B type). This results in different location of the merging nose (to the main line), with the nose in A type stays farther from Orugodawatta Intersection than in B type.



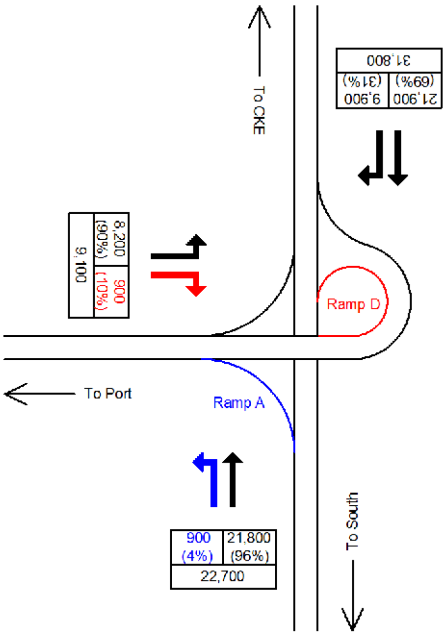
Source: JICA Survey Team

Figure 4.4.14 Trumpet B Type Interchange

Overall, trumpet designs are favorable. In order to secure ramp lengths between Kelanithissa Junction and Orugodawatta Interchange, A type (Original Design) is selected for Kelanithissa Juction.

In addition, the necessity of the ramps is studied. Project effect by the construction of Ramp A and D will be lower than those of other ramps in Kelanithissa Junction, since the traffic volume of these two ramps is small as shown in Figure 4.4.15. Traffic volumes of Ramp A and D are 900 and 900 pcu/day in 2022, respectively.

However, these two ramps are included in the Project in order to provide the services for all direction in the junction, even if the necessity is low until urban arterial road will be developed.



Source: JICA Survey Team

Figure 4.4.15 Traffic Volume of Ramp A and D in Kelanithissa Junction

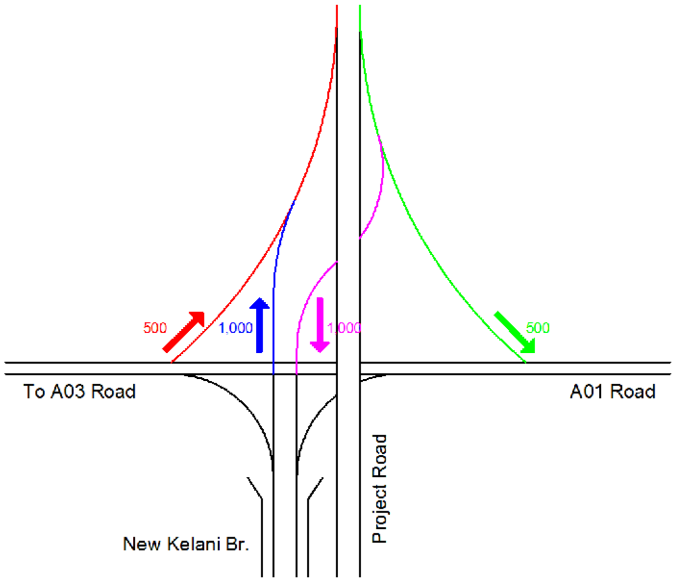
4.4.5 CKE Interchange

CKE Interchange is originally constructed in the CKE Project. However, it will be reconstructed in accordance with the alignment change of the Main Line in this Project.

Project effect by the reconstruction of CKE Interchange will be lower than those of other interchanges, since the traffic volume of CKE Interchange is small as shown in Figure 4.4.16. Traffic volumes of four ramps in CKE Interchange are 500 to 1,000 pcu/day in 2022.

Only vehicles from/to around this interchange will use this interchange.

However, CKE Interchange is included in the Project in order to keep existing service level, even if the necessity of the reconstruction is low.



Source: JICA Survey Team

Figure 4.4.16 Traffic Volume of CKE Interchange

4.5 Selection of the Bridge Type

4.5.1 Selection of the Main Bridge type

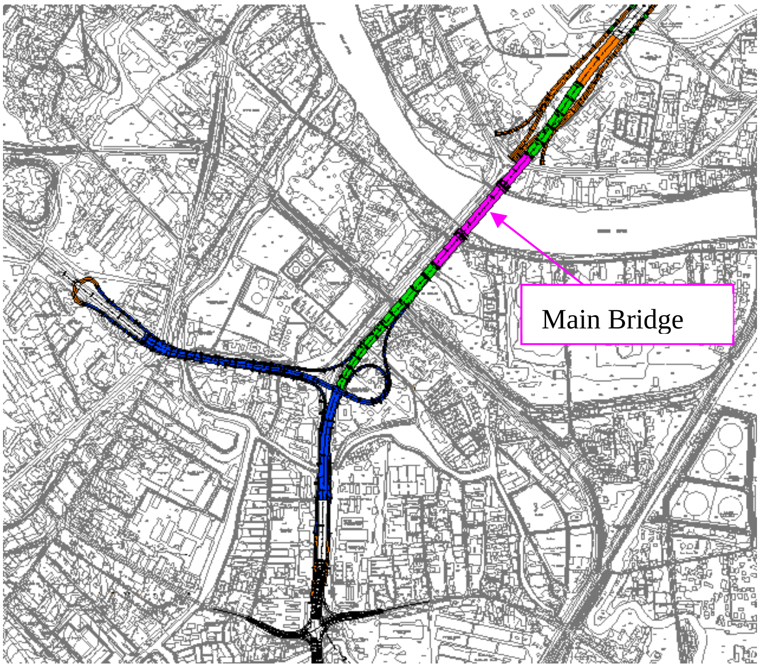
(1) Alternative Main Bridge Types

As the 2nd New Kelani Bridge will be constructed in the upstream side of the existing bridge, new bridge piers should be located with consideration of existing piers in order not to disturb the current flow as well as the navigation route under the existing bridge. Since the longest existing span in the river is 32.6m, the new bridge will have spans of at least 35m.

Regarding the structure type, even though the existing bridge is RC structure, this is not a desirable option for the new bridge considering the life span of RC structures (which is relative short in general, compared with other types of structures).

In addition, the steel bridges do not compare in this project because the steel bridges are higher than the concrete bridges.

Regarding the construction method, the cantilever method and the incremental launching method are favorable since the falsework method can only be applied for construction in river areas in the dry season, which will lengthen the construction time. Furthermore, construction works inside the river area can adversely impact on the traffic on the river.



Source: JICA Survey Team

Figure 4.5.1 Main Bridge Location

Overall, three options are considered for the Main Bridge.

1) Option 1: PC Box-girder Bridge

PC Box-girder bridges are very common bridges. This low-cost type can be constructed using the cantilever method. However, the applicable span range, which is from 50m to 150m, is shorter than the river width in this project. Bridge piers will thus have to be constructed in the river. Considering existing pier locations, the new bridge will have 3 spans with central span of 90m.

Source: The Pre-Preliminary Design (2012)

Figure 4.5.2 Computer Graphics for PC Box-girder Bridge

2) Option 2: Extra-dosed Bridge

Extra-dosed bridges have a longer applicable span range than PC Box-girder bridges and also could be constructed using the cantilever method. While more expensive, this type does not require piers to be built in the river as opposed to the previous option. For this reason, this type does not have an adverse impact on scouring and river environment. With applicable span from 120m to 200m, central span (two towers) is set to be 185m considering surrounding condition. Moreover, this type of bridge has a very good aesthetic aspect.

Source: The Pre-Preliminary Design (2012)

Figure 4.5.3 Computer Graphics for Extra-dosed Bridge

3) Option 3: Cable-stayed Bridge

Similar to the Extra-dosed bridges, Cable-stayed bridges do not require piers to be built in the river. Based on the applicable span length of 150m to 300m, this type is designed with spans of 170m and 140m (one tower). Cable-stayed bridges also have a very good aesthetic aspect.

Source: The Pre-Preliminary Design (2012)

Figure 4.5.4 Computer Graphics for Cable-stayed Bridge

(2) Outline Design of Main Bridge Types

1) Main Bridge Design

<u>Superstructure Cross Section</u>

Live load generated by vehicles and passengers is the dominant factor in deciding cross section of the superstructure. Regarding this factor, there is not much differenes among bridge design codes. Therefore, the cross section can be designed based on past records in Japan.

<u>Substructure Cross Section</u>

Substructure cross section design is governed by live load, superstructure weight and seismic force. It is stated in Bridge Design Manual (RDA, 1997) that there is no consideration for seismic force in Sri Lanka.

<u>Foundation</u>

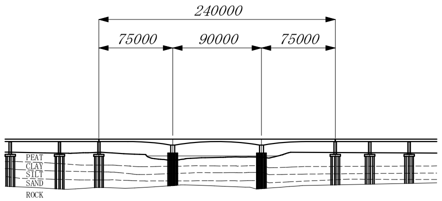
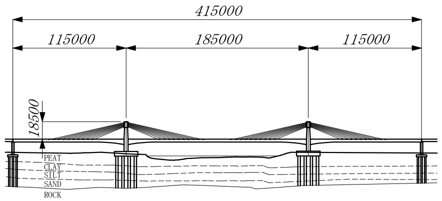
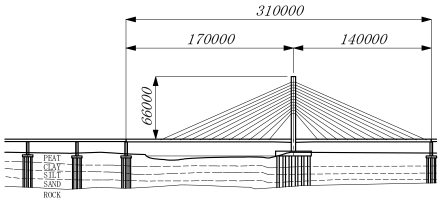
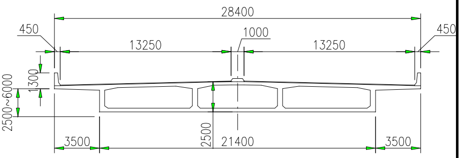
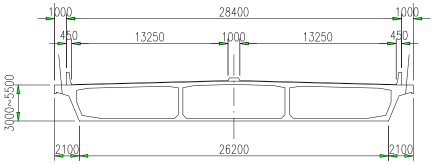
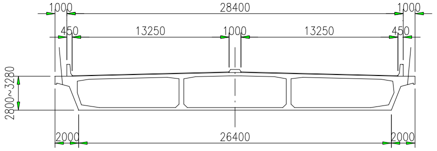
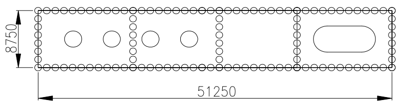
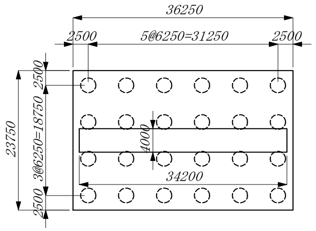
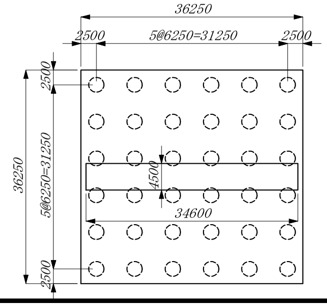
Foundation design is based on several factors, such as live load, structure self-weight (incl. superstructure and substructure) and ground condition. Since ground condition varies with locations, the method of design foundation based on past record is considered not desirable. Therefore, foundation design such as pile diameters and number of piles, are calculated and shown in 4.5.1

Furthermore, in the case of the PC Box-girder bridge, since piers are to be built inside the river, scouring issue should also be taken into account. As mentioned in 4.5.1, new piers are located with consideration to existing pier locations, scouring issue toward existing piers should be examined as well. One counter-measure for these issues is to use Steel Pipe Sheet Pile method. For other types (Extra-dosed and Cable-stayed), since there is no issue alike, cast-in-situ pile foundations are adopted for better economic performance.

2) Construction Schedule of Main Bridge

The construction schedule of each option is shown in Table 4.5.2.

Table 4.5.1 Foundation Type (Main Bridge)

Bridge Type		Option 1 PC Box-girder Bridge	Option 2 Extra-dosed Bridge	Option 3 Cable-stayed Bridge
Side View				
Cross Section				
Foundation		 The 2nd New Kelani Br.: 36 piles The existing New Kelani Br.: 78 piles		
Pile type		Steel pipe sheet pile	Cast-in-situ pile	Cast-in-situ pile
No.		36	24	36
Diameter	m	1.0	2.5	2.5
Length	m	30	30	30
Bearing Force/Pile	kN	2932	12623	12623
Live load	kN	6,500	10,900	16,800
Superstructure weight	kN	70,400	135,800	265,100
Substructure weight	kN	20,200	144,100	157,900
Total weight	kN	97,100	290,800	439,800

Source: JICA Survey Team

Table 4.5.2 Construction Schedule (Main Bridge)

Option 1-PC Box Girder Bridge

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Preparation			━	━	━	━					━												━																											
P1	SPSP driving	3.8M *1					━	━	━	━																																								
	Pile cap	4.0M									━	━	━	━																																		
	Pier	3.0M													━	━	━																															
	Pier head	4.5M																━	━	━	━	━																												
	Cantilever	6.5M *2																						━	━	━	━	━	━																					
	Side closing	4.0M *3																												━	━	━	━																	
P2	SPSP driving	3.8M *1									━	━	━	━																																		
	Pile cap	4.0M													━	━	━	━																														
	Pier	3.0M																	━	━	━																												
	Pier head	4.5M																				━	━	━	━	━																								
	Cantilever	6.5M *2																										━	━	━	━	━	━																	
	Side closing	4.0M *3																															━	━	━	━													
Center closing		2.0M																															━	━															
Deck work		5.0M																																			━	━	━	━	━								

*1 Total pile number is 114 per pier. The construction is carried out a day per pile.
*2 The superstructure is divided 26 blocks. The wagon assemble for 21 days, construct for 12 days per a block and dismantle for 11 days. The construction is carried out 2 parties.
*3 The length is 34m.

Option 2-Extra-dosed Bridge

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Preparation			━	━	━	━				━								━														━																		
P1	Pile	3.0M *1					━	━	━																																							
	Pile head	2.0M								━	━																																					
	Footing	3.0M										━	━	━																																		
	Pier	3.0M													━	━	━																																	
	Cantilever	10.0M *2																	━	━	━	━	━	━	━	━	━	━																						
	Tower	3.0M																		━	━	━																												
	Side closing	2.0M *3																										━	━																					
P2	Pile	3.0M *1									━	━	━																																					
	Pile head	2.0M												━	━																																			
	Footing	3.0M														━	━	━																																
	Pier	3.0M																	━	━	━																													
	Cantilever	10.0M *2																				━	━	━	━	━	━	━	━	━	━																			
	Tower	3.0M																					━	━	━																									
	Side closing	2.0M *3																													━	━																		
Center closing		1.5M																															━																	
Deck work		5.0M																																━	━	━	━	━												

*1 Total pile number is 24 per pier. The construction is carried out 3.7 days per pile.
*2 The superstructure is divided 44 blocks. The wagon assemble for 21 days, construct for 12 days per a block and dismantle for 11 days. The construction is carried out 2 parties.
*3 The length is 10m.

Option 3-Cable-Stayed Bridge

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Preparation			━	━	━	━					━										━																													
P1	Pile	4.5M *1					━	━	━	━	━																																					
	Pile head	3.0M										━	━	━																																		
	Footing	4.0M													━	━	━	━																														
	Pier	3.0M																	━	━	━																													
	Pier head	3.0M																				━	━	━																										
	Cantilever	16.7M *2																						━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━									
	Tower	17.0M																							━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━							
	Side closing	4.0M *3																																							━	━	━	━					
Deck work		5.0M																																											━	━	━	━	━

*1 Total pile number is 36 per pier. The construction is carried out 3.7 days per pile.
*2 The superstructure is divided 78 blocks. The wagon assemble for 21 days, construct for 12 days per a block and dismantle for 11 days. The construction is carried out 2 parties.
*3 The length is 37m.

Source: JICA Survey Team

(3) Evaluation of Main Bridge Types

1) Evaluation criteria

Aesthetic

The main bridge will cross the Kelani River just after the New Kelani Bridge Interchange, which will connect the International Airport to the Central Area of Colombo, becoming a new landmark of the city. As it will be one of the first major edifices that tourists see when arriving in Sri Lanka, it will have to symbolize the fast growing development of the country and its beauty. Emphasis should thus be put on the aesthetic aspect of the Main Bridge.

Environmental impact

Environmental impact includes the impact on the natural environment (Kelani River) and the impact on residents in the vicinity of the new bridge.

Since the new bridge will be constructed as a river crossing, the impact on the Kelani River is expected. Being constructed in the river bed, the new foundations could disturb the current flow; increase the risk of flooding and scouring problem. During the construction period, muddy water runoff and leakage of alkali substance in concrete from the construction site might generate water pollution. It is thus important to analyze the impact of new piers installed in the river bed to determine their impact on the on the river environment

On the other hand, as the new bridge alignment will go through a dense area in the Colombo side, it will affect the neighboring residence houses. This project is located in the area of already large traffic and this amount can drastically rise when the new bridge is open to operation. This increase will worsen the vibration and noise problems to the surrounding houses. All three options for the Main Bridge, which are concrete bridges, are proposed in order to minimize the vibration issue. However, the noise can still be generated from the expansion joints, which are installed to connect the bridge parts. The number of expansion joints will thus become a factor in assessing the noise problem.

Structural performance

The evaluation of structural performance for each option is based on the usage record of each type and their durability.

The usage record is the number of bridges of that type being constructed in the past. It is assumed that it is more reliable to secure/ predict the structural performance of the bridge with larger usage record (i.e. better known bridge type). Even among the same bridge type, the reliability in bridge performance varies due to span lengths. Therefore the past record is considered as one factor to assess the structural performance.

Durability of a bridge directly related to its life span, which means the higher the durability is, the longer the bridge can be used. Bridge consists of floor slab, girders, piers and piles. Unlike others, the floor slab is directly under the effect of live loads by passing vehicles and subject to fatigue problem. Among structures being used, RC slabs are of inferior durability to PC and composite slabs, thus have shorter life spans. Generally, RC slabs can be used for 50 years while PC and composite slabs can function roughly 100 years. For this reason, structural durability is evaluated based on the durability of floor slabs.

Constructability

Constructability indicates the level of difficulty regarding the construction site conditions and the construction work of the bridge itself.

As mentioned above, the new bridge will be built in the river area, where construction work will require the use of barges or jetties. Moreover, pile caps need to be in dry state to be used inside the river. Therefore, compared to works in land, works in the river is of greater difficulty and require better accuracy in implementation. Thus in this case, site conditions evaluation will be based on the amount of works in the river for each option.

Additionally, constructability of the bridge itself is also one of the important factors to be considered in order to achieve the work with high degree of safety. Constructability in this sense varies among erection methods and bridge types. Falsework is the simplest method, while the incremental launching or the cantilever methods are more difficult to implement. Extra-dosed and cable-stayed bridges, being built using the cantilever method, are even at higher level of difficulty with the additional requirement of constructing bridge cables. Therefore, constructability in this section is evaluated based on erection methods.

Maintenance

Regarding bridge maintenance, repainting and replacement work of bridge components are taken into consideration.

Repainting is the required work in order to lengthen bridges life spans. If neglected, steel corrosion might occur where paintwork has deteriorated, which could lead to severe damage later on. As painting can only stay protective around 20 to 30 years, repainting is necessary. Since repainting is costly, the structure without the need of repainting is desirable.

Replacements of bridge components are required actions in order to maintain the safety for bridge users. Components needed replaced include expansion joints, bearings. Replacing expansion joints is relatively easy compared to replacement of bearings as they are located between superstructures and substructures. Thus, this criterion evaluates the work of replacing bearings.

Construction period

The CKE is scheduled to start operating at the end of 2013, and will bring additional traffic into an area where road congestion is already a major issue. It is thus essential to select a type of bridge which can be built quickly, so as to minimize the period during which the traffic congestion generated by the new CKE will have impact on the area. Reducing the construction period is therefore one of the main criteria to ensure a successful project implementation.

Construction cost

Construction cost includes foundation, substructure and superstructure cost as shown in Table 4.5.3.

Maintenance Cost (For reference)

Maintenance cost is estimated assuming the life span of the bridge is 100 years.

Assuming in that life span, the numbers of replacement works are:

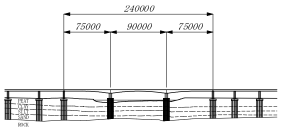
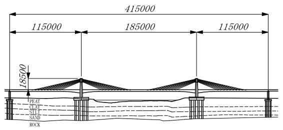
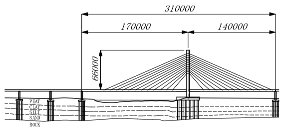
- Routine inspection: 100 times
- Periodical inspection: 20 times
- Repainting: 3 times
- Surface treatment (Carbonation measure): 3 times
- Expansion joint: 4 times
- Pavement: 9 times

The routine inspections are carried out by distant visual inspection. The periodic inspections are carried out by both distant and proximity visual inspection. Damages on girder, slab and pier are checked. As necessary, the inspectors carry out non-destructive test using hammers.

2) Evaluation result

The table below describes the evaluation result in selecting the bridge type for the Main Bridge.

Table 4.5.3 Type Evaluation for Main Bridge

			Option 1 PC Box-girder Bridge		Option 2 Extra-dosed Bridge		Option 3 Cable-stayed Bridge	
Side view								
Landscape	Aesthetic view		Normal	B	Good	A	Good	A
Environmental impact	Scouring/ Flood	Number of piers in main stream	Depth 9.3m	C	No problem	A	No problem	A
	Noise	Number of expansion joint	2	A	2	A	2	A
Structural performance	Record of usage		Many	A	Moderate	B	Moderate	B
	Durability	Durability of floor slab	PC slab	A	PC slab	A	PC slab	A
Constructability	Construction in the river	Difficulty level of construction	2 pier	C	No pier	A	No pier	A
	Quality control	Difficulty level of quality control	Normal	B	Slightly difficult	C	Slightly difficult	C
Maintenance	Painting		Not considered	A	Not considered	A	Not considered	A
	Periodic maintenance	Expansion joint numbers	2	A	2	A	2	A
		Pier with bearings	2	A	4	C	3	B
Construction period			40 month	B	36 month	A	48 month	C
Cost	Construction cost (million Rs)	Superstructure	2,074	B	3,047	A	4,317	C
		Substructure	1,550		1,460		1,094	
		Approach Bridge	1,025		0		615	
		Total	4,649		4,507		6,026	
		Ratio	(1.03)		(1.00)		(1.34)	
	Maintenance cost (For reference) (million Rs)		234		203		238	
	Life cycle cost (For reference)(million Rs)	Total	4,883		4,710		6,264	
		Ratio	(1.04)		(1.00)		(1.33)	
Evaluation					Recommended			

Legend: A excellent, B good, C poor

Source: JICA Survey Team

Option 1: PC Box-girder Bridge

This type is a very common structure which has no visual symbolic impact required for the new bridge to become a landmark at the entrance of Colombo.

Moreover, since this type requires two piers to be constructed in the river, there are concerns regarding the risk of scouring and its impact on surrounding area (current flow, river environment, etc.).

Additionally, the construction of piers in the river would be difficult and risky for workers and easily delayed due to natural events.

For the above reasons, Option 1 is less favorable than other two.

Option 2: Extra-dosed Bridge and Option 3: Cable-stayed Bridge

Both types have good aesthetic aspects and can become landmarks for the city of Colombo. As piers will be constructed on the riverbank in both cases, scouring risk is minimized and constructability is better than Option 1.

However, the Extra-dosed Bridge type can be constructed at a lower cost and shorter construction period.

Overall, the recommended solution for the Main Bridge: Option 2 - Extra-dosed Bridge.

Reason is the followings;

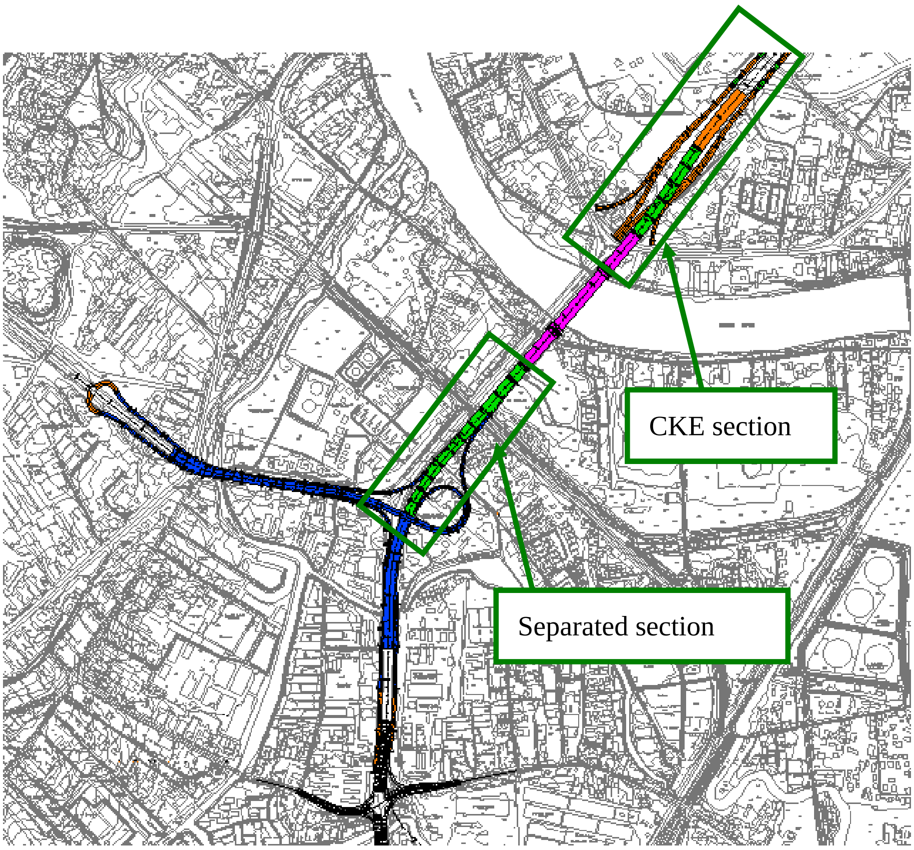
- Good aesthetic aspects as new symbol and landmark for the city gate of Colombo
- Small environmental impact because of no pier in the river stream
- Construction period is the shortest among alternatives
- Construction cost is the lowest among alternatives

4.5.2 Selection of the Approach Bridge type for CKE Section and Separated Section

(1) Alternative Approach Bridge Types for CKE Section and Separated Section

CKE section includes the approach bridge connecting the CKE to the Main Bridge, and ramps connecting CKE to existing roads. Approach bridge (and road) is of 250m long and goes over ramps. Ramps on both side of the approach bridge cross over one frontage road and one small canal before connect to CKE. For these crossings, bridges of 25m are installed (considering the widths of frontage road and canal are approximately 15m). For the approach bridge, since it only going over small existing roads, options such as Extra-dosed or Cable-stayed bridges are not considered in this section.

Separated Section connects the Overlapped section to the Main Bridge. This 415m long approach bridge will be constructed along the Baseline road and crosses over some narrow existing roads. Therefore, similar bridge types as CKE Section will be studied for Separated Section.



Source: JICA Survey Team

Figure 4.5.5 Approach Bridge Location (CKE Section and Separated Section)

1) Option 1: PC I-girder Bridge

PC I-girder bridges are highly common because of its extreme low cost among other bridge types. Main girders can be prefabricated in construction yards before being erected by crane. As the applicable span ranges from 25m to 45m, 40m span is selected for this approach bridge.

2) Option 2: PC Box-girder Bridge

Similar to PC I-girder bridges but with a longer applicable range, PC Box-girder bridges are also very common. The approach bridge can be constructed using the falsework method as a continuous girder bridge. The applicable span ranges from 30m to 110m, in which 50m is chosen for this section.

3) Option 3: Steel I-girder Bridge

Another common bridge type is the steel I-girder bridge. The superstructure can be fabricated in factories before transported to the construction site. This helps to reduce the amount of works on the site, shorten the construction period and also improve the accuracy of construction works. Moreover, because of its light-weight superstructure, the foundation scales can be reduced as well. The applicable range is 30m to 60m, in which 40m is planned for this section.

4) Option 4: Steel Box-girder Bridge

Steel Box-girder bridges can be constructed at longer spans than Option 3. From 40m to 80m range, 50m span is proposed for this section.

(2) Outline Design of the Approach Bridge Types for CKE Section and Separated Section

1) Approach Bridge Design (CKE Section and Separated Section)

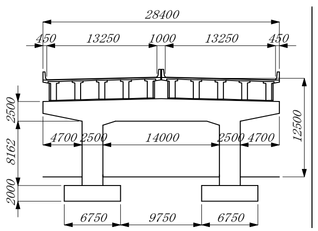
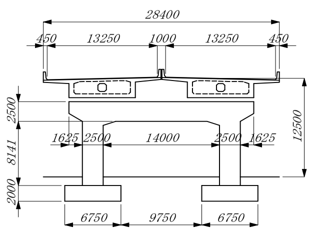
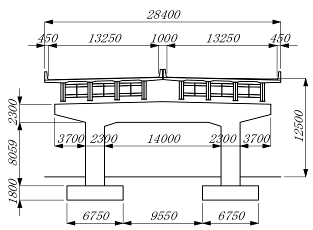
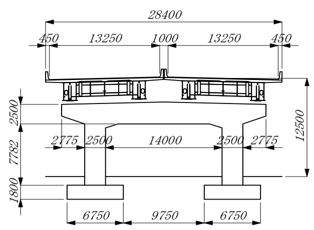
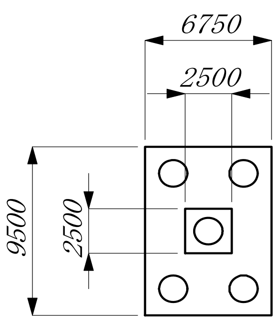
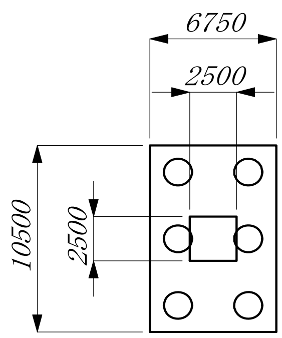
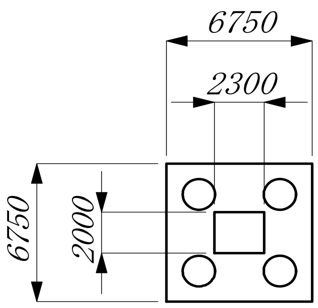
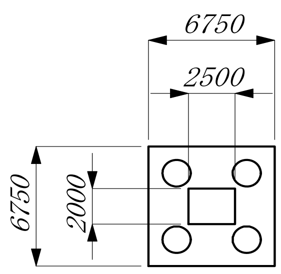
Refer to Main Bridge

However, there is no need to use Steel Pipe Sheet Pile for these sections.

2) Construction Schedule of Approach Bridge (CKE Section and Separated Section)

The construction schedule of each option is shown in Table 4.5.5.

Table 4.5.4 Foundation Type for Approach Bridge (CKE Section and Separated Section)

Bridge Type		Option 1 PC I-girder Bridge	Option 2 PC Box-girder Bridge	Option 3 Steel I-girder Bridge	Option 4 Steel Box-girder Bridge
Cross Section					
Foundation					
Pile type		Cast-in-situ pile	Cast-in-situ pile	Cast-in-situ pile	Cast-in-situ pile
No.		10	12	8	8
Diameter	m	1.5	1.5	1.5	1.5
Length	m	30	30	30	30
Bearing Force/Pile	kN	4261	4261	4261	4261
Live load	kN	20,500	26,600	14,300	18,800
Superstructure weight	kN	4,900	5,600	4,900	5,600
Substructure weight	kN	13,300	12,900	8,900	9,100
Total weight	kN	38,700	45,100	28,100	33,500

Source: JICA Survey Team

Table 4.5.5 Construction Schedule for Approach Bridge for CKE Section and Separated Section

Option 1-PC I Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Preparation			—	—																																						
Separated Section-1 (7-Piers, 6-Spans)	Pile	9.8M (1.4M/Pier)			—	—	—	—	—	—	—	—	—	—																										
	Pier	19.6M (2.8M/Pier)					—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																
	Erection	3.0M (0.5M/Span)																							—	—	—															
	Slab	16.2M (2.7M/Span)																								—	—	—	—	—	—	—	—									
	Deck work	3.0M																																—	—	—						
Separated Section-2 (5-Piers, 5-Spans)	Pile	7.0M (1.4M/Pier)			—	—	—	—	—	—	—																													
	Pier	14.0M (2.8M/Pier)					—	—	—	—	—	—	—	—	—	—	—	—	—	—																						
	Erection	2.5M (0.5M/Span)																	—	—	—																					
	Slab	13.5M (2.7M/Span)																		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—									
	Deck work	3.0M																																—	—	—						
CKE Section (7-Piers, 6-Spans)	S.G. Treatment	1.0M			—																																			
	Earthwork	5.0M				—	—	—	—	—																														
	Pile	9.8M (1.4M/Pier)									—	—	—	—	—	—	—	—	—	—																						
	Pier	19.6M (2.8M/Pier)											—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—										
	Erection	3.0M (0.5M/Span)																													—	—	—									
	Slab	16.2M (2.7M/Span)																														—	—	—	—	—	—	—	—			
	Deck work	3.0M																																						—	—	—

Option 2-PC Box Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Preparation			—	—																																						
Separated Section-1 (6-Piers, 5-Spans)	Pile	10.2M (1.7M/Pier)			—	—	—	—	—	—	—	—	—	—	—																									
	Pier	14.4M (2.4M/Pier)					—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																					
	Erection	17.5M (3.5M/Span)								—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—															
	Slab																																									
	Deck work	3.0M																										—	—	—												
Separated Section-2 (5-Piers, 5-Spans)	Pile	8.5M (1.7M/Pier)			—	—	—	—	—	—	—	—	—																											
	Pier	12.5M (2.4M/Pier)					—	—	—	—	—	—	—	—	—	—	—	—	—																							
	Erection	17.5M (3.5M/Span)								—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—															
	Slab																																									
	Deck work	3.0M																										—	—	—												
CKE Section (6-Piers, 5-Spans)	S.G. Treatment	1.0M			—																																			
	Earthwork	5.0M				—	—	—	—	—																														
	Pile	10.2M (1.7M/Pier)									—	—	—	—	—	—	—	—	—	—	—																					
	Pier	14.4M (2.4M/Pier)											—	—	—	—	—	—	—	—	—	—	—	—	—	—	—															
	Erection	17.5M (3.5M/Span)														—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—									
	Slab																																									
	Deck work	3.0M																																—	—	—						

Option 3-Steel I Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Preparation			—	—																																						
Separated Section-1 (7-Piers, 6-Spans)	Pile	8.4M (1.2M/Pier)			—	—	—	—	—	—	—	—	—																											
	Pier	15.4M (2.2M/Pier)					—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																				
	Erection	6.0M (1.0M/Span)																—	—	—	—	—	—																			
	Slab	11.4M (1.9M/Span)																	—	—	—	—	—	—	—	—	—	—	—	—												
	Deck work	3.0M																													—	—	—									
Separated Section-2 (5-Piers, 5-Spans)	Pile	6.0M (1.2M/Pier)			—	—	—	—	—	—																														
	Pier	11.0M (2.2M/Pier)					—	—	—	—	—	—	—	—	—	—	—																									
	Erection	5.0M (1.0M/Span)												—	—	—	—	—																								
	Slab	9.5M (1.9M/Span)													—	—	—	—	—	—	—	—	—	—																		
	Deck work	3.0M																							—	—	—															
CKE Section (7-Piers, 6-Spans)	S.G. Treatment	1.0M			—																																			
	Earthwork	5.0M				—	—	—	—	—																														
	Pile	8.4M (1.2M/Pier)									—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—																
	Pier	15.4M (2.2M/Pier)																				—	—	—	—	—	—															
	Erection	6.0M (1.0M/Span)																					—	—	—	—	—	—	—	—	—	—	—	—								
	Slab	11.4M (1.9M/Span)																																	—	—	—					
	Deck work	3.0M																																								

Option 4-Steel Box Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Preparation			—	—																																						
Separated Section-1 (6-Piers, 5-Spans)	Pile	7.2M (1.2M/Pier)			—	—	—	—	—	—	—	—																												
	Pier	13.2M (2.2M/Pier)					—	—	—	—	—	—	—	—	—	—	—	—	—	—																						
	Erection	2.5M (0.5M/Span)																	—	—	—																					
	Slab	12.5M (2.5M/Span)																		—	—	—	—	—	—	—	—	—	—	—	—											
	Deck work	3.0M																														—	—	—								
Separated Section-2 (5-Piers, 5-Spans)	Pile	6.0M (1.2M/Pier)			—	—	—	—	—	—																														
	Pier	11.0M (2.2M/Pier)					—	—	—	—	—	—	—	—	—	—	—																									
	Erection	2.5M (0.5M/Span)														—	—	—																								
	Slab	12.5M (2.5M/Span)															—	—	—	—	—	—	—	—	—	—	—	—	—													
	Deck work	3.0M																												—	—	—										
CKE Section (6-Piers, 5-Spans)	S.G. Treatment	1.0M			—																																			
	Earthwork	5.0M				—	—	—	—	—																														
	Pile	7.2M (1.2M/Pier)									—	—	—	—	—	—	—	—																								
	Pier	13.2M (2.2M/Pier)											—	—	—	—	—	—	—	—	—	—	—	—	—	—																
	Erection	2.5M (0.5M/Span)																							—	—	—															
	Slab	9.5M (1.9M/Span)																								—	—	—	—	—	—	—	—	—	—							
	Deck work	3.0M																																		—	—	—				

Source: JICA Survey Team

(3) Evaluation of the Approach Bridge Types for CKE Section and Separated Section

1) Evaluation criteria

Aesthetic

The approach bridge will be constructed in a fairly open space, which is easy to catch the attention of road users underneath and surrounding residents. Top view-wise, Option 1~ 4 is not much different from each other, but the views from below clearly give different impressions. Option 1 with 5 girders, Option 3 with 4 girders give the impression of complexity, which is, in the aesthetic point of view, not as good as Option 2 and Option 4 (2 box-girder).

Environmental impact

The construction of the approach bridge will have strong impact in the vicinity environment. Especially to the ground condition, piers construction works might cause impacts such as ground stability, soil waste disposal and water pollution.

Similar to the Main Bridge, residents in the vicinity of this bridge will be expected to face the issues of vibration and noise once the new bridge opens. The number of expansion joints is estimated in order to assess the noise problem.

Structural performance

Refer to Main Bridge

Constructability

Construction site condition: This section will be constructed over ramps of CKE (scheduled to open at the end of this year), therefore impact on the traffic in this site is expected. Traffic from CKE through ramps to existing roads will be temporarily stopped in order to carry out the construction of CKE section. On the other hand, Separated Section will be constructed along the Baseline road, which is handling a large amount of traffic every day. This is thus desirable to limit the construction area to minimize the impact on the existing traffic

For the constructability of the bridge itself, as stated in the Main Bridge, the erection method will be used as the criterion.

Maintenance

Refer to the Main Bridge.

Construction period

As this section will be built beside the existing roads, the impact during construction on the existing roads and its traffic flow will thus be minimized. Construction period is thus not as vital as for the Overlapped Section. Nevertheless, as the extension of the Main Bridge, the construction will still have to be done in shorter time than that of the Main Bridge.

Construction cost

Refer to Table 4.5.6

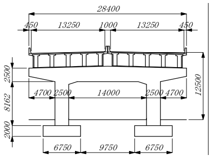
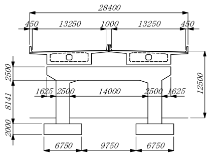
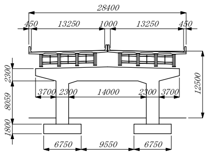
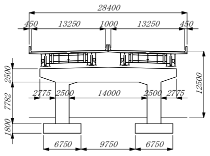
Maintenance Cost (For Reference)

Refer to the Main Bridge

2) Evaluation result

Evaluation result is shown in Table 4.5.6.

Table 4.5.6 Bridge Type Evaluation for Approach Bridge (CKE Section and Separated Section)

			Option 1 PC I-girder Bridge		Option 2 PC Box-girder Bridge		Option 3 Steel I-girder Bridge		Option 4 Steel Box-girder Bridge	
Cross section										
Criteria	Span length		40m		50m		40m		50m	
	Bridge Effective Width		13.25m, 2lane		13.25m, 2lane		13.25m, 2lane		13.25m, 2lane	
Landscape	Aesthetic view		Poor	C	Good	A	Poor	C	Good	A
Environmental impact	Natural environmental	Number of pier	7	B	6	A	7	B	6	A
	Regarding vibration problem		Good	A	Good	A	Poor	C	Poor	C
	Noise	Number of expansion joint	2	A	2	A	2	A	2	A
Structural performance	Usage record		Many	A	Many	A	Many	A	Many	A
	Durability	Durability of floor slab	PC slab	A	PC slab	A	RC slab	C	RC slab	C
Constructability	Impact on the existing road		More impact	B	Less impact	A	Less impact	A	Less impact	A
	Quality control	Difficulty level of quality control	Slightly difficult	B	Slightly difficult	B	Easy	A	Easy	A
Maintenance	Painting		No paint	A	No paint	A	Paint	C	Paint	C
	Periodic maintenance	Number of expansion joint	2	A	2	A	2	A	2	A
		Pier with bearings	7	B	6	A	7	B	6	A
Construction period			40 month	C	34 month	A	35 month	B	36 month	B
Cost	Construction cost (thousand Rs)	Superstructure	90,884	A	169,519	B	207,959	C	298,037	C
		Substructure	104,637		112,565		78,583		79,816	
		Total	195,521		282,084		286,542		377,853	
		Rs/m2	184		213		270		285	
		Ratio	(1.00)		(1.15)		(1.47)		(1.55)	
	Maintenance cost (For reference) (thousand Rs)		23,800		25,700		46,500		38,600	
	Life cycle cost (For reference) (thousand Rs)	Total	219,321		307,784		333,042		416,453	
		Rs/m2	207		232		314		314	
		Ratio	(1.00)		(1.12)		(1.52)		(1.52)	
Evaluation					Recommended					

Legend: A excellent, B good, C poor

Source: JICA Survey Team

As mentioned above, emphasis should rather be put on reducing construction cost than construction period. It is therefore preferable to use PC Girder Bridge types (Options 1 and 2) which are cheaper than the Steel Girder Bridge types (Options 3 and 4) for this section.

Between Option 1 and 2: Option 2 is slightly more expensive but has shorter construction period, better aesthetic aspect, is easier to maintain and has less impact on the surrounding environment.

Recommended Solutions for the CKE Section and Separated Section: Option 2 - PC Box Girder.

Reason is the followings;

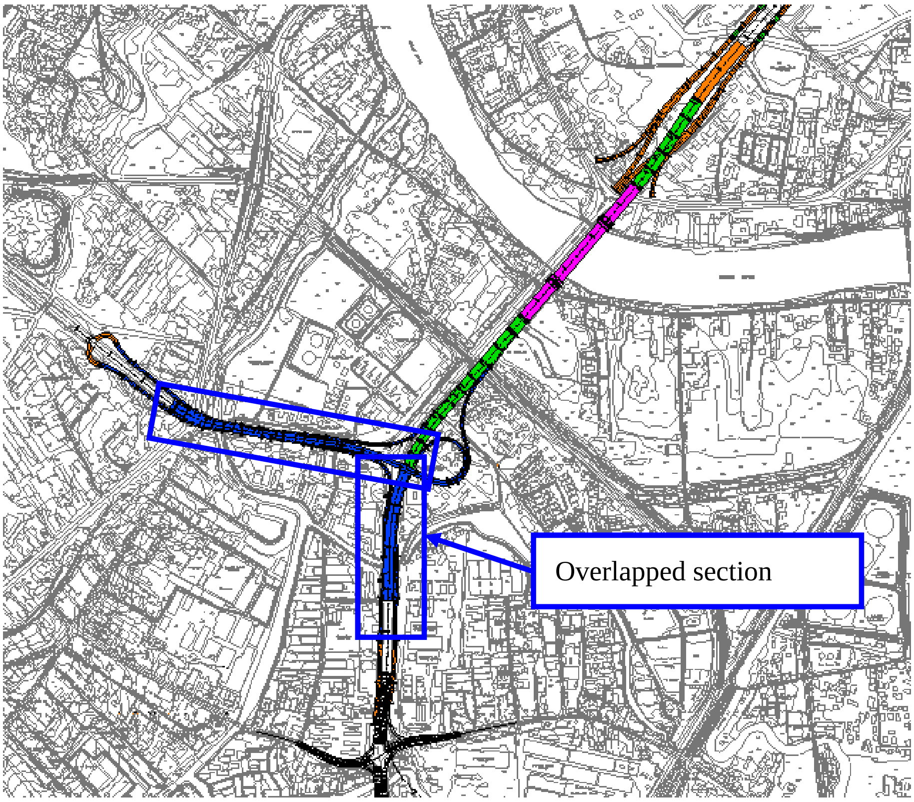
- Good aesthetic view of the bottom face of box girder and longer span length than plate girder
- Small environmental impact because of fewer number of pier
- No repainting of concrete girder against steel girder
- Construction period is the 2nd shortest among alternatives, but not critical
- Construction cost is the 2nd lowest among alternatives

4.5.3 Selection of the Approach Bridge type for Overlapped Section

(1) Alternative Approach Bridge Types for Overlapped Section

Overlapped Section, connecting Separated Section to the city center, includes two parts: one above the Baseline Road, the other above the Port Access Road. Since both parts are over existing roads, their construction will be carried out along with existing traffic, thus construction safety should be carefully considered.

These two parts will cross over the A1 road (approximately 20m wide), an existing small canal. Thus, there is no need to consider extra-dosed or cable-stayed bridges for this section.



Source: JICA Survey Team

Figure 4.5.6 Approach Bridge Location (Overlapped Section)

The following four options are considered:

1) Option 1: PC I-girder Bridge

Refer to CKE Section

2) Option 2: PC Box-girder Bridge

Refer to CKE Section

3) Option 3: Steel I-girder Bridge

Refer to CKE Section

4) Option 4: Steel Box-girder Bridge

For recommended span length: Refer to CKE Section

For substructure design: With the use of steel piers, while construction cost will be higher than concrete piers, construction period can be greatly shortened. This is important for

Overlapped Section as it will lessen the impact on existing traffic. Moreover, by using steel piers, rigid frame structure can also be adopted.

(2) Outline Design of Approach Bridge Types for Overlapped Section

1) Approach Bridge Design (Overlapped Section)

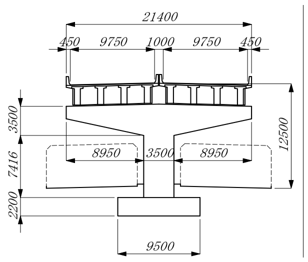
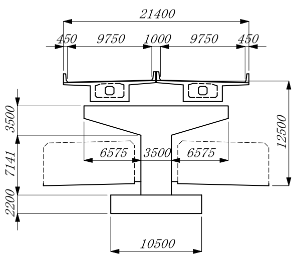
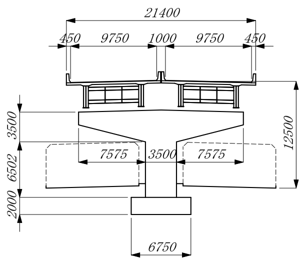
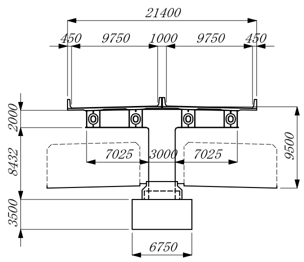
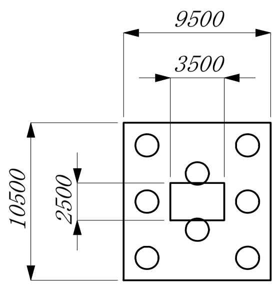
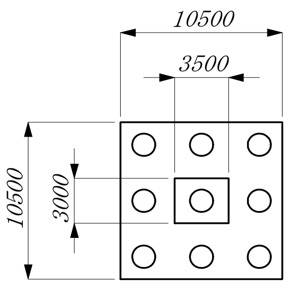
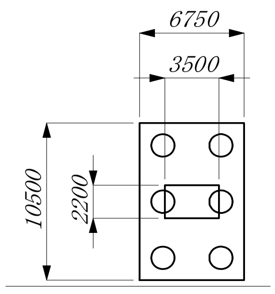
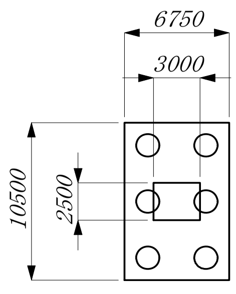
Refer to Main Bridge

However, there is no need to use Steel Pipe Sheet Pile for this section.

2) Construction Schedule of Approach Bridge (Overlapped Section)

The construction schedule of each option is shown in Table 4.5.8.

Table 4.5.7 Foundation Type of Approach Bridge (Overlapped Section)

Bridge Type		Option 1 PC I-girder Bridge	Option 2 PC Box-girder Bridge	Option 3 Steel I-girder Bridge	Option 4 Steel Box-girder Bridge
Cross Section					
Foundation					
Pile type		Cast-in-situ pile	Cast-in-situ pile	Cast-in-situ pile	Cast-in-situ pile
No.		8	9	6	6
Diameter	m	1.5	1.5	1.5	1.5
Length	m	30	30	30	30
Bearing Force/Pile	kN	4261	4261	4261	4261
Live load	kN	15,700	19,900	10,600	12,000
Superstructure weight	kN	4,000	4,600	4,000	4,600
Substructure weight	kN	10,700	11,200	7,300	6,700
Total weight	kN	30,400	35,700	21,900	23,300

Source: JICA Survey Team

Table 4.5.8 Construction Schedule for Approach Bridge (Overlapped Section)

Option 1-PC I Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Preparation			━	━																																						
Fabrication																																										
Mainline (11-Piers, 10-Spans)	Pile	13.2M (1.2M/Pier)			━	━	━	━	━	━	━	━	━	━	━	━	━	━																								
	Pier	24.2M (2.2M/Pier)					━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━											
	Erection	6.0M (0.6M/Span)																									━	━	━	━	━	━										
	Slab	21.0M (2.1M/Span)																										═	═	═	═	═	═	═	═	═	═	━				
	Deck work	4.0M																																					━	━	━	━
Port Access (11-Piers, 10-Spans)	Pile	10.8M (1.2M/Pier)			━	━	━	━	━	━	━	━	━	━	━	━	━	━																								
	Pier	19.8M (2.2M/Pier)					━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━											
	Erection	4.8M (0.6M/Span)																									━	━	━	━	━	━										
	Slab	16.8M (2.1M/Span)																										═	═	═	═	═	═	═	═	═	═	━				
	Deck work	4.0M																																					━	━	━	━

Option 2-PC Box Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Preparation			━	━																																						
Fabrication																																										
Mainline (9-Piers, 8-Spans)	Pile	11.7M (1.3M/Pier)			━	━	━	━	━	━	━	━	━	━	━	━																										
	Pier	18.9M (2.1M/Pier)					━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━																	
	Erection	24.0M (3.0M/Span)								━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━									
	Slab																																									
	Deck work	4.0M																																━	━	━	━					
Port Access (9-Piers, 8-Spans)	Pile	11.7M (1.3M/Pier)			━	━	━	━	━	━	━	━	━	━	━	━																										
	Pier	18.9M (2.1M/Pier)					━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━																	
	Erection	24.0M (3.0M/Span)								━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━									
	Slab																																									
	Deck work	4.0M																																━	━	━	━					

Option 3-Steel I Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Preparation			━	━																																						
Fabrication																																										
Mainline (11-Piers, 10-Spans)	Pile	9.9M (0.9M/Pier)			━	━	━	━	━	━	━	━	━	━																												
	Pier	22.0M (2.0M/Pier)				━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━															
	Erection	7.0M (0.7M/Span)																				━	━	━	━	━	━	━														
	Slab	18.0M (1.8M/Span)																					═	═	═	═	═	═	═	═	═											
	Deck work	4.0M																														━	━	━	━							
Port Access (11-Piers, 10-Spans)	Pile	9.9M (0.9M/Pier)			━	━	━	━	━	━	━	━	━	━																												
	Pier	22.0M (2.0M/Pier)				━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━															
	Erection	7.0M (0.7M/Span)																				━	━	━	━	━	━	━														
	Slab	18.0M (1.8M/Span)																					═	═	═	═	═	═	═	═	═											
	Deck work	4.0M																														━	━	━	━							

Option 4-Steel Box Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Preparation			━	━																																						
Fabrication					━	━	━	━	━	━	━	━																														
Mainline (9-Piers, 8-Spans)	Pile	8.1M (0.9M/Pier)			━	━	━	━	━	━	━	━	━																													
	Pier	7.2M (0.8M/Pier)					━	━	━	━	━	━	━	━																												
	Erection	4.0M (0.5M/Span)											━	━	━																											
	Slab	14.4M (1.8M/Span)												═	═	═	═	═	═	═	━																					
	Deck work	4.0M																				━	━	━	━																	
Port Access (9-Piers, 8-Spans)	Pile	8.1M (0.9M/Pier)			━	━	━	━	━	━	━	━	━																													
	Pier	7.2M (0.8M/Pier)					━	━	━	━	━	━	━	━																												
	Erection	4.0M (0.5M/Span)											━	━	━																											
	Slab	14.4M (1.8M/Span)												═	═	═	═	═	═	═	━																					
	Deck work	4.0M																				━	━	━	━																	

Source: JICA Survey Team

(3) Evaluation of Approach Bridge Types for Overlapped Section

1) Evaluation criteria

Road elevation

As Overlapped Section will go above existing roads, bridge heights will be designed with consideration to the clearance limit. Moreover, the ramp to Port Access Line needs to go over the Main Line, which makes the overall structure stand very high over the existing ground. If the main bridge heights are reduced, it will lower overall structure height and ramps construction cost.

Aesthetic

Refer to CKE Section. Note that for Overlapped Section, the aesthetic aspect is of even more importance since the existing traffic will go right under the new bridge.

Environmental impact

Unlike other sections, there are a large number of offices and commercial buildings along both existing roads under Overlapped Section. The impact on these should be carefully studied.

Structural performance

Refer to Main Bridge

Constructability

This section will be constructed above the Baseline road and the Port Access Road, therefore the level of difficulty will be higher than other sections. The impact on existing traffic should be used to assess construction site condition.

Maintenance

Refer to CKE Section

Construction period

As explained above, construction period should be shortened as possible to reduce the impact on existing road users.

Construction cost

Refer to Main Bridge

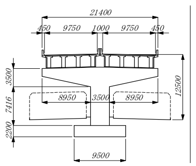
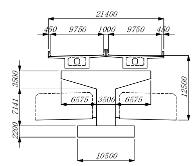
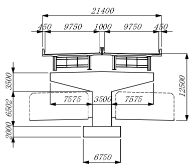
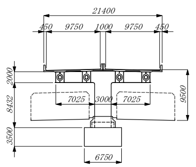
Maintenance Cost (For Reference)

Refer to the Main Bridge

2) Evaluation result

Evaluation result is shown in Table 4.5.9.

Table 4.5.9 Bridge Type Evaluation for Approach Bridge for Overlapped Section

			Option 1 PC I-girder Bridge		Option 2 PC Box-girder Bridge		Option 3 Steel I-girder Bridge		Option 4 Steel Box-girder Bridge	
Cross section										
Criteria	Span length		40m		50m		40m		50m	
	Bridge Effective Width		9.75m, 2lane		9.75m, 2lane		9.75m, 2lane		9.75m, 2lane	
Road elevation			High	C	High	C	High	C	Low	A
Landscape	Aesthetic view		Poor	C	Poor	C	Poor	C	Good	A
Environmental impact	Natural environmental	Number of pier	29	B	25	A	29	B	25	A
	Regarding vibration problem		Good	A	Good	A	Poor	C	Poor	C
	Noise	Number of expansion joint	8	A	8	A	8	A	8	A
	Traffic congestion during constraction stage		Poor	C	Poor	C	Poor	C	Good	A
Structural performance	Usage record		Many	A	Many	A	Many	A	Moderate	B
	Durability	Durability of floor slab	PC panel + RC slab	A	PC slab	A	Composite slab	A	Composite slab	A
Constructability	Impact on the existing road		More impact	C	More impact	C	More impact	C	Less impact	A
	Quality control	Difficulty level of quality control	Slightly difficult	B	Slightly difficult	B	Easy	A	Easy	A
Maintenance	Painting		No paint	A	No paint	A	Paint	C	Paint	C
	Periodic maintenance	Number of expansion joint	8	A	8	A	8	A	8	A
		Pier with bearings	25	C	29	C	25	C	8	A
Construction period			40 month	C	35 month	B	33 month	B	23 month	A
Cost	Construction cost (thousand Rs)	Superstructure	73,373	A	134,823	B	161,250	C	218,345	C
		Substructure	82,743		89,240		61,659		74,802	
		Total	156,116		224,063		222,909		293,147	
		Rs/m2	200		230		286		301	
		Ratio	(1.00)		(1.15)		(1.43)		(1.50)	
	Maintenance cost (For reference) (thousand Rs)		17,900		19,200		27,000		32,600	
	Life cycle cost (For reference) (thousand Rs)	Total	174,016		243,263		249,909		325,747	
		Rs/m2	223		250		320		334	
		Ratio	(1.00)		(1.12)		(1.44)		(1.50)	
Evaluation									Recommended	

Legend: A excellent, B good, C poor

Source: JICA Survey Team

While being the most expensive, Option 4 has the best constructability in the sense of minimizing impact on existing traffic, resulting in one year less than others in construction time. During this additional year for the other cases, the construction works of the approach bridges would continue impacting the traffic flow, generating traffic jams and longer transit time through traffic diversion. Road users would have to spend more time in congestion, resulting in higher consumption of fuel. Such economic loss would be the smallest in Option 4. This difference can compensate for the expensive construction cost in Option 4.

Moreover, Option 4 is the most aesthetic pleasing and has lowest road elevation as shown in Table 4.5.10.

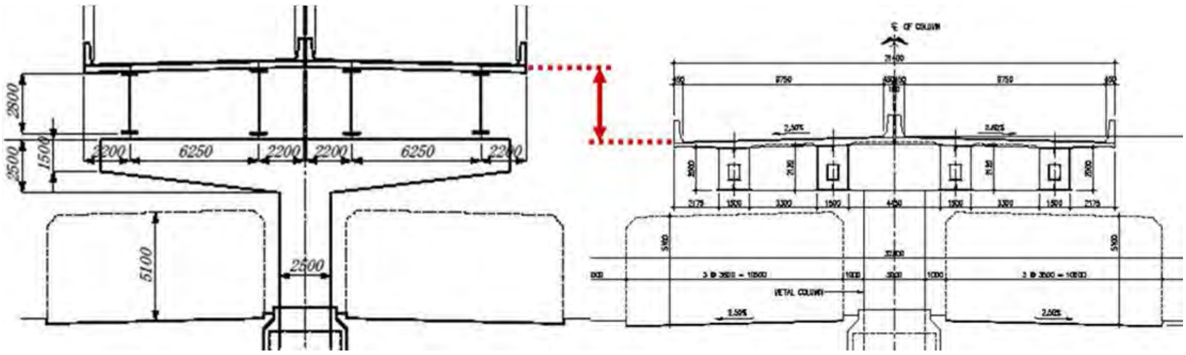
In addition, Option 4 can be kept at 40 m interval between the ramp bridge and Orugodawatta Intersection shown in Figure 4.5.7. Furthermore Option 3, cannot be kept at 40 m interval between the ramp bridge and Orugodawatta Intersection, because option 3 must be raised more than 2 m above the road elevation so as not to embed the steel box girder in the steel piers. Thus, Option 3 can only be kept at less than 40m interval between the ramp bridge and Orugodawatta Intersection and if Option 3 is adopted, the drivers will confuse route selection at the intersection due to the short distance.

<u>Recommended Solution for the Overlapped Sections: Option 4 - Steel Box-girder Bridge</u>

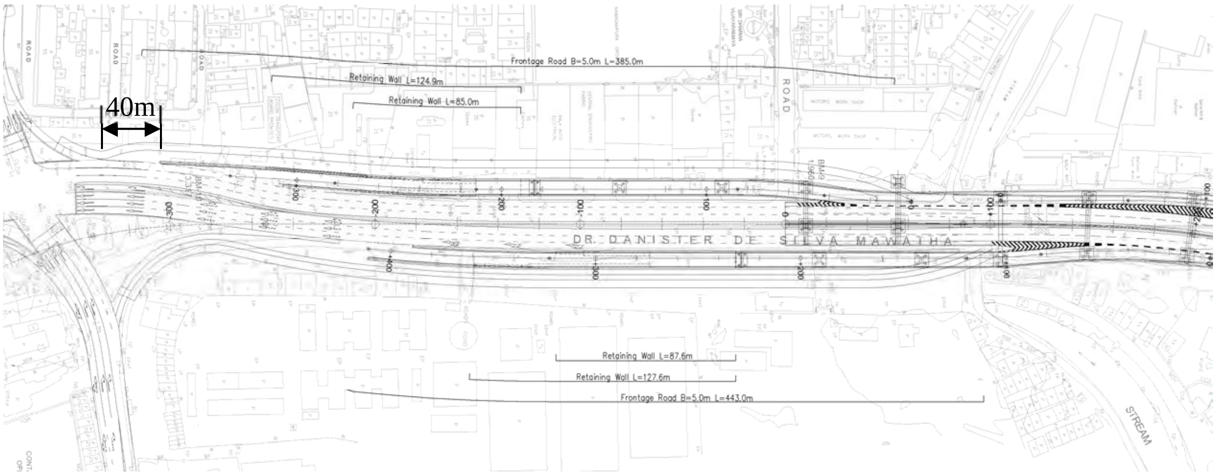
Reason is the followings;

- Good aesthetic view of the bottom face of box girder and long span length more than plate girder
- Small environmental impact because of fewer number of pier
- Minimum impact of traffic congestion and safety during construction stage
- Best constructability and the shortest construction period among alternatives
- Construction cost is the highest, however economic loss by traffic congestion during construction stage is the lowest

Table 4.5.10 Road Elevation

<table>
<tr><td></td><td></td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Options 1, 2 and 3 with concrete hammer-piers</td><td>Option 4 with steel piers embedded in the Steel Box-girder Bridge</td></tr>
</table>

Source: The Pre-Preliminary Design (2012)



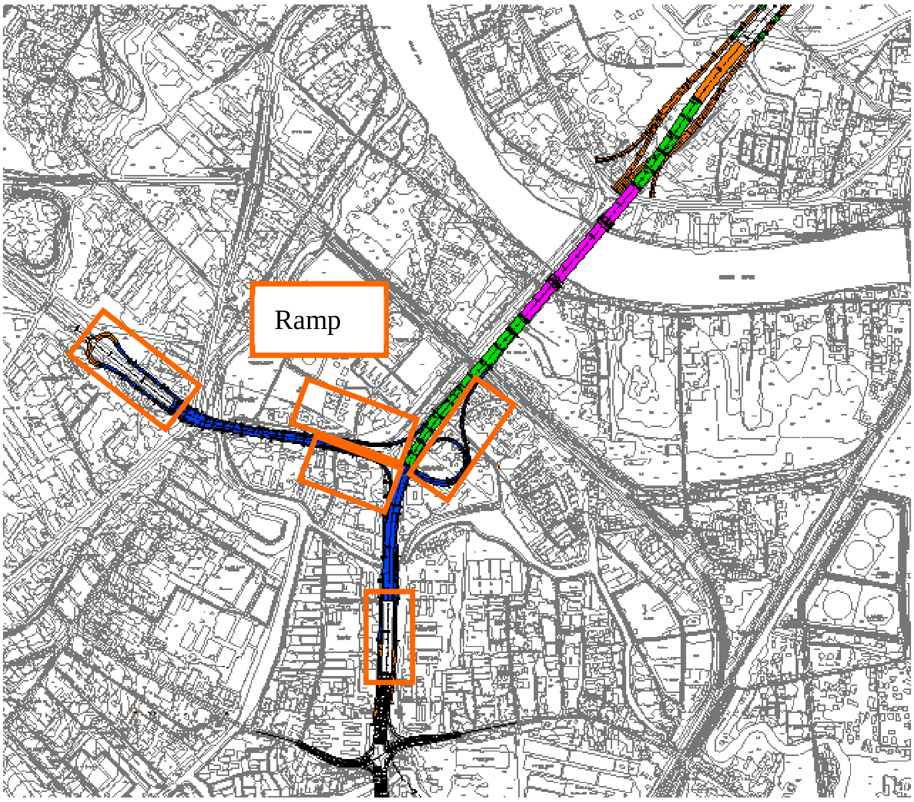
Source: JICA Survey Team

Figure 4.5.7 Orugodawatta Interchange

4.5.4 Selection of the Ramp Bridge type

(1) Alternative Ramp Bridge Types

Ramp bridges are designed to connect the new road (incl. Main Line and Port Access Line) to existing roads; or Main Line to Port Access Line. Ramp bridges will have to be built with minimized impact on existing traffic.



Source: JICA Survey Team

Figure 4.5.8 Ramp Bridges Locations

1) Option 1: PC Box-girder Bridge

Refer to CKE Section and Separated Section

2) Option 2: Steel Box-girder Bridge

Refer to Overlapped Section.

(2) Outline Design of Ramp Bridge Types

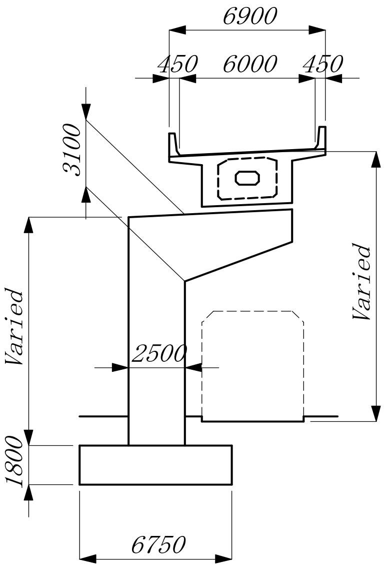
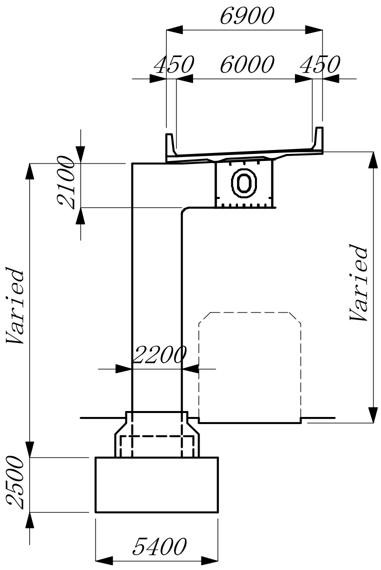
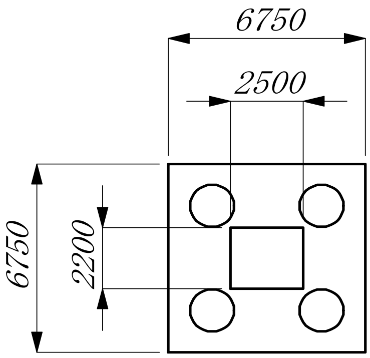
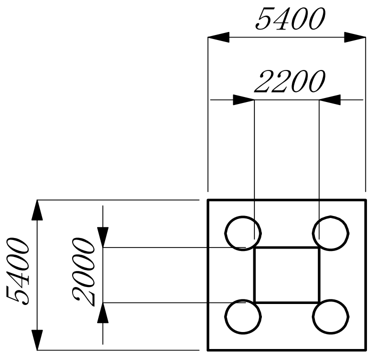
1) Ramp Bridge Design

Refer to Main Bridge without the use of Steel Pipe Sheet Pile.

2) Construction Schedule of Ramp Bridge

The construction schedule of each option is shown in Table 4.5.12.

Table 4.5.11 Foundation Type for Ramp Bridges

Bridge Type		Option 1 PC Box-girder Bridge	Option 2 Steel Box-girder Bridge
Cross Section			
Foundation			
Pile type		Cast-in-situ pile	Cast-in-situ pile
No.		4	4
Diameter	m	1.5	1.2
Length	m	30	30
Bearing Force/Pile	kN	4261	3067
Live load	kN	7,700	5,100
Superstructure weight	kN	1,700	1,700
Substructure weight	kN	5,400	2,300
Total weight	kN	14,800	9,100

Source: JICA Survey Team

Table 4.5.12 Construction Schedule for Ramp Bridges

Option 1-PC Box Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Preparation			━	━																																		
Fabrication					━	━	━	━	━	━	━																											
Orugodawatta ON (3-piers, 3-Spans) OFF (3-piers, 3-Spans)	Pile	3.6M (0.6M/Pier)			━	━	━	━																														
	Pier	6.6M (1.1M/Pier)				━	━	━	━	━	━	━																										
	Erection	6.0M (1.0M/Span)						━	━	━	━	━	━																									
	Slab																																					
	Deck work	2.0M												━	━																							
Ingurukada ON (5-Piers, 5-Spans) OFF (3-Piers, 3-Spans)	Pile	4.8M (0.6M/Pier)			━	━	━	━	━																													
	Pier	8.8M (1.1M/Pier)				━	━	━	━	━	━	━	━	━																								
	Erection	8.0M (1.0M/Span)						━	━	━	━	━	━	━	━																							
	Slab																																					
	Deck work	2.0M														━	━																					
Kelanittisa A (4-Piers, 5-Spans) B (4-Piers, 5-Spans) C-1 (5-Piers, 6-Spans) C-2 (7-Piers, 7-Spans) D (3-Piers, 4-Spans)	Pile	13.8M (0.6M/Pier)			━	━	━	━	━	━	━	━	━	━	━	━	━	━																				
	Pier	25.3M (1.1M/Pier)					━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━						
	Erection	27.0M (1.0M/Span)							━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━			
	Slab																																					
	Deck work	3.0M																																		━	━	━

Option 2-Steel Box Girder

Month			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Preparation			━	━																																		
Fabrication					━	━	━	━	━	━	━																											
Orugodawatta ON (3-piers, 3-Spans) OFF (3-piers, 3-Spans)	Pile	3.6M (0.6M/Pier)						━	━	━	━																											
	Pier	3.0M (0.5M/Pier)								━	━	━																										
	Erection	1.8M (0.3M/Span)										━	━																									
	Slab	1.8M (0.3M/Span)											━	━																								
	Deck work	2.0M													━	━																						
Ingurukada ON (5-Piers, 5-Spans) OFF (3-Piers, 3-Spans)	Pile	4.8M (0.6M/Pier)						━	━	━	━	━																										
	Pier	4.0M (0.5M/Pier)								━	━	━	━																									
	Erection	2.4M (0.3M/Span)										━	━	━																								
	Slab	2.4M (0.3M/Span)											━	━	━																							
	Deck work	2.0M														━	━																					
Kelanittisa A (4-Piers, 5-Spans) B (4-Piers, 5-Spans) C-1 (5-Piers, 6-Spans) C-2 (7-Piers, 7-Spans) D (3-Piers, 4-Spans)	Pile	13.8M (0.6M/Pier)			━	━	━	━	━	━	━	━	━	━	━	━	━	━																				
	Pier	11.5M (0.5M/Pier)						━	━	━	━	━	━	━	━	━	━	━	━																					
	Erection	8.1M (0.3M/Span)										━	━	━	━	━	━	━	━	━																		
	Slab	8.1M (0.3M/Span)											━	━	━	━	━	━	━	━	━																	
	Deck work	3.0M																				━	━	━														

Source: JICA Survey Team

(3) Evaluation of Ramp Bridge Types

1) Evaluation criteria

Aesthetic

As Ramp bridges will be implemented in a dense urban area, their aesthetic aspects should be taken into consideration so as not to adversely affect the cityscape.

Environmental impact

Refer to Main Bridge

Structural performance

Refer to Main Bridge

Constructability

The construction of ramp bridges will affect the existing traffic flow, especially at Orugodawatta Interchange, thus better constructability will help shorten the construction period.

Maintenance

Refer to Main Bridge

Construction period

Ramp bridges will be constructed at the end of the construction works. Their erection will thus be on the critical path and their required construction period will directly impact the overall construction period of the Project. Also with the above reason (Constructability) It is important to minimize their construction period.

Construction cost

Refer to Main Bridge

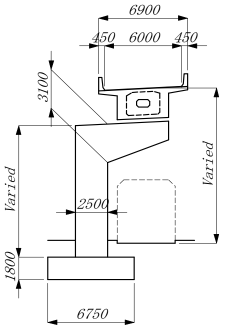
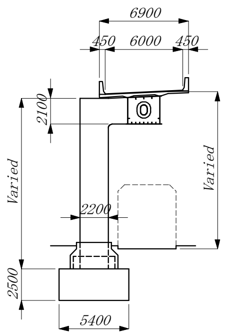
Maintenance Cost (For Reference)

Refer to the Main Bridge

2) Evaluation result

Evaluation result is shown in Table 4.5.13.

Table 4.5.13 Bridge Type Evaluation (Ramp Bridge)

			Option 1 PC Box-girder Bridge		Option 2 Steel Box-girder Bridge	
Cross section						
Criteria	Span length		50m		50m	
	Bridge Effective Width		6.0m		6.0m	
Landscape	Aesthetic view		Good	A	Good	A
Environmental impact	Natural environmental	Number of pier	49	A	49	A
	Regarding vibration problem		Good	A	Poor	C
	Noise	Number of expansion joint	19	A	19	A
Structural performance	Usage record		Many	A	Moderate	B
	Durability	Durability of bridge deck	PC slab	A	Compsite slab	A
Constructability	Impact on the existing road		More impact	C	Less impact	A
	Quality control	Difficulty level of quality control	Slightly difficult	B	Easy	A
Maintenance	Painting		No paint	A	Paint	C
	Periodic maintenance	Number of expansion joint	19	A	19	A
		Pier with bearings	49	C	19	A
Construction period			36 month	C	22 month	A
Cost	Construction cost (thousand Rs)	Superstructure	48,788	A	75,668	B
		Substructure	43,447		30,660	
		Total	92,235		106,328	
		Rs/m2	307		354	
		Ratio	(1.00)		(1.15)	
	Maintenance cost (For reference) (thousand Rs)		9,000		15,800	
	Life cycle cost (For reference) (thousand Rs)	Total	101,235		122,128	
		Rs/m2	337		407	
		Ratio	(1.00)		(1.21)	
Evaluation					Recommended	

Legend: A excellent, B good, C poor

Source: JICA Survey Team

Option 2- Steel Box-girder Bridge is recommended for Ramp bridges because this type can be constructed in 22 month, much less than PC Box-girder Bridge (36 months). This Option also has less impact on the existing traffic.

Recommended Solution for the Ramp Bridges: Option 2 – Steel Box-girder Bridge

Reason is the followings;

- Minimum impact of traffic congestion and safety during construction stage
- Best constructability and the shortest construction period among alternatives
- Construction cost is the highest, however economic loss by traffic congestion during construction stage is the lowest

5. PRELIMINARY DESIGN

5.1 Road Design

5.1.1 Geometric Design

(1) Horizontal Alignment

Horizontal alignment of the Project Road is determined taking into account the following conditions.

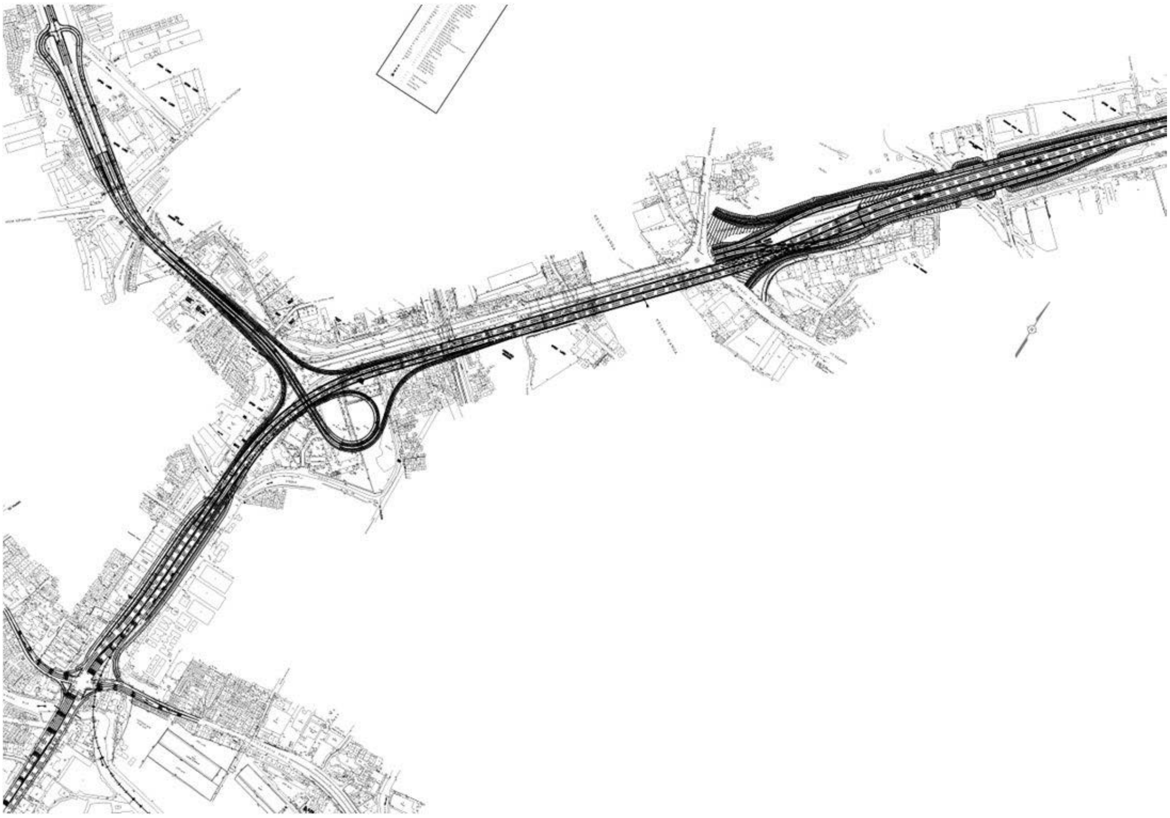
1) Horizontal Alignment of the Main Line

- From the beginning point to Kelanithissa Junction, there are a large number of large scale buildings along the Baseline Road. Therefore, the alignment is set above the Baseline Road.
- From the Kelanithissa Junction to Kelani River, the alignment is set along the A01 Road to connect to 2nd New Kelani Bridge constructed close to existing New Kelani Bridge.
- 2nd New Kelani Bridge as a part of the Project Road is constructed upstream of the existing New Kelani Bridge closely.
- The end point of the alignment is connected to CKE using S-curve.

2) Horizontal Alignment of the Port Access Road

- The alignment is set above the A01 Road to reduce the impact to houses, commercial building, power plant, etc. along the A01 Road as much as possible.

Horizontal alignment of the Project Road is shown in Figure 5.1.1.



Source: JICA Survey Team

Figure 5.1.1 Horizontal Alignment of the Project Road

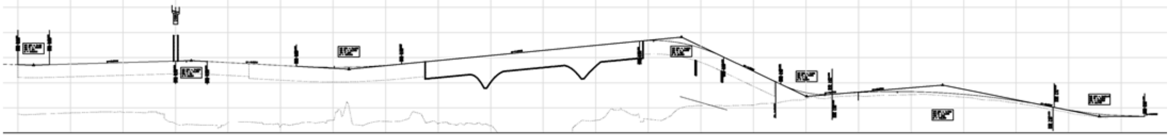
(2) Vertical Alignment

Vertical alignment of the Project Road is determined taking into account the following conditions.

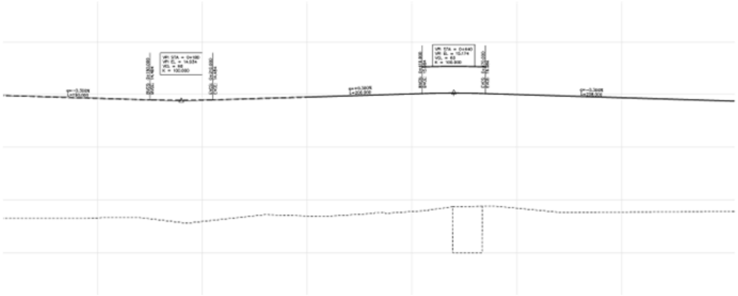
- Vertical clearance of the existing road under the Project Road is 5.1m.
- In addition to 5.1m of clearance, at least 1.0m of additional space under the bridge is provided so that bridge maintenance such as repainting can be carried out without interrupting the existing traffic.

Vertical alignment of the Project Road is shown in Figure 5.1.2.

(1) Main Line



(2) Port Access Road



Source: JICA Survey Team

Figure 5.1.2 Vertical Alignment of the Project Road

5.1.2 Intersection Design

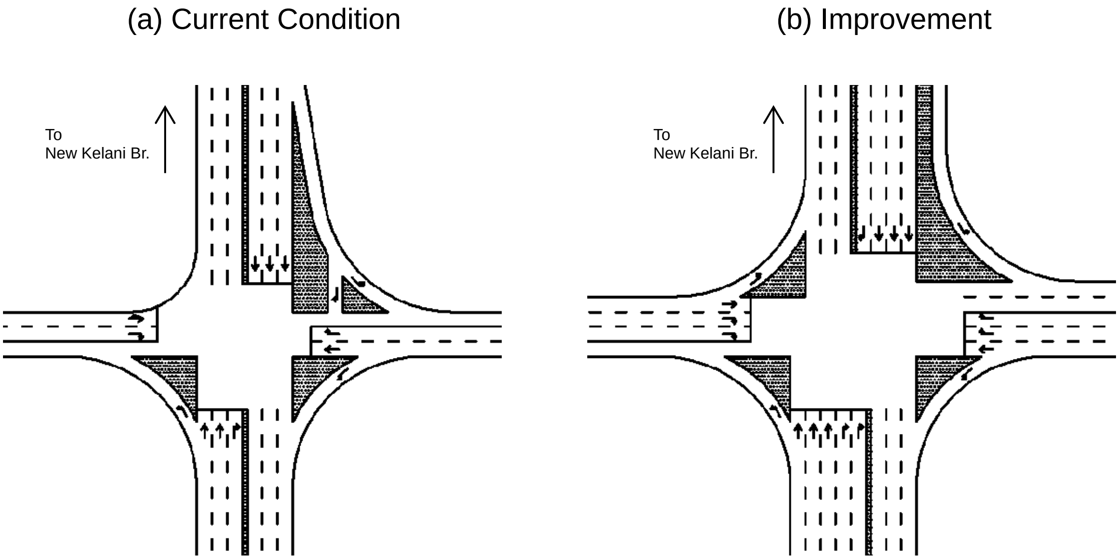
(1) Orugodawatta Intersection

1) Introduction

In addition to constructing the Project Road, Orugodawatta Intersection is improved in the Project, in order to handle the traffic generated from the Project Road.

2) Lane Arrangement

Number of lanes for each bound is determined based on intersection capacity analysis (see Table 4.4.3). Lane arrangement of Orugodawatta Intersection is shown in Figure 5.1.3.



Source: JICA Survey Team

Figure 5.1.3 Lane Arrangement of Orugodawatta Intersection

3) Right-turn Lane

Right-turn lane is provided for all bounds in Orugodawatta Intersection.

Lengths of right-turn lane, taper and lane shift are calculated by the following formula.

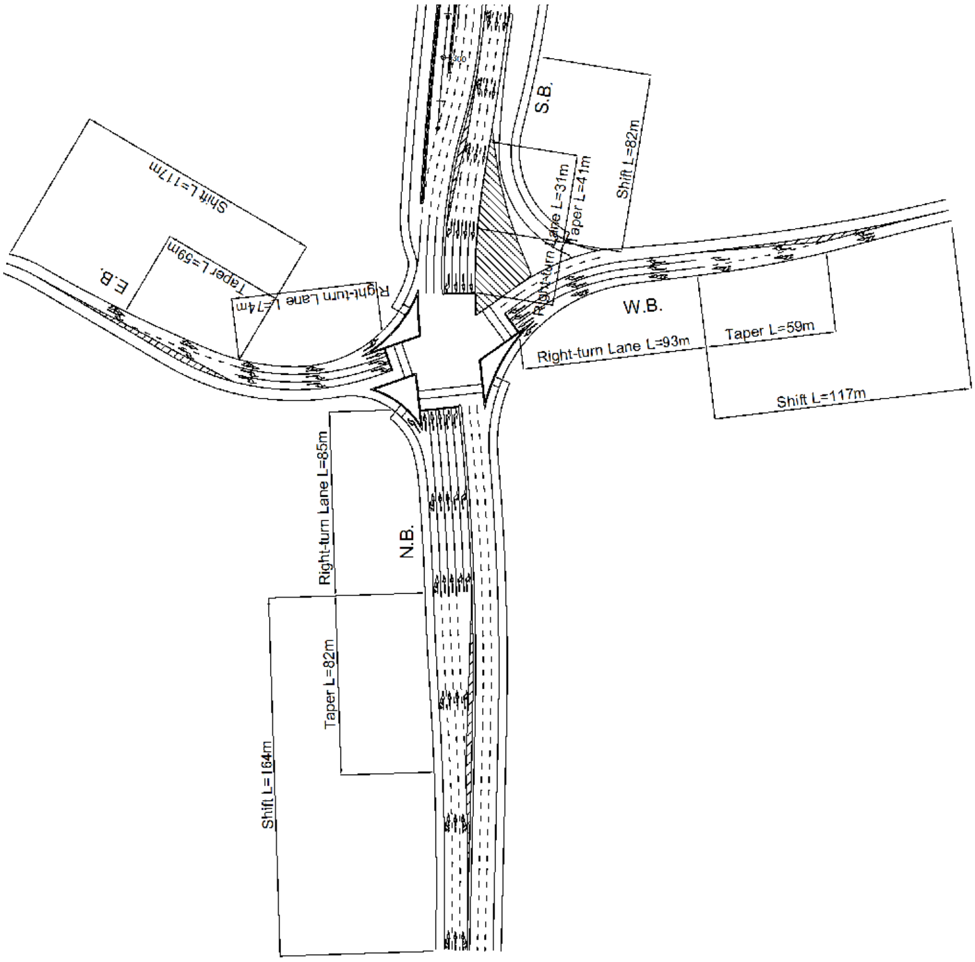
- Right-turn lane: 1.5 x (traffic volume) x (cycle time / 3600) x (car length)
- Taper: (design speed) x (shift width) / 6
- Lane shift: (design speed) x (shift width) / 3

Lengths of right-turn lane, taper and lane shift for each bound are shown in Table 5.1.1 and Figure 5.1.4.

Table 5.1.1 Length of right-turn Lane, Taper and Lane Shift

Bound	Right-turn Lane	Taper	Lane Shift
North Bound	85 m	82 m	164 m
South Bound	31 m	41 m	82 m
East Bound	74 m	59 m	117 m
West Bound	93 m	59 m	117 m

Source: JICA Survey Team



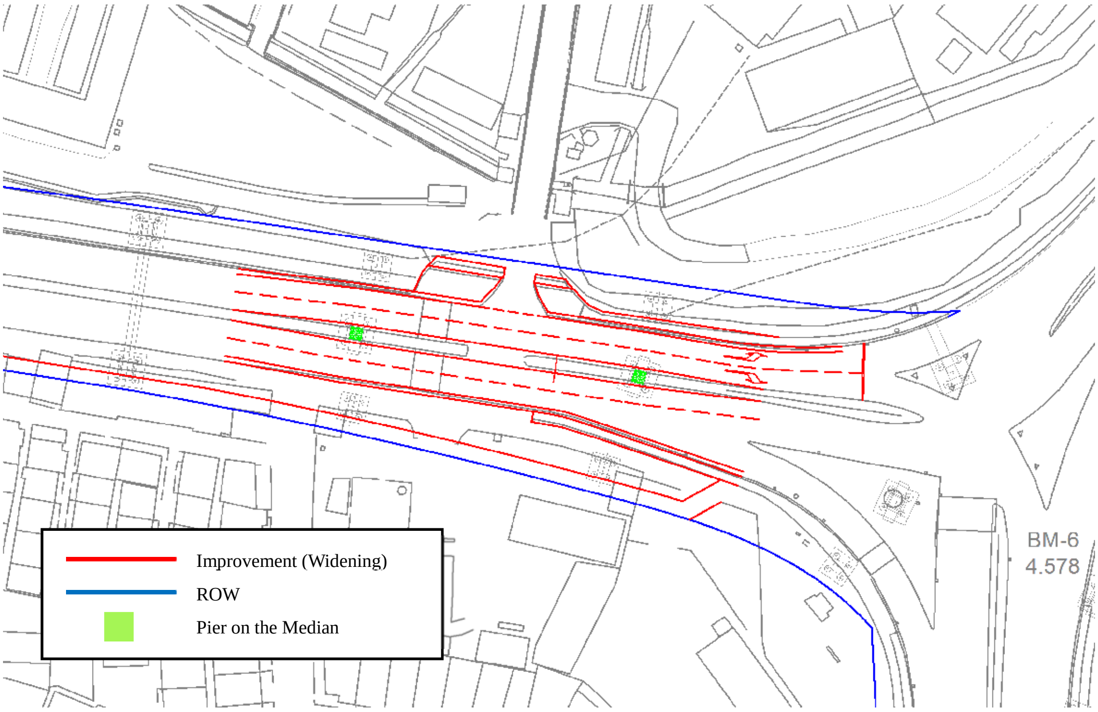
Source: JICA Survey Team

Figure 5.1.4 Length of right-turn Lane, Taper and Lane Shift

(2) Kelanithissa Intersection

In Kelanithissa Intersection, two piers for the Project Road are constructed on the median of existing Port Access Road. In order to construct the piers, the existing median is widened from 2.0 m of 3.5 m for approximately 100 m in length.

Kelanithissa intersection improvement plan is shown in Figure 5.1.5. 0.75 m of widening for both sides is carried out on the existing Port Access Road.



Source: JICA Survey Team

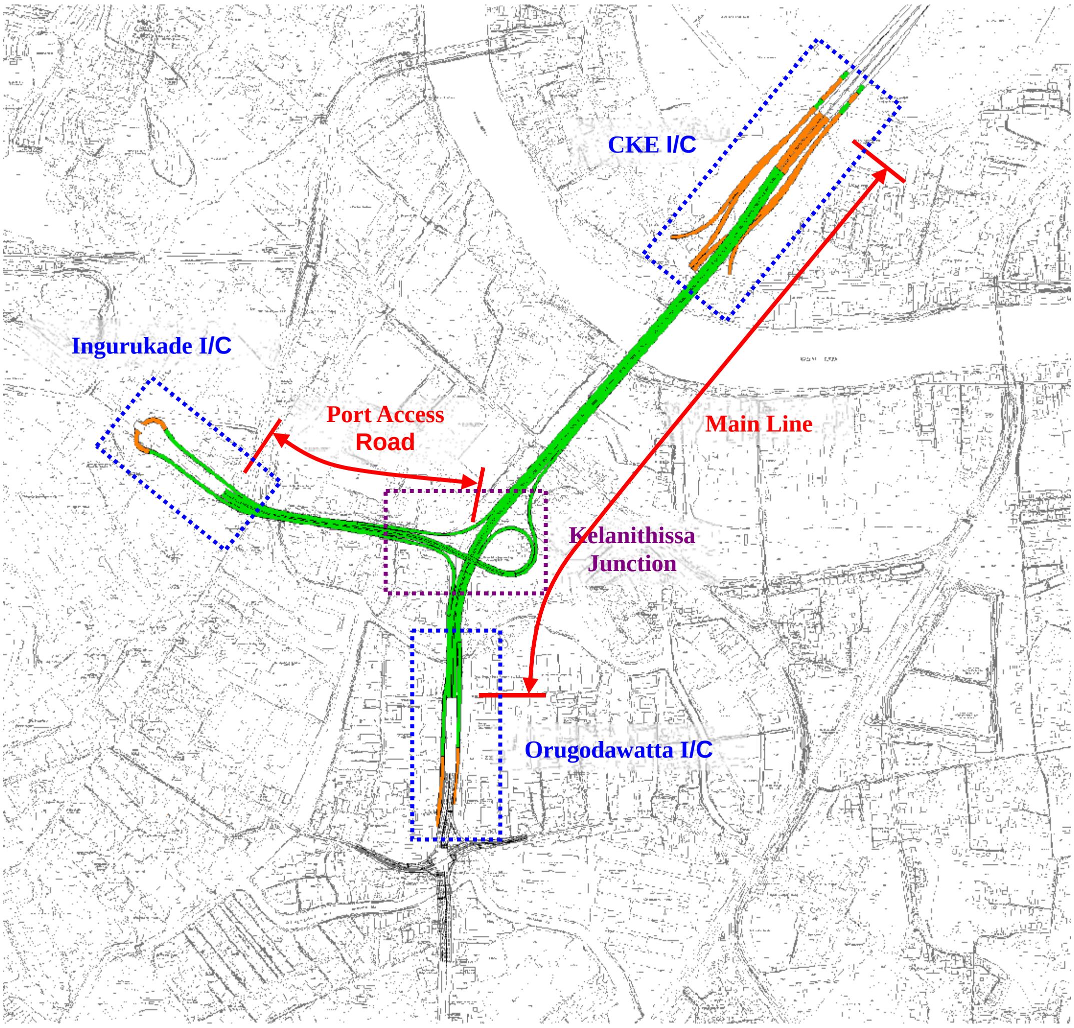
Figure 5.1.5 Kelanithissa Intersection Improvement Plan

5.1.3 Interchange and Junction Design

(1) Introduction

Following three interchanges and one junction are constructed in this Project. Location of interchanges and junction is shown in Figure 5.1.6.

- CKE Interchange (On/Off ramp)
- Orugodawatta Interchange (On/Off ramp)
- Ingurukade Interchange (On/Off ramp)
- Kelanithissa Junction (between Main line and Port access road)



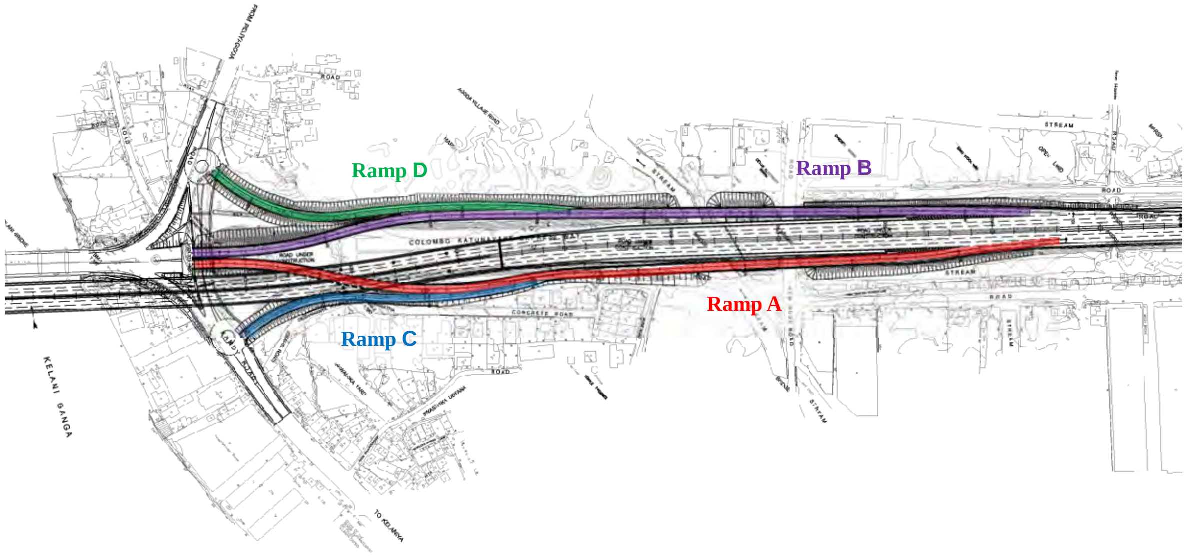
Source: JICA Survey Team

Figure 5.1.6 Location of Interchanges and Junction

(2) CKE Interchange

CKE Interchange is comprised of following four ramps. Plan view of CKE Interchange is shown in Figure 5.1.7.

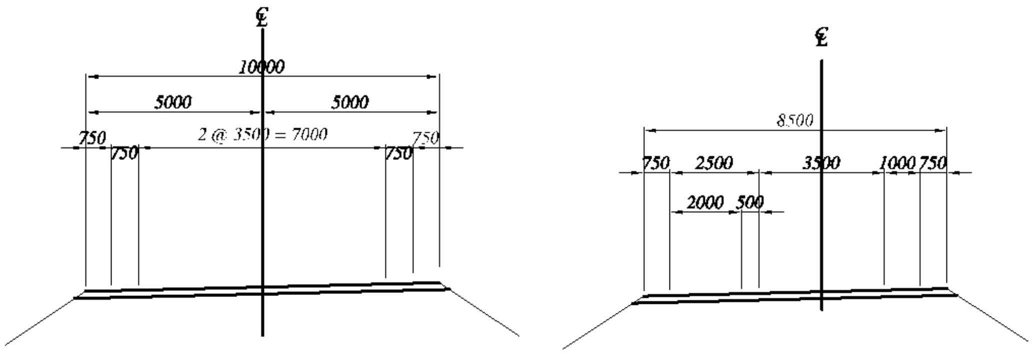
- Ramp A: Off ramp connecting to existing New Kalani Bridge
- Ramp B: On ramp connecting to existing New Kalani Bridge
- Ramp C: Off ramp connecting to roundabout on A01 Road
- Ramp D: On ramp connecting to roundabout on A03 Road



Source: JICA Survey Team

Figure 5.1.7 Plan View of CKE Interchange

Typical cross section for each ramp is shown in Figure 5.1.8.



(a) Ramp A, B (2-lane)

(b) Ramp C, D (1-lane)

Source: JICA Survey Team

Figure 5.1.8 Typical Cross Section of Ramps in CKE Interchange

Acceleration lane, deceleration lane and taper lengths are shown in Table 5.1.2.

Table 5.1.2 Acceleration Lane, Deceleration Lane and Taper lengths of CKE Interchange

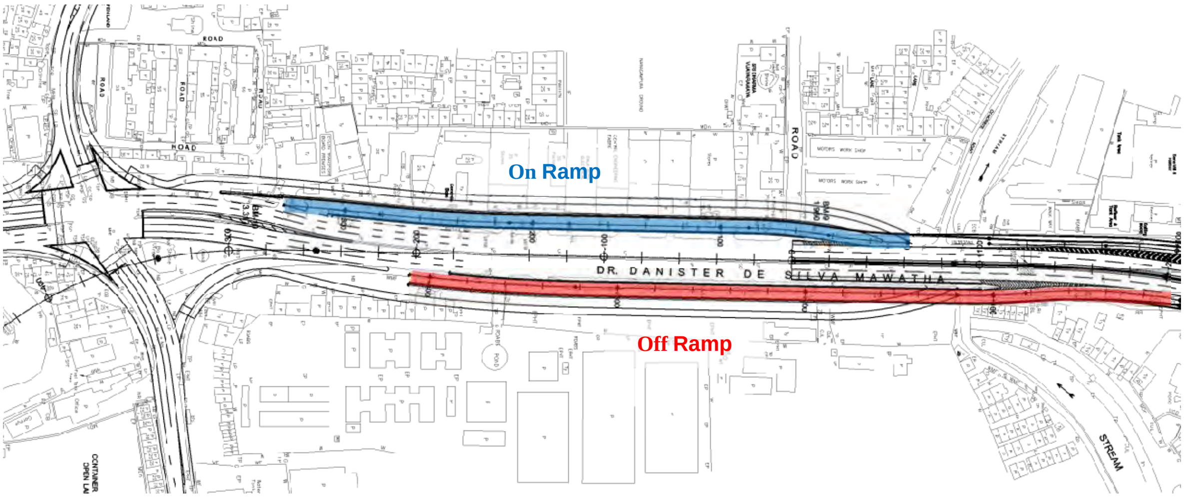
Item	Value	Note
Design Speed	80 km/h	
Vertical Gradient	0.9 %	- Correction is not required since the gradient is less than 2.0 %.
Acceleration Lane	160 m	
Taper for Acceleration Lane	80 m	
Deceleration Lane	110 m	
Exit Angle	1/15 - 1/20	

Source: Shutoko Metropolitan Expressway Standard

(3) Orugodawatta Interchange

Orugodawatta Interchange is comprised of the following two ramps. Plan view of Orugodawatta Interchange is shown in Figure 5.1.9.

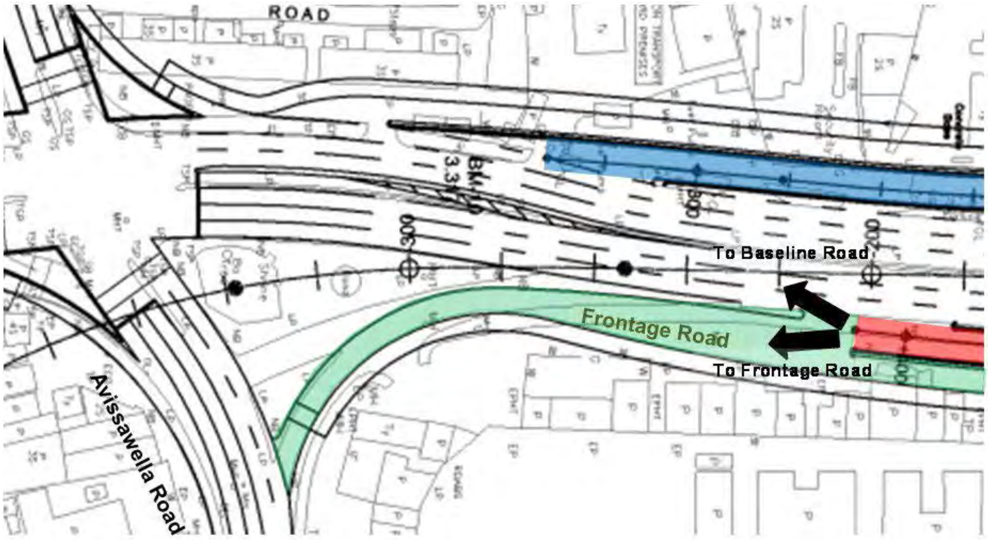
- On Ramp: On ramp connecting to Baseline Road
- Off Ramp: Off ramp connecting to Baseline Road and frontage road



Source: JICA Survey Team

Figure 5.1.9 Plan View of Orugodawatta Interchange

In the off ramp, vehicles from off ramp to Avissawella Road use the frontage road as shown in Figure 5.1.10.

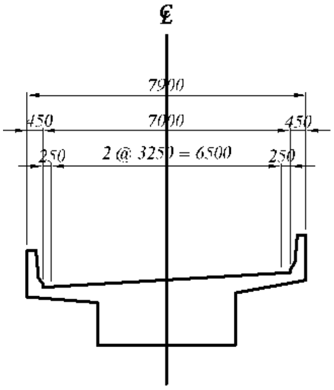


Source: JICA Survey Team

Figure 5.1.10 Orugodawatta Interchange Off Ramp

Typical cross section for each ramp is shown in Figure 5.1.11.

(a) On and Off Ramp (Temporary 2-lane)



Source: JICA Survey Team

Figure 5.1.11 Typical Cross Section of Ramps in Orugodawatta Inersection

Acceleration lane, deceleration lane and taper lengths are shown in Table 5.1.3.

Table 5.1.3 Acceleration Lane, Deceleration Lane and Taper lengths of Orugodawatta Interchange

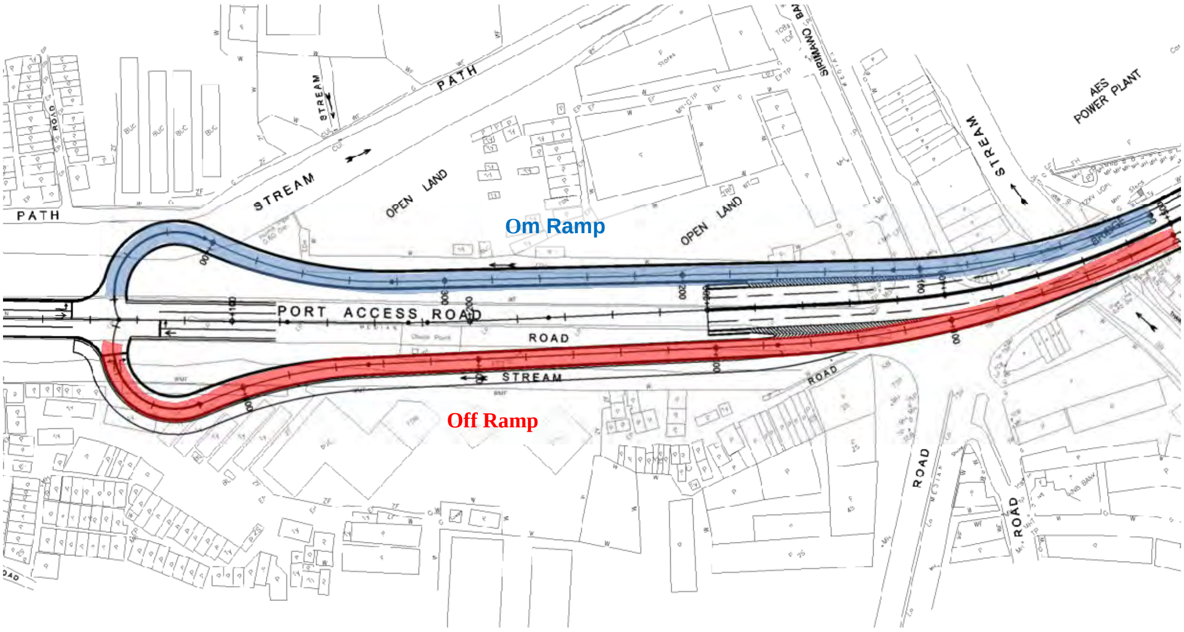
Item	Value	Note
Design Speed	60 km/h	
Vertical Gradient	0.3 %	- Correction is not required since the gradient is less than 2.0 %.
Acceleration Lane	120 m	
Taper for Acceleration Lane	-	There is no taper since ramp is connected to additional lane.
Deceleration Lane	90 m	
Exit Angle	-	There is no taper since ramp is connected to additional lane.

Source: Shutoko Metropolitan Expressway Standard

(4) Ingurukade Interchange

Ingurukade Interchange is comprised of following two ramps. Plan view of Ingurukade Interchange is shown in Figure 5.1.12.

- On Ramp: On ramp connecting to existing Port Access Road
- Off Ramp: Off ramp connecting to existing Port Access Road

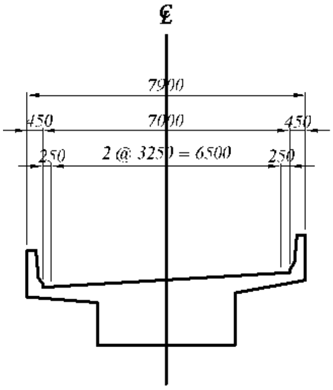


Source: JICA Survey Team

Figure 5.1.12 Plan View of Ingurukade Interchange

Typical cross section for each ramp is shown in Figure 5.1.13.

(a) On and Off Ramp (Temporary 2-lane)



Source: JICA Survey Team

Figure 5.1.13 Typical Cross Section of Ramps in Ingurukade Inersection

Acceleration lane, deceleration lane and taper lengths are shown in Table 5.1.4.

Table 5.1.4 Acceleration Lane, Deceleration Lane and Taper lengths of Ingurukade Interchange

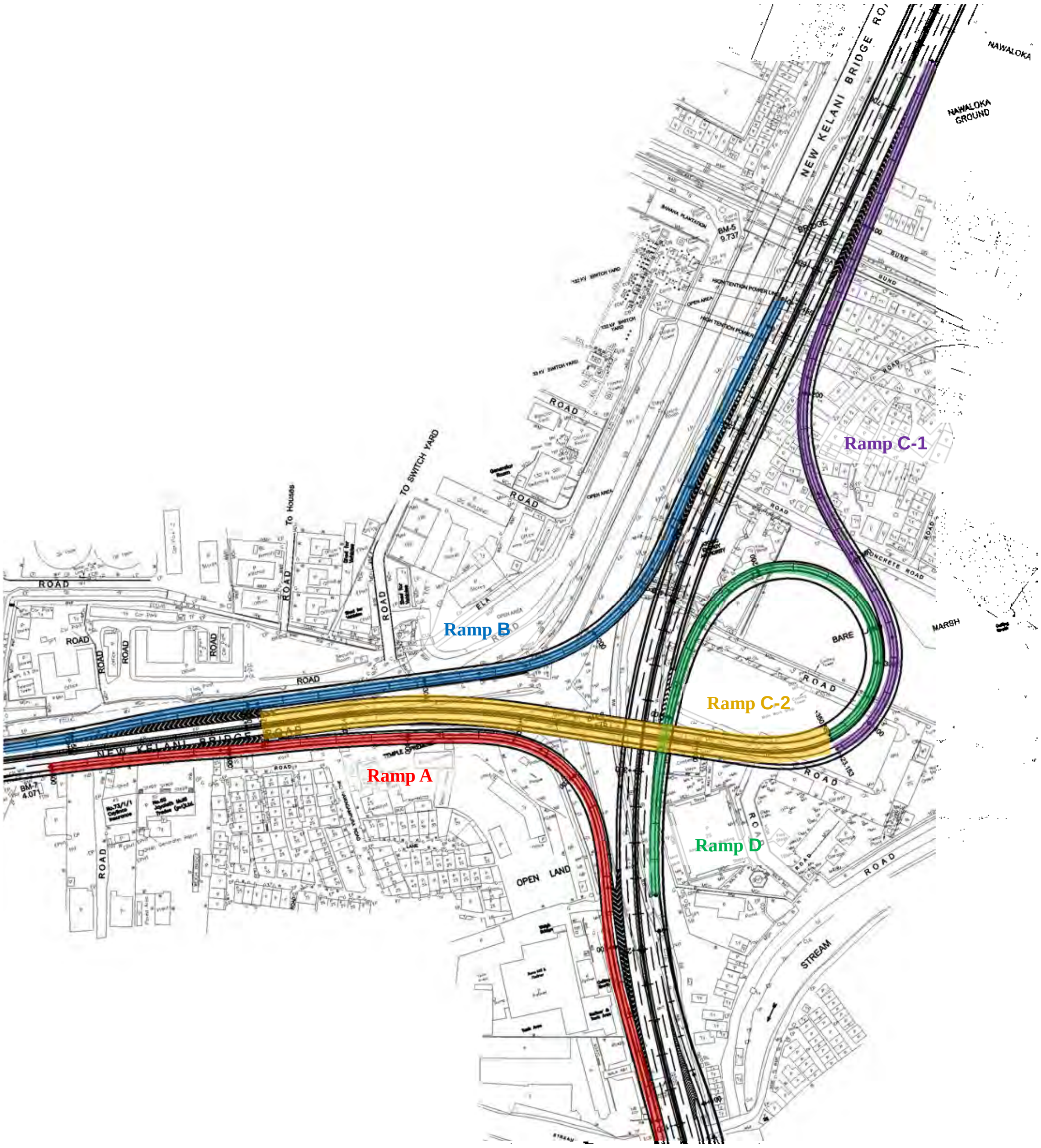
Item	Value	Note
Design Speed	60 km/h	
Vertical Gradient	0.3 %	- Correction is not required since the gradient is less than 2.0 %.
Acceleration Lane	120 m	
Taper for Acceleration Lane	60 m	
Deceleration Lane	90 m	
Exit Angle	1/15 - 1/20	

Source: Shutoko Metropolitan Expressway Standard

(5) Kelanithissa Junction

Kelanithissa Junction is comprised of following five ramps. Plan view of Kelanithissa Junction is shown in Figure 5.1.14.

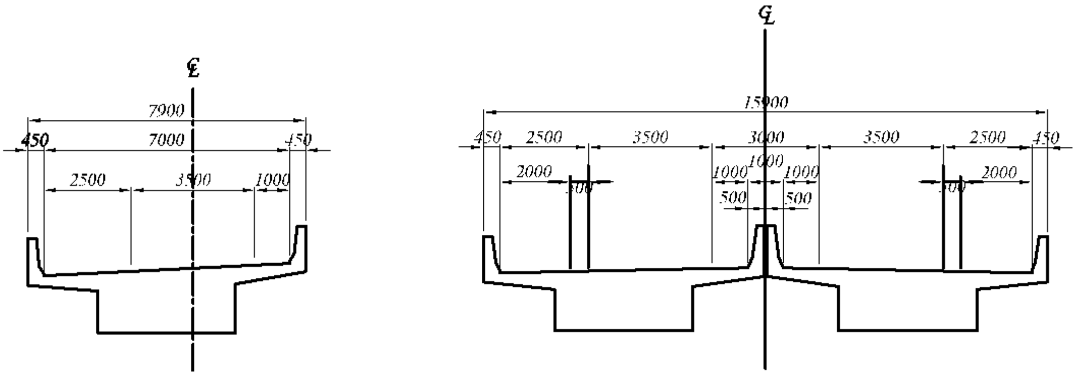
- Ramp A: Ramp from Main Line (south) to Port Access Road
- Ramp B: Ramp from Port Access Road to Main Line (north)
- Ramp C-1: Ramp from Main Line (north) to Port Access Road
- Ramp D: Ramp from Port Access Road to Main Line (south)
- Ramp C-2: Ramp between Ramp C-1 / Ramp D and Port Access Road



Source: JICA Survey Team

Figure 5.1.14 Plan View of Kelanithissa Junction

Typical cross section for each ramp is shown in Figure 5.1.15.



(a) Ramp A, B, C-1, D (1-lane)

(b) Ramp C-2 (1-lane + 1-lane)

Source: JICA Survey Team

Figure 5.1.15 Typical Cross Section of Ramps in Kelanithissa Junction

Acceleration lane, deceleration lane and taper lengths are shown in Table 5.1.5.

Table 5.1.5 Acceleration Lane, Deceleration Lane and Taper lengths of Ingurukade Interchange

Item	Value	Note
Design Speed	60 km/h	
Vertical Gradient	0.3 - 0.6 %	- Correction is not required since the gradient is less than 2.0 %.
Acceleration Lane	120 m	
Taper for Acceleration Lane	60 m	
Deceleration Lane	90 m	
Exit Angle	1/15 - 1/20	

Source: Shutoko Metropolitan Expressway Standard

5.1.4 Pavement Design

(1) Introduction

Pavement structure of the Project applies same structure of the CKE Project, since the earth work section in the Project is constructed adjacent to CKE Project. Pavement structure of the CKE Project is shown in Table 5.1.6.

Table 5.1.6 Pavement Structure of the CKE Project

Layer	Type	Thickness
Surface	Asphalt Concrete -13	40 mm
Binder Course	Asphalt Concrete -20	60 mm
Binder Course	Asphalt Concrete -25	80 mm
Base Course	5 % Cement Stabilized	320 mm
Subbase Course	Graded macadam	200 mm

Source: CKE Project

This structure is checked based on “AASHTO Guide for Design of Pavement Structures (hereinafter called AASHTO Pavement Guide)”.

In AASHTO Pavement Guide, the pavement layer thickness is determined so that it provides the load-carrying capacity corresponding to the design structural number (SN).

The design structural number (SN) is calculated by the following formula.

$$\log_{10}(W18) = Z_R \times S_0 + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

where

W18: Predicted number of 18-kip equivalent single axle load applications

Z_R: Standard normal deviate

S_0: Combined standard error of the traffic prediction and performance prediction

ΔPSI: Difference between the initial design serviceability index, P_0, and the design terminal serviceability index, P_t

M_R: Resilient modulus (psi)

SN: Design structural number

(2) Design Condition

1) Predicted Number of 18-kip Equivalent Single Axle Load Applications (W18)

Predicted number of 18-kip equivalent single axle load applications (W18) is calculated based on the traffic volume for 10 years (2022 - 2031) as the design period.

Axle load equivalency factor for the Project is shown in Table 5.1.7.

Table 5.1.7 Axle Load Equivalency Factor

Vehicle Type	Total Weight (ton)	Axle-1				Axle-2				Axle-3				**Axle Load Equivalency Factor for Vehicle**
		Type	Weight (ton)	Weight (kips)	Axle Load Equivalency Factor per a Axle	Type	Weight (ton)	Weight (kips)	Axle Load Equivalency Factor per a Axle	Type	Weight (ton)	Weight (kips)	Axle Load Equivalency Factor per a Axle	
Passenger Car	2.0	Sin	1.0	2.2	0.0004	Sin	1.0	2.2	0.0004					**0.0008**
Truck	9.5	Sin	1.9	4.2	0.0028	Sin	7.6	16.8	0.7738					**0.7766**
Trailer	45.0	Sin	5.6	12.3	0.2147	Tan	19.7	43.4	2.8530	Tan	19.7	43.4	2.8530	**5.9207**
Bus	10.0	Sin	5.0	11.0	0.1385	Sin	5.0	11.0	0.1385					**0.2770**

Source: JICA Survey Team

Predicted number of 18-kip equivalent single axle load applications (W18) for the Project is shown in Table 5.1.8.

Table 5.1.8 Predicted Number of 18-kip Equivalent Single Axle Load Applications (W18)

Vehicle Type	Design Traffic (2022-2031)	ESAL Factor	Design ESAL	**18-kip ESAL Traffic in Design Lane**
Passenger Car	201,875,885	0.0008	161,501	56,525
Truck	42,632,000	0.7766	33,108,011	11,587,804
Trailer	5,337,002	5.9207	31,598,788	11,059,576
Bus	15,745,819	0.2770	4,361,592	1,526,557
Total				**24,230,462**

Source: JICA Survey Team

2) Standard Normal Deviate (ZR)

Standard normal deviate (Z_R) for the Project is shown in Table 5.1.9.

Table 5.1.9 Standard Normal Deviate (ZR)

Reliability, R (%)	90
Standard Normal Deviate, ZR	**-1.282**

Source: AASHTO Pavement Guide

3) Combined Standard Error of the Traffic Prediction and Performance Prediction (S0)

Combined standard error of the traffic prediction and performance prediction (S_0) for asphalt pavement is “0.45”.

4) Difference between the Initial Design Serviceability Index, P0, and the Design Terminal Serviceability Index, Pt (∆PSI)

Difference between the initial design serviceability index, P0, and the design terminal serviceability index, Pt (∆PSI) for the Project is shown in Table 5.1.10.

Table 5.1.10 Difference between the Initial Design Serviceability Index, P0, and the Design Terminal Serviceability Index, Pt (∆PSI)

P_o	4.2
P_t	2.5
∆PSI	**1.7**

Source: AASHTO Pavement Guide

5) Resilient Modulus (psi) (MR)

Resilient modulus (psi) (M_R) is calculated by the following formula. CBR value of the roadbed soil in the Project is set as “6”.

Resilient Modulus (psi) (M_R) = 1500 x CBR

= 1500 x 6 = 9000

6) Design Structural Number (SN)

Design structural Number (SN) for the Project is calculated as “5.3”, based on the SN calculation formula with above stated design conditions.

(3) Pavement Layer Thickness

Pavement layer thickness is calculated by the following formula.

$SN = a1D1+a2D2m2+a3D3m3$

where

a_1, a_2, a_3: Layer coefficients representative of surface, base, and subbase courses, respectively

D_1, D_2, D_3: Actual thicknesses of surface, base, and subbase courses, respectively

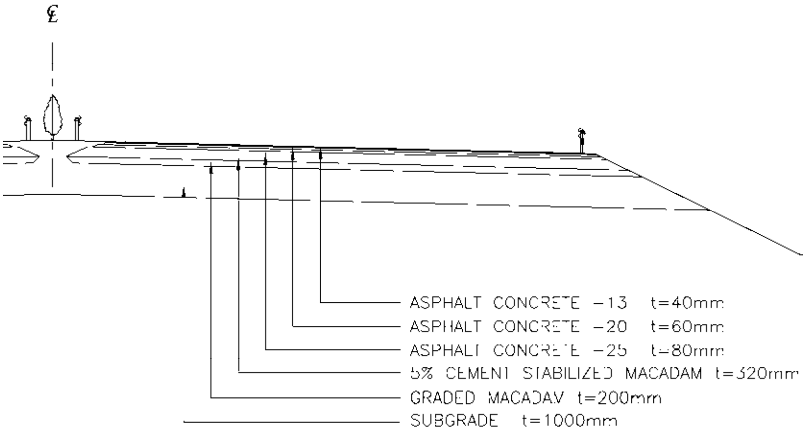
m_2, m_3: Drainage coefficients for base and subbase layers, respectively

Pavement layer thickness for the Project is shown in Table 5.11 and Figure 5.1.16.

Table 5.1.11 Pavement Layer Thickness

Layer	Material	a	m	D		SN		
				cm	inch			
Surface	Asphalt Concrete	0.42		4	1.575	5.6		
Binder Course	Asphalt Concrete	0.42		6	2.362			
Binder Course	Asphalt Concrete	0.42		8	3.150			
Base Course	Bituminous-treatd	0.14	1.00	32	12.598		>	5.3
Subbase Course	Granular Subbase	0.11	0.95	20	7.874			**OK**

Source: JICA Survey Team



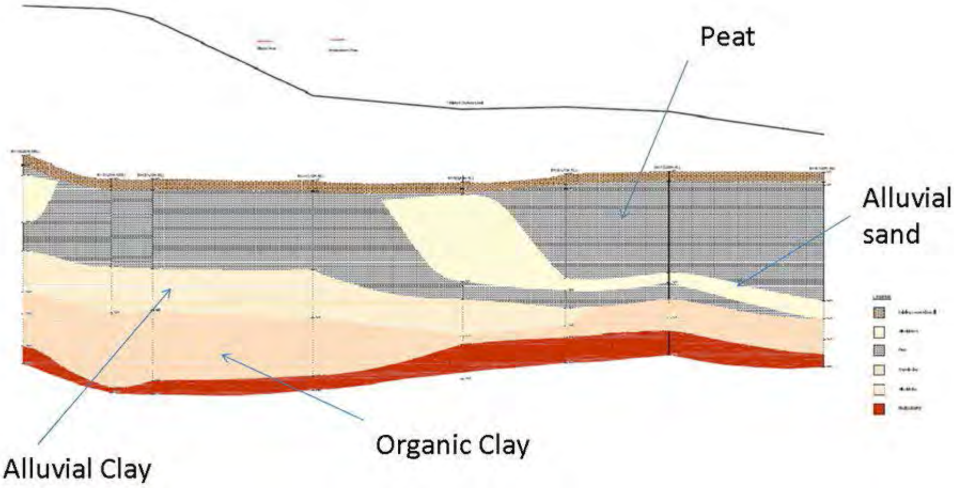
Source: JICA Survey Team

Figure 5.1.16 Pavement Layer Thickness

5.1.5 Soft Ground Treatment

(1) Introduction

The proposed alignment of the 2nd New Kelani Bridge and the associated ramps overlie weak compressible soils. Boreholes and Cone Penetrometer Tests (CPT) carried out for the CKE project indicate a thick layer of Peat, thickness ranging from 7.7m to 13m at the test locations, overlying alluvial clays which in turn overlying a layer of organic clay of 2 to 4m in thickness (see Figure 5.1.17 and Table 5.1.12). The peat layer is found to show little resistance to the CPT probes indicating the soft nature of the material. The organic clay layer characteristics appear variable from soft to stiff across the site and depth. These weak soils are compressible and therefore it is necessary adopt soft ground treatment (SGT) methods to improve the soils to reduce the risk of long-term settlements. In addition, construction of embankments on such weak soils could lead to instability and this has to be taken into consideration.



Source: CKE Project

Figure 5.1.17 Geological Profile

Table 5.1.12 Summary of Geological Profile

Layer	Thickness Range (m)	Maximum depth to the base (m)
Peat	7.7 to 13.0	14.3
Alluvial Clay	0.0 to 4.0	15.0
Organic Clay	2.0 to 8.0	21.1
Sand	0.5 to >2.7	>21.0

Source: CKE Project

(2) Existing Method for CKE

The existing CKE alignment has been improved by SGT methods. The methods used were:

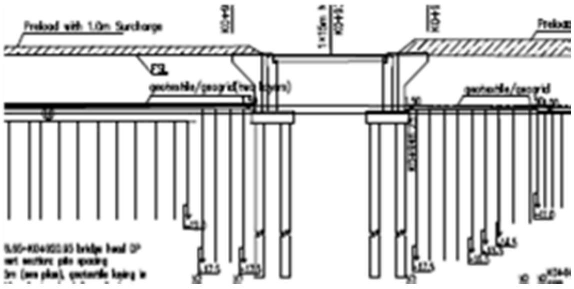
1) Sand compaction piles (SCP) plus 1m surcharge

This is the main SGT method adopted for the existing CKE alignment. SCP piles of 0.5 diameter and spaced at 1.5m in a triangular pattern is shown on the design drawings. The design drawings indicate that the piles have been constructed to the base of the peat layer only but the actual depth during construction needs to be confirmed. If SCP columns are terminated above the organic clay layer, the possibility of settlement due to the consolidation of that layer cannot be discounted. Further, the spacing of 1.5m for a 0.5 diameter pile indicates a low area ratio i.e. low stiffness increase in the subsoils.

The results of monitoring from the main alignment at one location indicate that the primary settlement for a 6.5m embankment is of the order of 4m and the time for 90% primary consolidation is about 1.5 years or more.

2) Piled Embankments

Piled embankments have been adopted at bridge approaches (see Figure 5.1.18). Generally a length of 30m from the abutment is treated with a pile embankment with the piles furthest away shortening so that a gradual grade change could be achieved.



Source: JICA Survey Team

Figure 5.1.18 Existing CKE – Piled Embankment adjacent to a Bridge

(3) Proposed Method for the 2nd New Kelani Bridge

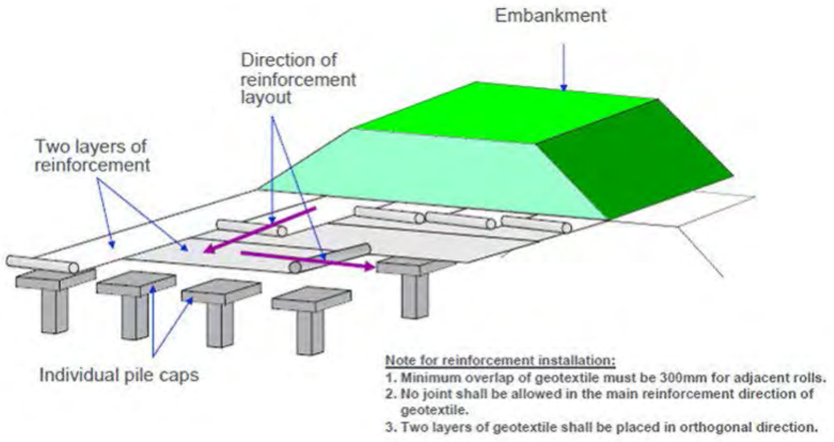
1) General

The areas where different techniques may need to be adopted could be categorized as follows:

- Bridge Abutments
- Existing CKE footprint
- Ramps Outside the CKE footprint

2) Bridge Abutments

Adjacent to the bridges, the settlements need to be small as possible to ensure minimum lateral movement on the abutment which could lead to excessive strains and forces. Further, as a bridge is a rigid structure, it is necessary to have a gradual grade change from the general embankment; else unacceptable grade changes could become a major issue on vehicle safety. A similar approach to the current CKE abutments was considered prudent and therefore the piled embankment solution was adopted (see Figure 5.1.19). A piled embankment consists of driven piles to a hard stratum, in the current case to the sand layer below organic clay, with a precast pile cap generally 1m x 1m with multiple layers of high strength geotextiles.



Note for reinforcement installation:
1. Minimum overlap of geotextile must be 300mm for adjacent rolls.
2. No joint shall be allowed in the main reinforcement direction of geotextile.
3. Two layers of geotextile shall be placed in orthogonal direction.

Source: JICA Survey Team

Figure 5.1.19 Proposed Ground Improvement - Piled Embankment

3) Existing CKE Footprint

The improvement required on the existing CKE footprint is limited to a length of about 100m. Any embankment height changes on the current CKE footprint would incur additional stresses which have not been considered in the original design of the CKE. Therefore SGT is required to mitigate such effects.

The current SGT adopted for the existing CKE project is SCP of 0.5 diameter at 1.5m spacing plus 1m surcharge. The depth of SCP appears to be to the base of the peat layer and not to the base of the organic clay layer below as per design drawings. The actual depth of construction needs to be confirmed. The surcharge has been in place over a long time and one monitoring location results indicate that 90% primary consolidation takes about 1.5 years.

The following options were considered:

- Option 1 – Use additional surcharge on the footprint
- Option 2 - Insert additional SCP within the area
- Option 3 – Use polystyrene (Geofoam) blocks

Option 1 – Additional Preload:

In this option, The SCP columns currently existing would be taken to act as conduits for excess pore water pressure dissipation. The time for consolidation from the monitoring results appear to be of the order of 1.5 years for 90 % consolidation. If the additional surcharge is designed for 75% rather than 90%, the preload duration drops to about 50% i.e. less than 1 year. However, the preload height requirement is greater than for the 90% consolidation solution.

Option 2 - additional SCP/GCP columns and surcharge:

Additional SCP or GCP columns could be inserted in between the current SCP columns if the current embankment is removed to expose the columns. The additional columns should increase the stiffness of the existing ground however there is the possibility that additional disturbance could disturb the soils and the overall coefficient of consolidation may reduce. If that were the case, the pore pressures generated by the additional surcharge may take much longer time and this is considered a project risk. The only way to confirm or otherwise would be to adopt a trial embankment which would not be possible within the time frame of the project.

Option 3 - Polystyrene (Geofoam) blocks:

Geofoam blocks are ultra-lightweight materials with a unit weight less than 1 kN/m3. If the additional fill is done by Geofoam with slight excavation of the existing profile, the additional stresses on the subsurface profile would be negligible and therefore further additional settlements would not occur. The steps involved are summarized below:

- Excavate to Final Pavement Level of the existing CKE minus, say, 1.0m

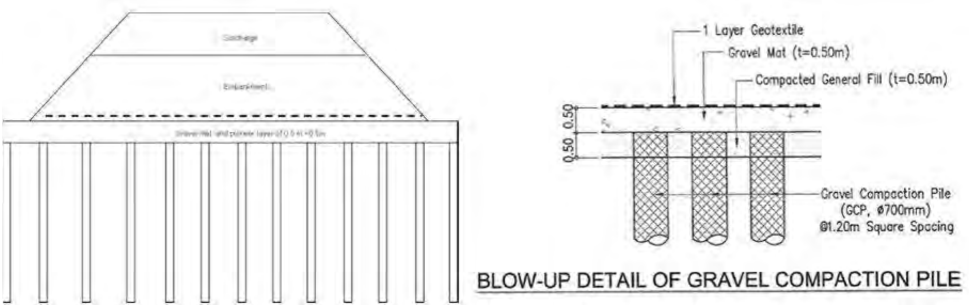
- Place EPS blocks wrapped in HDPE. Allow a HDPE thickness, say 1 or 2mm.
- Place a geotextile over Geofoam blocks to reduce the potential to damage when constructing above.
- Place a nominal 200mm compacted thickness of cement stabilized subbase quality material to expedite construction without damaging the Geofoam blocks, assume, say 1.5% cement (In lieu you could use a 100mm thick concrete slab). Compaction to be done by light rollers not exceeding 1 tonne.
- Place fill materials and pavement materials as per normal specs to the final profile.

Option 3 has the least geotechnical risk in terms of project time frame is concerned but is the most expensive. The rate adopted, SLR 22,000 per m3, allowed for 10% increase for freight. The cost assessed is found to be significantly higher than the other two options and therefore not considered further.

Option 2 has a high geotechnical risk and moderate cost implications. The high risk is because it is difficult to predict how the soil will behave if additional SCP columns are inserted in between the existing columns and therefore the disturbance it creates.

Option 1 has a low geotechnical risk as the behavior of the existing SCP columns could be assessed from the available monitoring results.

Based on the cost and geotechnical risk considerations, Option 1 was selected for the Project (see Figure 5.1.20).



Source: JICA Survey Team

Figure 5.1.20 Proposed Ground Improvement - GCP

4) Ramps outside the existing CKE footprint

Based on the ongoing highway projects affiliated to the proposed stretch and the adjacent ground treatment done for the CKE (which is SCP), it is considered prudent to use a similar treatment where possible to achieve the following outcomes:

- Avoid negative impacts to the treated ground by SCP from a different SGT method resulting significant differential settlement at merging sections.

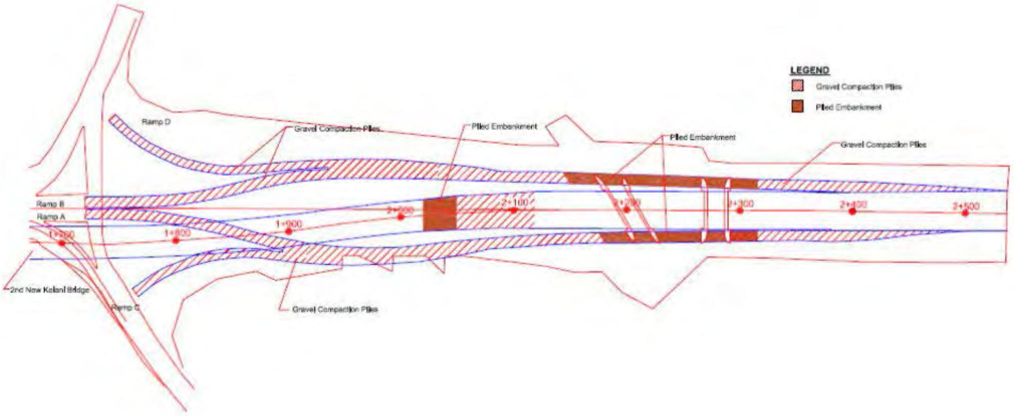
- Minimize the ground disturbances by reduce the volume of excavated soft soil for replacement.
- Increase the shear strength to ensure the stability of the permanent works.
- Reduce the consolidation settlement due to thick compressible layers
- Avoid practical difficulties encountered in surcharge at heavily congested areas.

Although SCP was used in the CKE project, GCP is a similar method and was considered better for the current project due to the following reasons:

- The monitoring results indicate that pore pressure dissipation is very slow, taking about 1.5 years for 90% primary consolidation. Although partly it could be due to the compressibility of the organic clay layer if soft, mostly it is likely to be the blocking of the surface of the column and therefore reduced permeability (reduced dissipation rates) of the interface. GCP columns are likely to be more resistant to finer particles blocking the passage of pore water and therefore faster dissipation could be expected. Further, recent projects confirm the rapid consolidation when GCP columns are adopted in similar type of peat and organic clay soils.
- GCP provides significantly higher strength/stiffness to the underlying soil which is most desirable at the merging sections where high embankments/preloads are expected and therefore greater stability.

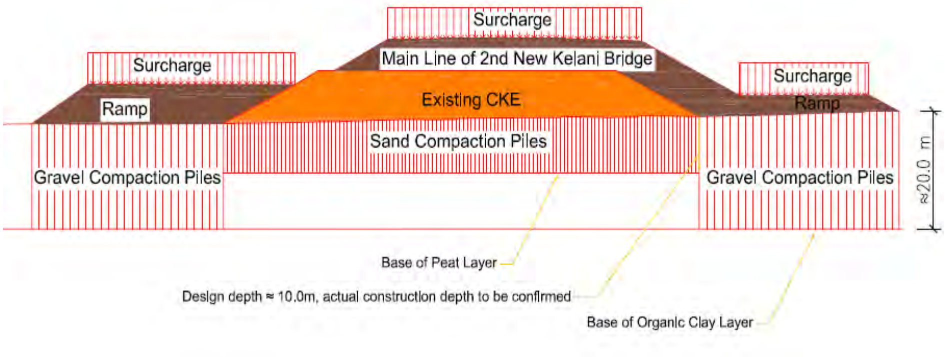
5) Conclusions and Recommendations

Taking into account the fact that settlement rate of SCP is low (more than 1.5 years for primary settlement) and that rapid construction may be required with little time for staging, GCP rather than SCP was selected due to stability concerns and faster rate of dissipation and piled embankments were considered as the best option at bridge abutments.



Source: JICA Survey Team

Figure 5.1.21 Layout and Areas to be Improved



Source: JICA Survey Team

Figure 5.1.22 Typical Cross Section of the 2nd New Kelani Bridge

5.2 Bridge Design

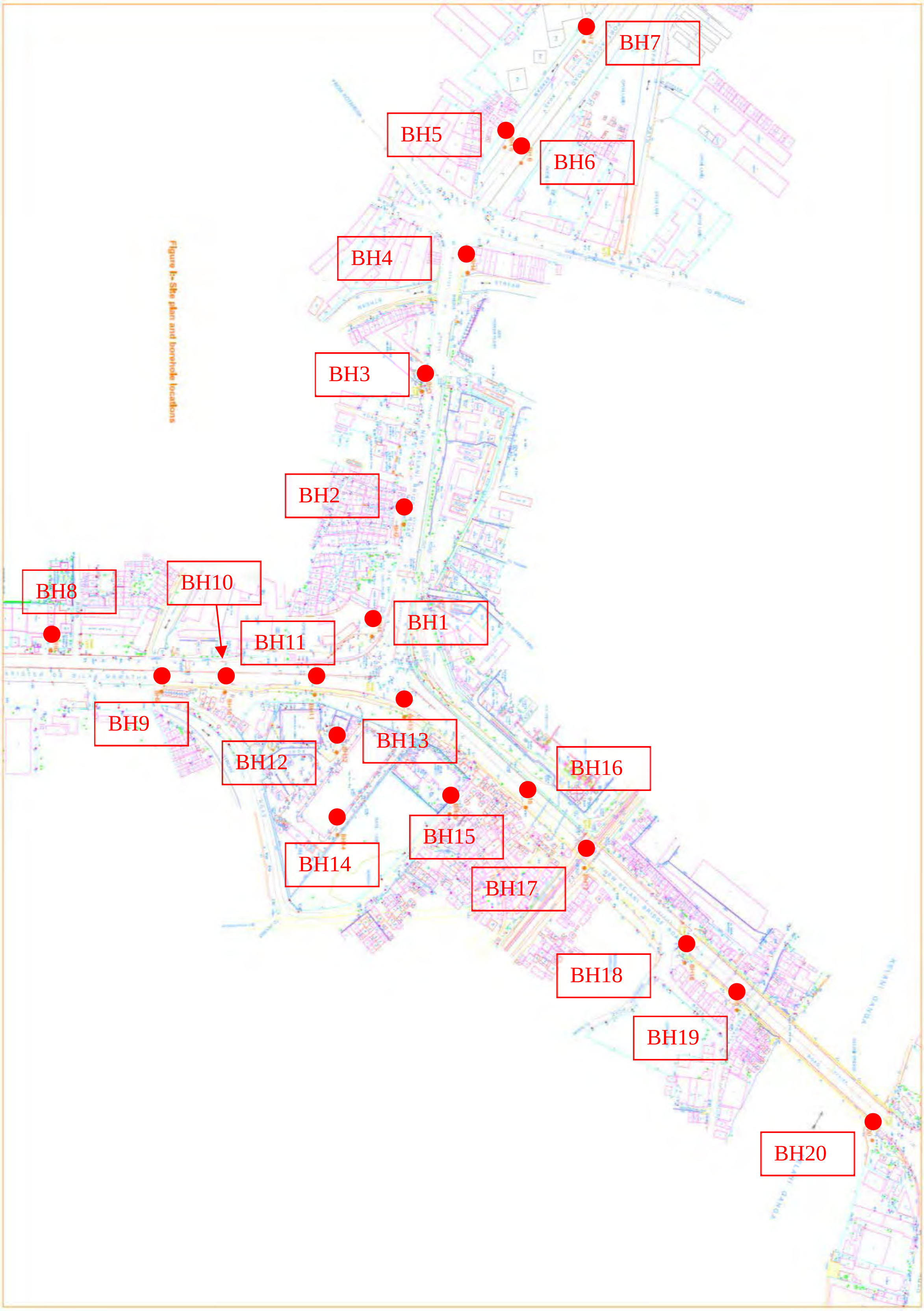
5.2.1 Geological Conditions

(1) Location of Borehole Survey

Borehole survey was conducted at twenty (20 nos.) points along the alignment of new bridges.

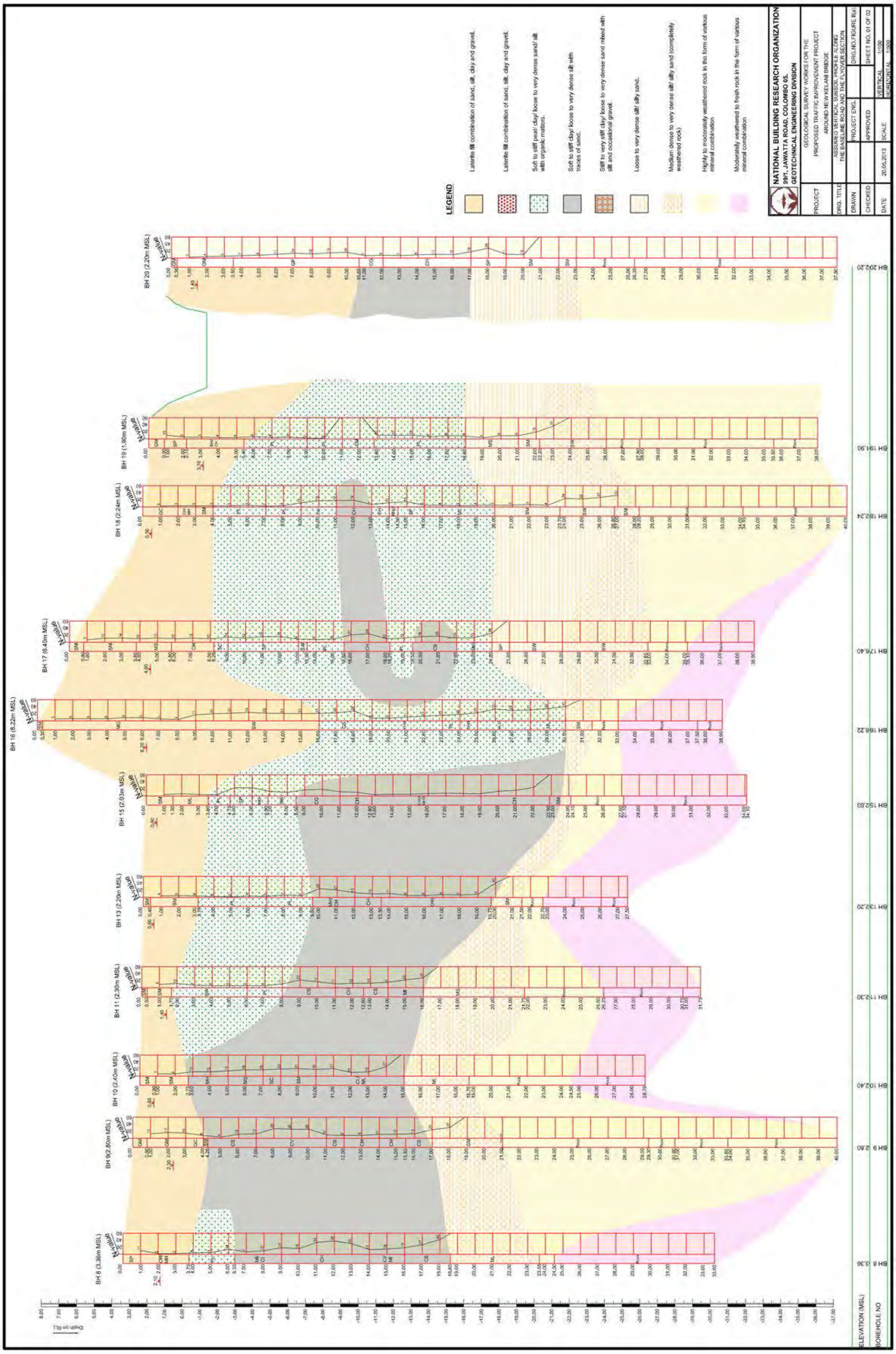
(2) Vertical Subsoil Profile

According to results of borehole survey, vertical subsoil profile was assumed.



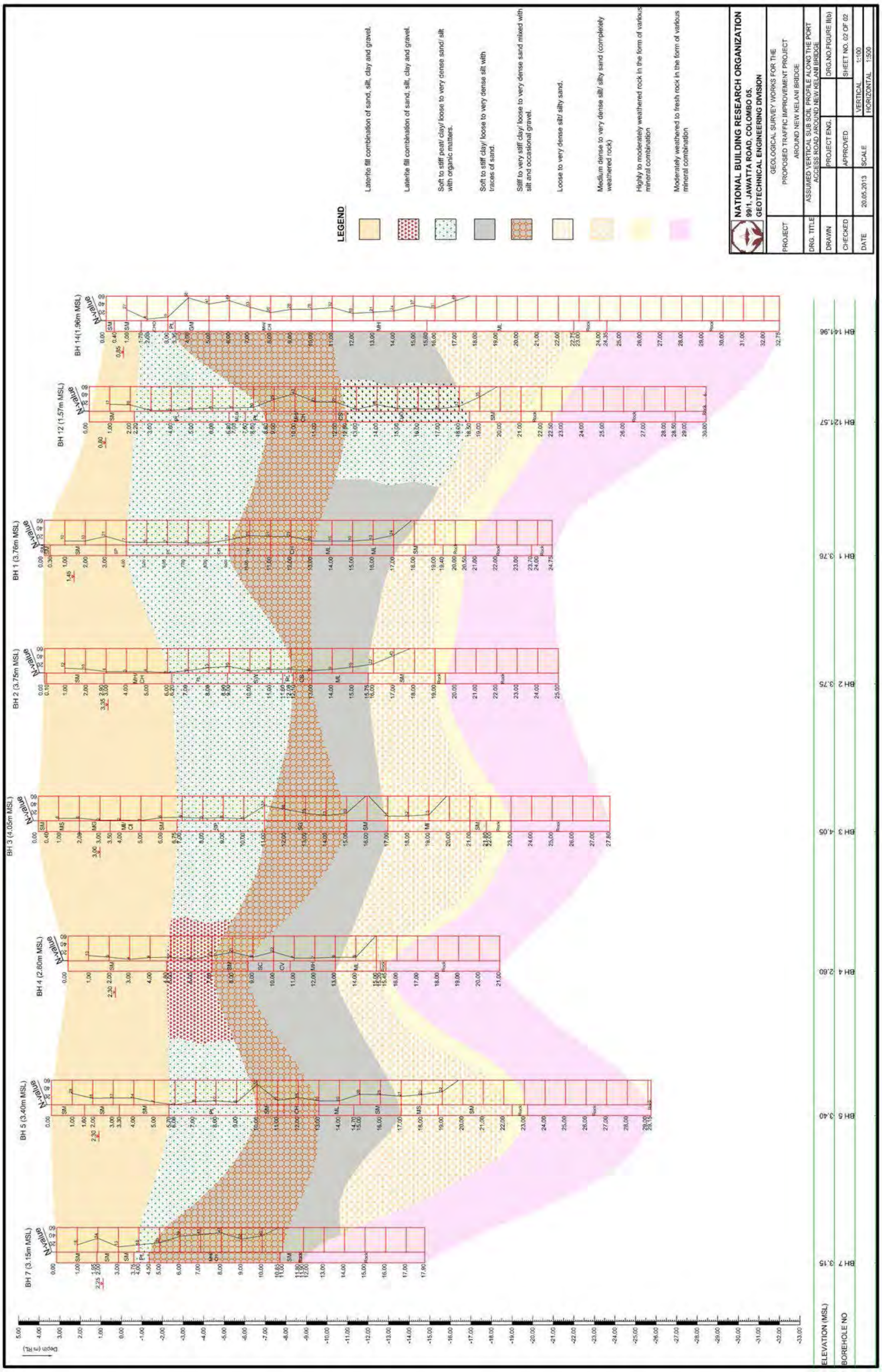
Source: JICA Survey Team

Figure 5.2.1 Borehole Survey Location



Source: JICA Survey Team

Figure 5.2.2 Assumed Vertical Subsoil Profile (1/2)



Source: JICA Survey Team

Figure 5.2.2 Assumed Vertical Subsoil Profile (2/2)

(3) Geological Conclusion of the Project Area

According to the geological (lithological, structural geology and geomorphological) observations at the proposed site area, following geological conclusions can be made for the proposed site.

- The proposed site is located on a large scale shear zone and nearly to the two numbers of normal fault zones. Therefore, different fracture condition (highly to slightly) of bedrock can be extent into the deep underground level of bedrock including low RQD (Rock Quality Designation) values within the proposed site area.

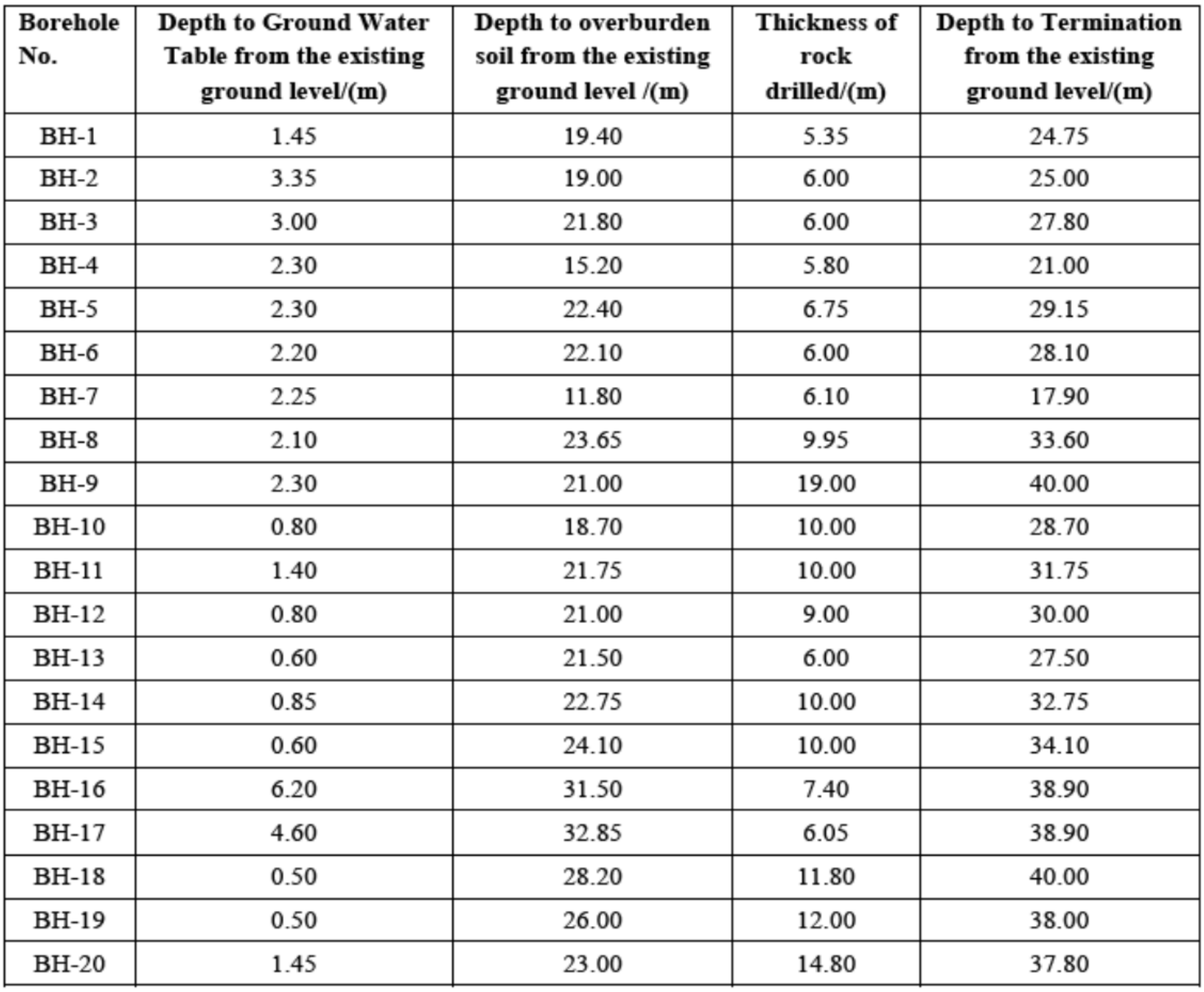
- Most of fracture planes (formed due to shearing and faulting of bedrock) of bedrock have very steep dip angles of the foliation plane. Ground water table of the many locations within the proposed site area was encountered at shallow depth of the ground. Therefore, weathered bedrock may be encountered into deep underground level as a result of moving of ground water into the deeper level along the fracture planes of bedrock. The weathering condition (highly to slightly) of bedrock into the depth is depend on the fracture index (FI) of bedrock (When the FI of bedrock is increased, the weathering of bedrock is increased).

- The most of rock core samples with good RQD values are present as tight fractured (visible or invisible) rock. Therefore, some rock core samples having good RQD value show low UCS (Unconfined Compressive Strength) value at the different depths of boreholes.

(4) General Observations of Borehole Investigation

The general observations of borehole investigation are summarized in the below table.

Table 5.2.1 General Observations of Subsurface Condition at Borehole Locations



Borehole No.	Depth to Ground Water Table from the existing ground level/(m)	Depth to overburden soil from the existing ground level /(m)	Thickness of rock drilled/(m)	Depth to Termination from the existing ground level/(m)
BH-1	1.45	19.40	5.35	24.75
BH-2	3.35	19.00	6.00	25.00
BH-3	3.00	21.80	6.00	27.80
BH-4	2.30	15.20	5.80	21.00
BH-5	2.30	22.40	6.75	29.15
BH-6	2.20	22.10	6.00	28.10
BH-7	2.25	11.80	6.10	17.90
BH-8	2.10	23.65	9.95	33.60
BH-9	2.30	21.00	19.00	40.00
BH-10	0.80	18.70	10.00	28.70
BH-11	1.40	21.75	10.00	31.75
BH-12	0.80	21.00	9.00	30.00
BH-13	0.60	21.50	6.00	27.50
BH-14	0.85	22.75	10.00	32.75
BH-15	0.60	24.10	10.00	34.10
BH-16	6.20	31.50	7.40	38.90
BH-17	4.60	32.85	6.05	38.90
BH-18	0.50	28.20	11.80	40.00
BH-19	0.50	26.00	12.00	38.00
BH-20	1.45	23.00	14.80	37.80

Source: JICA Survey Team

5.2.2 Selection of Foundation Type

(1) Comparative Study of Foundation Type

1) Soil Constants

Soil constants are established from soil investigation report as follows

Table 5.2.2 Soil Constants

Soil Layer	N value	Unit weight γt(kN/m3)	Cohesive C(kN/m2)	Internal friction angle φ(°)	Deformation coefficient αEo		
					Eo(kN/m2)		Normal state (α=4)
Silty Sand	9	17	0	30	6,300	※2	25200
Pit/Clay	8	14	10	0	5,600	※2	22400
Clay 1	16	18	50	0	11,200	※2	44800
Clay 2	28	18	50	0	19,600	※2	78400
Sand 1	14	17	0	25	9,800	※2	39200
Sand 2	43	19	0	30	30,100	※2	120400
Rock 1	50	26	14105	21	39,240	※2	156960
Rock 2	50	26	17918	21	39,240	※2	156960

※ Deformation coefficient to estimate ground reaction coefficient assumed a
※1：Horizontal loading test in borehole
※2：Estimation using N value (E=700N)

Source: JICA Survey Team

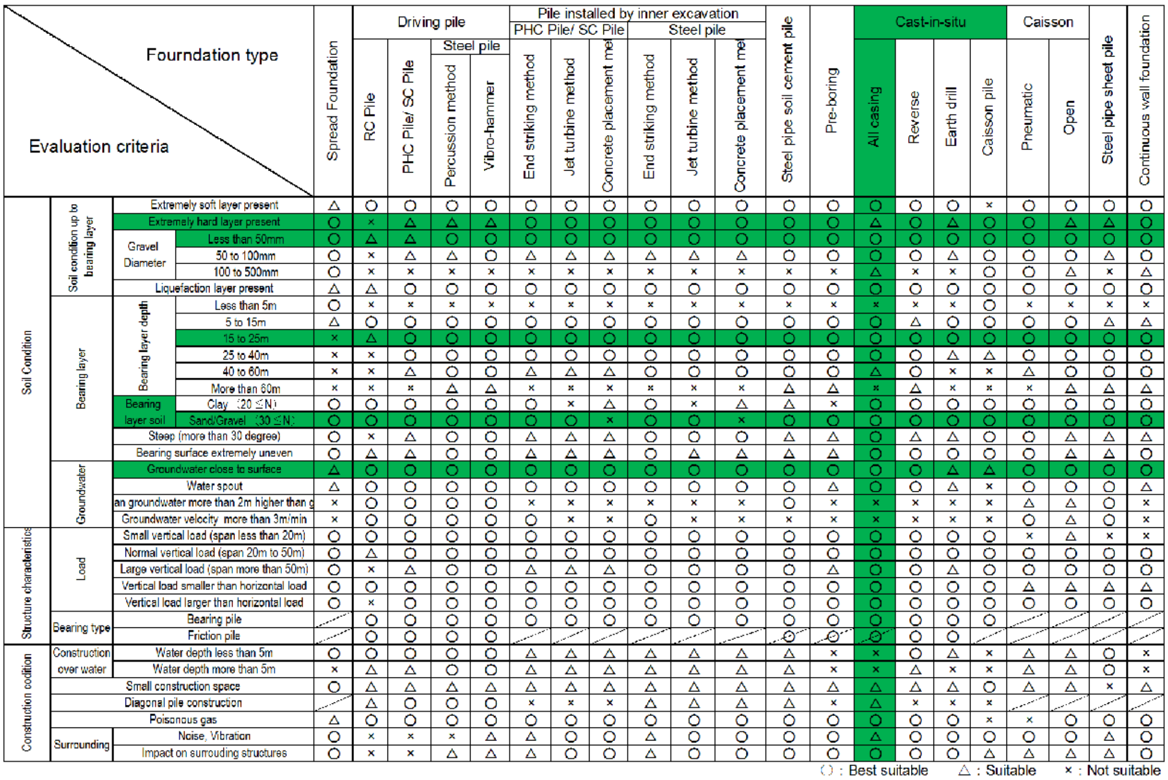
2) Selection of Foundation Type

(a) Main Bridge

Cast-in-situ pile foundation is selected for this section using following table.

Table 5.2.3 Foundation Type Selection for Main Bridge

Foundation type selection table



Fourndation type / Evaluation criteria			Spread Foundation	Driving pile				Pile installed by inner excavation						Steel pipe soil cement pile	Pre-boring	Cast-in-situ				Caisson		Steel pipe sheet pile	Continuous wall foundation
						Steel pile		PHC Pile/ SC Pile			Steel pile												
				RC Pile	PHC Pile/ SC Pile	Percussion method	Vibro-hammer	End striking method	Jet turbine method	Concrete placement me	End striking method	Jet turbine method	Concrete placement me			All casing	Reverse	Earth drill	Caisson pile	Pneumatic	Open		
Soil Condition	Soil condition up to bearing layer	Extremely soft layer present	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	○	○	○	○
		Extremely hard layer present	○	×	△	△	△	○	○	○	○	○	○	○	○	△	○	△	○	○	△	△	○
		Gravel Diameter: Less than 50mm	○	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		Gravel Diameter: 50 to 100mm	○	×	△	△	○	△	△	△	△	△	△	○	○	○	○	△	○	○	○	△	○
		Gravel Diameter: 100 to 500mm	○	×	×	×	×	×	×	×	×	×	×	×	×	△	×	×	○	○	△	×	△
		Liquefaction layer present	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Bearing layer	Bearing layer depth: Less than 5m	○	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	○	×	×	×	×
		Bearing layer depth: 5 to 15m	△	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	○	○	○	△	△
		Bearing layer depth: 15 to 25m	×	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		Bearing layer depth: 25 to 40m	×	×	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	○	○	○	○
		Bearing layer depth: 40 to 60m	×	×	△	○	○	△	△	△	○	○	○	○	○	△	○	×	×	△	○	○	○
		Bearing layer depth: More than 60m	×	×	×	△	△	×	×	×	×	×	×	△	△	×	△	×	×	×	△	△	△
		Bearing layer soil: Clay (20 ≦N)	○	○	○	○	○	○	×	△	○	×	△	△	×	○	○	○	○	○	○	○	○
		Bearing layer soil: Sand/Gravel (30 ≦N)	○	○	○	○	○	○	○	×	○	○	×	○	○	○	○	○	○	○	○	○	○
		Steep (more than 30 degree)	○	×	△	○	○	△	△	△	○	○	○	△	△	○	△	△	○	○	△	△	△
		Bearing surface extremely uneven	○	△	△	○	○	△	△	△	○	△	△	△	△	○	○	○	○	○	△	△	○
	Groundwater	Groundwater close to surface	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	○	○	○	○
		Water spout	△	○	○	○	○	○	○	○	○	○	○	○	△	○	○	△	×	○	○	○	△
		an groundwater more than 2m higher than g	×	○	○	○	○	×	×	×	×	×	×	○	×	×	×	×	×	△	△	○	×
		Groundwater velocity more than 3m/min	×	○	○	○	○	○	×	×	○	×	×	×	×	×	×	×	×	○	△	○	×
Structure characteristics	Load	Small vertical load (span less than 20m)	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	△	×	×
		Normal vertical load (span 20m to 50m)	○	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		Large vertical load (span more than 50m)	○	×	△	○	○	△	△	△	○	○	○	○	△	○	○	△	○	○	○	○	○
		Vertical load smaller than horizontal load	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△
		Vertical load larger than horizontal load	○	×	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Bearing type	Bearing pile	/	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	/	/	/	/
		Friction pile	/	○	○	○	○	/	/	/	/	/	/	○	○	○	○	○	/	/	/	/	/
Construction codition	Construction over water	Water depth less than 5m	○	○	○	○	○	△	△	△	△	△	△	△	×	×	○	△	×	△	△	○	×
		Water depth more than 5m	×	△	△	○	○	△	△	△	△	△	△	△	×	×	△	×	×	△	△	○	×
		Small construction space	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	○	△	△	×	△
		Diagonal pile construction	/	△	○	○	○	×	×	×	△	△	△	△	×	△	×	×	×	/	/	/	/
		Poisonous gas	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	×	○	○	○
	Surrounding	Noise, Vibration	○	×	×	×	△	△	○	○	△	○	○	○	○	△	○	○	○	○	○	△	○
		Impact on surrouding structures	○	×	×	△	△	△	○	○	△	○	○	○	○	○	○	○	△	△	△	△	○

○ : Best suitable △ : Suitable × : Not suitable

Source: Specifications for Highway Bridges from Japan Road Association

(b) Approach Bridge

Table 5.2.4 Foundation Type Selection for Approach Bridge

Foundation type selection table

Fourndation type / Evaluation criteria				Spread Foundation	Driving pile				Pile installed by inner excavation						Steel pipe soil cement pile	Pre-boring	Cast-in-situ				Caisson		Steel pipe sheet pile	Continuous wall foundation
					RC Pile	PHC Pile/ SC Pile	Steel pile		PHC Pile/ SC Pile			Steel pile					All casing	Reverse	Earth drill	Caisson pile	Pneumatic	Open		
							Percussion method	Vibro-hammer	End striking method	Jet turbine method	Concrete placement me	End striking method	Jet turbine method	Concrete placement me										
Soil Condition	Soil condition up to bearing layer	Extremely soft layer present		△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	○	○	○	○
		Extremely hard layer present		○	×	△	△	△	○	○	○	○	○	○	○	○	△	○	△	○	○	△	△	○
		Gravel Diameter	Less than 50mm	○	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
			50 to 100mm	○	×	△	△	○	△	△	△	△	△	△	○	○	○	○	△	○	○	○	△	○
			100 to 500mm	○	×	×	×	×	×	×	×	×	×	×	×	×	△	×	×	○	○	△	×	△
		Liquefaction layer present		△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Bearing layer	Bearing layer depth	Less than 5m	○	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	○	×	×	×	×
			5 to 15m	△	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	○	○	○	△	△
			15 to 25m	×	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
			25 to 40m	×	×	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	○	○	○	○
			40 to 60m	×	×	△	○	○	△	△	△	○	○	○	○	○	△	○	×	×	△	○	○	○
			More than 60m	×	×	×	△	△	×	×	×	×	×	×	△	△	×	△	×	×	×	△	△	△
		Bearing layer soil	Clay (20≦N)	○	○	○	○	○	○	×	△	○	×	△	△	×	○	○	○	○	○	○	○	○
			Sand/Gravel (30≦N)	○	○	○	○	○	○	○	×	○	○	×	○	○	○	○	○	○	○	○	○	○
		Steep (more than 30 degree)		○	×	△	○	○	△	△	△	○	○	○	△	△	○	△	△	○	○	△	△	△
		Bearing surface extremely uneven		○	△	△	○	○	△	△	△	○	△	△	△	△	○	○	○	○	○	△	△	○
	Groundwater	Groundwater close to surface		△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	○	○	○	○
		Water spout		△	○	○	○	○	○	○	○	○	○	○	○	△	○	○	△	×	○	○	○	△
		an groundwater more than 2m higher than g		×	○	○	○	○	×	×	×	×	×	×	○	×	×	×	×	×	△	△	○	×
		Groundwater velocity more than 3m/min		×	○	○	○	○	○	×	×	○	×	×	×	×	×	×	×	×	○	△	○	×
Structure characteristics	Load	Small vertical load (span less than 20m)		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	△	×	×
		Normal vertical load (span 20m to 50m)		○	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		Large vertical load (span more than 50m)		○	×	△	○	○	△	△	△	○	○	○	○	△	○	○	△	○	○	○	○	○
		Vertical load smaller than horizontal load		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△
		Vertical load larger than horizontal load		○	×	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Bearing type	Bearing pile		/	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	/	/	/	/
		Friction pile		/	○	○	○	○	/	/	/	/	/	/	○	○	○	○	○	/	/	/	/	/
Construction codition	Construction over water	Water depth less than 5m		○	○	○	○	○	△	△	△	△	△	△	△	×	×	○	△	×	△	△	○	×
		Water depth more than 5m		×	△	△	○	○	△	△	△	△	△	△	△	×	×	△	×	×	△	△	○	×
	Small construction space			○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	○	△	△	×	△
	Diagonal pile construction			/	△	○	○	○	×	×	×	△	△	△	△	×	△	×	×	×	/	/	/	/
	Poisonous gas			△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	×	○	○	○
	Surrounding	Noise, Vibration		○	×	×	×	△	△	○	○	△	○	○	○	○	△	○	○	○	○	○	△	○
		Impact on surrouding structures		○	×	×	△	△	△	○	○	△	○	○	○	○	○	○	○	△	△	△	△	○

○ : Best suitable △ : Suitable × : Not suitable

🟨 Suitable
🟩 Suitable for construction over existing road because of good constructability in small space
⬜ Suitable, however not available in Sri Lanka

Source: Specifications for Highway Bridges from Japan Road Association

Following options are considered according to above table.

- Steel Box Girder Bridge: cast-in-situ pile, Screwed Steel Pile
- PC Box Girder Bridge: cast-in-situ pile

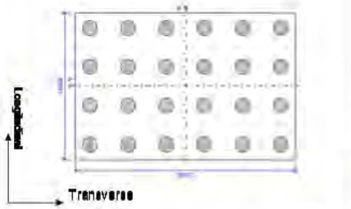
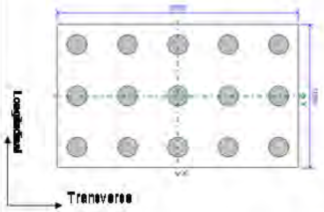
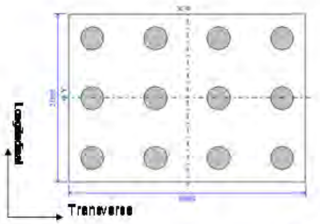
3) Pile Type and Pile Dimension Comparison

(a) Main Bridge (Extra-dosed Bridge)

As mentioned previous clause, cast-in-situ pile foundation is selected for the Extra-dosed Bridge (Main Bridge). D2.5m x 15 is recommended because of the lowest construction cost as in Table 5.2.5.

Table 5.2.5 Comparison Table for Pile Dimension (Extra-dosed Bridge)

Extradosed Bridge - Comparison Table for Pile Dimension

Items			Opt. 1 Cast-in-situ pile φ2000 (All casing method by Rotary boring machine)				Opt. 2 Cast-in-situ pile φ2500 (All casing method by Rotary boring machine)				Opt. 3 Cast-in-situ pile φ3000 (All casing method by Rotary boring machine)			
Plan View			 Unit mm				 Unit mm				 Unit mm			
Pile parameters			φ2000 L=21.0m 24 piles Rebar 1st layer: 44-D19				φ2500 L=21.5m 15 piles Rebar 1st layer: 56-D22				φ3000 L=22.0m 12 piles Rebar 1st layer: 66-D25			
Pile Cap size			19.000m	×	29.000m	× 3.000m	17.500m	×	30.000m	× 3.000m	21.000m	×	30.000m	× 3.000m
Direction			Longitudinal				Longitudinal				Longitudinal			
Normal state														
Buoyancy force			No				No				No			
Forces acting on center of footing's bottom surface	V	kN	288100.0				297200.0				17200.0			
	H	kN	0.0				0.0				0.0			
	M	kN·m	0.0				0.0				0.0			
Pile head displacement	δx	mm	0.0	<	15.0	0%	0.0	<	15.0	0%	0.0	<	15.0	0%
Driving force (Longitudinal)	Pnmax	kN	12004.0	<	13367.0	90%	19060.0	<	19566.0	97%	24500.0	<	26927.0	91%
Pulling force (Longitudinal)	Pnmin	kN	12004.0	>	- 3494.0	-344%	19060.0	>	- 4837.0	-394%	24500.0	>	- 6364.0	-384%
Compressive stress	σc	N/mm^2	3.6	<	8.0	45%	3.7	<	8.0	46%	3.2	<	8.0	40%
Tensile stress	σs,σt	N/mm^2	-54.1	>	-200	27%	-54.7	>	-200	27%	-48.5	>	-200	24%
Shear stress	τ	N/mm^2	0.000	<	1.700	0%	0.000	<	1.700	0%	0.000	<	1.700	0%
Foundation construction cost			Quantity		Unit price (thousand yen)	Construction cost (thousand yen)	Quantity		Unit price (thousand yen)	Construction cost (thousand yen)	Quantity		Unit price (thousand yen)	Construction cost (thousand yen)
Footing concrete			1,653.0	m^3	24.500	40,499	1,575.0	m^3	24.500	38,588	1,890.0	m^3	24.500	46,305
Earthwork (excavation)			3,592.0	m^3	0.410	1,473	3,507.3	m^3	0.410	1,438	3,992.7	m^3	0.410	1,637
Earthwork (filling)			3,592.0	m^3	0.700	2,514	3,507.3	m^3	0.700	2,455	3,992.7	m^3	0.700	2,795
Cast-in-situ pile			504.0	m	134.300	67,687	322.5	m	192.800	62,178	264.0	m	274.700	72,521
Direct construction cost						112,173				104,659				123,258
Cofferdam work			511	m2	24.19	12,366	506	m2	24.13	12,210	538	m2	24.55	13,213
Overhead cost (40%)						49,816				46,747				54,588
Total						174,354				163,616				191,059
Evaluation result			Middle		(Ratio	: 1.066)	Lowest		(Ratio	: 1.000)	Highest		(Ratio	: 1.168)
							Recommended							

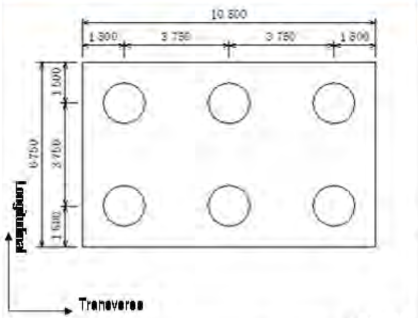
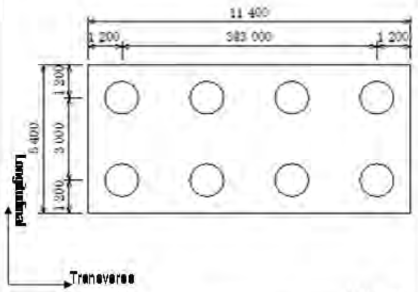
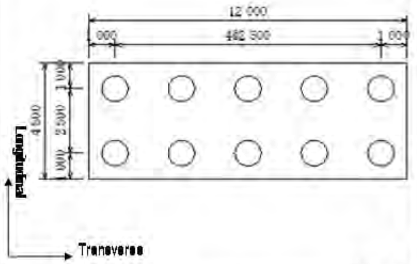
Source: JICA Survey Team

(b) Approach Bridge (PC Box Girder Bridge, Separated Section)

As shown in the below Table, D1.5m x 6 is selected because of the lowest construction cost.

Table 5.2.6 Comparison Table for Pile Dimension (PC Box Girder Bridge) MB-P16

PC Box Girder Bridge - Comparison Table for Pile Dimension

Items				Opt. 1 Cast-in-situ pile φ1500 (All casing method by Rotary boring machine)				Opt. 2 Cast-in-situ pile φ1200 (All casing method by Rotary boring machine)				Opt. 3 Cast-in-situ pile φ1000 (All casing method by Rotary boring machine)			
Plan View				 Unit mm				 Unit mm				 Unit mm			
Pile parameters				φ1500 L=25.5m 6 piles Rebar 1st layer: 32-D19				φ1200 L=25.5m 8 piles Rebar 1st layer 24-D16				φ1000 L=25.0m 10 piles Rebar 1st layer: 16-D16			
Pile Cap size				6.750m	×	10.500m	× 1.900m	5.400m	×	11.400m	× 1.900m	4.500m	×	12.000m	× 1.900m
Direction				Longitudinal				Longitudinal				Longitudinal			
Normal state	Buoyancy force			No				No				No			
	Forces acting on center of footing's bottom surface	V	kN	29700.0				29300.0				29000.0			
		H	kN	0.0				0.0				0.0			
		M	kN·m	0.0				0.0				0.0			
	Pile head displacement	δx	mm	0.0	<	15.0	0%	0.0	<	15.0	0%	0.0	<	15.0	0%
	Driving force (Longitudinal)	Pnmax	kN	4950.0	<	5492.0	90%	3662.5	<	4027.0	91%	2900.0	<	3119.0	93%
	Pulling force (Longitudinal)	Pnmin	kN	4950.0	>	- 2363.0	-209%	3662.5	>	- 1784.0	-205%	2900.0	>	- 1370.0	-212%
	Compressive stress	σc	N/mm^2	2.6	<	8.0	33%	3.1	<	8.0	39%	3.5	<	8.0	44%
	Tensile stress	σs,σt	N/mm^2	-39.0	>	-200.0	19%	-45.7	>	2-00.0	23%	-52.2	>	2-00.0	26%
	Shear stress	τ	N/mm^2	0.000	<	1.700	0%	0.000	<	1.700	0%	0.000	<	1.700	0%
Foundation construction cost				Quantity		Unit price (thousand yen)	Construction cost (thousand yen)	Quantity		Unit price (thousand yen)	Construction cost (thousand yen)	Quantity		Unit price (thousand yen)	Construction cost (thousand yen)
	Footing concrete			134.7	m^3	24.500	3,300	117.0	m^3	24.500	2,867	102.6	m^3	24.500	2,514
	Earthwork (excavation)			572.8	m^2	0.410	235	546.9	m^2	0.410	224	528.1	m^2	0.410	217
	Earthwork (filling)			572.8	m^3	0.700	401	546.9	m^3	0.700	383	528.1	m^3	0.700	370
	Cast-in-situ pile			153.0	m	87.000	13,311	204.0	m	72.000	14,688	250.0	m	64.000	16,000
	Direct construction cost						17,247				18,162				19,100
	Overhead cost (40%)						6,899				7,265				7,640
	Total						24,146				25,428				26,740
Evaluation result				Lowest		(Ratio	: 1.000)	Middle		(Ratio	: 1.053)	Highest		(Ratio	: 1.107)
				Recommended											

Source: JICA Survey Team

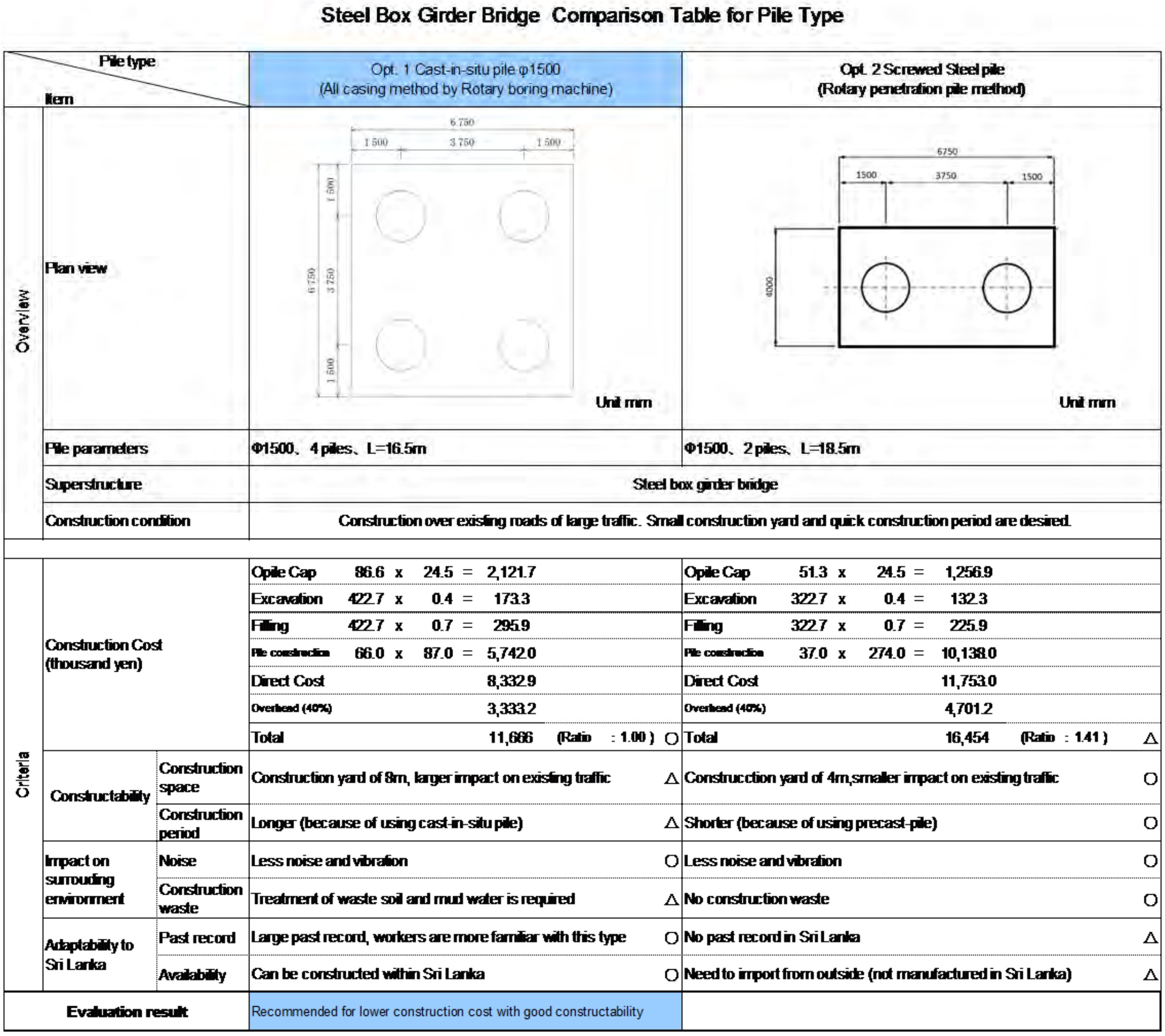
(c) Approach Bridge (Steel Box Girder Bridge, Overlapped Section)

a) Pile Type Comparison

Cast-in-situ pile is selected for the better construction cost and ability of constructing within construction width of 8.0m.

The T-shaped pier and the rigid pier support almost same reaction force for the superstructure. Following comparison table for pile types is applied for both of pier type.

Table 5.2.7 Comparison Table for Pile Type (Steel Box Girder Bridge) RC2-P6



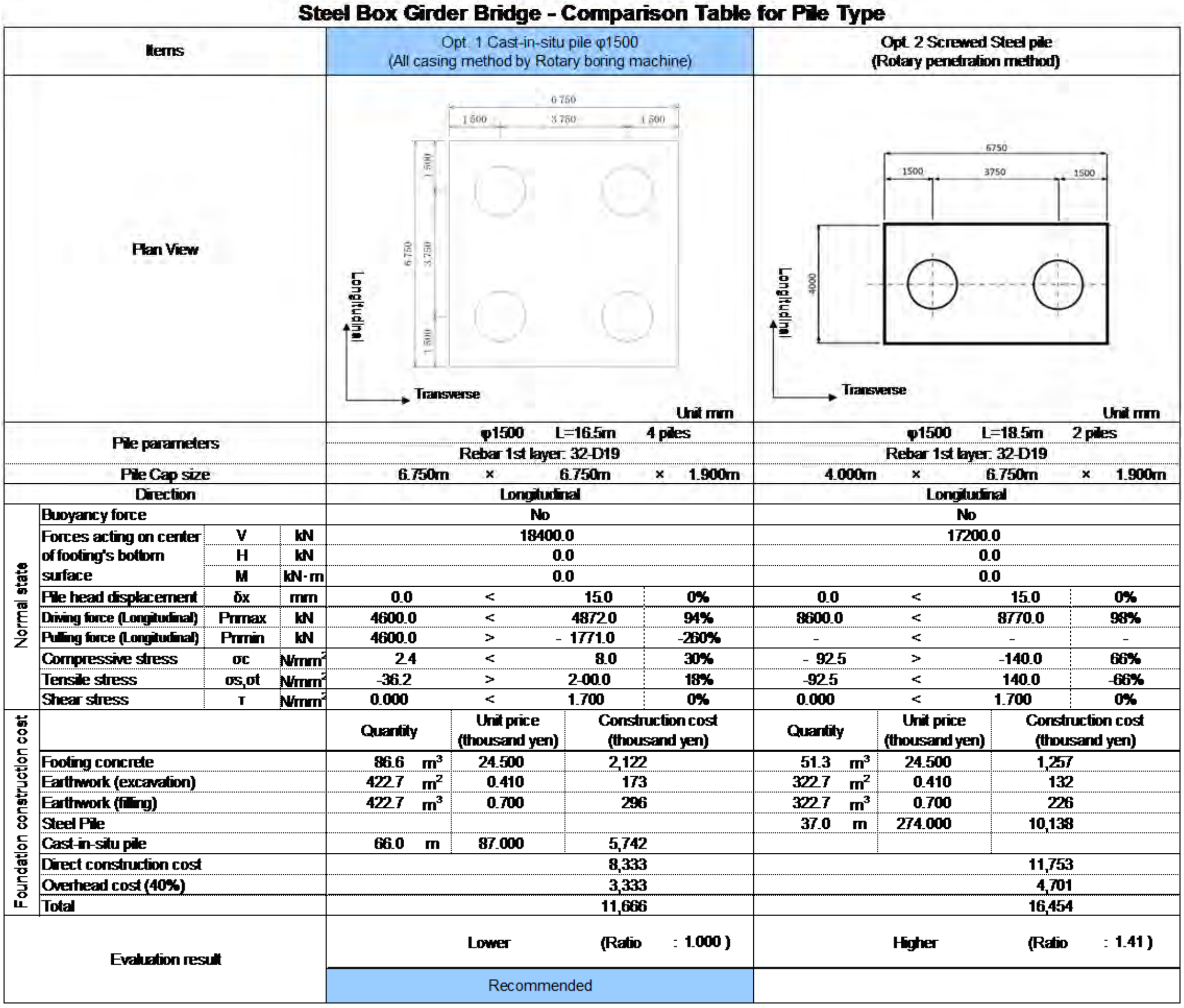
Steel Box Girder Bridge Comparison Table for Pile Type

Pile type / Item			Opt. 1 Cast-in-situ pile φ1500 (All casing method by Rotary boring machine)		Opt. 2 Screwed Steel pile (Rotary penetration pile method)	
Overview	Plan view		6 750 1 500 3 750 1 500 6 750 1 500 3 750 1 500 Unit mm		6750 1500 3750 1500 4000 Unit mm	
	Pile parameters		Φ1500、4 piles、L=16.5m		Φ1500、2 piles、L=18.5m	
	Superstructure		Steel box girder bridge			
	Construction condition		Construction over exisitng roads of large traffic. Small construction yard and quick construction period are desired.			
Criteria	Construction Cost (thousand yen)		Opile Cap 86.6 x 24.5 = 2,121.7		Opile Cap 51.3 x 24.5 = 1,256.9	
			Excavation 422.7 x 0.4 = 173.3		Excavation 322.7 x 0.4 = 132.3	
			Filling 422.7 x 0.7 = 295.9		Filling 322.7 x 0.7 = 225.9	
			Pile construction 66.0 x 87.0 = 5,742.0		Pile construction 37.0 x 274.0 = 10,138.0	
			Direct Cost 8,332.9		Direct Cost 11,753.0	
			Overhead (40%) 3,333.2		Overhead (40%) 4,701.2	
			Total 11,666 (Ratio : 1.00)	○	Total 16,454 (Ratio : 1.41)	△
	Constructability	Construction space	Construction yard of 8m, larger impact on exisitng traffic	△	Construcction yard of 4m,smaller impact on existing traffic	○
		Construction period	Longer (because of using cast-in-situ pile)	△	Shorter (because of using precast-pile)	○
	Impact on surrouding environment	Noise	Less noise and vibration	○	Less noise and vibration	○
		Construction waste	Treatment of waste soil and mud water is required	△	No construction waste	○
	Adaptability to Sri Lanka	Past record	Large past record, workers are more familiar with this type	○	No past record in Sri Lanka	△
		Availability	Can be constructed within Sri Lanka	○	Need to import from outside (not manufactured in Sri Lanka)	△
Evaluation result			Recommended for lower construction cost with good constructability			

Source: JICA Survey Team

※Note: For construction width, refer to (2) Selection of Foundation Type

Table 5.2.8 Calculation Result for Pile Type (Steel Box Girder Bridge) RC2-P6



Steel Box Girder Bridge - Comparison Table for Pile Type

Items				Opt. 1 Cast-in-situ pile φ1500 (All casing method by Rotary boring machine)				Opt. 2 Screwed Steel pile (Rotary penetration method)			
Plan View				Unit mm				Unit mm			
Pile parameters				φ1500 L=16.5m 4 piles Rebar 1st layer: 32-D19				φ1500 L=18.5m 2 piles Rebar 1st layer: 32-D19			
Pile Cap size				6.750m × 6.750m × 1.900m				4.000m × 6.750m × 1.900m			
Direction				Longitudinal				Longitudinal			
Normal state	Buoyancy force			No				No			
	Forces acting on center of footing's bottom surface	V	kN	18400.0				17200.0			
		H	kN	0.0				0.0			
		M	kN·m	0.0				0.0			
	Pile head displacement	δx	mm	0.0	<	15.0	0%	0.0	<	15.0	0%
	Driving force (Longitudinal)	Prnmax	kN	4600.0	<	4872.0	94%	8600.0	<	8770.0	98%
	Pulling force (Longitudinal)	Prnmin	kN	4600.0	>	- 1771.0	-260%	-	<	-	-
	Compressive stress	σc	N/mm²	2.4	<	8.0	30%	- 92.5	>	-140.0	66%
	Tensile stress	σs,σt	N/mm²	-36.2	>	2-00.0	18%	-92.5	<	140.0	-66%
	Shear stress	τ	N/mm²	0.000	<	1.700	0%	0.000	<	1.700	0%
Foundation construction cost				Quantity		Unit price (thousand yen)	Construction cost (thousand yen)	Quantity		Unit price (thousand yen)	Construction cost (thousand yen)
	Footing concrete			86.6	m³	24.500	2,122	51.3	m³	24.500	1,257
	Earthwork (excavation)			422.7	m²	0.410	173	322.7	m²	0.410	132
	Earthwork (filling)			422.7	m³	0.700	296	322.7	m³	0.700	226
	Steel Pile							37.0	m	274.000	10,138
	Cast-in-situ pile			66.0	m	87.000	5,742				
	Direct construction cost			8,333				11,753			
	Overhead cost (40%)			3,333				4,701			
	Total			11,666				16,454			
Evaluation result				Lower (Ratio : 1.000)				Higher (Ratio : 1.41)			
				Recommended							

Source: JICA Survey Team

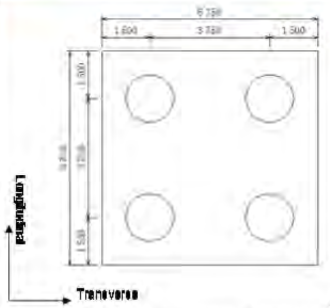
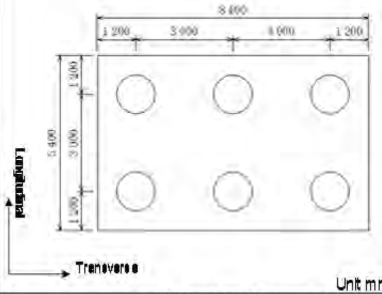
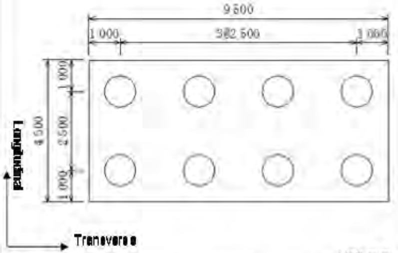
b) Pile Dimension Comparison

- Approach Bridge

Cast-in-situ D1.5m x 4 is selected because of the lowest construction cost.

Table 5.2.9 Comparison Table for Pile Dimension (Steel Box Girder Bridge) RC2-P6

Steel Box Girder Bridge - Comparison Table for Pile Dimension

Items				Opt. 1 Cast-in-situ pile φ1500 (All casing method by Rotary boring machine)				Opt. 2 Cast-in-situ pile φ1200 (All casing method by Rotary boring machine)				Opt. 3 Cast-in-situ pile φ1000 (All casing method by Rotary boring machine)			
Plan View				 Unit mm				 Unit mm				 Unit mm			
Pile parameters				φ1500 L=16.5m 4 piles Rebar 1st layer: 32-D19				φ1200 L=16.5m 6 piles Rebar 1st layer: 24-D16				φ1000 L=16.5m 8 piles Rebar 1st layer: 16-D16			
Pile Cap size				6.750m	×	6.750m	× 1.900m	5.400m	×	8.400m	× 1.900m	4.500m	×	9.500m	× 1.900m
Direction				Longitudinal				Longitudinal				Longitudinal			
Normal state	Buoyancy force			No				No				No			
	Forces acting on center of footing's bottom surface	V	kN	18400.0				18400.0				18200.0			
		H	kN	0.0				0.0				0.0			
		M	kN·m	0.0				0.0				0.0			
	Pile head displacement	δx	mm	0.0	<	15.0	0%	0.0	<	15.0	0%	0.0	<	15.0	0%
	Driving force (Longitudinal)	Pnmax	kN	4600.0	<	4872.0	94%	3066.7	<	3549.0	86%	2275.0	<	2763.0	82%
	Pulling force (Longitudinal)	Pnmin	kN	4600.0	>	- 1771.0	-260%	3066.7	>	- 1348.0	-228%	2275.0	>	- 1086.0	-209%
	Compressive stress	σc	N/mm²	2.4	<	8.0	30%	2.6	<	8.0	32%	2.7	<	8.0	34%
	Tensile stress	σs,σt	N/mm²	-36.2	>	2-00.0	18%	-38.3	>	2-00.0	19%	-41.0	>	2-00.0	20%
	Shear stress	τ	N/mm²	0.000	<	1.700	0%	0.000	<	1.700	0%	0.000	<	1.700	0%
Foundation construction cost				Quantity		Unit price (thousand yen)	Construction cost (thousand yen)	Quantity		Unit price (thousand yen)	Construction cost (thousand yen)	Quantity		Unit price (thousand yen)	Construction cost (thousand yen)
	Footing concrete			86.6	m³	24.500	2,122	86.2	m3	24.500	2,112	81.2	m3	24.500	1,989
	Earthwork (excavation)			422.7	m²	0.410	173	431.6	m2	0.410	177	434.8	m2	0.410	178
	Earthwork (filling)			422.7	m³	0.700	296	431.6	m3	0.700	302	434.8	m3	0.700	304
	Steel Pile														
	Cast-in-situ pile			66.0	m	87.000	5,742	99.0	m	72.000	7,128	132.0	m	64.000	8,448
	Direct construction cost						8,333				9,719				10,920
	Overhead cost (40%)						3,333				3,888				4,368
	Total						11,666				13,607				15,288
Evaluation result				Lowest		(Ratio	: 1.000)	Middle		(Ratio	: 1.166)	Highest		(Ratio	: 1.310)
				Recommended											

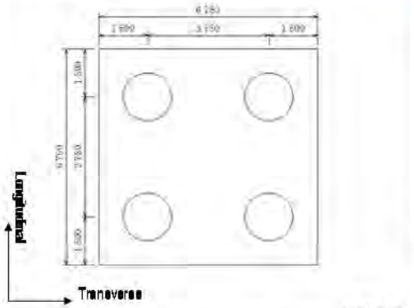
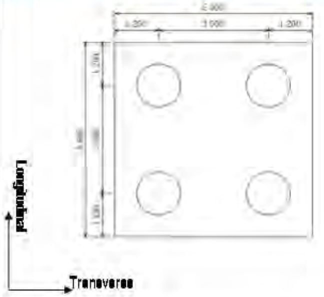
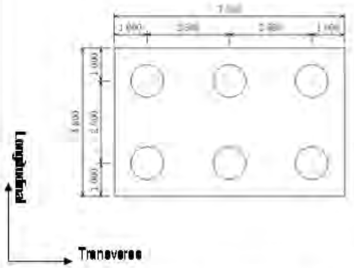
Source: JICA Survey Team

- Ramp Bridge

Cast-in-situ D1.2m x 4 is selected because of the lowest construction cost.

Table 5.2.10 Comparison Table for Pile Dimension (Ramp Bridge) RD-P4

PC Box Girder Bridge - Comparison Table for Pile Dimension

Items				Opt. 1 Cast-in-situ pile φ1500 (All casing method by Rotary boring machine)				Opt. 2 Cast-in-situ pile φ1200 (All casing method by Rotary boring machine)				Opt. 3 Cast-in-situ pile φ1000 (All casing method by Rotary boring machine)			
Plan View				 Unit mm				 Unit mm				 Unit mm			
Pile parameters				φ1500 L=17.0m 4 piles Rebar 1st layer: 32-D19				φ1200 L=16.5m 4 piles Rebar 1st layer 24-D16				φ1000 L=16.5m 6 piles Rebar 1st layer: 16-D16			
Pile Cap size				6.750m × 6.750m × 1.900m				5.400m × 5.400m × 1.900m				4.500m × 7.000m × 1.900m			
Direction				Longitudinal				Longitudinal				Longitudinal			
Normal state	Buoyancy force			No				No				No			
	Forces acting on center of footing's bottom surface	V	kN	13300.0				12500.0				12700.0			
		H	kN	0.0				0.0				0.0			
		M	kN·m	0.0				0.0				0.0			
	Pile head displacement	δx	mm	0.0	<	15.0	0%	0.0	<	15.0	0%	0.0	<	15.0	0%
	Driving force (Longitudinal)	Pnmax	kN	3325.0	<	5022.0	66%	3125.0	<	3549.0	88%	2116.7	<	2763.0	77%
	Pulling force (Longitudinal)	Pnmin	kN	3325.0	>	- 1862.0	-179%	3125.0	>	- 1348.0	-232%	2116.7	>	- 1086.0	-195%
	Compressive stress	σc	N/mm²	1.8	<	8.0	22%	2.8	<	8.0	33%	2.5	<	8.0	32%
	Tensile stress	σs,σt	N/mm²	-26.2	>	-200.0	13%	-39.0	>	2-00.0	19%	-38.1	>	2-00.0	19%
	Shear stress	τ	N/mm²	0.000	<	1.700	0%	0.000	<	1.700	0%	0.000	<	1.700	0%
Foundation construction cost				Quantity		Unit price (thousand yen)	Construction cost (thousand yen)	Quantity		Unit price (thousand yen)	Construction cost (thousand yen)	Quantity		Unit price (thousand yen)	Construction cost (thousand yen)
	Footing concrete			86.6	m³	24.500	2,122	55.4	m³	24.500	1,357	59.9	m³	24.500	1,466
	Earthwork (excavation)			422.7	m²	0.410	173	326.5	m²	0.410	134	348.5	m²	0.410	143
	Earthwork (filling)			422.7	m³	0.700	296	326.5	m³	0.700	229	348.5	m³	0.700	244
	Cast-in-situ pile			68.0	m	87.000	5,916	66.0	m	72.000	4,752	99.0	m	64.000	6,336
	Direct construction cost						8,507				6,472				8,190
	Overhead cost (40%)						3,403				2,589				3,276
	Total						11,910				9,060				11,467
Evaluation result				Highest (Ratio : 1.314)				Lowest (Ratio : 1.000)				Middle (Ratio : 1.266)			
								Recommended							

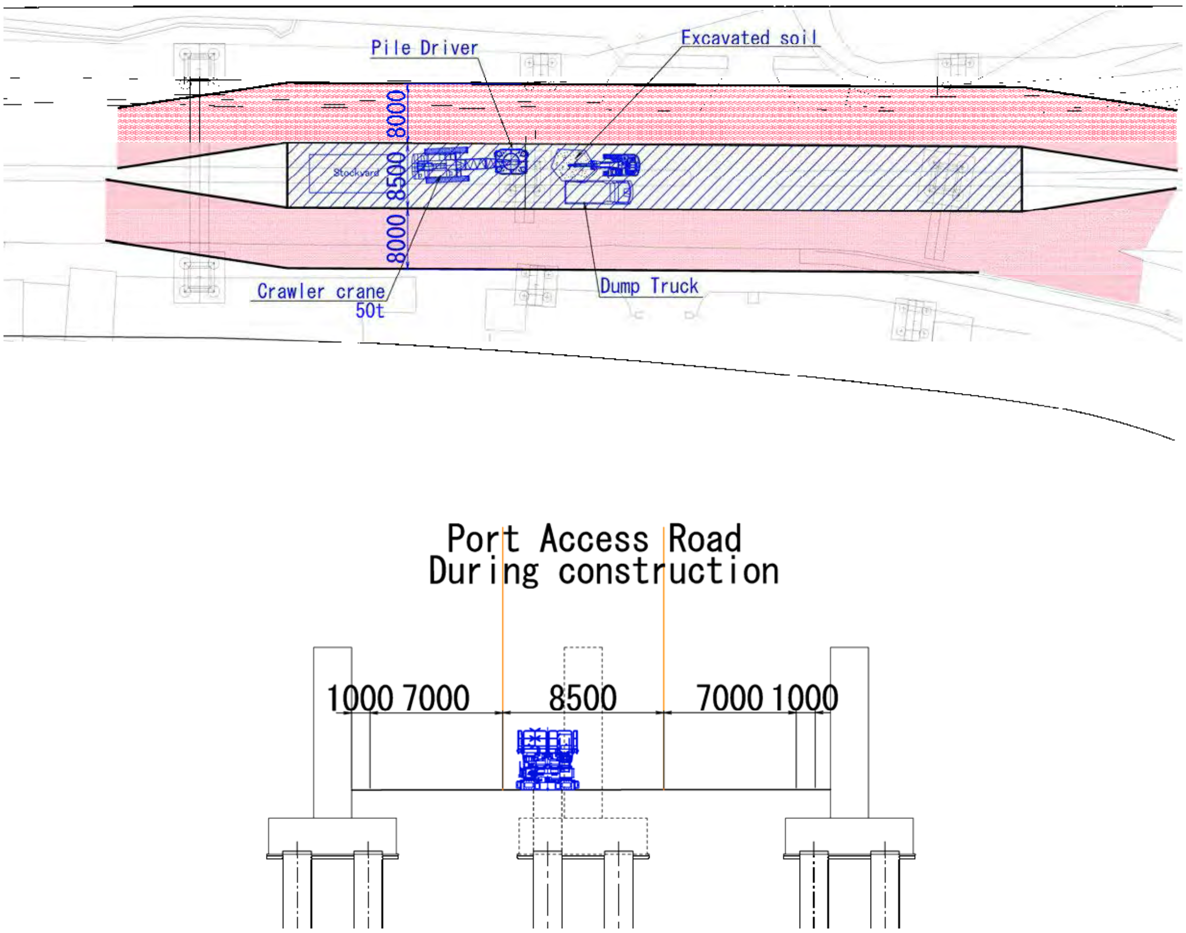
Source: JICA Survey Team

(2) Selection of Foundation Type

Figure 5.2.3 to Figure 5.2.6 shows the diagram of construction conditions for cast-in-situ pile and Screwed Steel Pile. For the following reasons, cast-in-situ pile is selected for Steel Box Girder Bridge.

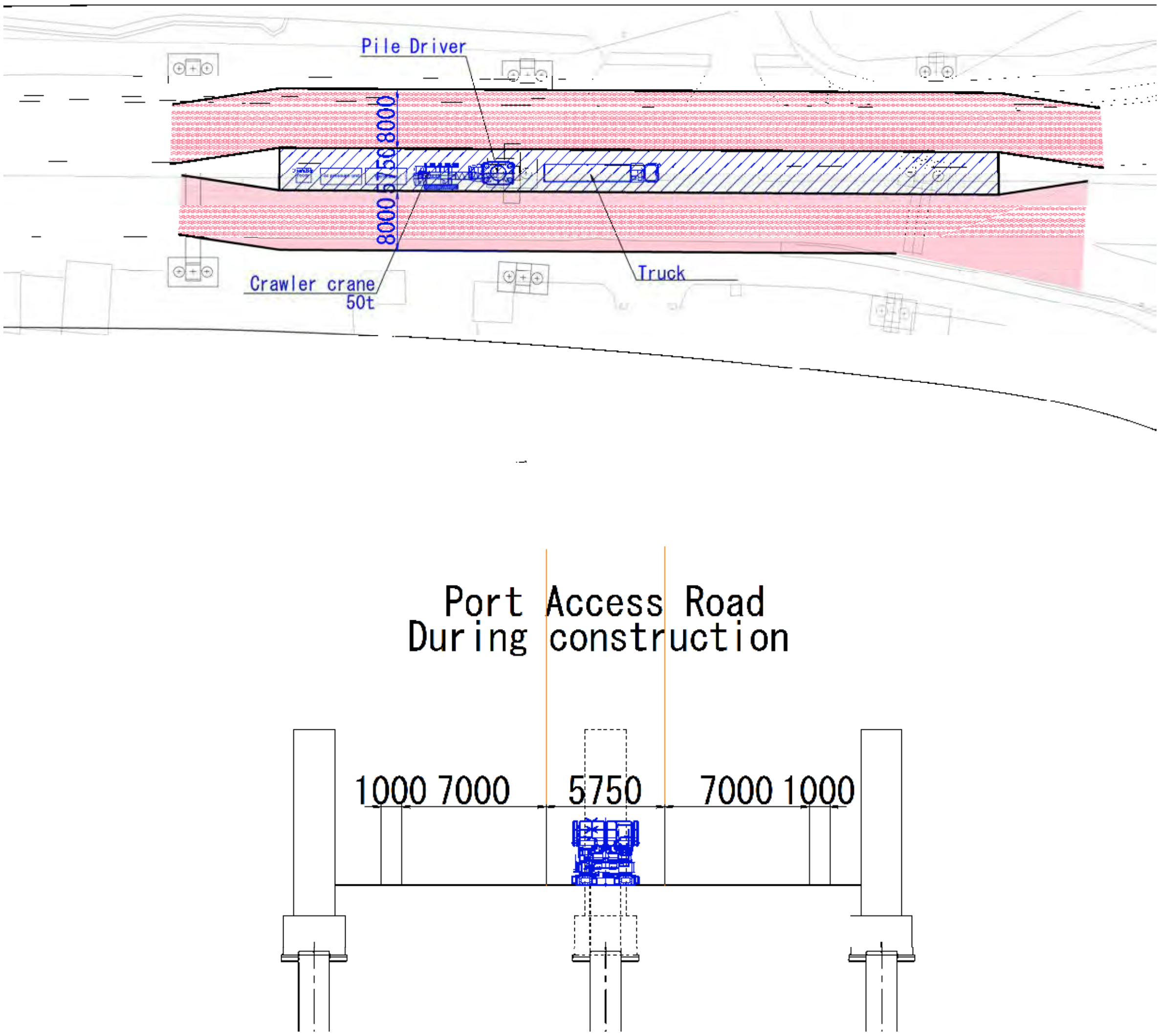
Cast-in-situ pile can be constructed within construction width of 8.5m. For construction in medians, traffic diversion can be carried out within construction yard.

In Port Access Road where piers are located in side walk, construction width (including borrowed yard) is small. The figure below demonstrates that construction condition with example of pier RC2-P7.



Source: JICA Survey Team

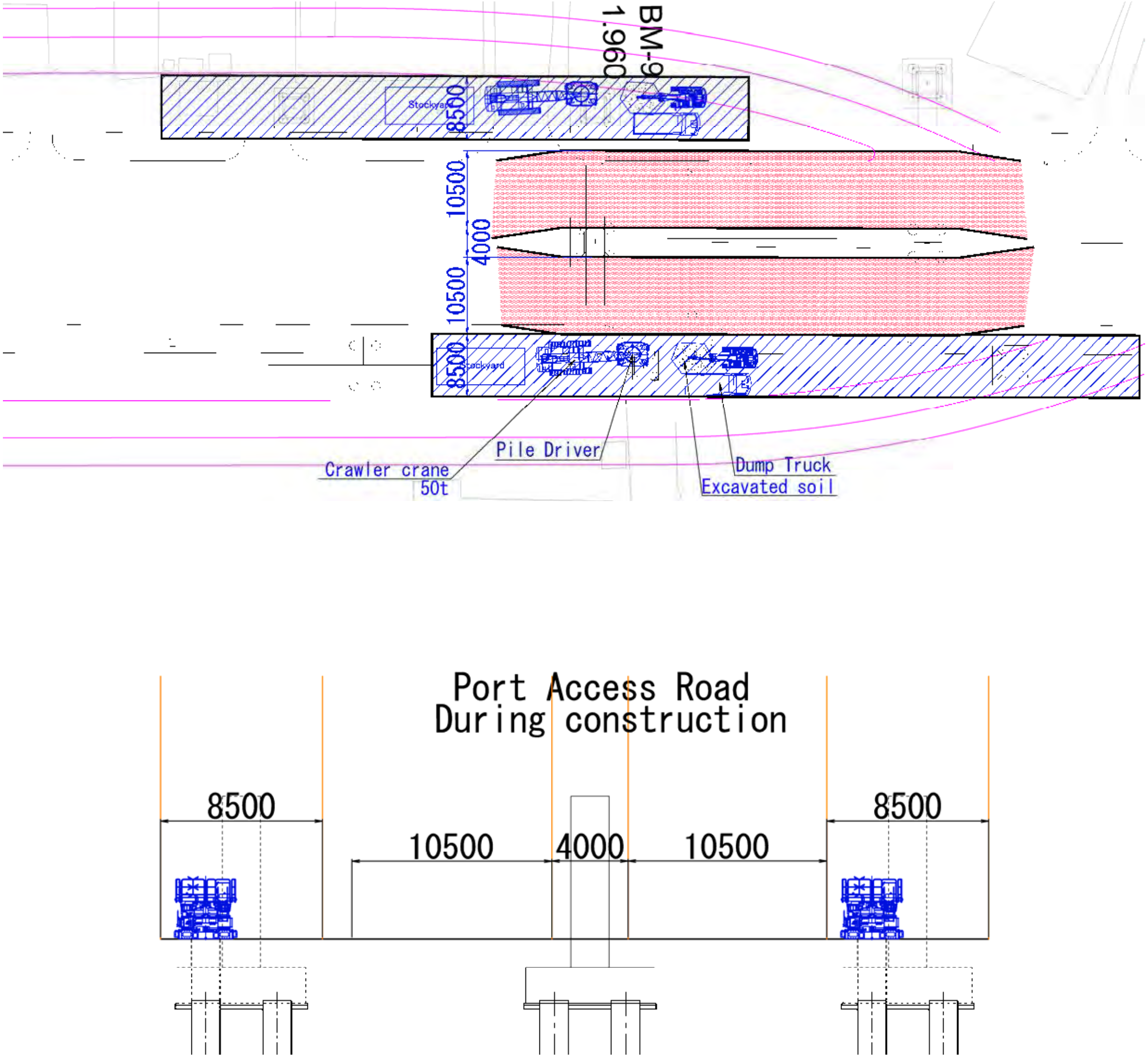
Figure 5.2.3 Median Foundation in Port Access Road RC2-P7, Cast-in-situ pile D1.5m



Source: JICA Survey Team

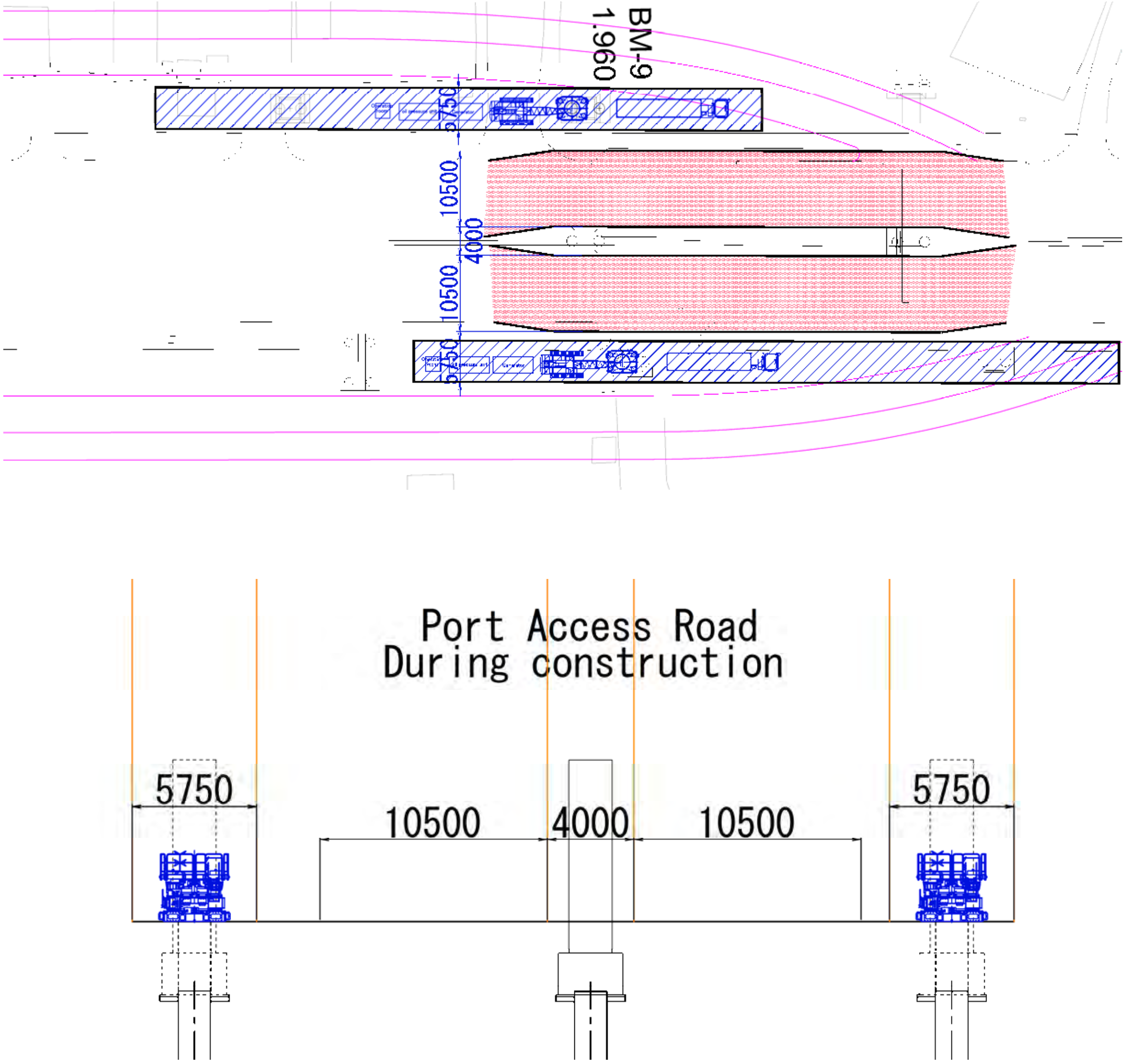
Figure 5.2.4 Median Foundation in Port Access Road RC2-P7, Screwed Steel Pile

Figure below demonstrates the construction condition in small construction width in the case of single-column pier on the side of Port Access Road with example of MB-P1.



Source: JICA Survey Team

Figure 5.2.5 Side Foundation in Port Access Road MB-P1, Cast-in-situ pile



Source: JICA Survey Team

Figure 5.2.6 Side Foundation in Port Access Road MB-P1, Screwed Steel Pile