CHAPTER 5 Monorail System and Structures

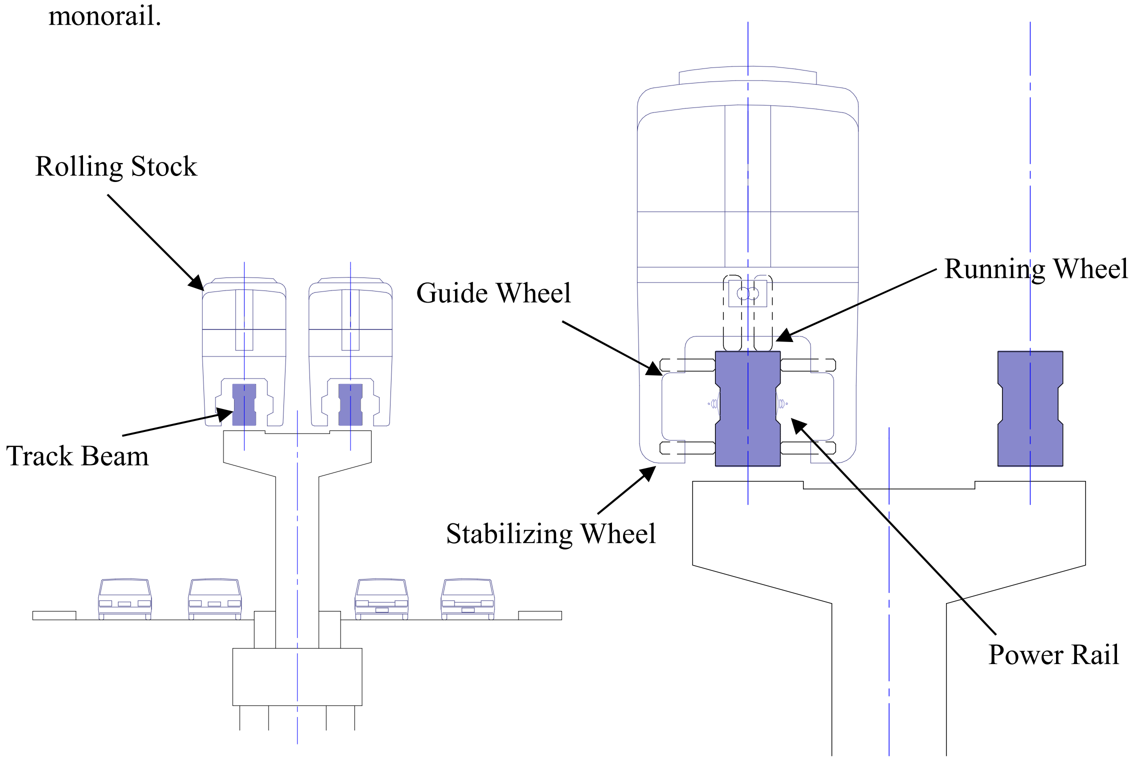
5.1 Outline of Monorail System

5.1.1 Outline of Monorail System

Proposed system is straddle type monorail system proven in 5 cities in Japan; 2 cities in the USA; Chongqing, People's Republic of China; Singapore; Dubai, the UAE; and Kuala Lumpur, and Malaysia. In view of these successes, a number of cities have recently decided to introduce a monorail as an urban transport solution. This includes Daegu, Korea; Mumbai, India; Sao Paulo, Brazil; Jakarta, Indonesia; Qom, Iran; and Riyadh, Saudi Arabia.

Rolling stock straddle on reinforced concrete beam and rubber tire is used for running gear. Therefore higher ride quality and steeper gradient is expected than steel rail and steel wheel system. Running wheels are installed under the car body and those wheels are running on the top of the concrete beam. Guide wheels are installed at the lower portion of the car to hold the beam at both side and they will support and guide the vehicle. Traction power is supplied by power rail installed at both side of concrete beam.

Figure 5.1.1 indicates the outline of the monorail and Figure 5.1.2 indicates the image of the monorail.



Source: SKYTRAIN Study Team

Figure 5.1.1 Outline of Monorail

Source: Hitachi Ltd.

Figure 5.1.2 Image of Monorail

Table 5.1.1 shows the outline of proposed monorail system.

Table 5.1.1 Monorail System

No.	Item	Specification
1	Type	[redacted]
2	Width of track	[redacted]
3	Minimum curve radius	[redacted]
4	Maximum gradient	[redacted]
5	Distance between track centre	[redacted]
6	Platform length	[redacted]
7	Power supply	[redacted]
8	Maximum axle load	[redacted]
9	Train consist	[redacted]
10	Length of train	[redacted]
11	Signalling system	[redacted]
12	Telecommunication system	[redacted]

Source: SKYTRAIN Study Team

5.1.2 Rolling Stock

(1) Outline of Rolling Stock

Rolling stock is a proven design straddle-type monorail vehicle. A train consists of [redacted] cars and the total length of the train is approximately [redacted] meters.

There are two bogies in one car and two axles in one bogie. Two rubber tire wheels are installed in one axle for running. Besides running wheels horizontal wheels are installed in the bogie for guiding and stabilising.

Floor level is higher than the running wheel to create a flat floor. Two passenger doors are provided in each car and opening and closing of the doors will be synchronised with the platform doors. Wheel chair space will be provided in at least two locations on a train.

Trains will be operated with an Automatic Train Operation (ATO) system, however, manual operation will be also available for manoeuvring in the depot or in case of ATO failure.

Electric power for the vehicle is [redacted] and is supplied from the power rail installed on both sides of track beam. The traction motor is an AC induction motor and is controlled by a Variable Voltage Variable Frequency (VVVF) inverter. Traction motors are installed in each bogie except for the end bogies of both leading cars. A total of [redacted] traction motors are installed in each train.

(2) Specification of Rolling Stock

Salient features of the rolling stock are indicated in Table 5.1.2.

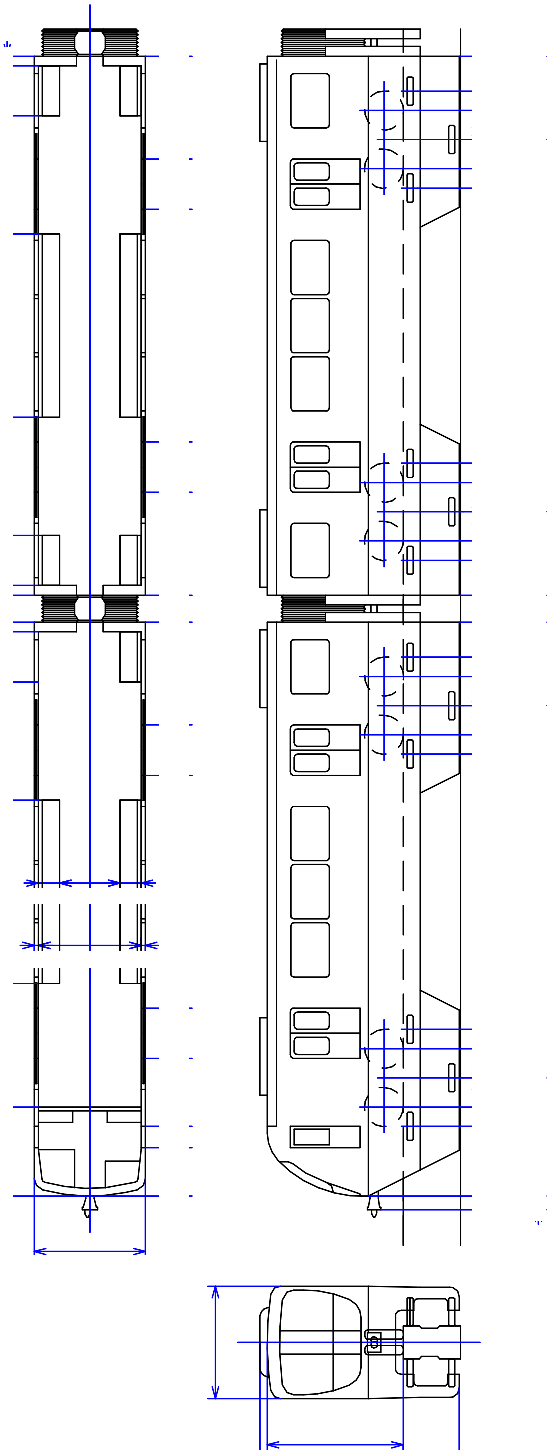
Figure 5.1.3 shows an image of the Monorail Vehicle.

Table 5.1.2 Specifications of Rolling Stock

No.	Item			Specification
1	Track	Beam width		[redacted]
2		Maximum gradient		[redacted]
3	Train formation			[redacted]
4-1	Dimensions	Length	Lead car	[redacted]
4-2			Inter mediate car	[redacted]
4-3		Train length		[redacted]
4-4		Width		[redacted]
4-5		Height		[redacted]
5-1	Weight	Tare load		[redacted]
5-2		Maximum Axle load		[redacted]

No.	Item			Specification
6-1	Performance	Maximum speed		[redacted]
6-2		Acceleration		[redacted]
6-3		Deceleration	Emergency brake	[redacted]
6-4			Maximum service brake	[redacted]
9	Traction power supply			[redacted]
10-1	Running gear	Bogie		[redacted]
10-2		Running wheel		[redacted]
10-3		Driving device		[redacted]
11	Traction control			[redacted]
12	Traction motor			[redacted]
13	Brake system			[redacted]
14-1	Passenger door	Type		[redacted]
14-2		Number		[redacted]
15-1	Air conditioning system	Type		[redacted]
15-2		Number		[redacted]
16	Auxiliary power supply			[redacted]
17	Train control			[redacted]
18	Passenger capacity			[redacted]

Source: SKYTRAIN Study Team



Source: SKYTRAIN Study Team

Figure 5.1.3 Image of Monorail Vehicle

(3) Subsystems of Monorail Vehicle

Subsystems of monorail vehicle are indicated below.

Body

The body shell will be made of aluminium-alloy to realise simplified structure and light weight. Underframe will be constructed of large-size materials, having a hollow truss structure with a railing underneath for fitting the equipment. A centralised duct is located at the centre to fit wiring to simplify under floor fitting.

The underfloor equipment will be covered by skirting and trucks will be placed in soundproof covers to reduce the noise level.

Bogie

The car body will be directly supported by the pneumatic springs on the bolsterless two-axle trucks, consisting of running wheels and horizontal wheels (guide wheels and stabilizing wheels). Design of bogie shall enhance riding comfort, reduce the weight and minimise the sliding parts for easier maintenance.

The running wheels will be N2 filled steel rubber tire and will be cantilevered to bogie frame for easy replacement. Driving device with traction motor and brake gear will be installed in the bogie.

Traction System

Traction system will be VVVF inverter controlled asynchronous motor. Traction motor will be mounted on bogie frame and torque will be transmitted to the axle of running wheel with Cardan driving device that will adopt the displacement of bogie frame and axle. Inverter will be IGBT base vector control or more recent system.

Braking System

Brake system will be electrical command air brake and regenerative brake with load-compensating to maintain constant deceleration regardless of load fluctuations for normal brake.

Auxiliary Power Supply

Train will be equipped with auxiliary power supply system transform DC 1500V to three phase AC power for air conditioning system, interior light and other devices. Auxiliary power supply system will have DC output connected to battery for controlling power and power source for emergency use.

Air-conditioning System

Air conditioning unit will be installed on the roof top of the vehicle. Air conditioning unit will have capability to maintain the temperature and humidity of passenger saloon in comfortable condition under the tropical climate. Refrigerant of the air conditioning system shall be ozone-safe.

5.2 Train Operation Plan and Depot Plan

5.2.1 Train Operation Plan

(1) Routes of the Monorail

The monorail system consists of two lines namely Line 1 from Kotahena to IT Park and Line 2 from National Hospital to Kollupitiya. Figure 5.2.1 shows the routes of the monorail.

Source: SKYTRAIN Study Team

Figure 5.2.1 Track Layout of the Monorail

(2) Operation Policy

Operation policy of this project is as follows.

(a) Operating hours are from 05:00 to 24:00

(b) Track is double track for the entire line and trains are operated on the left hand side.

(c) Trains stop at every station and express trains are not considered.

(d) Through operation between Line 1 and Line 2 is not considered.

(e) Depot is used in common for Line 1 trains and Line 2 trains.

(f) Trains consist of [redacted] cars.

(g) Longest headway in peak hours shall be [redacted] minutes.

(3) Demand Forecast

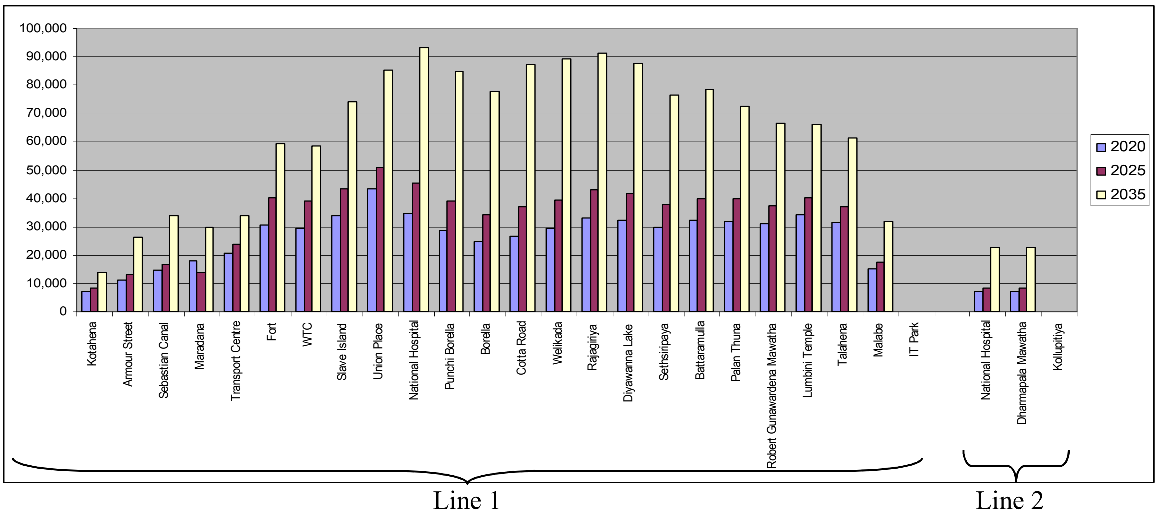
PPHPD (Passengers in Peak Hour per Direction) of peak section is indicated below.

Table 5.2.1 Passenger Demand at Peak Hour

Line	Year		
	2020	2025	2035
Line 1	7,800	9,200	16,800
Line 2	1,300	1,500	4,100

Source: SKYTRAIN Study Team

Sectional loading volume of a day is indicated below.



Source: SKYTRAIN Study Team

Figure 5.2.2 Daily Sectional Loading

(4) Transportation Capacity

A Train consists of [redacted] cars and capacity of a train is [redacted] passengers.

Transportation capacity at peak hour at each headway is indicated as follows.

Table 5.2.2 Transportation Capacity

Headway (min)		15	10	8	6	5	4	3	2.5	2
Transportation Capacity	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Source: SKYTRAIN Study Team

Based on demand forecast and transportation capacity described above, required headway of peak hour at each milestone year shall be shorter than indicated below.

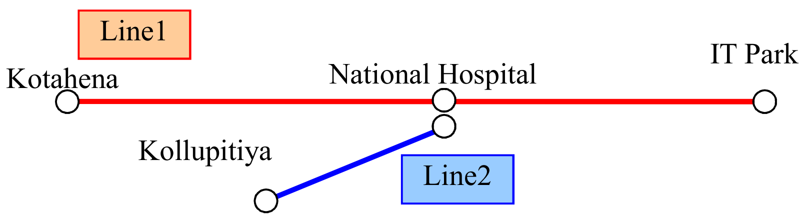
Table 5.2.3 Required Frequency

Year	2020		2025		2035	
Line	Line 1	Line 2	Line 1	Line 2	Line 1	Line 2
PPHPD	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Headway	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Capacity	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Load factor (%)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Source: SKYTRAIN Study Team

(5) Operation Pattern

Through operation with Line 1 and Line 2 is not considered. Following figure shows the operation pattern.



Source: SKYTRAIN Study Team

Figure 5.2.3 Operation Pattern

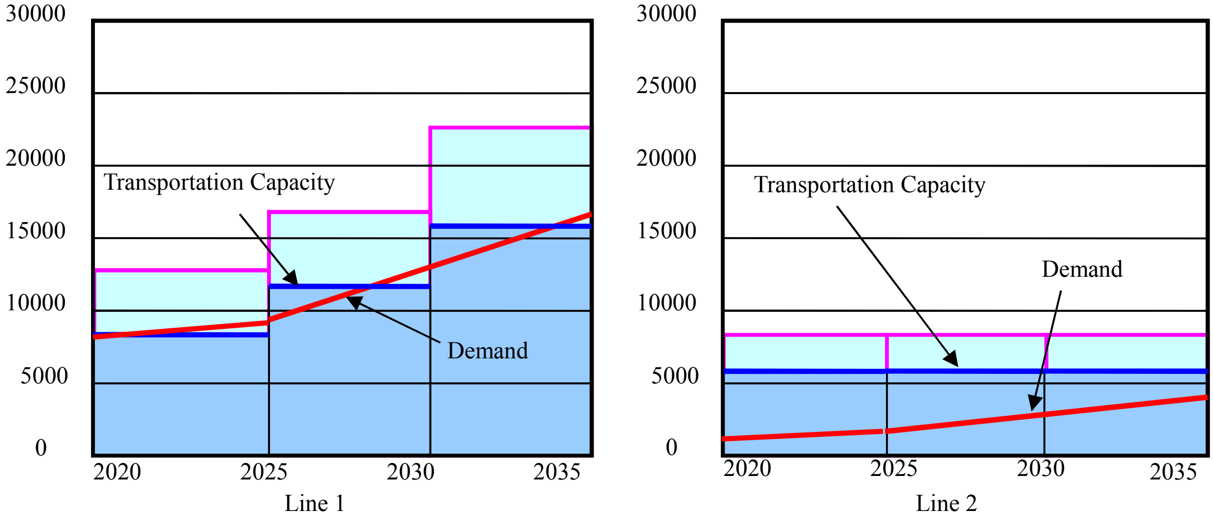
From year 2025 to year 2035 demand increase extremely. Train headway should be changed between year 2025 to year 2035. Assuming that demand increase proportional from year 2025 to year 2035 headway of each period is proposed as follows.

Table 5.2.4 Operation Headway

Year	2020～2024		2025～2029		2030～	
Line	Line 1	Line 2	Line 1	Line 2	Line 1	Line 2
Headway	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Source: SKYTRAIN Study Team

Demand and transportation capacity of peak section for each line is indicated below. The red line indicates forecast demand and the blue line indicates transportation capacity. In Line 1, demand will exceed the capacity after some years from the milestone year, however there is still some room for increase until reaching maximum loading condition, which is 10 passengers / square meter as indicated in pink line.



Source: SKYTRAIN Study Team

Figure 5.2.4 Demand and Transportation Capacity

(6) Traveling Time

Traveling time is calculated by simulation. Traveling time from terminal to terminal is indicated below.

Table 5.2.5 Travel Time

Section		Traveling time
Line 1	Kotahena – IT Park	53 min 45 sec
Line 2	Kollupitiya – National Hospital	4 min 53 sec

Source: SKYTRAIN Study Team

Turn back time at the terminal is different depending on the turn back facilities at the terminal. The following turn back times are considered to calculate round trip time but actual turn back time will be decided based on diagram.

Table 5.2.6 Turn Back Time

Terminal	Turn Back Time
Kotahena	[redacted]
IT Park	[redacted]
National Hospital	[redacted]
Kollupitiya	[redacted]

Source: SKYTRAIN Study Team

Minimum round trip time is calculated as below.

Table 5.2.7 Round Trip Time

Section		Traveling time
Line 1	Kotahena – IT Park	113 min 30 sec
Line 2	Kollupitiya – National Hospital	15 min 45 sec

Source: SKYTRAIN Study Team

(7) Train schedule

Required number of trains is determined by the train schedule in the peak hour. In the opening year headway in peak hour is [redacted] minutes in Line 1 and [redacted] minutes in Line 2. The train diagrams of both lines in peak hour are indicated below.

Source: SKYTRAIN Study Team

Figure 5.2.5 Train Diagrams in Peak Hour

A total of 19 trains are operated in Line 1 and 2 trains are operated in Line 2.

After 2025 trains will be operated with 4 minutes of headway in Line 1 and 8 minutes in Line 2. The train diagrams in peak hour of this stage are indicated below.

Source: SKYTRAIN Study Team

Figure 5.2.6 Train Diagrams in Peak Hour

A total of 15 trains are operated in Line 1 and 2 trains are operated in Line 2.

After 2030 trains will be operated with 3 minutes of headway in Line 1 and 8 minutes in Line 2. The train diagrams are indicated below.

Note: A total of 15 trains are operated in Line 1 and 2 trains are operated in Line 2.

Source: SKYTRAIN Study Team

Figure 5.2.7 Train Diagrams in Peak Hour

(8) Number of Rolling Stock

Required Number of Rolling Stock based on train diagram in peak hour is indicated below.

Table 5.2.8 Number of Trains

Year	2020～2024		2025～2029		2030～	
Line	Line 1	Line 2	Line 1	Line 2	Line 1	Line 2
Headway (min.)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Trains / hour	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Number of trains in operation	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Reserved Trains	[redacted]		[redacted]		[redacted]	
Total Number of Trains	[redacted]		[redacted]		[redacted]	

Source: SKYTRAIN Study Team

Rolling stock procurement plan is indicated below.

Table 5.2.9 Rolling Stock Procurement Plan

Item	2020	2025	2030
Number of Train Sets to Procure	[redacted]	[redacted]	[redacted]
Number of Rolling Stock to Procure	[redacted]	[redacted]	[redacted]

Source: SKYTRAIN Study Team

(9) Train Dispatching

Figure 5.2.8 shows examples of train diagrams for a weekday from 05:00 to 24:00 in Phase 1.

Source: SKYTRAIN Study Team

Figure 5.2.8 Examples of Daily Train Diagrams

At night time most of the trains are in the depot for stabling or inspection. Three trains will be stabled, one each at Kotahena, National Hospital and Kollupitiya stations. Stabling at a station will occupy only one track of the station so that maintenance vehicles can turn back and change the track and no train will be stabled at intermediate stations so that maintenance vehicles can pass.

It will take about one hour to go to Kotahena from the IT Park. Trains can deliver passengers from Kotahena to the park one hour after leaving the depot. The train stabled at Kotahena station in the night will provide the service from Kotahanena to the IT Park in the early morning. Yet it will take one hour until the next train comes from the Depot. In line 2 one pocket track is located at the National Hospital that will be available for stabling one train and one track in Kollupitiya is available for stabling two trains. The train stabled in Kollupitiya station will run on Line 1 after arriving at National Hospital station and provide service on Line 1. The train stabled in the National Hospital station will provide shuttle service in Line 2 until the train from the depot arrives.

At peak hour there will be [redacted] trains on line [redacted] and 2 on line 2. A total of [redacted] are required for operation. [redacted] trains will be reserved as spare trains. Two trains are reserved for maintenance and one train is reserved for accident or train failure. A total of [redacted] trains will be required.

The following figure shows the dispatch pattern of the trains.

Source: SKYTRAIN Study Team

Figure 5.2.9 Daily Train Schedule

In the morning, 18 trains are injected into the main line from the depot. Including the trains stabled in the station, [redacted] trains are operated at rush hour in the morning. After rush hour in the morning [redacted] trains return from the main line to the depot. A total of [redacted] trains are operating in off peak during the day time. Before rush hour in the evening [redacted] trains are injected into the main line from the depot. A total of [redacted] trains are operated at the rush hour in the evening. After rush hour in the evening trains return to the depot by midnight. A total of [redacted] trains will remain on the main line and will be stabled at the stations.

(10) Rolling Stock Maintenance Plan

Maintenance ranks are classified as follows.

Table 5.2.10 Classification of Rolling Stock Maintenance

Rank	Interval	Duration	Location	Works
Pre-departure inspection (daily inspection)	Before departure (every day)	30 minutes	Daily inspection shed, stabling yard	Function check
Train inspection	Within 6 days	2 hours	Daily Inspection shed	Function check and exchange consumables
Regular inspection (Quarterly inspection)	3 months	2 days	Monthly Inspection shed	Condition inspection of important parts Exchanging worn parts
Important part inspection (Semi-overhaul)	3 years	30 days	Workshop	Dismantling inspection of important parts
General inspection (Overhaul)	6 years	45 days	Workshop	
Tire exchange	Occasional (wear of tires)	1 day	Tire exchanging shed	Exchange worn tire
Occasional repair	Occasional (rolling stock failure)	Depending on need	Repairing track	
Cleaning (machine)	3 days	20 minutes	Cleaning track	Cleaning Outside by cleaning plant
Cleaning	10 days	5 hours	Manual cleaning track	Cleaning outside and interior

Source: SKYTRAIN Study Team

Based on the daily diagram, 6 hours will be available in the day time and 8 hours are available in the night time. Pre departure inspection, train inspection, and cleaning will be conducted while trains are assigned in operation but other work shall be conducted when trains are assigned as a reserved train.

(11) Monthly Maintenance Plan

The following figure indicates an example of a monthly maintenance schedule.

train set \ date	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
#1	S2	S2	S2	S2	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9
#2	1	2	3	4	S2	S2	S2	S2	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8
#3	21	1	2	3	4	5	6	7	S2	S2	S2	S2	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7
#4	20	21	1	2	3	4	5	6	7	8	9	10	S2	S2	S2	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6
#5	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	S2	S2	S2	S2	16	17	18	19	20	21	1	2	3	4	5
#6	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	S2	S2	S2	S2	19	20	21	1	2	3	4
#7	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	S2	S2	S2	S2	1	2	3
#8	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	S2	S2	S2
#9	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2
#10	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1
#11	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
#12	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
#13	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
#14	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
#15	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
#16	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
#17	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
#18	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	S1	S1	S1	S1	S1
#19	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	S1	S1	S1	S1	S1	10	11	12	13	14
#20	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	S1	S1	S1	S1	S1	4	5	6	7	8	9	10	11	12	13
#21	3	4	5	6	7	8	9	10	11	12	S1	S1	S1	S1	S1	19	20	21	1	2	3	4	5	6	7	8	9	10	11	12
#22	2	3	4	5	6	S1	S1	S1	S1	S1	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10	11
#23	S1	S1	S1	S1	S1	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1	2	3	4	5	6	7	8	9	10
#24	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2

monthly inspection (yellow)
overhaul or semi-overhaul (magenta)
reserved for accident (orange)

Source: SKYTRAIN Study Team

Figure 5.2.10 Example of Monthly Maintenance Schedule

Each number in a cell indicates an operation number and a number beginning with an "S" indicates a reserved train.

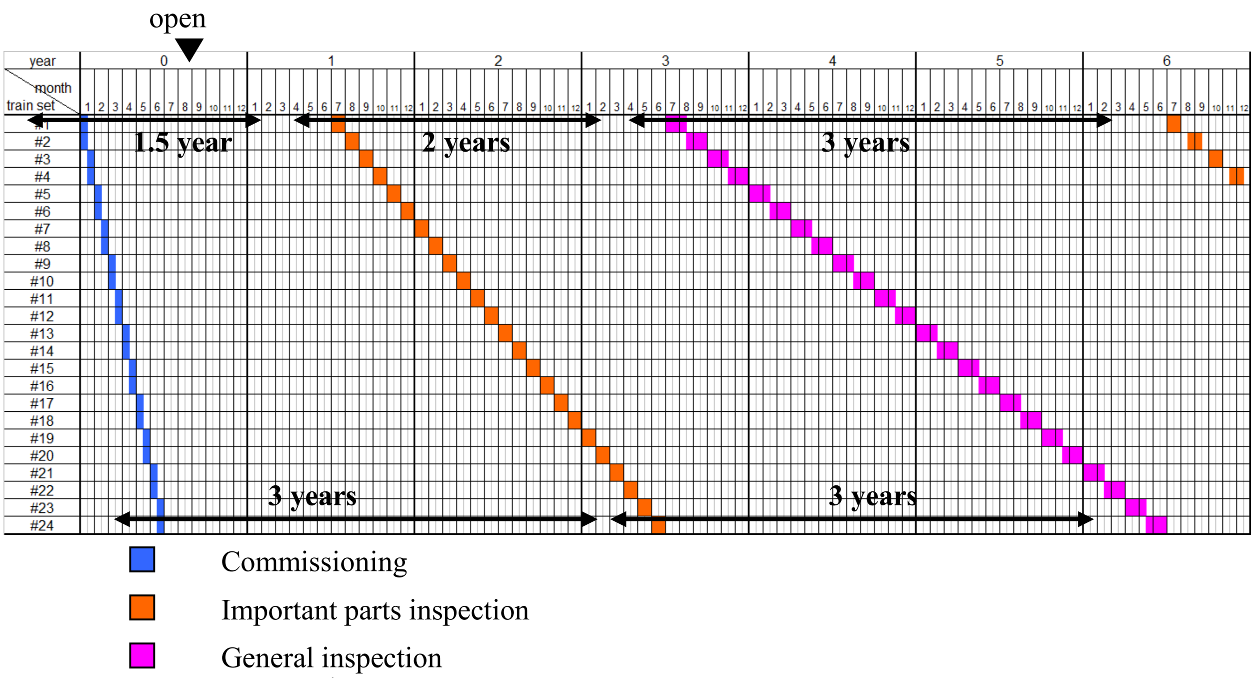
Yellow cells indicate monthly maintenance. The maintenance shed for monthly maintenance is occupied 16 days a month. With this condition 1 track for monthly maintenance is enough.

(12) Heavy Maintenance Plan

The following figure shows an example of a heavy maintenance schedule such as important parts inspection and general inspection for the first six years from opening of the line.

Trains will be delivered at least 6 months before opening for integrated testing and familiarizing of operation and maintenance staff. Usually trains for a newly opened line are delivered at almost the same time or within 6 months of each other. When following the interval as indicated in Figure 5.2.11, the heavy maintenance would be conducted for all the trains in the same year and there would be no work for the workshop for the next 2 years. This is not efficient utilization of workshop facilities or human resources.

To solve this issue, the first heavy maintenance will be conducted earlier than scheduled. The first important parts inspection of the first train will be conducted one year and six months after it begins operation. Then the next train will be in the shop in one year and 7 months. The important parts inspection of the last train will be conducted 3 years after commissioning. After 6 years the trains will come in for maintenance evenly.



Source: SKYTRAIN Study Team

Figure 5.2.11 Example of Heavy Maintenance Plan for Rolling Stock

In this stage, only one track is required for heavy maintenance in the workshop.

5.2.2 Depot Facilities

(1) General

Depot will be constructed along the line for stabling and maintenance of the rolling stocks. Depot will be the base of other maintenance work such as track, civil and electric as well and also will be the base of train drivers.

There is no train operation in the night time and facility maintenance will take place in the night. Rolling stock shall be stored in the depot to clear the track so that maintenance vehicle can pass. Depot should have enough capacity to stable all the trains except trains to stable in terminal for standing by the operation of next morning.

Maintenance of rolling stock will be conducted in the depot. Therefore depot shall have the facilities for maintenance of rolling stock.

(2) Location

Location of the depot shall be not in the city centre but at the other end of the line that is a residential area. In the morning, trains shall be injected from the depot to the line. Direction of the trains is going to the city centre and that is same direction as the movement of the people going to work. Similarly trains will go back to the depot when people are going back to their residences.

The depot is planned to be constructed north of the IT Park terminal, which is the eastly most terminal of the line as indicated in Figure 5.2.12. An access track to the depot will branch from a point east of the IT Park terminal. The access track will drop down from an elevated level to ground level where the depot is to be constructed at ground level.

Source: SKYTRAIN Study Team

Figure 5.2.12 Location of Depot

(3) Facilities

Following facilities are planned to be installed in Depot.

Table 5.2.11 Facilities of Depot

Category	Item	Facilities/Equipment	Remarks
Building	Administration office	Administration office Train clue office	
	Workshop	Technical staff office Facility maintenance office Body shop Machine shop Wheel and bogie shop Ware house Substation	
	Inspection shed		
	Tire exchanging shed		
Tracks	Stabling washing track		
	Lead track		
	Train washing track		Manual washing
	Train washing track	Train washing plant	
	Inspection track		In inspection shed
	Mantling/dismantling track	Overhead crane	In workshop
	Stabling track for maintenance vehicle	Maintenance vehicle	
	Train installation track		
Other Facilities	Water treatment plant	Water tank, waste water treatment plant	
	Car park		

Source: SKYTRAIN Study Team

(4) Capacity of Depot

Number of tracks for stabling and maintenance shall be decided based on number of trains.

Following table indicates number of trains in each milestone year calculated in train operation plan of this report.

Table 5.2.12　Number of Rolling Stock

2020	2020	2025	2030
Total Number of Trains	[redacted]	[redacted]	[redacted]

Source: SKYTRAIN Study Team

To minimise the cost, the depot will be constructed with train capacity adequate for the first 5 years after opening and the land for expansion will be reserved. It is also projected that the line will be extended north from Kotahena and east or north from the IT Park. In such case the number of trains is estimated to reach more than 90. Totally about 12 ha of land is reserved for the depot complex.

(5) Required number of tracks for depot and workshop

Based on the train operation plan, the required facilities and track for the depot and workshop is projected to be as follows.

Table 5.2.13　Required Number of Tracks for Depot and Workshop

	Item	year		
		2020~	2025~	2030~
Stabling yard	Stabling track	19	30	39
Inspection shed	Inspection track (monthly inspection)	1	1	2
	Inspection track (occasional inspection)	1	1	1
	Washing track with washing plant	1	1	1
	Washing track	1	1	1
workshop	Track for dismantling	1	1	2
	Shop-out inspection track			
	Repairing track	1	1	1
Tire exchanging shed	Tire exchanging track	1	1	1

Source: SKYTRAIN Study Team

The depot shall have enough capacity to store the trains at night while no trains are being operated. Considering that 3 trains will be stabled at the station and two trains will be stabled at the inspection shed for maintenance, the number of stabling tracks should be adequate to hold the total number of trains minus 5. The number of tracks for monthly inspection is defined based on the maintenance schedule.

In the opening year, the depot will be constructed with a capacity for 35 trains and it is projected to enhance the stabling track for an additional ten trains by 2030.

Figure 5.2.13 indicates the layout of the depot. The dotted lines indicate stabling tracks for expansion in year 2025. A total of 30 trains can be stored in the depot in the first stage in stabling tracks. The tracks will be expanded when procuring rolling stock. In the ultimate stage 60 trains can be stabled.

Figure 5.2.13 Depot Layout

5.3 Plan and Design for Structures and Facilities

5.3.1 General Criteria

The choice of structural solutions, appropriate for the congested urban setting of Metro Colombo, is in general governed by the following conditions:

- Structures and construction methods that are easier to construct and will minimise the impact on traffic, right-of-way, construction of temporary yards and the urban environment,
- Structure type that is cost-effective and faster to construct,
- Structural system that is resistant and reliable against expected loads,
- Structural type that is easy to maintain,

For Monorail viaduct structures carrying frequent loads through urban areas, the following considerations must also be addressed:

- The viaducts must provide emergency evacuation systems.
- Vibrations and deflections criteria – the limitations established for vibrations and deflections for rail structures are more stringent than typical highway loading due to the sensitivity of the train operations to structure movements
- Structure/vehicle interaction – vehicle interaction with the viaduct structure can affect its performance as related to support, steering, power distribution and traction components of the system.
- Ride quality. System specifications usually present ride quality criteria as lateral, vertical and longitudinal acceleration and jerk rates (change in rate of acceleration) as measured inside the vehicle.
- Noise control - the noise level created by trains is often a concern in areas where the alignment passes through residential areas or parks

(1) Existing Design and Construction Standards

Civil engineering facilities in Sri Lanka are designed and constructed in accordance with international standards and applicable local codes, regulations, standards and requirements of local statutory authorities and agencies. The MOT in Sri Lanka does not have a policy of enforcing particular international standards and such standards are set on an ad hoc project by project basis.

For the most recent project implemented by the MOT in Sri Lanka, the standards referenced in the road bridge structure are presented in Table 5.3.1.

Table 5.3.1 Bridge Design Standards Prevailing in Sri Lanka

No.	Standard Name
1)	Geometric Design Standards of Roads (1998)
2)	Bridge Design Manual (1997)
3)	British Standard BS 5400-2 (1978)
4)	Design Standards for Structures (The Outer Circular Highway to the City of Colombo)

Source: Preparatory Survey on Traffic Improvement Project around New Kelani Bridge

5.3.2 Design Standards and Specifications

(1) Civil Structures

Since there is no design standard for monorails in Sri Lanka, the monorail design is carried out based on the "Monorail Structural Standards" in Japan.

An outline of the design standard and criteria applied to monorail design shall be mentioned hereinafter but items for monorail structures not included in this clause shall be designed in accordance with the following guidelines and specifications and/or the design standard listed below.

1)	Road Bridge Specification, General And Steel Bridge Volumes	:	Japan Road Association
2)	Reinforced Concrete Road Bridge Design Specification	:	Japan Road Association
3)	Prestressed Concrete Road Bridge Specification	:	Japan Road Association
4)	Road Bridge Substructure Design Guidelines	:	Japan Road Association
5)	Road Bridge Seismic Design Guidelines	:	Japan Road Association
6)	Concrete Standard Specification	:	Japan Society of Civil Engineers
7)	Prestressed Concrete Design And Construction Guidelines	:	Japan Society of Civil Engineers

(2) Design Load

The following design loads have been particularly considered in the outline design of the monorail for a reference purpose. Each design load shall be calculated based on the actual condition since, for example, the live load depends on the product of the rolling stock and related loads will be changed accordingly.

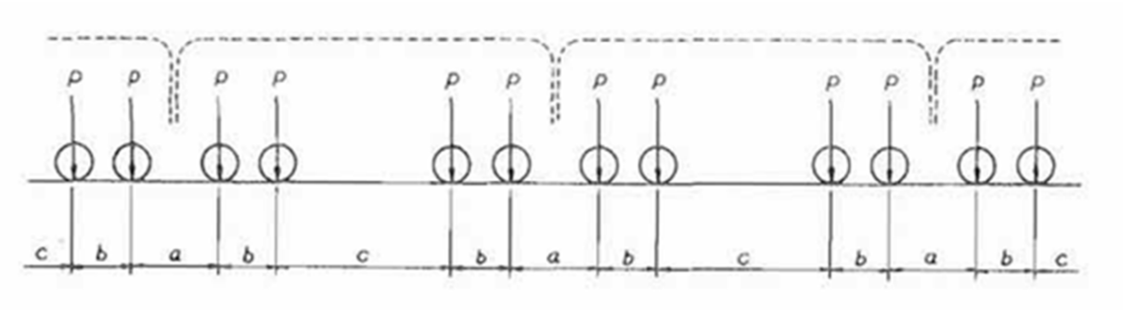
1) Dead Load

The nominal dead load initially assumed shall be accurately checked with the actual weights to be used in construction.

2) Live Load

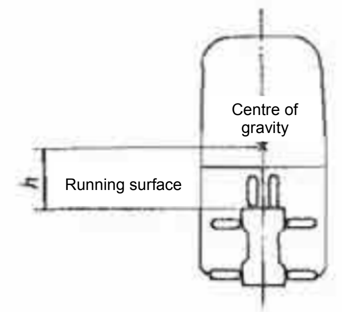
Live loads shall consist of the design monorail rolling stock load and the crowd load of the stations.

The design monorail rolling stock load shall be in accordance with Figure 5.3.1 and Figure 5.3.2 and Table 5.3.2 while the loading shall be as shown below.



Source: Design Guidelines for Monorail Structures Japan

Figure 5.3.1 Axial Arrangement



Source: Design Guidelines for Monorail Structures Japan

Figure 5.3.2 Location of Centre of Gravity

Table 5.3.2 Axle Loads and Values

Value / Type		Axle load P (ton)	Axial arrangement and dimensions (mm)			Centre of gravity h (mm)
			a	b	c	
Straddle-beam	Large	10.0	3,100	1,500	8,000	1,300
	Medium	7.0	2,600	1,400	4,700	1,250
	Small	2.5	1,700	800	3,200	1,150

Source: Design Guidelines for Monorail Structures Japan

- The design monorail rolling stock load shall be considered a drag load regardless of the number of cars per formation, and the load shall be applied so as to cause the most unfavourable stress on the members. However, the design monorail rolling stock load shall generally not be divided into more than two parts.
- When considering the impact of fatigue on support structures and viaducts which support double-tracked monorail guideways, single-track loading shall be applied.

Crowd load shall be applied as shown below.

- An equally distributed load of $5.0kN/m^2$ shall be applied for the design of floors and floor systems.
- An equally distributed load of $3.5kN/m^2$ shall be applied for the design of main girders.

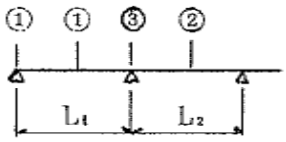
3) Impact Load

Live loads shall include impact loads. However, impact load shall not be considered for sidewalks, etc. The superstructure impact coefficient shall employ the span lengths (L) shown in and be calculated with the equation below.

The impact load caused by live loads need not be considered for the superstructure reaction force used in the design of substructures. However, it shall be considered for bearings and the bodies of substructures when these are made of concrete or steel girders or similar light materials.

$$i = \frac{20}{50+L}$$ i: impact load, L: span (m)

Table 5.3.3 Spans used when Impact Coefficients are Required

Type	Member	L (m)
Simple girder	Girder and bearing	Span
Continuous girder		L_1 for load ① L_2 for load ② $(L_1 + L_2)/2$ for load ③

Source: Design Guidelines for Monorail Structures Japan

4) Lateral Rolling Stock Load

The concentrated uniaxle live load shall be used for the lateral rolling stock load and shall be applied at the height of the running surface as well as horizontally and perpendicular to the guideway axis. It shall be 25% of the load on one axle of the design monorail rolling stock for coupled monorail rolling stock.

5) Seismic Impact

Structures in Sri Lanka do not need to be designed for loads due to earthquakes as Sri Lanka is not in a zone affected by earthquakes

6) Centrifugal Load

On curved sections, a centrifugal load determined with the following equation shall be applied at the height of the centre of gravity of the rolling stock, horizontally at the axes and perpendicular to the guideway. Impact load shall not be considered.

$0 < R \leqq 500m$ $\qquad F = 0.17P$

$500m < R$ $\qquad F = 85\left(\frac{1}{R}\right)P$

where F: centrifugal load (t)

R: curve radius (m)

P: axial load due to design monorail rolling stock load (t)

However, it shall be possible to reduce the above centrifugal load for the track girder by adding cant.

7) Collision Load

Sufficient protective facilities, such as concrete walls, shall be constructed for columns at risk for car collisions. If such protective facilities cannot be constructed, either of the following collision loads shall be applied at a 1.8m height from the road surface in the design.

In the direction of the guideway : 100t

Perpendicular to the guideway : 50t

When columns or piers are constructed on or close to sea routes where there is a risk of collision from ships, this shall be considered in the design.

If driftwood or other floating objects pose a collision risk, the collision force shall be calculated with the following equation and the force shall be applied at the same height as the water surface.

$$P = 0.1\ W * V$$

where P : collision force (t)

W: weight of floating object (t)

V: surface velocity (m/sec)

(3) Track

1) Curve Radius

The radius of a curve line shall be more than 100 meters. However, in case of terrain condition or other unavoidable reason, curve radius could be reduced as long as it does not hinder train operation.

2) Transition Curve

a) Except for curves incidental to turnouts, circular curves and straight lines in main tracks must be connected with transition curves.
b) The length of the aforementioned transition curve shall be more than or equal to the value from the following formula:

The straddle type is L=V3/14 R

The suspension type is L=V3/28 R

Where L: Length of transition curve (unit: m)

V: Design speed in curve (unit: km/h)

R: Curve radius (unit: m)

c) In case of connecting two circular curves in the same direction with different radius, the length of the transition curve to be inserted shall be more than the length of the difference between these transition curves obtained by the formula shown in the previous section.

3) S Curve

Except for curves incidental to turnouts, in general, the interior ends of the spiral transition of the S curve shall be connected by an intermediary straight line with a length equal to one or more of a rolling stock length. However, in case of terrain condition or other unavoidable reason, it is possible to directly connect the two transition curves.

4) Cant

a) Except in curves incidental to turnouts, cant for circular curves in the main track shall be less than or equal to 12%.

b) Cant shall be gradually decreased along the total length of the transition curve.

5) Slope

a) Slope of the line shall be less than 60‰. However, it may be less than 100‰ in case of terrain condition or other unavoidable reason.

b) If a curve is in a sloping section, additional value for the slope is calculated based on the following formula:

$g = 800/R$

where R: curve radius (unit: meter)

g: reduction of slope due to curve radius (unit: per-mil)

c) Slope of the main track in the station yard shall be less than 10‰. In addition, if a buffer stop, turnout or intersection is located in a station yard, slope in the station yard shall be less than 5‰.

d) In the parking area and coupling – decoupling area for rolling stock, the slope shall be less than 5‰.

6) Vertical Curves

A change in the slope of the main track shall be provided with a vertical curve with a radius equal to or more than 1,000 meters. However, it may be reduced to 400 m, in case of terrain condition or other unavoidable reason. This shall not be applied for a section where the change in slopes is less than 5‰ where insertion of a vertical curve is unnecessary.

7) Distance between Track Centres

Distance between track centres of the main track and main track / siding track shall be greater than the value obtained by adding the rolling stock clearance to:

a) 1/2 of the difference between the rolling stock clearance and construction clearance;

b) 1/2 of the lateral direction amplitude of the rolling stock occurring during normal train operation.

(4) Design Specification

For the conceptual design of the straddle-type monorail, the major design specifications to be applied to the project are considered based on the design standard as mentioned above and referring to cases of neighbouring countries as shown in Table 5.3.4.

Table 5.3.4 Design Specification

Item	Specification
Type of Monorail	Straddle-beam type
Car Size	Large size
Construction Gauge	Please refer to Figures 5.3.3 and 5.3.4
Minimum Curve radius	Main track R = 60 m Station R = 0 m Depot R = 50 m
Minimal distance between horizontal curves	30 meters
Maximum gradient	Main track 60.0 ‰ Station Level
Vertical curve	Minimum radius 1000 meters
Track Distance	Centre to centre minimal distance of adjacent tracks is 3.7 meters
Platform length	70 meters
Axis load	Axis load from monorail is 11 ton. Maximal load on a single beam is 66 ton.
Beam weight	55 ton per beam of 22 meters

Source: SKYTRAIN Study Team

The construction and car gauge of the straddle – type monorail are shown in Figure 5.3.3. The track centre spacing shall be 3.7m in a straight section, and the track centre spacing of the curved line section ensures the spacing according to each curve. Figure 5.3.4 shows the track centre spacing on the straight section.

Source: SKYTRAIN Study Team

Figure 5.3.3 Construction and Monorail Car Gauge for Large Size

Source: SKYTRAIN Study Team

Figure 5.3.4 Track Centre Spacing on the Straight Section for Large Size

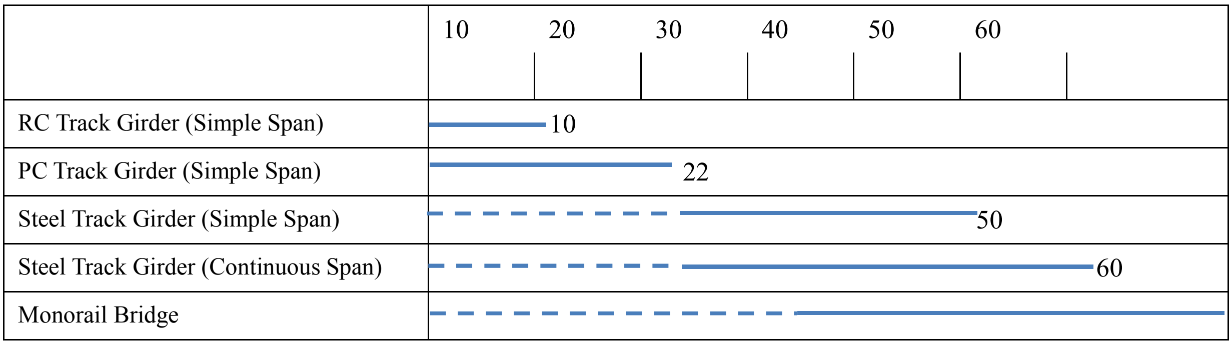
5.3.3 Structures and Facilities

(1) Viaduct

1) Super-structure

Structure Type

Structure type of the superstructure shall be determined based on the applicable span length, girder erection method, sectional form and local conditions of the construction technology. Figure 5.3.5 shows the structure type of superstructures (track girder and bridge for monorail girder) based on the span length. The superstructures are required to possess adequate safety against all loads during both service and construction stages, and are also required to possess appropriate performance for monorail running, maintenance as well as economic efficiency. From this point of view, the simple span pre-stressed concrete girder (PC-Girder) is selected as a standard type for the track girder (L < 22m). The PC-Girder can be manufactured with high accuracy and can secure high durability because the girder will be fabricated in a quality controlled plant. The steel girder will be applied to where a longer span is required due to the existing road condition (22m < L < 60m). Moreover, in the case that the larger span (out of range of steel girder) and particular girder erection method due to the existing road condition is required, a monorail bridge which can support the track girder will be used. The following figure shows the type of super-structure and its available span length.



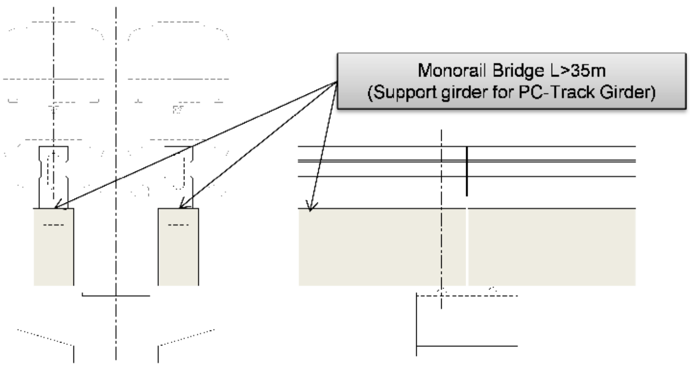
Source: SKYTRAIN Study Team

Figure 5.3.5 Type of Superstructure

The following photos show the PC track girder and steel track girder with mono-type piers.

Source: SKYTRAIN Study Team

Figure 5.3.6 PC Track Girders with Mono-type Piers.

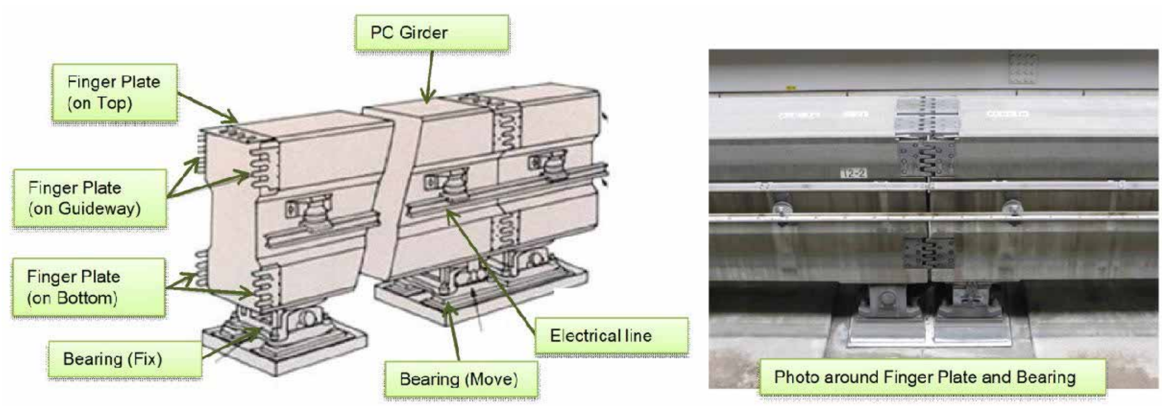


Source: SKYTRAIN Study Team

Figure 5.3.7 Monorail Bridge

<u>PC Track Girder (as a standard type for superstructure)</u>

As mentioned in the previous chapter, PC track girder is selected as a standard type for the super-structure. Since the girder will be used as both girder and track, the girder will support the rolling stock directly, and electrical lines will be set on the girder (see Figure 5.3.8). Considering the structural configuration of both rolling stock and PC-girder, the width of the girder is set as [redacted] mm. The height of the girder is set as [redacted]mm and the typical span length is set as [redacted]m according to the record of large-sized monorail (see Figure 5.3.9). The Photo below shows standard structure for a viaduct.



Source: http://www.tokyo-monorail.co.jp/fun/feature.html

Figure 5.3.8 Structural Details of PC - Girder

Source: SKYTRAIN Study Team

Figure 5.3.9 Structural Dimensions of PC-Girder

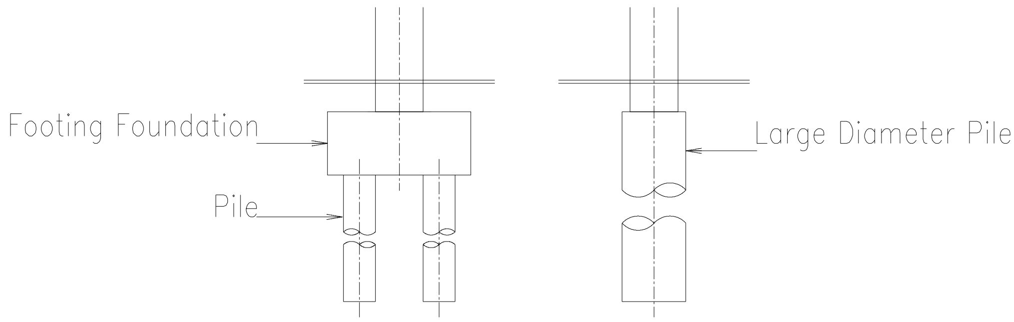
2) Foundation and Sub-structure

<u>**Foundation**</u>

The following are two types of foundation structures to be considered in this project (refer to Figure 5.3.10):

- Footing foundation consists of concrete bored piles of small diameter and pile cap.
- Single pile foundation with large diameter pile

The standard type of pier usually used is the footing foundation which is a conventional type that is easy to construct and is an economical one. The footing foundation will be adopted for fine ground conditions and places without restriction on construction. On the other hand, the single pile foundation will also be considered. Although the construction cost of this method is higher, it has an advantage to minimise the construction yard as a pile cap is not needed. Moreover, this type can shorten a construction period greatly. However, the ground must have enough strength to bear horizontal forces such as eccentric loads and earthquakes.



Source: SKYTRAIN Study Team

Figure 5.3.10 Section for Foundations

Sub-structure (Pier)

Structure type of the sub-structure will be determined based on the load scale of the super-structure, supporting method, location and condition of the bearing layer, ground water level, environmental issue and local conditions of the construction technology. The structure types which may be selected as the pier for the monorail structure are usually the following two types.

- Mono Type Pier
- Portal Type Pier

The standard type of pier used shall be the Mono Type Pier. For this project, the piers will be planned within the existing road area in principal. This concept does not affect the traffic lanes or sidewalks and can also keep the construction yard and land acquisition area small, and does not interfere with the visual range of road traffic. The pier structure will be made by cast in place reinforced concrete structure, which can respond flexibly to the design and construction of the site condition. Although the pier position is basically prepared in the centre of the road, when the width of the road is narrow, the pier may be arranged at the end side of the road. Figure 5.3.11 shows the general sections of the substructure.

Source: SKYTRAIN Study Team

Figure 5.3.11 General Sections of the Sub-structure

If the centre of the monorail girder is not aligned with the centre of the pier, an eccentric load depending on the distance between the centres (the monorail girder and the pier) will occur at the joints of the pier head and pier body, foundation and piles. Especially with existing roads that have a wider width, the distance between the centres tends to be larger and results in an increased eccentric load. Therefore, there may be some places where the adoption of the mono-type pier is structurally difficult and in such cases, the portal type pier can be used (refer to Figure 5.3.12).

Source: SKYTRAIN Study Team

Figure 5.3.12 General Section for Portal-type Pier

(2) Stations

1) Station Function and Type

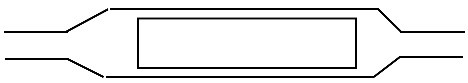
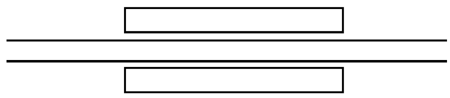
Basic Function

In order for stations to be functional, the planning of station buildings and facilities must assure passenger safety and comfort while making provisions for passenger convenience with user-friendly facilities. The stations must be designed to make adequate provision for disabled passengers and the station access ways must satisfy emergency egress requirements in the event of a fire.

Platform Type

The typical platforms types are the following two types including "a) Separate Platform type" and "b) Island Platform type". The type of platform at each station was selected following a comparative study of the characteristics of each station type, as shown in Table 5.3.5.

Table 5.3.5 Comparison of Platform Type

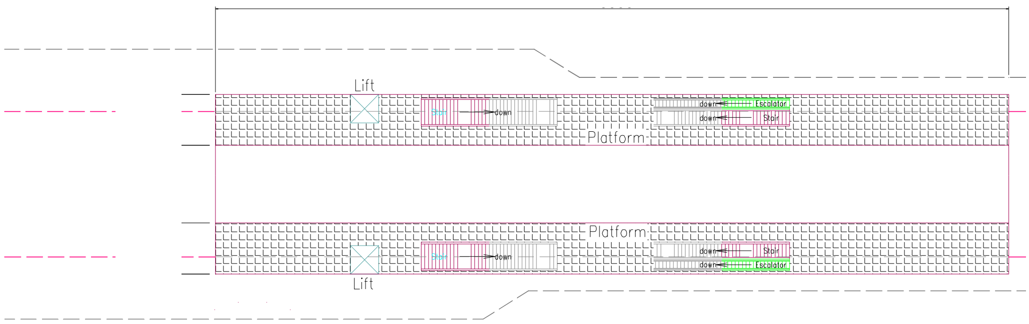
Type	Island Platform	Separate Platform
Outline Sketch		
Overall Width of Station	The overall width of the station with an island platform is narrower than that with separate platform.	The overall width of the station with separate platform is wider than that in an island platform.
Passengers Handling on the Platform	As there is one platform at the station, the passengers of departing and arriving trains can be handled on the same platform.	As there are separate platforms for each direction at the station, the passengers on each platform are handled separately.
Line Alignment	The curve sections should be installed at both ends of the station. Widening of the elevated structure for the track will be needed for a relatively longer section. It may give an oppressive feeling to the pedestrians and car drivers on the road.	As the line alignment is a straight line, the visibility of the train driver is good. The oppressive feeling of the pedestrians and car drivers on the road with an elevated structure will be less than that with an island platform.
Facilities for Platform access	As passengers for up and down trains will be accommodated on the same platform, the facilities for platform access/egress (stairs, elevators and elevators) can be shared.	The facilities for platform access/egress (stairs, escalators and elevators) must be installed at each platform.
Facilities Cost	The cost of access/egress facilities (stairs, escalators and elevators) for the island platform tends to be lower than that for the separate platform type.	The cost of access/egress facilities (stairs, escalators and elevators) for the separate platform type tends to be higher than that for the island platform.
Other Characteristics	Provides increased passenger convenience.	When the extension of the platform or the installation of a new station is needed, it is possible to construct them without any changes in the alignment.

Source: SKYTRAIN Study Team

After examining the comparison table above, the basic concepts for planning the station building and facilities are considered as follows.

- Typical platform type shall be the separate type platform considering ease of construction, good visibility for passengers and line alignment;
- The station types are categorised into three types which are the main station with separate type platform (with 2-ticketing gates), the general station with separate type platform (with 1-ticketing gate), and the National Hospital station with 2-platform and 3-lines of separate type platform;
- The effective length of each station platform is planned as [redacted]m which is composed of [redacted]m (one vehicle length) x [redacted] vehicles (the number of vehicles per train) [redacted] m (margin at each platform end). Moreover, a concourse floor will be installed in all stations;
- Access/egress facilities, emergency exits, the staff room and the electrical room will be installed at each station;
- Separate elevators will be installed in all stations for handicapped passengers to move easily from the ground level to the concourse floor (un-paid area) and from the concourse level to the platform (paid area).
- Platform doors (half-height) will be installed in all stations in order to prevent falling from the platform.

The plan and photos of a separate platform for a typical intermediate station are shown in the following figures.

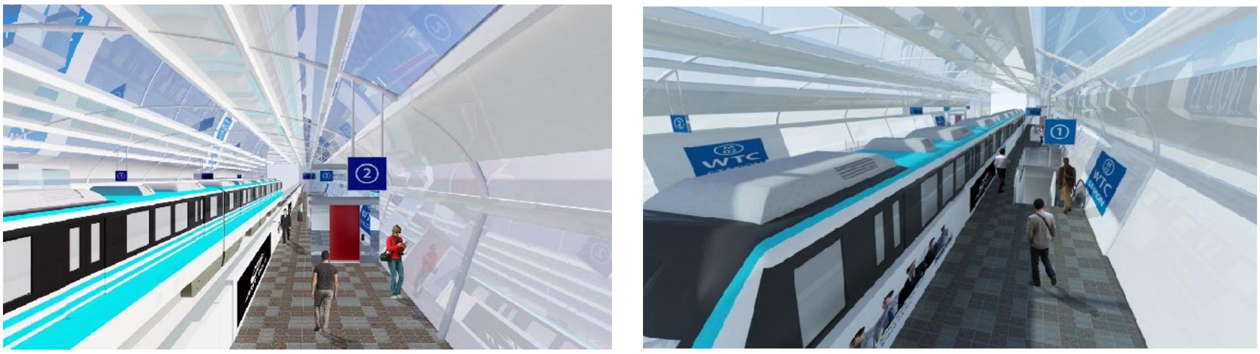


Source: SKYTRAIN Study Team

Figure 5.3.13 Plan of Separate Platform (General Station with 1-ticketing Gate)

Source: SKYTRAIN Study Team

Figure 5.3.14 Separate Platform Type (Tama Monorail Japan)



Source: SKYTRAIN Study Team

Figure 5.3.15 Images of Separate Platform

2) Station Facilities

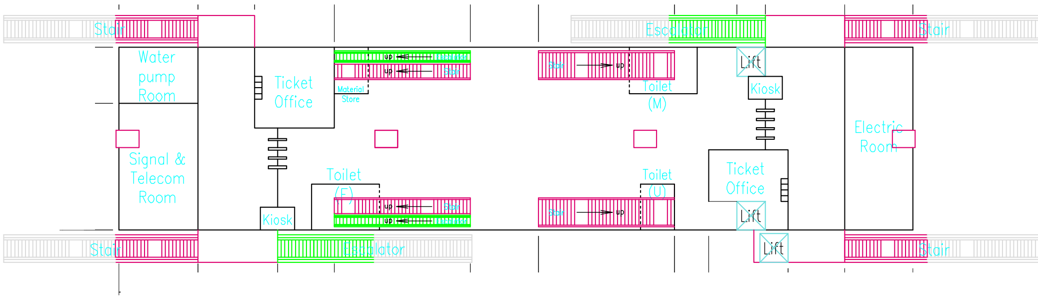
According to the basic concept for the station buildings and facilities described above, the types of facilities planned for each station are shown in Table 5.3.6.

Table 5.3.6 Station Facilities

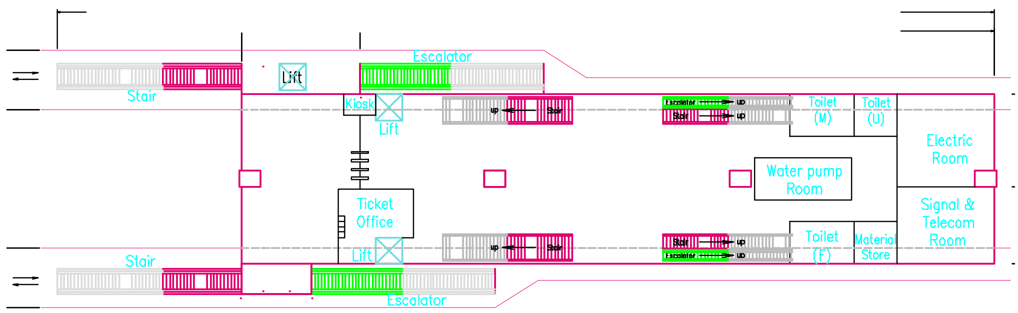
Item	Contents
Station Structure Type	a) Elevated
Platform Type	a) Separate platforms (two types include general stations with 2-ticketing gates and general stations with 1-ticketing gate) b) Separate two platforms with 3-lines (National Hospital)
Passengers' Access	a) Stairs and escalator (all stations) access from concourse level to platform level (paid area) b) Elevator access from ground level to concourse level at one side of the station c) Elevator access from concourse level to platform level (paid area) d) Emergency exit stairs at each platform, either to concourse level or to ground level.
Station Facilities	a) Lightning and electrical power b) Water supply system c) Drainage, sanitary and sewerage system d) Fire protection system e) Male and female facilities
Ticket Facilities	a) Ticket kiosks and ticket vending machines b) Automatic fare collection system
Passenger Aids	a) Platform Door b) Signage and graphic system (identification, directional, information and prohibition signs)
Facilities for Station Staff	a) Staff room/ locker room b) Office c) Toilet facilities d) Janitor room
Mechanical Room	a) Signalling room / telecommunication room b) Electrical room c) Elevator machine room
Concession Facilities	a) Non-paid area at concourse levels for development of commercial activities and concessionaire stalls (food and drink sale etc.)

Source: SKYTRAIN Study Team

The plan of a typical intermediate station and the photos of station facilities are shown in the following figures.



Station with 2-tickteing Gates

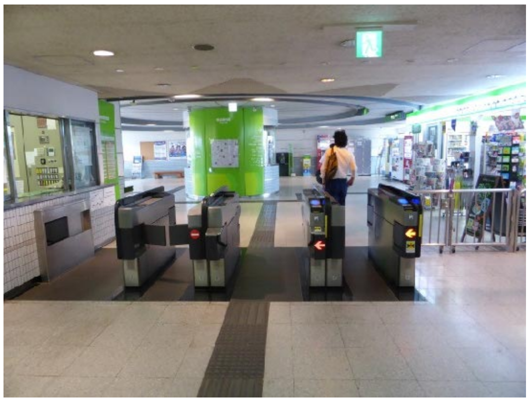


Station with 1-tickteing Gate

Source: SKYTRAIN Study Team

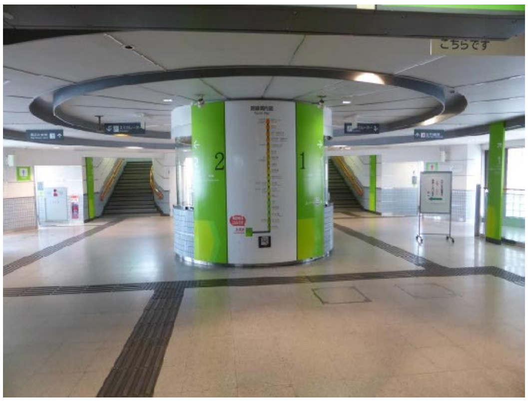
Figure 5.3.16 Plan of a Typical Intermediate Station (Concourse Level)

Ticket vending machines



Automatic fare collection

Kiosk in non-paid area



Signage (route information)

Stairs on platform

Elevator on platform

Platform door (closed)

Platform door (opened)

Source: SKYTRAIN Study Team

Figure 5.3.17 Station Facilities (Tama Monorail Japan)

Ticket vending machines and Automatic fare collection

Concourse (outside of ticketing gate)

Toilet

Concourse (inside of ticketing gate)

Source: SKYTRAIN Study Team

Figure 5.3.18 Images of Station Facilities

3) Station Structure Concept

The station structures are comprised of reinforced and pre-stressed concrete substructures supporting the concourse and platform levels with a structural steel superstructure frame supporting the station roof.

Mono-type pier with pile foundation structure is applied to the substructure for the station to support RC and PC slab, and steel super structure frame. RC and PC slab is installed as a base of the concourse floor and steel super structure. The steel super structure frame composes an external wall and platform level as well as a frame for the roof. Figure 5.3.19 shows the station structure concept for this study.

Source: SKYTRAIN Study Team

Figure 5.3.19 Station Structure Concept

Substructure

The current lane arrangement along the planned monorail corridor provides for two or four lanes in each road. Considering efficient land occupation and promoting smooth road traffic, the central piers which support the station structure on wide cantilever pier heads are adopted for typical stations.

A typical station illustrating the single central pier concept proposed and a photo of station building with single central piers (Tama Monorail Japan) are shown in the Figure 5.3.20 and Figure 5.3.21 below.

Source: SKYTRAIN Study Team

Figure 5.3.20 Section View for Typical Station with Single Central Piers

Source: SKYTRAIN Study Team

Figure 5.3.21 Station Building with Single Central Piers (Tama Monorail Japan)

<u>Station Roof</u>

The station roof will be selected in consideration of the scale, cost and material, landscape, and constructability etc. and be designed accordingly.

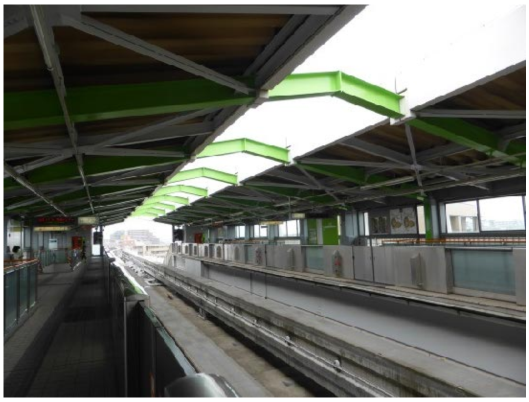
Since selection of the station roof needs to be discussed further during the design stage, only a sample and alternates of the station roof are introduced in this report.

A sample station roof illustrating the structure and photos of the station roof considering alternates are shown in the following figures.

Source: SKYTRAIN Study Team

Figure 5.3.22 A Sample of Station Building Roof

Tachikawa-minami station (Tama Monorail Japan)



Takamatsu station (Tama Monorail Japan)

Perspective image of a station of Daegu Monorail Korea

Source: Tama Monorail, SKYTRAIN Study Team; Deagu Monorail, Hitachi Ltd.

Figure 5.3.23 Station Roof

Source: SKYTRAIN Study Team

Figure 5.3.24 Perspective Image of a Station of SKYTRAIN Monorail

Safety Measures

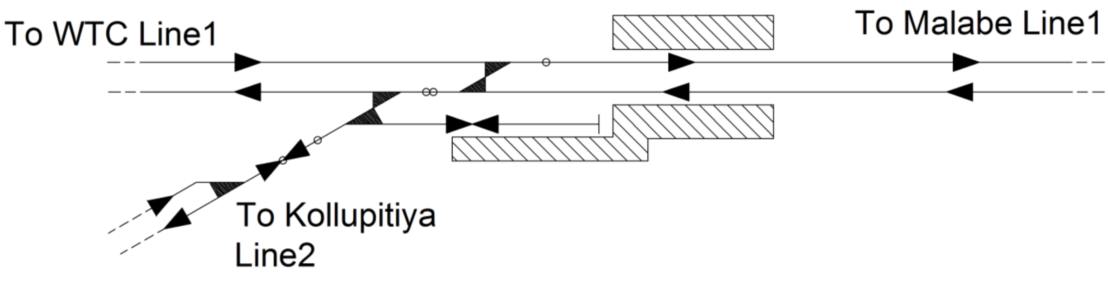
To quickly and safely evacuate passengers in an emergency situation, the following measures shall be taken:

- The station shall be equipped with facilities to transfer passengers safely through gangways to relief trains on the adjacent track.
- Evacuation routes shall be connected with a safe place.
- Except in an emergency situation and maintenance time, no person can enter the evacuation area.
- For fire control measures, the building structure shall use non-flammable, semi non-flammable or flame resistance material as much as possible. Fire control equipment shall be provided in stations.

4) National Hospital Station

Basic Concept

The two lines which are the Line-1 (Kotahena – Malabe) and the Line-2 (National Hospital – Bambalapitiya) will merge at the National Hospital station. The merging point of these two lines is planned on the same level. An overhead crossing which will impact surrounding landscape due to its height is not adopted in consideration of the harmony with the surrounding landscape. As a consequence, a station with two separate platforms with three lines will be applied for the National Hospital station. A schematic drawing of track alignment around the station is shown in Figure 5.3.25 and structural plans (plan and section) are shown in Figure 5.3.26 and Figure 5.3.27.



Source: SKYTRAIN Study Team

Figure 5.3.25 Schematic Drawing of Track Alignment around the National Hospital Station

Source: SKYTRAIN Study Team

Figure 5.3.26 Plan View around the National Hospital

Source: SKYTRAIN Study Team

Figure 5.3.27 Section View around the National Hospital Station

It is noted that a redevelopment project around the National Hospital is in progress. Therefore, further consultation to discuss the placement of the monorail station in the area will be required among the National Hospital, the developer, and MOT. In particular, at this moment, a portal type pier is planned to support the monorail track (girder) and station structure, however, in this case, confirmation of exact locations of the foundation of the portal-type pier and its construction yard which affect the development area will be needed.

<u>Accessibility around National Hospital</u>

There are many historical buildings around the National Hospital therefore it is necessary to consider accessibility between the station and such buildings. At the same time, since it is assumed that many patients and guests will use this station to visit the hospital, the passengers' mobility has to be well considered in this area.

To ensure the passengers' mobility concerned above, the pedestrian decks which connect between the station and the buildings are proposed as shown in Figure 5.3.28.

Source: SKYTRAIN Study Team

Figure 5.3.28 Proposed Pedestrian Decks between the National Hospital and Buildings

Since the proposed pedestrian decks are situated in front of historical buildings nearby the National Hospital, it is necessary to pay attention to the landscape to harmonise between the design of the pedestrian decks and the buildings. Further consultation will be required among the National Hospital, the developer, and the competent authorities.

(3) Depot Foundation

The depot area has to be set considering possible expansion to meet future passenger demand. Besides, the location of the depot is planned in a marshy area that has a retarding effect during flood, therefore, it is necessary to consider anti-flood measures when the design concept is made.

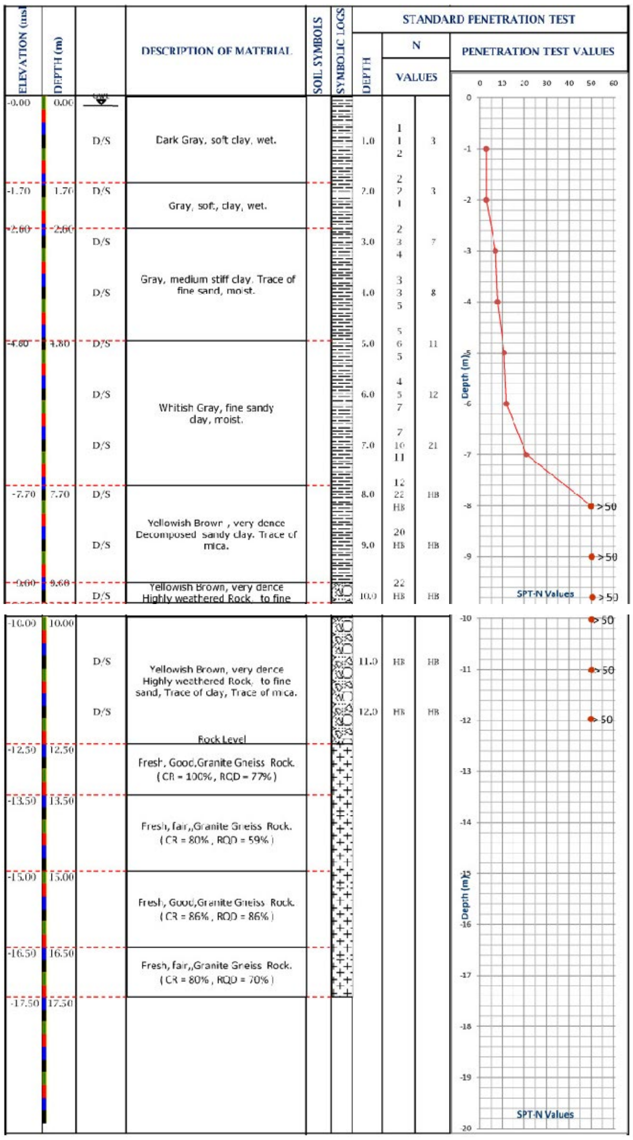
Source: SKYTRAIN Study Team

Figure 5.3.29 Depot Location

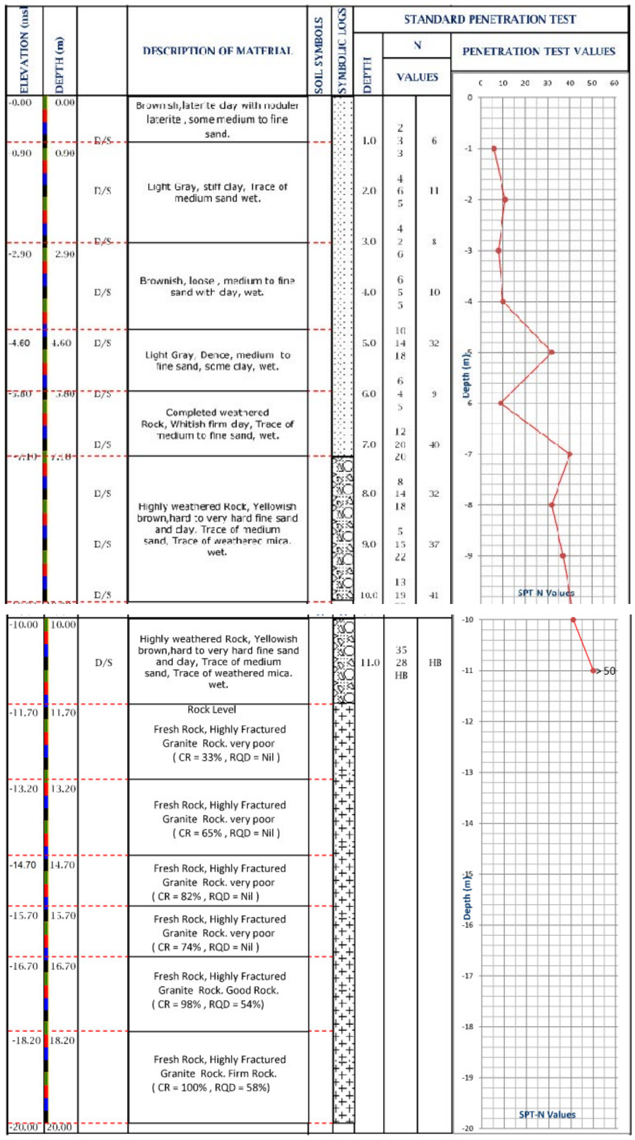
1) Soil Condition around Depot Area

The study team carried out soil investigations around the depot area for further examination as shown in Figure 5.3.30 below;

Location of Borings



Boring Log 1



Boring Log 2

Note: R: Rock, WR: Weathered Rock, HB: Hammer Rebounding - No penetration,

U/D: 60mm dia undisturbed Sample, D/S: Disturbed Sample

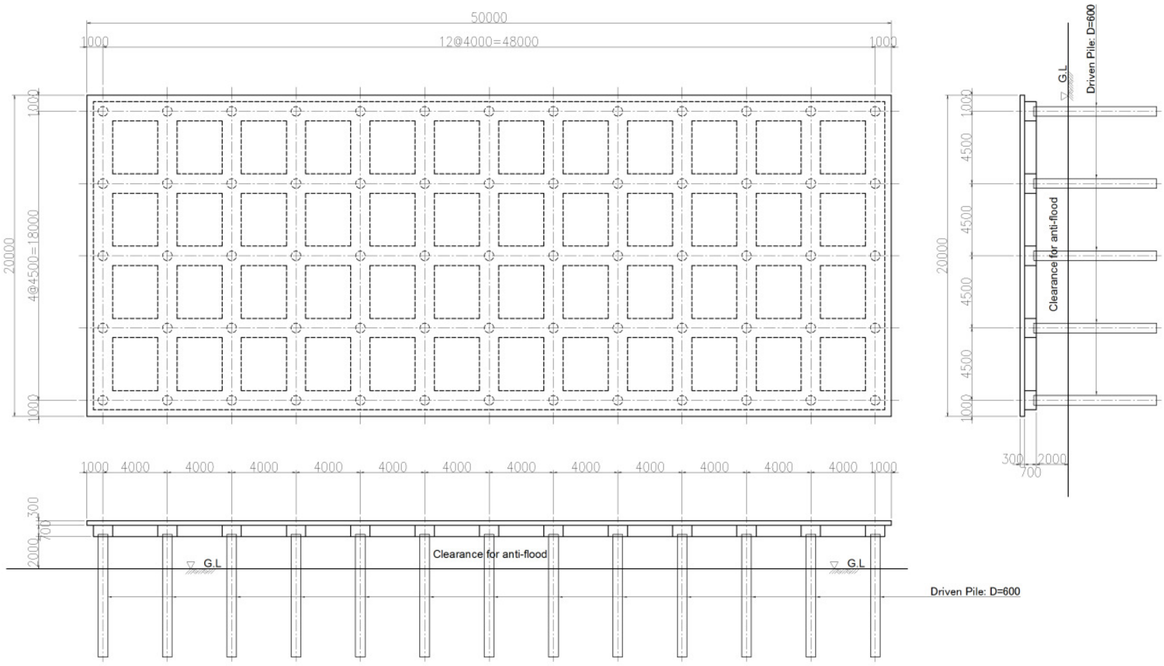
Source: SKYTRAIN Study Team

Figure 5.3.30 Boring Log

The sampling was made at only two points and therefore more data has to be obtained for further analysis. Since the soil condition at the boring log 1 is worse compared with the boring log 2, the conceptual structure analysis for the deport will be made referring to the boring log 1.

2) Civil Structure for Depot

Since the location of the planned depot is in a marshy area that has a retarding effect during flood, it is necessary to consider anti-flood measures. The study team proposes the slab + pile foundation to be stable at the depot area as shown in Figure 5.3.31 below.



Source: SKYTRAIN Study Team

Figure 5.3.31 Foundation Structure of Depot

The clearance between the ground level and soffit of the slab is considered to hold and retard the flood water. The allowable clearance height is set as 2.0m since the anticipated water level caused by flood surrounding this area is more than 1.0m according to the past experience. This clearance height has to be calculated and justified during the design stage.

The foundation structure shown in Figure 5.3.22 is a typical elevated platform unit. The Depot will be constructed by the elevated platform units as mentioned in 5.3.5 (5). The joint of each segment has to be made considering the shrinkage and expansion caused by temperature change.

Based on a rough analysis, the diameter of the driven piles will be 0.6m and the pile will be driven to a 10.5m depth from the ground level to where there is enough bearing capacity (N value more than 30).

5.3.4 Location of Station

(1) Basic Concept of Location Plan of Station

The station is located near the centre of the area, and simultaneously it becomes the connecting point with other transport modes. The station is an important place which connects the passengers and the monorail system. Therefore, the station location should be planned considering the efficient guide of passengers and access-friendly for passengers, and also the station is required to be a facility that provides safety and comfortable transfer.

Additionally, the station should be planned not only for transfer but also considering the availability of closely connected everyday life such as meeting places and shopping.

Points to consider for the location of the station are shown as follows.

1) To be access-friendly for passengers
2) To connect easily with other transport modes or surrounding roads
3) To be near the residential areas, business areas, commercial facilities and public facilities
4) To avoid obstacles such as existing houses, shops and buildings as much as possible
5) To avoid road crossings above ground near the station
6) To be close to an area that has a development plan

(2) Location and Type of Station

As for the standard type of station, 1-ticket gate type station and 2-ticket gate station are shown in Chapter 5.3.3. From the result of consideration based on the above mentioned concepts, 2-ticket gate type is preferable in the following conditions.

1) Other facilities exist at both ends of the station, and it is possible to secure the space for installation of lift facilities at both ends of the station.
2) The end of the station is located near an intersection, and it is possible to avoid crossing the road by installing a 2-ticket gate type.

(3) Location Plan of Station

Locations of each station were considered based on the basic concept of the station location plan. Additionally, layouts of lift facilities (e.g. staircase, escalator, lift) were considered. After conducting the site survey and discussions with the Ministry of Transport, the locations of stations and layouts of lift facilities were decided reflecting the site conditions.

Also according to the road conditions at the site, a pedestrian deck was planned for safety and easy access to station from distant places. This will provide access from distant places without crossing any roads.

Location plans of the station prepared based on the above mentioned considerations are shown in Appendix.3.

5.3.5 Construction Methods

(1) General

The construction of this project will require careful planning and organization, given the magnitude of the works, time constraints and the location of the works on busy national and arterial roads within Metropolitan Colombo Province.

The challenges faced during construction will be:

- to adopt rapid construction techniques while still ensuring quality,
- the planning and organization of all construction activities to ensure smooth flow of construction and the avoidance of delays on critical path activities,
- the organization and supervision of sufficient work teams and construction equipment and proper coordination with other contractors as necessary
- the construction and organization of a suitable temporary casting yard close to the site
- to implement well planned traffic management plans to ensure minimal impact on traffic, with traffic re-routing plans as necessary
- incorporating utility relocations, or design changes imposed by utility locations, into the construction planning,
- at all times to assure the safety of the construction operations.

(2) Viaduct

1) Foundation

The viaduct foundations are comprised of conventional bored piles and pile caps.

The bored piles will be constructed using high torque powered rotary drilling rigs mounted on crawler cranes and using various buckets, augers and chisels. Excavation typically will be carried out under a bentonite slurry without the use of temporary casings. Following the completion of the boring and the placement of the steel re-bar cage in the pile excavation, concrete is placed using a tremie pipe while the bentonite slurry is pumped away.

Critical issues during construction will be:

- proper mixing and recycling of the bentonite slurry to ensure the formation of a waterproof lining (“cake”) on the face of the excavation and allow clean placement of concrete
- ensuring that the end of the tremie pipe is always sufficiently embedded in the wet concrete as the bored pile concreting progresses
- avoidance of cold joints due to breakdown in supply of concrete
- overcasting of the pile and chipping back, or baling of the contaminated concrete while wet, to ensure good quality concrete at the pile head.

To allow sufficient space for the construction of the pier pile caps and to accommodate the construction equipment, a minimum width of 8m will typically be required as a work space on the central reserve of the affected roads. A typical section of the construction work space arrangement is given in Figure 5.3.32.

Source: SKYTRAIN Study Team

Figure 5.3.32 Typical Section of the Construction Work Space Arrangement

2) Substructure

Conventional reinforced concrete pier columns will be used for the viaduct substructures of the monorail structure. It is strongly recommended that the columns should be constructed using standardised steel forms to promote a good quality of finish and reduce construction cycle times. Typical construction sequence and schedule for one pier is shown in the table below.

Table 5.3.7 Typical Construction Sequence and Schedule for One Pier

Source: SKYTRAIN Study Team


Source: SKYTRAIN Study Team

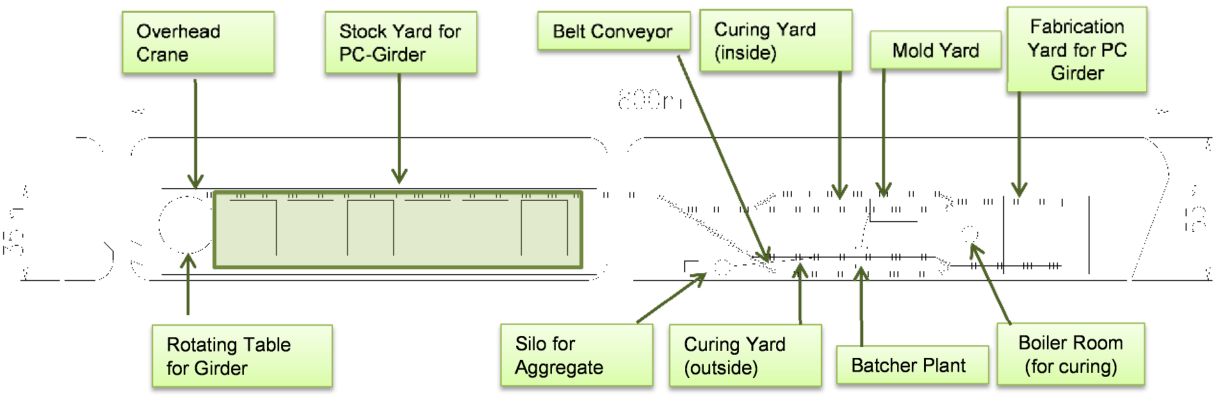
Figure 5.3.33 Pier Column Construction (Manila)

3) Superstructure

PC (Pre-stressed Concrete) Track Girder

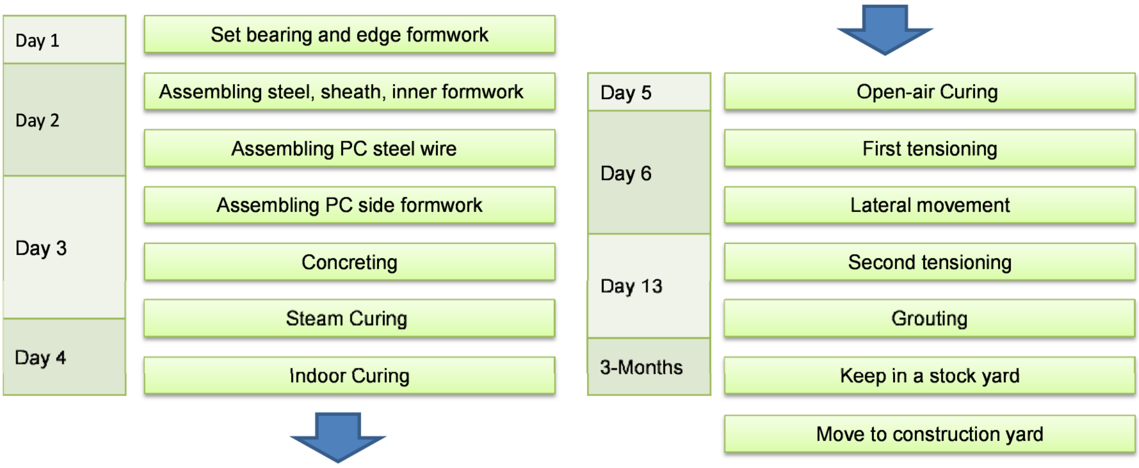
A pre-cast concrete method will be applied to the manufacturing of the PC track girder. The PC track girder for the monorail is difficult to manufacture due to its complex surface and shape, which also requires high-accuracy quality control. By producing pre-cast concrete in a controlled environment (typically referred to as a pre-cast plant), the difficulties can be managed. The pre-cast concrete also allows the opportunity for proper curing and can be closely monitored by plant employees.

Figure 5.3.34 shows an example of a pre-cast plant of the PC track girder (for Monorail). This pre-cast yard has a production capacity of 50-girders/months, approximately 1.7ha of manufacturing yard and 1.4ha of stock yard. Figure 5.3.35 shows the typical construction sequence for the manufacturing of the PC track girder.



Source: SKYTRAIN Study Team

Figure 5.3.34 An Example of a Pre-cast Plant for PC Track Girders



Source: SKYTRAIN Study Team

Figure 5.3.35 Typical Construction Sequence for Manufacturing of the PC Track Girder

Transportation and Erection of the PC Track Girder

Weight of the PC track girder is typically 50 – 55 (t), therefore a trailer which has an appropriate capacity is required for transportation of the girder. In addition, due to the heavy weight and long length of the PC track girder, the route from the stock yard to the site, including traffic management during transportation and girder erection, requires careful planning. In addition, it should be noted that there are limitations on weight and size on some roads and bridges. Therefore, discussion among the Contractor, road authority and police has to be conducted and careful construction management is needed during construction.

Regarding the girder erection method, in places where an adequate construction yard is secured, the girder will be erected at once using a crane, which can reduce construction cost as well as shorten construction duration. On the other hand, an erection girder will be used in city areas where securing a construction yard is not easy. Figure 5.3.36 and Figure 5.3.37 show a schematic drawing for girder erection.

Source: SKYTRAIN Study Team

Figure 5.3.36 Track Crane Girder Erection Method

Source: SKYTRAIN Study Team

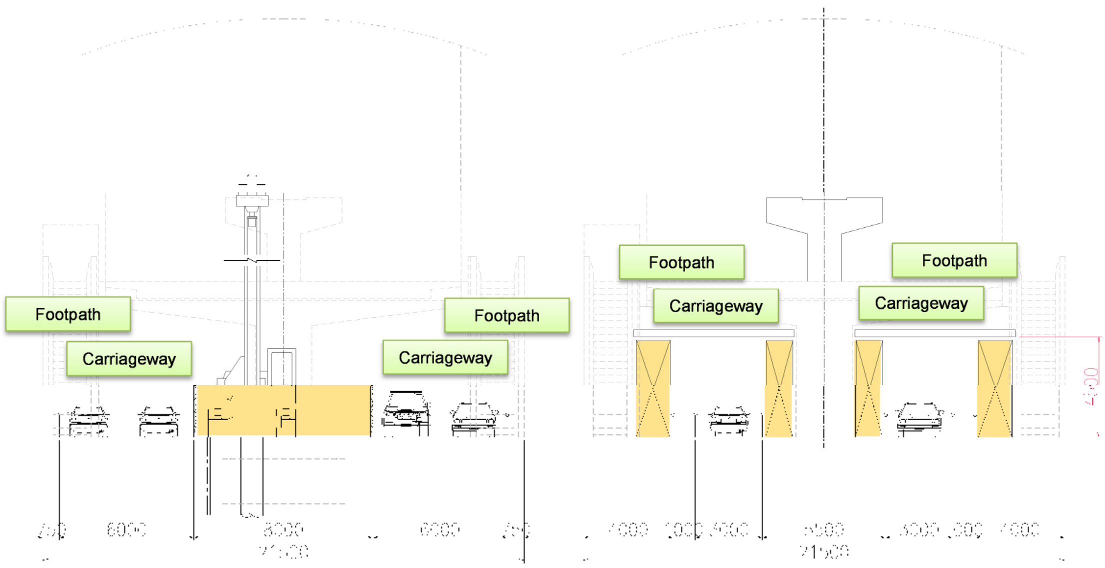
Figure 5.3.37 Erection Girder Method

(3) Elevated Stations

Most sections of the proposed line are planned to be constructed over the existing roads, and so are most of the stations. Some of the existing roads where the new stations will be built are not wide enough for construction and at the same time allowing traffic flow. In such a case for the station construction, permanent or temporary road blocks and detours during the construction period may be required.

For the elevated station design concept adopted in this Study, the station structure is supported entirely by centrally located piers with cantilever pier heads. The critical phase in terms of impact on traffic is during the construction of the cantilever pier heads. At this stage the central construction area will occupy a width of approximately 18m along the road to allow false work support to the cantilever ends of the pier head. The contractor will need to occupy two lanes in each direction along the road during the construction of the cantilever piers. However, once the pier heads are constructed and the concourse level supporting beams and floor are in place, the traffic lanes can be re-opened and construction can proceed with minimal impact on traffic flow, at least during daylight hours. The occupation of traffic lanes at each station is projected for approximately 6 months before station construction progresses sufficiently to allow full road access to the traffic.

For reducing the influence on traffic along the roads during the station construction, the contractor may be required to consider and select appropriate construction methods and procedures. For example, using pre-cast or pre-fabricated parts and sections for the structure, such as cantilever pier heads, the concourse level supporting beams and floor slabs, etc., instead of the cast in place method would shorten the construction period and minimise the impact on traffic flow. It would also be possible to install temporary protective structures over the existing road where the station is to be constructed. Although this structure may impose a height limitation for the traffic (slightly lower than the standard required height), it would be able to keep a minimum of one lane open to allow traffic through without the road blocked or detours in place. Wider land acquisition along the existing roads would be necessary for constructing some of the stations as well. The construction of National Hospital Station will require sufficient coordination regarding both sides of the land of the National Hospital. Typical work space layout during station pier and cantilever pier head construction and concourse level supporting beams and floor placing is shown in Figure 5.3.38.



Source: SKYTRAIN Study Team

Figure 5.3.38 Typical Work Space Layout for Station Pier Construction

Typical progress photographs of the elevated station construction are shown in Figure 5.3.39 to Figure 5.3.42. Although those photographs are not for a monorail station, but rather an LRT station, design, structure, construction method and procedure are mostly the same.

Source: SKYTRAIN Study Team

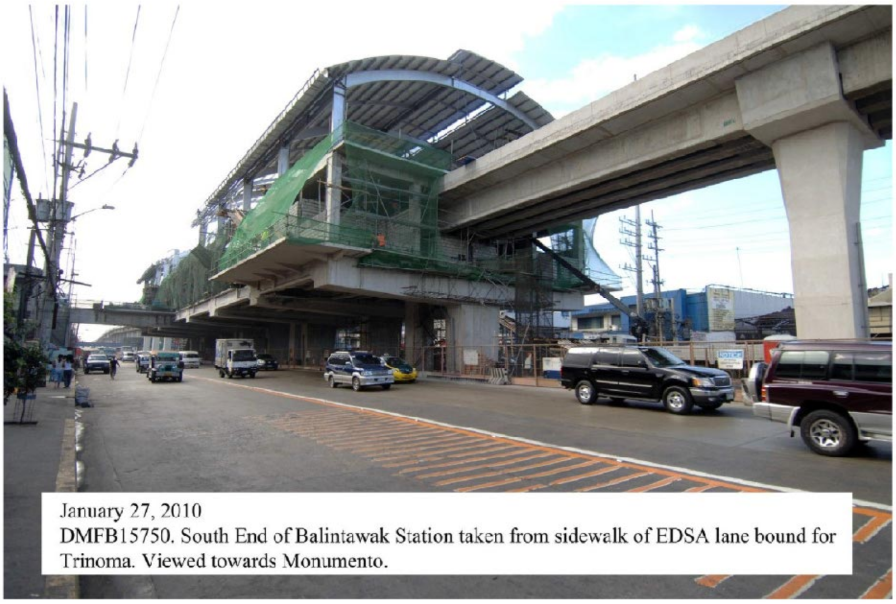
Figure 5.3.39 Station Cantilever Pier Construction (Sample)

Source: SKYTRAIN Study Team

Figure 5.3.40 Station Concourse and Platform Construction (Sample)

Source: SKYTRAIN Study Team

Figure 5.3.41 Station Platforms and Roof Frame under Construction (Sample)



Source: SKYTRAIN Study Team

Figure 5.3.42 Station Roof Covering under Construction (Sample)

Meanwhile, Sethsiripaya Station and Lumbini Temple Station are to be constructed off the existing road. However, a similar construction area will be necessary at the other stations to be constructed on the road. In addition, proper access is required for the construction of those two stations as well as for operation after completion of the construction.

The projected construction period for the elevated station substructures and frames (civil and architectural) excluding pier construction and truck girder installation is around eight months and that for electro-mechanical installations (E&M) is approximately another ten months, which is eighteen months in total for each station.

(4) Construction on the Section from Lumbini Temple to Malabe Station

General

For assuring the road traffic during the construction and the construction schedule as described in Chapter 7, construction method and sequence of civil works for package 3 which has the most narrow road section in the construction area will be briefly verified to confirm necessity of the road restriction and special treatment for traffic control. Figure 5.3.43 shows the location which has the most critical and narrow road section.

Source: SKYTRAIN Study Team

Figure 5.3.43 Location of the Section from Lumbini Temple Station to Malabe Station

Construction method and sequence of each structure considering the road traffic control and the schedule will be mentioned hereinafter.

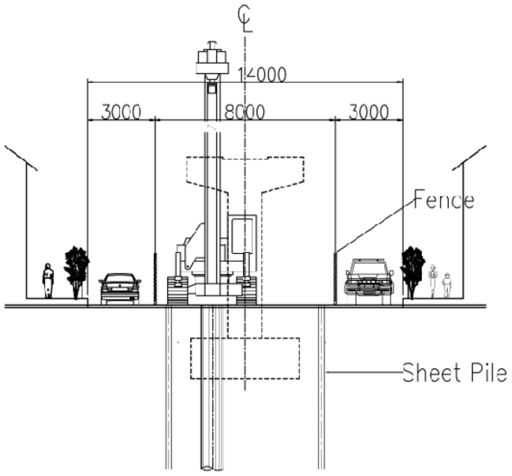
Substructure of Viaduct

In principle, a minimum width of 8m will typically be required for the construction work space on the central reserve of the affected roads as shown in Figure 5.3.44.

The road width on this section is around 12m with two lanes on the average according to the topographic data. It seems to be difficult to secure the road traffic without any restriction while the substructure construction is underway. If the road traffic is totally unable to be secured during the construction due to keeping necessary working space, the following countermeasures are supposed to be considered.

1) To block the affected roads and make temporary detours during the construction; or
2) To widen the affected roads considering the urban and road planning before the construction

Since the road section occupied by at least 8m width for the construction work space, it needs at least 14m width excluding the pedestrian pavement for securing one lane in each direction. Even 11m road width as a minimum is able to secure one lane in one direction only if it is not conditioned that the pier centre is the same position with the road centre. Figure 5.3.44 shows the typical section of road occupation during the construction.



Road width more than 14m

11m road width

Source: SKYTRAIN Study Team

Figure 5.3.44 Typical Section of Road Occupation during the Construction

<u>Superstructure of Viaduct</u>

The occupation by work space for superstructure as well as substructure is still needed until finishing erection of the girders on the pier top. As specified in Chapter 5.3.5 (2) 3) and shown in Figures 5.3.34 and Figure 5.3.35, the erection method will be either the track crane girder erection method or the erection girder method.

If an adequate construction yard is secured and the road blocks are allowable for necessary erection time to be taken, the track crane girder erection method will be applied. As the past experience in Japan, it is able to erect two girders in one night. On the other hand, the erection girder method will be applied to the areas where securing a construction yard is not easy.

<u>Power Lines, Signalling and Telecommunication</u>

The road occupation is not required while the cables for power lines, signalling and telecommunication are installed by the job cart on the track girders. But it is necessary to consider the storage area for materials and job cart under the elevated structure. Figure 5.3.45 shows the cable installation works on the girder.

Source: SKYTRAIN Study Team

Figure 5.3.45 Cable Installation Works

Station

Since the station area needs 21~22m width including the lifting devices such as stairs, elevator and escalator, the existing road is not wide enough. Therefore, as the major premise, the land acquisition must be carried out for widening the road section and securing sufficient area to build the station before the construction.

While the station structures are constructing, the road occupation for work space is necessary as well as the construction of viaduct piers. Although the road is still occupied for the protection work and a minimum working space for the construction of the cantilever pier heads, concourse level supporting beams and floor after construction of piers, a minimum of one lane will be kept to allow traffic through without the road blocked or detours in place as shown in Figure 5.3.36. Once the pier heads are constructed and the concourse level supporting beams and floor are in place, the traffic lanes can be re-opened and construction can proceed with minimal impact on traffic flow, at least during daylight hours.

Construction Schedule

The followings are the conditions for projecting the construction schedule of piers;

- Two piers will be constructed simultaneously considering construction efficiency;
- Thus, the construction work space will be made for covering two piers each;
- The construction work space will be dismantled and removed to next position after completing the designated substructure and finishing erection of the girders.

Considering the above condition, the period for construction of two piers in one work space is projected as shown in Figure 5.3.46.

Source: SKYTRAIN Study Team

Figure 5.3.46 Projected Construction Schedule of One Work Space

Since the construction of two piers will take approximately 5 months, the affected road will be occupied for the same period accordingly.

Meanwhile, the construction of substructure for package 3 which covers 9.1 km length is scheduled to be completed within 24 months. Considering this target schedule, it is necessary to equip at least 12 machines for pile construction according to the study team's estimation. The section from Lumbini Temple Station to Malabe Station has approximately 2.1 km therefore 3 machines for piling construction will be allocated to the construction of this section.

In addition, the construction period of station building and facilities is projected in 24 months and there has the influence on traffic along the roads during the period.

Taking consideration of the above conditions, the construction schedule on the section from Lumbini Temple Station to Malabe Station is made as shown in Figure 5.3.47.

Even though the construction will be completed within the target period according to the projected schedule, the contractor may be required to consider and select appropriate construction methods and procedures for reducing the influence on traffic during the construction.

Source: SKYTRAIN Study Team

Figure 5.3.47 Construction Schedule on the Section from Lumbini Temple to Malabe Station

<u>Additional Construction Cost</u>

Road width of Malabe Road or Kotte – Bope Rd, from Lumbini Temple St. to Malabe Station St. is narrow and meandering, and there are many places where the road width is less than 15m at the site for the new stations. However, as mentioned earlier, the construction yard with a minimum of 21~22m road width is needed for the construction of the station structure. Due to this situation, in the case that adequate construction is not secured, additional land acquisition or temporary land use may be required. Furthermore, during the construction of the station structures, road closures and detours at the site of the new stations will be required due to the road being occupied for work space. Therefore, counter measures, such as applying a construction method to minimise impact on the existing road, intensive construction work (adding extra equipment and workers) to reduce construction duration, etc. need to be considered.

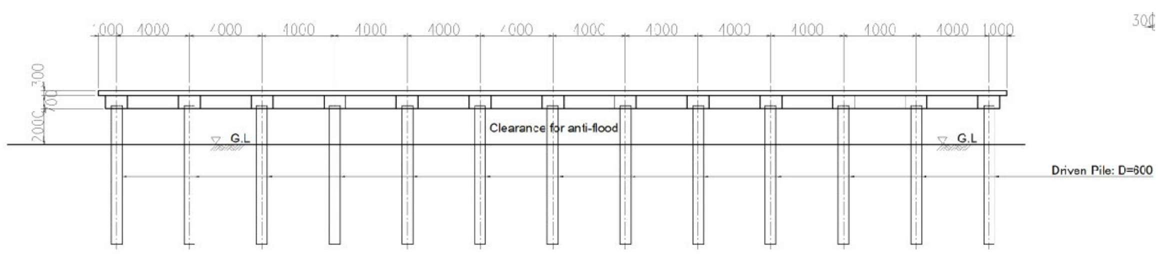
It is noted that the construction cost used in this study is calculated under normal construction conditions. Accordingly, in the case that these countermeasures are required, additional construction cost has to be added. If some kind of countermeasure was implemented, at least a 1～5% cost increase (excluding additional land acquisition and temporary land use) is estimated.

(5) Depot Civil Structure

The depot, which is planned to be located north of Malabe station will be constructed on elevated platform since the planned area occasionally has flooding. The elevated platform consists of pile foundations and slabs to create space over the existing ground for the flooding. Outline of the elevated platform is as follows:

- Precast reinforced concrete piles of approx. 10.5m long (8.5m under the ground level) and 600mm diameter to be driven down to the supporting layer;
- Distance between the piles is 4 m and 4.5 m centre to centre;
- Reinforced concrete slab of 300 mm thick with beams on the piles; and
- One unit of the elevated platform is 50 m by 20 m.

The planned elevated depot platform is shown in Figure 5.3.48.



Note: Overall Civil Structure of Deport is shown in Figure 5.3.31.

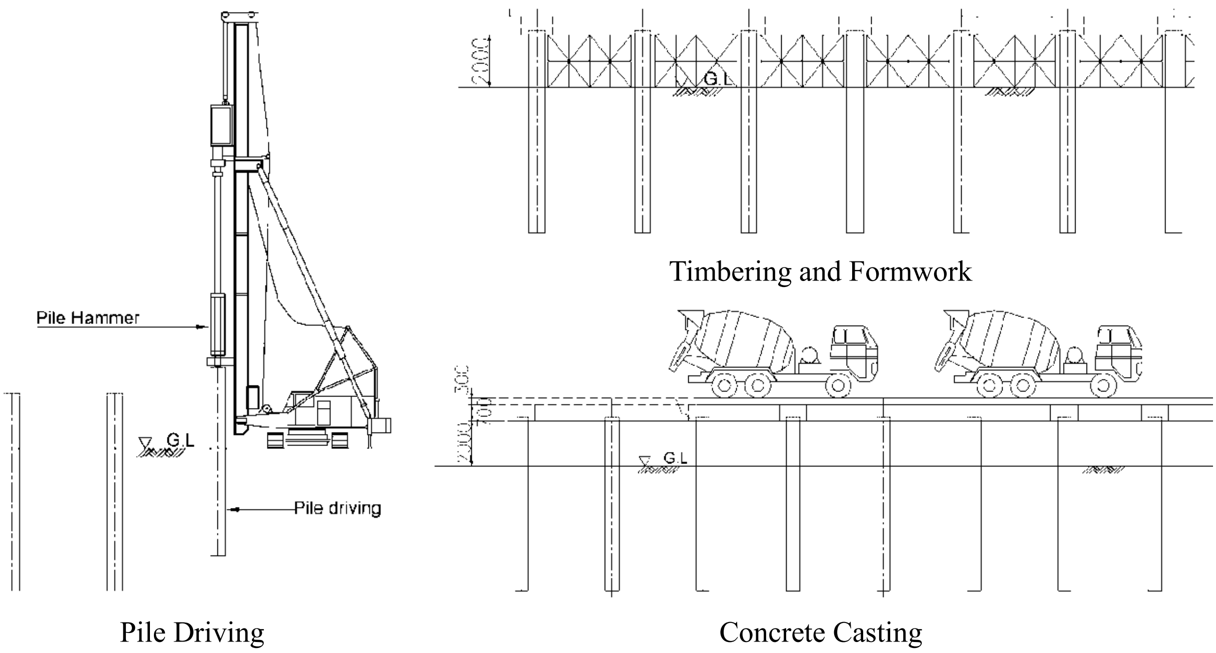
Source: SKYTRAIN Study Team

Figure 5.3.48 Planned Elevated Depot Platform

Construction procedure for the elevated platform is shown below.

1) Preparation works (clearing & grubbing, levelling, external and internal access roads construction, dewatering system installation, partial soft soil improvement work, etc.)
2) Precast reinforced concrete pile driving using pile driver
3) Manual pile head treatment
4) Pile testing such as static load test, pile integrity sonic test and pile dynamic analysis (PDA) test when required
5) Timbering for formwork for beam and slab construction
6) Formwork for beam and slab construction
7) Reinforcement bar installation for beam and slab
8) Concrete placing and curing for beam and slab
9) Dismantling formwork and timbering
10) Moving to the next unit of the elevated platform
11) Construction of the next elevated platform by repeating (2) to (9) above

Figure 5.3.49 and Figure 5.3.50 show typical construction methods of the elevated concrete slab (pile driving, timbering and formwork, and concrete casting) and projected construction schedule for one unit of the elevated depot platform.



Source: SKYTRAIN Study Team

Figure 5.3.49 Typical Construction Methods for the Elevated Depot Platform

Source: SKYTRAIN Study Team

Figure 5.3.50 Projected Construction Schedule for the Elevated Depot Platform (1 unit)

As mentioned earlier, the proposed area for the depot construction has a flood retardation function and its ground condition is soft and swampy, which may greatly affect the construction activities. In addition, the area of the elevated depot platform is extensive, and construction scale and quantities are large, however the construction period will be relatively short. Therefore, the contractor may be required to consider appropriate countermeasures for those adverse construction conditions as follows:

- Installation of sufficient dewatering system for preventing or minimizing the occasional flooding;
- Utilization of special pile driving machine for soft soil condition;
- Application of precast reinforced concrete slab method which would suffer less impact from the soft soil and flooding conditions, be able to shorten the construction period, and secure better quality of the structure.

For depot buildings and the other structures, such as office buildings, sub-station base, workshop, material storage, washing machine and water treatment facility, other types of separate foundations would be required to be designed and constructed for bearing the load.

5.4 Signalling, Communication and Fare Collection Systems

5.4.1 Signalling System and Train Operation Management System

The Signalling System and Train Operation Management System perform highly reliable and effective train operation control and management.

The system boasts:

- Minimised operation headway while maintaining a safe distance between trains
- Supervises speed continuously. When a driver ignores a signal or warning, an accident due to the driver's warning oversight is prevented by operating an automatic brake.
- Ensures safety by limiting the speed in the sections with speed limits
- Enhances flexible and accurate train control (especially in case of accident /delay)
- Improves efficiency in terms of use of trains as well as increase of operation quantity
- Improves the maintainability for signal and telecommunication equipment by introducing a system monitoring function

The route setting (track switches control) and display settings for signals are carried out intensively and automatically by a centralised control system in the area of not only the mainline but also the depot. The control of routes in-between is interlinked.

Even in case of an abnormal situation such as system failure or accident, the system features a manual control function implemented by the control terminal for each track switch installed both at the operation control centre and at the station. This ensures that trains on the route can continue their run.

The system consists of the following sub-systems in order to perform the above:

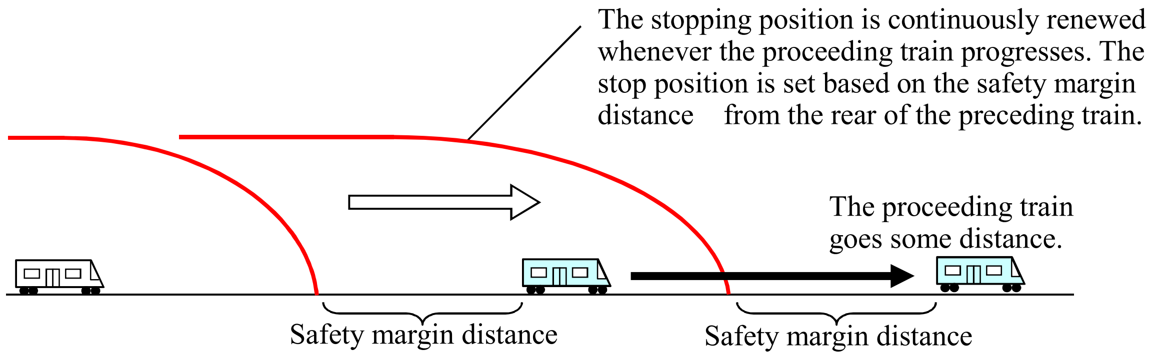
(1) Interlocking Equipment

This equipment is installed at the station where track switches are installed. The route is established based upon the Interlocking Logic by controlling the several track switches interlocked after receiving the command from a superior route setting system. The interlock device uses control based logic to prevent incorrect routes or interlocking control. This equipment is the key component for the safety aspect, and it requires the highest Severity Integrity Level (SIL).

(2) Automatic Train Protection (ATP)

ATP controls maintain a safe distance between trains by calculating the present position of each train and its speed. With such system the Train can stop safely without any crash or accident even if the driver makes a mistake in the stopping action. The system consists of an on-board train speed and position detector, radio communication equipment, wayside signalling equipment that manages/processes the sent data from on-board, and an on-board control unit that calculates/establishes the stopping pattern based upon data sent from the wayside.

The equipment ensures safety by redundant features. The train can be stopped automatically and safely even if the system is in malfunction.



Source: SKYTRAIN Study Team

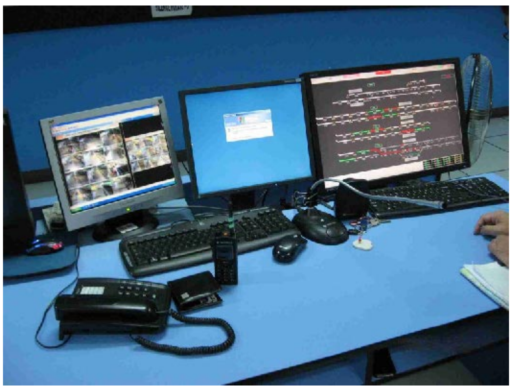
Figure 5.4.1 The Image of ATP Train Control

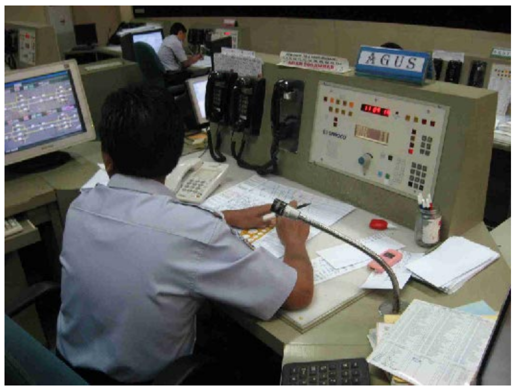
(3) Automatic Train Operation (ATO)

The ATO is a system using on-board patterns to control acceleration and deceleration, as well as stopping at predetermined points such as a station. It communicates with the wayside, by a transponder, exchanging information such as point information, the station name, destination, and train identification. If there are platform screen doors in a station, ATO opens and closes (command) the platform screen doors in conjunction with the landing doors of the train.

(4) Operation Control Centre (OCC)

Equipment for management and control of train operation are installed at the OCC. The OCC can monitor everything regarding the train operation. The OCC emits warnings when abnormalities occur, and it recommends directions to the commander.





Source: SKYTRAIN Study Team

Figure 5.4.2 Image of Operation Control Centre

(5) Emergency Stop Button (ESB)

An ESB is deployed at each platform in the station in order to prevent the train from entering the station to prevent damage or injury if a passenger or object falls onto the track, or a suspicious object is found

Source: SKYTRAIN Study Team

Figure 5.4.3 Image of ESB

5.4.2 Communication system

The roles of the system for the monorail are as follows:

- Efficient train control support
- Implementation of communication and operation support for train operation
- Provide communication measures in case of abnormal situation
- Provide necessary information to passengers

In order to realise the above purpose, the following sub-systems are provided;

(1) Telephone System

The telephone system consists of PBX and telephone terminals, and they are connected to each other by the network. It covers all voice communication demands. There are two types of systems, one is for command purposes, and the other one is for general communication purposes.

Source: SKYTRAIN Study Team

Figure 5.4.4 Image of Dispatch telephone terminal

(2) Public Announcement System (PA system)

This is the system for announcing from the OCC/station to necessary places. This consists of Microphones, AMPs, Speakers and networks. The manual announcement from the OCC to the stations is the most prioritised and any of those announcements temporally override subordinate announcements until the priority announcement is completed.

The simultaneous announcement can be carried out to multiple stations or grouped stations or areas.

The announcement can also be carried out from handy-portable radios and/or telephone systems, especially in the case of emergency. The system is also linked to the Signalling system and automatic announcements such as train arrival and/or departure are carried out.

Source: SKYTRAIN Study Team

Figure 5.4.5 Image of PA console

(3) Passenger Information Systems (PIS)

The passenger information system is the information display that shows passengers the train departure time, train operation status, or any other pieces of information necessary for the passenger at the platform, concourse or necessary place in each of the stations. The display also indicates any message inputted especially in the case of emergency.

Source: SKYTRAIN Study Team

Figure 5.4.6 Image of PIS display

(4) Clock System

The clock system provides accurate time information to passengers and command staff and the platform, concourse, station officer's room, technical rooms, machine room, work rooms, depot and/or any other places by deploying clock terminals that synchronise with the main clock system.

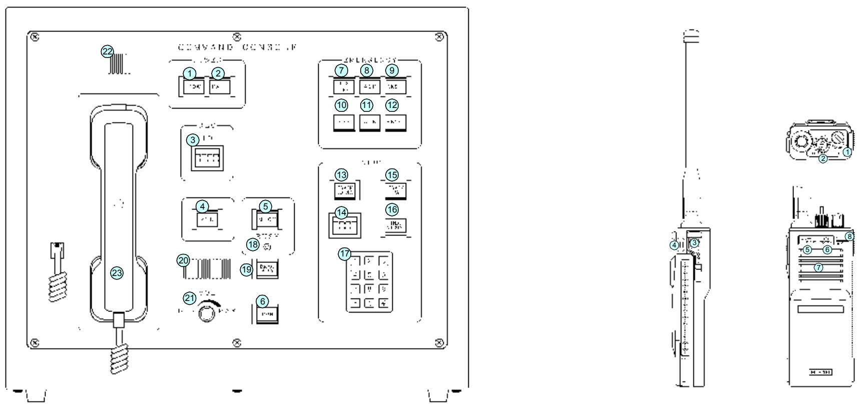
The system is also connected to the signalling system and/or other necessary systems to provide time information to synchronise with the time that system uses. The train operation can be completely carried out with the same time information synchronised with all related systems.

Source: SKYTRAIN Study Team

Figure 5.4.7 Image of Clock System Terminal

(5) Radio System

The system facilitates communication between the Operation Control Centre (OCC) operator and the drivers on-board, Station controller, or maintenance engineer. The station controller and/or Maintenance engineer also carry portable radio terminals and communicate with each other or the OCC operator directly. The radio antenna is deployed to cover all necessary communication areas. The system is also used in emergency situations, accidents, fire, and closure of a track, etc.



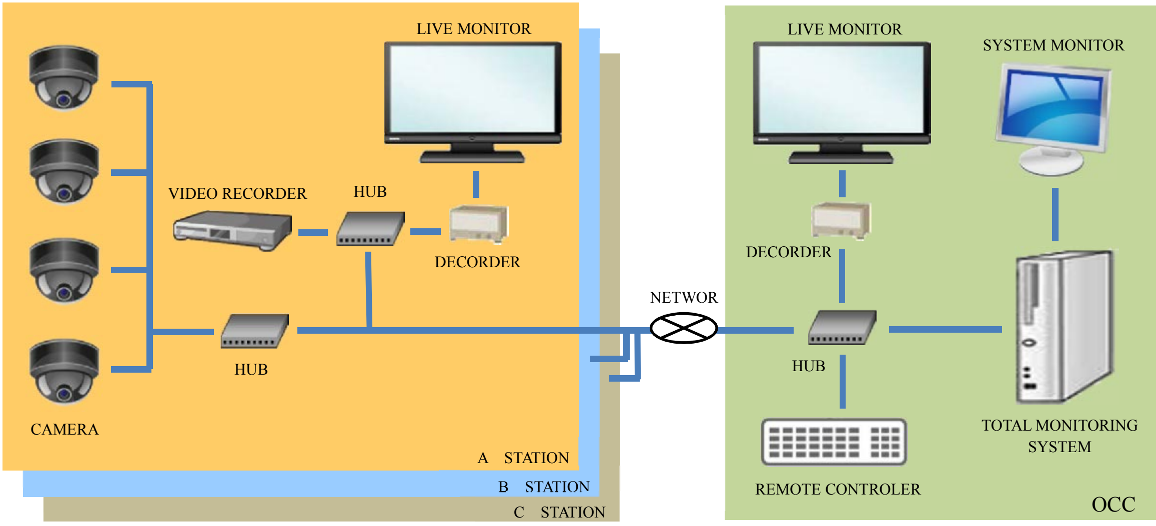
Source: SKYTRAIN Study Team

Figure 5.4.8 Image of Radio Console, Portable Radio Terminal

(6) CCTV System

The CCTV system is a system of remote monitoring with displays and cameras installed at platforms and concourses. The displays installed in the OCC and the station office show the situation of the platform and concourse.

The image can be recorded and stored for a certain period for use in investigations in case of accident or emergency.



Source: SKYTRAIN Study Team

Figure 5.4.9 The Image of CCTV System Configuration

(7) Fibre Optic Network System

The system is the high-speed and stable communication infrastructure for the communication system. The system is redundant and has a duplex configuration using optical fibre cable, and even if failure or physical damage occurs, the network is diverted and continuity can be maintained.

By downsizing or providing versatility for the fibre optic network system, it is possible and desirable to reduce space requirements and make equipment exchange easy.

5.4.3 Fare Collection System

An efficiently procured contactless 'Automatic Fare Collection System' (AFCS) will bring important benefits to the passenger using the Monorail, to the authorities operating those lines and if developed sensibly, also to the wider public.

The AFCS will allow the operating authorities to develop a service offering (including fare-charging arrangements, fare structures & fare policies) that better suits the needs of the passengers.

The AFCS will be developed and procured in line with current international best practice, it can service other transport modes (i.e., buses, taxi cabs, etc.),

A successful AFCS implementation may lead to a wider application outside of the public transport sector, inducing wider economic benefit. It may also serve to incentivise more people to get/use their bank accounts, which in turn will generate economic benefits.

(1) Outline of the AFCS

AFCS has been installed in many urban railways around the world. It consists of ticket vending machines (TVM), automatic gates (AG), automatic fare adjustment machines, data collecting machines and office booking machines. The summary and installation concept of AFC equipment are described below.

1) Ticket Vending Machines (TVM)

TVM is used for ticket selling and is a machine which automatically issues tickets by passengers paying money and choosing ticket types. TVM which is operated by the passengers is required to be simple and easy to use.

2) Automatic Gates (AG)

AG, which is installed at ticket gates or ticket collection gates, is a machine to rapidly and accurately read or collect tickets on behalf of station staff. The types of AGs are for entrance only, exit only and both entrance and exit. On entrance, the AG reads necessary information from a card or ticket and writes the entrance record onto it. On exit, the card is again passed over the card reader. At this time the fare is adjusted and confirmed based on the entrance record. If required information is not obtained on entrance or exit, the gate will be closed and the information will be confirmed by station staff.

3) Automatic Fare Adjustment Machines

A fare adjustment machine is installed inside ticket gates and used by passenger themselves for fare adjustment such as excess fare. The fare machine reads the ticket information when the ticket is inserted into the machine. At this time, the fare is deducted from the remaining balance on the ticket and balance due is displayed. After inserting the necessary amount of money, the adjusted-fare ticket will be dispensed, with which the passenger can pass through the AG.

4) Data Collecting Machines

A data collecting machine is a piece of equipment to collect and save daily data from the AFC system such as AGs, TVMs and fare adjustment machines, etc. The aggregated data is transferred to the data management department through online communication facilities. The data is also transferred from this department to the administration department and used for administrative strategic planning and the improvement of passenger services.

Automatic Gate (AG)

AG for Wheelchair
(at far right)

Ticket Vending Machine
(TVM)

Source: SKYTRAIN Study Team

Figure 5.4.10 The Image of Automatic Fare Collection System (AFCS)

(2) Outline of Smart Card System

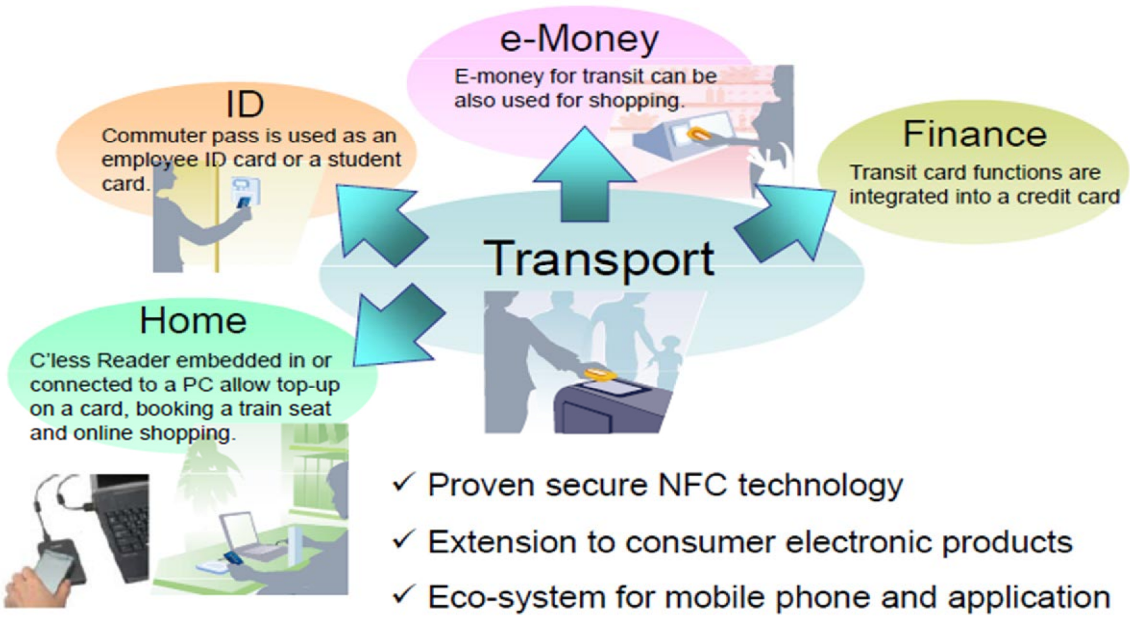
In many developed countries, payment of public transport fare by a smart card or an integrated circuit (IC) card is significantly increasing such as Japanese Suica and Hong Kong's Octopus Card. These smart cards utilize technology of the Near Field Communication (NFC). The International Organization for Standardization (IOS) and the International Electrotechnical Commission (IEC) defined several standards in this filed. ISO/IEC 14443 stipulates standards of identification cards, contactless integrated circuit cards, and proximity cards. Two types are defined. Type A is mainly developed by Philips Semiconductors (currently transferred to NXP Semiconductors). MIFARE is a trademark of Type A Smart Cards by NXP Semiconductors. Type B is mainly developed by Motorola. ISO/IEC 18092 also defines communication modes for Near Field Communication Interface and Protocol (NFCIP 1). FeliCa, a trademark of SONY Corporation's NFC card, is in line with this standard. This type is often called as Type C.

In Sri Lanka, several groups started to introduce smart cards in transport and other fields. MIFARE (Type A) smart card was employed by several groups. Dialog Axiata PCL with Hatton National Bank is promoting "Touch Travel Pass" using MIFARE. Touch Travel Pass is supported by Lanka Private Bus Owners Association. The system was introduced in several intra-provincial bus routes in the Western Province such as 138, 122 and 125.

Hatton National Bank (HNB) started to issue a NFC enabled multi-function payment card, "HNB One". NHB One is based on Felica of SONY. Several bus companies and associations such as Southern Province Bus Association, Matara passenger Transport Company and Uva Province Bus Association commenced pilot projects using HNB One.

Although several groups proposed and started to issue smart cards, these initiatives are still trial basis. As the several banks and mobile phone companies developed their own transaction system, there is no compatibility on these cards. Establishment of clearing house will help solving compatibility issue from consumer's perspective.

Our premise is that the prepaid smart card system should be a good starting point to let the non-cash payment system spread among the Society. Japanese vendors are well experienced for the introduction of the AFC system to the railway stations under heavy traffics. Independent operators' daily business will be on-line by using IC card system. A neutral operator or clearing house is desirable for the payment-clearing and settlement. Japanese smart card systems for train fares are used nation-wide and the one of the most successful implementation cases in the world.



Source: SKYTRAIN Study Team

Figure 5.4.11 The Image of Automatic Fare Collection System and Its Application

5.5 Power Supply System

Monorail traction uses electric motors and major equipment such as signalling systems and facilities in the stations and depot are powered by electricity. Therefore, power shortage or power interruption shall directly result in disruption in train service. As a solution, a power system with redundancy is necessary. The power system shall be designed to supply sufficient power for train operation service by applying system redundancy.

The Power Supply System shall be Large Scale Alternating Current (AC) Substation Type, in which large-scale Alternating Current (AC) substations receive electric power from the Power Company via electric transmission lines, and feed power to the traction stations and station service substations along the line.

(1) Large-scale Alternating Current (AC) Substation

There will be two large-scale AC substations, one at the DEPOT (Malabe) and one at Fort which receive AC 50 Hz /33kV or 11kV power from the power grid and supply AC 11kV power. For redundancy, the AC 11kV power shall be supplied to traction substations and service substations by two transmission lines. Each of these large-scale AC substations must have capacity to provide power to the whole line even if one of the substations is disabled. (Design Capacity: 20,000kW/h each substation).

At Fort substation, because 11kV power can be received from the power grid, a transformer is not necessary. Only a circuit breaker is to be installed before power is supplied to the traction substations and station service substations.

(2) Traction and Station Service Substations

Capacity of Substations

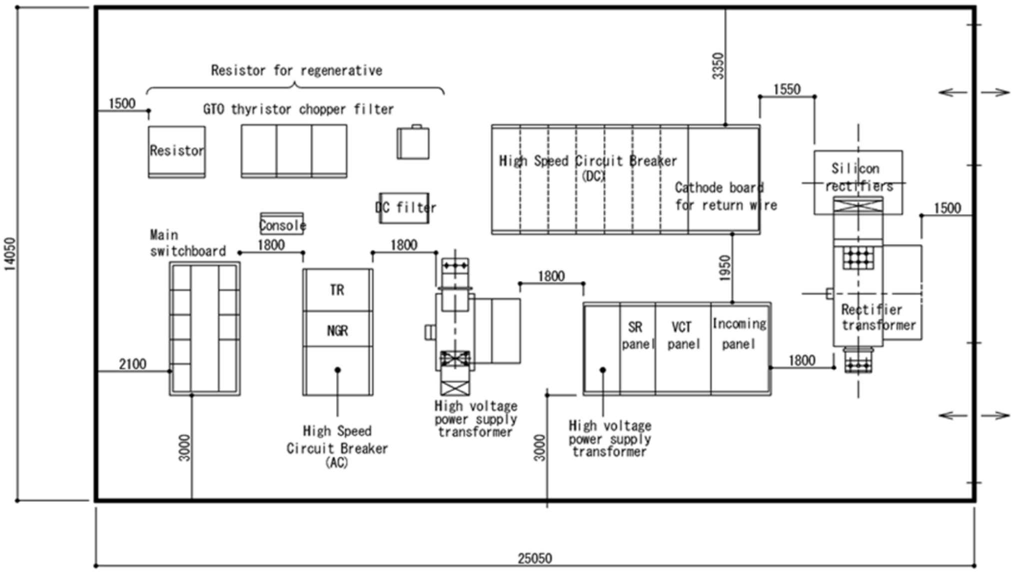
The capacity and the spacing of the substations are designed to secure normal operation even if a certain substation stops operation due to failure or for maintenance. In such a case, necessary power shall be supplied from the adjacent substations. The spacing between those substations should be less than 4 km so that when a substation is disabled, each of the two adjacent substations are capable of supplying power for half of the feeding section of the disabled substation. If the transmission distance between substations exceeds 5km, a serious voltage drop would be expected. Therefore, each substation shall feed power for a section of less than 5 km.

1) Traction Power

Traction power for the monorail is supplied by traction substations, which convert electricity from AC 11kV/50Hz to DC 1,500V. Traction voltage fluctuation can range from 1,800V to 1,000V in compliance with IEC standard.

2) Station Service Power Supply

Power for stations, the depot, signalling system and turnouts, is distributed to transformers at each station and each depot, and then supplied to each piece of equipment at appropriate voltage. These station service substations transform power from AC 11kV to AC6.6kV.

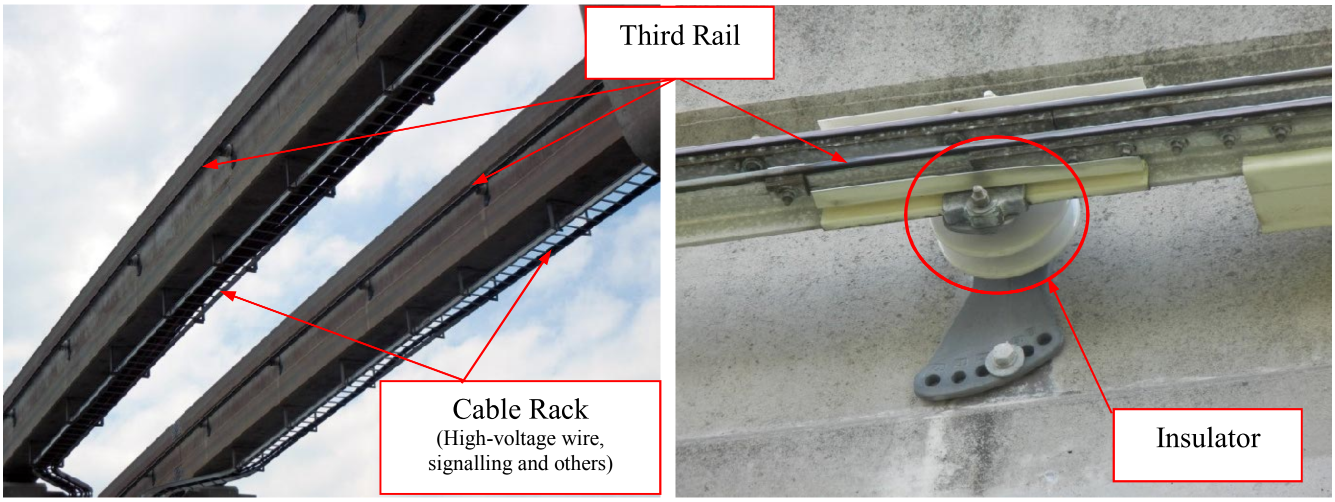


Source: SKYTRAIN Study Team

Figure 5.5.1 Layout of Equipment of Traction and Station Service Substations

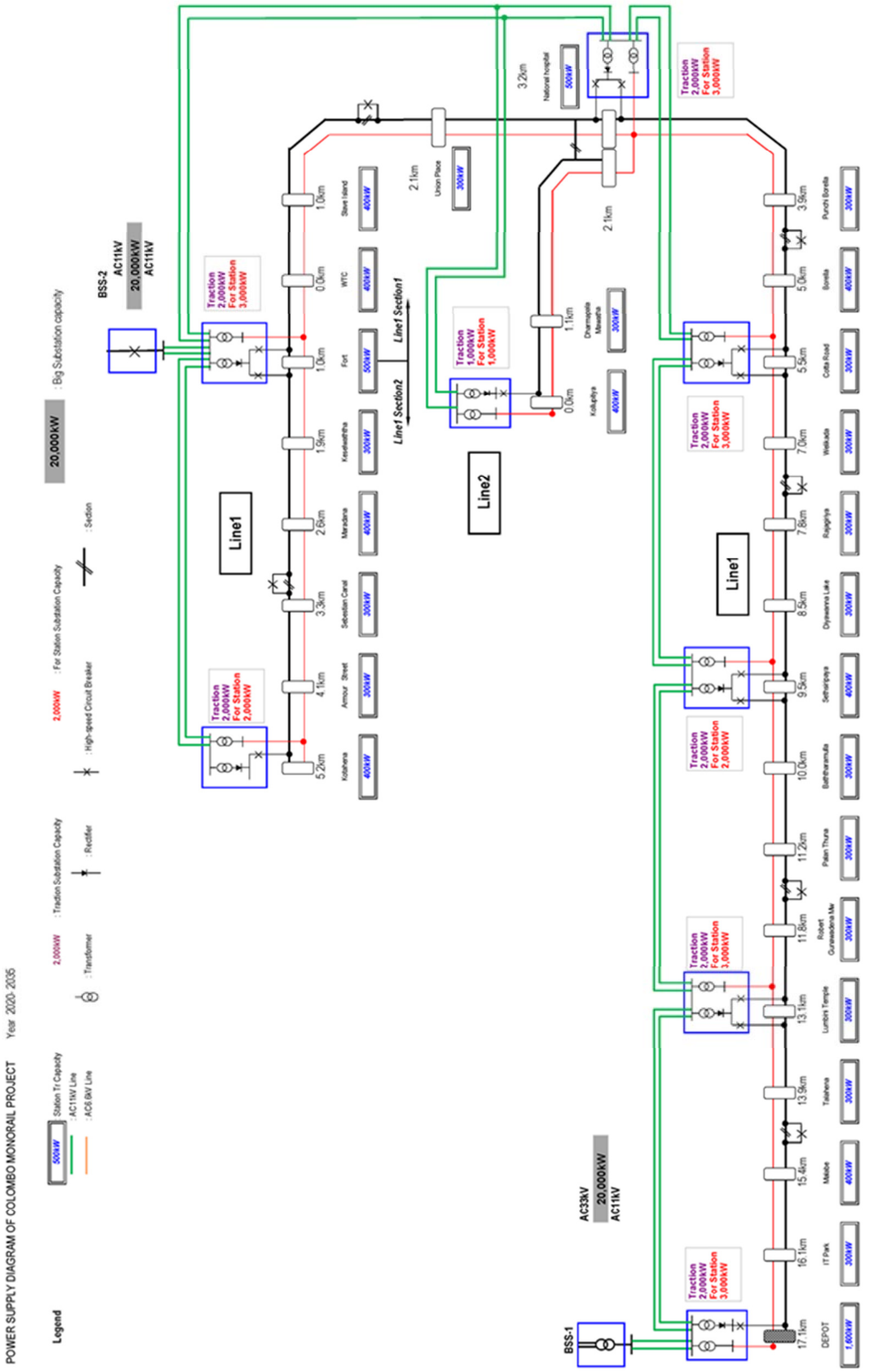
(3) Contact Line

The traction voltage of the proposed monorail is DC 1,500V. Third rails are arranged along the sides of both elevated girders. There is a positive electrode and a negative electrode. The third rail is fixed to the girders by insulators with spacing of about 5m. Expansion joints shall be arranged, where necessary, to absorb expansion and contraction due to change in environmental conditions such as temperature fluctuation.



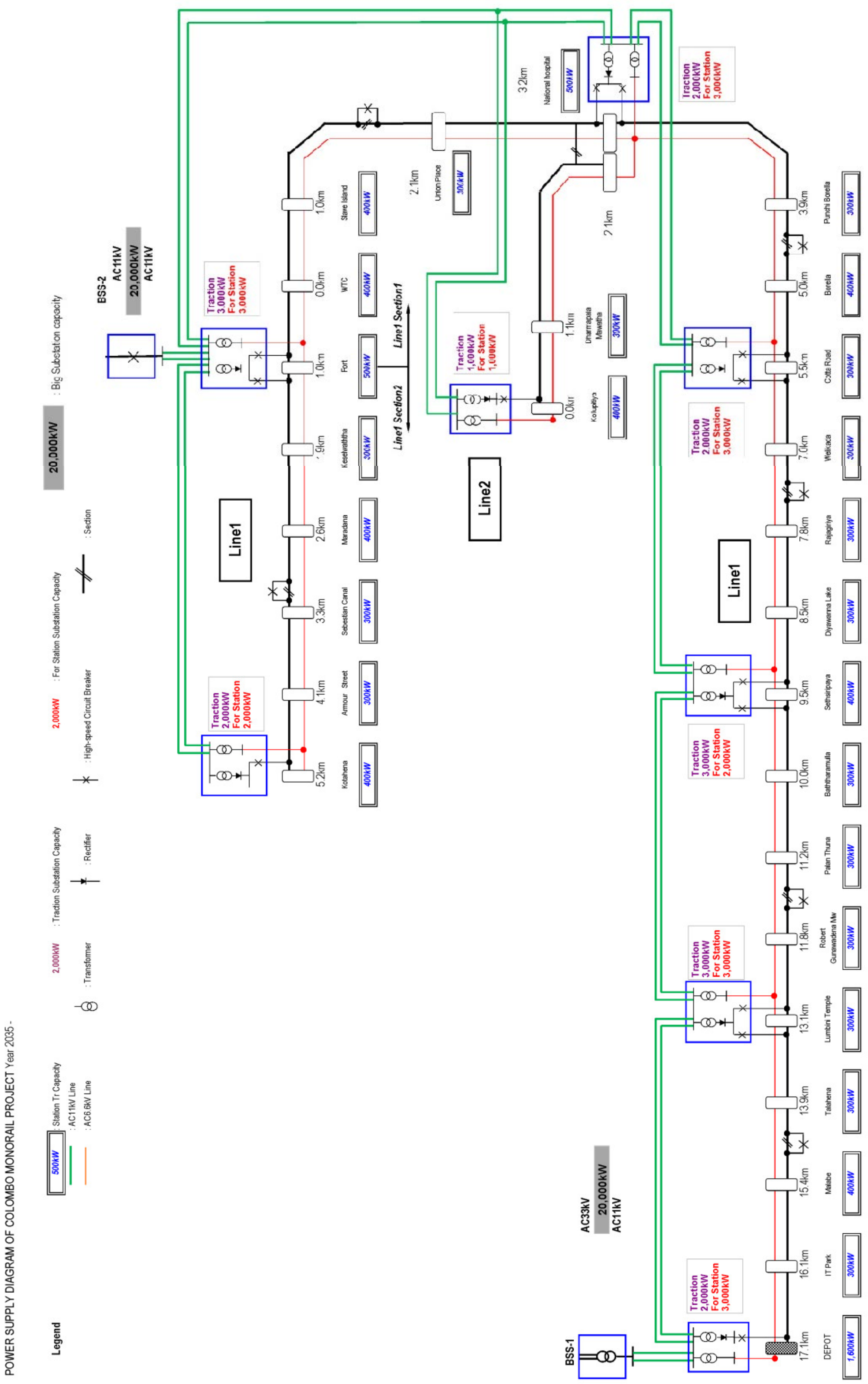
Source: SKYTRAIN Study Team

Figure 5.5.2 Image of Contact Line



Source: SKYTRAIN Study Team

Figure 5.5.3 Power Supply Program Year 2025



Source: SKYTRAIN Study Team

Figure 5.5.4 Power Supply Program Year 2035

(4) Power Control System

Power supply is controlled at the CTC centre via a SCADA System. SCADA is an abbreviation of Supervisory Control And Data Acquisition which is a centralised system that is able to monitor and control geographically distributed power equipment. The main purpose is for remote supervising, and it is suitable for monitoring and control of railway power supply systems. The monitoring of electrical equipment and circuit switching in case of emergency is controlled by SCADA.

CHAPTER 6 Project Cost Estimation

6.1 General Assumption

(1) Project Summary for Cost Estimation

The project summary for cost estimation is shown in the table below. The opening year of operation is 4 years after commencement of the construction works.

Table 6.1.1 Project Summary

Line	Contents
Line 1	Kotahena sta. - WTC sta. – IT Park (connecting to Depot) Total length 21.1 km, 24-stations
Line 2	Kolupitiya sta. - National Hospital sta. Total length 2.1km, 2-stations (exclude the National Hospital St.)
Depot & Work Shop	Area 8.34ha

Source: SKYTRAIN Study Team

(2) Conditions for Project Cost Estimation

Ratio of Budget Source:	JICA: 100%, Sri-Lanka: 0% (Note that it does not include utility diversion, land acquisition, compensation, admin costs, taxes)
Exchange Rate:	US$ 1 = 101.79 JPY US$ 1 = 130.4550 LKR 1 LKR = 0.7801 JPY
Base Year of Cost Estimation:	May 2014
Schedule:	From January 2014 to December 2029
Price Escalation Rate:	Foreign Currency: 1.3%, Local Currency: 1.3%
Physical Contingency:	Construction: 5.0%, Consulting: 5.0%
Billing Rate of Consultant:	Pro-(A): 2,753,000 JPY Pro-(B): 1,190,000 LKR Supporting Staff: 400,000 LKR
Rate of Tax:	VAT: 0%, Import Tax: 9.0%
Rate of Administration Cost:	10.0%
Rate of Interest during Construction:	Construction: 0.10 %, Consultant: 0.01%
Rate of Front End Fee:	0.2%
Payment Method for Interest during Construction and Front End Fee :	Loan-covered
Fiscal Year:	From January to December

6.2 Construction Cost

(1) Construction Cost

The construction works will be divided into the following four major works.

- E&M System, Rolling Stock, Track Switch and Maintenance
- Civil Works
- Station Construction
- Depot Construction

In determining the costs for E&M system, rolling stock, track switch and maintenance, the actual and/or calculated unit costs based on the past practice and the quotation provided suppliers are used for reference.

The construction unit costs such as civil and architecture work are estimated based on the reference construction costs of Sri Lanka (Outer Circular Highway project) and similar projects in Asia. The project cost is shown in Table 6.2.1. The base year for the construction cost is 2014.

Table 6.2.1 Project Cost Estimation

No.	Item			Unit	Quantity	Unit Cost		Construction Cost		Foreign Portion				Local Portion		Note
										STEP		Others				
						Cost	Unit	(mil.JPY)	%	(mil.JPY)	%	(mil.JPY)	%	(mil.JPY)	%	
1	Rolling Stock (Monorail)			trains												
2	Signalling			km												
3	Train Operation Management System			km												
4	Telecommunication System			km												
5	Traction Substation			Ls												
6	Power Line			km												
7	Track Switches			Ls												
8	Spare Parts			Ls												
9	Test & Commission			Ls												
10	Civil	Track Girder	PC-Girder Double Track (L < 22m)	km												
			PC-Girder Single Track (L < 22m)	km												
			Steel Girder (L > 30m)	km												
		Bridge for Switch	PC Bridge L=22	bridges												
		Substructure	Mono-Type Pier Double Track	km												
			Mono-Type Pier Single Track	km												
11	Stations	Stations (2-ticketing gates)		stations												
		Stations (1-ticketing gate)		stations												
		National Hospital		stations												
		AFC System Development Fee		Ls												
12	Train Depot	Buildings		Ls												
		Equipment for Train Inspection		Ls												
		Power Line		km												
		Track Switches		Ls												
		Track		km												
		Civil Work		Ls												

Source: SKYTRAIN Study Team

(2) Cost Breakdowns

Cost breakdown for the "Traction Substation (Detail. A)" is shown in Table 6.2.2

Table 6.2.2 Cost Breakdown for the Traction Substation (Detail. A)

	Unit	Quantity	Unit Cost		Construction Cost		Foreign Portion		Local Portion
							STEP	Others	
				Unit		Unit	(%)	(%)	(%)
Traction Substation									
Equipment for Receiving of Transmitted Electricity and Transformation of Electricity (20,000kw)	set								
Equipment for Receiving of Transmitted Electricity (20,000kW)	set								
Transformer / Rectifier (2000kw)	set								
Transformer / Rectifier (1000kw)	set								
Equipment for Transformation of Electricity (Depot) (3000kw)	set								
Transformer 11kV, (3000kW)	set								
Transformer 11kV, (2000kW)	set								
Transformer 11kV, (1000kW)	set								
Remote Surveillance System for Substation	Ls								
Equipment for Transformer (Station), (300kw)	set								
Equipment for Transformer (Station), (400kw)	set								
Equipment for Transformer (Station), (500kw)	set								
Equipment for Transformer (Station), (1600kw)	set								
Transportation Cost (3% of FP)	Ls								
Preliminaries (7%)	Ls								

Source: SKYTRAIN Study Team

Cost breakdown for the "Track Switches (Detail. B)" is shown in Table 6.2.3.

Table 6.2.3 Cost Breakdown for the Track Switches (Detail. B)

	Unit	Quantity	Unit Cost		Construction Cost		Foreign Portion		Local Portion
							STEP	Others	
				Unit		Unit	(%)	(%)	(%)
Sw itches for Main Track									
2-Ways Joint Flexible Type	set								
2-Ways Joint	set								
Preliminaries (7%)	Ls								
Cost of Sw itch for Main Track									
Sw itches for Depot									
2-Ways Joint	set								
3-Ways Joint	set								
5-Ways Joint	set								
Preliminaries (7%)	Ls								
Cost of Sw itch for Depot									

Source: SKYTRAIN Study Team

Cost breakdown for the "Civil Work (Detail. C)" is shown in Table 6.2.4.

Table 6.2.4 Cost Breakdown for the Civil Work (Detail. C)

	Unit	Quantity	Unit Cost		Construction Cost or Unit Cost		Foreign Portion		Local Portion
							STEP	Others	
				Unit		Unit	(%)	(%)	(%)
PC Double Track									
(1) Fablication, Election, Bearing	km								
(2) Cost for Construction Yard	Ls								
Preliminaries (7%)	Ls								
Sub Total									
Cost of PC Double Track (Subtotal / 23.2km)									
PC Single Track									
Fablication, Election, Bearing	km								
Preliminaries (7%)	Ls								
Sub Total									
Cost of PC Single Track (Subtotal / 0.9km)									
Steel Girder									
Fablication, Election, Bearing	km								
Preliminaries (7%)	Ls								
Sub Total									
Cost of Steel (Subtotal / 1.85km)									
Bridge for Sw itch									
PC Hollow Bridge	m2								
Preliminaries (7%)	Ls								
Cost of Bridge for Sw itch									
Mono Type Pier (Double)									
Mono Type Pier, Pile	km								
Pavement	m2								
Preliminaries (7%)	Ls								
Sub Total: (1) + (2)									
Cost of Mono Type Pier (Subtotal / 23.2km)									
Mono Type Pier (Single)									
Mono Type Pier, Pile	km								
Preliminaries (7%)	Ls								
Sub Total									
Cost of PC Single Track									

Source: SKYTRAIN Study Team

Table 6.2.5 shows location of steel bridges and these lengths.

Table 6.2.5 Table for Steel Bridges

Location	Bridge Length (m)	Note
Line-1(North: Fort-Kotahena)		
0+600		
0+900		
1+400		
2+300		
Line-1(Sourth: Fort-IT Park)		
0+400		
0+500		
0+700		
0+800		
0+900		
1+800		
3+500		
4+200		
5+300		
6+600		
6+800		
9+200		
11+600		
Line-2(Kollupitiya - National Hospital)		
0+600		
0+900		
Total		

Cost breakdown for the "Stations and AFC System Development Fee (Detail. D)" is shown in Table 6.2.6.

Table 6.2.6 Cost Breakdown for Stations and AFC System Development Fee (Detail. D)

	Unit	Quantity	Unit Cost		Construction Cost		Foreign Portion STEP	Foreign Portion Others	Local Portion
				Unit		Unit	(%)	(%)	(%)
Station									
Stations (2-ticketing gates)									
Civil (Pier and Slab for Station)	Ls								
Architect (Concourse, Platform, Roof, etc)	Ls								
E&M	Ls								
Cost of Transportation (3% of FP)	Ls								
Preliminaries (7%)	Ls								
Cost of Stations (2-ticketing gates)									
Stations (1-ticketing gate)									
Civil (Pier and Slab for Station)	Ls								
Architect (Concourse, Platform, Roof, etc)	Ls								
E&M	Ls								
Cost of Transportation (3% of FP)	Ls								
Preliminaries (7%)	Ls								
Cost of Stations (1-ticketing gate)									
Station (National Hospital)									
Civil (Pier and Slab for Station)	Ls								
Architect (Concourse, Platform, Roof, etc)	Ls								
E&M	Ls								
Cost of Transportation (3% of FP)	Ls								
Preliminaries (7%)	Ls								
Cost of Station (National Hospital)									
AFC									
AFC Equipment for Station (Hard and Soft)									
Automatic Gate	Ls								
Ticket Machine	Ls								
Card Reader/Processor (for Station Staff)	Ls								
Inquiry System	Ls								
Ticket Machine (for Charge)	Ls								
Server for Station	Ls								
Subtotal 1									
Others									
AFC for Central Control Room	Ls								
Training/Testingand Maintenace	Ls								
Other Equipment	Ls								
Subtotal 2									
Cost of AFC Equipment (Ground Total)									

Source: SKYTRAIN Study Team

Cost breakdown for the "Building and Civil work in the Depot (Detail. E)" is shown in Table 6.2.7.

Table 6.2.7 Cost Breakdown for the Building and Civil work in the Depot (Detail. E)

		Unit	Quantity	Unit Cost		Construction Cost		Foreign Portion		Local Portion
								STEP	Others	
					Unit		Unit	(%)	(%)	(%)
Architect for Depot Area										
Office		m2								
Substation		m3								
Workshop		m3								
Transportation Cost (3% of FP)		Ls								
Preliminaries (7%)		Ls								
Cost of Architect for Depot Area										
Civil for Depot Area										
Preparation Work										
Clearing & Grubbing		m2								
Soil improvement	Surface 2m	m3								
Access road	8m x 5km	m3								
Drainage system	2m x 2m x 5km	m								
Dew atering system		Ls								
Fence		m								
Subtotal 1										
Pilling Work										
PHC pile	600mm dia. 15mL	nos.								
Pile driving		m								
Pile head treatment	manual	nos.								
Pile test	Static load	nos.								
Pile test	Integrity sonic	nos.								
Pile test	Dynamic analysis	nos.								
Subtotal 2										
Beam Slab and Construction										
Timbering		nos.								
Re-bar	Grade 460	nos.								
Concrete	Grade 30	nos.								
Subtotal 3										
Preliminaries (3% of FP)		Ls								
Cost of Civil for Depot (Ground Total)										

Source: SKYTRAIN Study Team

Cost breakdown for the "Equipment for Depot Inspection (Detail. F)" is shown in Table 6.2.8.

Table 6.2.8 Cost Breakdown for the Equipment for Depot Inspection (Detail. F)

	Unit	Quantity	Unit Cost		Construction Cost		Foreign Portion		Local Portion
							STEP	Others	
				Unit		Unit	(%)	(%)	(%)
Equipment for Train Inspection									
Equipment for Train Inspection (Daily)	line								
Equipment for Train Inspection (Monthly)	line								
Train washing machine	line								
Equipment for railway maintenance vehicle	line								
Equipment for tire change	set								
Equipment for maintenance (Train)	line								
Equipment for maintenance (Bogie Track)	set								
Equipment for maintenance (Electrical)	set								
Equipment for maintenance (Break)	set								
Equipment for painting	set								
Equipment for general machine	set								
Equipment for maintenance (Electrical)	set								
Common equipment	set								
Others	set								
Transportation Cost (3% of FP)	Ls								
Preliminaries (7%)	Ls								
Cost of Equipments for Train Inspection									

Source: SKYTRAIN Study Team

(3) Consulting Services Cost

The consulting services costs were estimated by calculating man-months and direct costs for consulting services.

(4) Operation and Maintenance Cost

Operation and maintenance cost is described in subsection 8.4 of Chapter 8.

(5) Compensation Cost

The compensation cost shall include the following items:

1) Land Acquisition

Preliminary land acquisition cost is mentioned in subsection 12.11.8 of Chapter 12.

2) Resettlement of Houses, Public Structure and Private Structures

Preliminary cost estimates for resettlement of houses, public structures and private structures are mentioned in subsection 12.11.8 of Chapter 12.

(6) Utilities Diversion

Cost of diverting utilities shall be examined in the detailed design stage as it requires detail examination on underground utilities.

(7) Construction Package

The project is divided into 4 packages as follows, Civil Package 1 (Superstructure), Civil Package 2 (Substructure and stations), Civil Package 3 (Substructure, stations and depot), and E&M System and Rolling Stock. The detail of packaging condition is mentioned in "Chapter 7 Project Implementation Schedule".

(8) Total Project Cost

The total project cost of the monorail system that includes construction, physical contingencies, price escalation ant others, is estimated at JPY 160,126 million as shown in Table 6.2.9.

Table 6.2.9 Total Project Cost of the Monorail

Unit: million

Note: The total cost is excluding cost for utility diversion, land acquisition, administration cost, value added tax, import tax, interest during construction, and front end fee. Land acquisition cost is mentioned in Chapter 12.

Source: SKYTRAIN Study Team

6.3 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 cost and ratio of procurement from Japan is shown in Table 6.3.1.

Table 6.3.1 Procurement Ratio from Japan

Goods and Services Procured from Japan			
Items	**Cost (million JPY)**	**Ratio**	**Contents**
1. Rolling Stock	[redacted]	[redacted]	One service of design, manufacturing, transportation and carrying in.
2. Signalling	[redacted]	[redacted]	System, installing and adjusting of (ATC/TD/Interlocking)
3. Train Operation Management System	[redacted]	[redacted]	System, installing and adjusting of (Train Operation Management System)
4. Telecommunication System	[redacted]	[redacted]	Equipment and installation of (wireless communication, transmitter, telephone, information board, CCTV, broadcasting)
5. Power Line	[redacted]	[redacted]	Equipment and installation of Power line
6. Track Switches	[redacted]	[redacted]	Equipment and installation of Track Switches
7. Spare Parts	[redacted]	[redacted]	Spare parts for items of No.1 – 6 mentioned the above.
8. Test and Commission	[redacted]	[redacted]	
9. Civil Works	[redacted]	[redacted]	Materials (PC-cable (for PC girder), bearing shoes and expansion joints), material and manufacturing of steel girders
10. Architecture Works	[redacted]	[redacted]	AFC(Automatic Fare Collection), home door for platform, material and manufacturing of (PC-cable, steel for portal type piers)
11. Depot	[redacted]	[redacted]	Materials (PC-cable), Equipment and installation of Track Switches, Power Line and Train Inspection.
Total	[redacted]	[redacted]	[redacted]

Source: SKYTRAIN Study Team

CHAPTER 7 Project Implementation Schedule

7.1 Planning of Project Implementation Schedule

This monorail project will be divided into three stages categorised as the Design Phase, Tender Phase and Construction Phase, the latter of which includes Construction, Commissioning Testing, Trial Running, and Operational Testing. The study team has examined the packaging options in consideration of the construction cost as well as merit and demerit as basis for the selection of a preferable packaging option for the project as shown in Table 7.1.1.

Table 7.1.1 Comparison Chart for Packaging Options

Packaging	Contents	Cost (JPY)	Merit / Demerit	Evaluation
Option 1				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]		
Option 2				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]		
Option 3				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Based on the comparison and evaluation mentioned in Table 7.1.1, the Study team has chosen Option 1 for this study.

In general, the implementation schedule will be planned in consideration of the following two conditions "a) condition of contract for construction (method of ordering system)", and "b) construction package". General conditions for the implementation schedule are mentioned in Table 7.1.2.

Table 7.1.2 General Conditions for Implementation Schedule

No	Condition	Description
a)	Contract for Construction (method of ordering)	[redacted]
b)	Construction Package	[redacted]

Note: * The "Standard Bidding Documents under Japanese ODA Loans, Procurement of Works" (*JICA SBD (Works)* are based on the "Conditions of Contract for Construction for Building and Engineering Works Designed by the Employer, Multilateral Development Bank (MDB) Harmonised Edition", June 2010 (*FIDIC Pink Book*) and the "Conditions of Contract for Plant and Design Build For Electrical and Mechanical Plant, and For Building and Engineering Works, Designed by the Contractor", First Edition 1999 (*FIDIC Yellow Book*) by the International Federation of Consulting Engineers (FIDIC).

Source: SKYTRAIN Study Team

7.1.1 Procurement Method

In regards to the contract for construction, the method of JICA SBD (Works) is considered for the civil packages. The Design Build method of the FIDIC Yellow Book will be applied to the package for E&M systems and rolling stock. Based on these conditions, the schedule is planned with the following steps including, "Basic Design", "Detailed Design", "Tender" and "Construction".

7.1.2 Construction Package

The implementation schedule is made based on the packages condition mentioned in Table 7.1.3

Table 7.1.3 Packages for Draft Implementation Schedule

Package	Contents	Scope of Works
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

Source: SKYTRAIN Study Team

7.1.3 Implementation Schedule

The implementation plan is established based on the month/year for the milestones of key events of the Project. The plan includes the stages for detailed design, tender procedure and construction work. The construction period was estimated as 4 years in Figure 7.1.1.

It is assumed that International Competitive Bidding (ICB) is applied for procurement of the contractor and consultant for the Project. The time required for the procurement is assumed based on average actual time taken in Japanese ODA projects in Sri Lanka. The milestones for the implementation of the Project undertaken by a Japanese ODA Loan are formulated as follows:

- About 10 months will be required for the selection of a consultant for the detailed design, tender assistance and construction supervision.
- The period for preliminary and detailed design will be 24 months.
- 12 months will be required for the procurement of a contractor.
- Construction period will be 48 months.

The total implementation schedule will begin with the L/A, and the construction will be completed by the end of 8^{th} year. Assumptions for the project implementation schedule, in particular for construction are mentioned below.

1. All land acquisition must be completed before the construction work
2. All obstructions (including buried structures) must be replaced or removed before the construction work
3. Counter measures for public roads, such as securing the construction yard and single lane traffic are required during construction work. (Prior consultation with relevant authorities is needed)
4. In the case that the Contractor requests design modification of the detail design, an immediate approval is required by the Employer (Sri Lanka Government) based on the JICA SBD (Works).
5. In the case that the schedule (Figure 7.1.1) is requested to be shortened, the cost of construction (by the Contractor) and construction management (By the Consultant) will increase.
6. Since this construction will be within the Colombo city area, it is necessary that the Employer (Sri Lanka Government) provide the construction yard or any public land as and when required.
7. In the case that requests other than No.1-6 mentioned above is made, an immediate response for approval by the Employer (Sri Lanka Government) is required

Source: SKYTRAIN Study Team

Figure 7.1.1 Draft Implementation Schedule