MINISTRY OF TRANSPORT
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

PREPARATORY SURVEY FOR NEW INTEGRATED URBAN PUBLIC TRANSPORT SYSTEM INTRODUCTION PROJECT

FINAL REPORT

SUMMARY

JANUARY 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

4 R
J R
14-055

MINISTRY OF TRANSPORT
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

PREPARATORY SURVEY FOR NEW INTEGRATED URBAN PUBLIC TRANSPORT SYSTEM INTRODUCTION PROJECT

FINAL REPORT

SUMMARY

JANUARY 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

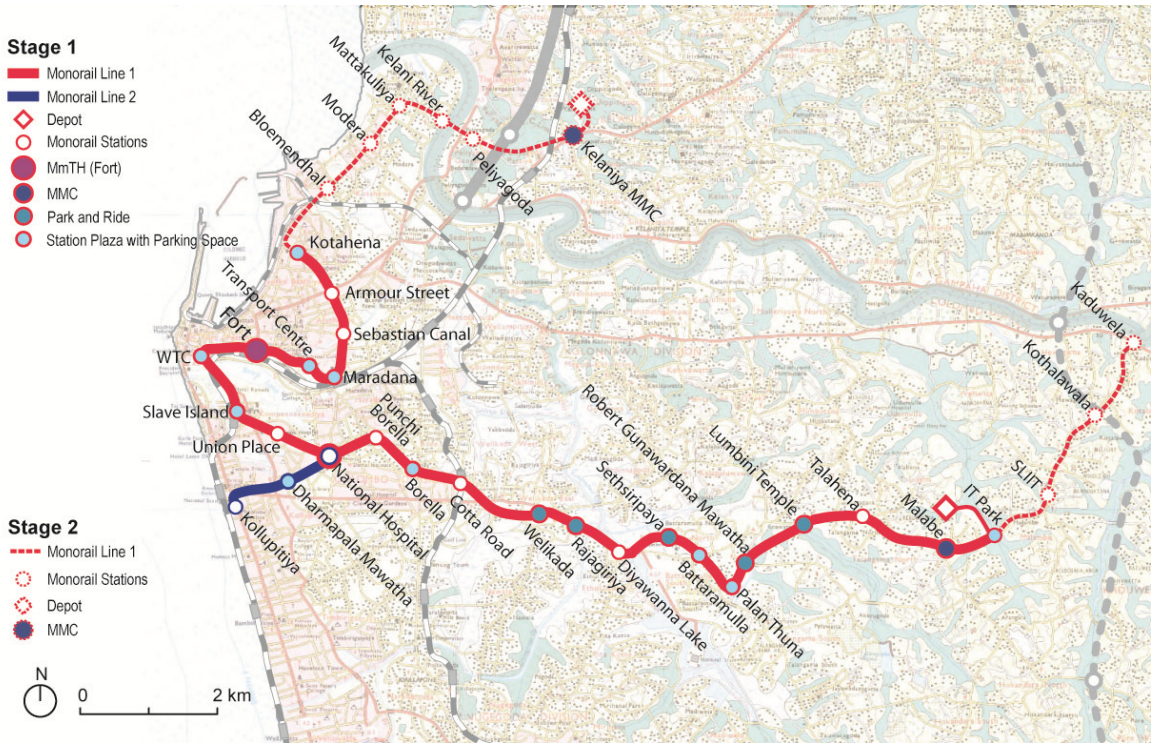
US$1.00 = LKR 130.4550
US$1.00 = JPY101.79

(Exchange rate of May 2014)

Images of Monorail Rolling Stocks and Civil Structures

Images of Monorail Station

Images of Monorail Station Interior



General Route Alignment

Outline of the Project

1.	**Country: The Democratic Socialist Republic of Sri Lanka**
2.	**Project Name: New Integrated Urban Public Transport System Introduction Project**
3.	**Execution Agency: Ministry of Transport**
4.	**Survey Objectives:** The transport demand has increased remarkably over the past few years, especially in Colombo Metropolitan Area. Current traffic congestion becomes serious during morning and evening peaks within and around the boundary of CMC and is expanding its area. In order to develop an efficient urban transport network and promotion of a reliable and safe transport system, the urban transport master plan has been formulated under the Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs (CoMTrans). The master plan prioritised the monorail in Malabe Corridor. This survey, therefore, examine feasibility of the monorail project from technical, economical, financial, institutional and environmental aspects.
5.	**Survey Contents:** On the proposed monorail Line 1 from Kotahena to IT Park at Malabe (21.4 km) and Line 2 from National Hospital to Kollupitiya (2.1 km), Multi-modal transport facilities, and the P&R facilities, the feasibility study shall cover the following components. 1) Conduct supplementary surveys 2) Prepare/select design standards for the project 3) Conduct preparatory design of the project 4) Conduct economic and financial analyses 5) Conduct EIA 6) Prepare an implementation strategy 7) Prepare an operation and maintenance strategy
6.	**Conclusions and Recommendations:** **(1) Conclusions** ・ The monorail system was designed as a technically and economically suitable and effective solution for the Colombo Metropolitan Area. The route and stations were selected to capture many passenger demands. It can help to alleviate traffic congestion and to match social and environmental considerations in urban area. ・ The project costs for the implementation of the monorail system will be economically covered by the large amount of benefits from the monorail system. ・ The public corporation might face financial difficulty in case of normal bus fare. However, the public corporation has the possibility to cover the operation and maintenance costs even from the fare revenue of normal bus level in case the public corporation receives the additional revenue from the multi-modal transport hub at Fort/Pettah with Mall-1. ・ Environmental Impact Assessment (EIA) study revealed that the potential impacts of the proposed project take place mainly during the construction stage and impact during operational stage is minimal. ・ Social study revealed that impact on agricultural land is relatively high due to land for a depot, however, the number of houses and commercial establishments to be relocated due to the project is relatively low. **(2) Recommendations** ・ Formulation of Project Management Unit (PMU) is required to successfully implement the project smoothly and effectively. ・ Institutional arrangement for monorail operation/management is essential. ・ EIA process should be completed for the implementation of the project. ・ In order to make a smooth implementation of land acquisition and resettlement, all the necessary arrangements and measures should be taken in accordance with the Resettlement Action Plan (RAP) prepared for the Project.

PREPARATORY SURVEY

FOR

NEW INTEGRATED URBAN PUBLIC TRANSPORT SYSTEM INTRODUCTION PROJECT

FINAL REPORT

SUMMARY

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 Introduction

1.1 Background

In the Colombo Metropolitan Area[1], which consists of Colombo Municipal Council (CMC) and adjacent areas, current traffic congestion becomes serious during morning and evening peaks within and around the boundary of CMC and is expanding its area. Furthermore, traffic congestion will worsen due to the anticipated increasing demand if appropriate countermeasures are not taken. Less utilisation of high occupancy vehicles, a lack of facilities for pedestrians and bus passengers, insufficient capacity of public transport and poor enforcement of traffic rules aggravate the situation.

In order to develop an efficient urban transport network and promotion of a reliable and safe transport system, the objectives of the Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs (herein under referred to as the CoMTrans Project) are:

- To prepare reliable transport data that can be utilised to evaluate and formulate transport development plans/projects in a scientific manner by conducting an area-wide transport survey.
- To formulate a comprehensive Urban Transport Master Plan for the Colombo Metropolitan Area including the six transport corridors prioritised by the Ministry of Transport with justification of selected priority/leading projects for short-term, mid-term, and long-term implementation.
- To conduct a feasibility study on the prioritised projects under the comprehensive urban transport master plan.

The CoMTrans project commenced in August 2012 and the urban transport master plan was proposed and discussed with the relevant government agencies including a series of Steering Committee meetings. The CoMTrans master plan proposed four goals for urban transport system development in CMA.

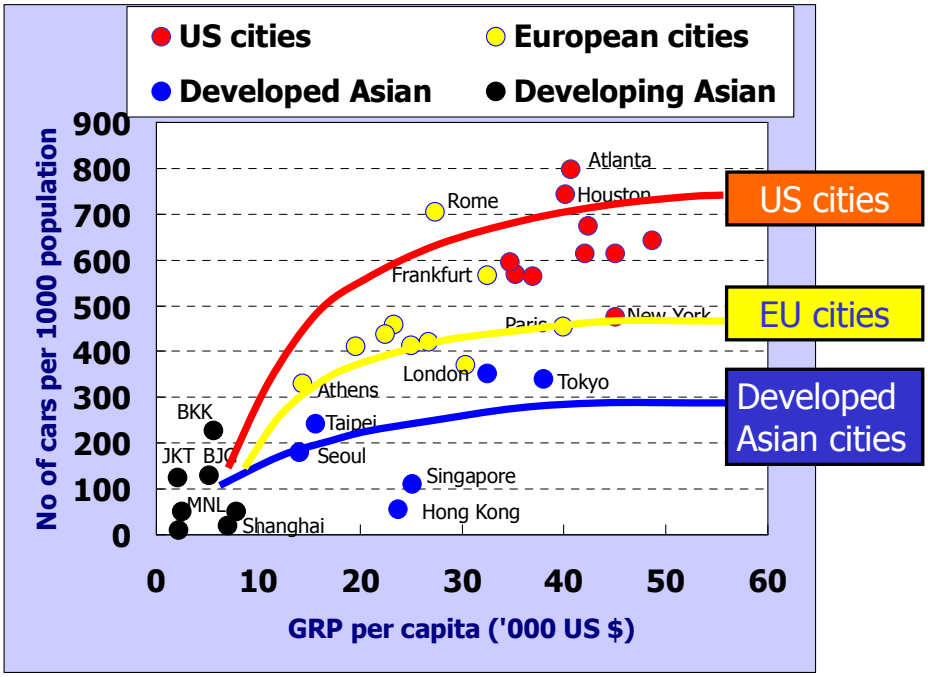
- Equity in Transport to All the Members of Society
- Efficiency in Transport Systems to Support Economic Activities
- Environmental Impact and Health Promotion Related to Transport
- Traffic Safety and Security in Transport

To achieve the aforementioned goals, the CoMTrans master plan made policies 1) to promote use of public transport, 2) to alleviate traffic congestion, 3) to reduce air pollutants/traffic noise and to promote health, and 4) to reduce transport accidents and to improve security.

[1] The CoMTrans urban transport master plan defines the area under the following Divistional Secretariat Divisions; Ja-Ela, Gampaha, Mahara, Wattala, Kelaniya, Biyagama, Kolonnawa, Colombo, Thimbirigasyaya, Kaduwela, Sri Jayawardenepura Kotte, Dehiwala, Maharagama, Rathmalana, Homagama, Kesbawa, Moratuwa, Panadura, Bandaragama and Kalutara.

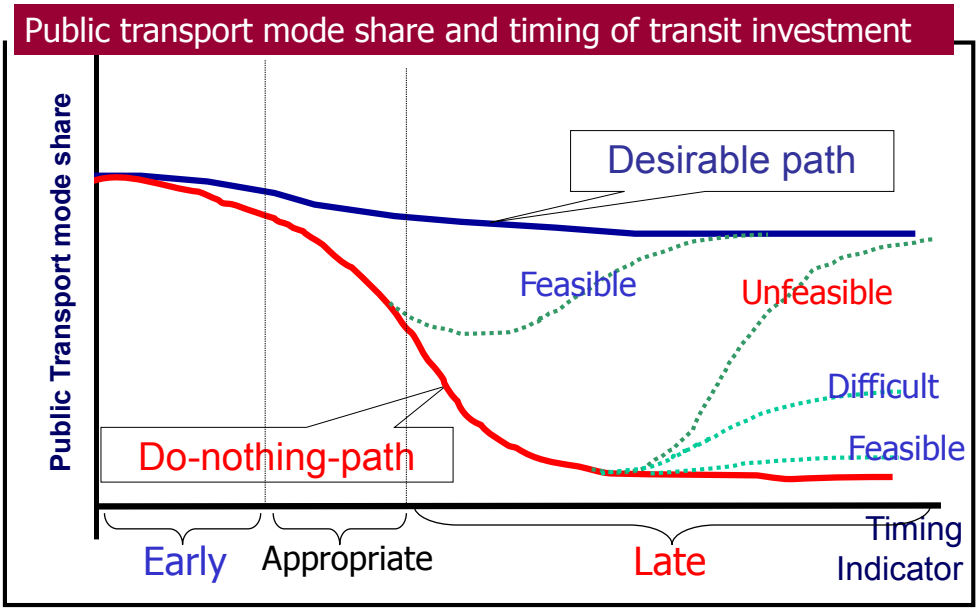
Figure 1.1.1 shows vehicle ownership and gross regional products (GRP) per capita of cities in the United States (U.S.), the European Union (EU) and Asia. Cities in U.S., EU and developed Asian cities took different paths. While U.S. cities are dependent on cars, developed Asian cities succeeded to deter vehicle ownership with development of public transport systems. As show in Figure 1.1.2, the share of public transport will continuously decrease with economic growth if the government does nothing. While some U.S. cities are recently trying to increase the share of public transport to reduce externalities of private mode of transports, a limited number of cities have succeeded to regain a share of public transport. Once car ownership and a share of private mode of transport increases, it is difficult to reverse it due to the captive characteristics of car users.

With the decrease of travel speeds on the roads due to the abovementioned severe traffic congestion, the travel time of buses will increase. This might accelerate the shift to private modes of transport. It is highly expected to break this vicious circle though provision of convenient, fast and high capacity public transport modes.



Source: Morichi, S and Acharya, S.R. (eds.) (2012) Transport Development in Asian Megacities -A New Perspective-, Springer

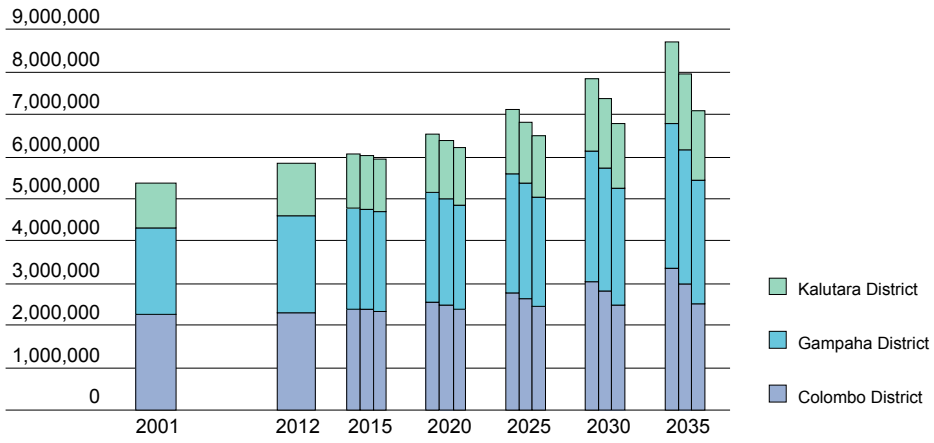
Figure 1.1.1 Vehicle Ownership and GRP per Capita of Cities in U.S., E.U. and Asian Cities



Source: Hanaoka, S. (2014) " International Experiences in Urban Transport Policies and Financial Options for Urban Transport Projects" presented for CoMTrans Special Seminar on Sustainable Urban Transport Development on 21st January, 2014

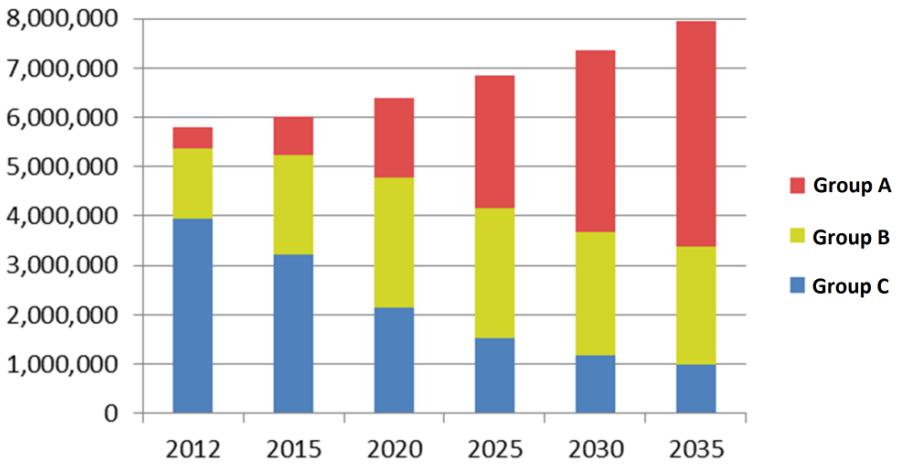
Figure 1.1.2 Public Transport Mode Share and Timing of Transit Investment

In the Western Province, significant growths in terms of population and economy are expected. The population of 5.8 million in 2012 is expected to increase to 7.1 million in 2035. It is also expected that the GRDP per capita is expected to increase to approximately 2.5 times of 2010 level. Therefore, in line with the economic growth, the share of income group with equal to or more than LKR 8,000,000 will be majority in 2035. This means that a number of people is affordable to purchase a passenger car.



Note: After 2015, the projected populations are shown in the High, Medium, and Low growth scenarios.
Source: CoMTrans

Figure 1.1.3 Population Projections to 2035



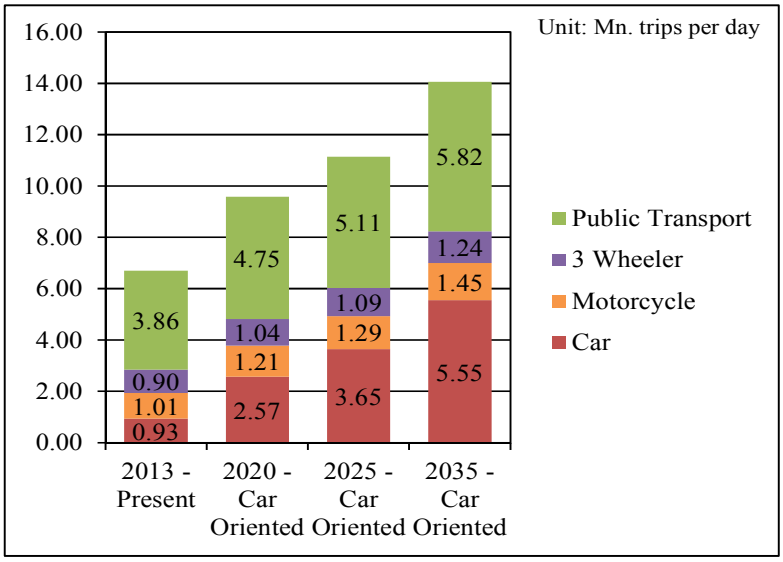
Note: Group C is less than LKR 40,000. Group B is LKR 40,000 - 79,999. Group A is LKR 80,000 and above.

2012 Estimation from CoMTrans Home Visit Survey. Income Unknown: 10,961 (0.2%)
2015-2035 projection, CoMTrans Study Team

Figure 1.1.4 Proportion of Projected Population by Income Level in Western province

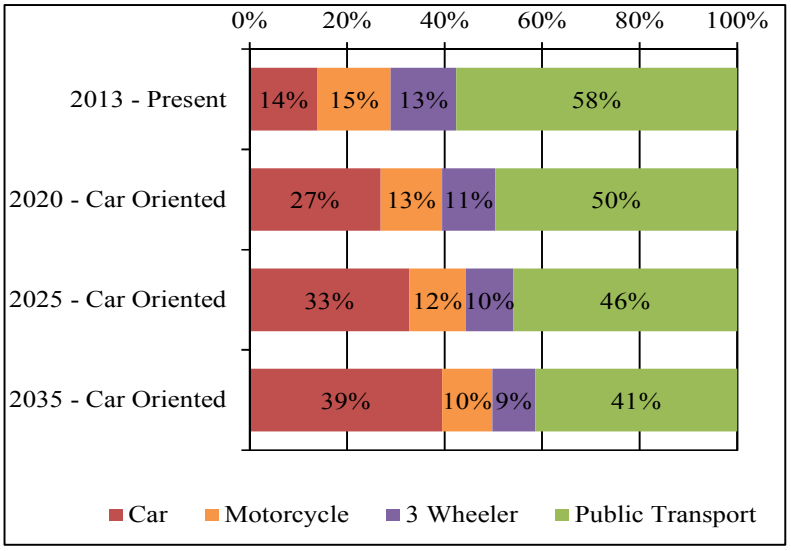
Total person trip demand would increase by 1.75 times from 2013 to 2035 however it should be noted that the trips made by private cars would increase from 0.93 million trips in 2013 to 5.55 million trips in 2035, which implies that the growth of trips by cars accounts for almost six times of the increase during the period as illustrated in Figure 1.1.5.

In 2013 the share of public transport in the Western Province is 58%; however, the share of public transport would fall to 41% in 2035 if no improvement of public transport was undertaken as shown in Figure 1.1.6. It is evident that Colombo Metropolitan Area also might follow the same path with U.S. cities if no action is taken. This phenomena is irreversible as shown in Figure 1.1.2. It is, therefore, essential and urgent to take drastic measures to improve service level of public transport.



Source: CoMTrans, Car Oriented Scenario, Excluding non-motorised transport

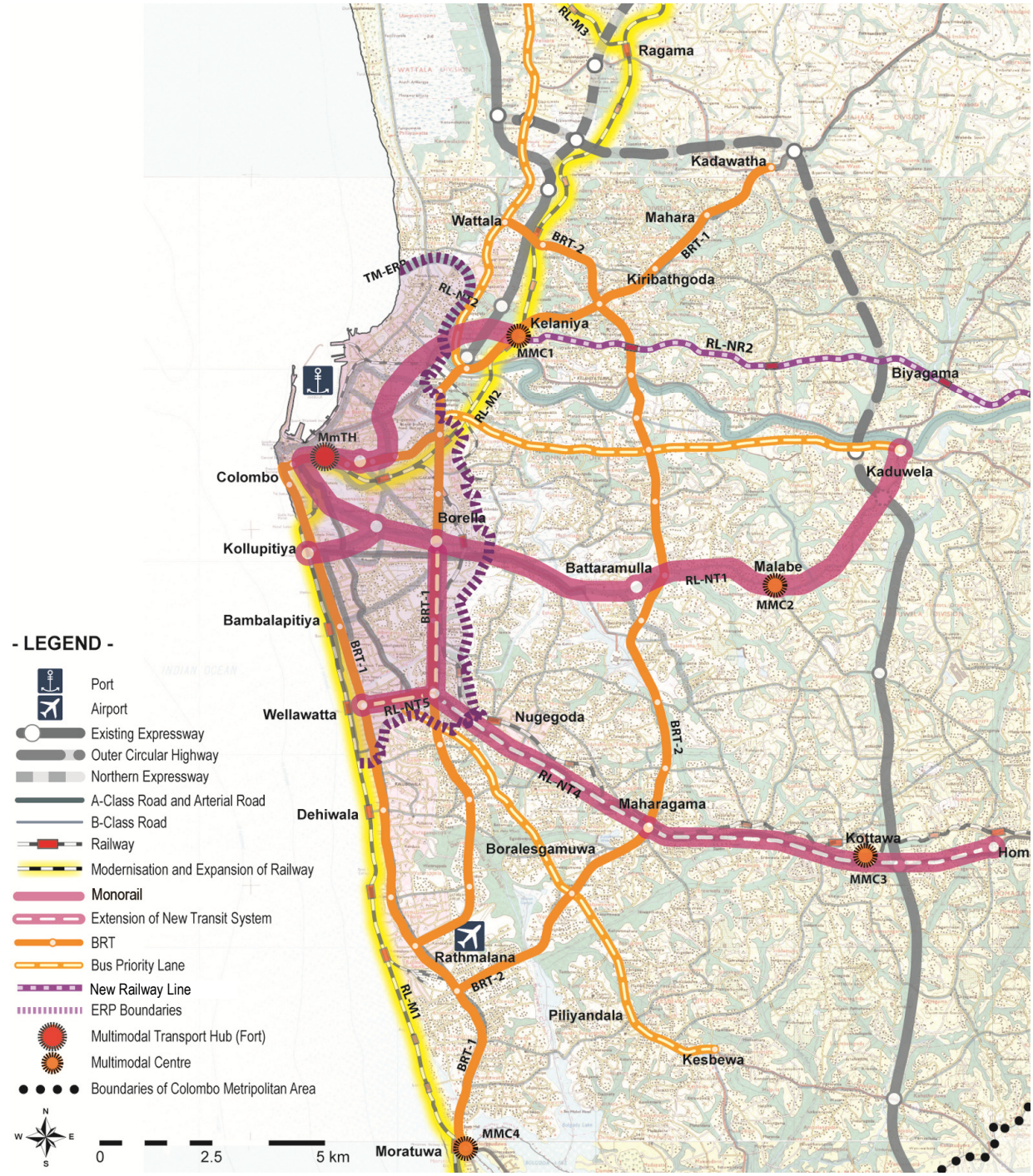
Figure 1.1.5 Increase of Person Trips by Mode of Transport: 2013 - 2035



Source: CoMTrans, Car Oriented Scenario, Excluding non-motorised transport

Figure 1.1.6 Change of Modal Share for Car Oriented Scenario: 2013 -2035

Under above mentioned major transport policies of the master plan, comprehensive analyses on major transport corridors, the inner city area and other areas have been conducted. The master plan study identified seven major transport corridors; Negombo, Kandy, Low Level, Malabe, High Level, Horana and Galle Corridors, due to their high level of traffic volume. Based on the formulated socio-economic framework and future demand forecast, solutions for the transport corridors were evaluated. Several transport policies were selected for these corridors. Inner city projects and non-corridor transport projects were also proposed and evaluated. The proposed public transport infrastructure development network is illustrated in Figure 1.1.7.



Source: CoMTrans

Figure 1.1.7 Entire Public Transport Network Plan in 2035

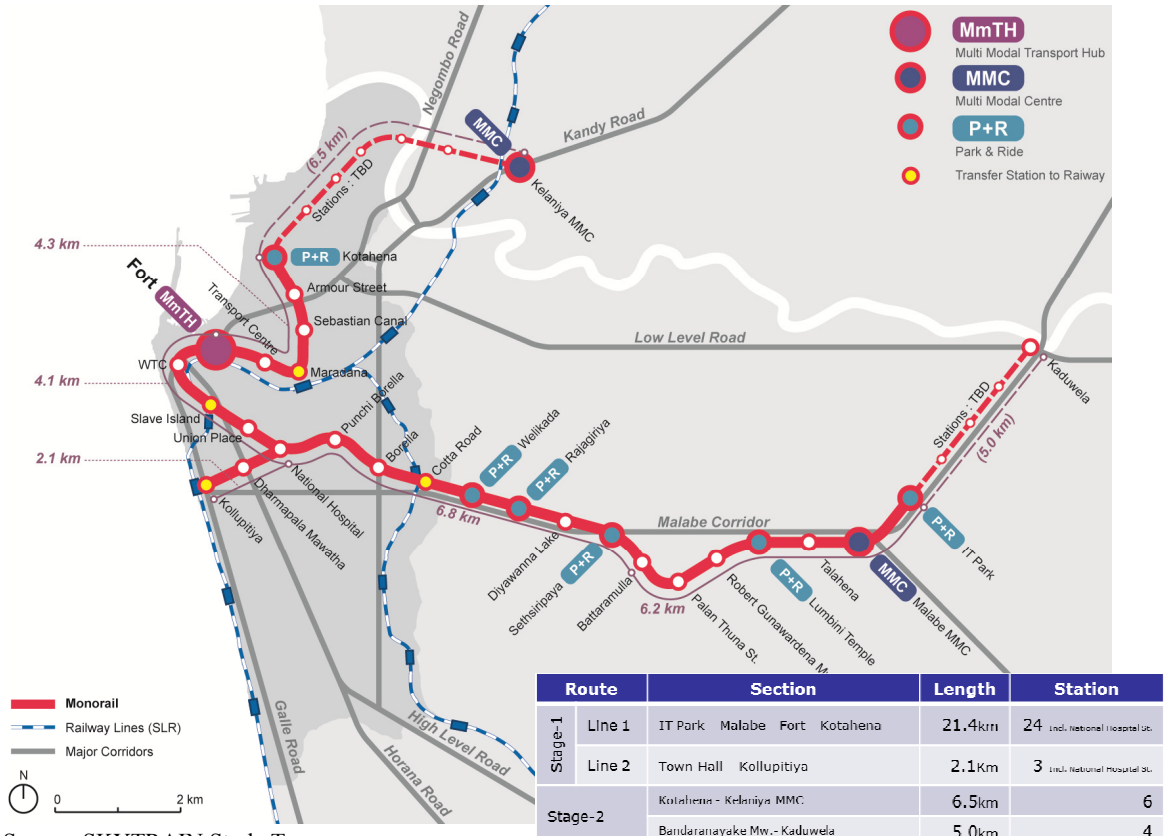
The transport network comprises links and nodes. While the aforementioned corridor projects and circular roads and public transport projects create links between traffic generating points, these links have to be connected in a proper manner at a node which means a railway station, an inner and intra provincial bus terminal, a BRT station, a monorail station and a parking facility. The smooth connection at a transport node of a network is essential to make a link project viable.

In the case of CMA, all the transport modes are concentrated in the Fort and Pettah areas. However, the linkages of these transport modes as well as with the hinterlands are not well organised.

Taking various factors into consideration such as current and future transport volume, degree of traffic congestion, accessibility to public transport, size of investment, public transport network development, urban planning perspective and economic and financial viability; the Steering Committee of the CoMTrans Project chaired by the Secretary of the Ministry of Transport has decided to focus on;

1. Monorail system for Malabe Corridor,
2. Multi-modal transport facilities,
3. Park and Ride facilities (P&Rs) at the monorail stations.

The Committee also named this package of projects as the "Integrated Transport System with Monorail, SKYTRAIN" with a view to the first elevated transport system on the Island. While each single component of the "**SKYTRAIN**" project might not be sufficient to significantly improve public transport ridership, this package mutually benefits each component by improving the convenience of the public transport system as a network. In this study, the feasibility study of the SKYTRAIN project is undertaken.



Route		Section	Length	Station
Stage-1	Line 1	IT Park Malabe Fort Kotahena	21.4km	24 Incl. National Hospital St.
	Line 2	Town Hall Kollupitiya	2.1km	3 Incl. National Hospital St.
Stage-2		Kotahena - Kelaniya MMC	6.5km	6
		Bandaranayake Mw.- Kaduwela	5.0km	4

Source: SKYTRAIN Study Team

Figure 1.1.8 Components of SKYTRAIN Project


Source: SKYTRAIN Study Team

Figure 1.1.9 Images of SKYTRAIN Project (Monorail)

1.2 Scope of the Feasibility Study

In order to achieve the SKYTRAIN project, the feasibility study shall cover the following components according to the Record of Discussions of the CoMTrans project:

1) Conduct supplementary surveys
2) Prepare/select design standards for the project
3) Conduct preparatory design of the project
4) Conduct economic and financial analyses
5) Conduct EIA
6) Prepare an implementation strategy
7) Prepare an operation and maintenance strategy

This Report was prepared to evaluate the viability of the SKYTRAIN project from the technical, economic, financial and environmental perspectives.

This summary consists of Chapter-2 on the feasibility study and Chapter-3 discussed the project evaluation.

The list of the members of the Steering Committee and the meetings are summarised in Table 1.2.1 and Table 1.2.2.

Table 1.2.1 List of the Members of the CoMTrans Steering Committee

Chair	
Secretary	Ministry of Transport
Members	
Additional Secretary	Ministry of Defense and Urban Development
Secretary	Ministry of Highways, Ports and Shipping
Assistant Director	Ministry of Private Transport Services
Assistant Director	Ministry of Environment
Additional Director General Director	Department of National Planning
Director	Department of External Resources
Director / Western Province	Urban Development Authority
Director (Planning)	Road Development Authority
Chairmen	Sri Lanka Transport Board
Additional General Manager	Sri Lanka Railways
Secretary	Western Provincial Council/Provincial Ministry of Transport
	Japan International Cooperation Agency
Provisional Members	
Director Engineering (Traffic, Design & Road Safety)	Colombo Municipal Council
Deputy Inspector General, Traffic (Western)	Sri Lanka Police

Note: Advisor(s) from academia attended the Steering Committee meeting with recommendation from chairman and the team.

Source: SKYTRAIN Study Team

Table 1.2.2 List of the CoMTrans Steering Committee Meetings

No.	Date	Topic
1	29th August, 2012	Comments on the Inception Report Decision on the Members of the Steering Committee and the Technical Committee Decision on the Undertakings of the Government of Sri Lanka
2	12th March, 2013	Progress of the Transport Surveys Goals of Urban Transport System Development Population Framework Road Network and Transit Network Options
3	17th May, 2013	Progress of the Transport Surveys Preliminary Results of the Transport Surveys Concept of Transit Route Options
4	21st June, 2013	Preliminary Results of Transport Surveys Concept of Transit Options by Corridor Proposal of Integrated Transport System with Monorail Concept of Multi-Modal Transport Hub
5	18th November, 2013	Draft Urban Transport Master Plan Current Transport Condition Vision, Goal and Strategies of the Master Plan Future Socio-Economic Framework and Demand Forecast Proposal and Evaluation of Corridor Project Options Proposal and Evaluation of Non-Corridor Project Options Benefit of the Master Plan Comments on the Master Plan
6	11th February, 2014	Concept of the Integrated Transport System with Monorail, SKYTRAIN Monorail System and Route Options MmTH Concept Design Cost Estimation and Economic Viability of the Project
7	12th August, 2014	Explanation of the Finalised Master Plan The SKYTRAIN Project Progress of the Environmental Impact Assessment (EIA) System Design of the SKYTRAIN Project Institutional Arrangement Economic and Financial Viability of the SKYTRAIN Project

Source: SKYTRAIN Study Team

CHAPTER 2 Outline of Monorail System

2.1 Corridor and Mode Selection

Why Malabe Corridor?

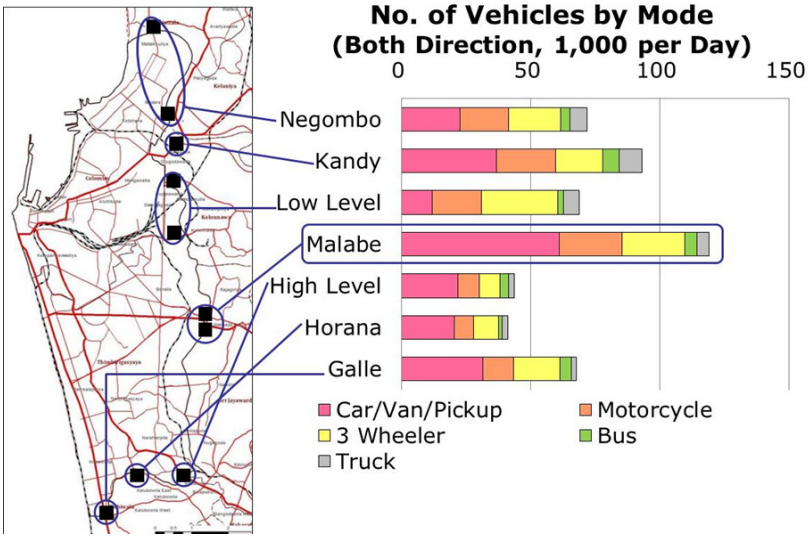
The CoMTrans Urban Transport Master Plan proposed public transport networks for 2020, 2025 and 2035 taking efficiency, environmental friendliness, equity, safety and security aspects into consideration. Based on the large-scale home visit survey (36,000 households samples) on travel behaviour, a series of transport surveys and secondary data from various resources; seven major transport corridors in the Colombo Metropolitan Area were identified.

The Screen Line Survey at the boundary of Colombo Municipal Council (CMC) results showed that Malabe Corridor has the highest number of vehicles followed by Kandy Corridor and Galle Corridor as shown in Figure 2.1.1.

Travel speeds of major transport corridors are show in Figure 2.1.2. Malabe Corridor and Galle Corridor were the lowest peak hour average travel speed of 13.8 km/h. The five percentile lowest travel speeds of the Malabe Corridor was 8.0 km/h which is the lowest among all transport corridors.

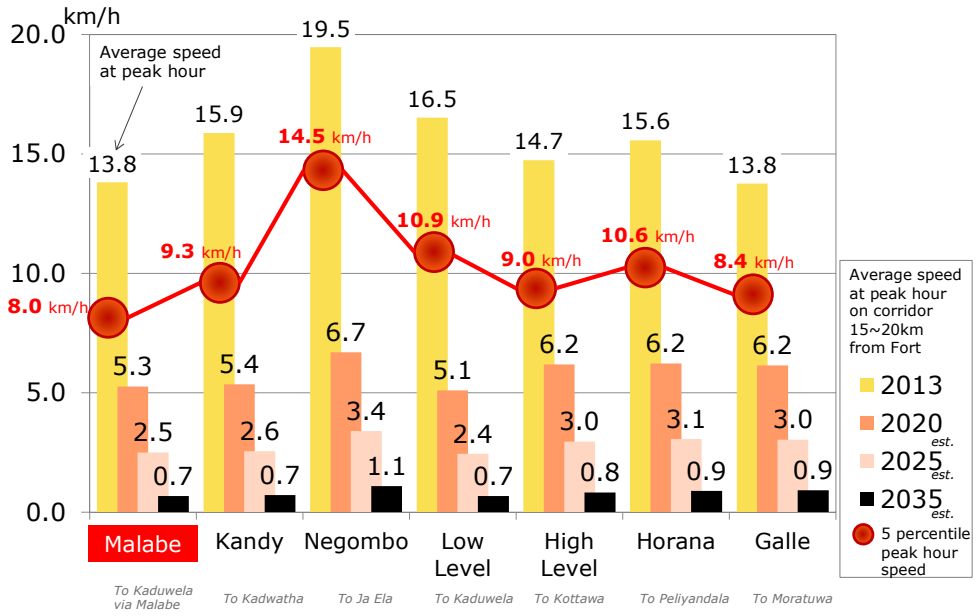
With preliminary transport demand forecasts the economic benefits, costs and other performance indicators of the potential projects were estimated for each transport corridor. Multi-criteria analyses were conducted to identify the best option for the seven transport corridors. Selected projects by corridor are summarised in Table 2.1.1.

A monorail system is also selected in the CoMTrans Urban Transport Master Plan taking capacity, speed, land acquisition, initial cost, operation and maintenance cost, day light interference and aesthetical aspects into consideration.



Source: CoMTrans Screen Line Survey, 2013

Figure 2.1.1 No. of Vehicles by Mode (Both Directions, 1,000 per Day)



Source: CoMTrans Travel Speed Survey for 2013 and CoMTrans estimates for 2020, 2025 and 2035 (Do Nothing Scenario).

Figure 2.1.2 Peak Hour Travel Speed of Major Transport Corridors

Table 2.1.1 Summary of Development Options for the Seven Corridors

Corridor/Area		Development Options in 2035		
		Monorail	Railway	BRT/Bus/Roads
Seven Corridors	Malabe	Monorail	-	-
	Galle	-	Modernized	BRT [w/ Marine drive Extension]
	Kandy	-	Modernized	BRT
	Negombo	-	Modernized	Bus priority
	High Level Road	Monorail	-	-
	Horana	-	-	Bus priority U. Expressway [via Nugegoda]
	Low Level Road	-	-	Bus priority

Note: "Modernized" includes electrification, double tracking, improvement of signalling and telecommunication, procurement of train cars, track layout improvement, improvement of station facilities etc. The modernization of the railway can significantly improve railway capacity.

Source: CoMTrans

1. The Highest Demand

Malabe Corridor connecting Colombo Municipal Council, Battaramulla, Malabe and Kaduwela has the highest vehicle volume among all seven transport corridors at 5,100 passenger car units per hour per direction while the passenger volume of the Malabe corridor is 23,500 passengers per hour per direction, the second highest following Kandy corridor. Travel speed on the corridor is 14 kilometres per hour during peak period at the boundary of Colombo Municipal Council.

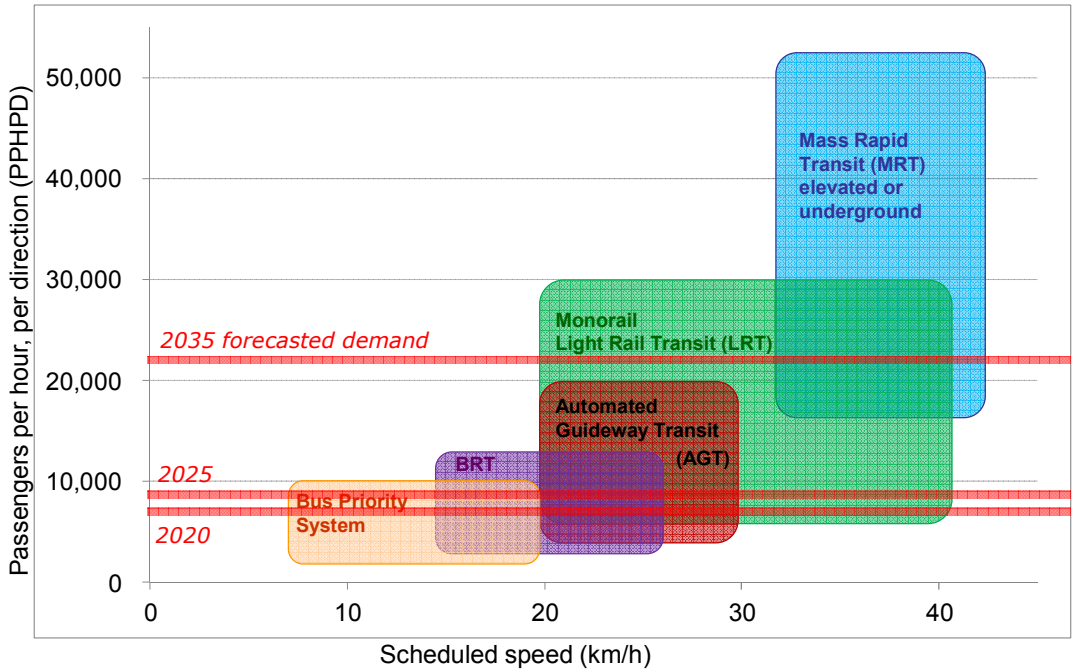
2. Corridor without a Transit System with Urban Development Projects

It also is the corridor without a rail based public transport system. Moreover, the current transport system is unable to handle increasing passenger demand due to the relocation of government offices to Battaramulla area, which will include the new Defence complex in Akuregoda. Therefore, in the CoMTrans master plan, the Fort-Malabe corridor has been identified as requiring urgent policy intervention to shift private mode users to public transport.

Why Monorail?

For the selection of transport mode, a variety of aspects must be taken into account. Conventionally, transport capacity and scheduled speed are key indicators for selecting the mode. The scheduled speed and passenger capacity of public transport modes is shown in Figure 2.1.3. The forecast demand for the selected corridor is 7,800 passengers per hour, per direction (PPHPD) in 2020, 9,200 PPHPD in 2025 and 21,000 PPHPD in 2035 in the high demand scenario. Assumptions, methodology, and detailed results of transport demand forecasts are described in Chapter 3 of the main report. While several options are applicable in 2020, only monorail, light rail transit (LRT) and mass rapid transit (MRT) are appropriate in 2035.

The bus priority lane system has remarkable advantages in low initial cost, no land acquisition, no daylight interference and no aesthetic concerns. However, transport capacity of the bus priority system, roughly 10,000 passengers per hour per direction (PPHPD), is far below transport demand in the Malabe corridor, 21,000 PPHPD in 2035. Noise of the system is not negligible. It is noteworthy that a modal shift to public transport is not expected due to lower travel speed.



Note: 2035 demand is demand forecast result with the SKYTRAIN Project Stage 1, Stage 2 and monorail on High Level Road with transport demand management policies assuming normal bus fare level for monorail. This is the highest possible demand.

Source: SKYTRAIN Study Team

Figure 2.1.3 Scheduled Speed and Passenger Capacity of Public Transport Modes

The Bus Rapid Transit (BRT) also presents similar merits with the bus priority lane system, such as low initial cost, no daylight interference and no aesthetic concerns. While capacity of the BRT, approximately 13,000 PPHPD, matches the forecast demand of Malabe Corridor of 9,000 PPHPD in 2025; a shortfall in capacity is expected in 2035 as the demand will increase to 21,000 PPHPD. Moreover, BRT requires a two-way road with at least 20m width or one-way road with 14m width. The selected alignment is on roads with less than 20m width such as E. W. Perera Mawatha, Kynsey Road, Dr. N. M. Perera Mawatha and Kotte Bope Road from Battaramulla to Malabe. This indicates that significant land acquisition is required for the project implementation. As rapid motorization is on-going, it is urgent to provide transit systems with a high service level to enhance the modal shift to public transport. The expected long delay in project implementation due to the huge land acquisition should be avoided.

Automated Guideway Transit (AGT) has its strength in the minimum curve radius of 20m. This might reduce the volume of land acquisition. However, some land acquisition is required for station sections. While the capacity of AGT, 20,000 PPHPD, is more than the forecast demand of 9,000 PPHPD in 2025, a slight shortfall is expected in 2035 as the forecast demand reaches 21,000 PPHPD. Although initial cost will be almost the same as the monorail and LRT, operation and maintenance cost per passenger can be slightly higher than the other modes of public transport. While the AGT mainly employs a driverless operation system, this might not reduce operation cost in CMA due to lower labour cost compared with developed countries. As AGT utilises a slab structure, it interferes with the daylight. There is an aesthetic concern due to

the slab structure. Considering the landscape of Malabe corridor and the inner city alignment with a number of parks and historic buildings, a slab structure is not preferable. Although AGT is a technically applicable system for Malabe corridor, limitations in capacity, daylight interference and aesthetic concern are negative aspects compared with a monorail.

Capacity and speed of Light Rail Transit (LRT) is almost the same as the monorail and matches the forecast demand of Malabe corridor. However, LRT has several drawbacks compared with a monorail. Due to LRT's characteristics of 3.5% maximum gradient and slab structure, it might require more land acquisition for installation in addition to station sections. Although initial investment and operation and maintenance cost are almost the same as the other systems, the slab structure will affect the aesthetics of the landscape along the corridor. Daylight also will be interfered with. As LRT uses steel rails and tires, noise level is higher than a rubber tire and concrete rail system.

Since both the elevated mass rapid transit (MRT) system and the light rail transit (LRT) system are steel rail-based modes of transport, physical characteristics such as daylight interference, aesthetic concerns and noise are common in general. As MRT has a higher capacity and speed compared with LRT, initial cost is higher than LRT. Considering the forecast demand in 2020 (8,000 PPHPD) and in 2025 (9,000 PPHPD), MRT capacity of 18,000 – 60,000 PPHPD can be an excessive investment as initial cost is generally higher than LRT. Land acquisition also will be essential due to the larger minimum curve radius (roughly 100-200m) and smaller maximum gradient of 3.5%.

Underground MRT is designed to avoid the disadvantages of the elevated and ground level structures such as daylight interference, aesthetic concerns, noise and land acquisition. The underground structure without level crossings allows high speed train operations. Capacity is the same as the elevated MRT where demand of 2020 and 2025 is far less than the capacity. The most significant point to be considered, is the huge initial investment. Underground structures can cost more than double or three times that of elevated.

In summary, the bus priority system, bus rapid transit (BRT) and underground mass rapid transit were screened out due to clearly negative aspects such as capacity, land acquisition and cost. Among the four modes of transport, monorail was selected for various aspects such as less impact on daylight and landscape due to simple beam structure, minimum land acquisition and appropriate capacity, cost and scheduled speed as shown in the multi-criteria analysis results of Table 2.1.2.

Table 2.1.2 Multi-Criteria Analysis on Mode Selection for Malabe Corridor

System	Requirement	Bus Priority System	BRT	AGT	Monorail	LRT	MRT - Elevated	MRT - Underground
Capacity*	6k ('20) 7k ('25) 22k ('35)	--- (-10k)	-- (3-13k)	- (4-20k)	+ (7-30k)	+ (7-30k)	-- (18-60k)	-- (18-60k)
Scheduled Speed	30km/h	-- (10-20 km/h)	- (15-25 km/h)	0 (20-30 km/h)	++ (20-40 km/h)	++ (20-40 km/h)	++ (30-40 km/h)	++ (30-40 km/h)
Land Acquisition	Nearly 0	+++ (no acquisition)	--- (along roads)	+ (only stations)	+ (only stations)	- (station & some roads)	-- (station & curve sections)	++ (station exit only)
Stop Spacing	0.5 – 1.0 km	+ 0.3 – 1 km	+ 0.5 – 1 km	+ 0.5 – 1 km	+ 0.5 – 1 km	+ 0.3 – 1 km	- 1.5 – 2 km	- 1.5 – 2 km
Initial Cost	N/A	+++ (USD ~1 M/km)	+++ (USD 2 M/km)	- (USD 30-60 M/km)	- (USD 30-60 M/km)	-- (USD 35-60 M/km)	-- (USD 45-60 M/km)	--- (USD 90-100 M/km)
O&M Cost	N/A	N/A	0 (USD 1.3 / car-km) ($0.03 per pax.)	- (USD 2.0 / car-km) ($0.04 per pax.)	0 (USD 2.5 / car-km) ($0.03 per pax.)	- (USD 4.0 / car-km) ($0.04 per pax.)	0 (USD 5.0 / car-km) ($0.03 per pax.)	0 (USD 5.0 / car-km) ($0.03 per pax.)
Daylight Interference	Minimum Interference	+++ (Not at all)	+++ (Not at all)	-- (Pier & Slab)	- (Pier & Beam)	-- (Pier & Slab)	-- (Pier & Slab)	+++ (Not at all)
Aesthetic Concern	Minimum Concern	+++ (No Concern)	++ (Station only)	-- (Pier & Slab)	- (Pier & Beam)	-- (Pier & Slab)	-- (Pier & Slab)	+++ (Not at all)
Noise	Minimum Noise	-- (Rubber Tire & Engine)	-- (Rubber Tire & Engine)	- (Rubber Tire)	- (Rubber Tire)	-- (Steel Rail & Tire)	-- (Steel Rail & Tire)	+ (No noise to ground level)
Total Evaluation		Not Suitable due to ---	Not Suitable due to ---	2	1	2	3	Not Suitable due to ---

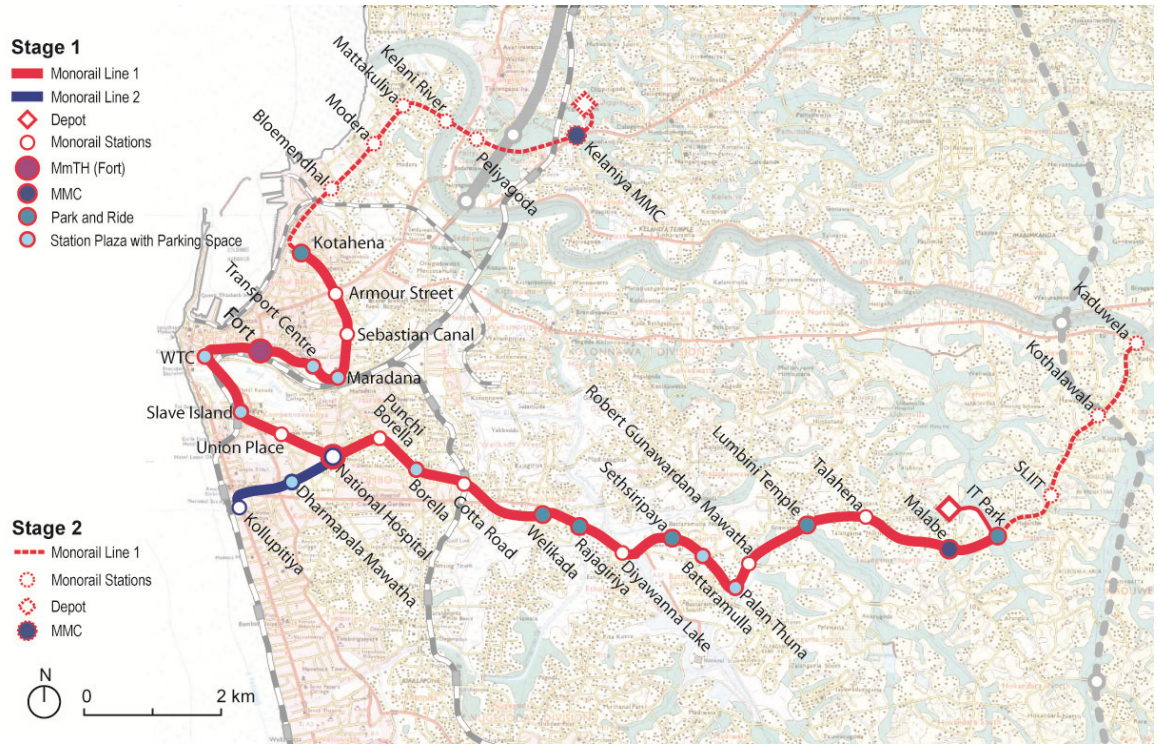
Note: * Capacities are in the number of passengers per hour, per direction. 1k means 1,000.

+++ Very Clearly Positive
++ Clearly Positive
+ Slightly Positive
0 Neutral Insignificant
N/A No Information
--- Very Clearly Negative
-- Clearly Negative
- Slightly Negative

Source: SKYTRAIN Study Team

2.2 Route and Passenger Demand

Taking the initial depot location, condition of the road widening project and passenger demand into consideration, phasing of the project is proposed as shown in Figure 2.2.1.



Source: SKYTRAIN Study Team

Figure 2.2.1 Proposed Route of SKYTRAIN Project

The demand forecast methodology is in line with the CoMTrans urban transport master plan. The CoMTrans master plan employed a four-step method which is empirically proven methodology with a number of applications in many countries. As a monorail is a new transport mode for Sri Lanka, a Stated preference (SP) survey was conducted. A stated preference survey is a survey method which requires respondents to indicate their preference in a certain fictive condition such as transport mode choice with a monorail system in the future.

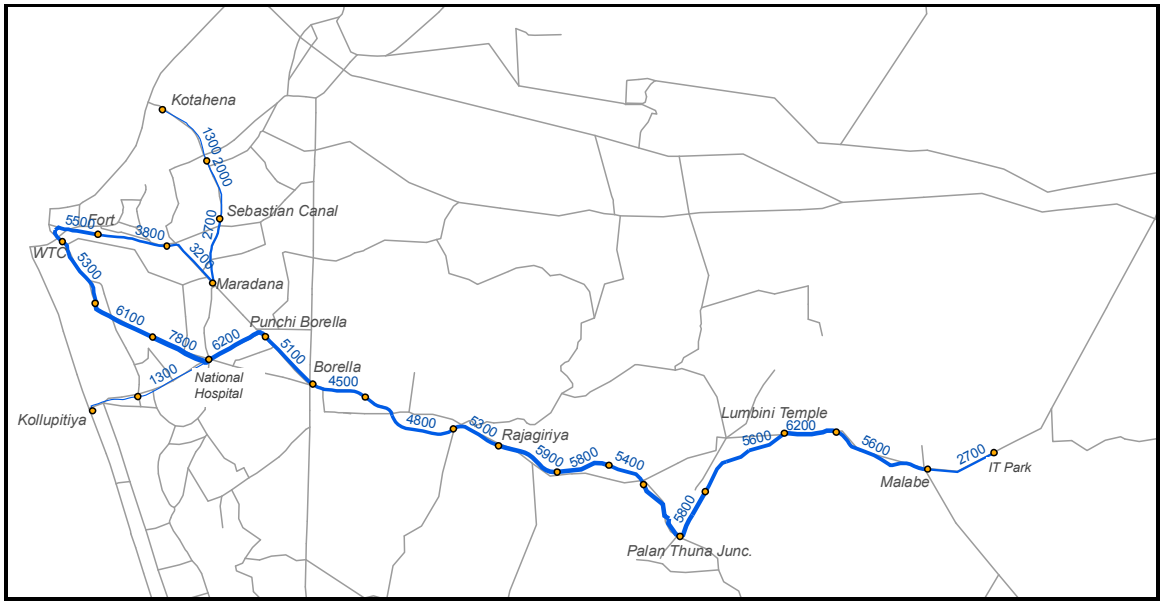
Based on the estimated daily passenger volume, peak hour sectional passenger volume was estimated assuming eighteen percent peak ratio. The estimated results of the transport demand for the monorail are summarised in Table 2.2.1. Daily passengers and passenger kilometres are expected to drastically increase by 2035 due to urban development projects along the corridor and improvement of public transport network.

Table 2.2.1 Summary of Demand Forecast Result

Indicator	2020	2025	2035
PPHPD of Line 1 Peak passenger per hour per direction at max. section	7,800 at Union Place – National Hospital	9,200 at Union Place – National Hospital	16,800 at National Hospital – Punci Borella
PPHPD of Line 2	1,300 at Dharmapala Mawatha – National Hospital	1,500 at Dharmapala Mawatha – National Hospital	4,100 at Dharmapala Mawatha – National Hospital
Daily Passengers in total monorail network	307,000	379,000	700,000
Daily Passenger-kilometres in total monorail network	1,190,000	1,480,000	2,840,000

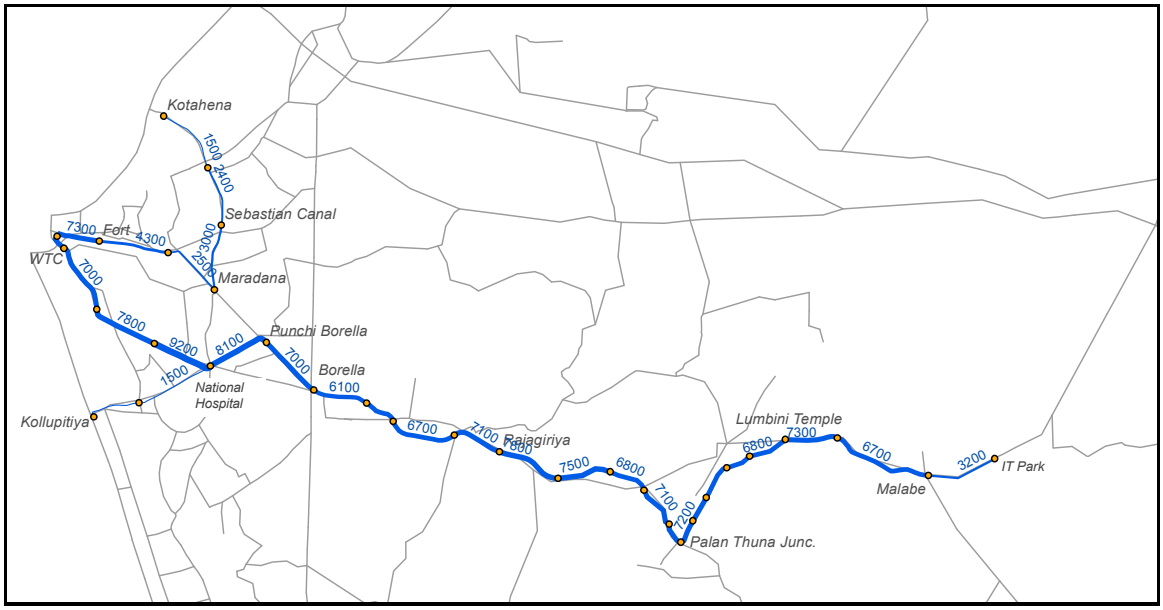
Source: SKYTRAIN Study Team

Peak hour traffic volumes in 2020, 2025 and 2035 are shown in Figure 2.2.2, Figure 2.2.3 and Figure 2.2.4 respectively.



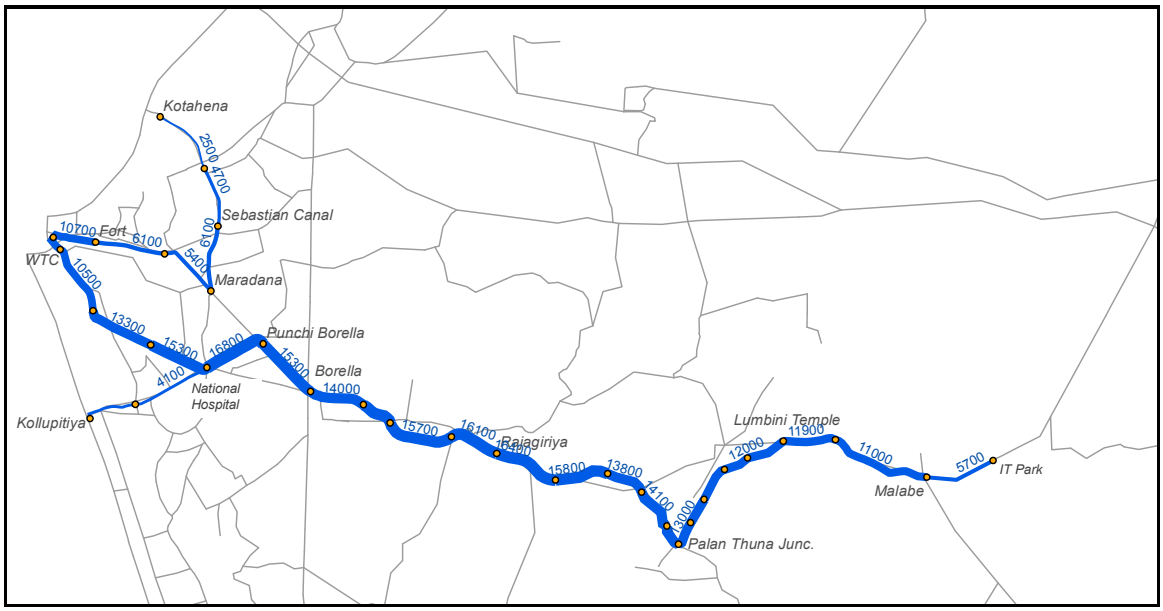
Source: SKYTRAIN Study Team

Figure 2.2.2 Peak Hour Passenger Volume per Direction in 2020 (Stage 1)



Source: SKYTRAIN Study Team

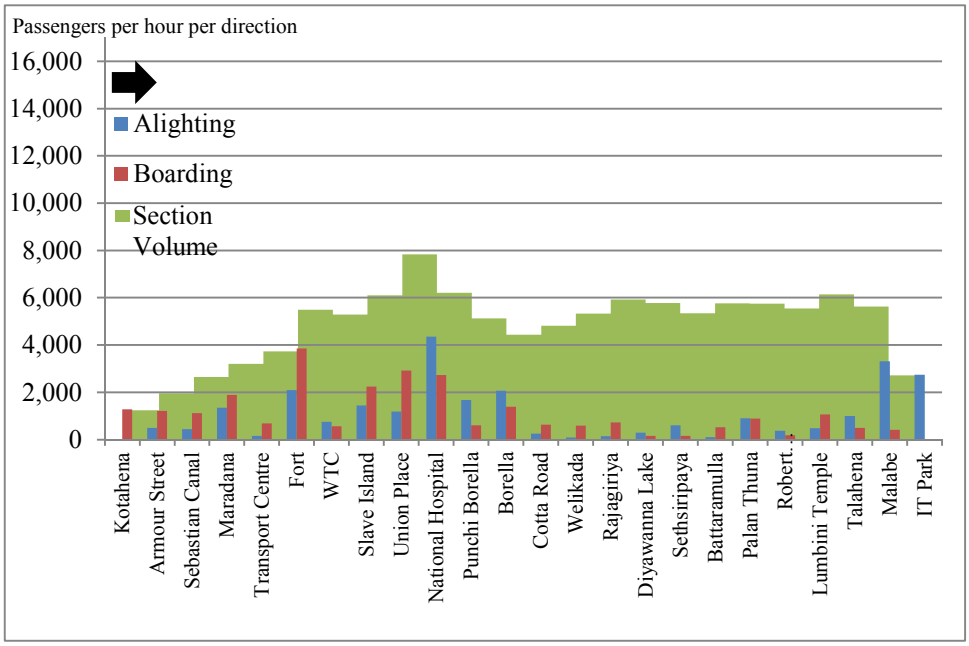
Figure 2.2.3 Peak Hour Passenger Volume per Direction in 2025 (Stage 1)



Source: SKYTRAIN Study Team

Figure 2.2.4 Peak Hour Passenger Volume per Direction in 2035 (Stage 1)

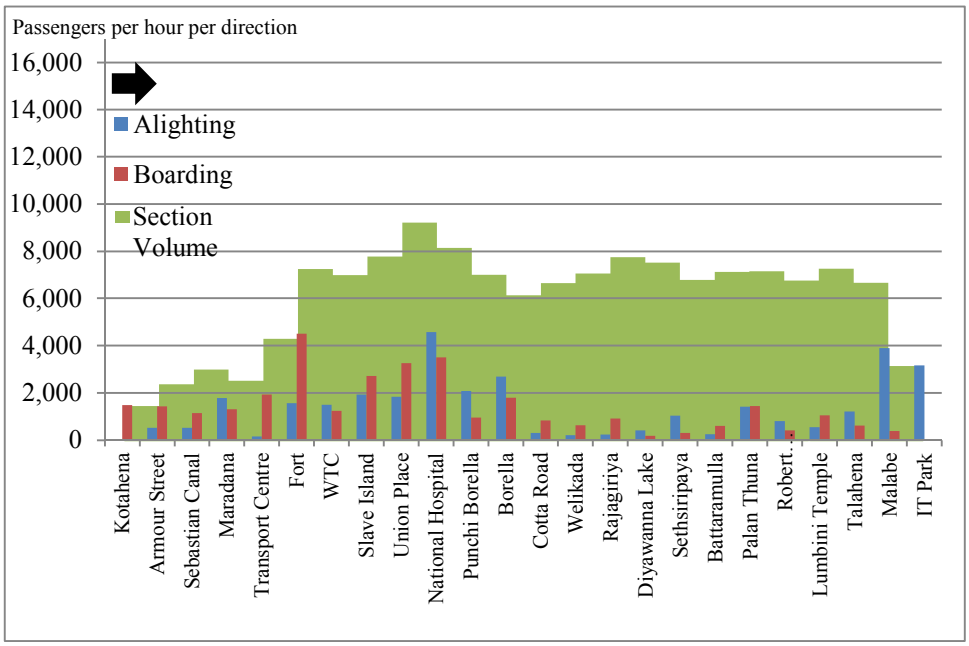
Boarding and alighting passenger volume by station and sectional passenger volume during peak hour in 2020, 2025 and 2035 are shown in Figure 2.2.5, Figure 2.2.6 and Figure 2.2.7 respectively.



Source: SKYTRAIN Study Team

Note: "Robert…" is "Robert Gunawardena Mawatha" station.

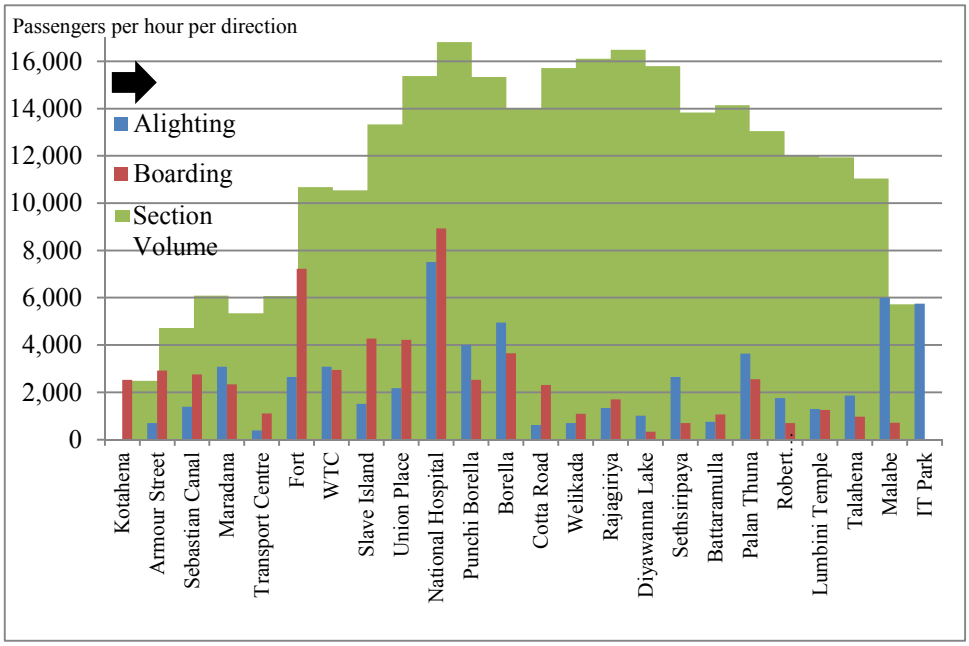
Figure 2.2.5 Peak Hour Passenger Loading by Station in 2020 (Stage 1)



Source: SKYTRAIN Study Team

Note: "Robert…" is "Robert Gunawardena Mawatha" station.

Figure 2.2.6 Peak Hour Passenger Loading by Station in 2025 (Stage 1)



Source: SKYTRAIN Study Team

Note: "Robert…" is "Robert Gunawardena Mawatha" station.

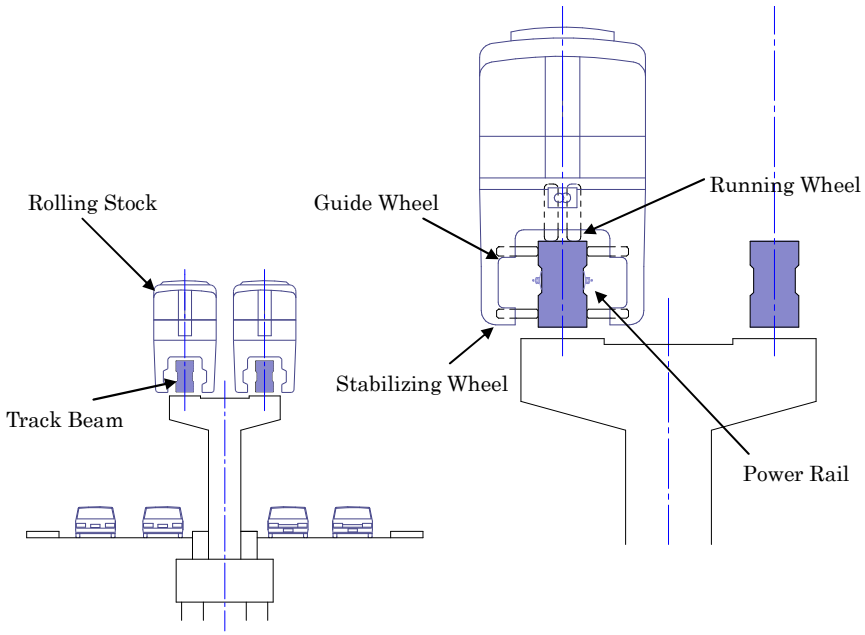
Figure 2.2.7 Peak Hour Passenger Loading by Station in 2035 (Stage 1)

2.3 Monorail System and Structure

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 2.3.1 indicates the outline of the monorail, Figure 2.3.2 indicates the image of the monorail, and Table 2.3.1 shows the outline of proposed monorail system.



Source: SKYTRAIN Study Team

Figure 2.3.1 Outline of Monorail

Source: Hitachi Ltd.

Figure 2.3.2 Image of Monorail

Table 2.3.1 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

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.

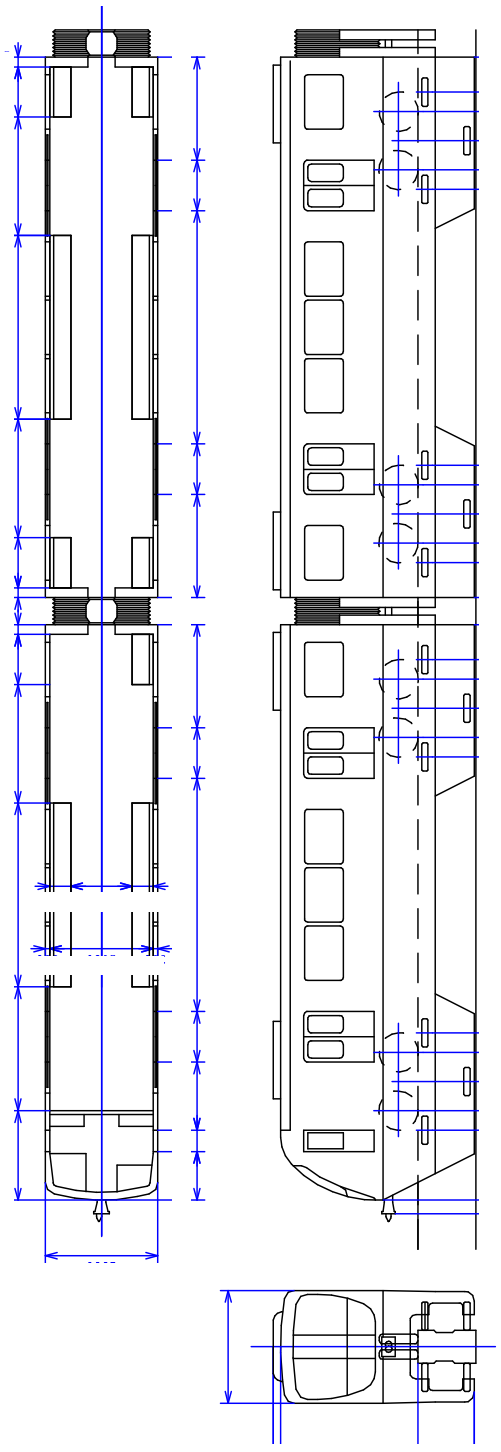
There are two bogies in one car and two axles in one bogie. Two rubber tire wheels are installed in one axle for running. Besides running wheels horizontal wheels are installed in the bogie for guiding and stabilising.

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.

Figure 2.3.3 shows an image of the Monorail Vehicle, and salient features of the rolling stock are indicated in Table 2.3.2.



Source: SKYTRAIN Study Team

Figure 2.3.3 Image of Monorail Vehicle

Table 2.3.2 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]
6-1	Performance	Maximum speed		[redacted]
6-2		Acceleration		[redacted]
6-3		Deceleration	Emergency brake	[redacted]
6-4			Maximum service brake	[redacted]
7	Traction power supply			[redacted]
8-1	Running gear	Bogie		[redacted]
8-2		Running wheel		[redacted]
8-3		Driving device		[redacted]
9	Traction control			[redacted]
10	Traction motor			[redacted]
11	Brake system			[redacted]
12-1	Passenger door	Type		[redacted]
12-2		Number		[redacted]
13-1	Air conditioning system	Type		[redacted]
13-2		Number		[redacted]
14	Auxiliary power supply			[redacted]
15	Train control			[redacted]
16	Passenger capacity			[redacted]

Source: SKYTRAIN Study Team

2.4 Train Operation Plan

The monorail system consists of two lines namely Line 1 from Kotahena to IT Park and Line 2 from National Hospital to Kollupitiya. Figure 2.4.1 shows the routes of the monorail.

Source: SKYTRAIN Study Team

Figure 2.4.1 Track Layout of the Monorail

Based on demand forecast and transportation capacity described above, required headway of peak hour at each milestone year was estimated and required number of rolling stock based on train diagram in peak hour is calculated. Table 2.4.1 shows the planned headway and required number of trains. Rolling stock procurement plan is indicated in Table 2.4.2.

Table 2.4.1 Number of Trains

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

Source: SKYTRAIN Study Team

Table 2.4.2 Rolling Stock Procurement Plan

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

Source: SKYTRAIN Study Team

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

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 station, which is the terminal of the line as indicated in Figure 2.4.2. Totally about 12ha of land is reserved for the depot complex. 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 2.4.2 Location of Depot

Design details of civil structures such as superstructure including beams, foundation and sub-structure of piers, station structure and facilities, depot structure are described in the main report together with construction methods. Signalling, Communication and Fare Collection System are proposed for the SKYTRAIN project in the main report. Power supply system is discussed how to allocate the sub stations and to install propose power control system.

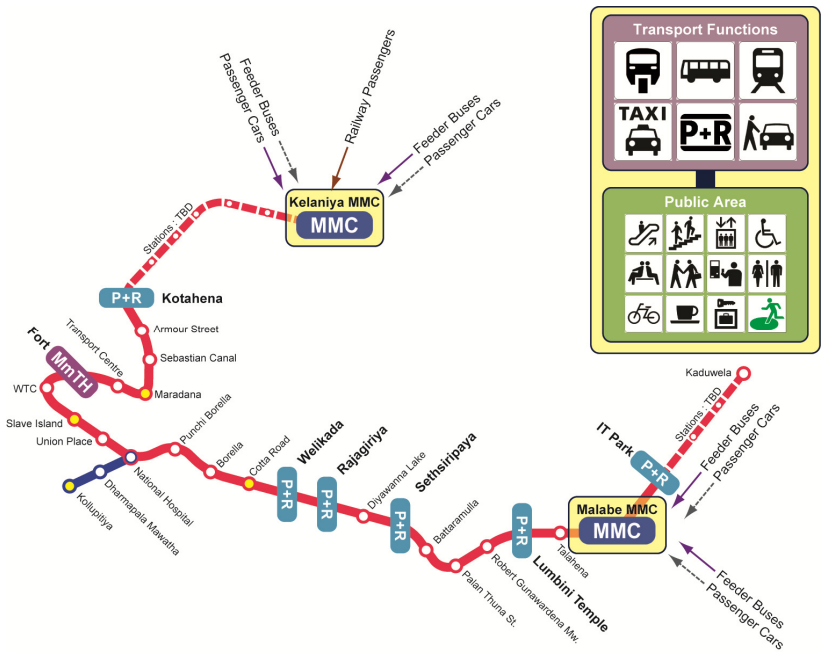
2.5 Multi-modal Transport Facilities and P&R Facilities

(1) Concept of MMC and P&R Facilities

Multi Modal Centres (MMC) are proposed in suburban areas. In the case of the Monorail, Malabe Station is selected for the first phase. They are the transferring stations for feeder buses from the surrounding areas, railway passengers, and passenger cars traveling to the monorail in order to get to central areas of Colombo easily. This contributes to ease the traffic congestion from the existing roads. It is also encourages developing the area as Transit Oriented Development (TOD).

Park and Ride (P&R) facilities are car parks with connections to public transport that allow passengers to leave their vehicles and transfer to public transport. This encourages using the Monorail and reducing the number of vehicles on the roads. The locations for P&Rs are identified and Welikada, Sethsiripaya, and Lumbini Temple stations are selected for the concept design, due to land availability and necessity for such P&R function.

Figure 2.5.1 illustrates the function of a MMC and the locations of the MMCs and P&R facilities.



Source: SKYTRAIN Study Team

Figure 2.5.1 Concept of MMC and Locations of MMC and P&R Facilities

(2) Functional Requirements of Malabe MMC

Calculated peak time demand based on the future bus demand at Malabe is approximately 2,700 bus/day in 2035. Thus, 15-22 bays will be required.

Table 2.5.1 Future Bus Demand (2035)

Future Bus Demand	Peak Ratio	Peak Bus Demand	Bay Capacity	Bay Demand
2,700 buses/day	Dp.: 8% Ar.: 9%	Dp.:108 buses/h Ar.:122 buses/h	Dp.:10-12 buses/h Ar.:15-20 buses/h	9-11 bays 6-11 bays

Source: SKYTRAIN Study Team

The facility scale of each transportation mode is estimated based on the access/egress transportation demand for the monorail at Malabe MMC, which is approximately 1,700 person/h. Access/egress facility demand for each transportation mode is as shown in Table 2.5.2.

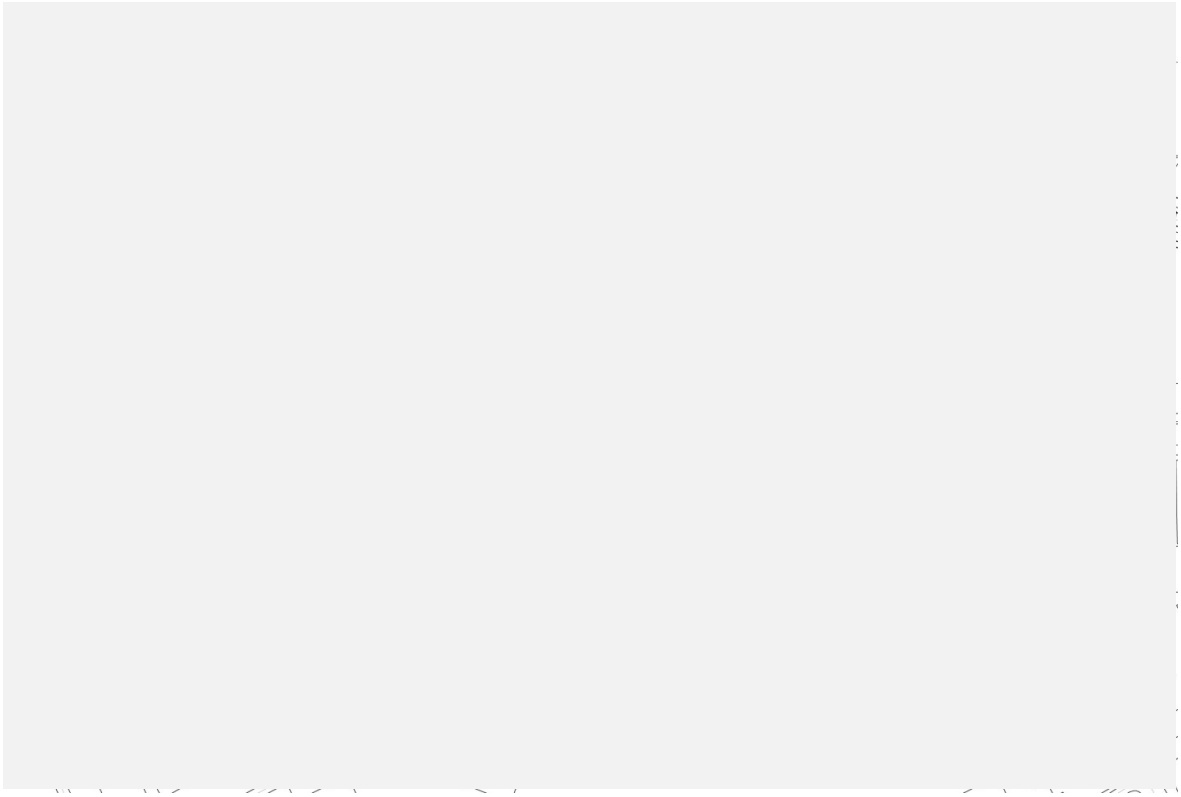
Table 2.5.2 Malabe MMC access/egress Functional Requirements (2035)

Mode	Share	Peak Demand	Facility Demand
Bicycles, Motorcycles	1-3%	20-50 bikes/h (100-300 bikes/day)	100-300 bike spots/day
Taxis,3-wheelers	2-3%	30-50 cars/h	1-2 bays Taxi pool 3-5 cars
Pick-up/staff-service	3-5%	40-80 cars/h	2-4 bays

Source: SKYTRAIN Study Team

(3) Layout Plan of MMC Malabe

Figure 2.5.2 is the layout plan on the ground floor of the Malabe MMC. The Malabe MMC is proposed on the existing bus stand area and the DSD office. The Malabe monorail station is located on the New Kandy Road, on the west side of Malabe Junction, just in front of the new bus terminal of the MMC Malabe. A pedestrian deck connects from the monorail station to the upper level of the bus terminal. In addition, a station plaza and taxi and 3-weeler bays are also set on the ground level, next to the bus terminal.



Source: SKYTRAIN Study Team

Figure 2.5.2 Layout Plan of MMC Malabe

(4) General Concepts of P&R Stations

Preliminary layout plans for the 3 selected Park and Ride facilities are prepared based on the same concepts; providing smooth transfer and access from the monorail stations to the station plaza and car parking. The main target to prepare the P&R stations is to encourage using the public transport for passenger car users. It is proposed that the pedestrian access connects from the car park to the monorail station, as well as to facilities located the surrounding area, such as government offices, public areas, and commercial facilities. A station plaza is also set in the P&R station facilities. The general conceptual section diagram is shown in Figure 2.5.3, and the layout plans are shown in Chapter 9 of the main report.

Source: SKYTRAIN Study Team

Figure 2.5.3 Conceptual Section Diagram of General P&R Stations

2.6 Cost Estimation and Implementation Schedule

(1) Cost Estimation of the Monorail System

Regarding the stage-1 of monorail system under the SKYTRAIN project (Line 1: Kotahena ~ IT Park, Line 2: National Hospital ~ Kollupitiya), the total project cost that includes construction, physical contingencies, price escalation ant others is estimated at JPY [redacted] million as shown in Table 2.6.1.

Table 2.6.1 Total Project Cost of the Monorail

Unit: million

Breakdown of Cost	Foreign Currency Portion (million JPY)	Local Currency Portion (million LKR)	Total (million JPY)
Civil Package 1 (Superstructure)			
Civil Package 2 (Substructure and Station)			
Civil Package 3 (Substructure, Station and Depot)			
E & M			
sub-total			
Price Escalation			
Physical Contingency			
Consulting Services			
Total			

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 of the main report.

Source: SKYTRAIN Study Team

(2) Implementation Schedule of the Monorail System

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. 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 2.6.2.

Table 2.6.2 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

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".

The implementation schedule is made based on the packages condition mentioned in Table 2.6.3.

Table 2.6.3 Packages for Draft Implementation Schedule

Package	Contents	Scope of Works
Package 1	Civil Works for Superstructure	[redacted]
Package 2	Civil Works for Substructure and Station	[redacted]
Package 3	Civil Works for Substructure, Station and Depot	[redacted]
Package 4	System & Rolling Stock	[redacted]

Source: SKYTRAIN Study Team

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 [redacted] years in Figure 2.6.1.

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

Figure 2.6.1 Draft Implementation Schedule

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 [redacted] 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 [redacted] months.
- [redacted] months will be required for the procurement of a contractor.
- Construction period will be [redacted] months.

The total implementation schedule will begin with the L/A, and the construction will be completed by the end of [redacted]. 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 2.6.1) 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

(3) Cost Estimation of MMC and P&R facilities

The construction costs of MMC Malabe and P&R Facilities are estimated and summarised in Table 2.6.4 and Table 2.6.5 respectively.

Table 2.6.4 Summary of the Estimated Construction Cost of MMC Malabe

Item	Cost per sqm (YEN)	Amount (th. YEN)	STEP (th. YEN)		Note
Total Construction Cost	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
A. Direct Construction Cost	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
B. Indirect Construction Cost	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
C. Administrative Expenses	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Source: SKYTRAIN Study Team

Table 2.6.5 Summary of the Estimated Construction Cost of the P&R Stations

Item	Amount (th. YEN)			Note
	Welikada	Lunbini Temple	Sethsiripaya	
I. Architectural Construction Cost A+B+C	[redacted]	[redacted]	[redacted]	[redacted]
A. Direct Construction Cost	[redacted]	[redacted]	[redacted]	[redacted]
B. Indirect Construction Cost	[redacted]	[redacted]	[redacted]	
C. Administrative Expenses	[redacted]	[redacted]	[redacted]	

Source: SKYTRAIN Study Team

2.7 Institutional Arrangement and Operation & Maintenance

2.7.1 Implementation Schemes of New Transit System

(1) Organizational Structure for Railway Sector

Proposal for the Establishment of Sri Lanka Mass Transit Authority (SMA)[2]

The creation of an autonomous ***Sri Lanka Mass Transit Authority (SMA)*** as a governing body for setting transport policy, regulatory parameters, and for implementing all Railway Programs, is recommended. The main objectives are to secure delivery by the industry of its regulatory obligations, assure satisfaction levels of passengers, equivalent to the best in railways and other forms of transport. The key tasks of the new entity are to provide for:

- Changes in the regulation of public transport operations for Government-owned operator as well as in joint venture with the private sector and, private operator,
- Health and safety regulation
- Land acquisition power,
- Access and market regulation,
- Setting up a transparent, consistent, efficient administrative mechanism to create a level playing field for all participants and protect the interests of all stakeholders,
- To prepare a projects list to be implemented under Government funds, ODA, or to be offered for PPP and take them forward, after approval from Planning Agency, with assistance of the highly qualified staff through a transparent selection process,
- Putting in place an effective and efficient institutional mechanism for speedy clearance of the projects.

[2] *Proposed name. Final name to be decided by Sri Lankan authorities*

This SMA would be funded through a combination of licence fees and a railway safety levy. Economic regulation activities are funded through the licence fee and health and safety activities through the safety levy.

The Implementing and Operating Agency (Agency/Corporation)

The ***SKYTRAIN*** would be the first urban mass transit project in Colombo, and even in the entire Sri Lanka. The operating organization is recommended to be a newly established under the umbrella of the future SMA, also under the MOT and supported by central Government. This section describes the organization plan of ***SKYTRAIN Corporation (STC)***[3] in terms of its positioning, role and responsibility as Railway Operator & Implementing Agency (or Corporation), and indicates those responsibilities and tasks that could be given in concession according to the type of PPP scheme, if any, adopted during the implementation of the SKYTRAIN.

Creation of PMU: During the implementation of the project under the STC, a ***Project Management Unit (PMU)*** shall be created as the organization to be in charge of the actual implementation of the project and liaison with the Consultant, Contractor, and other concerned stakeholders. As the formal establishment of the STC and SMA would take time, the core team for the SKYTRAIN project should take responsibility for the initial duties until the formal establishment of the PMU within STC. Some staffs of core team can be absorbed by the PMU.

Scope of Work of Agency: The STC would be responsible for the service operation and maintenance, specifically: Management and administration: to formulate policies, prescribe and promulgate the rules and regulations for the attainment of the objectives of the SMA, and the administration-related matters, such as administrative, finance, accounting, budget, human resources, etc.; Operations: to ensure the safe, reliable and efficient operating of the railway and satisfactory service to the passengers on a day-to-day basis; Maintenance: to perform the daily and the long term planning and execution of scheduled and unscheduled, preventive and corrective maintenance actions to ensure overall systems are ready for required operation at all times; others (Engineering & Construction).

Among the tasks and duties mentioned above, the Operations and Maintenance are the tasks that could be given in concession to a private party in case such party has entered into a PPP with STC and requires return on investment.

Organization Structure and Staffing of STC: Early identification of future leaders from the PMU organization will lead to early capability-building activities in the organization, as they develop competency and acquire a holistic understanding of the integrated systems.

The STC organization shall start with a core team (i.e. PMU), and it will gradually evolve into its full form before start of the O&M phase. With the STC in charge of all phases, the engineers, supervisors, technicians, and operators (required for O&M phase) can be trained during the construction phase by the system contractors and Original Equipment Manufacturers (OEMs) to equip them with necessary knowledge and skills to handle supervisory tasks for the O&M activities effectively.

The level of staff requirements for the revenue operation would vary greatly depending on the selected funding and contractual scheme, from a minimal requirement in case of a concession

[3] *Proposed name. Final name to be decided by Sri Lankan authorities*

operation with Net Cost scheme to the maximal requirement under a fully direct operation and maintenance by STC.

(2) Operation Scheme

Given the global trend and also the relatively recent introduction of Public Private Partnership (PPP) schemes, the possible type of contracts for the implementation of the SKYTRAIN could be some of the following:

(A) ODA including O&M Concession,

(B) Operation and Maintenance Concession under PPP Net Cost Scheme,

(C) Operation and Maintenance Concession under PPP Gross Cost Scheme,

(D) Direct Operation and Contracting Maintenance,

(E) Direct Operation and Direct Maintenance, and

(F) Direct Operations with Contractual and Outsourcing.

Given a proper setting of STC as mentioned above, STC should engage in the task of implementing the SKYTRAIN. After discussion with different high level authorities in Sri Lanka regarding the mode of implementation of this project, it was considered that the vision of the Government of Sri Lanka is to have the SKYTRAIN wholly government funded, probably with some considerable portion being an ODA.

It is still undecided if the O&M could be given in concession to a private party or not, thus leaving the Options (A), (D), (E), and (F) mentioned above as possible schemes to be applied in the implementation of the SKYTRAIN.

(3) Maintenance Schemes

The Maintenance Philosophy for the SKYTRAIN must not only provide for preventive maintenance, but also for predictive maintenance and to a certain extent trouble-shooting maintenance in respect of specific items. The aim will be that the operation of the rolling stock and other facilities provided, will be safe and the service and maintenance of all facilities and rolling stock will be carried out accurately so as to extend their life to a point economically and physically justified.

SKYTRAIN Study Team, taking in consideration all available information, site conditions, potential technical and financial capabilities of future STC, is suggesting the following maintenance scheme for the SKYTRAIN: The Concessionaire/Operator shall outsource the maintenance activities, preferably to a contractor closely linked or associated to the main OEM (Rolling Stock), including, among others, light & heavy maintenance, troubleshooting, and procurement of capital and consumable spare parts.

Accordingly, all parties (the Owner, Operator, and Maintenance Contractor) should adopt the concept of fully integrated teams.

2.7.2 Operation and Maintenance (O&M) Cost for SKYTRAIN

The summary of O&M costs per year and per item is presented in Table 2.7.1. The O&M Cost for the opening year (2021) would be around US$[redacted] million. This value is estimated considering that within the initial investment cost, the manufacturer is delivering spare parts equivalent to three years of operation. Hence that cost is not included for the period 2021-2023, however, a cost of US$[redacted] million per year is estimated for the necessary for consumable materials for maintenance, which are not included in the initial investment cost.

As a verification of the cost, the value of O&M cost per track km and per train-km of the SKYTRAIN was compared with the seven (7) existing monorail systems in Japan. The average of the existing Japanese systems is shown in Table 2.7.2. In turn, the ratios for the SKYTRAIN are [redacted] US$M/km and [redacted] US$/train-km, which indicates an acceptable range for the SKYTRAIN.

Table 2.7.1 Operation & Maintenance Cost

Unit : US$Mill

Item/Year	2021	2024	2025	2030	2035
Manpower					
Administration, OCC, fixed					
Stations					
Civil, Tracks					
Rolling Stock					
Power					
Cleaning Staff					
Spare Parts					
Power					
Total					

Source: SKYTRAIN Study Team

Table 2.7.2 Comparison with Existing Monorail Systems (million USD)

Operator	Operation	Stations	Cars	train-km	OM Cost	OM Cost/km	OM Cost/ train-km
	km			*1000 train-km/year*	*US$M/year*	*mil.US$/km*	*US$/train-km*
Tokyo (6cars)	17.8	11	120	3,321.5	75.6	4.25	22.76
Osaka (4cars)	28.0	18	84	2,284.0	38.9	1.39	17.04
Tama (4cars)	16.0	19	64	1,347.5	32.5	2.03	24.08
Chiba (2cars)	15.2	18	36	1,173.0	19.8	1.30	16.87
Okinawa (2cars)	12.9	15	26	1,047.0	13.6	1.06	13.03
Syonan (2cars)	6.6	8	21	617.3	11.2	1.70	18.13
Kitakyusyu (4cars)	8.8	13	40	666.8	12.1	1.37	18.14
					Japanese average:	1.87	18.58

Source: Japan Railways Annual Statistic Handbook, 2010

CHAPTER 3 Project Evaluation (Economic/ Financial Analysis)

3.1 Economic Evaluation

Economic evaluation was conducted for the monorail line between Kotahena and IT-park via Malabe Line (Line 1), the line between National Hospital and Kollupitiya (Line 2), the MMC at Malabe and the P&R facilities. It examines the economic feasibility of a project through cost-benefit analysis from a viewpoint of the national economy, where the quantified project benefits are compared with the economic cost of the project.

Total project cost of the monorail project consists of the construction work cost, rolling stock procurement cost, cost for consulting services, physical contingency and O & M cost of the project. It is also assumed that additional cost for the monorail rolling stock and the depot will be procured in 2030 to meet the increased demand. They were estimated in constant 2014 prices, identified by each category of foreign/local cost for the economic evaluation and then converted into economic prices for the economic evaluation under the assumptions described below.

a) Base Year: Year 2014

b) Project Life: 30 years after the start of operating services of the monorail considering the life period of the infrastructure.

c) Life Period: Life periods of the facilities are estimated as the following years based on the physical life period of the infrastructures and rolling stocks.

Civil works, structures and buildings:	50 years
Rolling stock:	30 years

d) Replacement cost of the facilities and rolling stock is estimated based on its life period.

e) Financial and Economic Costs: Considering value added tax other tax duties as well as subsidies from the government which should not be counted as economic cost for economic analysis, financial costs of the initial investment are converted into economic cost. Please refer the main report for the detail assumptions.

f) Discount Rate: A discount rate of 12% is used considering the description in "Assessing Public Investment in the Transport Sector 2001" by the Ministry of Finance and Planning as well as other projects in the transport sector in Sri Lanka.

g) Inflation: Inflation is not taken into account either in the benefit or cost estimates during the evaluation period.

h) Foreign Exchange Rate: The foreign exchange rate is fixed at the following rate as of 2014 and the shadow exchange rate is not considered.

US Dollar 1.00 is equivalent to LKR 130.4550, the monthly average exchange rates of May 2014, according to the Central Bank of Sri Lanka. US Dollar 1.00 is equivalent to 101.79

JPY, the monthly median exchange rates of Tokyo market of May 2014 according to Bank of Japan.

i) Fare level of the monorail is assumed to be as same as current normal bus fare.

The benefit of vehicle operating cost is estimated as the difference of vehicle operating cost between "With Project" and "Without Project". The vehicle operating cost is derived from the computed daily vehicle-kilometres for each operating speed and the unit vehicle operating cost for each speed by vehicle type. The daily vehicle-kilometres for both cases of "With Project" and "Without Project" are obtained as the traffic assignment results in the transport demand forecast.

The benefit of passenger travel time cost is estimated as the difference in passenger travel time cost between "With Project" and "Without Project". The passenger time cost is derived from the computed daily passenger-hours and the unit passenger time cost of the three income groups by vehicle type. The daily passenger-hours for both cases of "With Project" and "Without Project" are obtained from traffic assignment results.

The benefit of reduction in traffic accidents are also estimated as the difference of volume of accident loss between "With Project" and "Without Project". The benefit of reduction of carbon dioxide (CO_2) was considered as the difference of the emission between "With" and "Without" the Project.

Result of Cost Benefit Analysis

The Economic Internal Rate of Return (EIRR) was estimated at [redacted]. The net present value is estimated at [redacted] rupees. Cost benefit ratio was [redacted]

Sensitivity Analysis

The effect of variations in the costs and the benefits on the EIRR is examined, when the cost increases by 10% and the benefits decrease by 10%, simultaneously. The EIRR of the project is [redacted] % which is higher than the discount rate, [redacted]%.

In addition, there is a variety benefits derived from the monorail project implementation, although they are not included in the benefits of this economic evaluation:

- Land value along the monorail is also expected to increase "With Project". However it is difficult to distinguish and estimate the increased value solely due to the monorail project implementation, since there are a variety of factors to determine the land prices in addition to the monorail project implementation.
- The monorail project will reduce emission of air pollutants such as carbon monoxide, nitrogen oxide, sulphur oxide, and suspended particle matter from private vehicles. This can improve the health of residents in the Western Province.
- The project will also contribute to reduce the emission of greenhouse gas which has an impact on the global warming.

Taking these benefits into consideration, the monorail project is an economically viable project.

3.2 Financial Evaluation

Financial evaluation is implemented based on the estimation in terms of revenues, construction costs, and operation and maintenance costs (O&M). Additionally, required financial conditions are assumed.

As a first step of financial evaluation, based on the said estimation in terms of revenues, construction costs, and operation and maintenance costs, the financial internal rate of return (FIRR) without loan interest is calculated in order to examine the return on the total investment. In this case, FIRR is calculated regardless of financing conditions without interest cost in which it is assumed that the initial investment is done without any loan. Then, based on the assumption on the financing plan, the cash flow analysis is implemented by use of value for money (VMF).

The following are the assumptions for general conditions in the financial evaluation.

a) Base year: Year 2014

b) Evaluation period: 34 years after the start of operating services of the monorail considering the completion period of the loan repayment as well as the interest payment.

c) Life period and Replacement Cost: same as the assumptions of Economic Analysis

d) Discount Rate: A discount rate of 2.6% is considered as the following calculation.

Real rate of interest (2.6%) = Nominal rate of interest for the government bond (6.9%[4]) - Rate of inflation (4.3%[5])

e) Inflation: Inflation is not taken into account either in the revenue or cost estimates during the evaluation period.

f) Foreign Exchange Rate: same as the assumptions of Economic Analysis

Financial Cost

Total project cost of the SKYTRAIN project consists of the construction work cost, rolling stock procurement cost, cost for consulting services, physical contingency, and O&M cost of the project. It is also assumed that additional cost for the monorail rolling stock and the depot will be procured in 2025 and 2030 to meet the increased demand.

Revenue

The revenues are composed of the monorail fare and the railway related business as in the following Table 3.2.1. The monorail fare is set the same as the normal bus level which is [redacted] LKR million per year in the opening year of 2020. Based on the demand forecast, the annual fare revenue will be increased.

[4] May 2014
[5] The average from January to June 2014

Table 3.2.1 Estimation of Revenue

Item			Unit cost, area and operation rate	Amount (LKR mil)
Monorail	Railway related	Floor space for lease	[redacted] LKR/m²/month, [redacted] m², operation rate=[redacted]	[redacted]
		Advertisement space (station)	[redacted] LKR/m²/month, [redacted] m², operation rate=[redacted]%	[redacted]
		Advertisement space (inside monorail car)	[redacted] LKR/train/month, [redacted] trains, operation rate=[redacted]%	[redacted]
		Advertisement space (exterior monorail car)	[redacted] LKR/train/month, [redacted] trains, operation rate=[redacted]%	[redacted]
		Car parking at P&R	[redacted] LKR/hour, [redacted] hours/car, [redacted] cars/day, [redacted] days	[redacted]
			Total	[redacted]

Source: SKYTRAIN Study Team

Summary of Financial Evaluation

The NPV of the government cash flow funded by JICA STEP loan[6] shows less government deficit rather when compared to another loan in order to implement the SKYTRAIN Project.

When the government of Sri Lanka takes a STEP loan from JICA to cover the construction cost of the monorail and rolling stock, and then operates the monorail, and receives the revenue from the operation of the monorail, the NPV of the government cash flow shows the negative value of [redacted] LKR billion. If the government takes another loan from other country, which the interest rate is [redacted]% per annum, and the repayment of principals is [redacted] years including [redacted] years grace period, the NPV of the government cash flow shows the negative value of [redacted] LKR billion.

In the case that a public corporation operates the monorail, the corporation is responsible for the O&M cost and receives the revenue from the operations of the monorail, and the government is responsible for the construction cost of monorail, loan repayment and interest, and receives the loan. The NPV of the public corporation shows a negative value of [redacted] LKR billion with the fare level of normal bus.

In other cases of the fare level of semi-luxury bus and increase in steps[7], these NPVs show negative values as shown below. Only the NPV with the fare level of luxury bus shows a positive value of [redacted] LKR billion, though the cash flow indicates negative from the year of 2024 to 2034. This negative period is caused by the increase of O&M on the monorail due to the purchase of new rolling stocks in 2025 and the expansion of the depot in 2030 for catching up the increase of demand after 2030.

- Normal bus level : [redacted] LKR billion
- Semi−Luxury bus level : [redacted] LKR billion

[6] In the STEP loan, the purchase of additional rolling stocks in 2025 and 2030 as well as the construction cost of the depot for expansion in 2030 are not included. The total amount of STEP loan is [redacted] LKR billion.

[7] This fare is increased in steps, in which the normal bus level is set up from the opening year to 2024, semi-lux. level from 2025 to 2034 and lux. level from 2035.

- Luxury bus level : [redacted] LKR billion
- Increase in Steps : [redacted] LKR billion

To improve the financial sustainability, the case study which the public corporation includes the additional revenue from MmTH with Mall-1 ([redacted] billion LKR/year) is examined. It is found that this public corporation has the possibility to cover the O&M even from the fare revenue of normal bus level. (NPV with different bus fare level / Normal bus level: [redacted] LKR billion, Semi-Luxury bus level: [redacted] LKR billion, Luxury bus level: [redacted] LKR billion, Increase in Steps: [redacted] LKR billion)

CHAPTER 4 Findings and Recommendations

In this Final Report, the entire Feasibility Study result of the the Integrated Transport System with Monorail (SKYTRAIN) project, has been presented. As the summary of the result, following points are the findings of the project:

- The monorail system which includes civil structures and electrical and mechanical systems was designed as a technically and economically suitable and effective solution for the introduction of a new transit system in the Colombo Metropolitan Area. The route and stations were selected to capture many passenger demands under the constrains within the urban area of Colombo. It can help to alleviate traffic congestion and to match social and environmental considerations in urban area.

- The project costs for the implementation of the monorail system will be economically covered by the large amount of benefits from the monorail system.

- In terms of financial sustainability, the public corporation is difficult to operate a monorail system to increase the fare up to luxury bus level even if the monorail fare setting has the flexibility for demand control. When the public corporation receives the additional revenue from MmTH with Mall-1, the public corporation has the possibility to cover the O&M.

- In terms of environment and social aspect, EIA study revealed that the potential impacts of the proposed project take place mainly during the construction stage and impact during operational stage is minimal. Although the impact from the project during construction stage could be significant particularly for items such as noise/vibration, traffic and social infrastructure, the impact could be minimised and mitigated to a great extent if appropriate mitigation measures are implemented as suggested in the EIA study.

- Social study revealed that impact on agricultural land is relatively high due to acquisition of such land for construction of depot, however, the number of houses and commercial establishments to be relocated due to the project is relatively low, since the monorail route traverses mainly through the already existing road network.

Therefore, the project is expected to be implemented as the introduction of the new transit system not only for the public transport user but also the entire residence of Colombo city. In addition, it is to be desired that the monorail project is developed together with MmTH in terms of financial sustainability.

Recommendations on the Project

Formulation of Project Management Unit (PMU): In order to successfully implement the project smoothly and effectively, the project management unit (PMU) shall play an essential role in communicating among stakeholders and to drive the project. Before official approval of the project, it is necessary to reinforce the core team in the MOT since they play a role for the implementation of the project. Then, right after the approval, it is recommended to start formulating the PMU with a sufficient number of human resources from the necessary fields and preparing the actual implementation. It will be helpful to study similar experiences from other countries for the enforcement of the PMU.

Institutional Arrangement for Monorail Operation/Management: Close discussion on how to arrange the institutional arrangement of monorail operation is essential. This study provided several ideas of operational bodies for monorails, so that more effective operation/management methods should be examined before starting operation.

Environmental Impact Assessment: Draft EIA report was prepared according with TOR issued by CEA. The draft EIA report shall be submitted to CEA for adequacy checking and shall be finalized based on comment from CEA. After finalization of draft EIA, it is recommended to conduct stakeholder meeting to disclose the result of EIA study to public and seek any comment against the project. The comment raised from public shall be adequately considered and draft EIA report shall be updated to address a comment as necessary.

Resettlement and Relocation Activities: As we discussed in the report, the resettlement and relocation activities affect the construction plan and periods directly. In order to make a smooth implementation of land acquisition and resettlement, all the necessary arrangements and measures should be taken in accordance with the Resettlement Action Plan (RAP) prepared for the Project. It is also important to update the draft RAP based on the stakeholders' perceptions / opinions through continuous stakeholder meetings.