MINISTRY OF MEGAPOLIS AND WESTERN DEVELOPMENT
DEMOCRACTIC SOCIALIST REPUBLIC OF SRI LANKA

PREPARATORY SURVEY
ON
THE PROJECT FOR ESTABLISHMENT
OF
NEW LIGHT RAIL TRANSIT SYSTEM
IN
COLOMBO

FINAL REPORT

APPENDIX II

MAY 2018

JAPAN INTERNATIONAL COOPERATION AGENCY

Oriental Consultants Global Co., Ltd.
Japan International Consultants for Transportation Co., Ltd.
Tonichi Engineering Consultants, Inc.
Environmental Resource Management
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Appendix 13 EIA Report

Government of the Democratic Socialist Republic of Sri Lanka
Ministry of Megapolis and Western Development (MMWD)

ENVIRONMENTAL IMPACT ASSESSMENT FOR COLOMBO LIGHT RAIL TRANSIT (LRT) PROJECT

April 2018

Submitted to;
Central Environmental Authority

Submitted By;
Ministry of Megapolis and Western Development

Prepared By:
Oriental Consultants Global Co., Ltd, Japan
Consulting Engineers and Architects Associated (Pvt.) Ltd., Sri Lanka

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LIST OF ABBREVIATIONS

AAGR	Average Annual Population Growth Rate
AC	Alternating Current
ABL	Assessment Background Level
AFC	Auto Fare Collection
AGT	Automated Guideway Transit
A/L	Advance Level
ATO	Automatic Train Operation
ATM	Automated Teller Machine
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
AW	Added Weight
BCR	Benefit Cost Ratio
BOD	Biological Oxygen Demand
CBD	Central Business District
CBTC	Communications-Based Train Control
CCTV	Closed Circuit Television
CDM	Clean Development Mechanism
CEA	Central Environment Authority
CEB	Ceylon Electricity Board
CHEC	China Harbour Engineering Company
CIS	Centralised / Computerised Interlocking System
CMC	Colombo Municipal Council
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CoMTrans	Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs
CR	Critically Endangered
DD	Data Deficient
DEM	Digital Elevation Model
DS	District Secretariat
DO	Dissolved Oxygen
EA	Environmental Assessment
E&M	Electro-Mechanical

EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMMP	Environmental Management and Monitoring Plan
EN	Endangered
E&M	Electromechanical
ENL	Existing noise level
EPA	Environmental Protection Area
EPC	Engineering, Procurement and Construction
EU	European Union
GBH	Girth at Breast Height
GCE	General Certificate of Education
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic information system
GN	Gramaseva Niladhari
GoSL	Government of Sri Lanka
HSE	Health, Safety and Environment
HHH	Household Head
IAS	Invasive Alien Species
IC	Intelligent Card (Smart Card)
IEE	Initial Environmental Examination
IRR	Internal Rate of Return
IT	Information Technology
ITI	Industrial Technology Institute
JICA	Japan International Cooperation Agency
KMC	Kaduwela Municipal Council
LAA	Land Acquisition Act
LAN	Local Area Network system
LARC	Land Acquisition and Resettlement Committee
LAeq	Equivalent noise level
LAmax	Peak noise level
LC	Least Concern
LP	Liquefied Petroleum
LRT	Light Rail Transit

MCA	Multi Criteria Analysis
MOT	Ministry of Transport
MRT	Mass Rapid Transit
MmTH	Multimodal Transport Hub
MMWD	Ministry of Megapolis and Western Development
MSL	Mean Sea Level
MW	Mawatha
NEA	National Environmental Act
NO_2	Nitrogen Dioxide
NPV	Net Present Value
NSW EPA	New South Wales - Environmental Protection Agency
NT	Near Threatened
NWSDB	National Water Supply and Drainage Board
O&M	Operation and Maintenance
OCC	Operation Control Centre
ODA	Official Development Assistance
O/L	Ordinary Level
PAA	Project Approving Agencies
PAP	Project Affected People
P&R	Park and Ride
PC	Pre-stressed Concrete
PHC	Pre-Tensioned Spun High Strength Concrete
PIWQS	Proposed Inland Water Quality Standards
PM10	Particulate Matter (10 micrometers or less in diameter)
PMU	Project Management Unit
PSD	Platform Screen Door
PP	Project Proponent
PPE	Personal Protective Equipment
PPHPD	Passenger Per Hour, Per Direction
PPP	Public-Private Partnership
RAP	Resettlement Action Plan
RBL	Rating background level
RC	Reinforced Concrete
RDA	Road Development Authority

ROW	Right of Way
RRI	Route Relay Interlocking System
RSS	Receiving Substation
RTS	Rapid Transit System
RTU	Remote Terminal Unit
SJKMC	Sri Jayawardhanapura Kotte Municipal Council
SLLRDC	Sri Lanka Land Reclamation and Development Corporation
SLR	Sri Lanka Railway
SLS	Sri Lankan Standard
SLT	Sri Lanka Telecom
SO_2	Sulphur Dioxide
SRM	Standard Reken Method
SSS	Service Substation
STEP	Special Term for Economic Partnership
TEC	Technical Evaluation Committee
TOD	Transit Oriented Development
TOR	Terms of Reference
TSS	Total Suspended Solids
TSS	Traction Substation
UDA	Urban Development Authority
UITP	International Organisation for Public Transport
VVVF	Variable Voltage Variable Frequency
VU	Vulnerable
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

Executive Summary

The Light Rail Transit (LRT) project is a project implemented by the Ministry of Megapolis and Western Development (MMWD) designed according to the proposed transport plan for the Western Region Megapolis area. The LRT is an electrically operated train which runs on and elevated platform which consists of concrete pillars and concrete/steel beams. The center pillars of LRT mostly follows the centerlines of the existing A and B Class roads of Road Development Authority (RDA) except at the places of curves, Denzil Kobbekaduwa Mawatha and Chandrika Bandaranayaka Kumaranathunga Mawatha as outlined below.

The objective of the project is to provide an efficient and reliable mode of transport in Colombo and Malabe corridor (especially the route between Malabe to Borella) which is a heavily traffic congested area. The proposed LRT route will serve the transport needs (especially office transport) of the adjacent areas such as Town hall area where the National Hospital is located, Colombo Fort World Trade Center area, Pettah Central Bus Stand area, Port City, Borella and Sethsiripaya, and Suhurupaya etc are located.

The LRT route starts near Fort Railway Station at W E Bastian Mawatha and ends at the depot site in the paddy area adjacent to Chandrika Bandaranayaka Kumaranathunga Mawatha, Malabe and enters Battaramulla, Pannipitiya Road. It passes through Gamin Hall Junction after crossing the Fort Maradana Rail Road,Ibbanwala Junction, Lipton Circus , Ward Place , Borella Junction, Parliament Road near Rajagirita McDonalds. It crosses Diyawanna Lake at Diyatha Uyana and crosses Batteramulla Junction after traversing behind Sethsiripaya, Palan Thuna Junction (via Denzil Kobbekaduwa Mawatha), Koswatte Junction, Talahena, Malabe Junction and enters the depot site, which is adjacent to Chandrika Bandaranayaka Kumaranathunga Mawatha. The basic LRT route is shown in Figure 0.1

The Project will be financed by the Government of Sri Lanka (GoSL) and Japan International Corporation Agency (JICA). MMWD will form a new company with majority shares of the GOSL for the operation and maintenance work of LRT. It is expected to complete detailed design and start construction in 2020 and complete the Construction in mid-2024.

The basic civil works of the LRT will be consisted of concrete box girders spanned on concrete piers founded on bored or steel screwed piled foundations depending on the road width. The LRT platform, on which rails for rolling stocks will be fixed, will be at a height of approximately 10m from the road level. The rail compartments will run, on the longitudinal rails in various combinations, depending on the passenger transport requirements. The 16km LRT route has a total of 16 stations. The expected total journey time from Malabe Depot Site to Colombo Fort will be about 30 minutes and in every 3-4 minutes a train will arrive at a station during rush hours and during other times it will arrive in approximately every 10minutes.

The existing environment of the LRT route is highly urbanized with an altered natural environment. The LRT traverses through main roads, crosses canals of Colombo Canal system, crosses Diyawanna Lake at Diyatha Uyana Batteramulla and crosses partially abandoned paddy areas adjacent to Chandrika Kumaranathunga Mawatha. The LRT route will not cross protected areas (e.g. Sri Jayawardenapura Kotte Bird Sanctuary and Talangama Environmental Protection Area) and archaeologically important structures.

The proposed LRT will give rise to adverse construction impacts and negative and positive operational impacts to the environment. The main construction impacts identified include;

1) There will be noise nuisance from the construction activity of LRT structure as well as simultaneously pile driving operations for the Depot Site.

2) There will be reduction in traffic capacity, where the LRT construction takes place. Traffic congestion will occur at construction sites along the LRT route and its connecting routes.

3) There will be risks to community and occupational health and safety risks to workers involved at various stages of the project, particularly when there is heavy construction.

4) Livelihood of people will get affected by construction work. Livelihood of about 455 employees hired by around 100 businesses will be partially or fully affected by the Project. Among these, 108 employees belong to Car-Mart (Peugeot and Mazda). Together with Ishara Traders, these big businesses are in Ibbanwala Junction. There will be 66 structures which will be partially or fully affected by the Project (30 totally affected, and 36 structures partially affected). One residence will be fully affected and the residents may have to be resettled at the proposed IT Park Station. Also, forty-one (41) paddy land owners and 5 tenant farmers at the depot site will be affected.
5) Utility relocation (electricity, water, sewerage and telecommunication) will cause temporary public inconvenience.
6) Temporary hindrances to the drainage of limited number flood plains (Malabe Depot area) and canals (e.g. Beria Lake Canal, St. Sebastian Canal), lakes (Diyawanna Lake at Diyatha Uyana) and low-lying areas,
7) Wastewater and sewage from construction sites may contaminate surface water and groundwater
8) Pruning and excising branches of Bo Trees which have religious value. There are 14 Bo Trees found along the LRT Route but extent of impact will be determined at the detailed design phase.

The main operational negative impacts are;

1) Risks to occupational health and safety
2) Public inconvenience created by noise and vibration
3) Crack development possibilities in adjacent buildings owing to vibration.
4) Occurrence of unexpected events such as accidents, fire.
5) Wetland degradation and surface water quality degradation at Depot Site by wastewater and sludge release and solid waste (scheduled Waste) from the Depot Area and stations which would pollute surface and ground water quality and impacts bio diversity.

The only positive construction impact is the creation of a significant amount of employment opportunities.

The main positive operational impacts are;

6) Travel time saving by the reduction of traffic congestion by discouraging the use of private vehicles; Provision of a comfortable, safe and reliable public transportation mode to the people. Increased connectivity of different transport modes and accessibility of strategic locations
7) Generation of jobs and improvement of local and regional economy
8) Air quality improvement by the reduced use of fossil fuel powered vehicles. Saving of fossil fuels and reduction of greenhouse gas emissions to the atmosphere as the LRT runs purely on electricity;

The proposed mitigation measures for the negative construction impacts are;

9) Limiting piling work to day time. Provide noise reduction devices for the piling hammer, provision of noise barriers as necessary and informing the nearby residents about the ongoing piling activities and use well serviced low noise generation equipment, avoid noise generating night time work.
10) Undertake traffic management plans for critical road intersections with the help of Local Authorities and Traffic Police, create temporary alternative access, provide traffic signage.
11) Adoption of all standard safety measures and monitoring.
12) Monitor all vulnerable buildings, conduct crack surveys, control piling impulses in pile driving equipment.

13) Provision of compensation through adoption of the Land Acquisition and Resettlement Committee (LARC) system and provision of livelihood support programmes

14) Study the utility plans, liaise with the relevant line agencies, restoration of damaged utilities, provision of temporary services until utility damage is restored or utility relocation is complete

15) Avoid temporary blockage of the whole canal sections, flood plains, carry out emergency breaches in coffer dams, use rigs to minimize waterway blockage, remove temporary obstructions during floods, provide culverts and control height of the pilot road adjacent to Chandrika Bandaranayaka Kumaranathunga Mawatha

16) Provide standard sanitary toilets with septic tanks or mobile toilets for worksites.

17) Carry out necessary religious rituals with the blessings of the devotees and chief incumbents of temples if a Bo Tree belongs to a temple is to be cut or pruned.

The main mitigation measures for the operational impacts are

1) Noise monitoring and provision of permanent noise barriers to noise sensitive receptors based on the international noise standards (Railway noise standards of Japan and Australia)

2) Monitor the condition of adjacent buildings taking the pre-construction crack survey (dilapidation survey) as the baseline.

3) Provision of a wastewater treatment plant to the Depot site and connecting the sewer output the proposed Sri Jayawardenapura sewerage network

The summary of the major impacts and mitigation measures are given in Table 0.1 and Table 0.2 .

The responsibility of environmental impact mitigation will be borne by the Project Proponent while the implementation of such mitigation measures will be carried out by the Contractor (through contractual arrangements) under the supervision of PMU and CEA's monitoring mechanisms.

The main responsibility of monitoring the project activities will lie with the Project Proponent (MMWD) assisted by the Project Management Unit (PMU) of LRT Project, under the appointed "Engineer" – Resident Engineer (or Resident Project Manager) and the Environmental Manager working under the above setup. LRT Project PMU will facilitate the contractors in carrying out the required work.

The construction and operational stages of the LRT will be monitored through an appointed Inter Agency Monitoring Committee which consists of the line agencies Urban Development Authority (UDA), Road Development Authority (RDA), Sri Lanka Land Reclamation and Development Corporation (SLLRDC), Department of Agrarian Development, Irrigation Department, National Water Supply and Drainage Board (NWS&DB), Colombo Municipal Council (CMC), Kotte Municipal Council and Kaduwela Municipal Council. CEA will undertake independent monitoring. The EMMP will be further refined after the contract award, based on the "Method Statement" of the Contractor considering the specific contract execution methods and the details of the Detailed Design.

It could be concluded that the project will have some mitgable negative impacts during construction and during the operational stage. The number of houses and commercial establishments to be relocated due to the proposed project is relatively low, since a major portion of the LRT route traverses in the middle of existing road networks. The LRT is a low-emission solution by itself compared to even a usual fossil fuel driven train.

The Extended Cost Benefit Analysis of the project indicated that the proposed LRT project for Malabe traffic corridor can be considered as an economically viable project suitable for implementation as according to the ECBA, The Benefit Cost Ration BCR is 2.15, the Environmental Internal Rate of Return (EIIR) is 20.2% and the Environmental Net Present Value (ENPV) Rs. 169billion.

It is recommended that the proposed LRT project from Colombo Fort to Malabe is implemented as a solution to the traffic congestion of Borella Malabe corridor, to provide passengers with a safe, efficient, reliable and comfortable quick mode of environmentally friendly mode of transport. The EIA report's mitigation measures and EMP shall be made part and parcel of the tender/bid documents and shall be included within the construction contract.

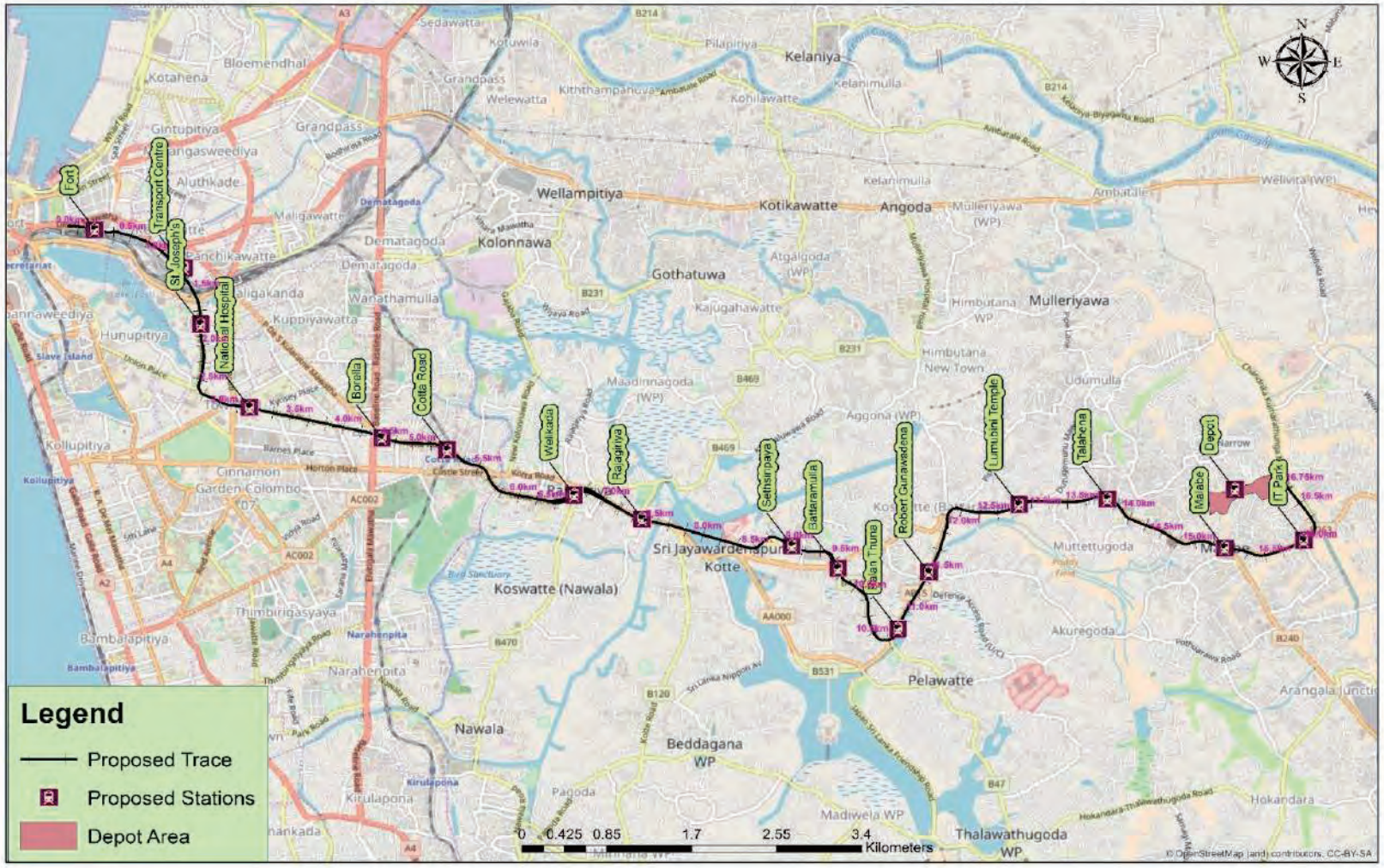


Figure 0.1 Proposed LRT Route and Stations

Table 0.1: Summary of expected impact and mitigation measure (Construction Phase)

IMPACT THEME	POTENTIAL IMPACT	PROPOSED MANAGEMENT MEASURE
NOISE	Increased noise levels in the vicinity of the construction site • The expected average noise level of 61 dB (Laeq) at 10m distance (nearest resident) is below CEA standard for construction activity at daytime (75dB (A)). • Projected maximum noise level (Lamax) at 10m distance (nearest resident) is 84dB. There is no limit stipulated for Lamax in Sri Lanka.	<u>For general construction site (LRT route)</u> • Fitting of exhaust baffles, maintaining vehicles and machinery in a high operable condition, • Use the, low-noise type machine and/or vehicles, • Construction site is separated with corrugated sheets or other suitable material especially at locations near noise sensitive receptors, particularly at National Hospital and school zone. • Scheduling of construction work that cause high noise and vibration to ensure least inconvenience to the public, • Avoid construction work on Poya days and days of other religious and/ or cultural importance, • Avoid high noise construction activities during the night time. • Establishing a complaint handling mechanism • Advance notification to the surrounding community <u>For Depot</u> • Conduct a test piling activity and check the noise level generated from the piling activity at Depot area. • Consider changing the height of hammer drop or weight of hammer to be used, depending on the result of test piling • Install a noise reduction equipment with piling hammer
VIBRATION	Increased vibration levels in the vicinity of the construction site • Vibration levels at a distance of 10m from the vibration source is estimated at 5-7 mm/s • Simultaneous piling activities will not have significant impacts on Type 1 and 2 structures that are located within 10m from the piling activities. • These activities may affect Type 3 and 4 structures located within the 10m boundary.	• Identification of type of building structure (Type 3 and Type 4). For Type 4 structure, the consultation with Department of Archaeology is required. • Carry out a property condition survey (crack survey) of nearby structures and record the present condition of the structure, to accurately assess any damage to these structures during the construction stage. • Vibration monitoring at selected area around the construction activities. • Regularly communicate with surrounding communities to inform the construction schedule. • Use of lower vibration generating device/machinery. • Scheduling of construction work that cause high vibration must be within authorized construction embodiment times, • Minimisation of piling energy (e.g. reduced hammer drop distance) as necessary depending on receptor distance. • Establishing a complaint handling mechanism and implementing a procedure to effectively deal with any issue raised by the community. • Provision of vibration cut-off trenches at locations required
TRAFFIC IMPACT	Road link capacity reduction • Reduction of traffic capacity up to 30% - 50% due to the construction activity. • Wider road network would be impacted due to congestion at road intersections.	• Preparation of traffic management plan for each construction stage such as diversion, lane control, safety measures. The traffic management plan will also take into consideration mobility and safety of vulnerable groups (e.g. school children, elderly). • Carry out traffic simulation for above traffic management plan • Road Intersection wise traffic analysis for the key road intersections affected by the study (See Section 1.4 of the Traffic Impact Assessment Report in Annex C for the

		affected intersections) • A stakeholder committee with the participation of project consultants, Colombo Municipal Council and the other relevant local government bodies, Road Development Authority and Traffic Police, will be appointed to give guidance on the developed traffic management plan • Monitoring of traffic flow during construction stage • Ensuring the safety during the construction period using standard safety measures. • Adherence to the workzone management guidelines formulated by RDA. • Provide minimum 3m lane width for bus routes • Maintain walkable paths for pedestrian movement especially where high density pedestrian traffic flows exist (e.g. Malabe, Rajagiriya Road, Olcott Mawatha, Justice Akbar Mawatha and Malay Street, access roads in depot area) • Retain access roads in depot area (slightly diverted) and ensure that design and construction of depot civil structures will not hamper movement of people and vehicles in the area.
LANDSCAPE	Impact on special values associated with aesthetics (e.g. nature, views of heritage structures), such as • Rajagiriya junction, • Ward place, • Ceremonial approach (Sri Jayawardenapura Road), • Densil Kobbakaduwa Mawatha.	• The major sensitive areas will be thoroughly studied in terms of landscape impact during detailed design stage through the consultation with concerned agencies. After detailed assessment of landscape impact, if it is found that alternative route is suitable, it will be a subject for supplementary EIA. • Micro level detailing, structures, colours, lighting, planting, trains designs and colours, stations, interactions will be part of the overall design depending on each section. • In order to realise the overall objectives, in the design team in addition to the design and structural engineers it will include; Tow Planners, Urban Designers, Architects, Landscape Architects, and Lighting Experts.
HEALTH AND SAFETY	Risks to occupational health and safety (e.g. accidents, health hazards to workers)	• Submission of an Occupational Health and Safety Management Plan (Construction Stage) prior to commencement of work. • Adoption of standard worker safety methods • Provision of personal protective equipment (PPE) • Provision of trainings and awareness programs to employees • Conducting hazard analysis and plan/provide adequate mitigation measures for such hazards identified, prior to carrying out major construction activities
	Risks to community health and safety • Increase of stress levels for affected residents and commuters • Risk to respiratory diseases due to dust • Hazards of communicable and infectious diseases	• The project site will be fenced and access points will not be available for the public. • Appropriate sanitary facilities will be provided at all construction sites. • Environmental pollution control measures, including watering proper maintenance of machinery shall be implemented. • Arrange construction activity and schedule to minimize the impact on surrounding community (e.g. prohibit high noise generating activity on night time)
SOCIO-ECONOMIC IMPACTS	Impact on livelihood and economic activities • Inability to park vehicles • Temporary loss or	• Provision of compensation to the Project Affected Parties (PAPs) using the compensation package decided for LRT Project based on LARC stipulations on assessing the financial and other losses of PAPs.

	impedance of access to business premises • Livelihood of about 455 employees hired by around 100 businesses will be partially and fully affected by the Project. 108 employees belong to Carmart (Peugeot and Mazda) and 75 employees belong to Lal and Nihal. • Impact on 41 paddy land owners and 5 tenant farmers	• Provision of alternative access to their premises as far as possible outside the construction sites to carry out their usual business activities and other domestic or related employment activities. • Develop a Livelihood Restoration Plan • Continual liaising with the Project Affected Parties (PAPs) will be undertaken to decide on the site-specific mitigation measures. • Consultation with people whose livelihood depend on modes of transportation that may be affected by the Project (e.g. 3-wheelers and bus operators). They will be included in the development of the traffic management plan.
BIOLOGICAL ENVIRONMENT	• No direct impact on protected areas as they were avoided by the design	• Monitoring of bird species will be conducted.
	• Trimming of some trees) 652 trees belonging to 82 species are located along LRT route. • 89 trees planted along Denzil Kobbekaduwua Mawattha, will need to be removed. • Two trees of one nationally endangered tree *Diospyros ebenum* which are planted which will not to be directly impacted. • Negligible impact on terrestrial and aquatic habitat • No impact on habitat fragmentation or disruption of movement patterns of species	• Offset trees of 10 times of that is cut down by the project • Enhancement of biodiversity through creation of various type of habitat such as wetland, forest zone and open area. • Use the native species which will enhance the value of ecosystem in the area • Creation of green buffer zone around the Depot by selection of tree species which grows high to mitigate the landscape impact
	LRT route will pass through these wetlands • left of the Madiwela East Diversion Canal (mostly abandoned paddy fields) • lower end of the command area of the Thalangama tank • Diyatha Uyana, which is an open water type habitat	• Minimize removal or pruning of trees • Introduce a wastewater treatment plant and • Collect scheduled waste for the "Ecocycle" process.
IMPACT ON UTILITIES	Underground Utilities: electricity cables, telecommunication lines, sewerage pipes, storm water conduits, water supply lines Overhead utilities: electricity lines, telecommunication lines.	• Close coordination with and provision of support to utility agencies, including CEB and NWSDB. • Adopt schedules for the shifting and temporary termination of infrastructure service supply • Make the public aware of schedules in advance to prevent ad hoc activities • Make timely payments as agreed • Assist in shifting of facilities

		• Obtain information from other on-going projects
LAND ACQUISITION & RESETTLEMENT	Impact on private properties (land and built structures) There will be 66 built structures which will be partially and fully affected by the Project. One residential house may be fully affected at the proposed IT Park Station.	• Develop and implement a Resettlement Action Plan (RAP) and Livelihood Restoration Plan • Carry out consultations with project affected persons (PAPs)
	Impact on government institutions and properties: • Existing roads (RDA) • Diyatha Uyana, Floating Market (UDA), Diyawanna Lake, SLLRDC • Maradana Railway Line (SLR)	• Consult relevant agencies (e.g. RDA, UDA, SLR) • Provide necessary assistance, such as relocation of affected properties.
SOLID WASTE	Erosion of excavated materials, spoil and other waste construction materials etc.	• Prevent stocking of loose earth by the road side • Cover temporary stockpile with polythene sheet and place weights • Manage sand stockpiles by compaction/haunching. • Provide temporary drainage around the sand stockpiles.
	Nuisance to pedestrians and other road users caused by construction wastes Impact on the aesthetics of the city (temporary)	• Careful planning of temporary storage and disposal • Segregate wastes properly. Recyclable materials will be handed to registered recyclers. • Scheduled wastes (e.g. oil) will be collected and carefully stored. Treatment and disposal of these wastes will be contracted out to a registered industrial waste company.
SURFACE WATER & GROUNDWATER	Impact on water quality of Diyawanna Lake	• Monitor water quality in the lake during construction period
	Impact on groundwater quality due to construction of foundation structures	• Monitor groundwater quality
CULTURAL HERITAGE	There are total 14 Bo trees along LRT route, with and without shrines. No uprooting of Bo tree is expected. Some branches of Bo tree overarching the LRT route may be cut downed/trimmed.	• Consult relevant stakeholders • Carry out religious rituals and communicate with relevant stakeholders (Monks and devotee) before the commencement of construction activities.
	Hindrance access to religious and culturally important sites	• A traffic management plan will be developed considering alternative access roads to religious and culturally important sites.
WASTEWATER	No workers camp at site is required, but limited construction workers may be accommodated at Depot site.	• Provide cylindrical septic tank or portable toilets at the construction areas; • Adequate facility such as sanitary latrines will be provided for temporal accommodation at Depot site.
	Spillage, leak and accidental discharge of oil from construction vehicles	• Proper use and maintenance of construction machines and heavy vehicles • Install Oil and grease traps in the drainage system • Establish and implement emergency and contingency plan in case of spills
WATER COURSE	LRT route will traverse Diyawanna Lake	• Use a two-dimensional flood model with a possible tentative blocking arrangement for construction rigs within the Diyawanna. • Conduct lake blocking part by part. • Limit construction of the foundation of LRT structure within the lake during dry season; avoid critical monsoon periods such as April- June and September to November. • Carry out temporary blocking of the lake section according to the instructions of SLLRDC; Re-run the model depending on the site-specific construction arrangements. • Prepare a suitable pumping arrangement in case of flood

		• If in the opinion of the Engineer that flooding is aggravated because of temporary construction blocks such blocks will be temporarily removed until the flood subsides. • Encourage the contractor to use less invasive designs such as balanced double cantilever bridge to cross the lake
	Construction activities may cause pocket flooding	• Opening of drainage paths over the road • Creation of temporary drainage path from the construction sites to the nearest drain, as necessary. • Removal of construction equipment from site if inundation occurs.
	Construction activities may cause backwater on flood plains.	<u>Depot Area</u> • Provide a 3m wide canal right round the fill area • Conduct of construction works in parts. • Control of height of fill; Allow water overtopping over the fill • Propose to improve the existing drainage canals in the low-lying paddy by desilting them. • Establish direct drainage connection between these canals and main canal. • Open culvert gates, in case of flood • Avoid blocking of existing drainages • Refining of the flood modeling; Lower part of the sub catchment will be made as a hydro dynamic model to represent the existing drainages and internal road culverts. • Breach fillings at strategic locations in case of flood <u>Pilot Road in the Low-Lying Areas Adjacent to Chandrika Bandaranayaka Kumaranathunga Mawatha</u> • Minimize height and width of the pilot road to a height of 0.6m. • Provide temporary culverts to all drainage paths and at places of the flood plain crossing the pilot road. • Breach filling at strategic locations in case of flood • Test pilot road using the flood model of SLLRDC
AIR QUALITY	Generation of dust Emissions from construction machineries and vehicles	• Wetting and water spraying • Covering of transport vehicles • Careful stockpiling of construction materials • Monitoring of dust levels • Proper maintenance of construction machineries and vehicles • Careful selection of location of construction yard • Limiting of vehicle speed • Proper planning and siting of construction activities • Set up dust barriers
UNUSUAL EVENTS	Impacts of unexpected events such as accidents and natural hazards	• Develop an Emergency Response Plan • Compliance with applicable performance specification, design standards and codes, health and safety regulations • Provision of firefighting system

Table 0.2: Summary of expected impact and mitigation measure (Operation stage)

IMPACT	POTENTIAL IMPACT	PROPOSED MANAGEMENT MEASURE
NOISE	Noise level will satisfy noise standard for both Peak noise level (LAmax) and Equivalent noise level (LAeq) awarding to Japanese and Australian Noise standards of LRT. However, there might be a disturbance especially around noise sensitive receptors.	• Consider noise mitigation measures (e.g. noise barrier), especially for sensitive areas. • Carry out noise monitoring along LRT route • Standard maintenance of trains, structure and tracks • Establish a grievance mechanism
VIBRATION	Vibration impact is expected, but the impact is not considered significant.	• Conduct monitoring of vibration at selected points along the route • Standard maintenance of trains, structure and tracks • Establish a grievance mechanism • Proper maintenance of train structure, tracks and rolling stocks
HEALTH AND SAFETY	Risks on occupational health and safety • Accident due to the maintenance of LRT structure and rolling stocks	• Develop Health and Safety Management Plan for operational stage • Provide of PPE • Deploy security guards • Develop an Emergency Response Plan • Adoption of standard worker safety methods, • Develop and implement an Occupational Health and Safety Management Plan (Operation Stage) • Provision of PPEs, • Putting up of warning signs, • Training of employees
SOCIO-ECONOMIC IMPACTS	Impact on livelihood and economic activities • Continuing livelihood restoration of PAPs • Conflict of interest with existing modes of transportation (e.g. buses, 3-wheeler drivers)	• Monitoring of the Livelihood Restoration Plan for the affected PAPs • Consultation with relevant stakeholders to seek optimum solutions for transport operators (e.g. buses, 3-wheelers) • Provisions to make new bus routes and shuttle services to connect stations to main towns • Propose developing terminals for 3-wheelers close to the trains stations.
SOLID WASTE	Waste from depot • Wastes generated at Depot will include Lubricant oil, sludge, Break shoe, metal scraps/particles, rubber tube and batteries.	• Segregate wastes. • Recyclable materials will be handed to registered recyclers. • Non-hazardous wastes will be disposed in accordance with relevant local regulations. • Regular collection and disposal of wastes • Scheduled wastes (e.g. oil) will be collected and carefully stored. Treatment and disposal of these wastes will be contracted out to a registered industrial waste company
	Waste from stations • Litter such as papers, waste as biodegradable waste (food waste, garden waste etc.), plastics, glass and paper empty plastic bottles will be generated at each stations	• Waste generated from stations will be collected according to the type of waste by registered waste contractor and treated through a registered waste disposal facility
WASTEWATER	There might be spillage, leak and accidental discharge of oil/contaminated water at Depot area	• Secondary containers will be placed in storage areas for hazardous substances(e.g. oil) • Spill kits will be provided • Provide drainage from chemical storage areas to oil separator (depot area)
	Wastewater will be generated from washing of rolling stocks as well as sanitary wastewater from	• Wastewater treatment system with sufficient treatment capacity will be installed in the depot area. Wastewater will be discharged to the public sewage system. • Periodical maintenance of Wastewater treatment system will be conducted.

IMPACT	POTENTIAL IMPACT	PROPOSED MANAGEMENT MEASURE
	administration building will be generated from the depot.	
	Wastewater generated from the stations is mainly sewage from the toilet facility.	• Sewage will be sent to public sewage system • Periodical maintenance of sewage system at station will be conducted.
BIOLOGICAL ENVIRONMENT (FLORA & FAUNA)	No direct impact on protected areas	• Monitoring of bird species will be conducted.
	Loss of green areas (e.g. agricultural land)	• Maintenance of restored zone under restoration program
URBANISATION	Conversion of green areas and paddy fields for the development/ expansion of train stations	• Coordinate with relevant agencies regarding possible alternatives
UNUSUAL EVENTS	Impacts of unexpected events such as accidents and natural hazards • Failure of rail component and structure • Failure due to extreme heat, equipment failure and accident • Flooding	• Develop an Emergency Response Plan

CHAPTER 1 Introduction

1.1 Background of the Project

Introduction of the Light Rail Transit (LRT) system is a proposed project, to be implemented by the Ministry of Megapolis and Western Development (MMWD). The LRT Project (hereinafter also referred to as "the Project") is an elevated electrically operated railway system that connects strategic locations and transport hubs from Fort to Malabe (e.g. Borella, Battaramulla). The proposed Project uses an elevated platform made of concrete pillars and concrete/steel beams. The center pillars of LRT mostly follow the centerlines of the existing roads. Besides the LRT route and 16 train stations, a depot area will be built in Malabe West for the maintenance and storage of trains (rolling stocks). A conceptual image of the LRT is shown in Figure 1.1. The detailed Project description is provided in Chapter 2. The Proposed route of the LRT is given in Figure 2.2.

Figure 1.1 Conceptual Image of the LRT

1.1.1 Background of the Project

Since the establishment of the current government of Sri Lanka (GoSL) in January 2015, the Ministry of Megapolis and Western Development (hereinafter referred to as "MMWD") which is responsible for planning the urban development in Colombo Metropolitan Area[1] has set out the "Western Region Master Plan - 2030". A priority concern of this master plan is to solve traffic congestion in Colombo Metropolitan Area by introducing an alternative public transport system.

According to the Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs (CoMTrans), among seven major corridors towards the city center, Malabe Corridor is observed to have the highest density of private cars and the lowest travel speed at peak hours. Based on the results of ComTrans and the Megapolis Transport Master Plan, the Rapid Transit System (RTS) has been identified as an option to improve public transportation.

The Megapolis Transport Master Plan lays out an RTS network, composed of seven lines, that stretches out to Colombo's suburban areas (see Figure 1.2). This network was formulated based on several factors such as the country's economic development, population growth, and projected

transport conditions (e.g. traffic volume in major corridors, modal share, and connectivity with other public transport mode).

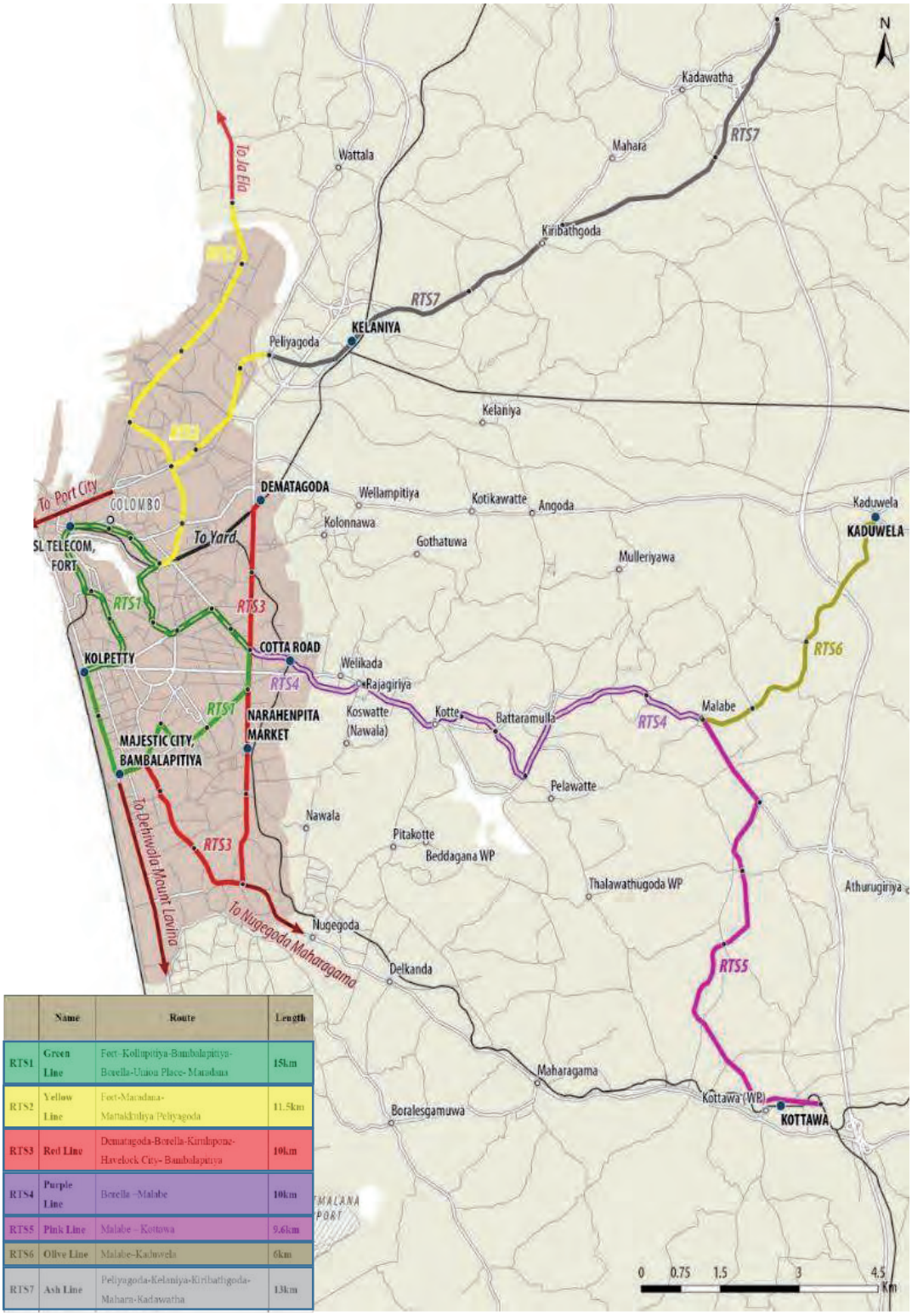
Within the RTS network, the GoSL made an official request for an ODA loan to the government of Japan to fund the section covering the Northern part of the circular line of RTS-1 and RTS-4, which run along Malabe Corridor. The proposed Colombo Light Rail Transit (LRT) system which constitutes part of RTS-1 and RTS-4, will be under the Special Term for Economic Partnership (STEP) between the two governments. This LRT is the subject matter of this EIA Report.

1.1.2 Current Status

The LRT project is in the Feasibility Stage. The Feasibility Study aims to conduct preparatory surveys for target routes in order to examine the necessity and feasibility of the Project for establishing the New Light Rail Transit System under the Western Region Megapolis Development. It also aims to prepare the necessary documents for the project appraisal as a candidate for Japanese ODA Loan.

1.1.3 Implementing Agency

The Project Management Unit established under the Ministry of Megapolis and Western Development (MMWD) is responsible for the implementation of the proposed LRT project. The organizational chart and operational mechanism is described in Chapter 2.



	Name	Route	Length
RTS1	Green Line	Fort-Kollupitiya-Bambalapitiya-Borella-Union Place-Maradana	15km
RTS2	Yellow Line	Fort-Maradana-Mattakkuliya-Peliyagoda	11.5km
RTS3	Red Line	Dematagoda-Borella-Kirulapone-Havelock City-Bambalapitiya	10km
RTS4	Purple Line	Borella –Malabe	10km
RTS5	Pink Line	Malabe – Kottawa	9.6km
RTS6	Olive Line	Malabe-Kaduwela	6km
RTS7	Ash Line	Peliyagoda-Kelaniya-Kiribathgoda-Mahara-Kadawatha	13km

Source: Transport Master Plan (MMWD)

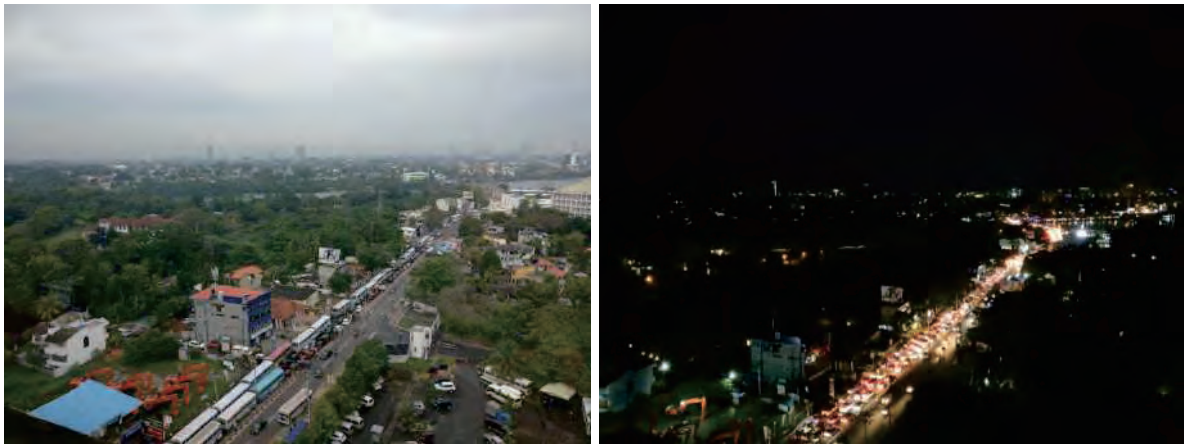
Figure 1.2 Proposed RTS Network

1.2 Objectives of the LRT Project (Project Justification)

1.2.1 Project Justification

In Sri Lanka, over 90% of people and cargo transport depends on road networks. Around 42% of GDP and 29% of the population are concentrated in the capital Colombo, especially in the Western provinces which has achieved solid economic growth since the end of civil war.

The number of traffic modes utilizing road networks such as automobiles, buses and motorcycles has been rapidly increasing. About 1 million people are entering into the center of Colombo every day, resulting in severe traffic congestion in Colombo and its surroundings. During morning and evening time, travel speed is observed less than 20 km/h, which is defined as traffic congestion. There are roads with less than 10 km/h travel speed which means that the current urban transport network may be reaching its limits. Malabe corridor is one of the most congested corridors in Colombo. Images of Malabe Corridor (facing towards Colombo) during peak hours in the morning and night time are shown in Figure 1.3 below.



a) Malabe Corridor (daytime) b) Malabe Corridor (night time)

Figure 1.3 Photos of Malabe Corridor during peak hours

Moreover, based on the results of CoMTrans, travel time between Fort Lake House Junction and Battaramulla Junction can reach up to 40-50 minutes during peak hours, when it would only take about 15 minutes to travel the same distance during off peak hours (refer to **4**). It means travel time increase by about 2-3 times. Such decline in traffic mobility will adversely affect the economic activity of the Colombo Metropolitan Area and it would create negative impact on the national economy.

The approach to develop roads cannot solve the traffic issue alone. Based on the current dense traffic condition at major roads in Colombo City, and from the efficiency of public transportation over private vehicles (in terms of transporting more people in a period of time), introduction of a new mode of public transportation system is urgently necessary. In particular, a railway based public transportation system is desired.

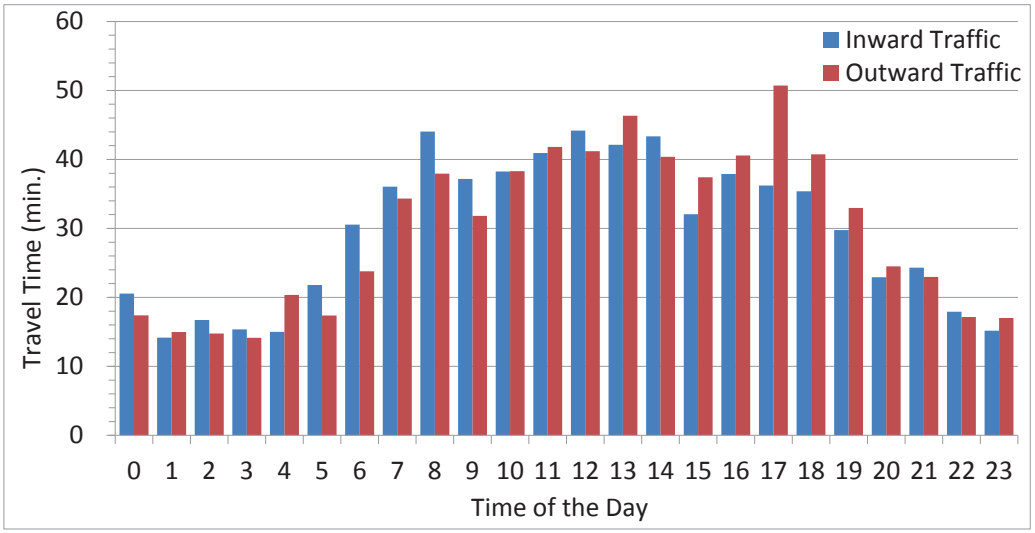


Figure 1.4 Travel time between Fort Lake House Junction to Battaramulla Junction

1.2.2 Objectives of the proposed Project

The main objective of the Project is to improve traffic conditions in Colombo metropolitan area by providing a comfortable, safe and reliable mode of public transportation. The proposed LRT route particularly targets to connect strategic locations and transportation hubs such as Fort, Town Hall/National Hospital, Borella, Sethsiripaya/Battaramulla, and Malabe (refer to Figure 1.5). Access to business centers, schools, hospitals and government offices (e.g. NIC, passport office) will be easier and transfer to other modes of transportation (e.g. provincial buses and railway) will also be convenient.

With the LRT project, travel time from Malabe to Fort will be cut to approximately 30 minutes. The reliability of travel time (not affected by road traffic) and ease of commute can enable commuters to travel comfortably. The proposed LRT system will serve the transport needs of people, particularly those who travel to and from Colombo via Malabe Corridor.

In addition, with the adoption of the LRT Project, traffic condition along the route will be reduced. Private vehicle users may be converted into using this alternative public transportation. This can lead to improved air quality and reduce economic losses due to traffic (e.g. gasoline consumption, maintenance of vehicles).

In a nutshell, the Project is aimed at:

- ≠ Easing traffic congestion in Colombo and its surrounding areas;
- ≠ Reducing travel time of passengers and commuters;
- ≠ Having improved connectivity of strategic locations and transport hubs;
- ≠ Increasing accessibility of places along the route;
- ≠ Providing a comfortable, reliable and safe alternative mode of public transportation; and
- ≠ Enhancing air quality by reducing greenhouse gas emissions from the transport sector

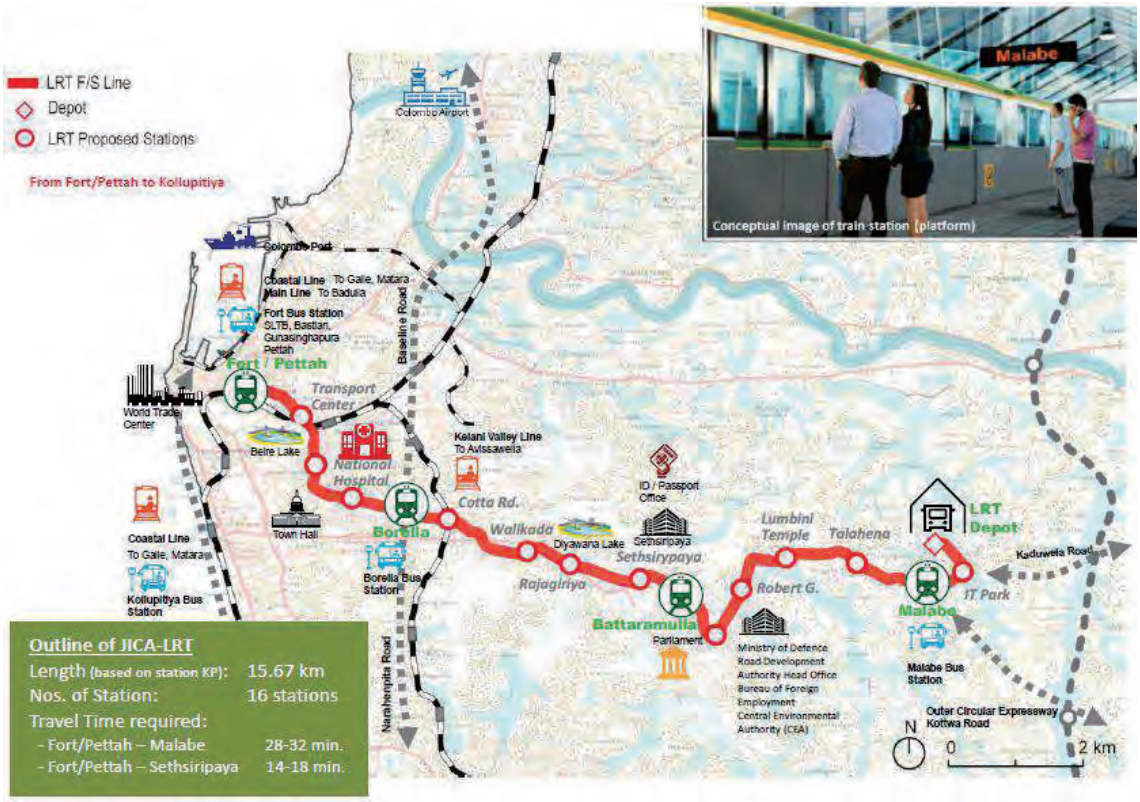


Figure 1.5 LRT Connectivity Map

1.3 Project Scope

The LRT Project will cover the 16 train stations, elevated structure, railway tracks, rolling stocks, depot, signaling and telecommunication system, and electrical and mechanical equipment. The Project will not cover the development of multi-modal transportation hubs/centers and parking facilities but these are considered in future planning.

1.4 Objectives of the EIA Report

The objectives of the EIA report are as follows:

- ≠ To study the existing environment of the proposed LRT corridor
- ≠ To ensure that alternatives to the proposed project have been studied and to determine whether the justification for the selection of the proposed project option is acceptable.
- ≠ To evaluate the potential adverse environmental impacts namely physical, physiochemical, social and ecological impacts of the project on the environment
- ≠ To propose suitable mitigation measures for the negative impacts. To assess the positive impacts of the proposed project.
- ≠ To meet requirements set by the CEA as stated in the Project's Terms of Reference.

The main objective of the EIA Report is to design a more environmentally and socially acceptable project with minimum social and environmental impacts. The EIA report and its recommendations will also enable the Project to comply with Sri Lankan National Environmental standards through the adoption of feasible and cost-effective mitigation measures. The EIA study

consists of the following activities:

- ≠ Carrying out baseline studies on noise, ambient air quality, surface and ground water quality as well as sociology along the project route.
- ≠ Have stakeholder and line agency consultations through official meetings, public meetings, focus group discussions, social interviews using structured questionnaires.
- ≠ Correctly identify the fully affected and partly affected stakeholder belongings such as residential houses, high rise buildings and public buildings.
- ≠ Assess the potential environmental and social impacts from the project and determine the major impacts which require mitigation, to ensure that the project causes minimum social and environmental impacts.
- ≠ Develop an environmental Management and Monitoring plan for the project, to ensure sustainable implementation of the project.

Scoping and Impact Assessment study according with JICA TOR was conducted separately and is attached in Annex M.

1.5 Methodologies and Technologies Employed for the EIA Study

The EIA was carried out on par with the ToR, covering the major Environmental components such as Physical, Physio-chemical, Biological, Social environs that are likely to get impacted during the project interventions.

1.5.1 Literature Survey, Data Collection

The relevant and available literature related to the EIA study was reviewed (refer to References) and pertinent data were collected through desk studies. The main source of data related to the feasibility aspects were extracted from the recent "Preparatory Study on The Project for Establishment of New Light Rail Transit System in Colombo", prepared by the Japan International Cooperation Agency (JICA) Study Team.

Reconnaissance visits and social surveys were conducted with the relevant key agencies to collect published and non-published data related to the project area. The data and the satellite images available for the maps were obtained from Survey Department and other relevant line agencies to develop necessary maps for the study area and its environmental settings. GIS data pertinent to Talangama Environmental Protection Zone was collected from CEA and that for Diyawanna Oya Sanctuary was collected from the Department of Wildlife Conservation.

1.5.2 Impact Assessment

In the analysis of impacts, the following impacts were studied:

- ≠ Impacts on hydrology (drainage network) due to bridge crossing across Diyawanna Lake and temporary land filling activities for the proposed depot was determined using flood models available at SLLRDC for Metro Colombo Environmental Improvement Project.
- ≠ Impacts on water quality (especially on the deport area) were determined using the measurements, and laboratory analysis.
- ≠ Impacts on ecology (flora and fauna) – Was studied through site knowledge based on the project activities and using information obtained from the site. Ecological information was also obtained from Colombo Wetland Development Project.

- ≠ Social impacts were assessed through site reconnaissance and social consultations through official meetings, public meetings, focus group discussions and through structured questionnaire surveys.
- ≠ Impacts on buildings and other social infrastructure were assessed in general by going through the construction methods, structure of nearby buildings etc. on the use of a services of a structural engineer.
- ≠ Impacts on the visual aspects of the landscape was studied by the use of the vertical profiles of the road against the existing landscape.

1.6 Conformity with Government policies and plans

Following applicable laws, regulations and policies will be complied by the proposed LRT project.

1.6.1 National Environmental Act (NEA) No 47 of 1980, and its' amendment Acts No. 56 of 1988 and Act No. 53 of 2000

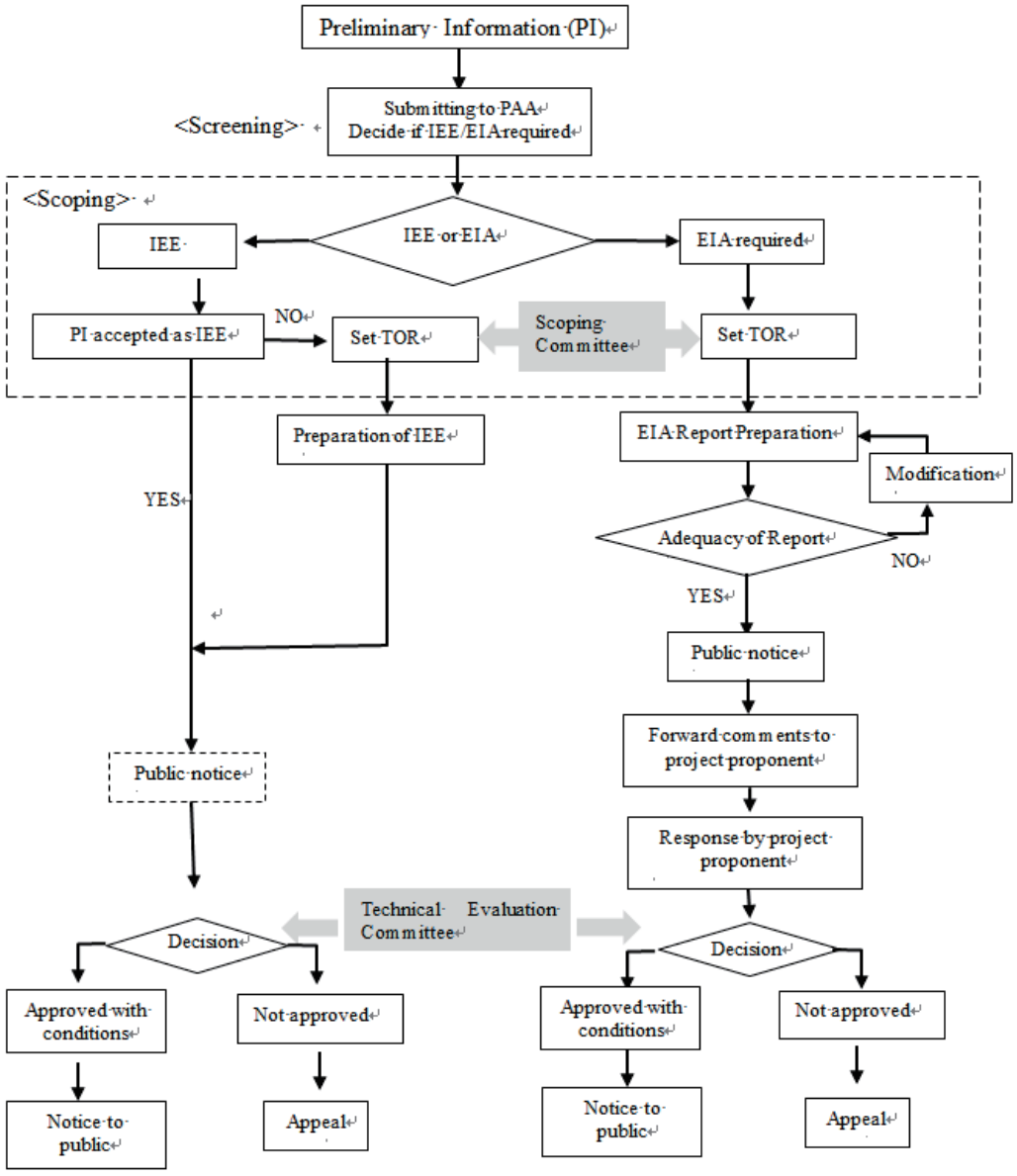
(1) Provisions

Under provisions of Part IV C of the NEA No. 47 of 1980 and subsequently stipulated in Gazette (Extra Ordinary) No. 772/22 dated June 24, 1993 the government of Sri Lanka (GoSL) made Environmental Assessment (EA) a legal requirement for a range of development projects. The list of projects requiring an EA in the form of Environmental Impact Assessment (EIA) or Initial Environmental Examination (IEE) is prescribed in the above Gazette notification.

In addition, the Gazette notification includes a list of line ministries and agencies that are designated as Project Approving Agencies (PAA). The PAA's are responsible for the administration of the EIA process under NEA. Prescribed projects requiring environmental assessments, listed in the same regulations relevant to the proposed project include;

- ≠ Construction of railway lines.
- ≠ Reclamation of land, wetland area exceeding 4 hectares;
- ≠ Mechanized mining and quarrying operations of aggregate, marble, limestone, silica, quartz, and decorative stone within 1 kilometre of any residential or commercial areas

There are 6 major steps in the IEE/EIA process; 1) Screening, 2) Scoping, 3) Preparation of the EIA/IEE, 4) Report review, 5) Approval with terms and conditions or rejection with reasons and 5) Post approval monitoring. The EIA process in Sri Lanka is shown in Figure **1.6**.



Source: CEA

Figure 1.6 EIA Process

(2) Applicability to the Project

The proposed LRT Project will require to undergo an Environmental Impact Assessment study as it falls under the category of projects which are listed in gazette no 772/ of (EIA Gazette).

There are also requirements for wastewater discharges, air emissions, noise and vibration which have been stipulated by the CEA under the provisions in the National Environmental Act. However, since this project does not fall under the category of industries, the noise level standards and air emission standards stipulated by the CEA under gazette notices (924/12 dated 23rd May 1996 and its amendment gazettes) will not be applicable to this project. Furthermore, the Light Rail Transit project does not result in any air emissions. However, there will be a certain amount of wastewater discharge from the depot and train stations. In addition to this there are Hazardous Waste Management Regulations under the NEA. These regulations will also have a bearing on this development project, as the project will be required to abide by the standards stipulated by the Central Environmental Authority for effluents discharged into inland surface water and Hazardous Waste Management Regulations as waste oil is considered as a hazardous waste.

1.6.2 Colombo District (Low Lying Areas) Reclamation and Development Board Act No. 15 of 1968

The Sri Lanka Land Reclamation and Development Corporation (SLLRDC) established under this act have power to declare low lying areas within the Colombo district as flood protection areas. The act was amended by Law No. 27 of 1976, Act No. 52 of 1982 and Act. No. 35 of 2006. - Since parts of the LRT route goes through low lying lands coming under the jurisdiction of SLLRDC their approval is required.

1.6.3 Crown lands Ordinance (Chapter 454)

This ordinance could be sited as "An ordinance to make provision for the grant and disposition of crown lands in Ceylon; for the management and control of such lands and the foreshore; for the regulation of the use of the water of lakes and public streams; and for other matters incidental to or connected with the matters aforesaid". This ordinance empowers the relevant minister to declare reservations for public streams and protect the source, course or bed of any public stream.

Since some parts of the land in the Light Rail route belongs to the Government, the provisions in this law will apply to this project.

1.6.4 Fauna and Flora Protection (Amend) Act (No. 49 of 1993)

The Fauna and Flora (Protection) Ordinance No. 2 of 1937, as amended by the Fauna and Flora (Amend) Act No. 49 of 1993 and Act No. 22 of 2009 provides regulations for the protection, conservation and preservation of the fauna and flora of Sri Lanka, for the prevention of the commercial exploitation of such fauna and flora; and to provide for matters connected therewith or incidental thereto". Offenses relating to amphibians and fish included in Schedules III and IV of the Act. Part IV (sects. 42 to 48) concerns the protection of flora. The provisions in this law will apply to this project, as the project may have impacts on both terrestrial fauna and flora.

1.6.5 Urban Development Authority Law No 41 of 1978

The Act grants authority to the Urban Development Authority to declare areas as Urban Development Areas. Upon obtaining permission from the Minister, UDA can sell, lease, and purchase land owned by the Authority.

Since the proposed development lies within an area which is under the jurisdiction of (CMC) the Urban Development Authority, the UDA will require to be represented in the Technical Evaluation Committee for the EIA.

1.6.6 Flood Protection Ordinance (Chapter 449)

Under this ordinance the relevant minister is empowered to declare any area in Sri Lanka to be a flood area. While such order remains in force, the area indicated shall form a flood area and be subjected to the provisions of this ordinance. According to the guidelines of this ordinance the Director of the Irrigation Department or any other person designated by the relevant minister shall prepare and carry out a scheme for the efficient protection of such area against floods.

1.6.7 Colombo District (Low Lying Areas) Reclamation and Development Board Act No. 15 of 1968

The Land Reclamation and Development Corporation (SLLRDC) established under this Act has the power to declare low lying areas within the Colombo district as flood protection areas. The Act was amended by Law No. 27 of 1976, Act No. 52 of 1982 and Act No. 35 of 2006.

1.6.8 Thalangama Environmental Protection Area: Government Notification under the National Environmental Act, No.47 of 1980, Order under Section 24C and Section D.

Thalangama Environmental Protection Area was designated as a protected area by the Central Environment Authority (Gazette Notification 2007 1st March、No.1,489/10). According to the Gazette Notification, permitted uses and activities within the area include the following:

- Cultivation of paddy field
- Fishing
- Nature trails
- Construction of towers for the bird watching
- Environmental educational information centre and a sales outlet
- Construction of a security post

Prior approval from the CEA is required when developing any infrastructure within the protected area.

1.6.9 Declaration of Sri Jayawardenepura Bird Sanctuary

The Sri Jayawardenepura Bird Sanctuary in Kotte was designated as a Sanctuary by the Department of Wildlife Conservation (No. 331/8 Wednesday January 9, 1985). Unlike National Parks, development in Sanctuaries may be allowed with the approval of the Department of Wildlife Conservation.

1.6.10 Municipal Council Ordinance No 29 of 1947

This ordinance will be applicable to the project within the Colombo Municipal Council Area limits. The said act is relevant to the drainage system, underground utilities such as the storm water system, sewerage system and buildings and roads coming within the jurisdiction of CMC.

1.6.11 Agrarian Development Act (No. 46 of 2000)

This act is applicable to the paddy field areas of the proposed Depot area and to the abandoned paddy field areas close to Talangama Environmental Protection Zone.

1.6.12 Road Development Authority Act (No. 73 of 1981)

This act is applicable as a major part of the proposed LRT system runs in the middle of A Class and B Class roads which comes under the jurisdiction of RDA.

1.6.13 National Thoroughfares Act No. 40 of 2008

This action is applicable to all roads of Sri Lanka and as LRT system runs on national roads and impacts even adjoining national roads outside the LRT route.

1.6.14 Sri Lanka Railways Authority Act (No. 60 of 1993)

The Act cited above is applicable to the proposed LRT system as it crosses railway lines at Maradana.

1.6.15 Antiquities Ordinance, No. 9 of 1940

This ordinance is applicable to the project as there could be roadside archeological monuments covered by this act.

1.7 Required Preliminary Approvals and Conditions Laid Down by State Agencies

1.7.1 Required Approvals

The approvals and consents required for the project are summarized in the Table below.

Table 1.1 Required Approval/Consent

Agency/Organization	Purpose
Road Development Authority (RDA)	To utilize existing roads and regarding the Right of Way
Urban Development Authority (UDA)	Approval to use their land
Sri Lanka Land Reclamation and Development Corporation (SLLRDC)	Approval for development of the site for the depot and construction of the Light Rail route through flood retention areas such as the deport area.
Department of Archeology	Clearance that archeological sites will not be affected
Local Authority	Concurrence approval (Relevant local authorities will be represented in the TEC (Technical Evaluation Committee for EIA approval)
Ceylon Electricity Board	Consent to relocate/ adjust electrical utilities (if any to give way to LRT structures)
National Water Supply and Drainage Board	Consent to relocate/ adjust underground water supply lines (if any to give way to LRT structures)
Sri Lanka Telecom	consent to relocate/ adjust underground and overhead telecommunication lines (if any to give way to LRT structures)
Wildlife Department	Clearance that the project is outside the boundaries of Sri Jayawardenepura Bird Sanctuary
Department of Agrarian Development (Kaduwela DS)	Approval for the use of Paddy Lands for depot area
Colombo Municipal Council	Consent to relocate/adjust existing sewer and storm water line (if any to give way to LRT structures)
Sri Jayawardenapura Kotte Municipal Council	Consent to relocate/adjust existing sewer and storm water line (if any to give way to LRT structures)
Kaduwela Municipal Council	Consent to relocate/adjust existing sewer and storm water line (if any to give way to LRT structures)

1.7.2 Conditions Laid Down by State Agencies

Conditions Laid Down by RDA

After LRT Construction To widen some of the road segments extra land acquisition will be needed. RDA has indicated their concerns as follows;

1. Widen the center median (present width 1.2m) of the road to match with the LRT column width.
2. Traffic management plan for the construction period to be addressed and RDA approval should be obtained
3. Number of lanes, and width of the traffic lane, width of the walkways and center median should be according to the drawing
4. RDA will undertake additional land acquisition required for road widening.
5. Funding for additional land acquisition should be provided by RDA

CHAPTER 2 Project Description

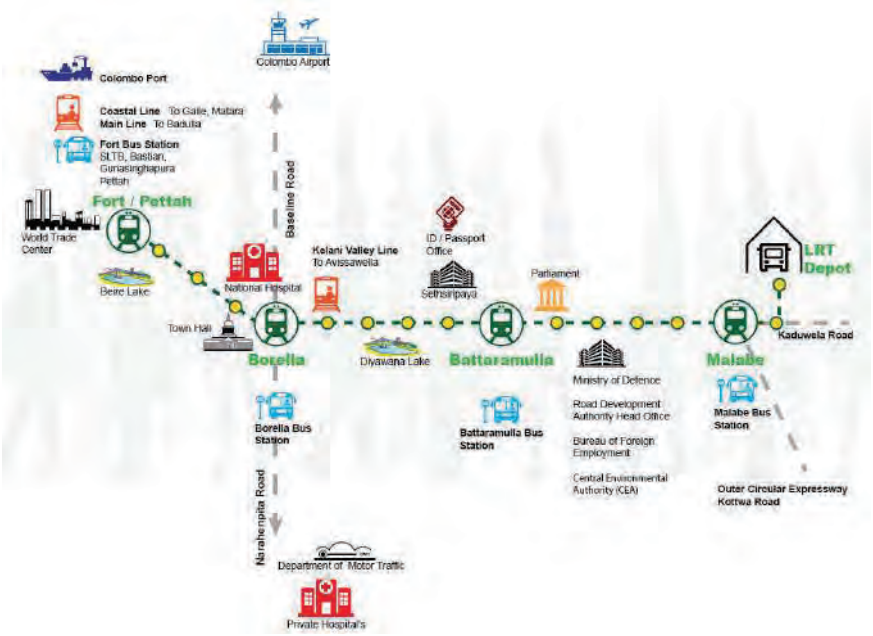
2.1 Description of the proposed project

2.1.1 Location of the Project

The LRT System will connect strategic locations and transport hubs from Malabe to Colombo. It will connect Malabe, Battaramulla, Borella and Fort/ Pettah. A simplified version of the route with key locations is shown in Figure 2.1. The proposed LRT is located within Colombo District. The location of the proposed LRT route is shown in Figure 2.2 below.

The LRT route starts from Fort station and enters the Railway Yard and Railway, T B Jayamawatha-D R Wijewardena Mawatha Junction (Gamini Hall) , T B Jayamawatha, takes a left turn at Ibbanwala Junction and enters Dr. Colvin R De Silva Mawatha, Lipton Circus, Ward Place , Borella Junction, Dr N M Perera Mawatha(Cotta Road) , takes a right turn and enters Sri Jayawardenapura Mawatha, crosses Diyawanna Lake (Diyatha Uyana) , takes a left turn at Polduwa Road , takes a right turn and enters the rear area of Sethsiripaya ,takes a left turn and enters Batteramulla Junction, Pannipitiya Road , Palan Thuna Junction, Denzil Kobbekaduwa Mawatha, Kaduwela Malabe Road , Low lying area on the Left side of Chandrika Kumaranathunga Mawatha and the depot site on the Left side of Madewela East Diversion Canal. The LRT includes 16 stations and 1 Depot.

Location map indicating the DS division and GN division are presented in **Figure 2.3** and **Figure 2.4**.



Source: JICA Study Team

Figure 2.1 LRT Connectivity Map

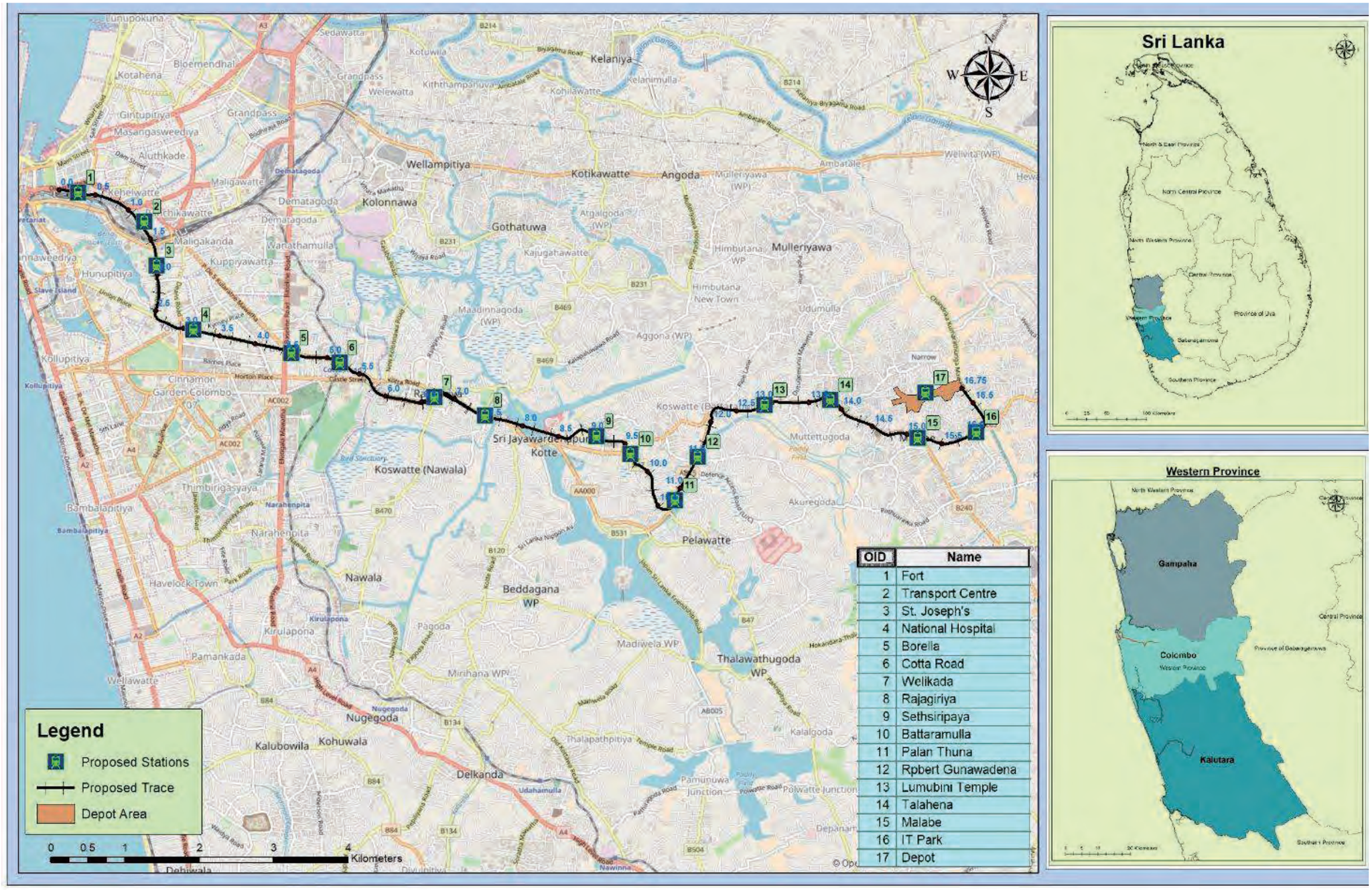


Figure 2.2 Location map of the LRT Project

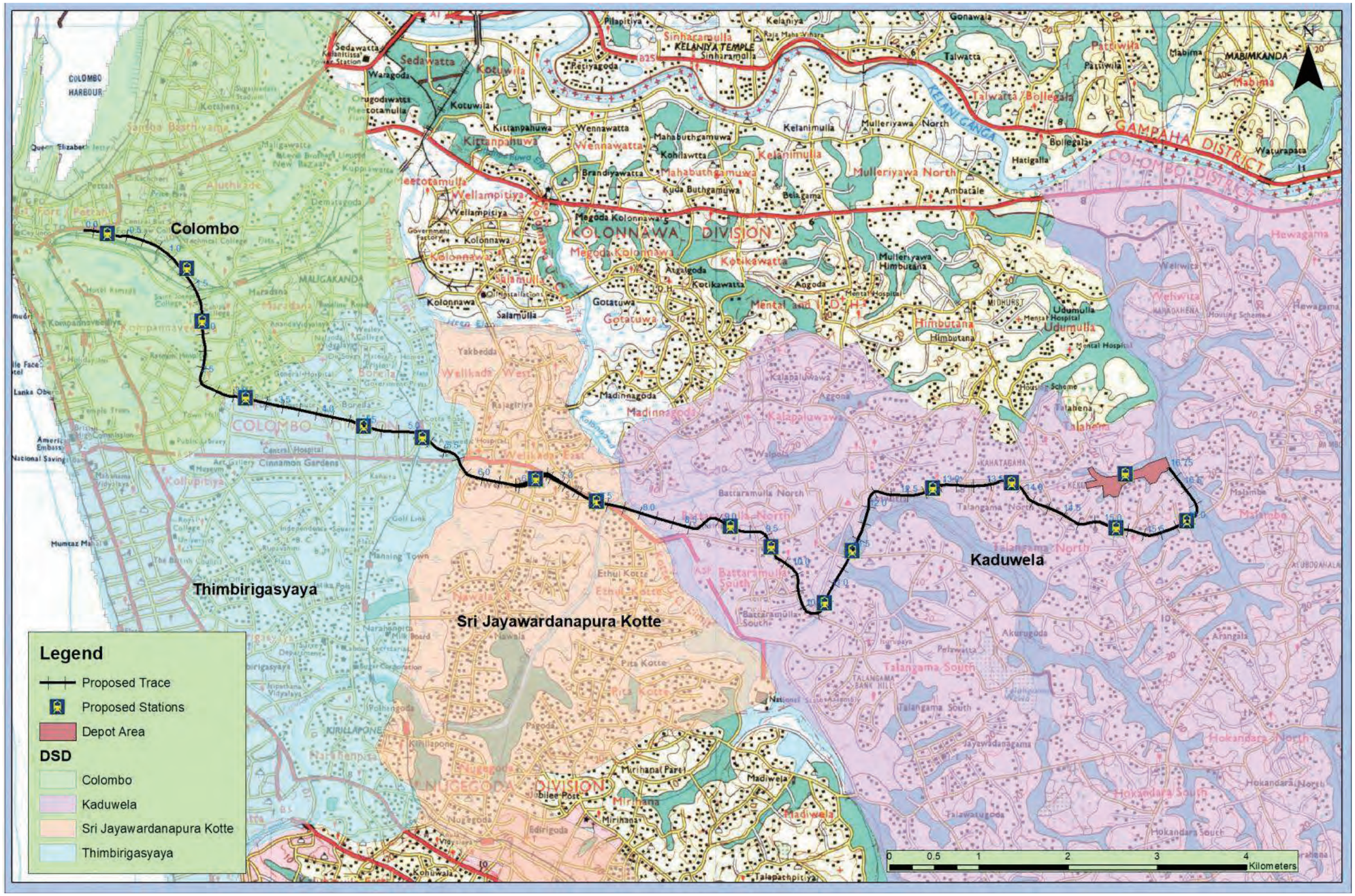


Figure 2.3 Affected DS Divisions

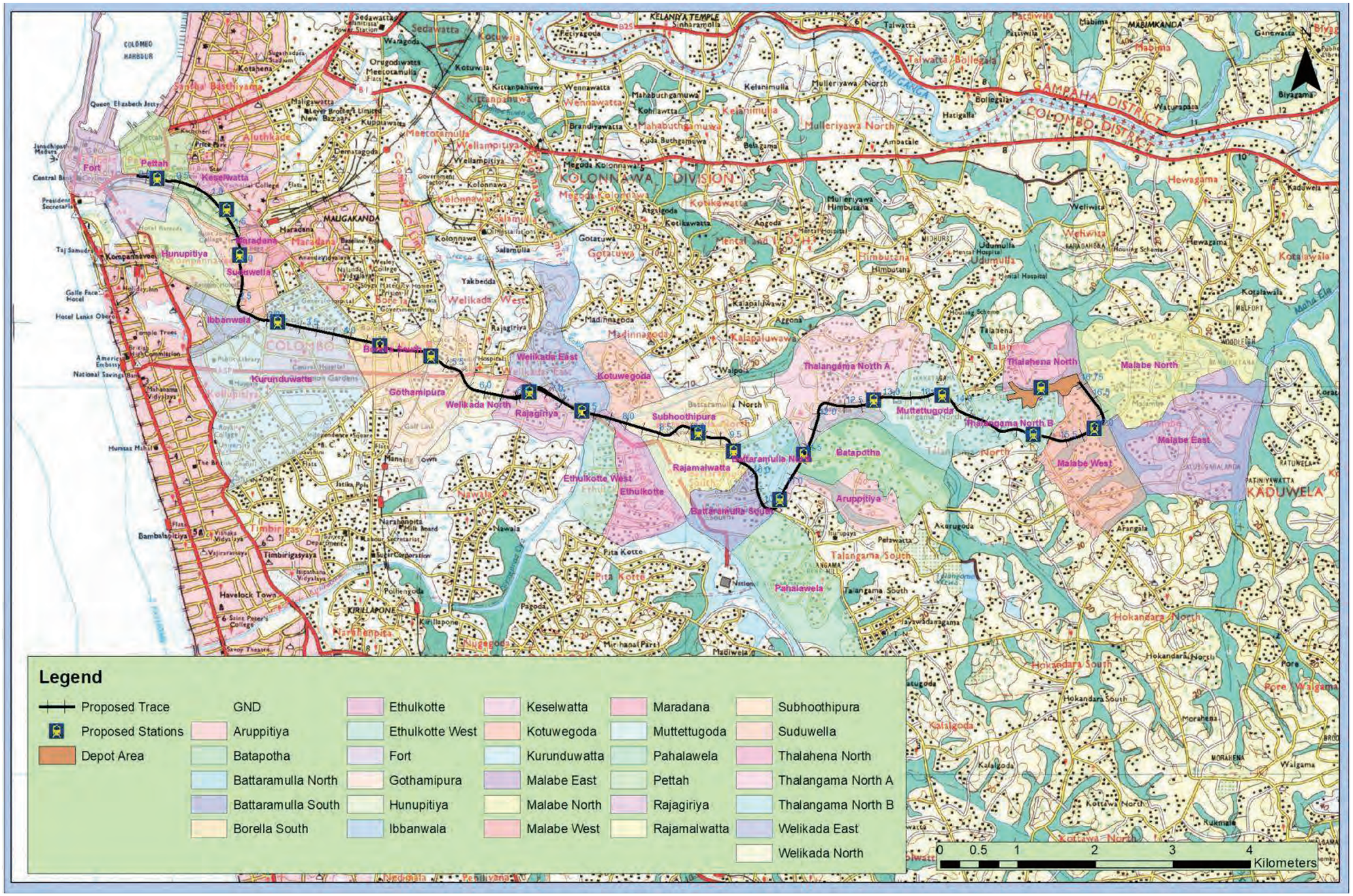


Figure 2.4 Affected Grama Niladhari Divisions

2.1.2 Ownership of the Project Site

The proposed LRT route is mainly located on national roads which belong to the Government of Sri Lanka. Most of these roads are A and B class Roads owned by RDA. Few segments of C Class roads also will be used (e.g. Polduwa Road at Diyatha Uyana) owned by the local authorities. There are other land strips which belong to Sri Lanka Railway (Railway Yard Pettah) and UDA (Diyawanna Lake and the rear are of Sethsiripaya).

The PMU is still in the process of obtaining the required consent from relevant agencies. Correspondence letters are attached in **Annex B**.

2.1.3 Project Components

The proposed LRT system is composed of the following: railway track, rolling stock, train stations, depot (parking and maintenance for rolling stock), signaling and telecommunications system, and electrical and mechanical facilities. Components of the project are described below in detail.

(1) **LRT Structure**

The LRT structure consists of three structural components – the girder (super structure that supports the railway track), the pier (sub-structure), and the foundation. An image of these components is shown in **Figure 2.5.**

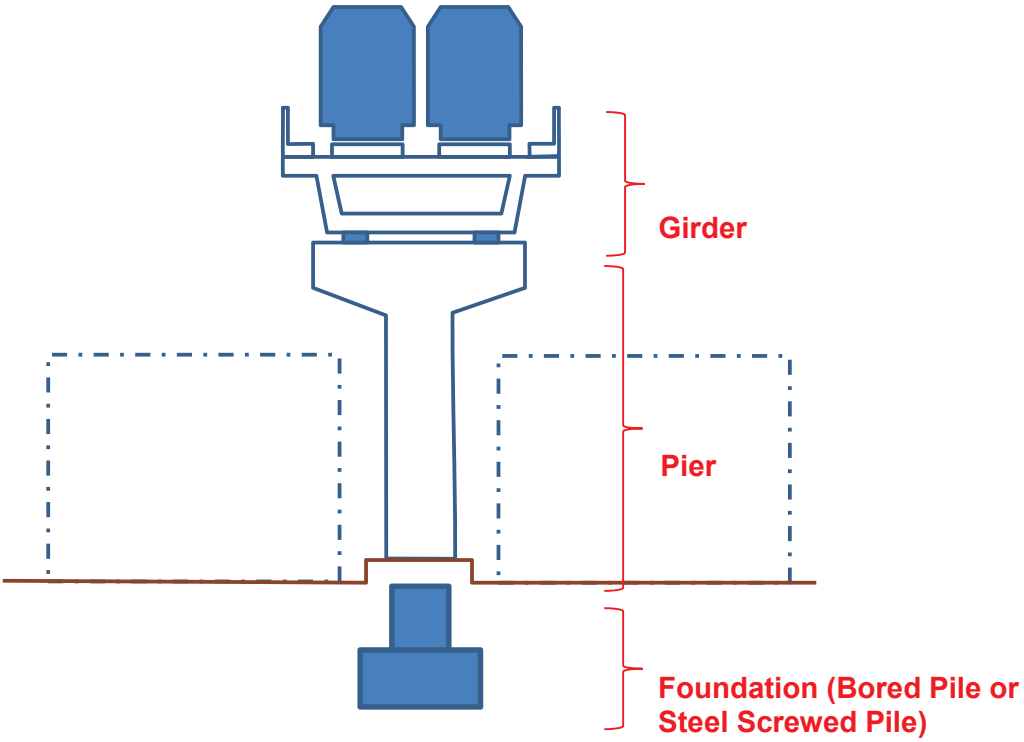
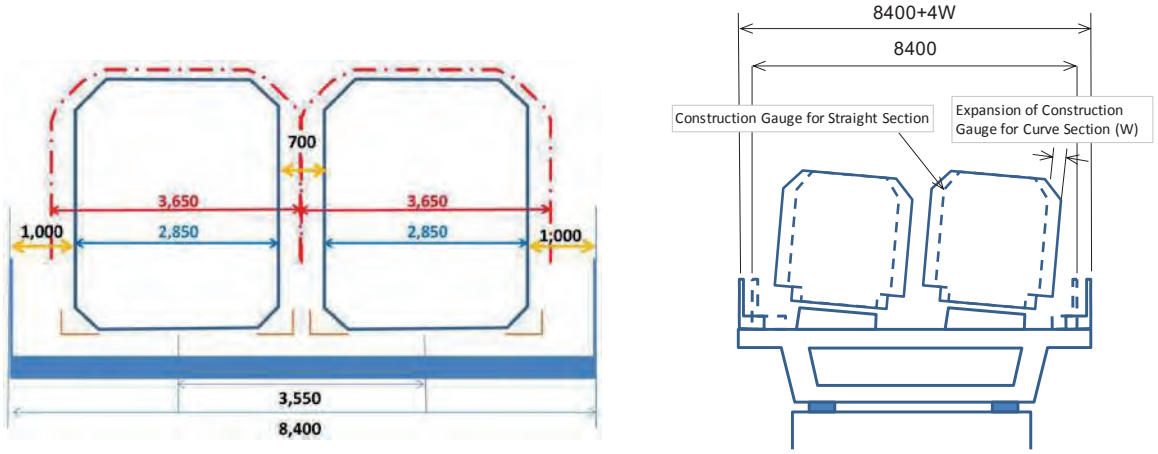


Figure 2.5 Components of the LRT Structure

The proposed 16km LRT structure will be built primarily on existing roads. The cross-section of the railway track on the girder is shown in **Figure 2.6**. It can be observed that the total width of the girder is approximately 8.4m (refer to **Figure 2.6**(a)). This width can accommodate two trains heading to opposite directions. The width of the rolling stock is approximately 2.85m and an inspection walkway at the outer sides of the rolling stocks has an allowance of approximately 1m.

It is important to note that the dimensions discussed above are for a straight section. In case of a curved section, more space is required for the railway track width. The required additional space is computed using the formula shown in **Figure 2.6** (b).



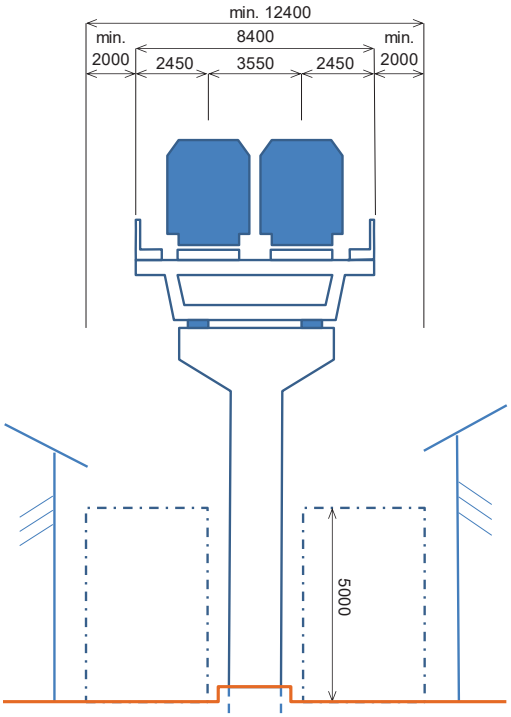
(a) Straight Section (b) Curved Section

Note: Dimensions in mm

Figure 2.6 Image of a Girder

The pillar of the elevated structure is approximately 1.5m x 1.5m. The average height is set at 10m with a minimum height of 5m, depending on the characteristics of certain locations (see **Figure 2.7**). An image of the railway track is also shown in the same Figure.

The Right of Way (ROW) of approximately 2m has been added at both sides of the railway track. This space is allocated as construction space for substructure and viaduct; and evacuation space in times of emergency (e.g. for access to buildings during fire). This width can be negotiable if the local conditions allows during detailed design stage.



(a) Cross-section of elevated railway track

Note: Dimensions in mm

(b) Conceptual image of elevated railway track

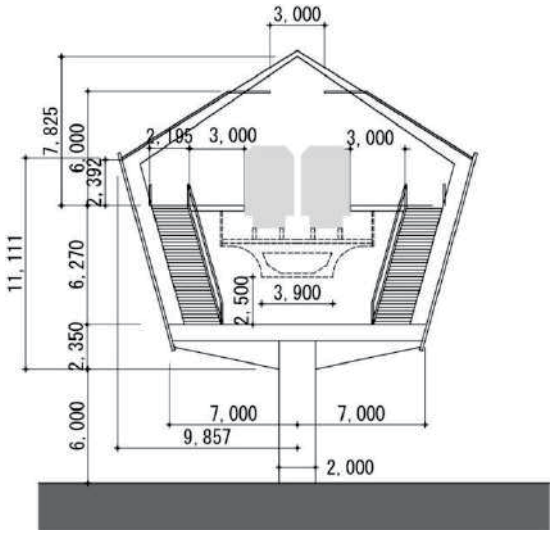
Figure 2.7 Image of a Pier

(2) Train Stations

The proposed LRT System is composed of 16 train stations from Fort to Malabe. The location of the stations is shown in Figure 2.2.

The cross-section image of the elevated train station is shown in **Figure 2.8**. The width of the platform is approximately 4m and the required width for the train station structure is approximately 14.65m. These dimensions include the space for ticket booth, ticket gates and stairs to the concourse. The minimum height of the station is also set at 5m.

The conceptual exterior and interior images of the proposed LRT train station are also shown in **Figure 2.8**.



(a) Cross-section of the train station

Note: Dimensions in mm

(b) Conceptual images of the train station

Figure 2.8 Image of a Train Station

(3) Rolling Stock

For the LRT system, 25 trains will be used. Each train is composed of 4 up to 6 cars (rolling stocks), depending on the time of operation. An image of the proposed train for the project is shown in **Figure 2.9**.

Figure 2.9 Image of LRT Rolling Stock

The selection of the right type of rolling stock depends on the following items:

- Maximum speed
- Gauge size
- Traction power supply
- Train formation
- Standard Passenger Capacity
- Capacity of a train
- Major dimension (length, width)
- Weight per train
- Body Materials
- Saloon design (door, seat type)
- Special facilities
- Traffic performance acceleration/deceleration)
- Propulsion system
- Brake control system
- Others (bogies, signal system, etc.)

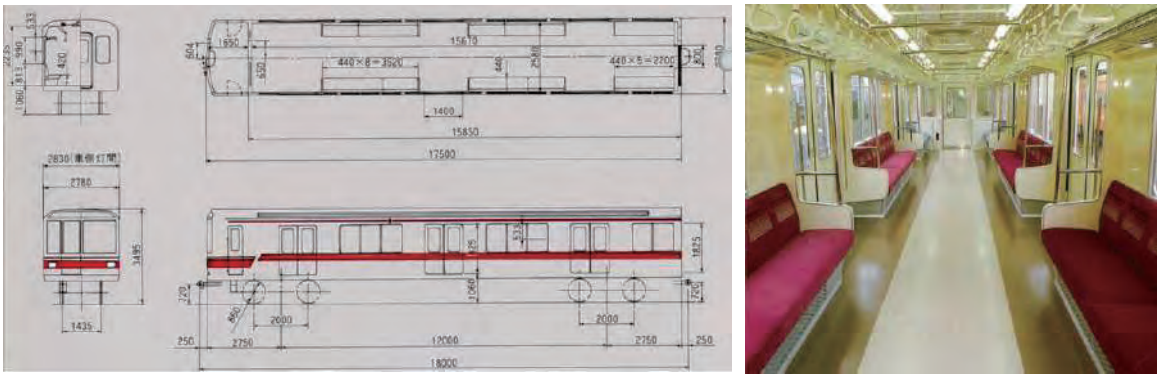
The proposed specifications for the LRT's rolling stocks are summarized in **Table 2.1**.

Table 2.1 Recommended specifications for the LRT

Technical Parameters	Specification		
Maximum Speed	80km/h		
Gauge	1,435mm (Standard gauge)		
Traction Power Supply	Third Rail System		
Train Formation *Tc: Trailer Car with driver's cab,* *M: Motor car*	2M2T (Tc+M+M+Tc)		
Passenger Capacity			
Standard Passenger Capacity	Seated	Standing (3.3 persons/m^2)	Total
Lead Car	42	86	128
Intermediate Car	52	84	136
Capacity of a Train (4 car-sets)	Per Car	Nos. of cars	Total
Lead Car	128	2	256
Intermediate Car	136	2	272
Total Passengers (3.3 persons/m^2) Including Seated passenger			528 (seated: 188)
Total Passengers in different AW (Added Weight due to standing passenger)			
AW-4: stand (4persons/m^2) + seat	600		
AW-6: stand (6persons/m^2) + seat	806		
Physical Characteristics			
Leading Car Length	18,000mm		
Intermediate Car Length	18,000mm		
Body Width	2,650~2,850mm		
Weight per Train (tare)	120t		
Body Materials	Light weight stainless steel or Aluminium		
Saloon Design			
Door Ways	3 doorways each side of car		
Door Type	Double slide doors 1,300 ~ 1,400mm width		
Seat type	Longitudinal seat type		
Special Facilities			
Wheel Chair Space	Equipped		
Baggage Space	Not Equipped		
Toilet	Not Equipped		
Traffic Performance			
Acceleration	3.2 km/h/s (0~30km/h)		
Deceleration	Service 4.0 km/h/s Emergency 5.0 km/h/s		
Propulsion System			
Power Collection System	DC 750 V, Collector shoe, (2set / 1 Bogie)		
Control System	VVVF inverter with IGBT, (1 unit/ M car)		
Brake Control System	All electric command electro-pneumatic brake		
Bogies	Bolster-less type (air suspension)		
Auxiliary Systems and Equipment			
Air Conditioning Equipment	Roof top type		
Auxiliary Power Supply Equipment	SIV: 3-phase inverter with IGBT		
Inter communication system	Communication system between front and rear cabin		
Passenger Information System	Public address system via loudspeaker Visual information system via LCD screens		
Security camera	Several security cameras are installed in each Rolling Stock.		
Signal System	ATP, CTC, Automatic Train Operation (ATO) CBTC or Track Circuit System		

Source: JICA Study Team

The exterior and interior images of the proposed rolling stock, which is currently in operation, are shown in **Figure 2.10**. Basically, it is equipped with a longitude type seat, handrails, interior security camera and digital signage.



Source: JICA Study Team

Figure 2.10 Proposed Rolling Stock (External & Internal Images)

In the case of bogies, simple and easy maintenance type is recommended as shown in below.

Source: JICA Study Team

Figure 2.11 Sample of Bolsterless Bogie with 3rd Rail Collector

(4) Depot

Depot is an indispensable facility to maintain the quality of train operation. Its main purpose is to serve as a parking lot for the rolling stocks and as a maintenance area to inspect, repair and prepare rolling stocks for operation. Its specific functions include:

- to park trains,
- to conduct inspections and preparations for the operation,
- to repair the failure on the train set, and,
- to overhaul rolling stock.

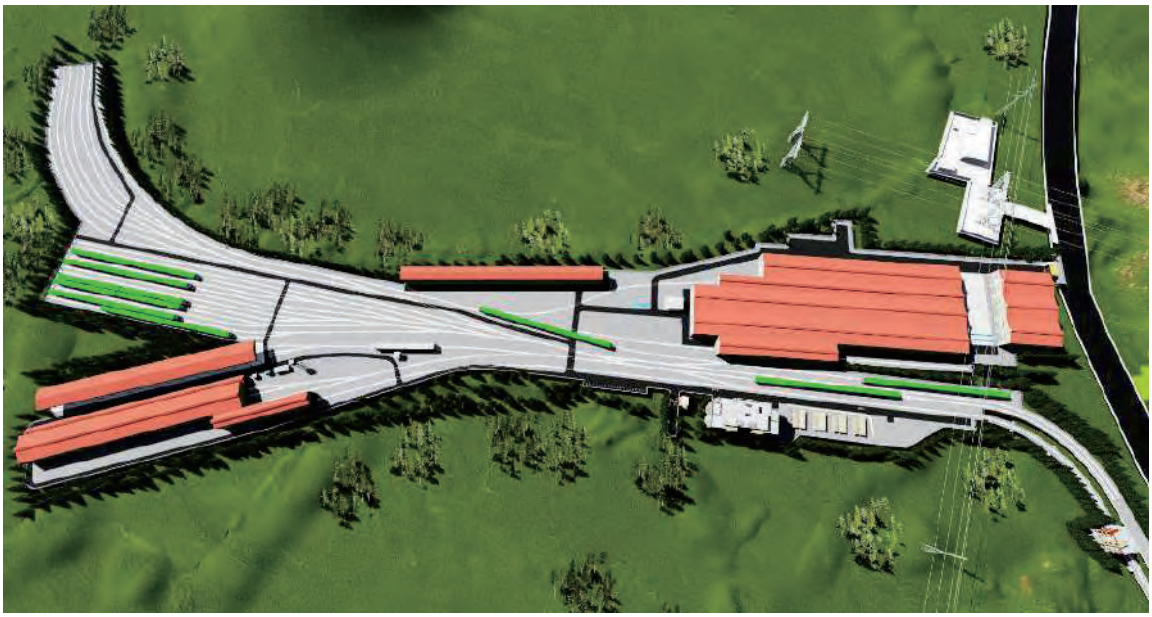
The proposed depot site is located in Malabe area. The site, approximately 15 ha of land, mainly consists of paddy land and abandoned land. Since the area is a water catchment area, the depot will be built on an elevated structure supported by pillars. Conceptual images of the planned depot

platform are shown in Figure 2.12. A photo of an existing elevated depot area is also shown below.

The distance between pillars will be 4-5 meters and the height of the pillar would depend on the topography of the area. However, the height of the bottom of the platform will be 1-2m from the level of an extreme flood event that happens once in 100 years (based on simulation).

The proposed location and layout for the depot area are shown in Figure 2.13. It consists of parking spaces for trains (stabling tracks), sheds for heavy and light maintenance, wastewater treatment system, power station, and administrative building.

A detailed description of the maintenance activities in the depot area is presented in Methodology of Operation (Chapter 2.1.8).



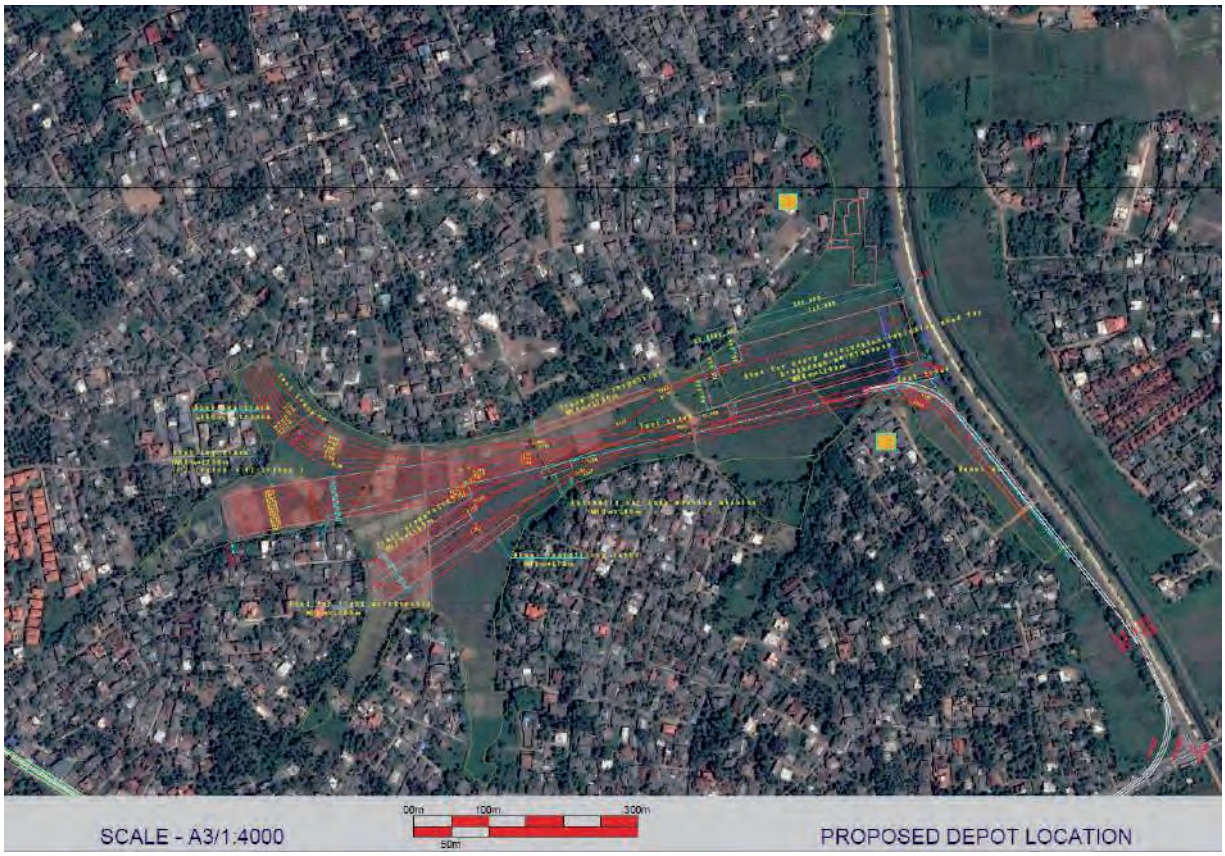
(a) Top View of Depot Area

C

(b) Side View of Depot Area

Figure 2.12 Conceptual Images of the Depot Area

Image of an elevated railway depot area (Source: Bhavesh Swami[1])



Source: JICA Study Team

Figure 2.13 Proposed Layout for the Depot Area

(5) Signaling and Telecommunications

The Signaling and Telecommunications are both important in order to control and operate the trains. S&T ensure safety and performance of running trains. It is also necessary for the provision of satisfactory service to passengers and response to special/unanticipated events. The life cycle of S & T equipment ranges from 15 years up to 20 years.

S&T consist of four systems, namely:

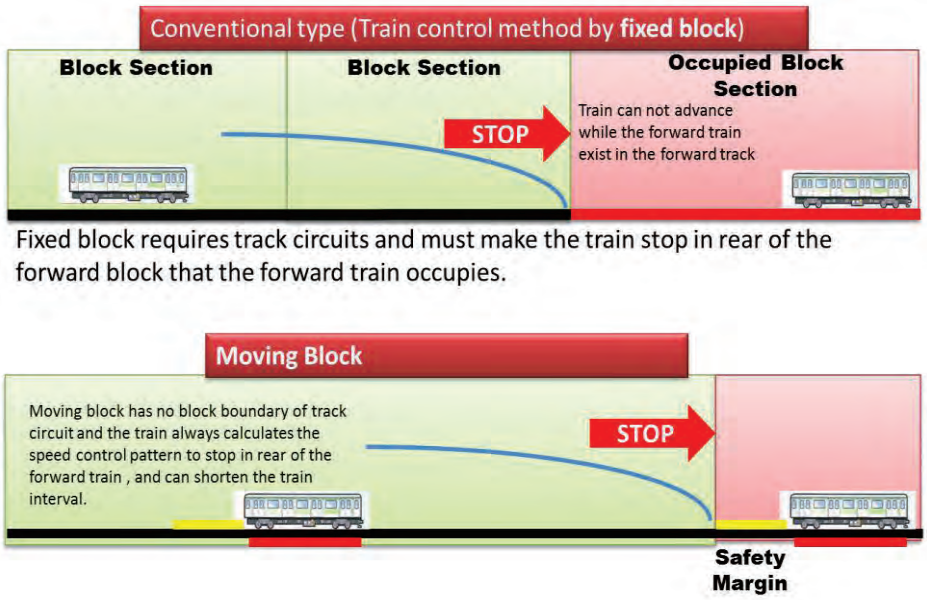
- ATP (Automatic Train Protection)
- ATO (Automatic Train Operation)
- ATS (Automatic Train Supervision)
- CIS (Centralized Interlocking System) to park trains,

For the planning on Telecommunications, the selecting the types of transmission means as well as collecting & monitoring the types of events and information will be described in the following sections.

1) ATP (Automatic Train Protection)

The automatic train protection system prevents train collisions by controlling mutual train interval and it limits the speed on the basis of route and temporary work conditions.

In order to accomplish automatic train protection system, there exist two types of methods based on different train detection system for its location, "Fixed Block System with Track circuits" and "Moving Block with CBTC (Communications-Based Train Control)". The description of these two types is shown in **Figure 2.14**.



Source: JICA Study Team

Figure 2.14 Image of ATP

2) ATO (Automatic Train Operation)

For the LRT, a semi-automatic train operation (Grade of Automation 2) will may be employed. According to the International Association of Public Transport (UITP), this grade of automation is characterized by automatic starting and stopping of trains, but a driver operates the doors, drives the train if needed and handles emergencies.

3) ATS (Automatic Train Supervision)

Train operation control system has the basic function of ensuring smooth operation of train groups, including train diagram control, operation record management, operation control and monitoring, route control, guidance display control, and information broadcasting for all trains on the main track and on the entry and exit sections to car depots.

4) CIS (Computerized Interlocking System)

The computerized interlocking system (CIS) and/or the RRI (Route Relay Interlocking System) will be installed on the main track at each of station and in the car depot to secure the safety of the route setting.

5) Telecommunications

Telecommunication system is used to ensure a smooth and efficient execution of the train operation and maintenance work. This system also functions as a medium of communication to the passengers, drivers and dispatchers in case of recovery of train operation after abnormality, special events and emergencies. Its compositions and functions are shown in **Table 2.2**.

Table 2.2 Telecommunications Equipment

Classification	Component
Train radio equipment	Train radio, maintenance radio, emergency warning, Train information (Delay, train information in other lines, Transfer)
Cable equipment	Dispatcher telephone, exchange telephone
Closed Circuit Television (CCTV)	Video monitoring
Optical transmission equipment, etc.	Optical fibre transmission, power supply
Passenger information display equipment, station announcement equipment	Train Operation guidance display (Train Delay Platform No. Departure time), guidance announcement (Train approach, Door closing, Abnormal event information)

Source: JICA Study Team

≠ Communication means between OCC and moving trains

The train radio equipment establishes communications between the dispatching centers, trains on the main track, and vehicles inside the car depot. This enhances train operational safety and facilitates the performance of duties. The emergency alarm equipment has emergency warning and emergency train stop functions which can be used as emergency measures.

≠ Optical transmission equipment

The optical transmission equipment will be required to install among OCC and stations independently, securing a high degree of transmission quality and transmission speed.

The optical transmission equipment is a transmission circuit used to ensure efficient and high-quality information on the communication between the central dispatching centre and field organizations and on the remote monitoring and control from the centre for a period of train operation and maintenance, even when there is a possibility of interference caused by lightning or electrical magnetic noise.

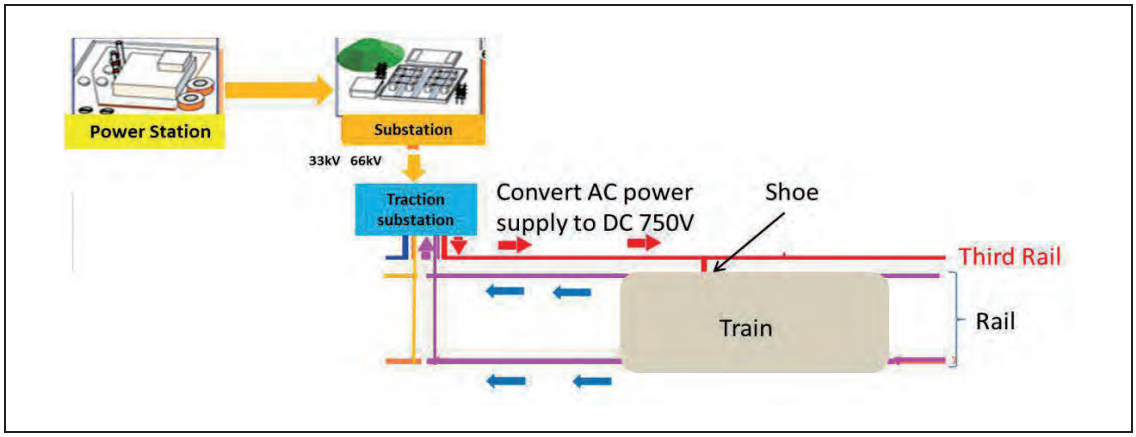
≠ CCTV (Closed Circuit Television) equipment

The CCTV equipment has CCTV cameras in the platforms and concourse of each station, which enables monitoring passengers getting on/off trains at the train cabin.

(6) Electrical and Mechanical

1) Electricity / Power Supply

Electricity will power the LRT System. A third-rail power supply system will be employed for the LRT. **Figure 2.15** shows the image of electricity flow for power supply to LRT train. The AC power is distributed from the power station to Receiving Substation (RSS) for LRT system via CEB's grid lines, and then RSS sends AC to Traction Substation (TSS) which converts to DC from AC. TSS supplies DC 750V on the third rail to motor in LRT vehicle for traction.



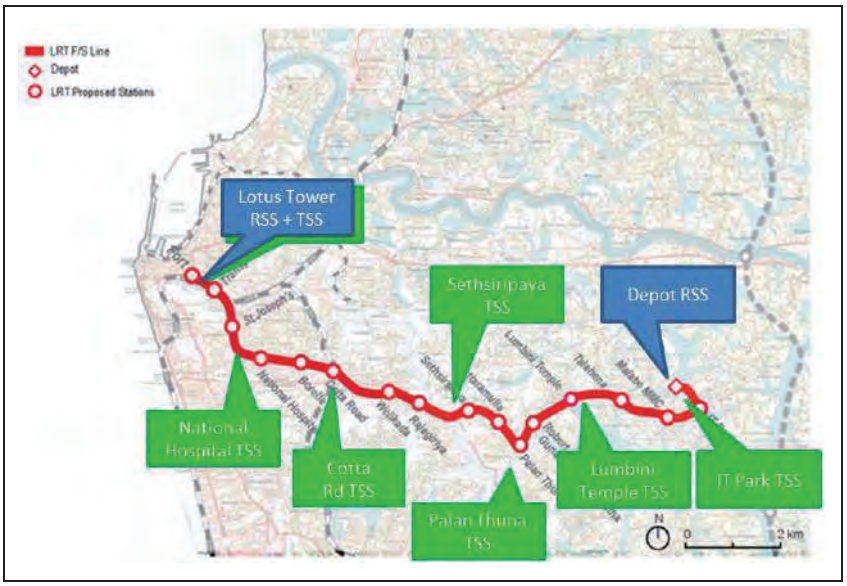
Source: JICA Study Team

Figure 2.15 Image of Electricity Flow for LRT System

Location of RSS and TSS

The candidates of location for RSS, where the 132 kV power can be received, are shown in **Figure 2.16**. Ceylon Electricity Board (CEB) confirmed enough existing capacity and lines.

On the other hand, TSS should be installed at every 2 to 3km when the feeding voltage is DC 750V. Seven TSS are planned to be installed. **Figure 2.16** shows the candidate locations for TSS, which satisfies land area requirements and space for intervals.



Source: JICA Study Team

Figure 2.16 Proposed Location of RSS and TSS

Other Electric Provision Facilities

Service Substation (SSS) provides electricity to electrical equipment in station. Therefore, it should be installed inside of station or nearest place in case of there is not enough space inside station.

Traction Electric Room is a room that supplies electricity to track lines in Depot and has only the main switch for each line is arranged. The equipment is installed at the "Depot RSS". The main switches for each line are listed as Entry Track, Outgoing Track, Maintenance, Heavy Repair, Test Track, Stabling Tracks and Other Tracks.

OCC Electric Room provides electricity for the operation control centre, which is installed at the ground floor of the OCC building at where OCC and Power SCADA are prepared. It equips two 33kV feeder lines transmitted from RSS and an emergency generator.

Electric Capacity for RSS/TSS/SSS

The required capacity for electricity based on the preliminary operation plan is presented in **Table 2.3**. Note that the figures will change when the train operation and alignment are changed.

Table 2.3 Required Capacity for Substation

No.	RSS Name	TSS Name	Required Capacity				
			Rectifier (kW)	Converting Rectifier Capacity to AC (kVA)	SSS (kVA)	TSS (kVA)	RSS (kVA)
1-1	Lotus Tower	Lotus Tower	3,516	3,710	770	4,480	16,830
1-2		National Hospital	2,104	2,240	630	2,870	
1-3		Cotta Road	3,752	3,960	630	4,590	
2-1	Depot	Sethsiripaya	3,851	4,080	910	4,990	16,250
2-2		Palan Thuna	2,673	2,820	--	2,820	
2-3		Lumbini Temple	2,813	2,980	639	3,610	
2-4		Depot	2.982	2,980	980	4,130	
2-5		OCC	--	--	700	700	

Source: JICA StSource: Source: Study Team
Note: In this table, the apparent power (kVA) uses a scalar sum as it is (In the event of the power factor exceeding 0.9, no large error occurs between the vector sum and scalar sum.). The rectifier adopts 12 pulse rectifier, since any standards in harmonic waves in Sri Lanka were not found, 12 pulse is selected according to Japanese standards that specify not to produce problems (Since the occurrence of harmonics is a physical phenomenon, there is no difference in occurrence by country.).

Countermeasures for Unexpected Events

For example, in case of shutdown of the Lotus Tower RSS, electricity cannot be transmitted to 2 TSS such as Fort and National Hospital. This will cause the train to stop. Even if a train stops between stations due to a power failure, it is not recommended that the operator let passengers walk on the elevated track. The LRT structure is fully elevated and has a third rail along the rail. When passengers walk on the deck, the third rail may be pressed and this may generate electric shock which can cause serious injury/ accident.

In order to prevent this situation and ensure uninterrupted operation even with the shutdown of one RSS, all RSS will require 40MVA capacity. If CEB cannot supply 40MVA for each RSS, train operation becomes limited (reduced number of services), when one RSS shuts down.

Regenerative Power Absorbing Device

With installation of the platform screen door (PSD), train should stop at fixed point. With this, a regenerative power absorbing device is required for fixed stopping. A battery system will be employed and these devices will be installed at the Fort TSS and the Lumbini TSS. It is important to note that detailed specifications will be determined during the detailed design stage.

Power SCADA

Power SCADA is a software responsible for monitoring and control of substations and electrical rooms, and placed in OCC. A terminal of Power SCADA is installed in each substation and electric room, and it monitors and I/O (input and output) for controlling. This terminal device is

named as Remote Terminal Unit (RTU). Power SCADA and RTU are connected by double looped optical cable.

Third Rail

The third rail supplies power to trains along the track as shown in **Figure 2.17**. It is supported by insulator and touch with shoe of train.

Source: JICA Study Team

Figure 2.17 Image of Third Rail

2) Mechanical System

Mechanical equipment, which will be installed in the station facilities, will be decided during detailed design. Components of the mechanical system to be considered are listed in **Table 2.4**.

Table 2.4 Components of the Mechanical System

Item.	Facilities
1) Air conditioning equipment	• Air conditioning equipment, (including attached piping construction) • Exhaust fans • Duct (including outlet, inlet, intake, exhaust)
2) Water supply and drainage facilities	• Water tank and accessories • Feed water pump • Sanitation equipment • Piping
3) Fire protection equipment	• Fire alarm equipment • Fire water tank • Fire protection water pump • Fire hydrant related • Fire-fighting piping • Inert gas injection facility • Portable fire extinguisher
4) Electrical equipment	• Power supply equipment (equivalent to electric SSS) • Power distribution equipment • Uninterruptible power system • Interior lamp and outlet • Ground fault facility • Building related automatic equipment
5) Elevator Escalator	• Elevator • Escalator
6) Platform screen door (PSD)	• Half height PSD • Controllers • Power Supply System with UPS
7) AFC (Auto Fare Collection)	• Ticket Vending Machine • Passenger Gate • Fare Adjustment Machine • Money Management Facilities • Station Server • Contactless IC Card • Card Initializing System

Source: JICA Study Team

2.1.4 Layout plans

As discussed in Chapter 2.1.3, 12.4m of ROW will be secured for LRT route. As LRT will mostly traverse on existing road, there will be limited reservation required. Some reservation is required at areas around train stations, the low-lying area adjacent to Chandrika Kumaranatunge Mawatha, and the area for the proposed Depot. Detailed layout plans for LRT system are being prepared carrying

out fine adjustments to minimize building damage and land acquisition. Layout of LRT system and Depot is given in Chapter 2.1.3.

2.1.5 Future Expansion

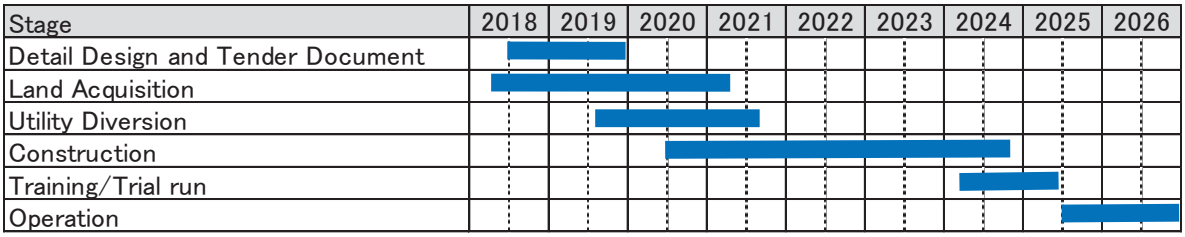
As discussed in Chapter 1.1.1, The Megapolis Transport Master Plan lays out an RTS network, composed of seven lines, that stretches out to Colombo's suburban areas. This LRT project will be part of the network (Part of RTS-1 and RTS-4) and extend to formulate LRT network according to the master plan.

A multimodal transportation hub (MmTH) is planned to be developed at Fort station. Therefore, LRT system will be integrated with MmTH in future.

2.1.6 Pre-Construction and Construction Activities

(1) Phased Implementation Schedule

The tentative implementation schedule for the Project is shown in the figure below. It is aimed to start the construction by middle of 2020 and to start the operation by 2025.



Source: JICA Study Team

Figure 2.18 Project Timeline

(2) Pre-construction activities

Planning and design of the LRT system is the main pre-construction activity. The EIA study which was done in parallel with the said feasibility studies is also a major pre-construction activity. Other pre-construction activities will be site surveys, geotechnical investigations, studying the underground or overhead utility plans carrying out the Resettlement Action Plan (RAP) through social consultations, preparation of detailed cost estimates and the contract document and the contract award.

Prior to the commencement of construction of the LRT structures, relocation of utilities interfering in the LRT structure construction such as high voltage lines and pylons, under- and above ground electric power lines and telephone cables, underground water and sewer pipes, etc. is necessary. In addition, some of the trees and branches affecting the LRT structure construction need to be felled, and existing structures within the Right of Way are required to be demolished or shifted. These pre-construction works will take approximately two years.

(3) Construction Activities

The construction activities of the LRT system include the following: trench excavation, mid pier construction, utility removal and relocation, temporary earth filling in low lying areas (in the depot area of the paddy fields near Chandrika Kumaranathunga Mawatha), installation of steel platforms in Diyawanna Oya Lake for the construction of piers, piling, standard concrete work, pier

construction, pre-casting and launching of girders, underwater concrete work, sheet piling for shoring, use of heavy machinery, disposal of construction waste, installation of rails and the rolling stock along with other LRT furniture such as signaling equipment etc.

2.1.7 Construction Methods

The construction of this LRT 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 Colombo Metropolitan Area.

There are different types of construction methodologies depending on the area and the type of structure which will be built. This section discusses construction methodologies for the following:

- Construction of elevated structure (viaduct) on existing roads
- Construction of elevated structure (viaduct) on surface water
- Construction of elevated train station
- Construction of depot civil structures

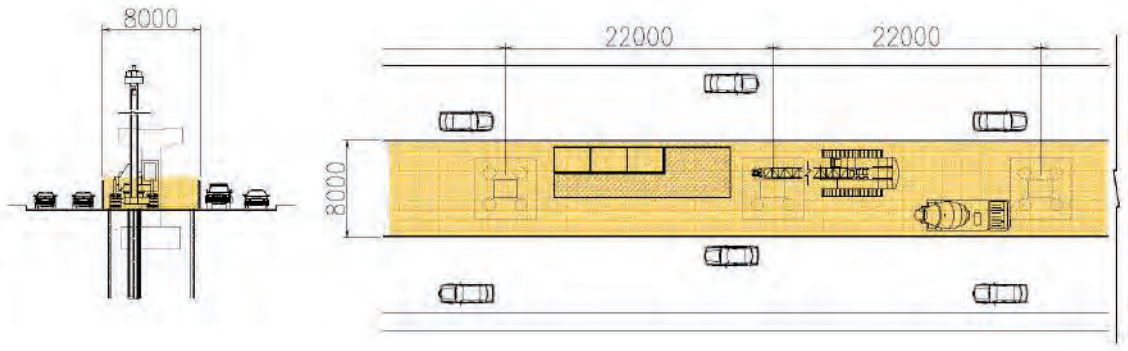
(1) Construction of Elevated Structure (Viaduct) on Existing Roads

Construction methodologies of the three parts of the elevated structure (foundation, pier and girder) are described below.

(1) Foundation

The viaduct foundations consist of conventional bored cast in-situ RC (reinforced concrete) 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.

To secure sufficient space for the construction of the pier pile caps and to accommodate the construction equipment, a minimum width of 10m will typically be required as a working space on the center of the affected roads. A typical section of the construction work space arrangement is given in Figure 2.19



Source: JICA Study Team

Figure 2.19 Typical Section of the Construction Work Space Arrangement

For reducing the width of the working space on the center of the roads, screwed steel piles may be introduced, which can narrower the width of the working space down to 8m and make construction period shorter.

(2) Construction of Pier / Sub-structure

Conventional reinforced concrete pier columns will be used for the viaduct substructures of the LRT viaduct. It is considered that the columns would be constructed using standardized steel forms to promote a good quality of finish and reduce construction cycle times. For shortening the construction period, steel pier columns can be an alternative. Typical construction sequences and daily schedules are shown in the **Table 2.5** below. Images of construction of pier are shown in **Figure 2.20**

Table 2.5 Typical Construction Sequence and Daily Schedule for Substructure

No.	Work	Reinforced Concrete Structure		Steel Structure	
		Contents	Days	Contents	Days
1	Preparation	Securing working space, mobilization	10	Securing working space, mobilization	5
2	Piling	Cast in-situ RC piles construction (3 days for 1 pile)	12	Screwed steel piles (1 day for 1 pile)	4
3	Excavation	Sheet piling, excavation, leveling concrete	7	Sheet piling, excavation, leveling concrete	3
4	Pile Head Treatment	Chipping	1	Re-bar welding	1
5	Footing	Re-bar arrangement, formwork, concrete casting	7	Re-bar arrangement, formwork, concrete casting	7
6	Pier	Scaffolding, falsework, re-bar arrangement, formwork, concrete casting, curing, formwork dismantling (20 days for pier, 10 days for pier head)	30	Scaffolding, installation, shop welding, painting	10
Total (working days)			67		30

Source: JICA Study Team

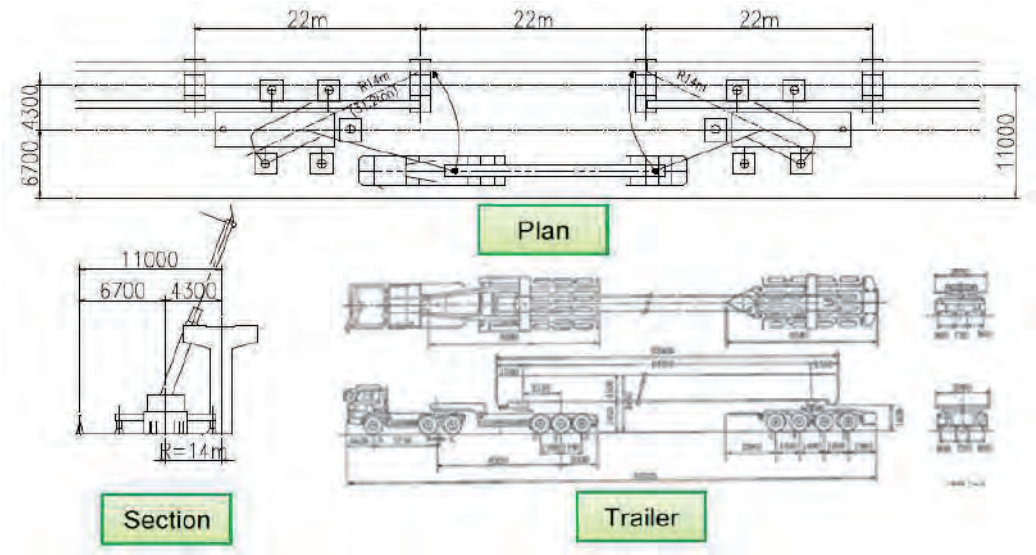
Source: JICA Study Team

Figure 2.20 Pier Construction (Manila)

(3) Construction of Girder / Superstructure

A pre-cast concrete method will be applied to the manufacturing of prestressed concrete (PC) girders. **Figure 2.21** shows an example of a pre-cast plant of the PC girders. Candidate area locations of the manufacturing yards along or close to the LRT planned route are under consideration and will be confirmed in a later stage. PC girders will be transported by a trailer from the manufacturing yard to each construction site.

The PC girders will be erected at once using a crane where construction space can be secured. Meanwhile, an erection girder will be used in city areas where a construction yard can hardly be kept, and in erecting PC box girders. **Figure 2.21** shows a schematic drawing for the PC girder erection using cranes.



Source: JICA Study Team

Figure 2.21 Track Crane Girder Erection Method

For sections where construction has to be completed in a short period or a girder is erected for a long span, steel material may be selected.

When installing girders at stretches with sharp bends, segmental pre-casting and launching may be required

(4) Construction of Viaducts (Bridge) on the Surface Water (Diyawanna Lake)

Structure types of the viaducts to be constructed on the surface water are basically the same as those to be constructed on the ground. However, construction methods are different. Installation of a temporary jetty (stage) parallel to the LRT alignment and an access to the jetty is required. Steel members are to be used for the jetty and width of the stage will be 10 to 12m. In addition, cofferdams to be built using steel sheet piles are necessary for the piling work and substructure construction. The cofferdam is to make a dry area inside and enable construction works.

Source: Internet Sites

Figure 2.22 Sample Photos of Temporary Jetty and Cofferdam

Superstructure works also utilizes the jetty. Girders and/or segments will be transported on to the stage and erected using cranes or an erection girder. After completion of the viaducts construction, the temporary jetty will be totally dismantled and removed.

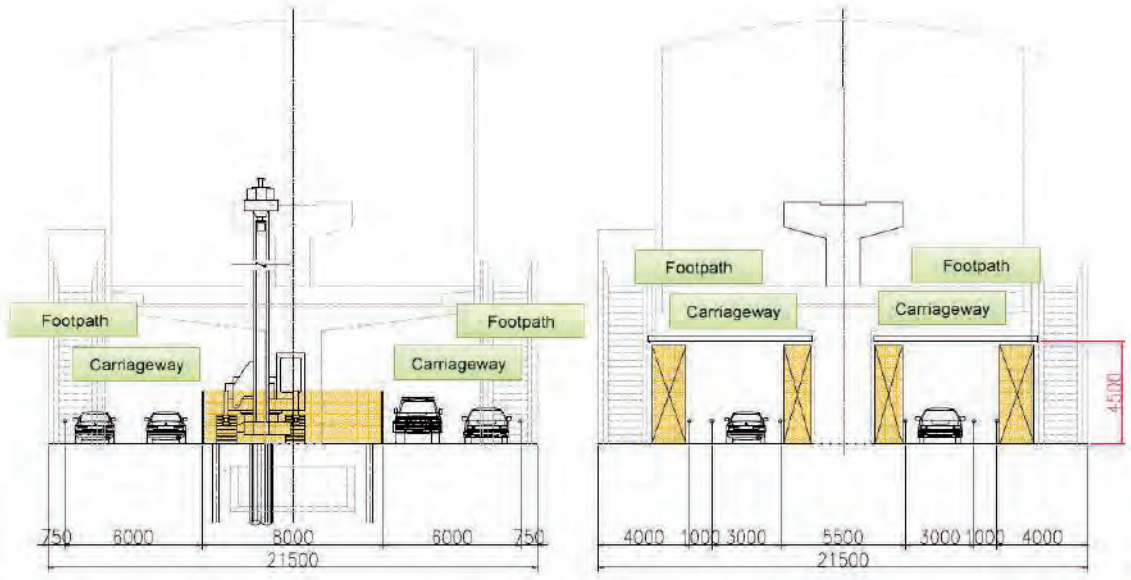
During the detailed design stage, an option to construct the superstructure section over the lake with balanced double cantilever design may be considered.

The period of the LRT viaducts construction works in the Diyawanna Lake will be approximately one year.

(5) **Construction of Elevated Station**

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 the stage of the cantilever pier heads construction, 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 at least two lanes in each direction along the road during the construction of the cantilever piers. 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.

Typical work space layout during station pier and cantilever pier head construction and concourse level supporting beams and floor placing is shown in **Figure 2.23**.



Source: JICA Study Team

Figure 2.23 Typical Work Space Layout for Station Pier Construction

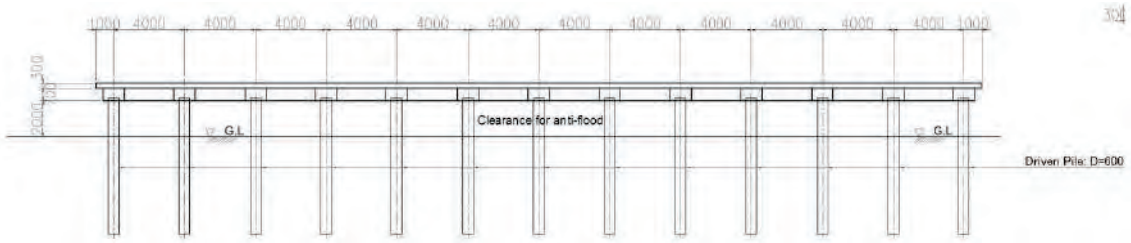
The projected construction period for the elevated station substructures and frames (civil and architectural) excluding pier construction and girder installation is around eight months and that for electro-mechanical installations (E&M) is approximately another ten months, which is eighteen months in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

(6) **Construction of Depot Civil Structures**

The depot, which is planned to be located north of Malabe Station, will be constructed on elevated RC platform since the planned area has seasonal flooding. The elevated platform consists of pre-tensioned spun high strength concrete (PHC) pile foundations and RC slabs to create space over the existing ground for the flooding. Outline of the elevated platform is as follows:

- Pre-tensioned spun high strength concrete (PHC) piles of approximately 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 4m and 4.5m center to center;
- Reinforced concrete slab of 300mm thick with beams on the piles; and
- One unit of the elevated platform is 50m by 20m.

The planned elevated depot platform is shown in **Figure 2.24**.



Source: JICA Study Team

Figure 2.24 Planned Elevated Depot Platform

(7) **Method of lowland filling and fill level**

Temporary land filling will be required for the depot area and for the low-lying areas. See Figure for these areas and approximate extents for filling. Since construction stage is short term, fill levels for these places were determined using the 10-year flood levels, which is 4.8m MSL with a 3m wide peripheral canal. These flood levels were obtained from SLLRDC flood models formulated for Metro Colombo Environmental Improvement Project.

2.1.8 Resources for Construction

(1) **Construction Material (Raw Material) Requirements**

Construction materials to be used for the LRT project and the approximate quantities required are listed below.

- Cement: 45,000ton (900,000 50kg bags)
- Sand: 95,000ton (36,000m^3)
- Reinforcing bar: 13,000ton
- Steel: 19,000ton (2,500m^3)
- Rail: 92,000m

These materials will be sourced from the approved sources. River sand will be used for concrete construction. Metal will be obtained from licensed quarries. Cement and steel reinforcement and railings will be imported.

(2) **Requirement and Availability of Workforce during Construction**

Construction works will be awarded to major recognized construction contractors who will recruit necessary labor force from inside and outside of the country based on the stages of the project. It is not intended to construct temporary labor camps in construction sites. However, temporary construction yards will be designated. It is estimated that a maximum of 2,500 workers per day will be involved in construction activities at peak stage.

(3) **Area Required for Landfill**

Since the LRT mainly goes on built up area, no landfill will be required except for the Depot area and the segment from the start of Chandrika Kumaratunga Mawatha to the Depot. However, even for these areas, there will be no large-scale land fill activity, but minimum temporary access construction is expected, since the LRT and the Depot is constructed with piles and piers as described in the previous section.

2.1.9 Operation and Maintenance

(1) **Operation of the LRT**

Operation of the LRT involves the following tasks:

- Driving train
- Controlling train operation by Operation Control Centre (OCC)
- Providing service for passengers at stations (including selling tickets, giving information and supporting disabled passengers, security concerns activities, kiosk)
- Providing service for passengers in trains

- Taking appropriate measures when emergencies or abnormalities event.

During operation, it is estimated that 222 trains will run per day and 18 trains will run during peak hours. The travel time between Fort and Malabe will be approximately 30mins.

(2) Maintenance of the LRT

Maintenance of the LRT system involves the following tasks:

- Checking daily condition of rolling stock
- Inspection for rolling stock and facilities including track, power supply system, signaling and communication system and Automatic Fare Collection (AFC) system
- Overhauling rolling stock
- Repairing rolling stock and facilities.

1) Maintenance of Rolling Stock

Maintenance for rolling stock can be divided into 3 types – preventive maintenance, breakdown maintenance, and train preparation. An outline of these maintenance systems are outlined in **Table 2.6**.

Table 2.6 Maintenance System for Rolling Stock

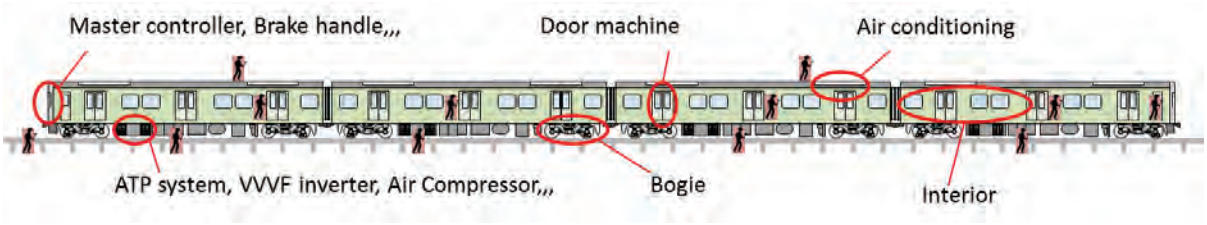
Category			Maintenance Main items	Period
Preventive Maintenance	Departure Inspection		Check Conditions and Functions to operate the train service.	Before Departure from Depot
	Light Maintenance	Daily Inspection	Check Consumables, Check Conditions and Functions, Check facilities for passengers.	Within 10days
		Monthly Inspection	Daily Inspection Items, Inspect Conditions and Functions.	Within 3 months
	Heavy Maintenance	Semi Overhaul	Monthly Inspection Items, Overhaul Significant Equipment.	Within 4 years or 600,000 km
		Overhaul	Semi-Overhaul Items Overhaul All Equipment	Within 8 years
	Wheel Re-profiling		Re-profile the wheel set.	(Depends on Route alignment & Operation plan)
Breakdown Maintenance			Check the conditions and Functions, Repair the failure on a train.	(The failure on a train occurs)
Train Preparation	Daily Cleaning		Pick up waste on a train, Clean interior of a train if dirty.	After operation
	Car-Body Cleaning		Wash car body by the machine.	Every 3 or 4 days
	General Cleaning		Clean interior, Wash car body.	Within 30 days

Source: JICA Study Team

Preventive Maintenance

≠ Light Maintenance

The main purpose of Light Maintenance is to check or inspect the condition and the function of a rolling stock in operating condition (**Figure 2.25**).

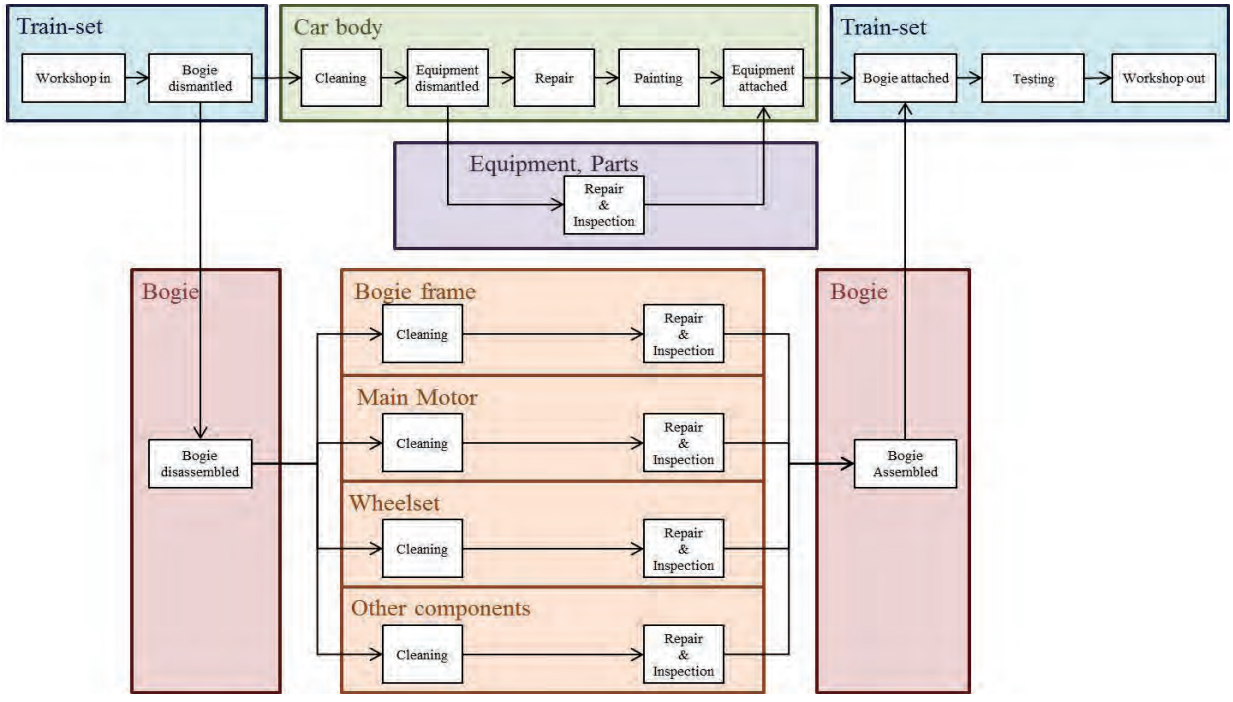


Source: JICA Study Team

Figure 2.25 Example image of Light Maintenance

≠ Heavy Maintenance

The main purpose of Heavy Maintenance is to overhaul the equipment. The work flow of Heavy Maintenance is shown in **Figure 2.26**.

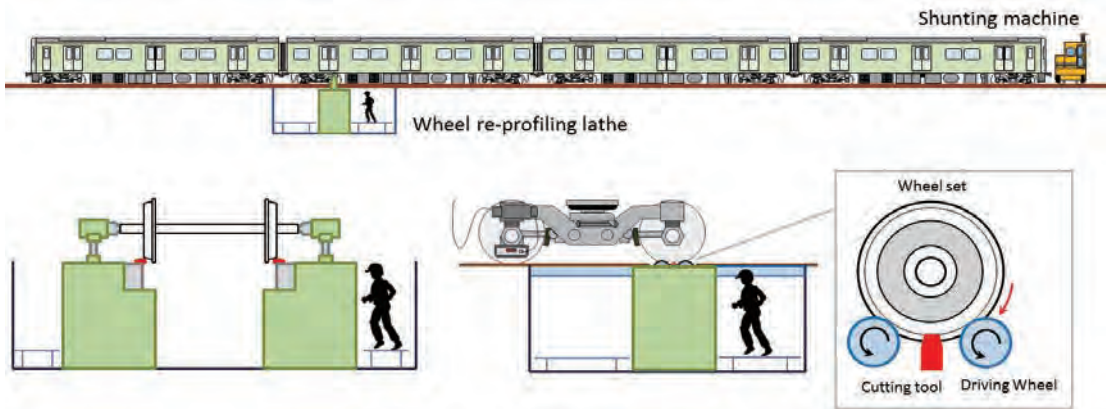


Source: JICA Study Team

Figure 2.26 Work flow of Heavy Maintenance

≠ Wheel re-profiling

The main purpose of Wheel re-profiling is to enhance shape of the wheel with a wheel re-profiling machine, to maintain riding comfort (**Figure 2.27**). The wheel re-profiling is conducted irregularly, depending on the condition of wheel tread.

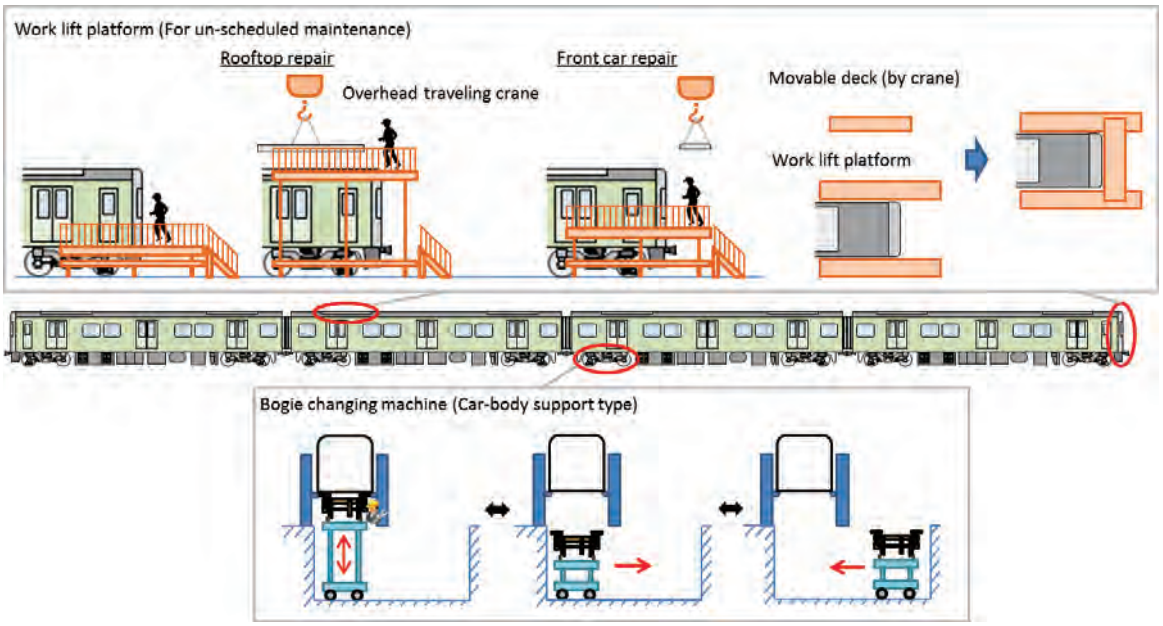


Source: JICA Study Team

Figure 2.27 Example image of Wheel re-profiling

Breakdown Maintenance

The main purpose of Breakdown Maintenance is to repair the failure on a train. The train has various kinds of equipment on the roof, under floor, in the car (**Figure 2.28**). In case of this study, it is assumed that exchanging of bogie is often conducted because the shape of wheel tread will be deformed due to route alignment (many curves).

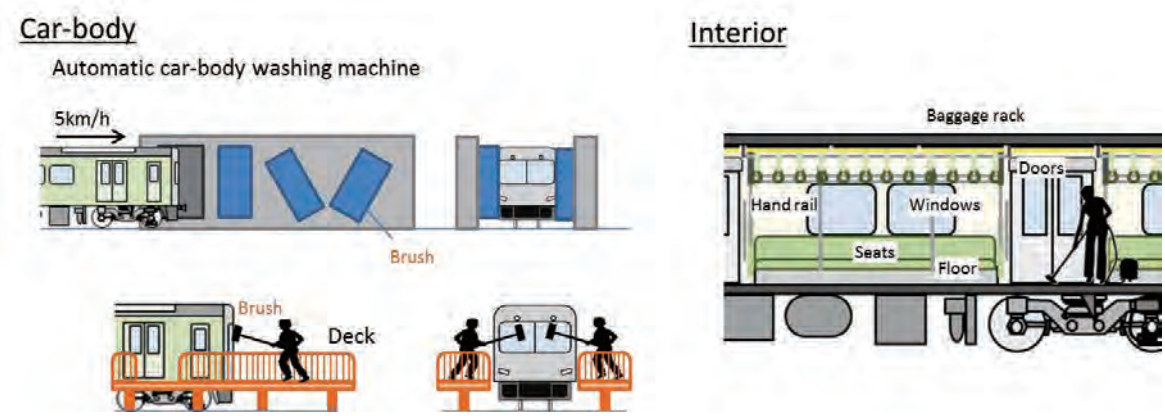


Source: JICA Study Team

Figure 2.28 Example image of Breakdown Maintenance

Train Preparation

The main purpose of train preparation is to wash and clean a train in order for passengers to feel comfortable when using the train. Train Preparation involves 3 activities – cleaning after operation every day; washing train cars every 3 or 4 days; and washing car bodies and cleaning all facilities such as lighting, seats, floor, windows etc. (see **Figure 2.29**).



Source: JICA Study Team

Figure 2.29 Example image of Train Preparation

(3) **Institutional arrangements**

In order to implement the project, there will be a Regulator and an Operator. The Regulator empowered with authority (a Commissioner) will be appointed by the Government through an Act of Parliament (e.g. "Sri Lanka Light Rail Transit System Act", which is in draft level). The Act will also stipulate the establishment of a government-owned O&M company which will be composed of a working group from different ministries.

The proposed organizational structure for the O&M Company is shown in **Figure 2.30**. Environmental and occupational health concerns (including related complaints and grievances) are handled by the Health, Safety, and Environment (HSE) Division. However, compliance and monitoring are under the responsibility of other relevant divisions.

Source: JICA Study Team

Figure 2.30 Proposed organizational structure for O&M Institution

2.1.10 Energy Requirement

The type of energy to be used for the operation is electrical energy which will be supplied by CEB. The details have been discussed in Section 2.1.3 (Electrical and Power Supply).

2.1.11 Wastewater Sources

(1) During Construction

Wetting activities and rainwater can generate wastewater at construction sites. Sewage will also be generated from portable toilets that will be installed for workers at construction sites. There will be no labor camps that will be built, within the site

Wastewater during construction will mainly be potentially contaminated rainwater and waste water from portable toilets at the Depot site.

Wastewater collection, treatment and final disposal during construction phase is discussed in the impact assessment part of this Report (Chapter 4).

(2) During Operations

During operation wastewater will be released from the stations and the depot site in which repair and maintenance work will be carried out. In addition, wastewater will be generated from administration building, such as from toilet and wash areas/sinks.

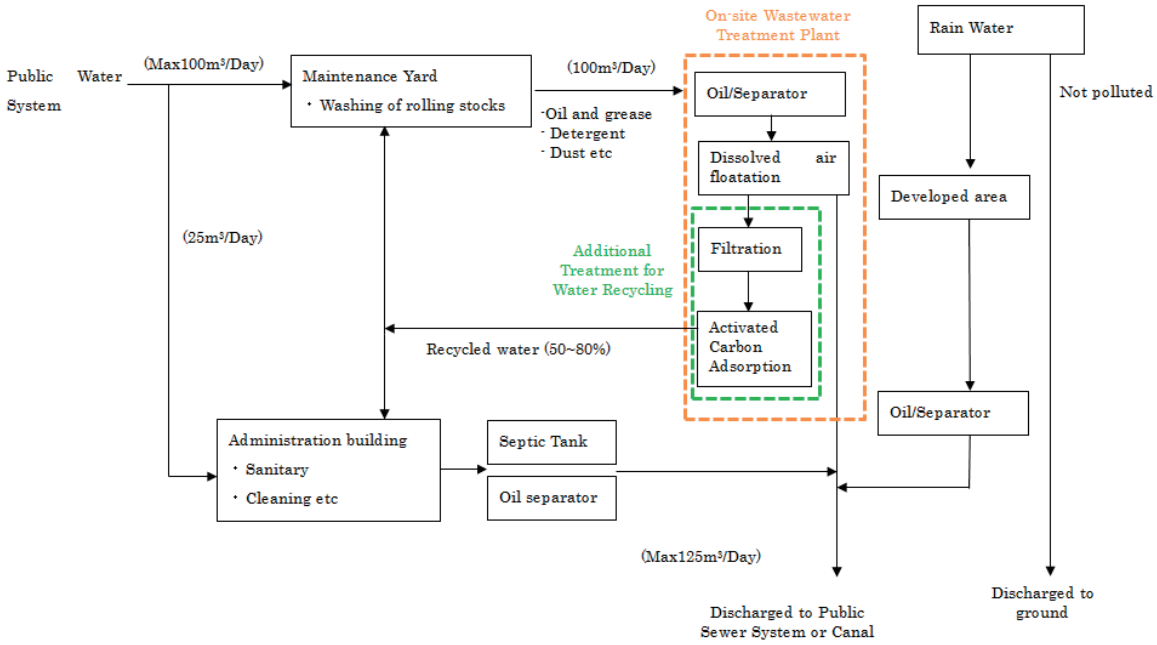
Wastewater from the depot area is generated from maintenance activities, such as carriage washing or parts cleaning. Approximately 100m3/day of wastewater is expected to be generated from these activities. Wastewater generated may contain oil and grease, detergent, dust (And possibly metal particles.

Wastewater collection, treatment and final disposal during operation phase is discussed in the impact assessment part of this Report (Chapter 4).

(3) Conceptual Layout of the Proposed Wastewater Plant

A wastewater treatment system will be installed in the Depot Area. Figure 2.31 shows the water flow and treatment methods to be used.

This system will mainly treat wastewater coming from the maintenance yard. It consists of an oil separator unit and a dissolved air flotation unit. Oil separators will be used to treat both wastewater from maintenance activities and potentially contaminated rainwater. In order to recycle some of the water and use as greywater for both maintenance yard and administrative building, additional units (filtration and adsorption) may also be included in the wastewater treatment system. The plan is to recycle 50 up to 80 percent of wastewater generated.



Source: JICA Study Team

Figure 2.31 Water Flow Diagram

(4) Sludge

Limited amount of sludge from the wastewater treatment system would be generated and this would depend on the amount of dirt, dust, oil/grease accumulated by the trains.

2.1.12 Other Wastes

(1) Construction Solid Waste

Wastes generated during construction stage will mainly comprise construction wastes (e.g. rubble, wood plants, metals), excavated soil, domestic wastes, and oil wastes. These wastes will be generated for the entire LRT route.

It is estimated that around 60,000m^3 of excavated soil and rubble will be generated when constructing the LRT route and stations and around 80,000m^3 will be generated from temporary fillings that need to be removed after constructing the depot. However, it should be noted that at

this stage it is difficult to estimate the exact amount of waste that will be disposed offsite. This will depend on materials that cannot be reused or recycled.

(2) Solid Wastes During Operation

The depot area is the place where maintenance, washing and servicing of rolling stock are conducted. Typical solid wastes generated at the depot and workshop area are listed in Table 2.7. General solid wastes, which include domestic solid wastes, are generated at an approximate amount of 200kg per day.

It is important to note that the amount of wastes generated depends on operation conditions and may vary significantly. The estimated amounts are just indicative figures.

Table 2.7 Waste generated during operational stage

Waste	Source	Estimated amount generated
1. Lubricant oil	air compressor and gear box	7 liters/day
2. Sludge	wastewater treatment plant (when cleaning train and its parts);	200kg/day
3. Brake shoe (brake pad)	brake equipment	
4. Metal scraps/ particles	wheel re-profiling lathe, etc. (wheel reprofiling, and exchanging parts)	550kg/day (ave)
5. Rubber tube	brake system (need to exchange every 8 years depending on its specs)	
6. Batteries	Rolling stock	5000pcs/2yrs

Source: JICA Study Team

2.1.13 Other Infrastructure Facilities

(1) Energy including fossil fuel/electricity and sources

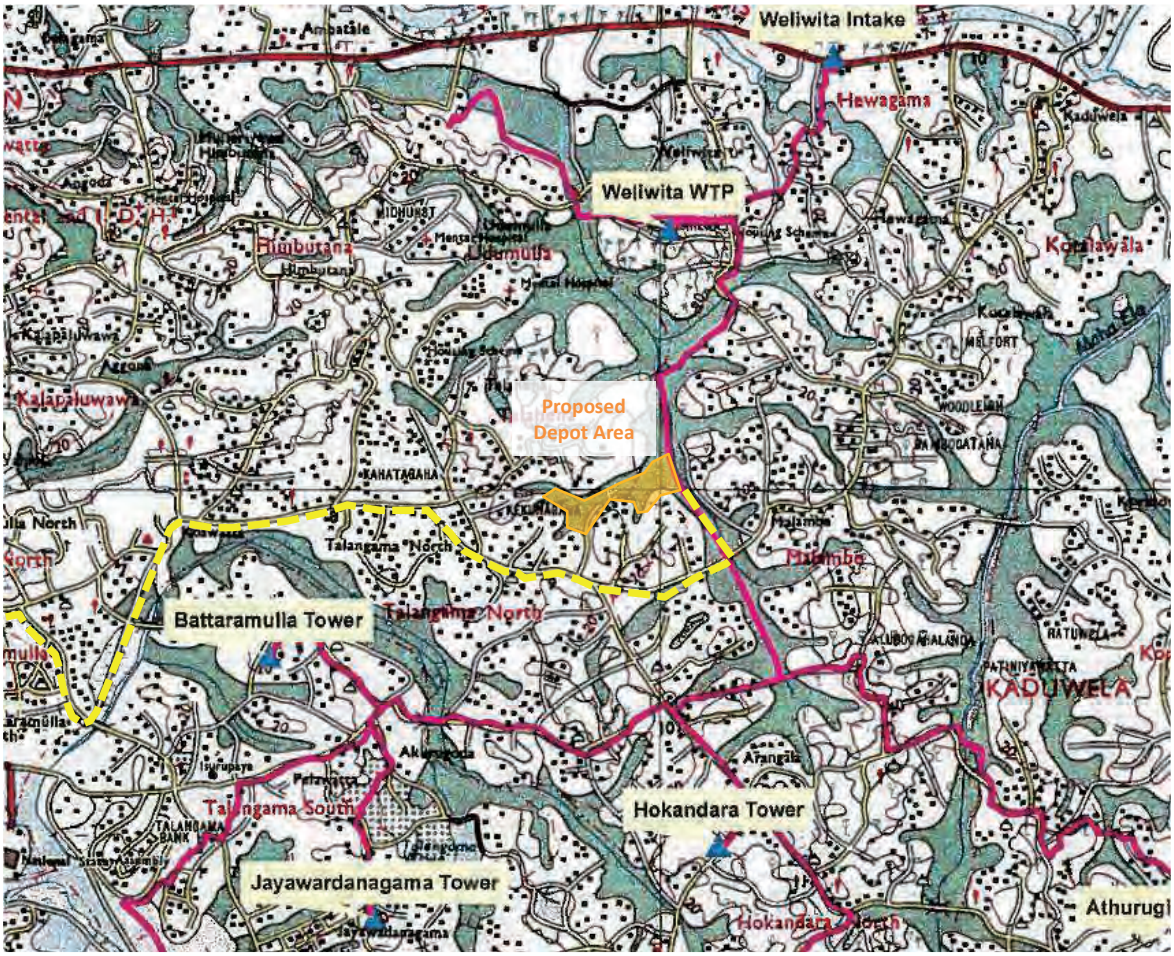
Electricity will be supplied by CEB from the existing electricity grid. For details, refer to Power Supply (Section 2.1.3)

(2) Water and sources

During Construction, water will be obtained from NWSDB mainly through temporary water connections.

During operation, water will be used for maintenance activities, washing purposes (office building and train stations), and emergency purposes (e.g. firefighting) Water will be supplied from a proposed Weliwita water treatment plant (WTP), which will have a water supply line adjacent to the proposed depot area (see Figure 2.32). Water will be withdrawn from the Kelani River and this will be supplied to the WTP, where it will be treated to the desired water quality specifications. The water will then be supplied to the network located south of the WTP. Approximately 180,000 m3/day of water can be supplied by the WTP. Operation of the Weliwita WTP is estimated to start by 2020.

As an alternative, in case the Weliwita WTP will have delays or problems with implementation, the LRT Project may opt to use groundwater resources in the area.



Source: National Water Supply and Drainaige Board

Figure 2.32 Potential Water Supply Source in Weliwita

(3) Access roads

The LRT trace traverses the existing roads, thus no extra access roads will be necessary. Access will be obtained from the existing road network itself. Access will be required for the depot area and for the low-lying paddy area adjacent to Koswatta Malabe Road. Access will be taken from the pilot road of the LRT.

Since most of the LRT route will be built on existing roads, space to keep construction materials and equipment is limited. During construction, temporary construction yards will be selected by the EPC contractor.

2.1.14 Project Investment and Funding Sources

The funding source of the project will be from the Government of Sri Lanka and Japan International Corporation Agency (JICA)

2.2 Alternatives Analysis

2.2.1 No Project Option

In Sri Lanka, under its stable economic growth, the number of traffic modes on the road network such as private car, buses, and moto-bicycles is projected to increase rapidly. Currently, about 1 million people are entering to the center of Colombo every day and this causes severe traffic congestion in the city center and surrounding road networks. It is predicted that existing road networks may not be able to handle future traffic demand.

Without having a rail-based public transport, especially, the LRT project on Malabe corridor, the following losses are predicted in future.

· Declining efficiency of economics activities due to large travel time loss by traffic congestion

· Increasing air pollution due to heavy vehicle transports

· Increasing noise pollution due to road transport

· Increasing road traffic accidents

Therefore, for both environmental and social aspects, it is undesirable not to implement the LRT.

2.2.2 Alternatives of Structural Options

In the official request for the LRT project, elevated structure (viaduct) is applied in the entire route. In order to compare with other structural options, namely underground and on street (existing road), 3 options were compared from the points of views described in the **Table 2.8**. Elevated option was considered as the most desirable option.

Table 2.8 Alternative of structural option

Items	Underground	On Street (Existing Roads)	Elevated(Viaduct)
Distance for Construction	Less than Elevated option	Almost same as elevated structure	As original
Construction cost	Highest of Civil Cost (approx. 3times or more than elevated option)	Civil structure itself is not expensive. However civil costs for intersections at SLR railway crossing and land acquisition costs will be higher than other options	As for civil cost: it is middle among the option As for total cost: it will be most economical option
Structural characteristics	With expensive "shield machine", construction period can be reduced on ground, however, it is difficult for installation of its machine into underground and of construction of underground stations.	Structure can be simple; however, many flyover sections are required as complicated structures at SLR crossings and road intersections.	Numbers of piers on route is required.
Workability	Proper underground soil conditions and underground information for building is highly required. Highest difficulties exist in construction.	Easiest for construction on street but enough road space is required. It is not seen anywhere for applicable section in the route.	Construction of piers is installed at road median. It is necessary to grasp utility pipes at the installation point of piers. Traffic management during the construction is required.
Traffic Problem	Occur at the underground station area with large space.	Reduce existing road space and accelerate traffic congestion by car	Need traffic management (lane configuration, parking space) due to decrease width by piers
Natural condition	High risk of effect on groundwater and ground settlement	Noise and vibration affect residents living near roadside.	Noise and vibration are generated from the top of viaduct during
Land Acquisition, Resettlement	Need to confirm the rights of land in underground	Many land acquisitions are required.	Land acquisition is the limited among three options.
Landscape	Large structure happens at the entering of underground station,from/to undergroundnear deport.	New scenery by tram on street	Consideration about appearance of elevated structure is required.

Items	Underground	On Street (Existing Roads)	Elevated(Viaduct)
Safety	Consideration for evacuation at the time of flood or emergency stop	Consideration when crossing residents and cars at intersections	No crossing to residents and cars, relatively safe to operate
Noise and vibration	Although it is less than other options, vibration is transmitted to buildingsdepends on underground condition.	The largest noise and vibration affect residents living roadside compared to other options.	There are some noise and vibration to buildings with same height near the viaduct.
Total evaluation	Not recommended due to construction cost and technical familiarity	Not recommended since not enough space on ground and large land acquisition required	Most desirable option in this project

2.2.3 LRT Alternative Routes

For LRT Alternative Routes analysis, following 3 sections has been studied.

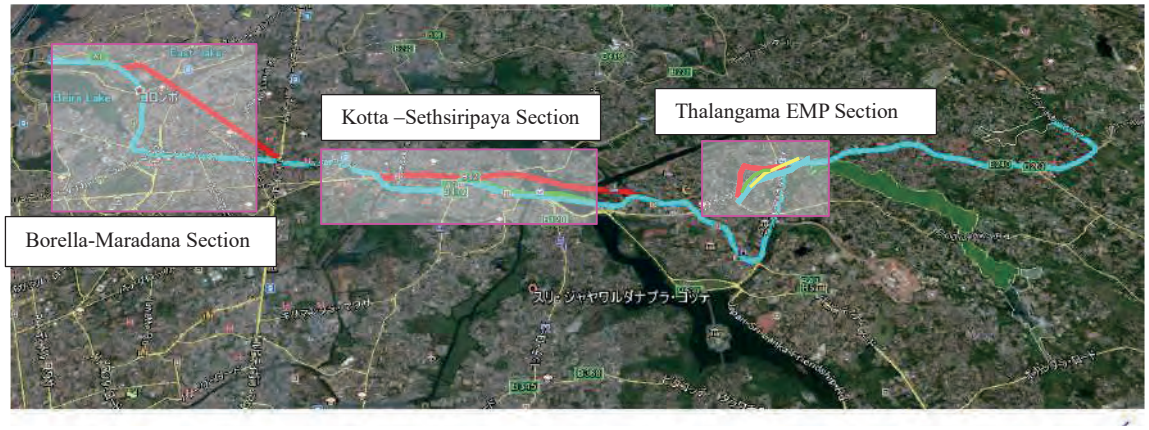


Figure 2.33 Sections of Alternative Route Analysis

(1) Borella – Maradana Route

For the section between Borella and Maradana, following 2 alternative routes were studied. The result of alternative analysis is shown in **Table 2.9**.

- **Alternative 1:** The route via National Hospital area. It serves the high employment area of the CBD, provides connection to commercial and city centre, and enables direct access to the National Hospital.
- **Alternative 2:** The route along P De S Kularatne Mawatha. It connects Residential and educational area.

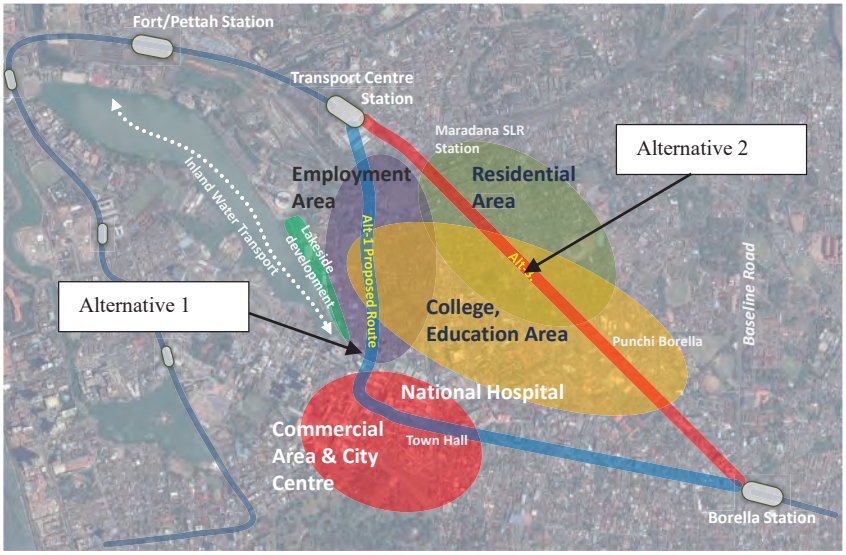
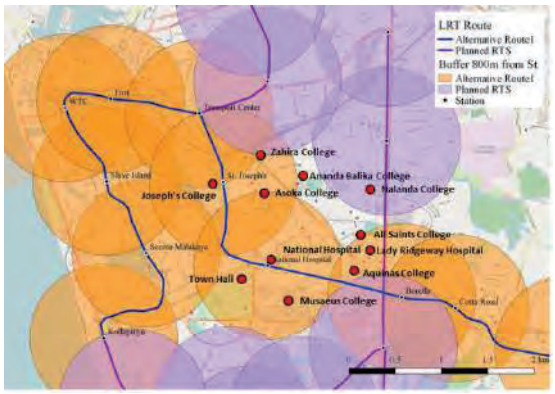


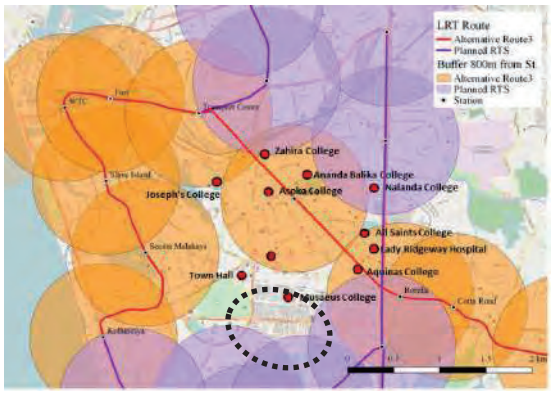
Figure 2.34 Two alternative routes between Borella and Maradana

Table 2.9 Alternatives analysis in Maradana-Borella Section

Item	Alternative 1 (Blue Route)	Alternative 2 (Red Route)
Description	The route via National Hospital area. It serves the high employment area of the central business district (CBD), provides connection to commercial and city centre, and enables direct access to the National Hospital	The route along P De S Kularatne Mawatha. It connects Residential and educational area
Length	• 400m longer than Alt 3.	• 400 m shorter than Alt 1.
Technical aspect	• More integrations are required with the future rehabilitation of Maradana road bridge due to electrification of SLR • More curve section required	• The line can be integrated with Maradana station. • Longer flyover is required to cross Sri Lanka Railway. • Straight line route
Transport catchment	• The route will cover public transport catchment widely including the center of the city (e.g. Town Hall area) (**Figure 2.35**)	• Public transport catchment is relatively small compared with Alt 1. (**Figure 2.35**)
Social aspect	• Several commercial shops are required to be acquired	• No significant issue
Aesthetic	• Adverse impact on Ward place road which is quiet residential zone with large street trees. • There are several heritage buildings.	• No significant issue
Hydrology	Not applicable	Not applicable
Ecological Environment	Greenery will be affected	No significant issue
Overall	Alternative 1 was recommended due to the overriding advantage of transport network	Alternative 2 was not recommended



Alternative Route 1 and Other RTS Routes



Alternative Route 3 and Other RTS Routes

Source: JICA Study Team, the base map from OpenStreetMap

Figure 2.35 Catchment area of LRT Stations of Alternative Route and Other RTS Lines

(2) Kotte - Sethsiripaya

For the section between Kotte and Sethsiripaya, following 2 alternative routes were studied. The result of alternative analysis is shown in **Table 2.10**.

- **Alternative 1**: The route via Sri Jayawardana Mawatha through Diyawanna lake.
  The proposed route is considered to be a Ceremonial approach into the Capital City of Sri Lanka under special planning regulations prepared by UDA in early 1980. Even though these regulations could not be fully implemented with undue influences and the envisaged Ceremonial Character has yet to be achieved, the UDA is now in the process of regaining such character by various means.
- **Alternative 2**: The route via Old Kotte Road and go behind Diyawanna Lake.
- **Alternative 3**: The route goes side road of Sri Jayawardana Mawatha to avoid LRT at centre of road.

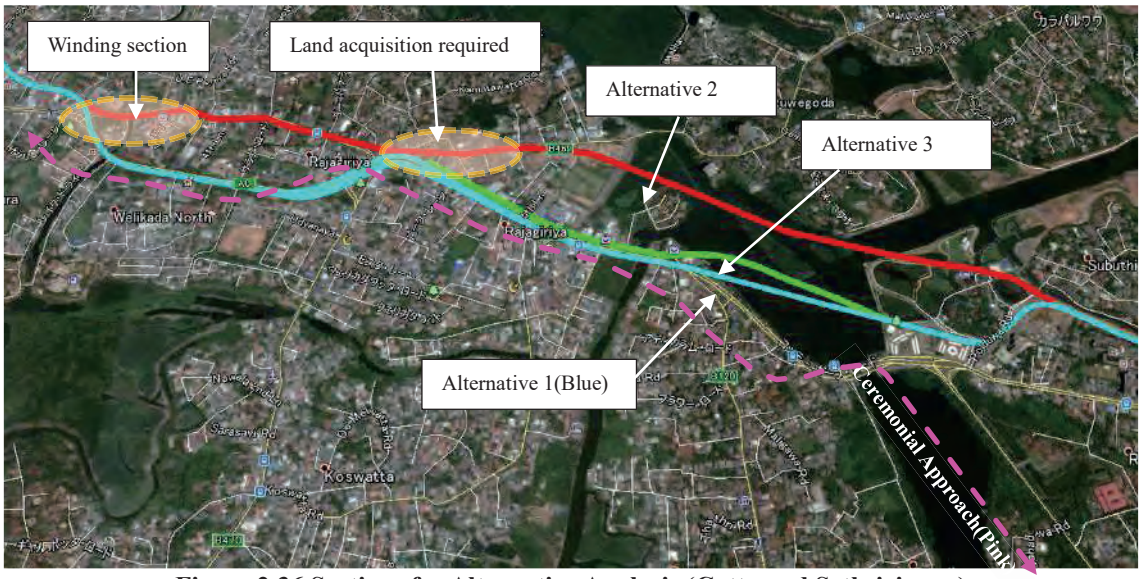


Figure 2.36 Sections for Alternative Analysis (Cotta and Sethsiripaya)

Table 2.10 Alternatives analysis in Kotte-Sethsiripaya Section

Item	Alternative 1 (Blue Route)	Alternative 2 (Red Route)	Alternative 3 (Green Route)
Description	The route via Sri Jayawardana Mawatha through Diyawanna lake See **Figure 2.37**.	The route via Old Kotte Road and go behind Diyawanna Lake	The route goes side road of Sri Jayawardana Mawatha to avoid LRT at centre of road. See **Figure 2.37** in detail.
Length	• Base	• 100m shorter than alternative 1	• Almost same as alternative 1
Technical aspect	• Although it is technical feasible to go along the sides of Rajagiriya fly over section, the cost is high. • Less sharp curve	• Going along Rajagriya fly over is not required • Old Kotta road has more sharp curves, requiring more land acquisition.	• Although it is technically feasible to go along the sides of Rajagiriya fly over section, the cost is high. • Less sharp curve
Transport catchment	Information not available	Information not available	Information not available
Social aspect	• Can be mostly managed with no land acquisition.	• Approximately 20 houses to be relocated	• 2~3 buildings and commercial property need to be acquired.
Aesthetic	• Disturb the concept of Ceremonial approach. However, area is already impacted with high raised buildings	• No significant impact	• Possible to mitigate the landscape impact on the concept of Ceremonial approach by having LRT route on the side of road
Hydrology	• Shortest Diyawanna Lake section	• Longest Diyawanna Lake section	• Second shortest Diyawanna Lake section
Ecological Environment	• No significant issue	• Island with mangrove in Diyawanna lake which is habitat of birds will be affected	• No significant issue
Overall	Alternative 1 is selected due to less land acquisition involved.	Alternative 2 is not preferred option due to the land acquisition issue, which can be studied further.	Alternative 3 can still be examined further during the detail design stage considering land availability along the road.

Figure 2.37 Two alternative routes on Ceremonial approach section

(3) **Thalangama EPA Route**

For the section between Denzil Kobbekaduwa Mawatha and B240 (Malabe road), 4 alternative alignment was studied. The best alignment in terms of technical and practical point of the view (low curvature, no obstructions (houses), shortness) was considered to be the alignment which passes through Thalangama Environmental Protection Area (EPA) shown as blue route in **Figure 2.38**. Thalangama EPA was designated as EPA by CEA and only limited activities are allowed in EPA. Therefore, following alternative alignments were studied further and the comparison of potential impact is summarized in **Table 2.11**.

- **Alternative 1**: Passing through Thalangama EPA (400m) and shortest route:
- **Alternative 2**: Passing through Thalangama EPA with minimum distance (200m)
- **Alternative 3**: Passing outside of EPA boundary (buildings will be affected)
- **Alternative 4**: Passing on existing route

Considering the importance of Thalangama EPA as well as the social impact (land acquisition), the Red route (passing on existing route was considered to be preferred route.

Source: Study Team

Figure 2.38 Alternative analysis in Thalangama EPA

Table 2.11 Alternatives analysis in Thalangama Area

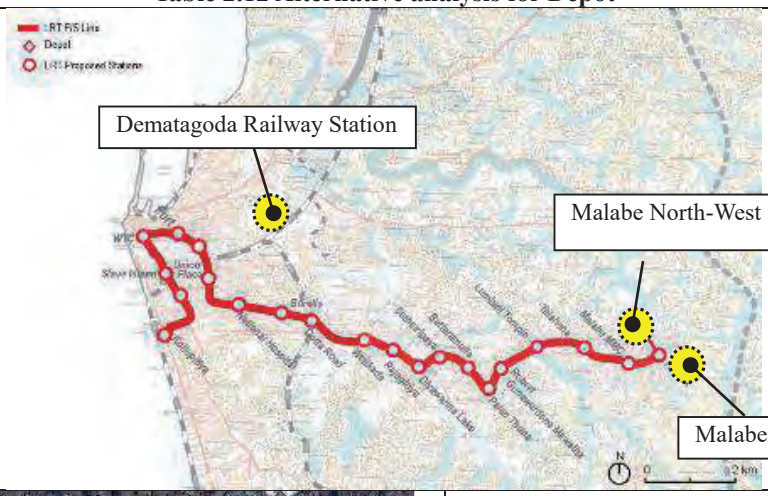
Item	Alternative 1 (Blue Route)	Alternative 2 (Yellow Route)	Alternative 3 (Green Route)	Alternative 4 (Red Route)
Description	• The shortest route passing through Thalangama EPA	• The shortest and less curve route crossing a portion of Thalangama EPA	• The route that goes outside of Thalangama EPA boundary.	• The route goes on existing road.
Length	• Shortest	• Second shortest	• Second longest	• longest
Technical aspect	• No significant issue	• No significant issue	• No significant issue	• Sharp curve at the corner • Increase in travel
Transport catchment	Approximately same for all routes			
Social aspect	• Less impact	• Less impact	• Approximately 20 houses to be relocated	• One commercial building and 3-4 houses might be relocated.
Aesthetic	• Most significant due to the disturbance of EPA	• Less significant compared with Alt.1	• Less significant compared with Alt1 and 2.	• Not significant issue

Item	Alternative 1 (Blue Route)	Alternative 2 (Yellow Route)	Alternative 3 (Green Route)	Alternative 4 (Red Route)
Hydrology	• Minor impact due to disturbance of flooding plain	• Minor impact due to disturbance of flooding plain	• Minor impact due to disturbance of flooding plain	• No significant issues
Ecological Environment	• The route runs through the northern edge of Thalangama EPA.	• The route runs through the northern edge of Thalangama EPA.	• No significant issue	• No significant issues
Overall	Not recommended due to legal restriction of EPA	Not recommended due to legal restriction of EPA	Not recommended due to land acquisition issue	Selected as recommended route since there is no legal restriction and significant land acquisition issue

(4) **Depot site**

Alternative analysis for the depot site has been conducted as shown in below **Table 2.12**. Three potential sites have been identified, which include: 1) Dematagoda Railway Station site, 2) Malabe South-East and 3) Malabe North-West. Based on the alternative analysis, Dematagoda Railway Station site and Malabe South-East site are not considered as feasible options. The required area for depot is approximately 15ha.

Table 2.12 Alternative analysis for Depot



1) Dematagoda Railway Station site

This site is an existing railway depot with an area of approximately 7ha. The site needs to be leased from the Railway Department. Since the site is located 1.5km away from proposed LRT route, it is difficult to make a connection.

2) Malabe South-East

There is an agricultural land available near the proposed LRT route. However unoccupied land is only about 3.5ha. The land can be used as part of the depot, but resettlement is required in order to secure sufficient area for Depot.

3) Malabe North-West

There is agricultural land available near the proposed LRT route with an area of approximately 10~15ha. Although sufficient land can be secured for Depot, agricultural land needs to be acquired. It is to be noted that the site is considered as a flood retention area.

Source: Study Team

CHAPTER 3 Description of the Existing Environment

3.1 Description of the Study Area

The study area was defined as 500m buffer from the project components, taking account of the nature of the impact as shown in Figure 3.1. The study area falls under four divisional secretariat (DS) divisions namely; Colombo, Thibirigasyaya, Sri Jayawardanapura kotte and Kaduwela. Map with relevant DS boundary is shown in Figure 2-3.

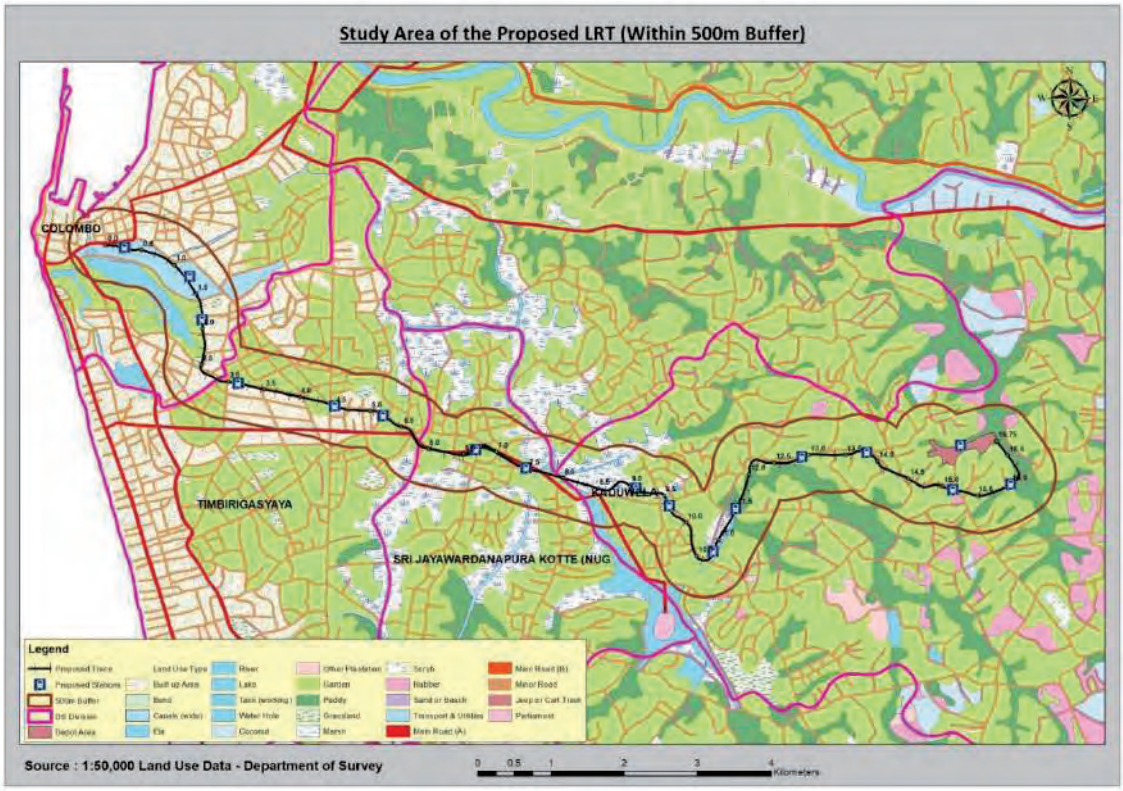


Figure 3.1 Study area of the project

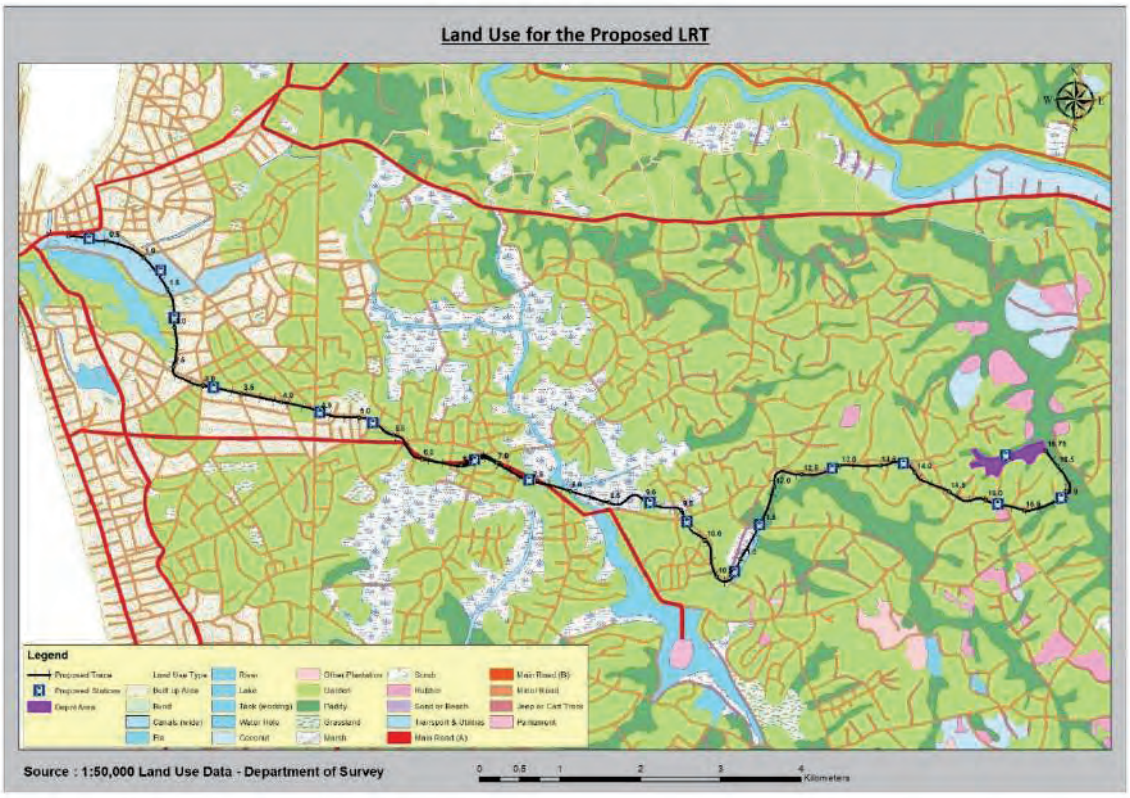
3.2 Physical Environment

3.2.1 Existing Land Use

The Light Rail will be constructed primarily on existing roads. The land use along the LRT route is shown in Figure 3.2. The Figure shows that the land use changes from a highly dense built-up area to a more semi-urban landscape as the LRT goes from Fort Station to the depot area (Malabe town towards Chandrika Bandaranayaka Kumaranathunga Mawatha). Along the planned route, there are commercial facilities such as, office buildings, shopping malls and administrative buildings and public facilities including hospitals and stations (Fort and Maradana, etc). There are residential buildings around Ward Place. In addition, Beira Lake and Diyawanna Lake are the major water bodies along the route. Diyawanna Lake serves as a key leisure zone.

In general, Western side of the project area, including business capital of Fort area is more

business-oriented zone, while eastern area toward Malabe becomes semi-urban area with open green spaces. The photos of project areas are shown below.



Source: Department of Survey

Figure 3.2 Land Use of LRT's Surrounding Areas

View at around Fort station

View at Lipton Circle.

View at Pelawatta Road

View at near Robert Gunawardena Mawatha

3.2.2 Topography

The terrain of the LRT is generally flat since it follows the existing roads. The terrain adjacent to Chandrika Bandaranayake Kumaratunga Mawatha is a low-lying flood plain.

3.2.3 Climate

(1) Temperature and Rainfall

Colombo has a tropical monsoon climate. It is fairly temperate all throughout the year. From March to April, the average high temperature is around 33°C. The monsoon seasons are from May to August and October to January. During these months, Colombo experiences heavy rain with thunder and strong wind every year.

Table 3-1 shows recorded average temperature and rainfall in Colombo in a year. The city sees little relative diurnal range of temperature, wherein the average temperature ranges from 25°C up to 31°C. Rainfall in the city averages around 200mm a year.

Table 3-1 Average Temperature and Rainfall

Month	Mean Temperature (°C)		Max. Rainfall (mm)
	Min	Max	
Jan	24.2	32.4	65.3
Feb	24.9	32.5	106.7
Mar	26.0	32.9	91.3
Apr	26.5	33.3	185.9
May	25.8	31.6	752.4
Jun	26.8	31.1	132.3
Jul	26.3	30.7	49.2
Aug	27.1	31.0	1.1
Sep	26.5	30.6	29.0
Oct	25.7	31.1	374.0
Nov	24.3	30.7	404.8
Dec	24.2	31.4	165.1

Source: Department of Meteorology

3.2.4 Ambient Air Quality

As updated ambient air quality data in project area are not readily available, the ambient air quality monitoring conducted for the other development projects in Colombo (New Kelani Bridge Project in Colombo) was referred to. Since the location of the project is geographically close to the proposed project, and no additional air major emission source (such as power plant or other industrial facilities) have been implemented recently in these areas, it is considered that data can be used to represent the air quality in the project area.

Table 3-2 shows the maximum concentration measured in the Year 2013. The air quality measurement was conducted at around the proposed New Kelani Bridge. The result shows that SO_2, NO_2, CO and PM_{10} were below the Ambient Air Quality Standards stipulated by the Ministry of Environment and Natural Resources of Sri Lanka. Also measured existing ambient air quality levels with respect to SPM was within the Ambient Air Quality Standards stipulated under the Extraordinary Gazette, No.850/4, December 20, 1994, by the CEA of Sri Lanka.

Table 3-2 Result of maximum concentration in Colombo in 2013

Parameter	Average	Unit	Result	Permissible Air Quality Standards, Sri lanka	WHO Ambient Air Quality Guideline
SO2	24hr	ug/m^3	31	80	20 -125
NO2	24hr	ug/m^3	33	100	200 (1 hour)
CO	8hr	ppm	6.7	9.00	-
CO2	1120	ppm	1120	-	-
SPM	168	ug/m^3	168	-	-
PM10	24hr	ug/m^3	68	100	50

Source:EIA of the New Kelani Bridge Project in Colombo

3.2.5 Noise and Vibration

(2) Noise

Noise measurements were carried out at selected locations mainly aiming sample noise sensitive receptors such as temples, schools, residential areas etc. Noise measurements were carried out by ITI. Noise levels were measured at strategic locations during week days and weekend. Locations for noise levels measurements have been indicated in Table 3-3 and Figure 3.3 below.

Sample average noise levels day, evening and night during a weekday are presented in

Table 3-4 below. In addition, 15-minute interval noise measurements for these locations for 24 hours are available. All the baseline noise levels are indicated in Annex D.

From the sample noise measurements, it seen that at some locations both day and night time noise levels have exceeded the permitted noise levels of the National Environmental (Noise Control) Regulations No. 1 of 1996 i.e. for urban residential areas day time 60dB and night time 50dB. Such noise level exceedances are mainly due to traffic noise.

Table 3-3 Noise Measurement Locations

Measurement Location	G.P.S. Point	Location
N 1	6°54'31.98"N 79°57'26.93"E	No. 852/71, Asokarama Road, Malabe
N 2	6°54'13.22"N 79°57'25.36"E	Malabe Boys' School, Malabe
N 3	6°54'2.12"N 79°55'37.11"E	Central Environmental Authority, 104, Denzil Kobbekaduwa Mawatha, Battaramulla
N 4	6°54'14.17"N79° 54'41.83"E	Diyatha Uyana (Park in Sri Jayawardenepura Kotte), Kaduwela Road, Sri Jayawardenepura
N 5	6°54'41.80"N 79°53'15.69"E	Jayawardanaramaya Temple, Dr. N.M. Perera Mawatha, Colombo 08
N 6	6°54'56.22"N79° 52'23.66"E	Windsor Tower, Ward place, Colombo 08
N 7	6°55'1.83"N 79°51'57.45"E	National Hospital Colombo, 10

Figure 3.3 Noise Sampling Points

Table 3-4 Noise Level Results

Measurement Location	Assessment time period- Day (6:00-18:00)			Assessment time period- Evening (18:00-22:00)			Assessment time period- Night (22:00-6:00)		
	ABL **dB(A)**	***RBL*** **dB(A)**	***ENL*** **dB(A)**	***ABL*** **dB(A)**	***RBL*** **dB(A)**	***ENL*** **dB(A)**	***ABL*** **dB(A)**	***RBL*** **dB(A)**	***ENL*** **dB(A)**
N1	61	67	72	64	67	72	51	53	67
N2	61	62	73	56	60	69	49	50	65
N3	41	45	57	43	47	57	41	43	54
N4	56	57	63	54	56	65	46	49	56
N5	55	61	67	53	56	62	44	49	56
N6	58	66	75	61	64	75	45	46	68
N7	64	66	72	59	62	69	43	45	63

ABL -Assessment background level (LA90,15min);
RBL - Rating background level (LA90,15min);
ENL -Existing noise level (LAeq,h) h-hour

(3) Vibration

Vibration measurements recorded in 2014 at several points along the LRT route is shown in Table 3-5. Location of the sampling points is shown in Figure 3.4. The results show that existing vibration levels at some points along the route are way below the vibration limits for sensitive structures (made of lightweight materials), set by the CEA.

Table 3-5 Vibration Level Results

Location	Run time (min)	Vibration level	
		Frequency Range (Hz)	Vibration in ppv (mm/sec)
Interim Standard for Vibration Levels by the CEA (Type 3 structures, made of lightweight materials)		0-10 10-50 over 50	2.0 4.0 8.0
1	0-15min	10-50	0.19
	15-30min	10-50	0.30
	30-45min	10-50	0.38
	45-50min	10-50	0.29
2	0-15min	0-10	0.22
	15-30min	10-50	0.14
	30-45min	0-10	0.14
	45-50min	0-10	0.16
3	0-15min	0-10	0.22
	15-30min	0-10	0.21
	30-45min	0-10	0.18
	45-50min	0-10	0.25
4	0-15min	0-10	0.21
	15-30min	0-10	0.36
	30-45min	0-10	0.34
	45-50min	0-10	0.26
5	0-15min	10-50	0.07
	15-30min	10-50	0.07
	30-45min	10-50	0.09
	45-50min	10-50	0.08
6	0-15min	10-50	0.10
	15-30min	10-50	0.20
	30-45min	10-50	0.21
	45-50min	10-50	0.16

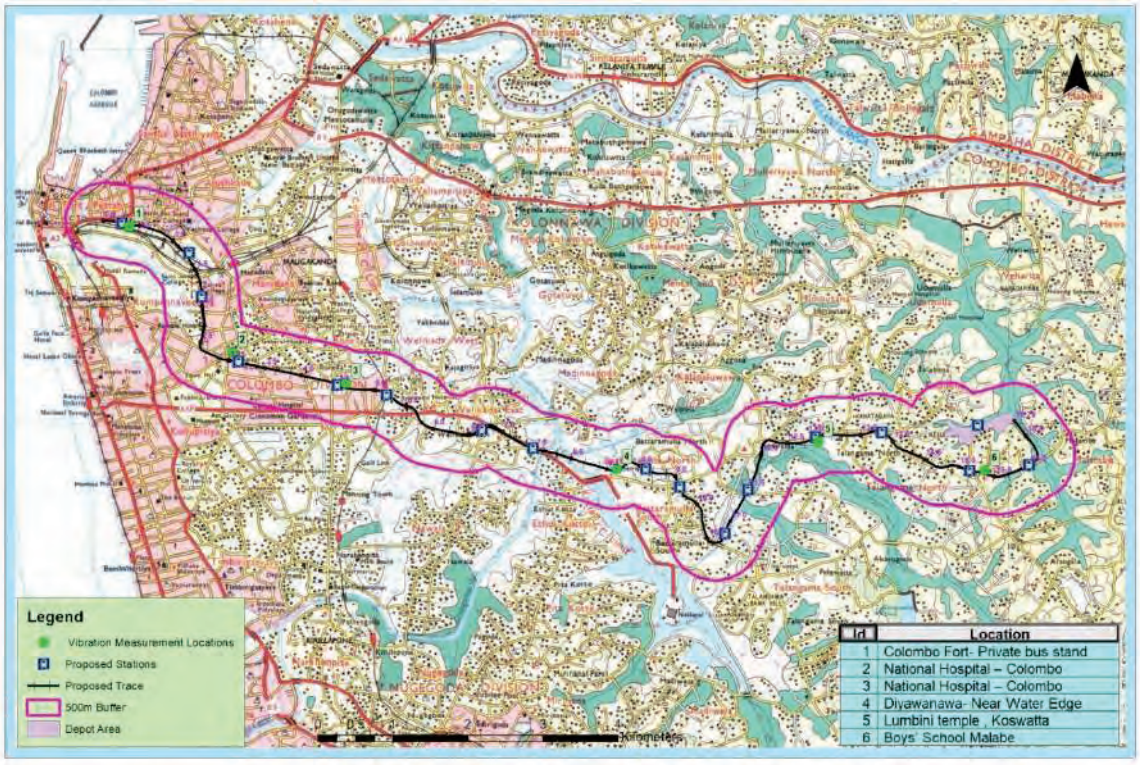


Figure 3.4 Vibration measurement points

3.2.6 Surface and Groundwater Quality

(1) Surface Water

Surface water quality was measured in the main waterbodies such as Diyawanna Lake (1), Palanthuna Junction Canal (2), Madewela East Diversion (3)-the canal close to the proposed depot and Beria Lake (4). Parameters pH, Temperature, Dissolved Oxygen(DO), Turbidity, Biochemical Oxygen Demand (BOD), Oil and Grease and Total Suspended Solids (TSS) were measured. Measurements were carried out by the Industrial Technology Institute (ITI) Sri Lanka. Results are given in Table 3-6. Water quality report is given in **Annex E**.

These parameters were compared with the Proposed Inland Water Quality Standards (PIWQS) for Different Uses (Drinking water – Only Disinfection, Bathing, Fish and Aquatic Life, Drinking Water Conventional Treatment, Irrigation and Agriculture, Other) (refer to Table 3-7 below). The analysis results are summarised in

Table 3-8. In general, all sites are compliant with the set standard for certain parameters, except Beira Lake (exceeded pH, DO and BDO).

Table 3-6 Surface Water Quality Measurements

Test	Unit	Method	Results				L.O.D	EU % (K=2)
			01	02	03	04		
# pH *	-	APHA 4500 – H^{+} B	7.07 at 31 ^{0}C	6.63 at 31 ^{0}C	6.50 at 30 ^{0}C	8.6 at 31 ^{0}C	-	-
Temperature,* ^{0}C	-	APHA 2550 B	31	31	30	31	-	-
Dissolved Oxygen	mg/L	APHA 4500 O & G	4.0	2.4	3.4	6.5	-	-
# Turbidity	NTU	APHA 2130 B	2.9	12.0	619.5	154	-	20
BOD_3 at 30 ^{0}C	mg/L	APHA 5210 B	2	2.5	ND	6	2	-
Oil & Grease	mg/L	APHA 5520 B	ND	ND	ND	ND	2	-
# Total Suspended Solids at 103 – 105 ^{0}C mg/L	mg/L	APHA 2540 D	7	31	247	81	-	3

Source: ITI Water Quality Report- Annex.
Note: Sample Location Identification- Diyawanna Lake (1), Palanthuna Junction Cana (2), Madewela East Diversion (3)-the canal close to the proposed depot and Beria Lake (4). ND= Not Detected

Table 3-7 Proposed Ambient Water Quality Standards for Inland Waters in Sri Lanka

I කොටස : (I) ඡේදය - ශ්‍රී ලංකා ප්‍රජාතාන්ත්‍රික සමාජවාදී ජනරජයේ අති විශෙෂ ගැසට් පත්‍රය - 2008.02.01 7A
PART I : SEC. (I) - GAZETTE EXTRAORDINARY OF THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA - 01.02.2008

SCHEDULE I

TOLERANCE LIMITS FOR THE DISCHARGE OF INDUSTRIAL WASTE IN TO INLAND SURFACE WATERS

No.	*Parameter*	*Unit type of limit*	*Tolerance Limit values*
01.	Total suspended solids	mg/l, max.	50
02.	Particle siz of the total suspended solids	µm, less than	850
03.	pH at ambient temperature	-	6.0 - 8.5
04.	Biochemical oxygen demand (BOD_5 in five days at 20°c or BOD_3 in three days at 27°c)	mg/l, max.	30
05.	Temperature of discharge	°C, max.	Shall no exceed 40° C in any section of the stream within 15 m down stream from the effluent outlet
06.	Oils and greases	mg/l, max.	10
07.	Phenolic compounds (as C_6H_5OH)	mg/l, max.	1
08.	Chemical oxygen demand (COD)	mg/l, max.	250
09.	Colour	Wavelength Range	Maximum spectral absorption coefficient
		436 nm (Yellow range)	$7m^{-1}$
		525 nm (Red range)	$5m^{-1}$
		620 nm (Blue range)	$3m^{-1}$
10.	Dissolved phosphates (as P)	mg/l, max.	5
11.	Total Kjeldahl nitrogen (as N)	mg/l, max.	150
12.	Ammoniacal nitrogen (as N)	mg/l, max.	50
13.	Cyanide (as CN)	mg/l, max.	0.2
14.	Total residual chlorine	mg/l, max.	1.0
15.	Flourides (as F)	mg/l, max.	2.0
16.	Sulphide (as S)	mg/l, max.	2.0
17.	Arsenic (as As)	mg/l, max.	0.2
18.	Cadmium (as Cd)	mg/l, max.	0.1
19.	Chromium, total (as Cr)	mg/l, max.	0.5
20.	Chromium, Hexavalent (as Cr^{6+})	mg/l, max.	0.1
21.	Copper (as Cu)	mg/l, max.	3.0
22.	Iron (as Fe)	mg/l, max.	3.0
23.	Lead (as Pb)	mg/l, max.	0.1
24.	Mercury (as Hg)	mg/l, max.	0.0005
25.	Nickel (as Ni)	mg/l, max.	3.0
26.	Selenium (as Se)	mg/l, max.	0.05

8A I කොටස : (I) ඡෙදය - ශ්‍රී ලංකා ප්‍රජාතාන්ත්‍රික සමාජවාදී ජනරජයේ අති විශෙෂ ගැසට් පත්‍රය - 2008.02.01
PART I : SEC. (I) - GAZETTE EXTRAORDINARY OF THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA - 01.02.2008

SCHEDULE I *(Contd.)*

TOLERANCE LIMITS FOR THE DISCHARGE OF INDUSTRIAL WASTE IN TO INLAND SURFACE WATERS

No.	*Parameter*	*Unit type of limit*	*Tolerance Limit values*
27.	Zinc (as Zn)	mg/l, max.	2.0
28.	Pesticides	mg/l, max.	0.005
29.	Detergents/surfactants	mg/l, max.	5
30.	Faecal Coliform	MPN/100 ml, max	40
	Radio Active Material :		
31.	(*a*) Alpha emitters	micro curie/ml, max	10^{-8}
	(*b*) Beta emitters	micro curie/ml, max	10^{-7}

Note 1 : All efforts should be made to remove unpleasant odour as far as possible.

Note 2 : These values are based on dilution of effluents by at least 8 volumes of clean receiving water. If the dilution is below 8 times, the permissible limits are multiplied by the 1/8 of the actual dilution.

Note 3 : The above mentioned general standards shall cease to apply with regard to a particular industry when industry specific standards are notified for that industry.

Note 4 : Pesticides as per World Health Organization (WHO) and Food and Agriculture Organization (FAO) requirements.

Table 3-8 Comparison of Water Quality Results and PIWQS

Parameter	**Location No. and Name**			
	1- Diyawanna Lake	**2-Palan Thuna Junction Canal**	**Madiwela Est Diversion Canal**	**Beria Lake**
PH	7.07	6.63	6.50	8.6
Comments on pH	**Within limits for all use types**			**Has exceeded the upper limit 8.5 by 0.1**
Temperature	31	31	30	31
Comments on Temperature	**Not given in the standard but no high temperature values exit.**			
Dissolved Oxygen(DO)	4.0	2.4	3.4	6.5
Comments on DO	**Lower than the minimum upper limit (5 for Bathing)**			**Above the maximum lower limit (6 for Drinking & Aquatic Life)**
Turbidity	2.9	12.0	619.5	154
Comments on Turbidity	**Not given in the standard**			
BOD	2	2.5	ND	6
Comments on BOD	Within the limits for all uses	Exceeds drinking water limit (2) by 0.5 mg/l	Good for all uses	Exceeds maximum standards for all users
Oil & Grease	ND	ND	ND	ND
Comments on oil & grease	Has not exceeded minimum limits			
Total Suspended Solids	7	31	247	81
Comments on Total Suspended Solids	Not given in the standards			

(2) Groundwater

Water quality of groundwater was measured in selected dug wells close to the LRT trace. The locations are Well at Parakumbura Maha Vidyalaya (1), Well at the premises of P W Joachim 487/11 Talahena (2), Well at the premises of D P R Dias 146 Batalawatte Talahena (3), Well at Asokatamaya Temple Malabe (4) Measurements were carried out by Industrial Technology Institute. Results are shown in

Table 3-9. Water quality report is given in Annex E.

Table 3-9 Groundwater Quality Measurements

Test	Unit	Method	Results				L.O.D	EU % (K=2)
			01	02	03	04		
# pH *	-	APHA 4500 – H^+ B	6.48 at 28 ^{0}C	5.31 at 29 ^{0}C	4.40 at 29 ^{0}C	3.95 at 29 ^{0}C	-	-
Temperature,* ^{0}C	-	APHA 2550 B	28	29	29	29	-	-
Water Level * (From Ground Level)	m	-	3.3	5.3	11.0	9.2	-	-
BOD_3 at 30 ^{0}C	mg/L	APHA 5210 B	ND	3	2	ND	2	-
# Electrical Conductivity	µS/cm	APHA 2510 B	417	160	186	137		4
Total Coliforms/100 mL (Confirmed MPN)	-	APHA 9221 C	2200	2800	$2.4x10^3$	230	-	-

Source: ITI Water Quality Report- Annex E.

Note: Sample Locations - Well at Parakumbura Maha Vidyalaya (1), Well at the premises of P W Joachim 487/11 Talahena (2), Well at the premises of D P R Dias 146 Batalawatte Talahena (3), Well at Asokaramaya Temple Malabe (4)

These parameters were compared with Sri Lanka Potable Standards 2013 for drinking water (SLS 614) and the comments on each parameter have been set out in Table 3-10 below.

Table 3-10 Groundwater Quality Measurements

Parameter	**Sample Locations** - Well at Parakumbura Maha Vidyalaya **(1)**, Well at the premises of P W Joachim 487/11 Talahena **(2)**, Well at the premises of D P R Dias 146 Batalawatte Talahena **(3)**, Well at Asokaramaya Temple Malabe **(4)**				**Values Given in SLS 614 Potable Water Standard**
	1	**2**	**3**	**4**	
PH	6.48	5.31	4.4	3.95	6.5 to 8.5
Comments on pH	**Within tolerance limits. Satisfactory.**				
Temperature	28	29	29	29	Not Given
BOD	ND	3	2	ND	Not Given
Electrical Conductivity	417	160	186	137	Not Given
Total Coliform	2200	2800	$2.4X10^3$	230	3
Comments Total Coliform	**Outside tolerance limits. Unsatisfactory.**				

Notes: Units for parameters are given in Table.. above.

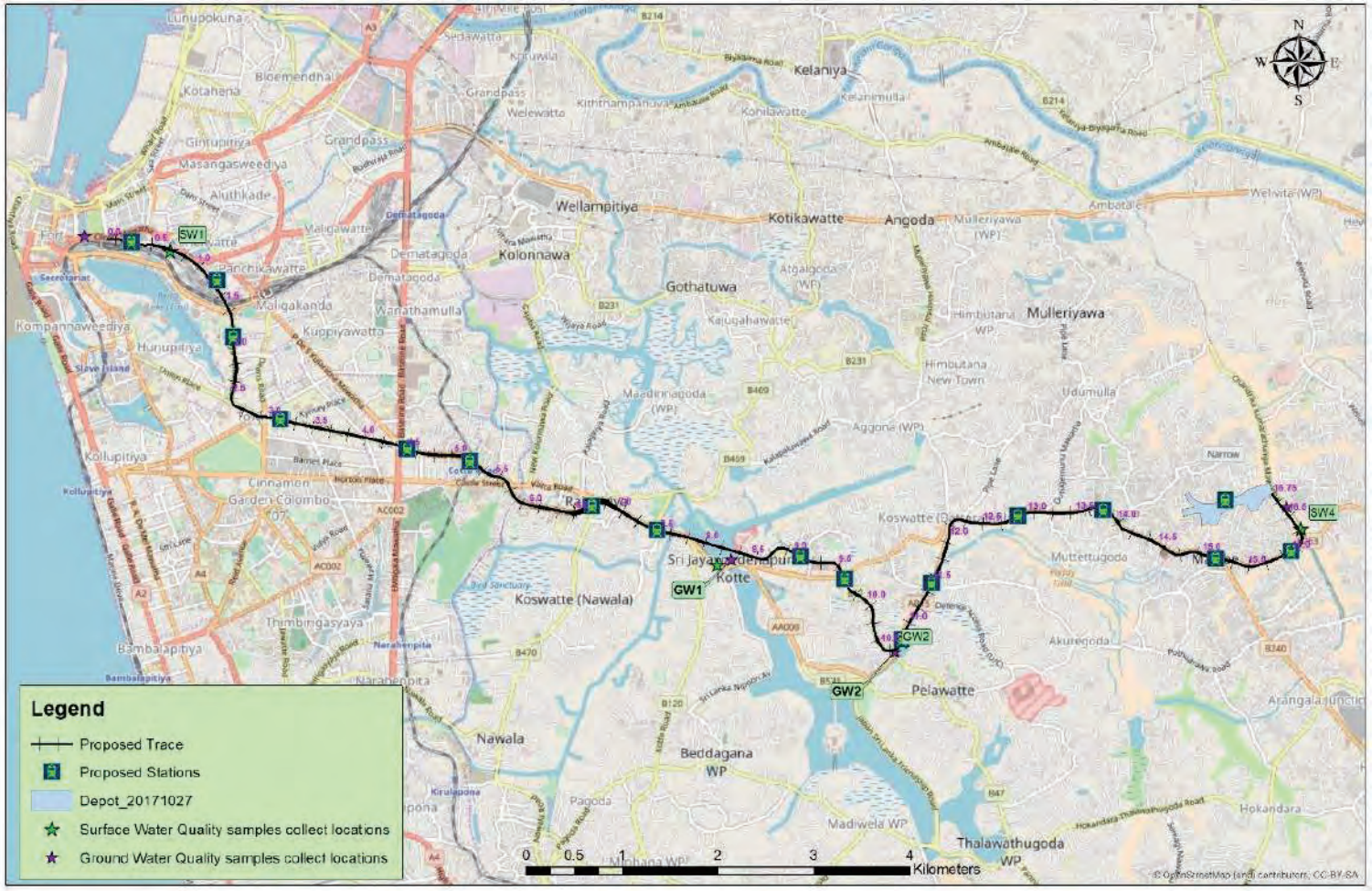


Figure 3.5 Surface & Groundwater Sampling Points

3.2.7 Geology

The geological details of the area around the LRT route are presented as a map in Figure 3.6 below. Based on the Figure, the main geological strata of the LRT route consist of quartzites, undifferentiated Proterozoic gneiss, garnet-sillimanite-biotite gneiss.

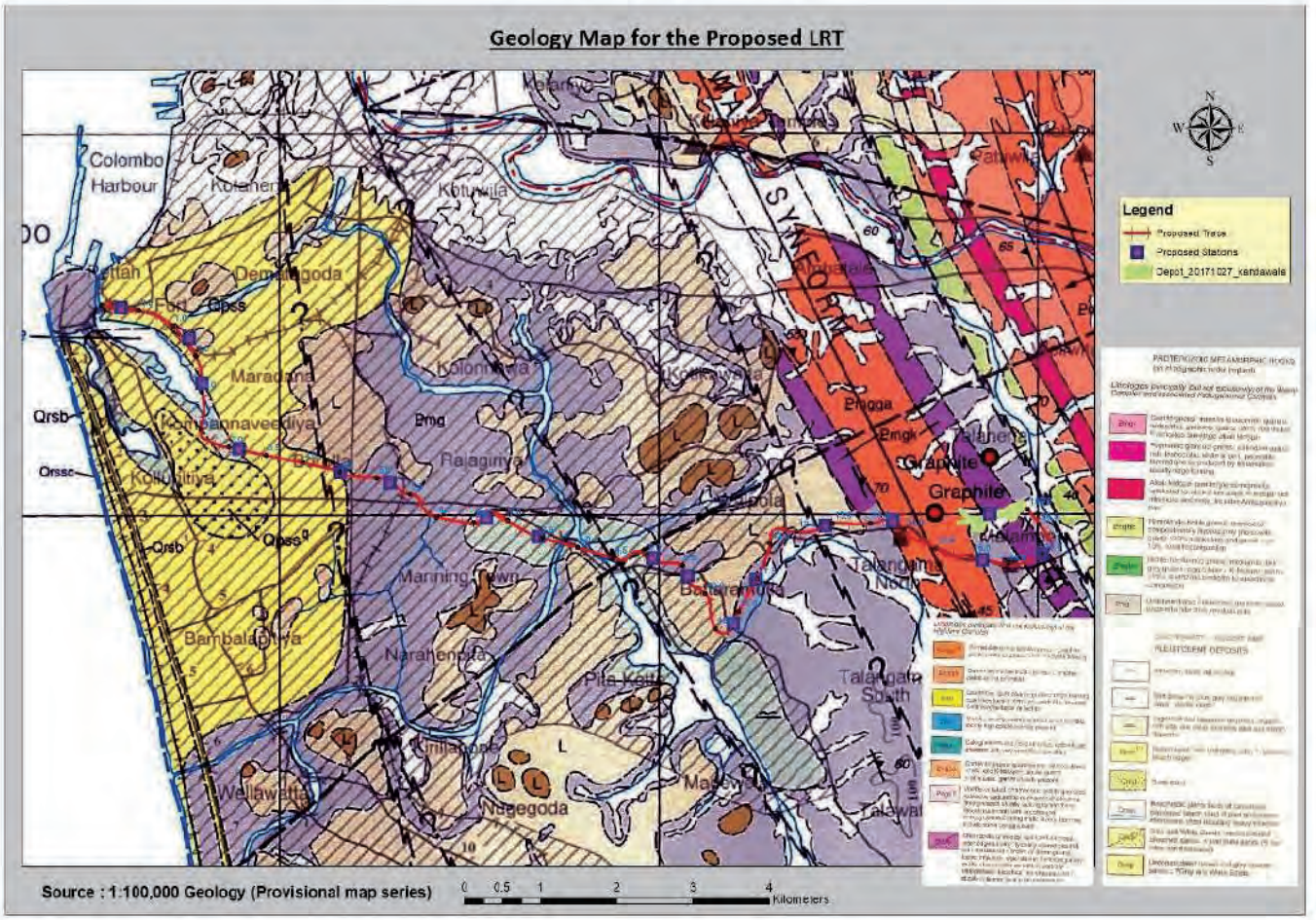


Figure 3.6 Geology Map

3.3 Socio-cultural Environment

3.3.1 Socio-Economic Profile of the Project Area

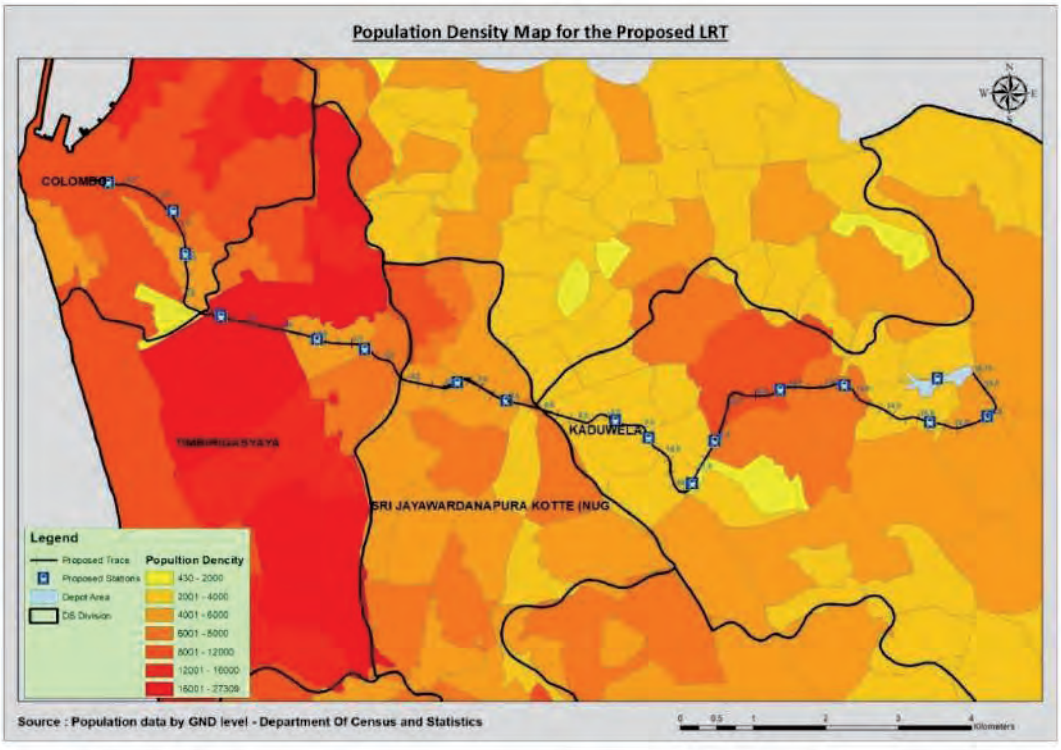
(1) Demography

The estimated mid-year population in 2016 in Colombo district is 2,395,000 persons and this includes 1,175,000 males and 1,220,000 females. This is the highest populated district in the country representing 11.4% of population with a population density of 3438 per km^2 (Source: Department of Census and Statistics 2012). Table 3-11 presents the population data of affected DS divisions. The highest populated DS division is Colombo. Figure 3.7 presents the population density map. It can be seen that population density decreases as one goes outside of Colombo.

Table 3-11 Population Distribution (Gender)

Divisional Secretariat Division	Male	Female	Total
Colombo	162,798	160,459	323,257
Thibirigasyaya	118,660	119,397	238,057
Sri Jayawardhanapura Kotte	51,992	55,933	107,925
Kaduwela	123,572	128,469	252,041
Total	457,022	464,258	921,280

Source: Department of Census and Statistics 2012



Source: Census Data (2013)

Figure 3.7 Population Density Map

In consideration of the ethnicity of the district population, 76.5% are Sinhalese, 11.2% are Tamil, 10.7 are Moor and 1.6% is other (Source: Department of Census and Statistics 2012). The sample of 200 surveyed in the light rail corridor further confirmed this ethnic distribution having 86% of Sinhalese household heads and 9.5% of Moor household heads.

In terms of education, a little over one third of the total population (35%) has completed the secondary education and only 3% have not gone to school. Further, around 6.2% of the population have attained graduate or post graduate qualifications.

Table 3-12 Educational Attainment

Divisional Secretariat Division	Primary	Secondary	GCE (O/L)	GCE (A/L)	Degree and Above	No schooling	Total
Colombo	71,175	127,855	49,694	28,635	5,174	13,383	295,916
Thibirigasyaya	35,607	70,962	45,456	44,798	20,166	6,627	223,616
Sri Jayawardhanapura Kotte	13,175	27,224	21,744	25,671	11,799	2,278	101,891
Kaduwela	32,883	73,561	56,413	51,068	16,286	3,975	234,186
Total	152,840	299,602	173,307	150,172	53,425	26,263	855,609

Source: Department of Census and Statistics 2012

The education attainments of the population of the project area through the sample survey are similar to the above situation. Around 43% of the population has studied up to G.C.E O/L and G.C.E. A/L and around 25% have passed G.C.E. A/L.

(2) Livelihood

Out of the 15 years and above population in four DS divisions, 48% are employed while another 48% are considered as economically not active. The unemployed rate is around 2%. The table below depicts this information.

According to the labour force survey-2015, in Colombo district, majority of the employed population (70.5%) is engaged in the service sector and around 27.7% are engaged in Industries. The agriculture sector is around 1.8%.

Table 3-13 Employment Status

Divisional Secretariat Division	Employed	Unemployed	Economically Not Active	Total
Colombo	110,920	6,209	123,301	240,430
Thibirigasyaya	93,421	3,960	93,432	191,113
Sri Jayawardhanapura Kotte	45,778	2,191	40,155	88,124
Kaduwela	101,044	4,820	92,982	198,846
Total	351,163	17,180	349,870	718,513

Source: Department of Census and Statistics 2012

Establishments along the proposed LRT route are primarily commercial or business premises. According the survey conducted, 53 out of 62 establishments (approximately 85%) surveyed are commercial establishments. The survey team has identified 92 workers employed in these business premises. Around 75% of business places has employed up to four number of employees around 12% of business places have employed 10-24 number of employees.

In Kaduwella DS division, there are areas used for paddy cultivations. Majority of these paddy lands are cultivated by tenant (*Ande*) farmers. These cultivations are making a significant contribution to households' food security.

(3) Health

According to the Annual health bulletin 2015, in Colombo district crude birth rate for 1,000 population is 14.4% and the crude death rate is 7%. Maternal mortality rate is 12.5% and infant mortality rate is 13.6%. The district maintains an average situation compared to other districts.

(4) Vulnerable Households

The poverty headcount index is 1.4% in Colombo and it is the lowest in the country. Thibirigasyaya, Sri Jayawardanapura Kotte and Kaduwella are categorised as least poor DS divisions. The table below summarises the number of samurdhi beneficiaries in the project area. The sample consists of 16% of female-headed households and around 12% of the participants is above 65 years and more.

Table 3-14 Samurdhi Beneficiaries in the Project Area

Divisional Secretariat Division	Number of Beneficiaries	Population	% of Beneficiaries
Colombo	5,901	323,257	1.8
Thibirigasyaya	3,232	238,057	1.3
Sri Jayawardhanapura Kotte	1,863	107,925	1.7
Kaduwela	5,019	252,041	1.9
Total	16,015	921,280	1.7

Source: District Secretariat, Colombo – 2017

3.3.2 Existing Social Infrastructure

(1) Physical Structures

Physical structures located in the project affected DS divisions are presented in Table 3-15. Around 94% of the units are classified as permanent structures. Single single-story buildings are higher in Kaduwela DS division while above two-story buildings are a higher number in Colombo and Thibirigasyaya DS divisions. Flats and condominiums are also higher in these DS divisions compared to other DS divisions. When considering the tenure, 72% are owned by the owners and around 16% rent or lease private owned.

Table 3-15 Physical Structures in the affected DS Divisions

Divisional Secretariat Division	Permanent	Semi-Permanent	Improvised	Un-classified	Total
Colombo	60,512	5,157	121	41	65,831
Thibirigasyaya	49,955	2,758	50	0	52,763
Sri Jayawardhanapura Kotte	25,442	1,636	66	0	27,144
Kaduwela	61,867	2,646	126	152	64,791
Grand Total	**197,776**	**12,197**	**363**	**193**	**210,529**

Source: Department of Census and Statistics 2012

As discussed above. Most of the structures along the study area are commercial in nature. Residential strips are mixed with commercial establishments (e.g. at Ward Place). There are also public and religious establishments such as Hyde Park, Pettah Railway Yard, Temples, Churches and two considerably old buildings (Railway Museum and Peoples' Bank Building near Pettah Railway Yard). The photos below present some of the structures located along the LRT Route.

Business premises located at Ibbanwala Junction

Lakviru Sevana

Borella Super Market

(2) Service Uses

Information about energy, water and sanitary utilities being used in the project area is summarized below. Detailed information can be found in Annex G.

≠ Around 89% of the population use drinking water supplied by the National Water Supply and Drainage Board.

≠ 96% use electricity as source of lighting.

≠ 63% use LP gas, while 26% use electricity for cooking,

≠ Majority (73%) use private latrine facilities and 25% use public facilities. Majority use flush toilets (52%) and water sealed (42%) facilities.

3.3.3 Noise Sensitive Receptors

The LRT is traversing along the existing roads where schools, hospitals and religious places are located in the vicinity of the project area. The noise sensitive receptors are listed in Table 3-16 and mapped in Figure 3.8. There are seven hospitals, eight schools and four religious place/temple.

Table 3-16 Noise Sensitive Receptors

DS division	Names of the place (school, Hospital and Religious Places)	
Kaduwela	Sri Indrajothi Vidyalaya	School
	Malabe Boys College,	School
	Rahula Balika Maha Vidyalaya,	School
	Shalawanodyaramaya,	Temple
	Asokaramaya,	Temple
	Sri Lumbini Wiweka Senasanaya,	Religious
	Santa Dora Hospital	Hospital
Sri Jayawardenapura Kotte	Ayurweda Teaching Hospital,	Hospital
	President College	School
	Rajagiriya Jayasekhararamaya,	Temple
	Victoria Home for Incurables	Hospital
Thibirigasyaya	National Eye Hospital,	Hospital
	National Hospital,	Hospital
	Borella Private Hospital,	Hospital
	Western Hospital	Hospital
Colombo		
	Zahira College,	School
	St. Joseph College,	School
	Maradana Technical College,	School

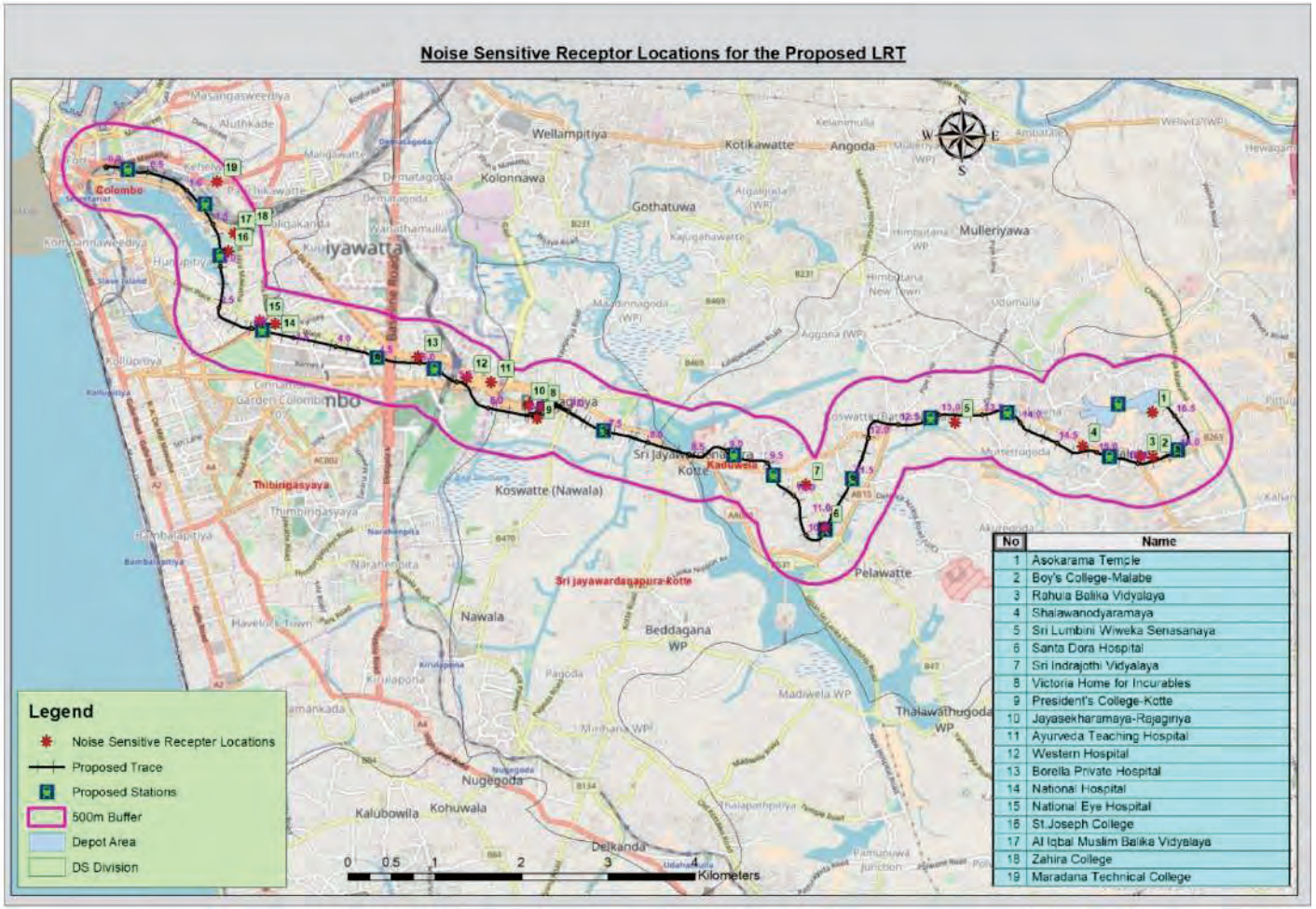


Figure 3.8 Noise Sensitive Receptors

3.3.4 Cultural Heritage

(1) Cultural Heritage Sites

A significant number of religious centers can be seen within 500-meter radius from the boundary of the proposed rail trace. These centers will not be directly impacted, however, there can be some disturbances during construction phase of the project.

Religious and culturally important properties which are located in the study area include six (06) temples, one (1) church, one (1) mosque and three (3) religious places. Details of the culturally and historically significant places are presented in Figure 3.9.

Table 3-17 Culturally and historically significant places

DS division	Names of the place	
Kaduwela	Sri Lumbini Wiweka Senasanaya,	Religious place
	Shilawanodyaramaya,	Temple
	Asokaramaya	Temple
Sri Jayawardenapura Kotte	Sri Vijayashramaya Viharaya,	Temple
	Rajagiriya Jayasekhararamaya,	Temple
	Jayawardanaramaya	Temple
	Bethany Christian Centre	Religious place
Thibirigasyaya	Cinnamon Gardens Baptist Church	Church
	Dawatagaha Jumma Masjid and Shrine	Mosque
	Borella Bodhiya,	Religious place
	Thilakaratnama Viharaya	Temple
Colombo	-	-

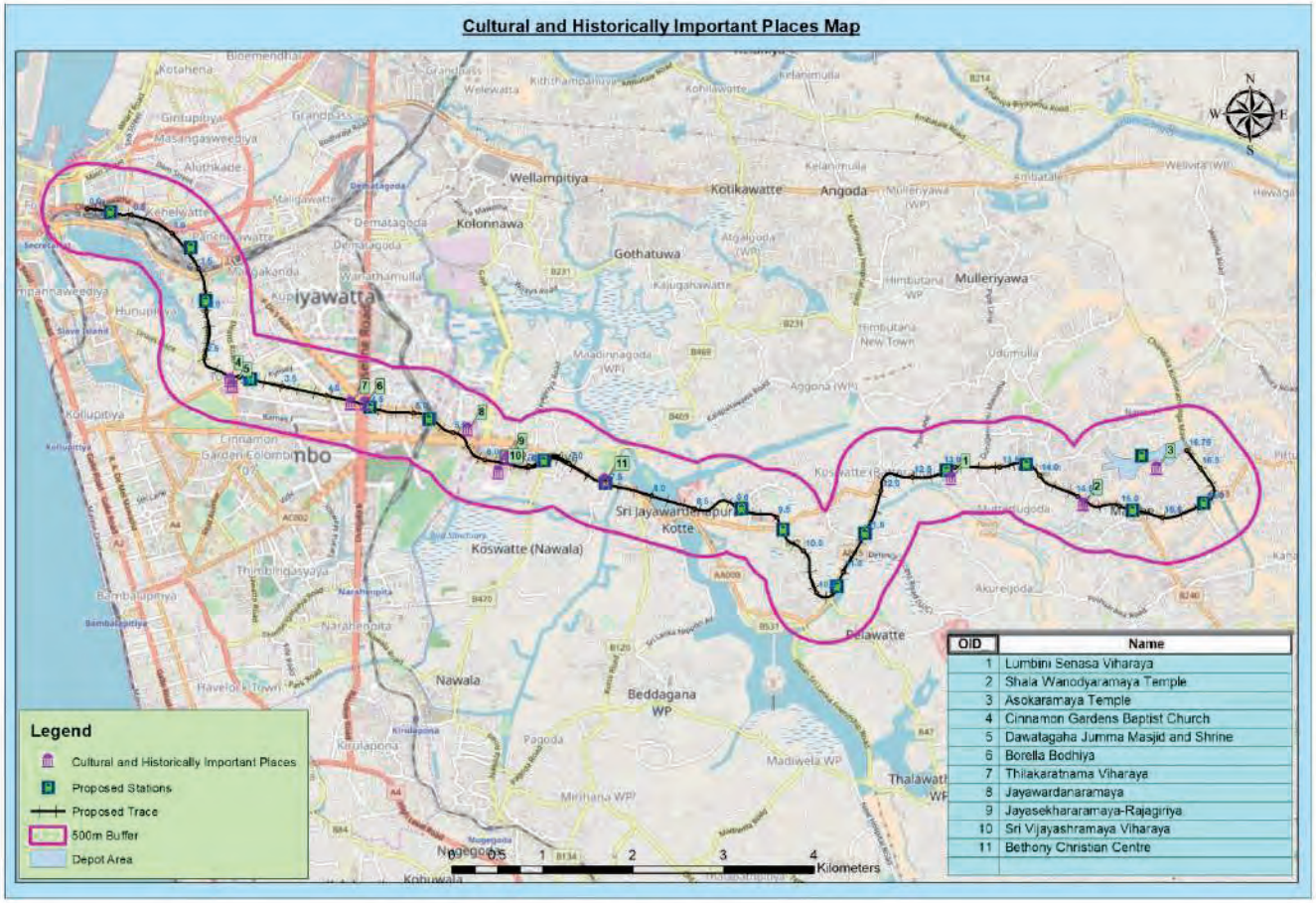


Figure 3.9 Location of Culturally and Historically Important Places

(2) Bo Trees

The reconnaissance surveys revealed that there are 14 Bo Trees (sacred trees) along the LRT route. The location of these Bo trees is shown in Figure 3.10. Some of photos of these Bo Trees are provided below. **Annex F** provides more details about the Bo trees.

Shalawanodyaramaya Bo Tree (in between Thalahena and Malabe) A branch of the Bo tree may be impacted

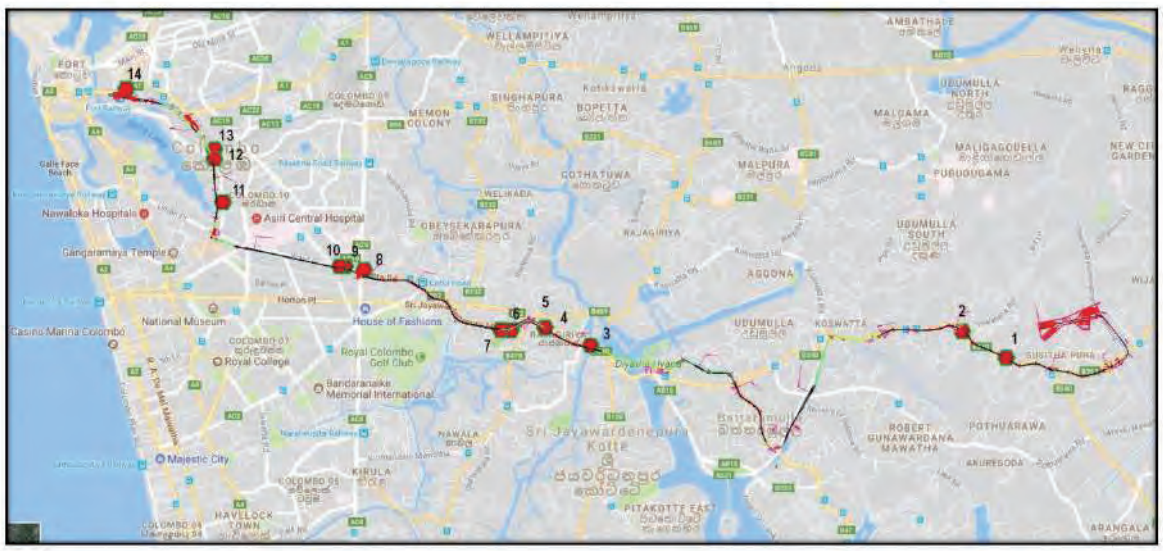
Bo Tree Near Rajagiriya President's College

Thalahena Bo Tree

Bo Tee at Gamini Hall Junction

Bo Tree at Borella Junction

Borella Bo Tree, A branch may need trimming.



ID	NAME OF PLACE	LATITUDE	LONGITUDE	ID	NAME OF PLACE	LATITUDE	LONGITUDE
1	Salawanoddyaramaya Temple Bo Tree	6°54'16.93"N	79°57'0.92"E	8	Borella Junction Bo Tree	6°54'52.59"N	79°52'40.42"E
2	Thalahena Junction Bo Tree	6°54'29.05"N	79°56'42.27"E	9	This Bo Tree belongs to Thilakarathnaramaya Temple	6°54'53.10"N	79°52'35.80"E
3	Close to KFC (Rajagiriya) Bo Tree	6°54'22.92"N	79°54'12.61"E	10	The Bo Tree Near the Word Place	6°54'53.71"N	79°52'33.37"E
4	Near Rajagiriya Fly Over Bo Tree	6°54'32.56"N	79°53'49.41"E	11	The Bo Tree Near the Nestle company	6°55'17.46"N	79°51'43.55"E
5	Rajagiriya Junction Bo Tree	6°54'34.33"N	79°53'45.65"E	12	Gamini Hall Bo Tree	6°55'36.76"N	79°51'42.26"E
6	In front of Rajagiriya Victoria Home Bo Tree	6°54'30.32"N	79°53'37.47"E	13	Near the Gamini Hall Bo Tree	6°55'37.69"N	79°51'41.79"E
7	Rajagiriya Janadhipathi Vidyala Mawatha Bo Tree	6°54'29.84"N	79°53'34.98"E	14	E.W Bestian Mawatha Bo Tree	6°56'2.68"N	79°51'4.05"E

Figure 3.10 Affected Bo Trees

(3) Archaeologically Important Places

Based on the preliminary archaeological survey conducted by the Department of Archeology, there are two buildings along the trace that are potentially significant. These are Peoples' Bank premises and the Railway Museum close to it. Locations of these two places are indicated in Figure 3.11 below.

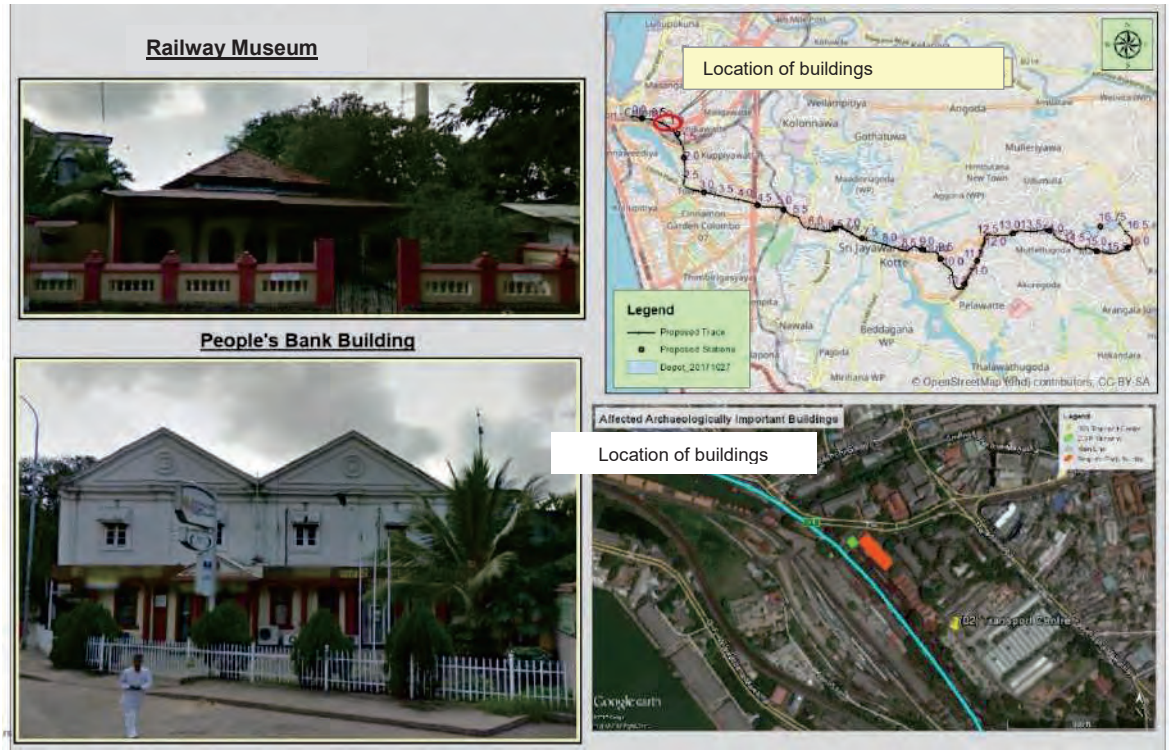


Figure 3.11 Archaeologically Important Structures

(4) Existing Utilities

All the national roads through which LRT trace runs have been used to establish drinking water, sewerage lines, telecommunication transmission lines and electricity lines which both includes underground and overhead lines. To collect a data/information regarding utilities, several consultations have been conducted with relevant agencies/organizations including, National Water supply and Drainage Board, Sri Lanka Telecom, Ceylon Electricity Board and Lanka Electricity Company. Based on these consultations and utility layout maps, it is likely that, in most of the cases, drinking water lines, telecommunication lines and electricity lines have been buried in one side of the national roads. Depth of these lines are considered to be around 1~3m below from the ground level, but depth and location of these lines vary depending on the area.

On the proposed route, there are many distribution lines crossing roads. Height of lines crossing is approximately 5 m. There are mainly two transmission lines running near the project area. One is 132kV line which runs northside of LRT route and pass the northern edge of marshland which is proposed Depot site. The other one is 220kV line which run south/north direction and cross Malabe road between proposed Malabe station and IT park station.

Storm water sewers and sewerage network maps obtained from CMC is given in **Annex G**.

3.3.5 Existing Transport Network

The LRT line will be constructed on existing roads for majority of its route except for the sections near Sethsiripaya Station and near Kotte-Bope Road. The characteristics of the roads along the proposed LRT route and other roads affected at key intersections are listed in Table 3-18. According to the Table, several roads are multi lane roads with centre median and in some areas, one-way traffic schemes are in place. Besides vehicular traffic, there is high pedestrian flow along most of these roads.

Also, the proposed LRT route is located along heavily congested highway network within Colombo City and along one of the major arterial roads that carry traffic to Colombo from Malabe - Battaramulla direction. Peak hours are often congested with speeds in the range of 10km/hr or less (see Figure 3.12). In addition to bus routes which run on the road links where the LRT will be constructed, most other bus routes pass through key nodes in the network (e.g. Borella and Pettah).

Therefore, the existing traffic condition presents a good opportunity for an alternative mode of public transportation. The LRT can cater to existing road users and provide good connectivity to transportation hubs and strategic locations (e.g. business centers, government offices).

Table 3-18 Characteristics of Roads affected by the LRT Construction

No.	Road Name	Class	Start node (a)	End node (b)	Node Type (a)	Node Type (b)	Road type	No. of lanes	Carriageway width (m)	Sidewalk width (m)
1	W E Bastian Mawatha		1	2	3	4S	One way	2	10	2.0-4.0m
2	Olcott Mawatha	A01	2	3	4S	3	Divided	5	21	> 4.0m
3	Trace Ln		3	4	3	3	Undivided			
4	T B Jayah Mawatha		4	5	3	3S	Divided	4	18	> 4.0m
5	Dr Colvin R de Silva Mawatha		5	6	3S	RS	Median Seperated	4	13	2.0-4.0m
6	Ward Place		6	7	RS	5S	Divided	4	13	2.0-4.0m
7	Cotta Rd	B62	7	8	5S	4S	Median Seperated	4	15	2.0-4.0m
8	Sri Jayawardenepura Mawatha	B240	8	9	4S	5	Median Seperated	6	24	2.0-4.0m
9	Sri Jayawardenepura Mawatha	B240	9	10	5	-	Median Seperated	6	21	> 4.0m
10	Sri Jayawardenepura Mawatha		10	11	-	3	-		-	-
11			11	12	3	3S	-	-	-	-
12	Battaramulla Rd	B47	12	13	3S	4S	Median Seperated	4	14	2.0-4.0m
13	Denzil Kobbekaduwa mawatha		13	14	4S	-	Undivided	4	12	> 4.0m
15	Kaduwela Rd	B240	14	15	-	3	Undivided	2	10	2.0-4.0m
16	Kaduwela Rd	B240	15	16	3	3	Undivided	2	10	<2m
17	Kaduwela Rd	B240	16	17	3	3	Undivided	2	10	<2m
18	Chandrika Kumaratunga Mwa		17	18	3	-	-	2	-	2.0-4.0m

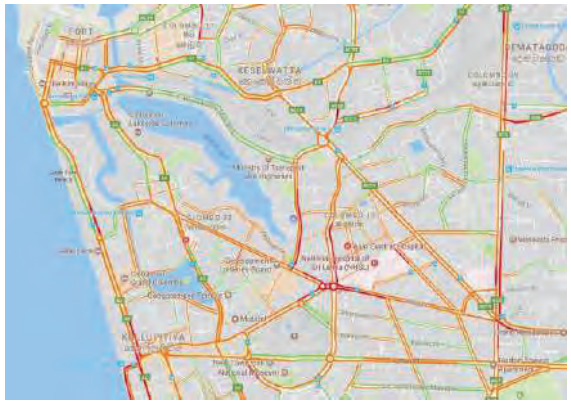
Note: The junction type (at the node) and the traffic control mechanism is indicated as follows,

3 3 way (Y/T junction) 4 4 way R Roundabout *S Signalized

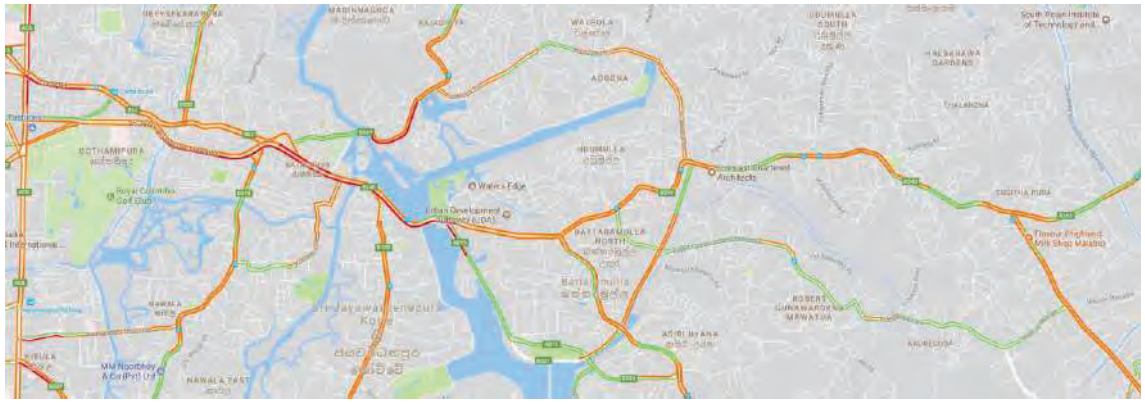
Note

Midblock nodes are indicated as empty

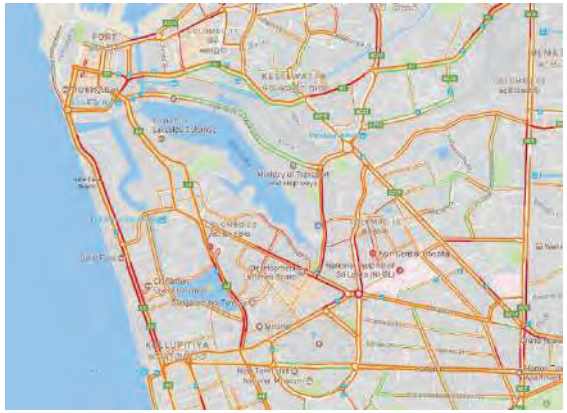
Sections that are not constructed over existing major road links are highlighted in grey.



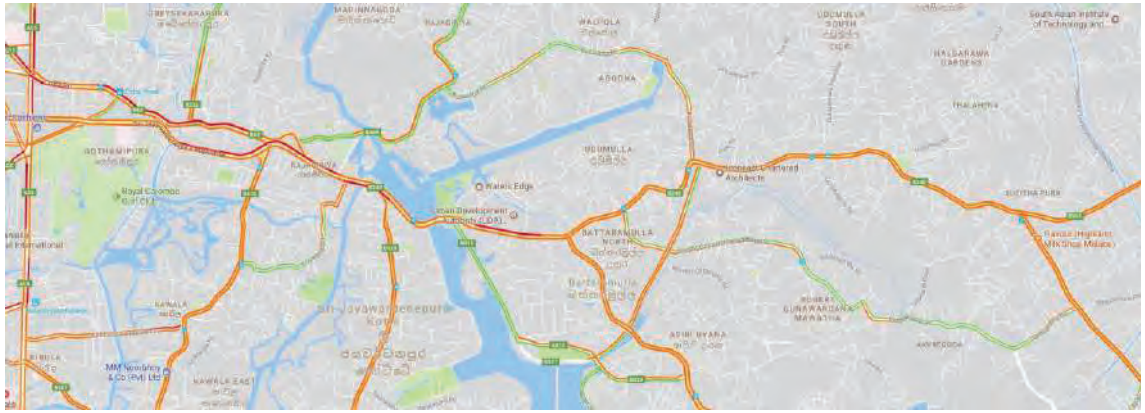
a) Colombo area (AM)



b) Kotte Area (AM)



c) Colombo area (PM)



d) Kotte Area (PM)

Figure 3.12 Traffic Condition in the Study Area during Peak Hours

3.3.6 Planned Development Activities

Some planned development activities in the vicinity of LRT route consist of several highway projects and real estate developments. One big development project is the Colombo Port City Development Project wherein a combination of retail, business and residential premises will be developed on a reclaimed area close to the existing port.

The locations of these planned developments are shown in Figure 3.13.

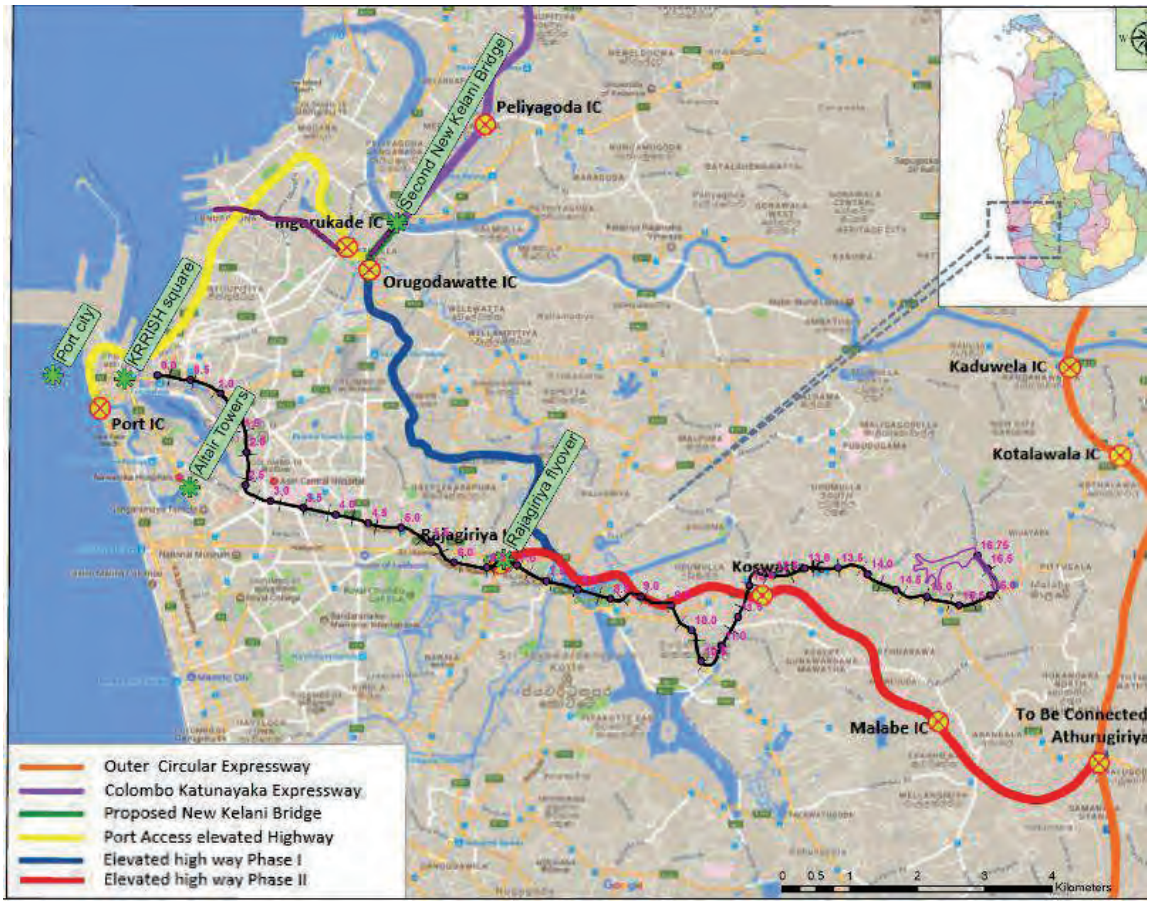


Figure 3.13 Planned development projects in Colombo

(1) Transformation of Fort Area into a Multimodal Transport Hub Project

There are plans to develop Fort Station into a multi-modal transport hub. Upon the development of the LRT, the Fort Station will be a focal point to several transportation modes such as buses, and provincial railway lines. The Project is still in the conceptual stage. Thus, the LRT Project needs to closely coordinate with the responsible entities of the MmTH project to ensure proper integration and optimum resource use.

(2) Elevated Highway from New Kelani Bridge to Rajagiriya – Phase 1

An elevated highway project is planned by RDA from proposed New Kelani Bridge to Rajagiriya. The proposed project will start from Orugodawatta new bridge over Kelani River and will connect

the Buthgamuwa road of Rajagiriya. The project will be a four-lane elevated road with a length of 7 km. The environment and social assessments for the project is ongoing.

(3) Port Access Elevated Highway

This proposed project of RDA starts from the interchange to Port of proposed New bridge over Kelani River project. The project has two major components; first is construction of an elevated expressway from Ingurukade junction to Port city. The width of this road varies from 23.4m to 32.3m. The expressway will be equipped with toll gate facilities and street lighting. The second component of the project is widening of existing Port access road to be six lane road.

(4) Rajagiriya Flyover

The flyover construction at Rajagiriya junction is an ongoing project by RDA. The length of the flyover is 534m including ramps. The flyover is four lane and width is approximately 17.4m. The objective of the project is to ease the traffic and accidents at the four-legged junction.

(5) Colombo Port City Development Project

The Colombo Port city project is a Public-Private-Partnership (PPP) between government of Sri Lanka and China Harbor Engineering Company (CHEC). The project proponent is Ministry of Megapolis and Western Development. The project includes 269 hectares of land development and this total land area will be divided in to separate purposes such as commercial areas, residential areas, public areas and beach areas.

(6) Sewerage Construction Project of Sri Jayawardanapura Kotte

National Water Supply and Drainage Board (NWSDB) is implementing a sewerage improvement project in Sri Jayawardanapura Kotte DS division. It is a project funded by JICA and this division was selected under 15 major cities of Sri Lanka. The main objective of the project is to alleviate water pollution through implementation of sewerage development.

(7) Sewerage Project Colombo

The Greater Colombo Wastewater Management Project is designed to improve the urban environment and public health for the urban and suburban residents in Colombo through improvements of wastewater management services. The project involves in upgrading the sewerage infrastructures, strengthening institutional and operational capacity and project management and implementation.

(8) KRRISH Transworks Mixed Development Project

This project is named as “KRRISH Square” and is a mega multi complex real estate project with about five million square feet and includes super tall structures. It comprises 1. Ultra-luxury residential apartments 2. Commercial space for shopping and recreational activities and 3. A 450 room five-star hotel with banquet halls and suits. The project is located in Fort GND in Colombo DS division along York Street, Chatham Street, Lotus road and Chittampalam A Gardiner Mawatha. The project proponent is Krrish multi-national company based in New Delhi, India.

(9) Mix Development Condominium Project

The proposed project focuses on developing mix development condominium facility and the project proponent is E.A. Macro Holdings. The total land area of the project is 3,870 m^2. The project is

located in Bambalapitiya GN division of Thibirigasyaya DS division along Colombo – Galle road.

3.4 Biological Environment

3.4.1 Surrounding Environment

Existing biological (both floral and faunal) environment of the project area and immediate surrounding was considered under two categories. First, the general LRT route that is planned along the existing main road where the effect on the existing vegetation will be minimal and second, specific locations where the LRT route traverses away from the main road where vegetation will be affected due to construction activities.

The habitats found within LRT trace can be described as a mosaic with number of different habitat types found intermixed with one another creating various ecotones. These habitats can be broadly categorized in to six major types based on the vegetation such as tree dominated wetlands (woodlands), herb dominated wetlands (Marshes), water bodies with submerged or floating vegetation, open water bodies, tree-dominated terrestrial habitats and roadside vegetation.

3.4.2 Wetlands and Streams

Wetlands, water bodies, flood plains within the project area comprise a major part of Colombo's drainage network. The drainage pattern of the project area, which include lakes and wetland areas crossed by the LRT, is shown in Figure 3.14, along with the proposed LRT route.

Although the proposed LRT route mostly follows the existing roads, it can be noticed in the Figure below that there are four areas part of the drainage network, that are close to and are part of the route. These areas are:

≠ LRT Depot to Malabe-Kaduwela Road passing through herb dominated wetlands (mostly abandoned paddy fields) on to the left of the Madiwela East Diversion Canal;

≠ Koswatta to Palan Thuna Junction that passes through the lower end of the command area of the Thalangama tank that is a mosaic of tree dominated wetlands (woodlands), herb dominated wetlands (Marshes), water bodies with submerged or floating vegetation, open water bodies and tree-dominated terrestrial habitats;

≠ Battramulla to Pita Kotte junction that passes through the Diyatha Uyana, which is an open water type habitat; and

≠ Rajagiriya that passes over Heen ela, which is an open water type habitat.

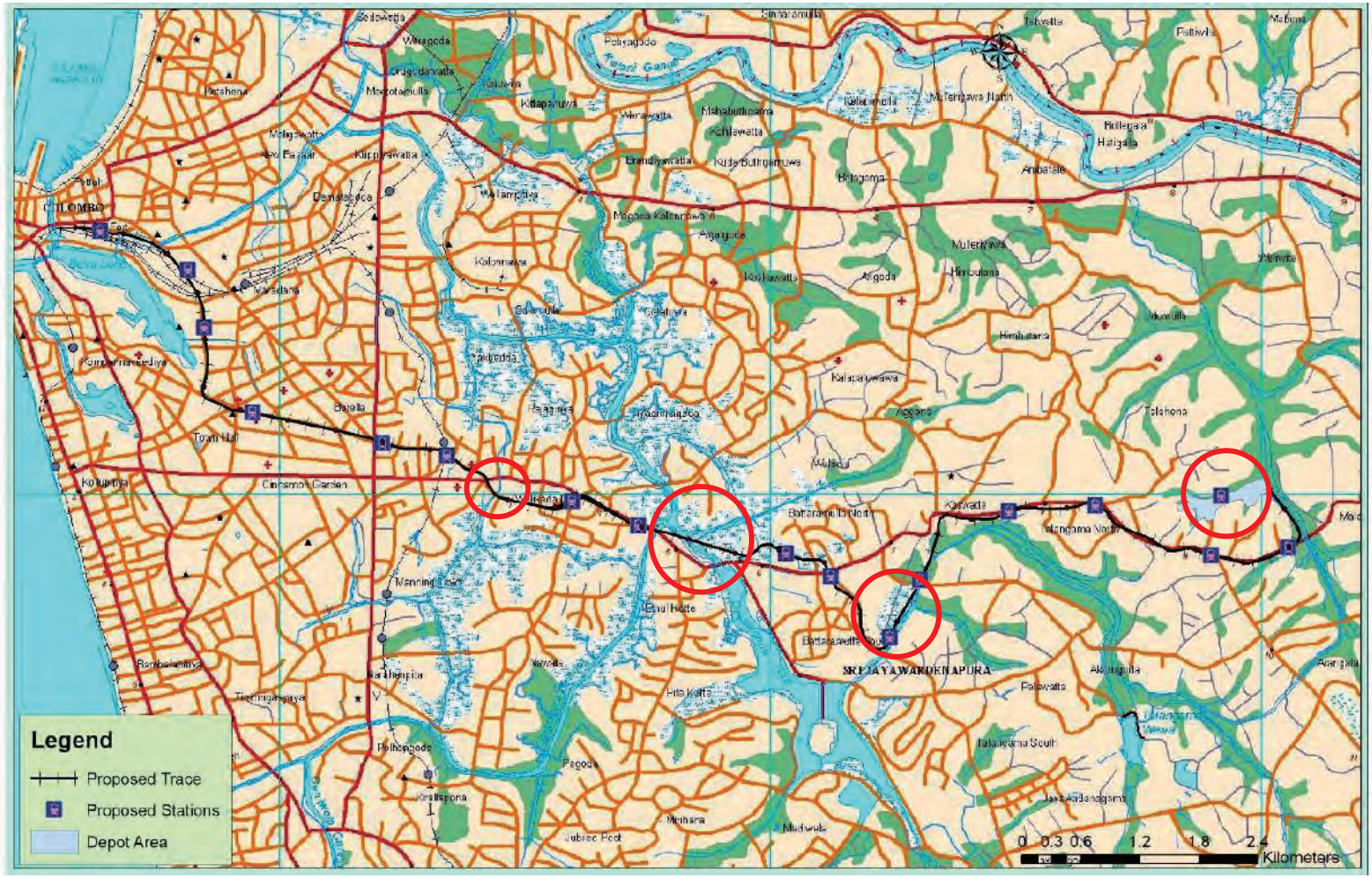


Figure 3.14 Drainage Map

3.4.3 Flora

An ecological survey conducted along the LRT route reveals that a total number of 203 plant species exist. This included 3 endemic, 3 nationally threatened and 5 nationally near threatened plant species. About 45% (93 species) of the recoded plant species are exotic to the country indicating that the vegetation present in the habitats located on the LRT trace is highly disturbed by human activities. Further, these exotic species included nine plants that are listed as Invasive Alien Species (IAS) in Sri Lanka (Wijesundara, 2010[1]). A detailed list of the plant species recorded in the habitats found in the LRT trace is given in Annex H.

3.4.4 Fauna

A total number of 132 animal species including 4 endemic species were recorded during the field survey (Table 3-19). The species recorded also included 6 threatened species (Endangered (EN) - 3 and Vulnerable (VU) - 3). Further, 5 species listed as Near Threatened (NT) was also recorded. The faunal species recorded included 5 species of introduced or exotic species which included 3 species of potentially invasive alien fauna listed for Sri Lanka. A detailed list of the animal species recorded during the field survey within LRT trace is given in **Annex H**.

Table 3-19 Observed Fauna along the LRT route

Taxonomic Group	Total	Endemic	Exotic	Conservation Status				
				CR	EN	VU	DD	NT
Dragonflies	19	0	0	0	0	1	0	4
Butterflies	52	0	2	0	0	2	0	1
Freshwater fish	8	2	3	0	1	0	0	0
Amphibians	3	0	0	0	0	0	0	0
Reptiles	13	1	0	0	0	0	0	0
Birds	33	0	0	0	0	0	0	0
Mammals	4	1	0	0	2	0	0	0
Total	132	4	5	0	3	3	0	5

Abbreviations Used: CR - Critically Endangered, DD - Data Deficient, EN- Endangered, LC - Least Concern, NT - Near Threatened, VU- Vulnerable

Three main threatened species was observed in and around the project affected area. These include Fishing cat (*Prionailurus viverrinus*), Purple-faced leaf langur (*Semnopithecus vetulus*) and Eurasian otter (*Lutra lutra*). Out of these three species, Purple-faced leaf langur is listed as Globally and Nationally Endangered (EN) species, Fishing cat as Nationally Endangered and Globally Vulnerable species while Eurasian otter is listed as Nationally Vulnerable and Globally Near threatened species.

Figure 3.15 shows the locations where the three endangered mammal species were recorded in the project area. Red dots indicate Fishing cat, Yellow dots indicate Purple-faced leaf langur and the blue dot indicates Eurasian otter. Purple-faced leaf langur shows a wide distribution in the project area as it inhabits many home gardens. It is listed as threatened as their habitat is severely threatened due to rapid urbanization. The other two species Fishing cat and Eurasian otter occurs mostly in

wetlands where the former shows a much wider distribution in the wetlands of the Colombo Metropolitan region while the latter shows a much-restricted distribution.

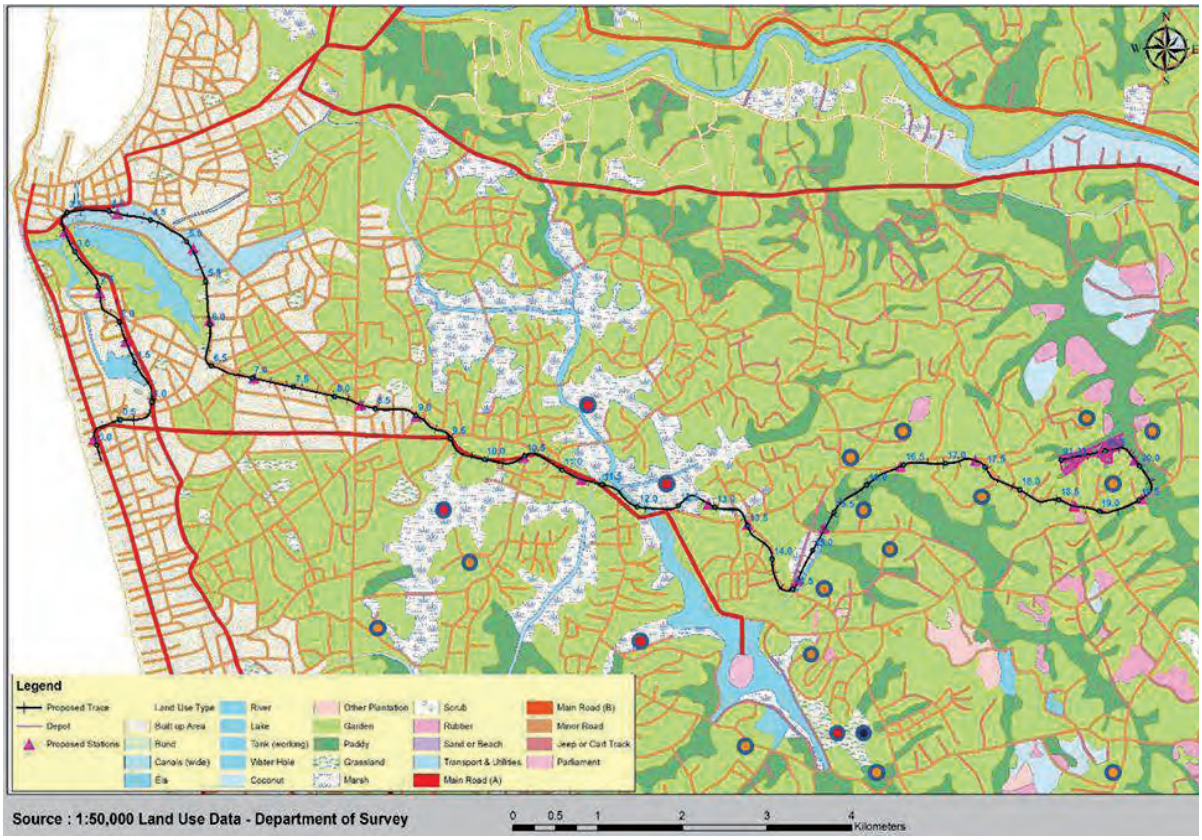


Figure 3.15 Planned development projects in Colombo

3.4.5 Affected Trees

To assess the tree species that can be potentially impacted by the establishment of the LRT the proposed LRT trace was divided into 6 sections, namely:

- ≠ LRT Depot to Malabe,
- ≠ Malabe to Koswatta,
- ≠ Koswatta to Battaramulla,
- ≠ Battaramulla to Borella Junction,
- ≠ Borella Junction to Floating Market, and
- ≠ Floating Market to Fort Station.

A tree survey was carried out on 12th August and 26th September 2017 in each of these sections and the trees observed on either side of the LRT trace were identified and recorded along with the height and GBH (Girth at Breast height in cm) for each tree observed. Refer to Annex H for the detailed list of trees recorded in these 6 sections along with the GBH and height of each of the trees recorded.

Altogether, 652 trees belonging to 82 species have been identified along the proposed LRT route. However, it should be noted that the extent of impact (how many trees will be affected) is difficult to determine at this stage. This can only be assessed once the LRT track is finalized and the exact ROW has been determined because even if the trace shifts by few meters the impact can change completely (from pruning to uprooting or vice versa). Approximately 64% of the identified 652 trees that is likely to be impacted by the proposed LRT comprise of exotic species (417 trees represented by 44 species). These 652 trees included 1 endemic tree (*Dipterocarpus zeylanicus;* Hora) and 234 (37%) native trees represented by 37 species. Refer to Annex H for a detailed list of trees that is likely to be impacted by the proposed LRT in the six sections surveyed long with the GBH and height of each tree and their value.

The 652 trees that is likely to be impacted by the proposed LRT included 1 tree species that is listed as Nationally Endangered (*Diospyros ebenum*; Ebenum - 2 trees), 1 tree species that is listed as Nationally Vulnerable (*Pericopsis mooniana*; Nedun - 1 tree) and 3 tree species that are listed as Nationally Near Threatened (*Dipterocarpus zeylanicus*; Hora - 1 tree, *Lagerstroemia speciosa*; Murutha - 17 trees and *Madhuca longifolia*; Me - 18 trees).

With respect to use value the 84 species that are likely to be affected by the establishment of the proposed LRT, comprise of 29 species that has timber value, 15 species that are considered as fruit trees, 7 species that are listed as ornamental plants, 3 species that can be used as vegetables, 4 species that provide multiple uses, 1 species of medicinal plant, 1 species of spice value, 1 species of religious value (refer to Section 3.3.4 for a detailed description of the distribution of these trees and stakeholder perceptions) and 2 species that can be used as fodder.

3.4.6 Landscape

The ROW of the LRT passes mainly along the centre line of the main roads. The first three sections of the ROW from the LRT depot to Battaramulla have a high green cover and accounts for about 52% of the trees affected by the proposed project. The remaining three sections accounts for the other 48% of the trees affected. The total removal of trees are expected in the first three segments while in the remaining three sections mostly pruning is expected as the trees are located on the periphery of the proposed ROW.

3.4.7 Protected Areas

There are two wetland sites, Sri Jawardenapura-kotte and Thalangama Tank, in close proximity to the project affected area that have been designated as protected areas under the Fauna and Flora Protection Ordinance and National Environment act respectively.

Sri Jawardenapura Bird Sanctuary, with an extent of 449 ha has been declared in 1985 as a sanctuary[2] considering the value of this area as a wetland ecosystem that supports high species diversity, especially aquatic birds and three globally endangered mammal species, namely fishing cat (*Prionailurus viverrinus*), otter (*Lutra lutra*) and Purple-faced langur (*Semnopithecus vetulus*). It also serves as a high security zone for the Sri Lanka's parliament.

The Thalangama Environmental Protection Area (EPA)[3] comprises of Thalangama Tank and its command area that spreads across a land extent of 118 ha. The Thalangama tank is an ancient irrigation tank managed by the Department of Irrigation. The EPA has been declared in 2007 due to the high biodiversity supported by the Thalangama tank. Altogether, 110 plant species including three endemic species, three threatened species and five near threatened species as well as 174 faunal species including 16 endemic species, six threatened species and five near threatened species have been recorded in the Thalangama tank and associated marshes. Therefore, it is one of the

wetlands within Colombo Metropolitan Area that supports high biodiversity. The tank is also used as a roosting and breeding site by large number of aquatic birds.

The proposed LRT trace passes through the periphery of these two protected (see Figure 3.16) areas and therefore does not have a significant impact on either of these protected areas.

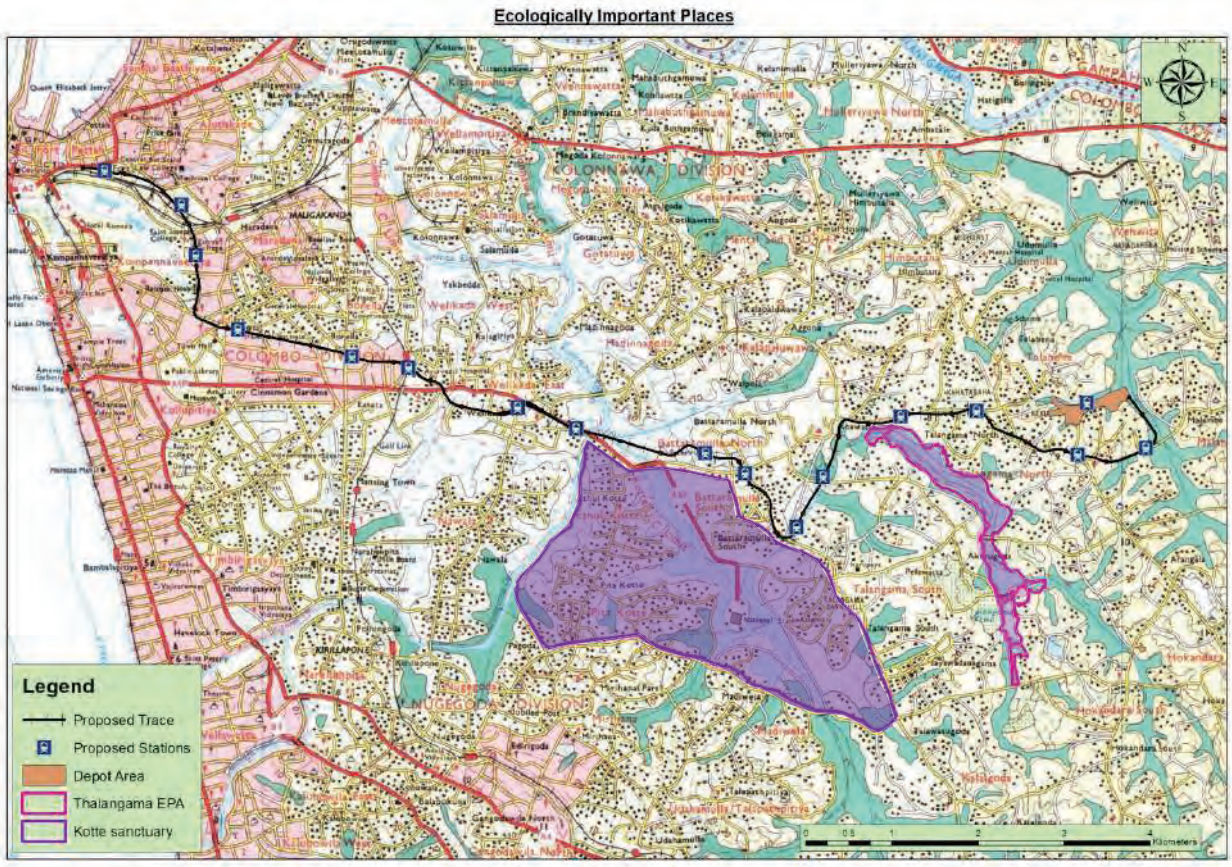


Figure 3.16 Protected Areas along the LRT Route

3.4.8 Rare, threatened and endemic species

The plants recorded in the project affected area included 3 endemic, 3 nationally threatened and 5 nationally near threatened plant species (see
Table **3-20**).

Table 3-20 Threatened, Near Threatened and Endemic Flora

Family	Scientific Name	Common English Name	NCS	Origin
Araceae	*Lagenandra praetermissa*	Ketala	LC	E
Dipterocarpaceae	*Dipterocarpus zeylanicus*	Hora	NT	E
Ebenaceae	*Diospyros ebenum*	Kaluwara	EN	N
Leguminosae	*Pericopsis mooniana*	Nadun	VU	N
Linderniaceae	*Lindernia ciliate*		NT	N
Lythraceae	*Lagerstroemia speciosa*	Murutha	NT	N
Rhizophoraceae	*Carallia brachiate*	Dawata	NT	N
Rubiaceae	*Oldenlandia auricularia*	Geta Kola	VU	E
Sapotaceae	*Madhuca longifolia*	Me	NT	N

Note: CR-Critically Endangered, DD-Data Deficient, EN-Endangered, LC-Least Concern, NT-Near Threatened, VU-Vulnerable

Altogether four endemic faunal species, six threatened species and five near threatened species were observed in the project affected area (Table 3-21).

Table 3-21 Threatened, Near Threatened and Endemic Fauna

Family	Scientific Name	Common English Name	NCS	Origin
Hesperiidae	Parnara bada	Smallest Swift	NT	N
Nymphalidae	Ideopsis similis	Blue Glassy Tiger	VU	N
Hesperiidae	Telicota bambusae	Dark Palmdart	VU	N
Libellulidae	Orthetrum luzonicum	Marsh Skimmer	NT	N
Libellulidae	Orthetrum pruinosum	Pink Skimmer	NT	N
Libellulidae	Neurothemis intermedia	Paddyfield Parasol	NT	N
Libellulidae	Rhodothemis rufa	Spine-legged Redbolt	NT	N
Coenagrionidae	Onychargia atrocyana	Marsh Dancer	VU	N
Aplocheilidae	Aplocheilus dayi	Day's killifish	EN	E
Cyprinidae	Dawkinsia singhala	Filamented barb	LC	E
Colubridae	Dendrelaphis schokari	Schokari's bronze back	LC	E
Cercopithecidae	Semnopithecus vetulus	Sri Lanka Purple-faced langur	EN	E
Felidae	Prionailurus viverrinus	Fishing cat	EN	N

Note: CR-Critically Endangered, DD-Data Deficient, EN-Endangered, LC-Least Concern, NT-Near Threatened, VU-Vulnerable

CHAPTER 4 Impact Assessment

4.1 Noise and Vibration Impacts

4.1.1 Noise Impacts

(1) Construction stage

Construction of railway structure and station

During construction, noise levels would increase in the vicinity of the construction site. The major sources of noise pollution during construction are the noise generating activities at the construction site, including pilling, excavation or compaction. Although the noise from construction activities will be significant, the effect would be temporary. Table 4.1 presents noise level of construction activities.

Table 4.1 Approximate noise levels of construction equipment

Construction equipment	Noise level (dB(A))
Excavator	113
Earth driller	97
Crawler Crane	98
Truck Crane	110
Bulldozer	104
Backhoe	107
Tractor shovel	107
Clamshell	97
Macadam roller	100
Tire roller	94
Asphalt paver	102
Concrete mixer	101
Concrete pump car	105

Source:JICA study team

Using the values given in**,** noise levels generated from the equipment in construction works were calculated. Noise levels experienced in the vicinity of working places (noise source) is given by the following equation and predicted noise level generated from construction work is shown in Table 4.2.

$$L = Lw - 20\log(r) - 8dB(A)$$

Where,
L = Noise level at a distance of r (m) from the noise sources (dB (A))
Lw = Noise power level of noise source (dB (A))
8dB(A)= Noise level at l m from the noise source

In addition, the combined noise level generated from the operation of several construction machineries is given by the following equation;

$$L = 10\log(\frac{10^{L1}}{10} + \frac{10^{L2}}{10} + \cdots + \frac{10^{Ln}}{10})$$

Where,
L = Combined noise level (dB (A))
L1, L2,…, Ln=Noise level of each equipment (dB (A))

Table 4.2 Predicted noise level generated from construction works

Construction type	Major Tasks	Activity	Equipment	Noise power level (dB(A))	Predicted noise at Project boundary	Cumulative noise level (dB(A))	With Noise Barrier Fence
LRT general elevated structure/ station	Structure construction	Concrete placement	Concrete pump car	105	77.0	78.5	68.5
			Concrete mixer	101	73.0		
		Pilling	Crawler Crane	98	70.0	85.0	75.0
			Excavator	113	85.0		
		Temporal work/ sheet pile	Crawler Crane	98	70.0	82.5	72.5
			Truck Crane	110	82.0		
			Earth driller	97	69.0		
		excavation/ filling	Backhoe	107	79.0	82.0	72.0
			Tractor shovel	107	79.0		
	Road work	clearance/ excavation	Bulldozer	104	76.0	77.8	67.8
			Macadam roller	100	72.0		
			Tire roller	94	66.0		
		Roadbed work	Macadam roller	100	72.0	73.0	63.0
			Tire roller	94	66.0		
		Pavement	Macadam roller	100	72.0	76.5	66.5
			Tire roller	94	66.0		
			Asphalt paver	102	74.0		
LRT crossing over reservoir	Temporal bridge	Construction road/temporary bridge placement	Bulldozer	104	76.0	86.5	76.5
			Tractor shovel	107	79.0		
			Crawler Crane	98	70.0		
			Excavator	113	85.0		
	Base structure	temporal work	Excavator	113	85.0	86.2	76.2
			Crawler Crane	98	70.0		
			Backhoe	107	79.0		
			Clamshell	97	69.0		
	Upper structure	Concrete placement	Truck Crane	110	82.0	83.6	73.6
			Concrete pump car	105	77.0		
			Concrete mixer	101	73.0		

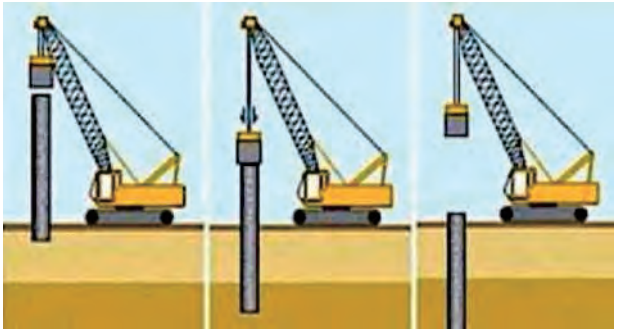
Construction type	Major Tasks	Activity	Equipment	Noise power level (dB(A))	Predicted noise at Project boundary	Cumulative noise level (dB(A))	With Noise Barrier Fence
		Pavement	Macadam roller	100	72.0	76.1	66.1
			Asphalt paver	102	74.0		
Depot	Depot	Levelling/excavation	Backhoe	107	79.0	83.0	73.0
			Tractor shovel	107	79.0		
			Bulldozer	104	76.0		
		Pilling	Crawler Crane	98	70.0	85.0	75.0
			Excavator	113	85.0		
		structure construction	Concrete pump car	105	77.0	78.5	68.5
			Concrete mixer	101	73.0		
		levelling/ pavement	Bulldozer	104	76.0	79.3	69.3
			Macadam roller	100	72.0		
			Tire roller	94	66.0		
			Asphalt paver	102	74.0		

Source: JICA study team

Noise associated with construction works will be high when several equipment and machineries are used at the same time. Thus, during construction works, surrounding communities may be disturbed since noise levels tend to exceed the permissible day time limit (75dB (A)), stipulated in Sri Lanka's noise regulation. With the use of noise barrier fence (3m height), noise level can be reduced by up to 10 dB. Therefore, by using the noise barrier fence, noise levels from most of the construction activities can be managed to meet noise standards.

Construction of Depot

The Depot will be an elevated structure consisting of slab and pile foundation. Several piling activities will be conducted simultaneously, which would create cumulative noise impact. The pilling activities will be carried out using a drop hammer with crawler crane. In hammer piling, a hammer, with approximately the weight of the pile, is raised a suitable height in a guide and released to strike the pile head (refer to Figure 4.1).



Source: The Constructor Civil Engineering Home

Figure 4.1 Hammer piling

The elevated structure will be composed of 120 units. Each unit has a dimension of 50m x 20m. As an estimate, there will be 4 to 5 contractors, which will construct the Depot area simultaneously and each contractor will work at each unit. Therefore, 4 to 5 piling activities will

be conducted simultaneously to construct each 50 x 20 unit.

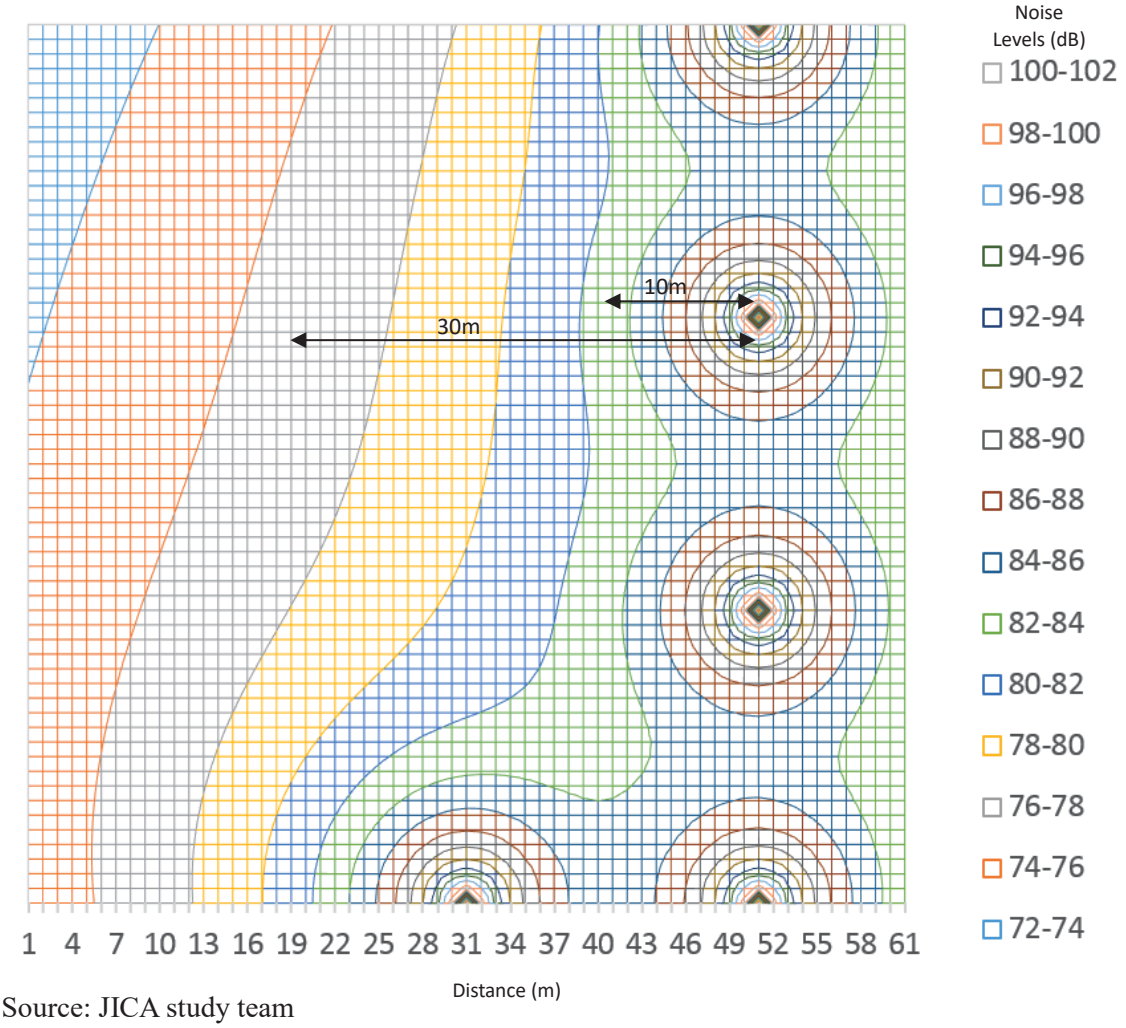
For noise prediction for the construction at Depot area, assumptions are listed in Table 4.3 below.

Table 4.3 Assumptions for Modelling of Cumulative Vibration Impacts

Item	Unit
Maximum noise level from piling activity	97.9dB[1]
Number of piling per day	3 piles
Number of hit per piling	80 times
5 piling activities are conducted simultaneously	-

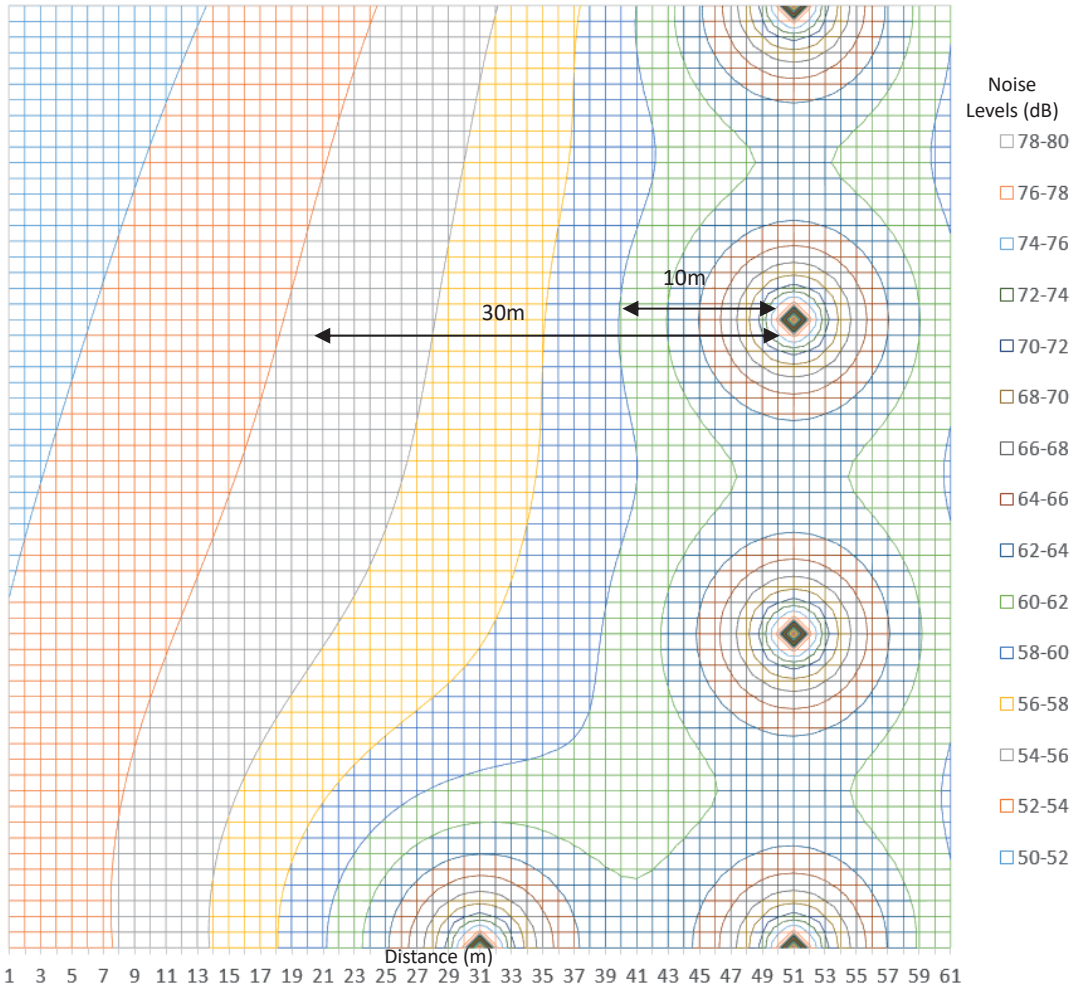
Source: JICA Study Team

The cumulative noise level is calculated using same formula used in above calculation. The noise contour of cumulative noise level is shown in Figure 4.2 for maximum noise level and in Figure 4.3 for average noise level.



Source: JICA study team

Figure 4.2 Cumulative maximum noise level (Lamax)at Depot area



Source: JICA study team

Figure 4.3 Cumulative average noise level (Laeq)at Depot area

Noise level at the closest residential area, which is about 10m from the noise source, is expected to be around 61dB for average noise level (Laeq) (average of 12 hours in day time) and about 84dB for maximum noise level (Lamax). The expected average noise level of 61 dB (Laeq) is below CEA standard for construction activity at daytime (75dB (A). There is no limit stipulated for Lamax in Sri Lanka.

It is important to consider that the duration of construction work at each unit will be approximately 1 month (no work during night-time and weekend). Thus, exposure such noise level at a certain area will be 1~2 months. As the construction moves forward from one zone to the next one, noise level at a certain area will be reduced. Considering that the working unit is 20 m x 50m, the noise source will move at least 20m far away after the completion of piling activity at one unit. This means that after completion of the first unit and the piling activity will move forward by 20m, the noise level at the closest residential area will be 77dB(Lamax) for maximum noise level and 55dB (Laeq) for average noise level.

Although the noise level from the construction activity at Depot area will meet the noise limit (Laeq), appropriate mitigation measures will be implemented to minimise the disturbance to the residence around the area. The mitigation measures are described in the mitigation chapter (Chapter 5).

(2) Operational stage

During operation, noise generated from the LRT depends on volume, speed, and the type of vehicle. Generally, an increase in volume, speed or vehicle size will increase traffic noise levels. Vehicular noise is a combination of noises from the engine and tyres. Noise impact from the LRT operation was examined with reference to "Proposal of a Prediction Model for Noise of Conventional Railway, Noise Control Engineering 1996, Institute of Noise Control Engineering, Japan" and "EIA report for Kita-Osaka railway extension project, Osaka Prefecture".

1) Noise Standard

Due to the unique characteristic of noise, noise standard specific for railway noise is normally set up for those countries with an established railway system. Since there is no such rail way noise standard in Sri Lanka, noise level guidelines for railway in in Japan (Japan Noise Guideline) and in Australia (NSW Noise Guideline) have been used as reference for this study.

As discussed in both guidelines, noise levels from the LRT would relatively have a constant in magnitude when a train passes by. Average noise level (LAeq) metric represents the equivalent continuous noise level over a specific time period. However, as discussed in the Australian guideline, LAeq metric by itself is not an adequate predictor of the potential noise level that may disturb people. Thus, it is proposed to also use LAmax to addresses the maximum noise level due to individual pass-by events and to account for the potential disturbance from such individual events (NSW EPA, 2013). Based on these guidelines, a noise standard for this project is set as Table 4.4.

Table 4.4 Noise Standard for LRT project

Noise Standard dB (A)			
Metric	Day (7am – 10pm)	Night (10pm – 7am)	Evaluation point
LAmax	80*	80*	Residential receiver
LAeq	60**	55**	12.5m from center of railway system at 1.2m height

Source:
*Rail Infrastructure Noise Guideline, Environmental Protection Agency in New South Wales (2013)
**Manual for noise measurement of general rail, Ministry of Environment, Japan (2010) and Rail Infrastructure Noise Guideline, Environmental Protection Agency in New South Wales (2013)

In order to confirm the compliance with Noise standard set for LRT project, the following noise assessment studies were conducted (Table 4.5).

Table 4.5 Approach for noise assessment

No	Subject of noise assessment	Methodology
1	Noise prediction against LRT Peak noise level (LA_{max})	Review of actual noise monitoring result for noise level of similar elevated LRT system in Japan
2	Noise prediction Equivalent noise level (L_{Aeq})	Use of noise modeling software (IMMI)

Source: JICA study team

2) LRT Peak noise level (LAmax)

In order to evaluate the noise impact expected from the proposed LRT system and to compare with the established noise standard, expected noise level from the LRT system was studied. Measured average peak noise

level (LAmax) of some elevated railway system in Japan are described in Table 4.6. The measurement point was 12.5m from the centre of Railway system and at 1.2m above the ground, in accordance with noise level guideline in Japan. Calculated peak noise levels range between 68 ~74dB with speed of 38 ~73km/hr. These values are below the noise standard for noise peak level (80dB). Considering that average speed of proposed LRT for most of the route would be between 35 ~40dB, the LRT peak noise level would be similar or below than the examples in Japan. Therefore, it is expected that LRT Peak noise level would be maintained below noise standard.

Table 4.6 Approach for noise assessment

Railway system	Location	Structure	Speed (km/hr)	Peak Noise(dB)	Noise Standard(dB)
Keihintohoku-line	NakaRokugo	Elevated	-	70.0[1]	80
Tokyu-Oiamchi-line	Nakanobe	Elevated	58	74[2]	
Keio Inokashira-line	Kichijyoji	Elevated	38	73[2]	
Toei Mita-line	Itabashi Sakashita	Elevated	60	68[2]	

Source:
1 Railway noise monitoring result for Tokaido line and Keihintohoku-line in 2012(Tokyo prefecture)
2 Railway noise monitoring result in Tokyo in 2008 (Tokyo prefecture)

3) Equivalent noise level (LAeq)

In order to calculate the equivalent noise level around the project area, noise modelling was performed with internationally recognized noise modelling software (IMMI). For noise modelling, LRT operational condition (speed, traffic volume), LRT structure and surrounding environment including building height was used as inputs.

a. LRT operational Condition

The number of train trips and expected speed are summarized in Table 4.7.

Table 4.7 The number of operated trains

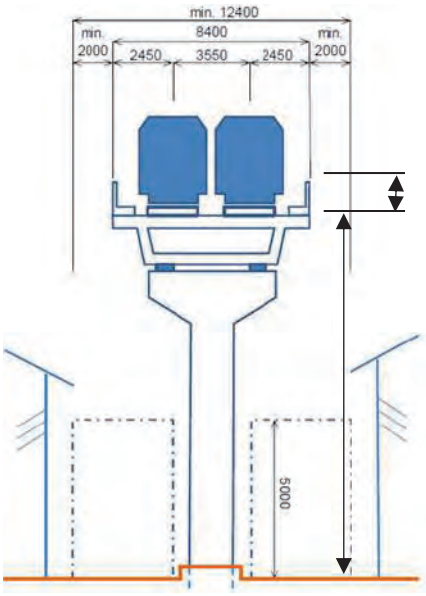
Track	Day Time		Night Time	
	Number	Km/hr	Number	Km/hr
Track -1	176	40	33	40
Track- 2	176	40	33	40

Source: JICA study team

b. Structural Condition

Structural characteristics of LRT system used for the noise modelling are described below (refer to Figure 4.4).

- ≠ Height from ground to noise source (railway): 10m
- ≠ With of elevated structure: 8.4m
- ≠ Slide wall (Noise Barrier): 1m



Source: JICA Study Team

Figure 4.4 Structural condition of LRT system

c. Modelling assumptions

Following assumptions were made during the modelling work.

- ≠ **Use the noise emission spectrum of a single Train according to "SRM LL" element library.**

This element library contains the Dutch calculation method for railway noise. IMMI implements the SRM II railway noise. SRM is an acronym for "Standard Reken Methode". This Dutch calculation method for railway noise is fully compliant with the requirements of both EU Directive 2002/49/EC and recommendation 2003/613/EU. Since the type of train implemented for LRT project is not yet decided, as a conservative approach, the category with highest noise emission was selected from the library and applied to the modelling Table 4.8.

Table 4.8 Noise spectrum of a single train unit at 40kmh.

Frequency/Hz	63	125	250	500	1000	2000	4000	8000
Sound Pressure Level/dB (A)	72.0	79.6	92.2	97.6	94.2	90.5	84.1	76.0

Source: IMMI

- ≠ **Environmental parameters**

The following values were considered as environmental parameters for the modelling.

Table 4.9 Environmental Parameters for Noise Modelling

Parameters	Day Time	Night Time
Temperature	31°C	26°C
Relative humidity	60%	80%

Source: ITI noise modelling report

d. Horizontal Grid Noise Map

Noise mapping study was conducted at following selected sections, considering its noise sensitivity. The predicted vertical noise contour maps were generated considering LRT operation

and buildings surrounding.

Table 4.10 Selected Locations for Noise Modelling

ID*	Section
L1	National Hospital Area-Ward Place
L2	Windsor Tower apartment Area– Ward Place
L3	Rajagiriya Ayuweda Hospital

To present the modelling results, colour contour noise maps were generated with 5dB steps for selected locations. The horizontal grid calculation is performed at a height of 1.2m from the ground level in accordance with Japan's noise guideline.

Noise contour maps are shown in Figure 4.5 up to Figure 4.10 below. Based on the results, noise propagation highly depends on the presence of obstacles such as buildings – particularly, the location and geometry. Most buildings located near the LRT lines have average noise levels below 60dB (A) at day time and bellow 55dB (A) at night time – both levels are below the applicable noise standard. However, some areas along Sri Jayawardenapura mawattha is predicted to have noise level of 60-65dB.

Source: ITI noise modelling report

Figure 4.5 Noise Mapping at National Hospital-Ward Place: Day time

Source: ITI noise modelling report

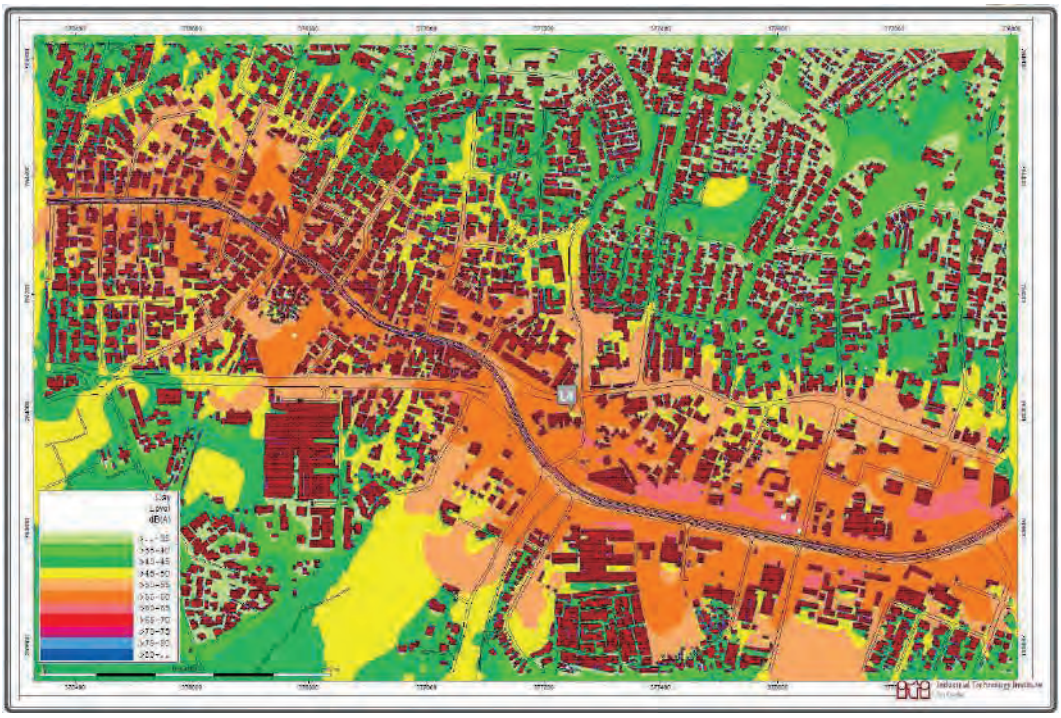
Figure 4.6 Noise Mapping at National Hospital-Ward Place: Night time

Source: ITI noise modelling report

Figure 4.7 Windsor Tower apartment – Ward Place: Day time

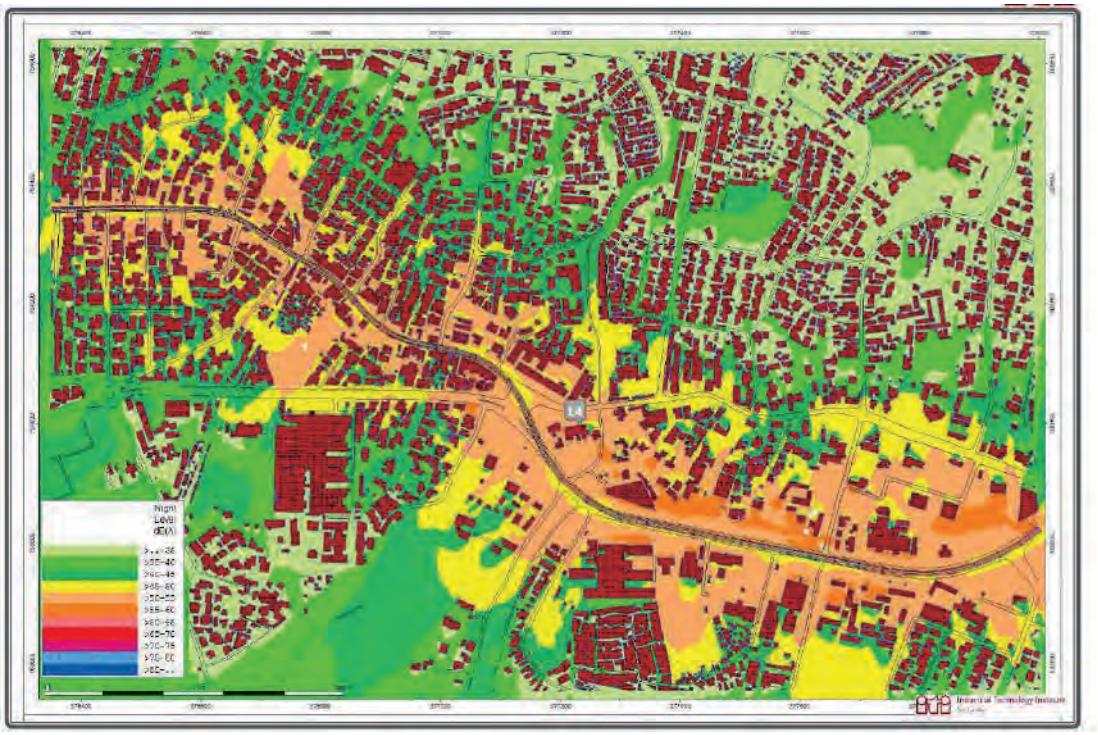
Source: ITI noise modelling report

Figure 4.8 Noise Mapping at Windsor Tower apartment: Night time



Source: ITI noise modelling report

Figure 4.9 Noise Mapping at Rajagiriya Ayuweda Hospital Day time



Source: ITI noise modelling report

Figure 4.10 Noise Mapping at Rajagiriya Ayuweda Hospital Night time

e. Prediction Result: Vertical Noise Map

The LRT noise of the equivalent noise level (LAeq) is predicted for the following cases at various receiving points. The results are shown in the Table 4-11 and Table 4-12 below. Vertical noise mapping results are presented in Figure 4.11 up to Figure 4.14.

≠ Without building

≠ With building (height of receptor is up to 16.2m (level of 5th floor of the building))

≠ Receptor point is 8m from Center of LRT

≠ Receptor point is 12.5m from Center of LRT

Table 4.11 Predicted Noise Level without Building nearby LRT structure

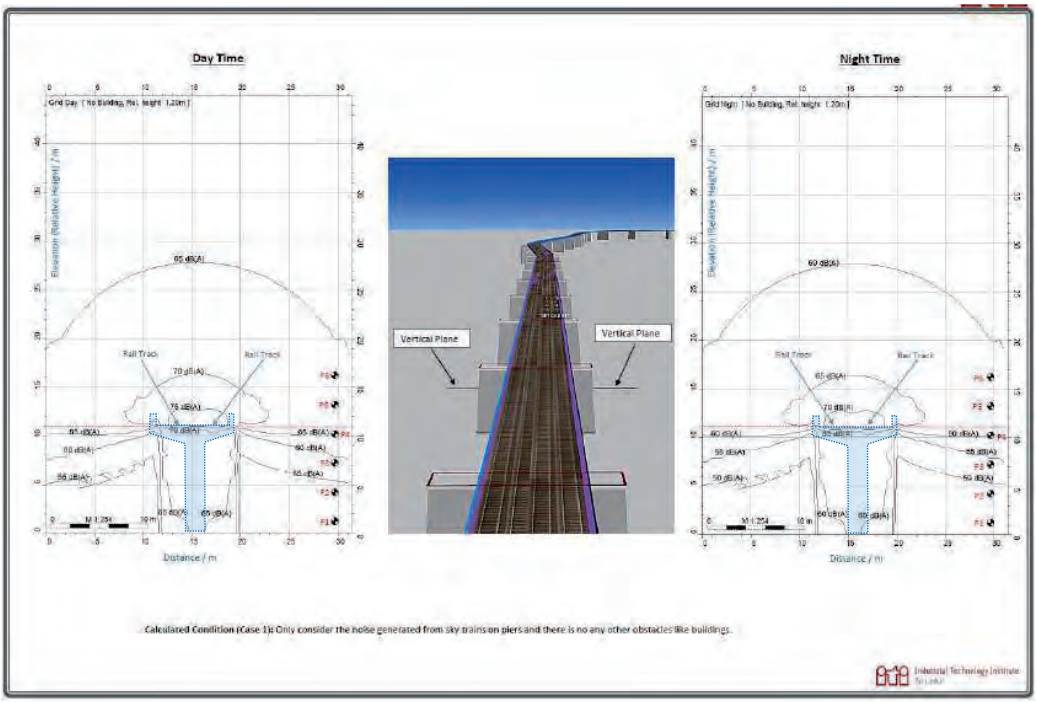
Height of receptor	Noise level at 8.0m from Center of LRT(LAeq)		Noise level at 12.5m from Center of LRT(LAeq)	
	Day	Night	Day	Night
1.2m	52.6	47.6	52.1	47.1
4.2m	55.0	50.0	54.1	49.1
7.2m	57.4	52.4	56.2	51.2
10.2m	65.9	60.9	65.1	60.1
13.2m	67.5	62.5	69.0	64.0
16.2m	65.8	60.8	67.2	62.2
Noise standard	NA	NA	60	55

Source: ITI noise modelling report

Table 4.12 Predicted Noise Level with Building nearby LRT structure

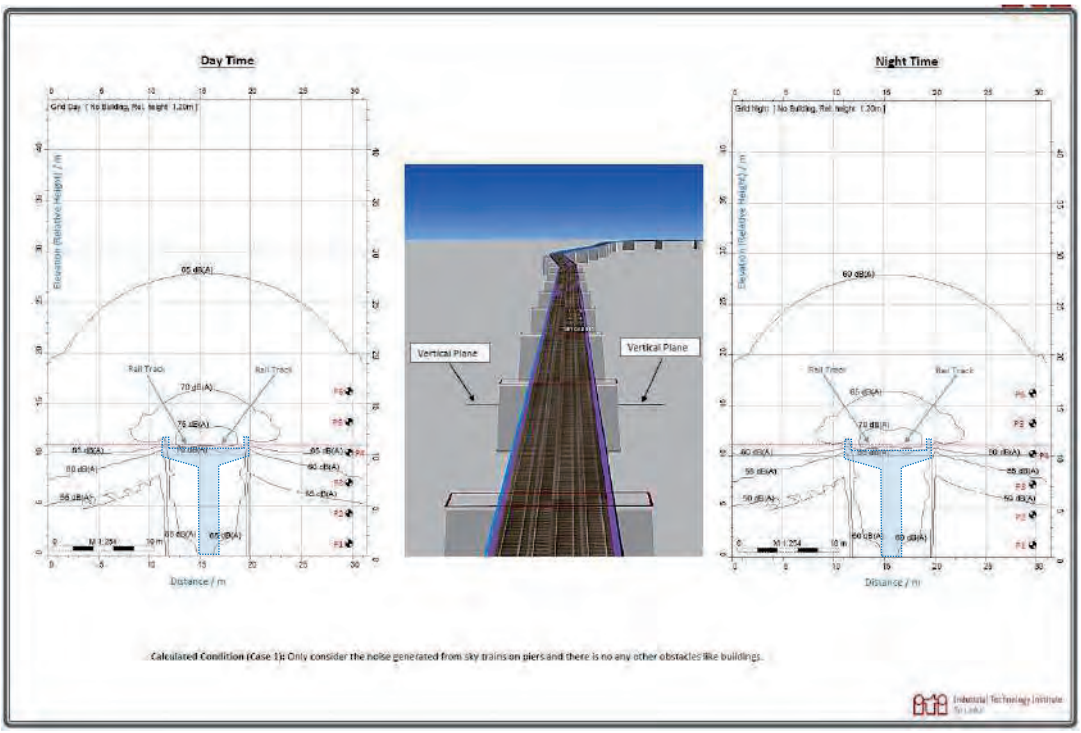
Height of receptor	Noise level at 8.0m from Center of LRT(LAeq)		Noise level at 12.5m from Center of LRT(LAeq)	
	Day	Night	Day	Night
1.2m	52.1	47.1	52.6	47.6
4.2m	54.1	49.1	55.0	50.0
7.2m	56.2	51.2	57.4	52.4
10.2m	65.1	60.1	65.9	60.9
13.2m	69.0	64.0	67.5	62.5
16.2m	67.2	62.2	65.8	60.8
Noise standard	NA	NA	60	55

Source: ITI noise modelling report



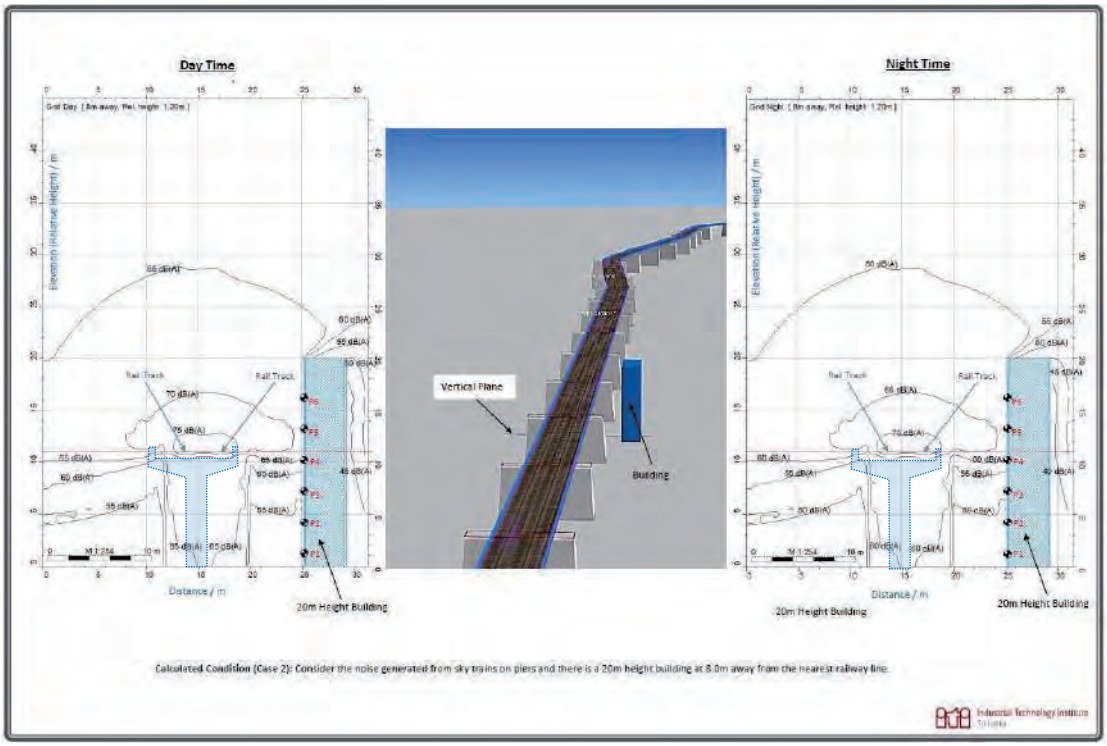
Source: ITI noise modelling report

Figure 4.11 Vertical Noise Mapping: reception point at 8.0m



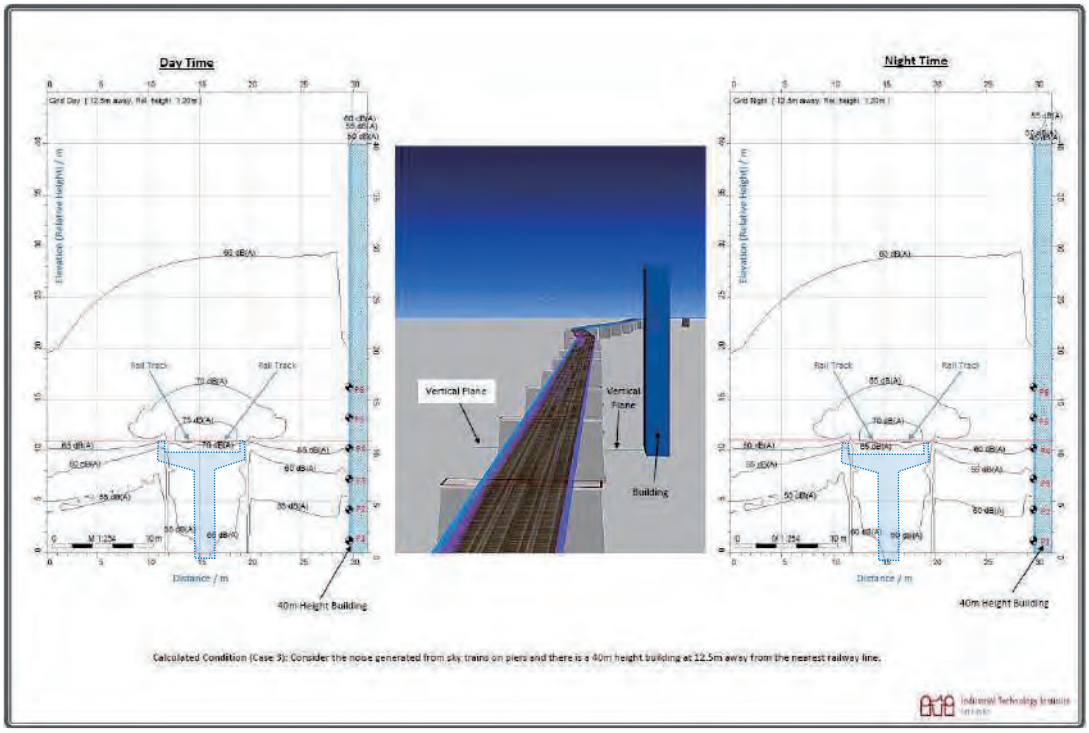
Source: ITI noise modelling report

Figure 4.12 Vertical Noise Mapping: reception point at 12.5m



Source: ITI noise modelling report

Figure 4.13 Vertical Noise Mapping: Building located at 8.0m from Centreline of Track



Source: ITI noise modelling report

Figure 4.14 Vertical Noise Mapping: Building located at 12.5 m from Centreline of Track

4) Cumulative noise level

Cumulative noise level at each noise measurement location was analysed, while taking into consideration the baseline noise level measured for this study in order to evaluate the impact on noise sensitive receptors. Receptors along the LRT route include hospitals, schools, and temples. Cumulative noise level was calculated based on the expected noise level from LRT alone and baseline noise level.

Noise level of 52.6dB (Day) and 47.6dB (Night) (LAeq) was used for LRT noise for this study. The result is shown in Table 4-13.

The result indicates that cumulative noise level exceeds Noise Standard except N3 of Denzil Kobbekaduwa Mawatha. Exceedance can be attributed to high background noise level. The expected increase over the existing ambient noise due to LRT operation is approximately between 0.01 and 1.35 dBA. An increase of 3dB is generally considered to be negligible, which means that the noise impact at at the noise sensitive receptors would be minor. Also, Sri Lanka National Noise regulation (Schedule II (Regulation 3) stipulates that an increase of 3dB from baseline noise level is allowed, if the background noise level already exceeds the limit.

Table 4.13 Cumulative noise level

ID	Location	Background Noise Level (dB (A))		LRT Noise level (dB (A))		Cumulative Noise Level(dB (A))		Increased Noise level		Noise Standard	
		Day	Evening	Day	Evening	Day	Evening	Day	Evening	Day	Evening
N1	Asokarama Road, Malabe	72	72	52.6	47.6	72.05	72.02	0.05	0.02	60	55
N2	Malabe Boy`s School	73	69	52.6	47.6	73.04	69.03	0.04	0.03	60	55
N3	Denzil Kobbekaduwa Mawatha	57	57	52.6	47.6	58.35	57.47	1.35	0.47	60	55
N4	JiyathaUyana	63	65	52.6	47.6	63.38	65.08	0.38	0.08	60	55
N5	Jayawardana ramaya Temple	67	62	52.6	47.6	67.15	62.15	0.15	0.15	60	55
N6	Windsor Tower,Ward place	75	75	52.6	47.6	75.02	75.01	0.02	0.01	60	55
N7	National Hospital	72	69	52.6	47.6	72.05	69.03	0.05	0.03	60	55

Source: JICA study team

5) Conclusion on Noise Impact

≠ During the operation of the LRT project, noise level from LRT is expected to meet the noise level standard for railway for both Peak noise level (LAmax) and Equivalent noise level (LAeq).

≠ In terms of vertical noise level, noise level at receptor point may exceed the level of noise standard both for 8m and 12.5m at a height above 10.2m. However, noise sensitive receptors along the LRT route are not high-rise facilities. Most of the high-rise facilities along the LRT route are commercial buildings.

≠ For cumulative noise impact (Baseline and LRT noise level), expected increase over the existing ambient noise due to LRT operation is expected to be between 0.01 and 1.35 dBA. An increase of 3dB is generally considered to be negligible

≠ There might be a disturbance especially around noise sensitive areas as identified in Chapter 3.2.4, including six hospitals including General hospital and Ayurveda hospital, five schools and four education institutes. Therefore, implementation of noise mitigation measures at these areas such as noise barriers or double pane windows shall be considered during detail design stage for the use of operational stage.

4.1.2 Vibration Impacts

(3) Construction stage

Depending on construction methods and activities employed by the prospective Contractor, there could be vibration impacts especially on the buildings adjacent to the LRT route. Vibration could be generated through the following activities:

- boring the road surface to excavate the trench for the pillars,
- vibrators used to compact concrete and
- construction equipment travelling, launching of beams/girders.

In general, ground vibration from construction activities very rarely reach the level that can damage structures but can reach levels that are audible and can be felt by humans close to the construction site.

1) Human exposure

Prediction method

The prediction model for human exposure developed in the Technical Handbook for Environmental Impact Assessment of Roads (2007) is applied. Vibration transmits from a source to a receiving point according to the following formula:

$$L_{(r)} = L_{r_o} - 15log_{10}\frac{r}{r_o} - 8.68\alpha(r - r_o)$$

Where,
$L_{(r)}$ = Vibration level at receiving point (dB)
$L_{(ro)}$ = Vibration level at reference point (dB)
r = Distance from a source (e.g. construction machinery) to receiving point (m)
r_o = Distance of reference point (=5m)
$\boldsymbol{\alpha}$ = Internal damping ratio

Vibration level at reference point

The power levels of main construction machinery are shown in Table 4.14

Table 4.14 Vibration Level of Construction Machinery and Damping Ratio

Construction machinery	Vibration level at reference point (dB)	Internal Damping Ratio
Pile drivers (hydraulic pile hammer)	81	0.01
Rock drilling (soft rock)	64	0.001
Slope surface splay	48	0.01
Asphalt pavement	59	0.01

Source: JICA study team

Location of vibration source and receiving point

The construction machinery is assumed to be set on the center of the track. During the construction temporary wall (3.0m) will be set at the edge of the ROW (construction limit). The height of the receiving point is 1.2m.

Results of the prediction and evaluation

The projected vibration levels during construction were calculated based on the formula above. The results are shown in Table 4.15. In Sri Lanka, there is no standard for human perspective threshold.

Table 4.15 Vibration Level of Construction Machinery and Damping Ratio

Construction work		Distance from the edge of the ROW to Receiving point (m)					Perspective threshold of vibration for human (dB)[2]
Activity[1]	Vibration level (dB)	0	5	10	15	20	
Pile drivers	81	77.6	75.0	72.3	70.1	68.3	55
Rock drilling (soft rock)	64	60.9	58.5	56.2	54.4	53.0	
Slope surface splay	48	44.6	42.0	39.3	37.1	35.3	
Asphalt pavement	59	55.6	53.0	50.3	48.1	46.2	

Source: : JICA Study team
1 Technical Handbook for Environmental Impact Assessment of Roads, 2007
2 Technology and Laws Regulation for pollution control, 2000" Japan Environmental Management Association for Industry"

It is predicted that vibration from the operation of pile driver and rock drilling may be felt at areas close to the construction site as these exceed the human perspective threshold.

2) Vibration effects on building contents

Construction of railway structure and station

In Sri Lanka, the maximum permissible vibration levels for different type of structure are regulated by the Central Environmental Authority. In general, transportation and construction sources generate vibration levels within the range of 10-30Hz, normally close to 15Hz. [1] Applying this range in an intermittent method, the applicable vibration permissible limits for different types of structures, are shown in the table below.

The potential vibration impacts (at different points away from the source) from major construction activities with relatively high vibration levels (e.g. piling and rock drilling), have been identified through secondary sources. These estimates are also presented in Table 4.16 below to compare with the applicable vibration standards.

Table 4.16 Vibration levels of construction activities

Construction activity	Predicted vibration level (mm/s)	Maximum permissible vibration level (mm/sec) [3]			
		Structure type (see below reference)			
		Type1	Type2	Type3	Type4
Pile Driver[1]	8.5mm/s at 5m 4.5mm/s at 10m 1~3mm/s at 15~20m	15.0	8.0	4.0	1.0
Rock drilling[2]	4.5mm/s at 5m 1.30mm/s at 10m 0.4mm/s at 20m				
Type1	Multi story buildings of reinforced concrete or structural steel, with filling panels of block work, brick work or precast units not designed to resist earthquakes				
Type2	Two-storey domestic houses and buildings constructed of made of reinforced block work, precast units, and reinforced floor & roof construction, or wholly of reinforced concepts or similar, not designed to resist earthquakes.				
Type3	Single and two storey houses and buildings made of lighter construction, using lightweight materials such as bricks, cement blocks etc, not designed to resist earthquakes.				
Type4	Structures that, because of their sensitivity to vibration, do not correspond to those listed above 1,2 & 3, & declared as archeologically preserved structures by the Department of Archaeology				

Source: CEA
1 comparison between ground vibrations induced by impact piling and boing piling (ICSBE2016-231)
2 EIA report for Northern Expressway Environmental Impact Assessment Report
3 Maximum Permissible interim Vibration levels (Intermittent, Vibration Frequency at 10-50Hz), CEA

Considering that construction activities that may cause vibration, will be conducted at the center of roads, the distance of the vibration source to the structures is more than 10m. Based on the results in Table 4.17, rock drilling will not have significant impact on all Types of structures (except Type 4). However, piling activities my impact Type 3 and 4 structures. For some sections, such as Malabe area where road width is narrow, the distance could be around 8m. Based on Table 4.17, it is predicted that vibration levels from construction activities will exceed the maximum permissible limit for Type 3 and 4 structures and potentially for Type 2.

Overall, special care must be taken for old, fragile buildings located along the LRT route, which may have cultural/historical significance (preserved structure by the Department of Archaeology).

Construction of Depot

As mentioned in the Noise section, several piling activities will be conducted to construct the numerous columns that would support the elevated depot structure. This means around 4-5 pile drivers may be operated at the same time. Similar to noise impact, simultaneous piling activities may generate vibration impacts that may affect humans and surrounding built structures.

In order to estimate the vibration impacts on surrounding areas of simultaneous piling activities, modelling has been conducted. Cumulative vibration impact was calculated with the following assumptions (refer to Table 4.16 below).

Table 4.17 Assumptions for Modelling of Cumulative Vibration Impacts

Item	Unit
Vibration level at point source (e.g. pile driver)	90dB
Distance of nearest receptor	10m
Internal damping ratio	0.01
Five machineries (e.g. pile driver) operate at the same time	-

Note: Internal damping ration is 0.01-0.02 for clay; 0.02-0.03 for sand-silt
Source: JICA Study Team

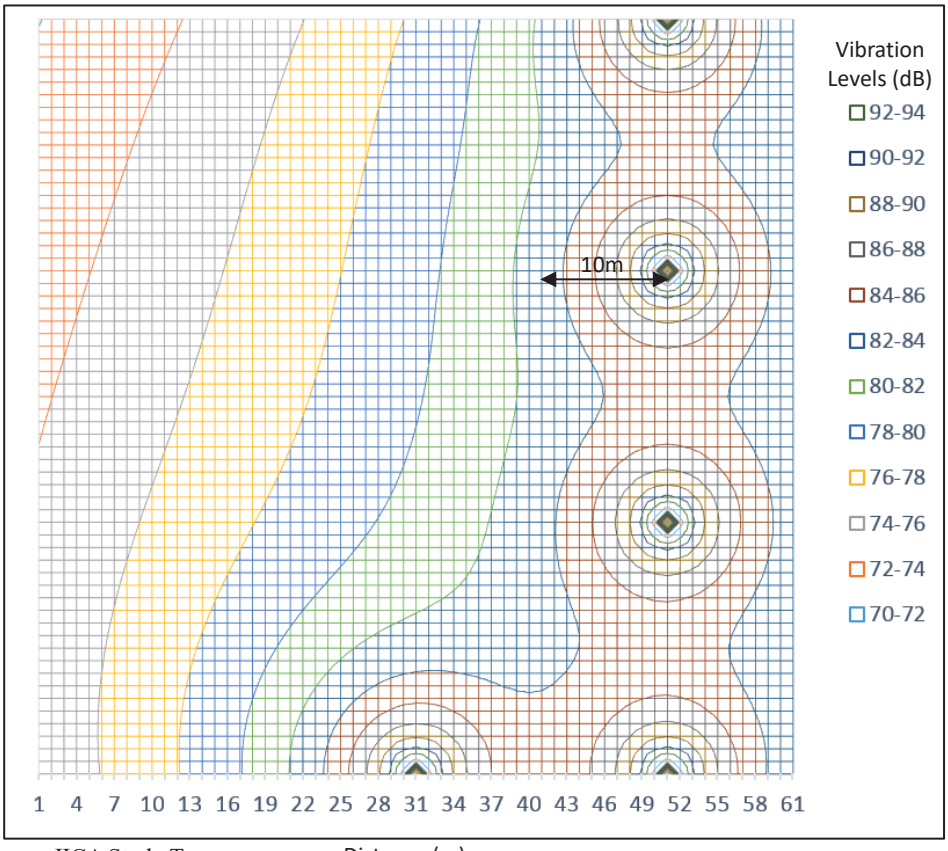
The following equation was used to calculate the cumulative vibration level (similar to combined noise level):

$$L = 10\log(\frac{10^{L1}}{10} + \frac{10^{L2}}{10} + \cdots + \frac{10^{Ln}}{10})$$

Where,
$L_{(sum)}$ = Combined vibration level (dB)
L1, L2,…, Ln = Vibration level of each equipment (dB)

The modelling results are presented in Figure 4.15. The Figure maps out vibration levels of surrounding areas, assuming that five pile drivers operate at the same time. It is assumed that piling activity would create 90dB vibration at 10m from the source for a conservative approach[3]. However, the vibration acceleration values had to be adjusted to remove human perception intrinsic in the measurement methods.

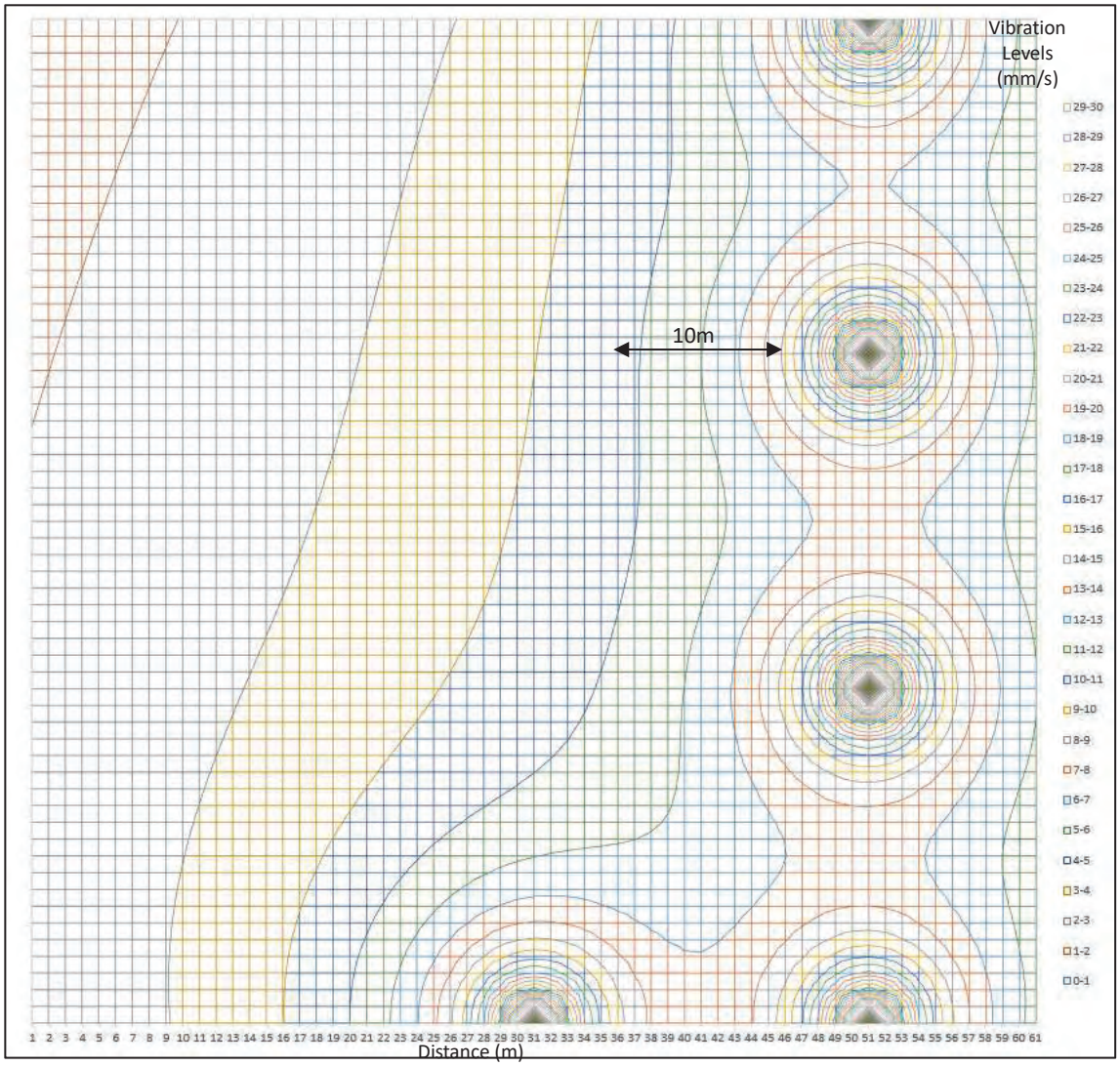
Based on the results, vibration level at 10m away from the vibration source (middle of circle), is expected to be approximately 82-84dB (refer to Figure 4.15). This result reflects the combined impact from the other piling activities. This range is higher than the human perceivable vibration level.



Source: JICA Study Team

Figure 4.15 Cumulative vibration level (dB) at Depot area

It is important to note that vibration limits stipulated in the Sri Lankan regulation is in terms of peak particle velocity (PPV) in the unit mm/s (millimetre per second). This measurement takes into account movement of particles in the ground and the potential impacts on built structures. The modelling results have been converted into PPV unit (mm/s)[4] in Figure 4.16. According to the results, vibration levels at a distance of 10m from the vibration source (both in the left and right side of the source in the Figure) is estimated at approximately 5-7 mm/s, depending on the location.



Source: JICA Study Team

Figure 4.16 Cumulative vibration level (mm/s) at Depot area

As mentioned earlier, transportation and construction sources generate vibration levels within the range of 10-30Hz, normally close to 15Hz.[3] Thus, the same regulatory limits (Intermittent, Vibration Frequency at 10-50Hz) apply (Refer to Table 4.18). As a result, it is estimated that simultaneous piling activities will not have significant impacts on Type 1 and 2 structures that are located within 10m from the piling activities. However, these activities may affect Type 3 and 4 structures located within the 10m boundary.

Table 4.18 Vibration levels of simultaneous piling activities

Construction activity	Predicted vibration level (mm/s)	Maximum permissible vibration level (mm/sec)			
		Structure type (see below reference)			
		Type1	Type2	Type3	Type4
Simultaneous piling activities	9mm/s at 5m 6mm/s at 10m 3~5mm/s at 15~20m	15.0	8.0	4.0	1.0

Type1	Multi story buildings of reinforced concrete or structural steel, with filling panels of block work, brick work or precast units not designed to resist earthquakes
Type2	Two-storey domestic houses and buildings constructed of made of reinforced block work, precast units, and reinforced floor & roof construction, or wholly of reinforced concepts or similar, not designed to resist earthquakes.
Type3	Single and two storey houses and buildings made of lighter construction, using lightweight materials such as bricks, cement blocks etc, not designed to resist earthquakes.
Type4	Structures that, because of their sensitivity to vibration, do not correspond to those listed above 1,2 & 3, & declared as archeologically preserved structures by the Department of Archaeology

Source: Maximum Permissible interim Vibration levels (Intermittent, Vibration Frequency at 10-50Hz), CEA

Overall, special care must be taken for old, fragile buildings located close to the boundaries of the proposed depot, particularly those structures made of lightweight materials.

(4) Operation Stage

During the operation of the LRT, there will be vibration on the pillars and on the foundation which could be transmitted to nearby buildings through ground. In order to evaluate the vibration impact from the proposed LRT system, vibration measurement conducted for elevated railway systems in Japan is analysed. The measurement point was at 12.5m from the centre of the railway system and at 1.2m above the ground according with noise level guideline in Japan. Measured average vibration levels are as shown in Table 4-19.

According to the measurement result, peak vibration level was measured at 49-57dB with speed of 38-60km. considering that the average speed of the proposed LRT is between 35 and 40dB, it can be inferred that vibration generated by the LRT would be below than the results of railway systems in Japan.

Therefore, the vibration level from the LRT operation may potentially exceed the perceptible threshold of humans (55dB). However, it is expected that there would not be significant adverse vibration impact on surrounding structures.

Table 4.19 Vibration levels of elevated railways in Japan

Railway system	Location	Structure	Speed (km)	Vibration level (dB)	Perspective threshold of vibration for human (dB)[3]
Keihintohoku-line	NakaRokugo	Elevated	-	49[1]	55
Tokyu-Oiamchi-line	Nakanobe	Elevated	58	51[2]	
Keio Inokashira-line	Kichijyoji	Elevated	38	57[2]	
Toei Mita-line	Itabashi Sakashita	Elevated	60	54[2]	

4.2 Traffic Impacts

4.2.1 Road Link Capacity Reduction during Construction Stage

The proposed LRT line will be constructed on the major arterial roads in Colombo. More than 50% of these roads have a daily vehicle traffic demand in excess of 50,000 vehicles. There are several critical intersections that will be affected during construction activities that may have network wide impacts. These critical intersections include the following:

- ≠ T.B.Jaya Mw – D.R.Wijewardene Mw intersection
- ≠ Ibbanwala junction
- ≠ De Soysa Circus / Lipton Circus
- ≠ Borella junction
- ≠ Ayurveda junction
- ≠ Rajagiriya junction
- ≠ Koswatta junction

A minimum of 10m wide work-zone is required for the LRT construction. Therefore, most road links may lose 2-3 lanes as per standard lane width allocation. Assuming, temporary lane widths of 2.7m given and 1-2m of sidewalks allocated for temporary roadways during the construction stage, the number of temporary lanes that can be provided on the affected roads is estimated and given in Table 4-20. This would require removal of the existing centre medians, if any and relocation of road side utility facilities. The temporary lane allocation would result in a capacity reduction of 30%-50% on most roads.

Table 4.20 Temporary lane number estimation

Link	Road Name	Road type	No. lanes	Carriageway (m)	Sidewalk (m)	Width avail. During construction	Temp. lanes
1	Colombo-Batticaloa Highway	Median Separated	6	23	> 4.0m	15	5
2	Olcott Mawatha	One way	5	20	2.0-4.0m	12	4
3	Olcott Mawatha	Divided	5	21	> 4.0m	13	4
4	W E Bastian Mawatha	One way	2	12	2.0-4.0m	3	1
5	T B Jayah Mawatha	Divided	4	18	> 4.0m	10	3
6	Dr Colvin R de Silva Mawatha	Median Separated	4	13	2.0-4.0m	5	1
7	Ward Place	Divided	4	13	2.0-4.0m	5	1
8	Cotta Rd	Median Separated	4	15	2.0-4.0m	6	2
9	Sri Jayawardenepura Mawatha	Median Separated	6	24	2.0-4.0m	16	5
10	Battaramulla Rd	Median Separated	4	14	2.0-4.0m	6	2
11	Denzil Kobbekaduwa mawatha[1]	Undivided	4	12	> 4.0m	9	3
12	Kaduwela Rd[1]	Divided	2	10	2.0-4.0m	7	2

Source: JICA study team
Note: 1. Assume LRT line will be constructed on the edge of the carriageway and 5m on the existing roadway will be utilized for construction work zone.

The traffic impact assessment given in **Annex C** has identified the following traffic impacts.

- ≠ Temporary road lane allocation for LRT construction will reduce the traffic capacity of the affected roads by 30%-50%.
- ≠ Seven road intersections will be affected by the LRT construction
- ≠ There will be road network wide impacts in addition to the impacts on individual roads because of the impacts on road intersections.

The LRT route will run along already congested roads and will mostly be built at the center median. Thus, traffic congestion may worsen due to the construction activities at the centre of the road. Vehicular speed at the road intersections and in the roads on which the LRT will be constructed will slow down. In addition, the following impacts are expected to the traffic impact described in above chapter, following impact is expected.

- ≠ **Pedestrian movement**

Pedestrian movement will be severely hindered during construction work; therefore it is recommended to ensure walkable paths maintained for pedestrian movement especially where high density of pedestrian flow is expected at areas such as Olcott Mawatha, Liberty Roundabout, and Borella junction area.

Also, there are one access road and one-foot path across the proposed depot area in Malabe which may not be passable during construction.

- ≠ **Bus operation**

Bus operations are likely to be severely affected during the construction work. This includes the recently established bus lane operation in some corridors. It would be required to change the operational path of some bus routes and to relocate bus stops etc. The most critical segment would be that of Olcott Mawatha and Bastian Mawatha where the bus and rail terminals are located.

4.2.2 Road Link Capacity Reduction During Operation Stage

After completion of the LRT balance road lane width will become insufficient in some of the narrow road segments such as Battaramulla Pannipitioya Road and Denzil Kobbekaduwa Mawatha. Because of the insufficient lane width there will be traffic congestion.

4.2.3 Improvement of Traffic Condition in off LRT Routes During Operational Stage [Positive Impact]

Once the LRT project becomes operational, traffic condition is expected to improve in Colombo. The phase one of the LRT covers Colombo – Malabe corridor, which will be extended to cover other corridors in the future. This corridor has the potential to cover/cater to densely populated suburban areas (i.e. Kaduwela DS – 252,041 population, Homagama DS – 237,905, Seethawaka – 113,807, Maharagama – 196,423, Sri Jayawardhanepura Kotte – 95,506 population 2012). Thus, the LRT project would trigger the development of a more comprehensive public transport network, providing a solution to the traffic issue in Colombo. The LRT project can offer an alternative mode of transportation for the public and this can contribute to address and ease traffic congestion in Colombo.

4.3 Landscape Impacts

4.3.1 General

In terms of the aesthetic aspect, the impacts of the LRT project on existing and proposed land use pattern of the catchment area, built and natural environment as a whole depends on the: (i) degree of "Sensitivity" of the existing built and natural environment, and (ii) the design of the LRT

system. Since currently the project is under feasibility study level, this evaluation is focused on the sensitivity of the road trace. Analysis of aesthetic aspects is somewhat questionable and arguable because the outcomes are mostly associated with value judgments. Therefore, the following criteria were used for the analysis;

- ≠ Existing and proposed land use pattern;
- ≠ Scenic areas (built environment, natural environment, and the streetscape route trace);
- ≠ Existing and proposed urban re-generation projects/programmes;
- ≠ Existing road widths; and
- ≠ Objectives of the urban development plans/urban designs of the project areas

In order to establish details of the impacts, the road trace is divided into 12 sections as illustrated in Figure 4.17 to Figure 4.20. These figures show land use zoning plans prepared by the UDA for the respective urban areas (i.e. City of Colombo, Sri Jayawardhanapura Kotte, and Kaduwela Municipal Council Areas). The division of the road trace into 12 sections is based on its sensitivity.

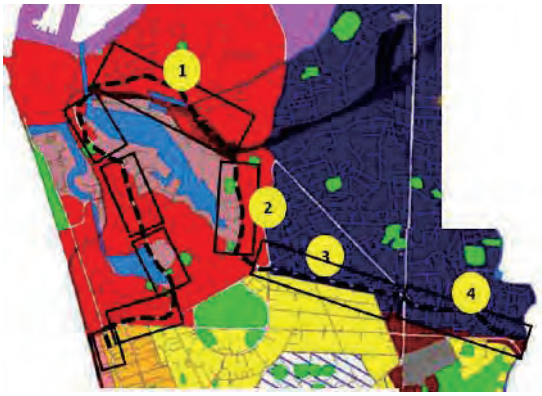


Figure 4.17 From Fort to Cotta Road (Ayurveda Hospital Junction)

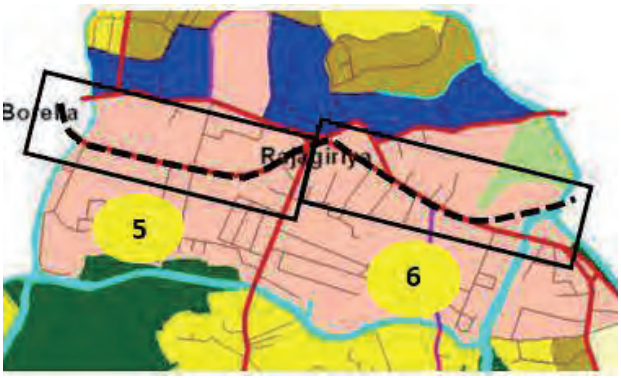


Figure 4.18 From Ayurveda Junction to Rajagiriya Junction, and to Ethulkotte Junction

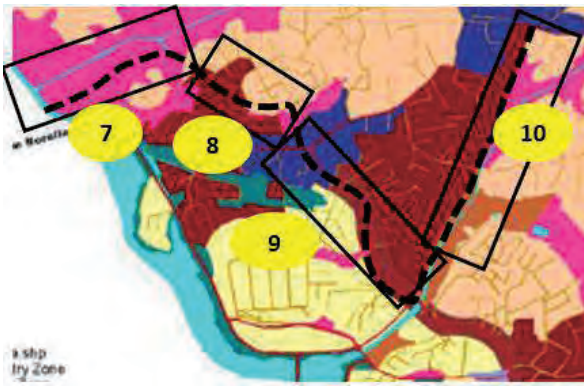


Figure 4.19 From Ethulkotte Junction to Koswatta Junction

Figure 4.20 From Koswatta Junction on Kaduwela Road up to LRT Depot

4.3.2 Landscape Aesthetic Degradation

Section 1 –Olcot Mawatha – Bastian Mawatha

Description	At present, the only interesting urban landscape along this stretch is the Floating market and the integrated water front recreational facility along Bastian Mawatha. The LRT will create additional "built up congestion atmosphere to the only open space available at this location.
Degree of impact	Minor
Mitigation Measure	Introduction of hard and soft landscaping elements along the LRT trace to make it integrated with the Beira Lake open space, using compatible hard and soft landscape materials.

Section 2 - Along Railway Yard up to Gamini Hall Junction

Description	No impacts can be enumerated due to the current status of the built and natural environment of the area.
Degree of impact	Minor
Mitigation Measure	The design team of the LRT need to study the proposed urban regeneration programme for Pettah and Railway Yard and integrate the LRT with the proposals of the urban regeneration programme.

Section 3 – T.B. Jaya Mawatha

Description	No major impacts on the existing aesthetic environment are enumerated.
Degree of impact	Minor
Mitigation Measure	This section of the LRT should require more landscaping, mostly soft landscaping to reduce the impact of the existing congested urban environment, particularly on the left hand side of the road. Thus, the LRT on this section can make a positive impact.


Photos of Ward Place

Section 4 - Hyde Park Corner via Union Place around Lipton circle, ward place to Borella Junction-

Description	**From Union Place to Lipton Circus** The modern LRT structure particularly its height will have an adverse impact on the heritage buildings, particularly that of the Victoria Memorial Building of the hospital. An overhead pedestrian bridge constructed across the Ward Place near the Victoria Memorial Building earlier was removed due to the adverse negative impact it created on the heritage value of the Victoria Memorial Building. **Ward Place** The surface coverage of the road by the LRT structure will reduce and shrink the openness of the ward place built and natural environment. Most of the buildings along the road are 2-3 floors. Therefore the proposed structure will cover most of the buildings completely horizontally and vertically.
Degree of impact	**Major**
Mitigation Measure	▪ From the Baptist Church to the Victoria Memorial building, the LRT structure should follow a compatible architecture design to make it a part of such buildings and light colours to reduce its bulkiness. (i.e. arches similar to those structures) ▪ The section on Ward Place should be of light colours with softer landscaping to match the existing built environment.

Section 5 - Cotta Road- Borella Junction to Ayurveda Junction

Description	Other than the visual impacts for the residents and workers of high rise buildings at the LRT level, no major visual impacts can be enumerated, as this section of the LRT trace does not have a special character.
Degree of impact	Minor
Mitigation Measure	▪ The LRT along this stretch can be designed to add special character to the area. It needs to be made the most prominent and unique physical feature in the streetscape and thereby it will wipe off the gloomy nature and the sense of deadly feeling along the stretch. A mix of both hard and soft landscaping can be considered, with more attention to soft landscaping. The structure can have brighter colours so as to highlight its image.

Photo of Sri Jayawardenepura Mawatha close to Rajagiriya (Welikada)

Section 6 - Sri Jayawardenapura Road (Ceremonial Drive) - From Ayurveda Junction to Rajagiriya Junction

Description	The special characters maintained along the road will be destroyed. Further, Sri Jayewardenepura Road is not planned for public transport (other than the recently introduced bus lane) and presently all buses are operating along Cotta road running parallel to Sri Jayawardenapura road.
Degree of impact	**Major**
Mitigation measure	▪ During the detailed design stage, all the efforts must be taken to see the possibility of using Cotta Road up to Rajagiriya Junction, which is suitable from all the aspects other than the need for acquisition of several commercial buildings for striating the LRT line. ▪ In case of the inability to continue the trace on Cotta road, special care needs to be taken to design this section of the road to be an integral element of the Ceremonial Road. The design team in addition to the Design Engineers, should include Urban Planners, Urban Designers, Architects, Landscape Architects, and Lighting Experts. The final outcome should not be alien but enhance the existing built and natural environment.

Section 7- Continuation of Sri Jayawardenapura Road (Ceremonial Drive) Rajagiriya Junction to Ethul kotte Junction

Description	**Rajagiriya Junction – to the length of the overhead bridge** ▪ The existing overhead bridge (under construction) has covered a considerable space of the carriageway and another structure parallel to it will totally discard the urban form maintained along Sri Jayawardeanapura Mawatha. Rajagiriya Junction will turn into a stressful built environment for all the road uses (pedestrians and motorists) including the inhabitants living along the road sides. **Bridge at Etul Kotte Junction** ▪ The scenic value of Diyawanna Oya Water Body together with the recently developed "Diyatha Uyana" Public Outdoor Recreational Space is considered a treasure of the Urban Environment of the new city. The balance between the natural environment and the built environment in Diyatha Uyana is adequately maintained. Although the public administrative buildings recently developed within the "Sethsiripaya" area has distorted the balance to some extent, since there is a clear demarcation of such built environment from Diyatha Uyana, the impact of those administrative buildings is not largely noticed ▪ In the trace of the LRT, it is proposed to cut across the lake and to get connected behind the administrative complexes at Battaramulla. This trace will destroy the scenic value of Diyatha Uyana and the additional built environment will be "too much" to destroy the present balance.
Degree of impact	**Major**
Mitigation measure	▪ During the detailed design stage, all the efforts will be taken to see the possibility of placing the LRT route along Buthgamuwa Road, behind "Diyatha Uyana". ▪ In case of the inability to continue the trace on Buthgamuwa road, special care needs to be taken to design this section of the road to be an integral element of the Ceremonial Road and Diyatha Uyana Open Space. The design team in addition to the Design Engineers, will include Urban Planners, Urban Designers, Architects, Landscape Architects, and Lighting Experts. The final outcome should not be alien but enhance the existing built and natural environment of Ceremonial Access, Diyawanna Lake and Diyatha Uyana.

Section 8-.Behind administrative complexes- Battarmulla Junction

Description	No major negative impacts can be enumerated as the area consists of largely built environment related to administrative uses with adequate open spaces.
Degree of impact	Minor
Mitigation measure	▪ The designers should give a consideration the existing administrative buildings and the proposed UDA developments in the area in the design of the LRT structure, to integrate "open space" character to the LRT, as it runs through a heavily built up area.

Section 9- Thalawathugoda road (Battaramulla Junction to-Three Bridge Junction)

Description	No significant negative impacts can be enumerated. One of the potential visual impacts would be the LRT running at the same elevation of most of the buildings (both residential and commercial) as nearly 30%-40% of the residential and commercial buildings are of two storied structures. Thus, having a visual impact of both horizontally and vertically. On the other hand, a positive impact can be expected if the LRT design and its landscaping elements will enhance the built environment of the trance.
Degree of impact	Minor
Mitigation measure	▪ Maintaining a balance of soft and hard landscaping.

Section 10-. Densil Kobbakaduwa Mw (Three Bridge Junction to Central Environmental Authority (CEA)

Description	The Aesthetic value of the stretch will be modified. The LRT will require to cut off branches of the trees as currently the branches of the trees on either side meet together at the centre making a green umbrella.
Degree of impact	**Major**
Mitigation measure	▪ Design the LRT structures of this section to resemble the existing "green" character of the stretch. ▪ Underneath the LRT trace and on the structure, introduce "soft Landscaping" with native flora. ▪ The colours of the columns and the other elements of the super structure should represent the colours of the natural environment. ▪ In order to compensate the trees that will be affected, new trees of medium to large size with at least medium sized canopies should be plated in appropriate locations. ▪ Investigate the possibility of using the service road maintained by the UDA adjoining the public administrative buildings for the LRT.

Photos of Denzil Kobbakaduwa Mawatha

Section 11 -Kaduwela Rd - IT Park Junction (from Koswatha Junction onwards)

Description	No major negative visual impacts can be enumerated. Visually a positive feature in the built environment can be expected if the LRT design can be made an interesting element of the built environment. Most of the buildings along the road are 2-3 floors. Therefore, the proposed structure will cover most of the buildings completely horizontal and vertical. There are nearly 20%-30% of residential and non-residential uses. The occupants will become victims of the direct visual impact living in the immediate impact zone as permanent residence. However, there has been a tendency to convert residential uses to non-residential uses due to the high land/rental values on the road front properties. Thus, the residential uses on the "impact zone" will experience a gradual diminish.
Degree of impact	Minor
Mitigation measure	▪ The designers need to make this part of the LRT an integral part of the whole urban corridor with integrated design interventions – architectural, landscaping, lighting etc.

Section 12- - Chandrika Kumaranatunge Mw (IT park junction to LRT station)

Description	Since this part of the road has only two lanes without a centre median, the LRT will cover the whole road width. It may further require further reclamation as to accommodate the columns of the SLR a centre median needs to be created, which will result in widening the road more towards leftward, needing reclamation of the wetlands. However, there is road winding project proposed by RDA to 4 lanes. The LRT depot will cover a large extent of wetlands, even though it is constructed on stilts the impact on the aesthetic environment of the wetland cannot be conserved.
Degree of impact	**Major**
Mitigation measure	▪ Impact on landscape due to the presence of Depot can be mitigated through landscaping, such as planting trees around the structure of Depot. ▪ Special consideration will be given in the architectural design of the depot so that it would intersperse with the environment.

4.4 Health and Safety Impacts

4.4.1 Communities' health and safety degradation during construction stage

There are anticipated temporary health impacts such as increase of stress levels of commuters and residents living nearby construction sites. Other impacts that may affect community health include noise, vibration, dust generation that may cause respiratory diseases and accidents.

4.4.2 Occupational health and safety degradation during construction stage

The project is a major infrastructure development project that will involve a number of skilled and unskilled labourers. These workers will be working at site, manoeuvring heavy machinery and material. Risk of injuries and accident at the work site cannot be ignored.

The workers may have to use power tools in making the elevated structure and there are risks of accidents and injuries. The risk of fire and electrocution will also be considered at work sites during a major project.

Exposure of works in to hazardous fumes and flames is another occupational hazard during construction. Falling from heights may also happen if the workers do not use proper safety measures when working at heights above 2 m from ground level.

Stagnant water collected from rains and waste at construction sites may lead to spread of mosquitoes and flies and may increase the risk of spreading vector-borne diseases to workers and neighbouring communities. Unhygienic site conditions will lead to spread of domestic pests. Communicable diseases also need significant consideration due to the involvement of migrant labour.

4.4.3 Occupational health and safety during operational stage

There is a risk of accidents due to improper working practice such as maintenance work at depot and inspection of the LRT structure.

4.5 Socio-economic Impacts

4.5.1 Disruption to Livelihood and economic activities during Construction stage

During construction stage, disruption of the livelihood and economic activities of businesses which are located along the LRT route is expected. These businesses will get hampered because of traffic congestion, inability to park vehicles, and temporary loss and/or impedance of access to such business premises. Details of affected business premises are given in Section 4.2.6.

Minimising land acquisition and negative social impacts is one of the major considerations in determining the LRT route. A total of 66 structures will be partially and fully affected and more than 80% of these are commercial buildings. The affected commercial places include all types of businesses: groceries, restaurants, well established vehicle sales, vegetable stalls etc.

The partially affected structures may have space to rebuild in the same land but, the fully affected structures must be relocated elsewhere. There are employees working in these commercial places. When the structures are partially affected, there will be temporary impact on the businesses and the employees may lose income temporarily. However, if the commercial places are fully affected and if they need to be relocated elsewhere, there can be permanent impact. The income of employees working in these commercial places will also be affected. They may have to find other jobs or will have to face difficulties until the businesses are re-established.

There will also be an impact on paddy lands where Depot is proposed in the Kaduwela DS division. Paddy land owners and tenant farmers may permanently lose their livelihood.

The Project may also impact people whose livelihood is linked with existing modes of transportation (e.g. 3-wheelers, bus operators) due to inaccessible roads and/or worsened traffic conditions.

4.5.2 Impact on livelihood during Operational Stage

The LRT project boosts regional economic activities along the route by providing an efficient mass transit system, which enhances workforce mobility from suburbs to centre of Colombo. In addition, presence of the stations will also attract future commercial development around the area.

While the LRT Project can increase connectivity of existing bus routes through multi-modal transport centers/hubs, it may pose as a competitor for existing transport operators (e.g. buses, 3-wheelers) in terms of servicing passengers/commuters.

4.5.3 Travel Time Saving [Positive Impact]

Once the LRT becomes operational there will be a significant travel time saving on the passengers.

4.5.4 Employment Generation [Positive Impact]

LRT will bring various employment opportunities during the construction and operational stages.

4.6 Impacts on the Biological Environment

4.6.1 Disturbance to Protected area

The proposed project will have no direct impact on the two protected areas, Sri Jawardenapura-kotte Bird Sanctuary and Thalangama EPA found in the project area as they were avoided by the design. However, there may be possibilities of indirect impacts.

4.6.2 Fauna and flora Disturbance

Altogether, 652 trees belonging to 82 species have been observed along the LRT route. These trees may be affected due to the construction of the LRT in the proposed trace. Approximately 64% (417 trees represented by 44 species) of the identified trees that are likely to be impacted by the proposed LRT comprise of exotic species, and about 37% (234 trees represented by 37 species) are native species. Among these, one endemic tree (*Dipterocarpus zeylanicus*), which is also nationally endangered, was identified along the LRT route. Since this species is a forest species observed in the dry zone of Sri Lanka, it is most likely a planted tree.

Around 89 tress along Denzil Kobbekaduwua Mawattha may need to be removed to give way to the LRT structure. Other trees along the route that may be affected will be trimmed or branches will be cut down. However, the exact impact on these three trees can be assessed only after the final ROW for the LRT has been established during the detailed design phase. Even though a large number of trees may be affected by the Project the impact on native flora is not significant because more than 64% of the identified trees are exotic species.

The LRT Project will be built within a highly urbanized and significantly altered environment. The area supports mostly common species of fauna associated with such urban habitats. As such, these species are highly adapted to disturbance and human presence. The Project will not have direct impacts on identified threatened fauna species (Fishing cat, Purple-faced leaf langur, and Eurasian otter). Also, no major avian movements were observed across the proposed light rain trace and road kills of birds are hardly recorded along the light rail trace. Thus, considering that the maximum speed of LRT is 80km/hour (average is about 40km/hour) the chances of bird strikes are likely to be near zero as these birds are highly habituated to live in a highly urbanized environment.

Overall, the impact of the project on flora and fauna in this region is negligible as the LRT route passes mainly near or on the road network.

4.6.3 Wetland Degradation

As described in section 3.3 wetlands are present in five locations of the LRT route. These are:

1) The section of the LRT route from the LRT Depot to Malabe-Kaduwela Road passing through herb dominated wetlands (mostly abandoned paddy fields) on to the left of the Madiwela East Diversion Canal
2) The section of the LRT route from Koswatta to Palan Thuna junction that passes through the lower end of the command area of the Thalangama tank that is a mosaic of tree dominated wetlands (woodlands), herb dominated wetlands (Marshes), water bodies with submerged or floating vegetation, open water bodies and tree-dominated terrestrial habitats.
3) The section of the LRT route from Battramulla to Pita Kotte junction that passes through the Diyatha Uyana, which is an open water type habitat

In addition, the proposed LRT depot will be located on a wetland that can be described as an

abandoned paddy land. The approximate area impacted is approximately 15 ha. The depot will be established as an elevated platform and therefore the entire wetland area will not be impacted by the proposed project. However, during the construction stage some sections will have to be filled in order to facilitate the construction activities. During the operational stage nearly 50% of the wetland will become shaded due to the elevated structure which will result in loss of species that prefer direct sunlight while shade loving species will benefit from the increased shade. The site does not contain any critical species such as threatened or endemic species and therefore, the proposed activity will not have a significant impact on the overall wetland biodiversity of the region.

LRT trace has been designed to pass over most of the other wetlands with little or no direct impact to wetlands as the construction work will take place mostly in the highland adjacent to the wetland except in few places. Therefore, the overall impact of the proposed project on aquatic habitats is negligible. Likewise, the terrestrial habitat that is affected mostly is the roadside vegetation that is a manmade habitat that supports only a few species that are highly adapted to withstand disturbance such as noise that may result due to construction work. Since, the LRT route will be based on an elevated platform and therefore, this will not result in habitat fragmentation or disruption of movement patterns of species. The only disturbance expected is at the places where stations and bases are erected to support the viaduct. However, the expected loss of habitat is less than a few hectares speeded over a large area. Thus, the proposed project will not have a significant impact on the aquatic and terrestrial habitats in the project affected area.

Photo of the Madiwela East Diversion Canal

4.7 Impacts to utilities such as water, electricity, telecommunication During Construction

4.7.1 Disruption to Underground Utilities

As the LRT pillars will be in the middle of the existing roads there is a possibility of damaging underground utilities such as electricity cables, telecommunication lines, sewerage pipes, storm water conduits and water supply lines. During the EIA study, the Project Proponent has been coordinating continuously with the line agencies relevant to the utilities i.e. Ceylon Electricity Board (CEB), Sri Lanka Telecom (SLT), CMC and National Water Supply and Drainage Board (NWSDB). The details of utilities (layout plans) are presented in **Annex G**.

4.7.2 Disruption to Overhead Utilities

Urban and commercial activities in the affected area are facilitated by all the infrastructure

facilities such as water, electricity, and telecommunication. As the LRT trace is going on an elevated structure, shifting of electricity and telecommunication lines may be required. The shifting and rearrangement of these electricity and telecommunication lines can make a temporary impact on the day today life of people near the project area. Majority of people in the project influential area depend on pipe born water and water lines can get damage during construction period due to excavations. This also can make a temporary impact to people in project area.

There are two high voltage transmission lines crossing LRT route, which need to be shifted or lifted up. One of them is 132kV transmission line, passing on Diyatha Uyana and the other is 22kV transmission line which run south/north direction and cross Malabe road.

4.8 Land Acquisition Impacts

4.8.1 Land Acquisition and resettlement of people and relocation of structures/ buildings etc. During Construction

(5) General

The proposed LRT will mainly traverse on existing major roads in four DS divisions in Colombo district. With the ribbon development in existing roads, a number of lands and structures will be affected. However, as the LRT will traverse on an elevated structure and will use existing roads as the corridor, the land acquisition will be minimal. Further, project had also taken measures to minimize displacement of people as much as possible by considering design alternatives.

(6) Project Impacts on Built Structures

There are approximately 66 built structures which will be partially and fully impacted by the project. The distribution of partially and fully impacted structures is presented in the Table below. It should be noted that only one residential houses will be impacted and around 80% of the impacted structures are commercial business premises.

Table 4.21 Structures that may be affected by the Project

DS Division	GN Division	Residential Structures		Commercial Structures		Total	
		Totally	Partially	Totally	Partially	Totally	Partially
Colombo	Fort	0	0	24	3	24	3
	Ibbanwala	0	0	1	3	1	3
Kaduwela	Kotuwegoda	0	0	0	1	0	1
	Subuthipura	0	0	2	6	2	6
	Battaramulla S	0	0	3	1	3	1
	Udumulla	0	0	2	0	2	0
	Malabe North	0	0	1	13	1	13
	Malabe West	1	0	2	3	3	3
		1	0	35	30	36	30
TOTAL						**66**	

Source: Socio-economic Survey (2017)

(7) Details of Affected Residents

There are only two residences, located in the proposed IT Park Station (Malabe West, Kaduwela DS Division), which may be fully affected by the Project. Although the residences will be affected, the owners still own surrounding properties (land and commercial building in front). One residential house is currently not being occupied because the owner is living abroad. Depending on the detailed design of the station, relocation of families may not be necessary.

(8) Details of Affected Business Units

Since structures along the JICA-LRT route are mostly commercial in nature, the Project will primarily impact business premises, along the route and areas near proposed JICA-LRT stations. It is estimated that approximately 100 business premises, 37 property owners, 73 tenants and approximately 455 employees will be affected by the project. The clusters of businesses which will be fully affected are located in Fort, Battaramulla, Palan Thuna Junction, Koswatta Junction, and West Malabe, including food and beverage stores, motor repair workshops, bank, car dealer offices and other commercial shops. The biggest cluster of small businesses is the government-owned commercial area with a lane of hotels, canteens and fruits stands, located near Fort Station.

(9) Details of Affected Paddy Lands

For the construction of the Depot and the IT Park Station at Malabe (IT Park Junction), partially abandoned and partially cultivated paddy lands in Kaduwela DS Division may be acquired. The 2 paddy land areas have an approximate total area of about 17 Ha (in Thalahena North, Thalahena North B, Malabe North & Malabe West GN Divisions in Kaduwela DSD).

According to the list of farmers which was received from the Agrarian Services Office in Malabe and from the socio-economic survey, there are approximately 41 paddy land owners and 5 tenants (Ande farmers). (Table 4-22)The total sum of family members of both paddy land owners and Ande farmers is estimated at around 116 persons. However, the actual number is more than this figure because the survey response rate was only 70-80%.

Table 4.22 Affected Paddy Field Owners and Tenant Farmers

DS Division	Total No of paddy land owners & farmers	No of affected paddy land owners		No of affected Renters ("Ande" Farmers)		Total land extent (Approximately)
		HHHs	Family members	HHHs	Family members	
Kaduwela	46	41 (37*)	99	5 (4*)	17	206,195m^2**

* No. of Persons Interviewed **Measurement based on preliminary design drawings.
Source: Socio-economic Survey (2017)

(10) Extent of Impact on Properties (Lands and Building Area)

The extent of project impact in terms of affected land is summarised in Table 4-23 below. Aside from the use of existing roads, the Project will require the use of approximately 254,000m^2(25.4 Ha) of land, which comprises of about 45,000m^2(4.5 Ha) government land, 8,000m^2(0.8 Ha) private land and 200,000m^2(20.0 Ha) agricultural land. It can be observed that a bulk of the land that needs to be acquired is the agricultural land for the proposed depot area.

It is important to note that figures presented are only indicative and are subject to change during the detailed design phase. Also, some buildings have multiple storeys, thus it is difficult to calculate the actual floor area of buildings/structures, which will be affected by the project.

Table 4.23 Extent of Impact on Affected Properties

DS Division	Estimated Area of Impact**(Ha)	Remarks
Colombo	2.5244Ha	Mainly SLR lands / structures
Sri Jayawardanapura - Kotte	0.0163 Ha	Patches of land at the corner of Rajagiriya flyover and before entering Diyawana Lake
Kaduwela	20.6195 Ha	Paddy lands for Depot & Station area (IT Junction)
	1.5786 Ha	Government land (e.g. Diyata Uyana, Sethsiripaya, Battaramulla, Lakviru Sevina corner)
	0.5105 Ha	Proposed Station area (high land only)
	0.095 Ha	Others (Land strips of either sides of the route and the extent of the Structures
Total	25.3444 Ha	

*

Measurements are based on preliminary design drawings
Source: Socio-economic Survey (2017)

(11) Impacts to Government Institutions and properties

The LRT trace traverses mainly on a few government owned properties, including those of Sri Lanka Railway Department (SLR), UDA and SLLRDC.

- ≠ SLR: LRT will cross the property of SLR around Fort station, where Multimodal Transport Hub (MmTH) has been proposed. LRT will consider the future Integration with MmTH.
- ≠ UDA: UDA owns the floating market at Pettah, Diyatha Uyana, and Lakviru Sevana.
- ≠ SLLRDC owns Diyawanna Lake

4.8.2 Socio-economic benefits During Operation [Positive Impact]

Although LRT project as any other development project bring negative impacts to small population, the project will bring benefits to the majority of the population living in Colombo district. A summary of benefits from the project is shown in Table 4-24.

The project will be a solution for the traffic in the Malabe corridor. Battaramulla is developing as the new administrative centre with many government departments located in Sethsiripaya, Suhurupaya and around Battaramulla city. The Proposed LRT project will facilitate these government employees, school children and other commuters to travel comfortably with less travel time. The suburb areas, Malabe, Jayawardanapura Kotte and Kaduwela will be developed with the project.

The proposed LRT project is electricity driven and this diversified mode of public transport will enhance the quality of the environment. There will be less of accidents and road safety will be improved. According to the results of the socio-economic survey (refer to Annex L), perceived socio-economic benefits are summarised in the Table below. Majority of the respondents believe that the travel time will be reduced, and public transport will be improved with the proposed facilities.

Table 4.24 Perceived Economic Benefits of the project for the community

Economic benefits	Frequency	Rating %
Reduce Travel Times	175	32.96
Develop Extra Income	92	17.33
Reduce Living Expectance Rate	91	17.14
Improve Commercial And Work Premises	83	15.63
Develop Infrastructure	67	12.62
Fuel Effectiveness	23	4.33

Source: Socio economic survey, August 2017

Table 4.25 Perceived Social Benefits of the project for the community

Social benefits	Frequency	Rating %
Improved Public Transport Facilities	174	29.85
Received a Comfortable Transport Services	168	28.82
Increase Security	122	20.93
Increase Demand For Surrounding Lands	57	9.78
Increase Land Value	48	8.23

Source: Socio economic survey, August 2017

The details of economic benefits are outlined in the extended cost benefit analysis in Chapter 6.

4.9 Neighbouring land users related Impacts

4.9.1 Impact on neighbouring land users due to Severance of Light during Operation

The proposed LRT runs through three local authority areas namely, Colombo Municipal Council (CMC), Sri Jayawardhanapura Kotte Municipal Council (SJKMC), and Kaduwela Municipal Council (KMU). Thus, the planning and building regulations related to light and ventilation requirements of buildings are governed by the development plans prepared by Urban Development Authority for these three local authority areas. Accordingly, the light and ventilation of buildings should be managed within the sites. However, when lands are located abutting public streets, the provisions are available to obtain light and ventilation from the public streets. The impact of LRT on the light and ventilation of the buildings located along the road is minimal due to the following reasons;

- ≠ The LRT runs on the centre of the existing roads, and all such roads consist of four lanes and pedestrian walks. At the deck level, the LRT will occupy approximately 7 meters wide strip that is the space of two lanes. Thus regarding planning and building regulations, there will be adequate space for the roadside buildings to get legal light and ventilation.
- ≠ The LRT from Fort to Ibbanwala junction will largely run from North to South direction. Some parts of the trance of this section (i.e. Bastian Mawatha, Railway Yard) are void of buildings. From Gamini Hall Junction to Hyde Park junction, buildings to the East occupy relatively large plots and mostly faces Beira lake and therefore will have undisturbed light and ventilation from the East. The buildings on the other side which occupy relatively two-story type which have been in the process

of redevelopment into high rise buildings and that will have adequate contacts with the East.

≠ From the Hyde Park corner onwards the LRT rout gradually deviates towards East-West Direction, where buildings on either side face North and South directions. Along the ceremonial road, due to the existence of wide building setbacks, there will not be a significant impact on light and ventilation.

≠ Since the LRT is an elevated structure, the natural ventilation for ground floor buildings will not be impacted. Further, since the LRT deck rests on columns between which wide void spaces are maintained, no significant impact on the light and ventilation can be expected.

4.10 Impacts due to Solid Waste

4.10.1 Erosion of excavated materials, construction materials etc. and spoil and other waste generated from construction activities during Construction Stage

As the LRT route mostly follows the existing tarred roads and there is no room to temporarily store excavated material as such will be disposed to a designated disposal site, the chances of erosion of excavated material is minimal.

The LRT Project will generate both solid and liquid wastes during construction and operation stages. These can affect the quality of surface water, groundwater, and soil, if not handled and managed properly. A more detailed discussion of wastes generated and the potential impacts to water and soil quality is given below.

Wastes generated during construction stage will mainly comprise of construction wastes (e.g. rubble, wood plants, metals), excavated soil, domestic wastes, and oil wastes. These wastes will be generated for the entire LRT route.

During the construction stage the waste will consist of mostly building rubble, excavated soil, and construction waste which will be generated all along the LRT route. It is estimated that around 60,000m^3 of excavated soil and rubble will be generated when constructing the LRT route and stations and around 80,000m^3 will be generated from temporary fillings that need to be removed after constructing the depot. However, it should be noted that at this stage it is difficult to estimate the exact amount of waste that will be disposed offsite. This will depend on materials that cannot be reused or recycled.

The waste generated during the construction stage will be of a temporary nature. Construction waste if not properly managed will be a nuisance to pedestrians and other road users. The aesthetics of the city in the LRT route will be temporarily impacted.

4.10.2 Waste generated from Depot during the Operation Stage

The depot area is where maintenance, washing and servicing of rolling stocks are conducted. Typical solid and liquid wastes generated at the depot and workshop area are listed in the Table 4-26 below.

Table 4.26 Type of waste generated during operational stage

Waste	Source	Estimated quantity
Lubricant oil	air compressor and gear box	7liters/day
Sludge	wastewater treatment plant (when cleaning train and its parts)	200kg/day
Brake shoe (brake pad)	brake equipment	
Metal scraps	wheel re-profiling lathe, etc. (wheel reprofiling, and exchanging parts)	200kg/day
Rubber tube	brake system (need to exchange every 8 years depending on its specs)	
Batteries	Batteries in rolling stocks	5,000pcs/2yrs
General wastes	waste from rolling stocks, administrative buildings	200kg/day

Source: JICA Study Team

General wastes from administrative buildings in depot area will be segregated. Recyclable materials (e.g. paper, glass) will be handed to registered recyclers. Non-hazardous wastes will be disposed to in accordance with relevant local regulations (e.g. disposal to designated disposal sites). Hazardous wastes (e.g. used batteries, light bulbs) will be collected and carefully stored. Treatment and disposal of these wastes will be contracted out to a registered industrial waste company. Wastes will be collected and disposed regularly to prevent accumulation, which may cause pollution and safety risks.

4.10.3 Waste generated from Station during the Operation Stage

Domestic solid waste will be generated at the stations, by the people who use the LRT. Such waste in the stations will be mostly litter such as papers, waste as biodegradable waste (food waste, garden waste etc.), plastics, glass and paper empty plastic bottles etc. From the depot various waste belonging to railway furniture could be generated. Such waste will be various mechanical and electrical parts which has undergone wastage. These parts if dumped haphazardly in the depot site or outside will mar the aesthetics of the open spaces.

4.11 Impacts on Surface and Ground Water Quality during Construction

4.11.1 Surface water Quality Degradation during Construction

There are possibilities of surface water quality degradation during the construction of piers for Diyawanna Lake crossing and the depot. Water turbidity and alkalinity could increase.

4.11.2 Groundwater Quality Degradation during Construction

Insertion of concrete underground during construction of the structures' foundation may affect the alkalinity (pH) of groundwater. This may occur when hardening of the cement is done underground because alkaline substances dissolve in the water. For the depot area, solid concrete foundation structures will be installed. Thus, potential impact on groundwater is very limited because alkaline substances will not dissolve in the water.

Once built, the foundation structures will have negligible impact on groundwater quality.

4.12 Impacts to Culturally and Historically Important aspect during construction

4.12.1 Disruption to Bo trees and shrines

As described in Chapter 3.3.4, there are 14 Bo trees along the LRT corridor. Some of these Bo trees have small shrines and worshiped by the public. LRT route was designed to avoid and minimize the impact on Bo trees. No uprooting of Bo tree is expected, however, some braches of Bo tree overarching road may be cut downed/trimmed. Details of the likely impacts on Bo Trees as well as result of consultation with stakeholder related with Bo tree are given in Annex F.

In addition, during the constriction stage, access to religious and culturally important sites may be impaired temporarily.

4.12.2 Potential Impact on archaeological buildings

The LRT mainly goes on the existing roads and only limited number of buildings will be directly affected by the project. Based on the preliminary archaeological survey conducted by the Department of Archaeology, there are two buildings (People's Bank building and Railway Museum) that may be transversed by the LRT route. However, these structures are not designated as archeologically important.

4.13 Wastewater Impacts

4.13.1 Disposal of wastewater generated from workers camp (depot area) and construction site during construction stage

Regarding wastes generated by construction workers, there will be no workers camp required for the project since the project area is within an urban area and it is expected that construction workers will commute from their accommodation. As such, there will be no domestic waste or sewage generated during this period. However, there may be labourers who will reside in the Depot site and their waste water and sewerage will be diverted to standard cylindrical septic tanks installed for temporary toilets.

4.13.2 Spillage, leak and accidental discharge of fossil oil, waste oil generated from construction and operation stage

Construction Stage

Soil and surface water might be contaminated during construction works due to leaks and accidental spills of fuel and lubricants from construction vehicles and machineries. This could only happen from construction vehicles and equipment and such occurrences are very rare. All construction equipment will be maintained at good condition to minimize such incidents.

Operational Stage

Similar impacts could occur during the operation stage.

4.13.3 Disposal of wastewater generated from Depot (terminal buildings, rolling stocks maintenance, washing, serving etc.) during the Operational Stage

Wastewater arising from the depot operations is generated from maintenance activities, such as carriage washing or parts cleaning. Approximately 100$m^{3/}$day of wastewater is expected to be generated from an activity at Depot operation. Wastewater generated from maintenance activities may contain oil and grease, detergent, dust (possibly containing steal power).

4.13.4 Disposal of wastewater generated from stations during the Operational Stage

The wastewater generated from the station is sewage from the toilet and washing facility. It is estimated that around 20$m^{3/}$day wastewater will be generated in each station.

4.14 Impact on Water Courses

4.14.1 Backwater at Lake Crossings - During Construction and Operation

As a major part of the proposed LRT route traverses on the main roads except for the flood plains, there will not be a significant impact on the drainage pattern of the area. However, the proposed LRT route will cross Diyawanna Lake and the depot will be built in a flood-prone area. With this, there will be a marginal impact on backwater of the respective canals during the operational stage of the project. Coffer dams or sheet piling will be needed during construction stage and these coffer dams will hinder the canal water flow during flood situations. Such temporary blockage will cause flood lift impacts on the parliamentary building if implemented without mitigation measures.

4.14.2 Construction Disruption at Pocket Flooding Locations

Some places of the LRT route even outside the normal flood plains could be subject to pocket flooding and such flooding could hamper construction and could damage exposed utilities and open pile trenches. Location of areas prone to pocket flooding is presented in Figure 4.21 Details of flood levels are indicated for these places are given in Table 4-27 below.

Table 4.27 Places in LRT route subjected to pocked flooding

Location Location description	Ground level m MSL	50Yr flood height wrt ground level (m)	100Yr flood height wrt ground level (m)	50 Year Flood Level (m) above MSL	100 Year Flood Level (m) above MSL
1) Dr N.M.Perera Mawatha/Gothami Road Junction	3.00	0.36	0.56	3.36	0.92
2) Bauudhaloka Mawatha/Sri Jayawardanapura Mawatha Junction	2.14	0.42	0.59	2.56	1.01
3) Ward Place / BorellaCross Road Junction	6.25	0.45	0.61	6.70	1.06

Source: Colombo Municipal Council

Figure 4.21 Places of Pocket Flooding LRT

4.14.3 Backwater on flood plains

The impact of the LRT on flood plains was determined through two-dimensional (2D) flood modelling. Flood modelling was carried out by SLLRDC using the available flood model for Metro Colombo Development project.

In order to predict potential flood levels in the future, the magnitude of past floods from 1986 to 2011at Kelani River was used to calculate flood levels at certain return periods (refer to Table 4.28).

Table 4.28 Historical Flood Levels at Kelani River (1986-2011)

MAGNITUDE OF PAST FLOODS KELANI RIVER (AT AMBATALE) IN WATER LEVELS

Date	Water Level in (m)		Return Period	Water Level in m MSL
2/17/1986	4.37		2	4.29
10/27/1987	4.68		5	5.30
9/9/1988	4.27		10	5.96
6/7/1989	6.28		20	6.60
11/4/1990	4.35		50	7.43
6/1/1991	4.55		100	8.05
10/15/1992	4.98			
10/9/1993	4.88			
5/29/1994	4.19			
10/9/1995	4.58			
9/23/1996	4.68			
9/17/1997	4.88			
7/25/1998	4.45			
4/21/1999	5.36			
9/21/2000	4.575			
10/22/2001	3.38			
6/7/2002	3.66			
7/11/2003	3.813			
11/2/2004	4.423			
11/22/2005	5.16			
11/12/2006	4.68			
10/23/2007	4.04			
4/30/2008	5.483			
5/21/2009	4.27			
5/17/2010	4.728			
1/1/2011	0.661			

Note: The data in the table 4.28 above is more relevant to the depot site.

The impacts on flood plains will take place:

- ≠ During construction due to the pilot road which is temporarily needed to progress with the construction activities. This may cause the loss of storage areas for flood water in these areas, which may lead to extra flood lift
- ≠ During the operational stage due to the pillars of the LRT, which can cause extra flood lift. However, this flood lift will not be significant.

4.14.4 Flood Modelling for Construction and Operational Stages

(1) Hydrological/Hydraulic Modelling

The 2D modelling undertaken will show the baseline flood levels and the project induced flood levels for the Construction Stage and the Operational Stage. The model could also show the delays in flow recession if any. Hence aggravated flood lift and delayed flood recession are the hydrological impacts caused by the LRT during its construction and operation stages.

(2) Sub Models for Sensitive Flood Plains

SLLRDC uses one dimensional flood model to model flood scenarios of the Metro Colombo area. MIKE 11 flood model which is a product of Danish Hydraulic Institute is being used for this purpose. This main flood model was used to extract basic parameters for two 2D sub models using Sobek 2D flood model. Two 2D sub models were created for the following areas;

- ≠ Sub Model 1-Parliamentary lake and the flood plains of Parliament Lake (Diyawanna Lake)
- ≠ Sub Model 2-Depot area and the entry route to the proposed depot are from Malabe Kaduwela Road to the low-lying area on to the left of Chandrika Bandaranayaka Kumaranathunga Mawatha. On the flood plains of Madiwela East Diversion Canal. The Depot area is situated.

(3) Geometric Parameters Used for The Model

Following main geometric parameters were used to represent the LRT in the flood model for the construction and operational stages

Construction Stage

- ≠ Maximum temporary fill height for the depot 0.6m from existing ground level

Operational Stage

- ≠ LRT pillar size 1mx1m
- ≠ LRT pillar spacing 10m
- ≠ LRT Depot pillar spacing 10mx10m grid

(4) Modelling Results

Modelling results for the depot area and Diyawanna Lake are shown in the figures and tables below.

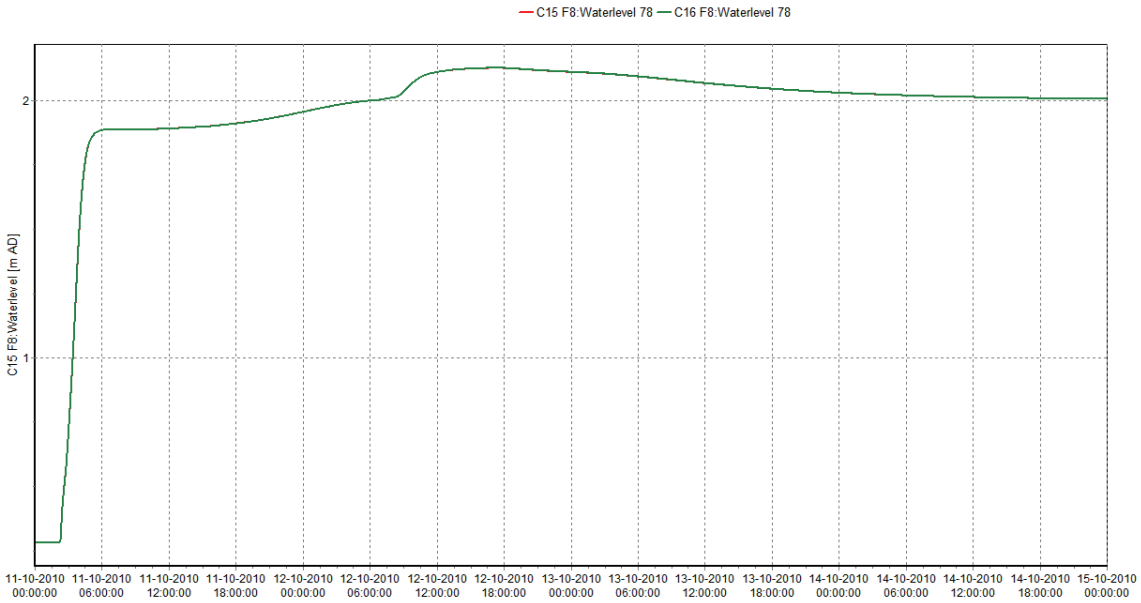


Figure 4.22 Stage Hydrograph for Diyawanna Oya with and without LRT

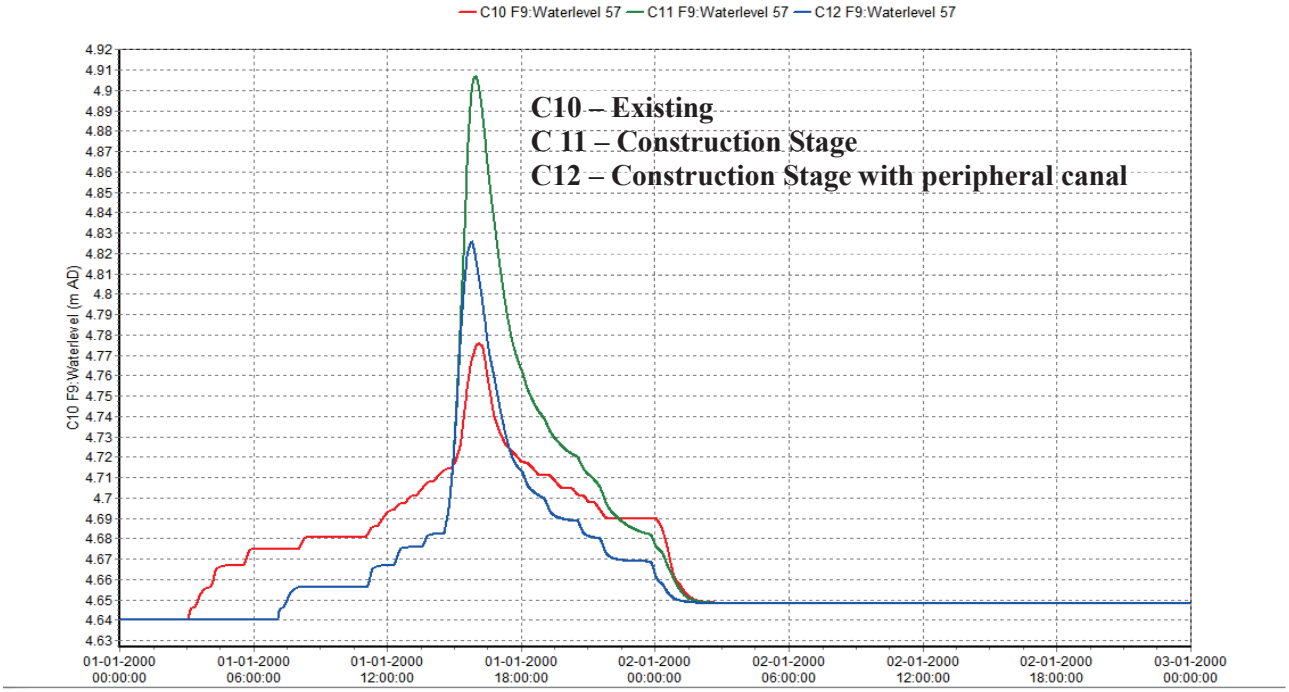
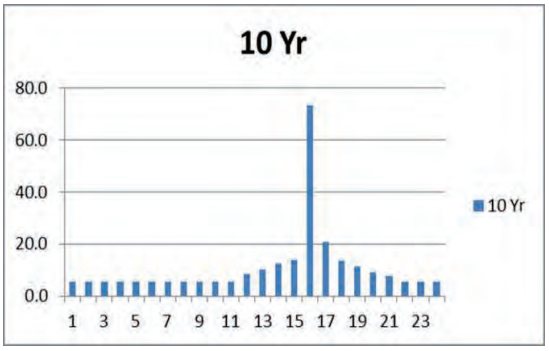
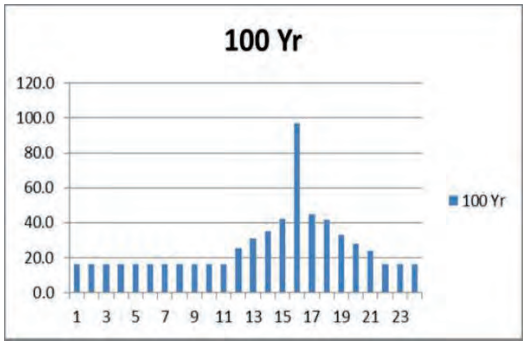


Figure 4.23 Stage Hydrograph for the Depot with and without LRT

Hyetographs used for 10 year and 100 year return periods using the updated IDF curve for Colombo are presented in the Figure below.





10yr (construction stage) 100yr (operation stage)

Figure 4.24 Hyetograph for different scenarios

Water levels with and without LRT for different scenarios for Diyawanna Lake, Depot Area and Parliament are shown in the Table below. Based on the results, significant backwater may occur at the depot area during construction stage if a peripheral canal is not provided.

Table 4.29 Water levels and extra flood lift (backwater) for selected scenarios

No	Scenario	Place	Flood Level (m)			Remarks
			Without LRT MSL	With LRT MSL (m)	Backwater (Flood Lift) (m)	
1	Baseline-10 Year	Diyawanna Lake	2.1	2.1	Nil	No significant backwater
2	Construction-10 Year					
3	Baseline-10 Year	Depot Area	4.62	**	**	**
4	Construction-10 Year		**	4.91	0.29	Backwater is considerable
5	Construction-10 Year with 3m wide peripheral canal		**	4.8	0.18	Backwater reduces with the proposed canal
6	Baseline-50 Year/100 Year		7.16/8.38	**	0.09/0.06	No backwater during the Operation Stage
7	Operational-50 Year/100 Year		**	7.25/8.42		
10	Baseline-100Year	Parliament	3.16	3.16	**	There is no difference in WL due to introduction of LRT pillars
11	Construction-100 Year		**	3.16	0.00	

Flood recession times with and without LRT for different scenarios for Diyawanna Lake, Depot Area is shown in the table below. Based on the results, flood recession at the depot area during construction stage may take several hours and a proposed canal can significantly minimize this.

Table 4.30 Delay in flood recession for selected scenarios

No	Scenario	Place	Flood Recession Time			Remarks
			without LRT (hrs)	with LRT (Hrs)	Delay (hrs)	
1	Baseline-10 Year	Diyawanna Lake	As there is no backwater no change in recession time.			
2	Construction-10 Year					
3	Baseline-10 Year	Depot Area	16	**	14	Flood recession delay is significant with temporary filling
4	Construction-10 Year		**	More than 30		
5	Construction-10 Year with 3m wide peripheral canal		**	15	-1.0	Proposed canal reduces recession time.
6	Baseline-50 Year/100 Year		19.5/20	**	0/0	
7	Operational-50 Year/100 Year			19.5/20		
8	Baseline-10 Year	Parliament	Since there is no backwater for both construction and operational stages for Diyawanna Oya Lake there is no backwater near Parliament which is upstream.			
9	Construction-10 Year					
10	Baseline-100Year					
11	Construction-100 Year					

Note: The durations are based on animation and propagation of flood of 2D simulation.

Flood extent maps for depot area for different scenarios are shown in the figures below.

10 Year Flood Extent (Baseline)

10 year flood extent construction period

50 yr flood extent (operational project)

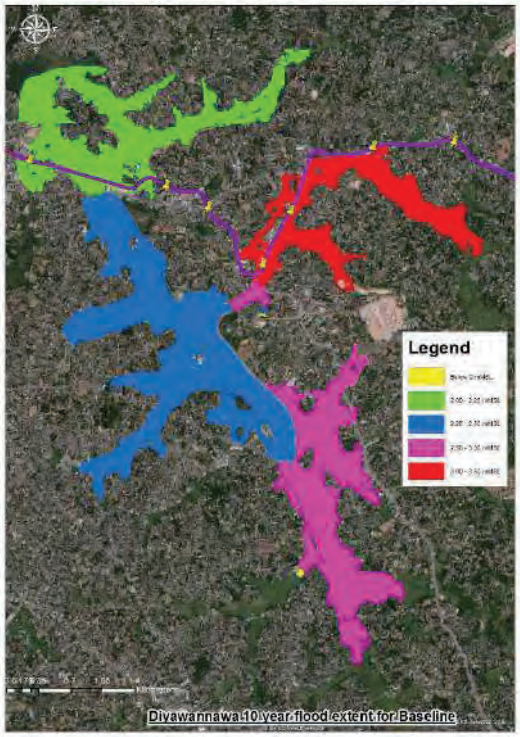
50 year Flood extent (Baseline)

100yr Flood Extent (Baseline)

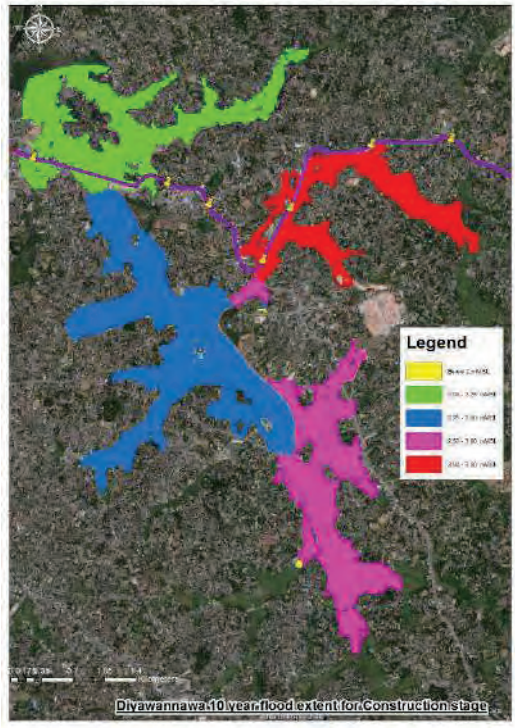
100yr flood extent (operational period)

Figure 4.25 Flood Extent Maps for the Depot Area with and without LRT

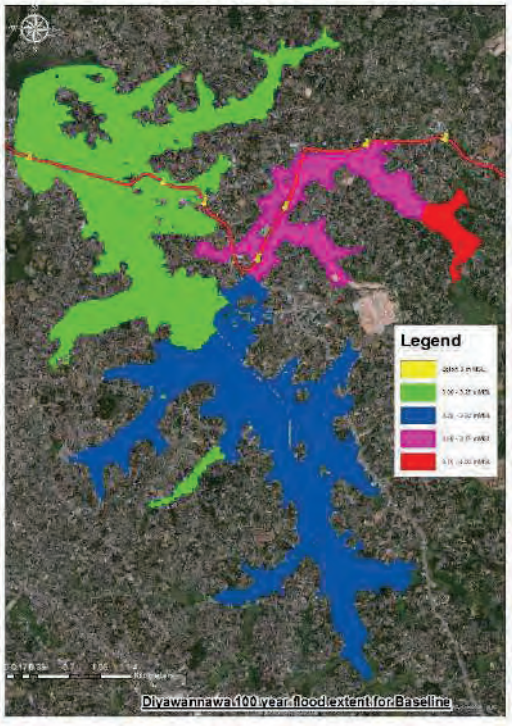
Additional information on flood modelling is given in Annex L**.**



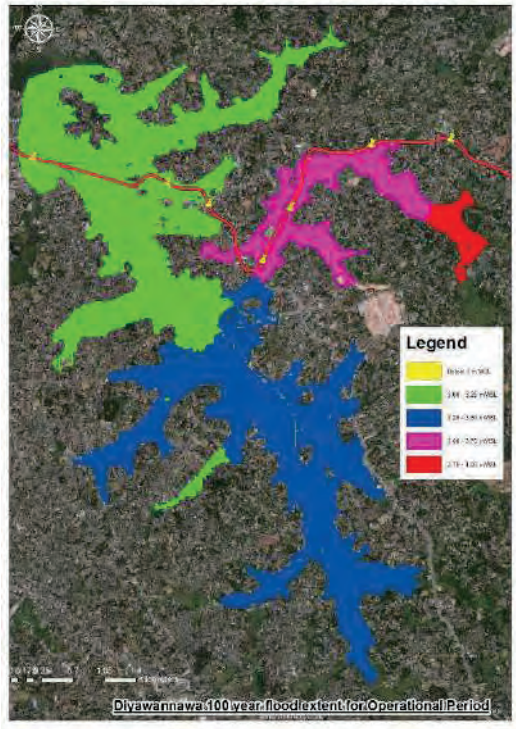
10 Year (Baseline)



10 Year (Construction)



100 Year (Baseline)



100 Year (Operational)

Figure 4.26 Flood Extent Maps for the Diyawanna Lake Area with and without LRT

(5) Determination of 100 Year Flood Level for the Depot

One hundred flood level for the depot site was independently obtained using the flood frequency analysis of Kelani River water levels at Ambatale which the closest river gauging station for the Depot is. The flood frequency curve Figure 4.27 and the flood frequency analysis Table 4-31 are given below. Depot elevation will be kept above 100-year flood level.

Table 4.31 Flood Frequency Details for Ambatale-Kelani River

Return Period	Frequency Factor	WL in m
2	-0.151	4.29
5	0.888	5.30
10	1.575	5.96
20	2.235	6.60
50	3.089	7.43
100	3.728	8.05

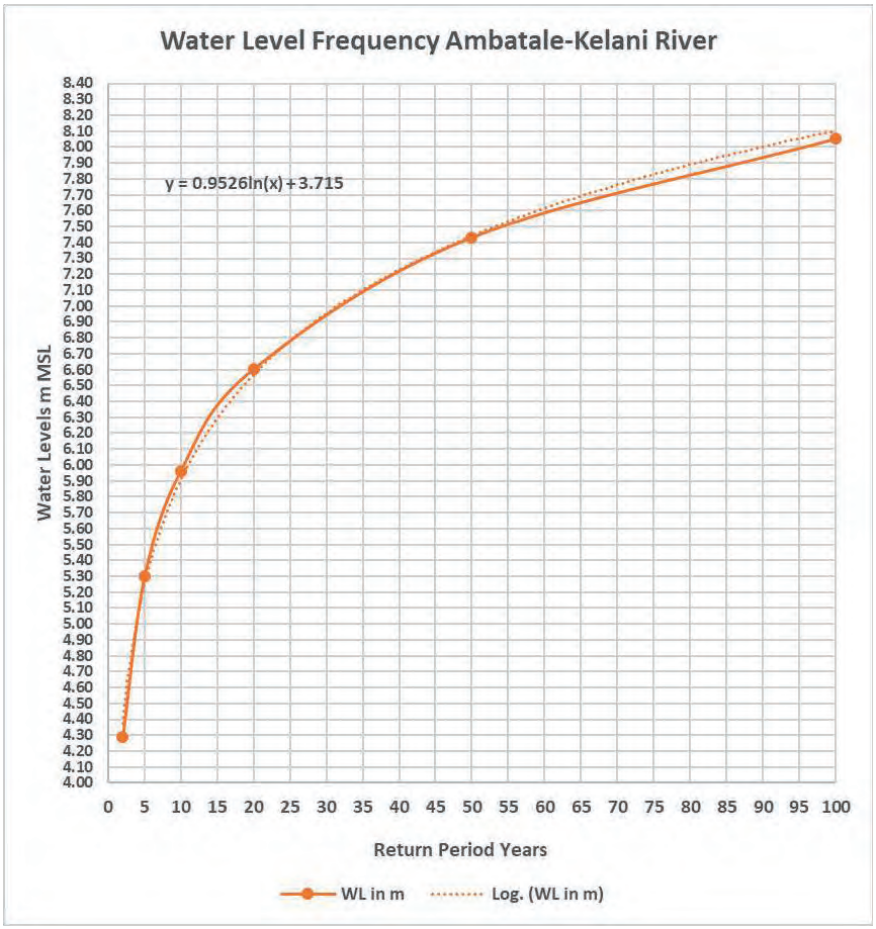


Figure 4.27 Flood Frequency Curve in Ambatale-Kelani River

A detailed description of the hydraulic modelling activities is presented in Annex L.

4.15 Air quality Impacts

4.15.1 Air Quality Degradation Construction stage

Although operation of the LRT itself has no impact on air quality, there is a possibility of impacts on air quality during the construction stage. This is mainly due to the impact of dust generated by the construction activities. However, in this type of construction dust generation could mainly come from the depot area. The fugitive emissions in form of dust are expected due to cut & fill of earth, loading, unloading and transport of fill material materials during the site development and construction of Depot. The potential for dust to be emitted during site preparation and construction activities is strongly dependent on the type of activities taking place, such as the movement of vehicles along the working width and their speed, soil stripping, cutting, back-filling and reinstatement. Wind speed and a particular wind direction may carry emitted particles towards receptors located in the adjacent residential area. Effects of dust emissions are heightened by dry weather and high wind speeds and effectively reduced to zero when soils and/or ambient conditions are wet. However, dust generated from the site development and construction activity will generally settles down on the adjacent areas within a short period due to its larger particle size. This temporary dust generation from the construction activities is not expected to significantly affect the ambient air quality of the study area

Heavy vehicles transporting construction materials are also potential sources of air pollution during the construction stage, as these vehicles could emit excessive amounts of pollutants such as Sulphur Dioxide, Oxides of Nitrogen, Carbon Monoxide and Particulates.

4.15.2 Air Quality Improvement in the Operation stage

The emissions from the LRT project during operation will be limited to operation of machinery for the maintenance of the rolling stocks at the depot area.

There is a possibility that the air quality might improve, since people using private vehicles may opt to use the LRT instead. It is, however, difficult to exactly predict improvement in air quality.

4.16 Urbanization Impacts

4.16.1 Increased urbanization During Operational Stage

The population of Colombo District continuously increased from 1,699,241 in 1981, to 2,251,274 in 2001, and 2,324,349 in 2011. Although the Average Annual Population Growth Rate (AAGR) has come down from 1.4 between 1981 – 2001 to 0.35 between 2011 – 2011, the population has increased even at a decreasing rate. Major capital investments in roads, water supply, health, education, irrigation, and industrial estates have resulted in curtailing migration of rural population to Colombo.

However, Colombo being the location for the administrative and commercial capital of Sri Lanka experiences high population density. Particularly, after the establishment of the peace in the country, Colombo started to regain its vibrant urban development process as demonstrated by large-scale urban regeneration projects taking place in both the City of Colombo and its suburban areas.

With regard to the sustainable urban development principles, Colombo Urban Area has been undergoing three serious issues namely;

- ≠ Spread of urban population along main roads in the form of low-density settlements
- ≠ Lack of high-quality public transportation resulting in environmental, economic, and social losses, and further encouraging outward bound development
- ≠ Colombo, losing its competitiveness in the region.

The LRT project will provide a positive impact, on resolving the above key issues, provided that the urban planning institutions will integrate future land use system with Transit Oriented Development, based on the proposed LRT. The expected results would be;

- ≠ Increasing the urbanisation process in the City of Colombo and suburban areas, in the form of concentrated development, creating a cost-effective, efficient, and market-driven urban economy.
- ≠ Increasing the competitiveness of the city due to the reduction in the level of pollution, traffic congestion, social and economic losses, and improving the aesthetic appearance of the cityscape.
- ≠ The reduction in the accidents. According to the information of the Ministry of Transport and Civil Aviation, in 2016, 53,118 accidents were recorded in Sri Lanka of which 3003 were deaths, and 2824 were fatal accidents. Of them, a large proportion consisted of Motor Bicycles and three Wheelers.

The phase one of the LRT covers Colombo – Malabe corridor, which will be extended to cover other corridors in the future, covering large population concentrated suburban areas (i.e. Kaduwela DS – 252,041 population, Homagama DS – 237,905, Seethawaka – 113,807, Maharagama – 196,423, Sri Jayawardhanepura Kotte – 95,506 in 2012). Thus, urbanisation of Kaduwela, Sri Jayawardhanapura Kotte, Colombo, and Thimbirigasyaya DS areas will be further strengthened during the phase one of the project and others during the next phases, making those areas attractive for urban investment.

On the other hand, there is a risk that with increased urbanization, conversion of paddy lands and green areas, particularly close to the train stations will also increase. These areas may be converted to park-and-ride facilities, commercial/residential buildings and/or developed into a multi-modal transport center or hub.

4.17 Contingency Impacts

4.17.1 Unexpected events (for both Construction and Operation Stages)

Accidents and natural hazards may impact the project and pose both environmental and social risks when not identified and addressed at an early stage. An emergency response plan will be prepared for both construction and operation phases.

- ≠ Failure of rail component and structure
- ≠ Fire due to extreme hot weather, equipment failure and accident
- ≠ Impact due to flooding

4.18 Impact Analysis using a Leopold Matrix

4.18.1 Project Activities vs. Induced Environmental Impacts

To assess the degree of environmental and social impacts of the project, the Leopold Matrix Impact Assessment Method was employed. In order to calculate the impact scores, physical, physiochemical, social and ecological impacts cause by project activities during the main stages of the project (i.e. construction stage and operational stage), were identified and evaluated. Positive scores were assigned for positive impacts while negative scores were assigned on negative impacts. The impacts scores were assigned on two major themes i.e. the **Magnitude [M]** and the **Significance[S]**. The scores were assigned based on the nature of the impacts identified during the EIA studies. The score ranges and the degree of the impact Magnitude [M] and Significance[S] are presented in the following table.

Table 4.32 Scoring Method for the Environmental Impact Magnitude [M] and Significance [S]

+ Positive	- Negative
Magnitude[M]/Significance[S]	
"Blank"	Not relevant
1-3	Insignificant
4-6	Significant
7-9	Very significant

4.18.2 Calculation of Impact Scores

Impact scores are calculated by multiplying assigned values for the Magnitude [M] and the Significance[S] of impacts. Negative values were used for negative impacts and positive values were used for positive impacts. The impact scores were illustrated using a colour code within the Leopold Matrix as indicated in the table below.

4.18.3 Sub Colour Coding Range for the Cumulative Scores

Table 4.33 Colour Coding for the Cumulative Effect of the Impact i.e. Magnitude[M]x Significance[S]

	Magnitude [M]								
Signinificance [S]	POSITIVE IMPACTS								
Significance	1	2	3	4	5	6	7	8	9
1	1	2	3	4	5	6	7	8	9
2	2	4	6	8	10	12	14	16	18
3	3	6	9	12	15	18	21	24	27
4	4	8	12	16	20	24	28	32	36
5	5	10	15	20	25	30	35	40	45
6	6	12	18	24	30	36	42	48	54
7	7	14	21	28	35	42	49	56	63
8	8	16	24	32	40	48	56	64	72
9	9	18	27	36	45	54	63	72	81
	NEGATIVE IMPACTS								
Significance	-1	-2	-3	-4	-5	-6	-7	-8	-9
1	-1	-2	-3	-4	-5	-6	-7	-8	-9
2	-2	-4	-6	-8	-10	-12	-14	-16	-18
3	-3	-6	-9	-12	-15	-18	-21	-24	-27
4	-4	-8	-12	-16	-20	-24	-28	-32	-36
5	-5	-10	-15	-20	-25	-30	-35	-40	-45
6	-6	-12	-18	-24	-30	-36	-42	-48	-54
7	-7	-14	-21	-28	-35	-42	-49	-56	-63
8	-8	-16	-24	-32	-40	-48	-56	-64	-72
9	-9	-18	-27	-36	-45	-54	-63	-72	-81

4.18.4 Score Assignments for the Environmental Impacts

Scores assignment for the environmental impact Magnitude [M] and Significance [S] was done based on the results of the environmental assessment. Judgement was exercised in assigning scores for each item. High negative scores were used to show most significant negative impacts (Scores -56 to -81) .

4.18.5 Leopold Matrix for the LRT's Environmental Impacts

The simplified version of the Leopold Matrix showing the impact scores, is given in Table 4.34 and the full version is given in Annex M. The degree of positivity and the negativity is illustrated for each impact through the colour coding process. Hence, the very significant negative impact items could be readily spotted in the Leopold Matrix from red colour coding range. Green colour coding shows the positive impacts. The impacts for both Construction Stage and the Operational Stage have been sorted according to the total impact score. Thus, the most significant negative impacts appear on the top of the matrix and the most significant positive impacts are at the bottom of the matrix.

4.18.6 Outcome of the Leopold Matrix

The impacts were accorded scores (based on the EIA study finding and the judgement of the expert team) and the impacts were sorted according to the total score. One of the main assumption when adducing scores is that there are no mitigation measures except for the mitigations-by-design. The reason is that by this exercise only the significance of impacts is determined to provide mitigation measures. After the screening process the identified most significant negative impacts in the order of priority are;

Construction Stage – Negative Impacts

1. Noise
2. Road link capacity reduction
3. Landscape/aesthetic degradation
4. Community health and safety Degradation
5. Occupational health and safety degradation
6. Vibration
7. Disruption of livelihood and economic activities
8. Fauna flora disturbance
9. Wetland degradation
10. Disruption to underground utilities
11. Land acquisition/Resettlement of people /structures
12. Neighbouring Land Users-Severance of light
13. Erosion of excavated material
14. Surface water quality degradation
15. Disruptions to Bo Trees and shrines
16. Construction disruption at pocket flooding locations
17. Spillage and accidental leakage
18. Disruption to overhead utilities
19. Backwater at lake/stream crossings
20. Wastewater from worker camps
21. Backwater at flood plains
22. Disruption to archaeological buildings
23. Ground water quality degradation
24. Air quality degradation

Construction Stage – Negative Impacts

1. Employment generation
2. Travel time saving

Operation Stage – Negative Impacts

1. Occupational health and safety degradation
2. Noise
3. Unexpected events -structure failure, equipment failure and flooding
4. Spillage and accidental leakage
5. Wetland degradation
6. Solid waste generated from Depot
7. Wastewater generated from depot
8. Surface water quality degradation
9. Vibration
10. Wastewater generated from stations
11. Road link capacity reduction
12. Solid waste generation from station
13. Ground water quality degradation
14. Disruption of livelihood and economic activities
15. Neighbouring Land Users-Severance of light
16. Fauna flora disturbance
17. Disruptions to Bo Trees and shrines
18. Landscape/aesthetic degradation

Operation Stage – Positive Impacts

1. Air quality improvement
2. Increased Urbanisation
3. Boost of Regional Economic Activities
4. Socio-economic benefits
5. Employment generation
6. Travel time saving

4.18.7 Application of Mitigation Measures for Impacts

The most significant impacts indicated above need careful and stringent mitigation measures. It is seen from the table above most negative impacts exist during the Construction Stage which require mitigation measures. Many positive impacts are seen during the Operational Stage. However, the positivity of the impacts during the operational stage is mainly based on the long term economic returns as indicated in the Extended Cost Benefit Analysis. The overall impact cannot be judged from the results of the Leopold Matrix alone for such indirect positive impacts on the economy. There are also negative impacts during the Operational Stage needing mitigation measures.

Table 4.34 Leopold Matrix (Summary)

Impact Causing Activities-Construction Stage																					
Impact Themes	Structure demolition to clear trace bends	Excavation for foundations for LRT pillars	Utility diversion(Power lines, water supply, telecom cables)	Construction of light rail pillars	Traffic diversions(Human and vehicular)	Pilot Road construction with excavated material in low lying	Tree removal and tree branch pruning	Installation of construction rigs in Diyawanna Oya	Underwater concreting for pillars in streams ands lakes	Construction of elevated stations	Girder /Superstructure construction	Construction of the elevated depot on the low lying area	Installation of rolling stocks	Installation of the wastewater treatment plant for the deport site	Removal of the pilot road and construction waste disposal	Landscaping	Power supply installations	TOTAL SCORES
Noise	-64	-36	-9	-49	-36	-36	-16	-49	-36	-42	-56	-81	-9		-16		-8	-543
Road link capacity reduction	-49	-64	-64	-64	-72	-10	-9			-36	-63	-15	-54		-20	-2	-4	-526
Landscape/aesthetic degradation	-24	-48	-36	-40	-16	-42	-40	-36	-24	-48	-40	-32	-32	-18	-20		-16	-512
Community health and safety Degradation	-36	-36	-48	-36	-56	-25	-4	-16	-16	-48	-25	-64	-25		-36	-16	-25	-512
Occupational health and safety degradation	-25	-25	-36	-36	-20	-25	-16	-36	-36	-36	-36	-48	-36	-25	-25	-8	-36	-505
Vibration	-9	-16	-9	-49	-4	-9	-3	-25	-49	-36	-49	-81	-25					-364
Disruption of livelihood and economic activities	-36	-64	-64		-36					-72		-64		-9				-345
Fauna flora disturbance		-16			-4	-36	-24	-16	-16	-16		-36		-36	-16		-4	-220
Wetland degradation		-4		-4		-64		-36	-24			-64		-12	-9			-217
Disruption to underground utilities	-36	-81	-64			-16						-4						-201
Land acquisition/Resettlement of people /structures	-9		-48			-21				-20		-81		-12				-191
Neighboring Land Users-Severance of light				-8						-25	-36	-48	-36			-16		-169
Erosion of excavated material	-4	-49	-20			-30	-12	-4				-4			-16	-16		-155
Surface water quality degradation								-36	-48			-36						-120
Disruptions to Bo Trees and shrines				-16			-36			-16	-16		-6					-90
Construction disruption at pocket flooding locations		-16	-16	-16		-24												-72
Spillage and accidental leakage	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-68
Disruption to overhead utilities				-36			-16						-16					-68
Backwater at lake/stream crossings				-16				-16	-16									-48
Wastewater from worker camps	-4	-4	-4					-4		-4	-4	-4	-4		-6		-4	-42
Backwater at flood plains				-8		-16						-48			36			-36
Disruptions to archaeological buildings		-9		-16														-25
Ground water quality degradation				-4			-4	-4										-12
Air quality degradation	-4			-6														-10
Air quality improvement																		0
Boost of Regional Economic Activities																		0
Disturbance to protected areas																		0
Increased Urbanization																		0
Socio-economic benefits																		0
Solid waste generated from Depot																		0
Solid waste generation from station																		0
Unexpected events -structure failure, equipment failure and flooding																		0
Wastewater generated from depot																		0
Wastewater generated from stations																		0
Employment generation		81	81	81		36	18	16	16	36	25	81	36	16	16	36	25	600
Travel time saving																		
TOTAL SCORE																		-4451

Impact Causing Activities-Operational Stage									
Impact Themes	Driving Train(including test runs)	Passenger services in stations	Emergency action	Regular Maintenance	Breakdown maintenance	waste disposal from depot and stations	Sludge disposal from depot	Wastewater disposal from depot from wash and clean process	TOTAL SCORES
Occupational health and safety degradation	-36	-24	-81	-36	-49	-24	-25	-36	-311
Noise	-64	-24		-25	-16				-129
Unexpected events -structure failure, equipment failure and flooding	-16	-16	-36	-16	-16	-8	-8	-8	-124
Spillage and accidental leakage				-16	-30	-16	-25	-30	-117
Wetland degradation						-36		-81	-117
Solid waste generated from Depot						-64	-36		-100
Wastewater generated from depot								-81	-81
Surface water quality degradation	-4					-4	-36	-36	-80
Vibration	-36		-16	-8	-16				-76
Wastewater generated from stations						-64			-64
Road link capacity reduction	-48								-48
Solid waste generation from station		-36							-36
Ground water quality degradation							-16	-9	-25
Disruption of livelihood and economic activities			-16						-16
Neighboring Land Users-Severance of light	-16								-16
Fauna flora disturbance	-4		-4						-8
Disruptions to Bo Trees and shrines	-4								-4
Air quality degradation									0
Backwater at lake crossings									0
Backwater at flood plains									0
Community health and safety degradation									0
Construction disruption at pocket flooding locations									0
Disruption to overhead utilities									0
Disruption to underground utilities									0
Disruptions to archaeological buildings									0
Disturbance to protected areas									0
Erosion of excavated material									0
Land acquisition/Resettlement of people /structures									0
Wastewater from worker camps									0
Landscape/aesthetic degradation				81		-8	-8	-8	57
Air quality improvement	81					-4			77
Increased Urbanization	81								81
Boost of Regional Economic Activities	81	36		16					133
Socio-economic benefits	81	81							162
Employment generation	20	81	16	81	64	36	16	16	330
Travel time saving	81	81	81	81	81	81	81	81	648
TOTAL SCORE									136

CHAPTER 5 Proposed Mitigation Measures

5.1 Mitigation Measures for Noise and Vibration

5.1.1 Mitigation measures due to Impacts on Noise

Construction stage

All construction equipment will be used in good service condition and low noise/vibration generating construction equipment will be used. Heavy noise/vibration generating construction work are not expected. There could be some noise during trench excavation for foundations and the placement of steel beams on columns etc. Such noise or vibration will be minimum and limited to the construction stage and such impacts are not continuous but sporadic. No noise generating night work will be allowed especially in the areas where there are residences (e.g. Ward Place etc.).

Noise and vibration nuisance would be significant only during the construction stage where a piling operations and structure construction works would commence. Therefore, noise levels will be well monitored during the construction stage. If ambient levels are far higher than the stipulated level of 75 dB (A) for daytime construction and 50 dB (A) for night time, mitigation measure given below will be implemented. The impact of noise and vibration nuisance could be minimized through the following measures;

1) Fitting of exhaust baffles and maintaining construction vehicle and machinery in a high operable condition,
2) Use the noise, low-vibration type machine and/or vehicles,
3) The construction site is separated with corrugated sheets or other suitable material especially at locations near noise sensitive receptors, particularly at National Hospital and school zone.
4) Scheduling of construction work that cause high noise and vibration must be within authorized construction embodiment times with the least inconvenience to the public,
5) Avoid construction work on Poya days and days of other religious and/ or cultural importance,
6) Avoid high noise construction activities during the night time.
7) Establishing a complaint mechanism and implementing a procedure to effectively deal with any issue raised by the community.
8) Inform surrounding community of the construction schedule and proposed activity in advance

For the construction activity at Depot, following mitigation measures will be implemented.

1) Conduct a test piling activity and check the noise level generated from the piling activity at Depot area.
2) Consider changing the height of hammer drop or weight of hammer to be used, depending on the result of test piling

3) Install a noise reduction equipment with piling hammer

Operational stage

During the operation of LRT project, noise level from LRT will meet the noise level standard for railway both Peak noise level (LAmax) and Equivalent noise level (LAeq) of Japanese/Australian standards. However, noise level would be gradually increased up to the 13m height. In addition, there would be a disturbance especially around noise sensitive areas as identified in Chapter 3.3.3, including hospitals such as General hospital and Ayurweda hospital, schools and education institutes. Therefore, following mitigation measure will be implemented.

1) For section along noise sensitive areas, implementation of noise mitigation measures such as noise barriers or double pane windows shall be considered during detail design stage as well as operational stage.

2) Carry out noise monitoring along LRT routes at the location conducted for noise measurement survey (total 7 locations). Additional monitoring point will be added based on comments raised from stakeholders along LRT route.

3) Standard maintenance of trains, structure and tracks

4) Regular reconditioning of train and its components, such as suspension system, brakes and wheels.

5) Establishing a complaint mechanism and implementing a procedure to effectively deal with any issue raised by the community.

5.1.2 Mitigation Measures for Vibration

Construction stage

Mitigation will include the following actions;

1) Identification of type of building structure (Type 3 and Type 4). For Type 4 structure, the consultation with Department of Archaeology is required.

2) Carry out a property condition survey (crack survey) of nearby structures and record the present condition of the structure, to accurately assess any damage to these structures during the construction stage.

3) Vibration monitoring at selected area around the construction activities.

4) Regularly communicate with surrounding communities to inform the construction schedule.

5) Use of lower vibration generating device/machinery.

6) Scheduling of construction work that cause high vibration must be within authorized construction embodiment times,

7) Minimization of piling energy (e.g. reduced hammer drop distance) as necessary depending on receptor distance.

8) Establishing a complaint mechanism and implementing a procedure to effectively deal with any issue raised by the community.

Operation stage

Although no significant vibration impact is expected, following mitigation measure will be implemented.

1) Design of rail tracks must incorporate measures to reduce level of vibration, such as use of long rail, sleeper with the anti-vibration mat.
2) Vibration monitoring at selected area along the LRT route.
3) Standard maintenance of trains, structure and tracks
4) Regular reconditioning of train and its components, such as suspension system, brakes and wheels.
5) Establishing a complaint mechanism and implementing a procedure to effectively deal with any issue raised by the community.

5.2 Mitigation Measures for Traffic Impacts

5.2.1 Road Link Capacity Reduction during Construction Stage

A comprehensive traffic study will be carried out during the detailed design stage to assess the different scenarios of stage-wise construction, traffic diversion options for each construction phase and its impact on the network traffic flow. This study will be accompanied by a traffic engineering model within the study area to assess possible changes that will be made in the future. A separate intersection wise analysis will be conducted at the key intersections affected by the study. Any changes made to the traffic management schemes in the area, such as bus lane implementation, traffic signal installation etc. will be incorporated in the model.

A stakeholder committee with the participation of project consultants, Colombo Municipal Council and the other relevant local government bodies, Road Development Authority and Traffic Police, will be appointed to give guidance on the developed traffic management plan as well as to continuously monitor its implementation during construction stage. The traffic management plan will be made available to the public and adequate time will be provided to allow familiarization of the new routes.

Based on the above, a traffic management scheme for each stage of construction and mechanism for monitoring will be set up to monitor the traffic flow characteristics during the construction stage.

1) Preparation of traffic management plan for each construction stage such as diversion, lane control, safety measures. The traffic management plan will also take into consideration mobility and safety of vulnerable groups (e.g. school children, elderly).
2) Carry out traffic simulation for above traffic management plan
3) Road Intersection wise traffic analysis for the key road intersections affected by the study (See Section 1.4 of the Traffic Impact Assessment Report in Annex C for the affected intersections)
4) A stakeholder committee with the participation of project consultants, Colombo Municipal Council and the other relevant local government bodies, Road Development Authority and Traffic Police, will be appointed to give guidance on the developed traffic management plan

5) Monitoring of traffic flow during construction stage

In addition to the mitigation measures described in above for traffic impact, following mitigation measures will be implemented to minimize the impact on existing road users, including pedestrian and bus user.

1) Ensuring the safety during the construction period using standard safety measures.
2) Adherence to the work zone management guidelines formulated by RDA.
3) Provide minimum 3m lane width for bus routes
4) Maintain walkable paths for pedestrian movement especially where high density pedestrian traffic flows exist (e.g. Malabe, Rajagiriya Road, Olcott Mawatha, Justice Akbar Mawatha and Malay Street, access roads in depot area)
5) Retain access roads in depot area (slightly diverted) and ensure that design and construction of depot civil structures will not hamper movement of people and vehicles in the area.

5.2.2 Road Link Capacity Reduction During Operation Stage

During the detailed design of the LRT structure, coordinate closely with RDA in determining how to integrate the LRT structure and future road development (e.g. number of lanes, road width).

5.2.3 Mitigation Measures for Improvement of Traffic Condition in off LRT Routes during Operational Stage

This is a positive impact for which no mitigation measures are necessary.

5.3 Mitigation Measures for Landscape Impacts

5.3.1 Mitigation Measures for Landscape and Aesthetic Degradation

The LRT road trace falls largely on built up areas. The road trace is very diverse in both its natural and built environment, thus its impacts vary from section to section. Further, other than the most critical areas, the impacts on the other areas can be mitigated through good design intervention. Such design intervention will be comprehensive to treat the whole LRT trace as an integral part of the urban corridor, as to make it an interesting element of the trace.

1) The major sensitive areas will be thoroughly studied in terms of landscape impact during detailed design stage through the consultation with concerned agencies. After detailed assessment of landscape impact, if it is found that alternative route is suitable, it will be a subject for supplementary EIA.
2) Micro level detailing, structures, colors, lighting, planting, trains designs and colors, stations, interactions will be part of the overall design depending on each section.
3) In order to realize the overall objectives, in the design team in addition to the design and structural engineers it will include; Tow Planners, Urban Designers, Architects, Landscape Architects, and Lighting Experts.

5.4 Mitigation measures due to impacts on Health and safety

5.4.1 Mitigation measure for community health and safety during construction stage

Mitigation measures are required to protect people and work force from accidents in the work sites. The construction activities will be performed on existing roads and on elevated structures. The project will take optimum measures to assure the protection of people living, working and moving in the project areas.

In order to mitigate the impact on health and safety risk of surrounding communities, following mitigation measures will be considered.

1) The project site should be fully fenced and access points should not be available for the public.
2) Temporary sanitary facilities should be provided at all construction sites, especially for the Depot site.
3) Environmental pollution control measures, including watering standard maintenance of machinery will be implemented.
4) Arrange construction activities and schedule to minimize the impact on surrounding communities (e.g. prohibit high noise generating activity on night time)

5.4.2 Occupational Health and safety during Construction stage

Adoption of standard worker safety methods such as provision of helmets, earplugs, dust masks, warning signs, safety display posters and safety gear. Suitable advice will be obtained from the District Factory Inspection Engineer –Department of Labour and action will be taken to conform to his requirements.

These safety arrangements will be examined periodically by the officers of PMU. Adhering to safety measures will be made compulsory and needs for such safety precautions will be specified in the EMP and in the contract documents. Contractors shall submit an Occupational Health and Safety Management Plan in accordance with the guidelines set by the Labour Department, prior to

commencement of work.

Workers Health will be impacted from dust and noise. However, dust stir is minimum as there will be only very little excavation work which will only be needed for foundation trenches. Workers will be instructed to wear dust masks as a mitigation measure. Dust stir will also be minimized using dust curtains, water sprinkling etc. No serious health impacts are expected from the construction work as there will not be any works with hazardous chemicals (except for paints) and obnoxious gases.

Power transmission lines are the objects causing most harmful accidents with lethal impacts on drivers and machine operators unless they work with proper precautionary measures. Hence awareness programs for the machine operators will be held to educate them with this aspect. Engineers from Ceylon Electricity Board have been seconded to the PMU and they will provide necessary advice to the Contractor. Power lines will have to be temporarily switched of for critical construction work with adequate notice to the affected public.

5.4.3 Mitigation Measures for Occupational health and safety during Operational stage

There may be risk of accidents due to improper work practice, which would be a threat to health and safety of workers at the station, Depot and LRT structure. Health and Safety Management Plan for operational stage will be developed and implemented by the O&M Company which will be created for the operation of the LRT. All workers undertaking maintenance work will be provided with appropriate personal protective equipment (PPE). Security guards will be deployed in Depot and all stations. Emergency Response Plan will be established by the Project Proponent.

5.5 Mitigation Measures for Socio-economic Impacts

5.5.1 Mitigation measures due to Disruption to Livelihood and economic activities during Construction Stage

The proposed LRT project has significant impact on livelihood and economic activities of commercial property owners, residential property owners and paddy land owners. Special attention will be paid to these affected people to mitigate the impacts on them.

Compensation will be paid to the affected parties according to the stipulations of the Land Acquisition Act (LAA) and Land Acquisition and Resettlement Committee (LARC). Payments for loss of business (temporary or permanent), loss of livelihood, loss of wages employment will be provided to affected parties, as compensation. Further, there are stipulations in the LARC on an ex gratia payment for paddy lands to be acquired.

The livelihood of the persons occupying in business premises and residences will be temporarily disturbed by the construction of the LRT and following mitigation measures in summary will be implemented.

1) Provision of compensation to the Project Affected Parties (PAPs) using the compensation package decided for LRT Project based on LARC stipulations on assessing the financial and

other losses of PAPs.

2) Provision of alternative access to their premises as far as possible outside the construction sites to carry out their usual business activities and other domestic or related employment activities.

3) Develop a Livelihood Restoration Plan

4) Continual liaising with the Project Affected Parties (PAPs) will be undertaken to decide on the site-specific mitigation measures.

5) Consultation with people whose livelihood depend on modes of transportation that may be affected by the Project (e.g. 3-wheelers and bus operators). They will be included in the development of the traffic management plan.

5.5.2 Impact on livelihood during Operational stage

Positive impact is expected since the LRT project would boost regional economic activities along the route and presence of stations will attract future commercial development. No mitigation measure is required.

For PAPs whose livelihood had been affected during construction stage, monitoring of the implementation of the Livelihood Restoration Plan will be conducted. The Cabinet Memorandum on the application of LARC to the LRT project is given in Annex I.

For bus operators and 3-wheel drivers whose livelihood may be affected by the operation of the LRT (a potential competitor in terms servicing passengers/commuters), continued consultation together with relevant agencies will be conducted to seek optimum solutions. In addition, developing terminals for 3-wheelers close to the trains stations will be proposed.

5.5.3 Travel Time Saving during Operation

This is a positive impact for which no mitigation measures are necessary.

5.5.4 Employment Generation

This impact is a positive impact for both stages and no mitigation measures are necessary.

5.6 Mitigation Measures for Impacts on the Biological Environment

5.6.1 Mitigation Measures for the Disturbance on Protected Areas

The proposed project will have no direct impact on the two protected areas, Sri Jawardenapura-Kotte Bird Sanctuary and Thalangama EPA found in the project area as they were avoided by the design. However, there may be possibilities of indirect impacts. Thus, in order to identify any potential indirect impact, monitoring of bird species, which could be an indicator species of these areas, will be conducted.

5.6.2 Mitigation Measures for impacts on flora and fauna (aquatic/ terrestrial habitats).

No significant impacts are anticipated with respect to aquatic and terrestrial habitats except at the LRT depot site where a low land (agricultural land) with an extent of about 15 ha will be affected. However, since the depot will be established as an elevated platform the low land will not be filled except temporary filling that may take place during construction stage in order to gain access for construction work. However, after the construction work is completed, all the fill material will be removed, and the low land will be restored to its original physical condition.

As mitigation measure, restoration program will be planned which will be a creation of wetland and green buffer at open area and surrounding of depot Restoration program will be developed during the detailed design stage and the budget of 20,000,000Rs will be secured for the restoration program. Also, off set of losing 89 trees along Denzil Kobbekaduwua Mawatha will be part of restoration program.

The restoration plan will include following concepts;

- Offset trees of 10 times of that is cut down by the project
- Enhancement of biodiversity through creation of various type of habitat such as wetland, forest zone and open area.
- Use the native species which will enhance the value of ecosystem in the area
- Creation of green buffer zone around the Depot by selection of tree species which grows high to mitigate the landscape impact

5.6.3 Mitigation Measures for Wetland Degradation

During the operational stage some sections will be subjected to increased shade due to the overhead structures. However, there still will be light penetration in to the wetland. This aspect will be taken into consideration when selecting plant species for restoration of the wetland during the post construction period.

Other than this, special mitigation measures are not required in the other sections of the LRT trace with respect to habitats and species. However, removal or pruning of trees will be kept to a minimum level during construction.

Wetland degradation in the form of water quality degradation will be mitigated by the introduction of the wastewater treatment plant and collection of scheduled waste for the “Ecocycle” process.

5.7 Mitigation Measures for utilities such as Water, Electricity and Communication

5.7.1 Disruption to Underground Utilities

Utility details such as wastewater sewer lines, have already been obtained from the relevant line agencies. Hence there is a rough idea about the utility relocation. However, the detailed information about these utilities (exact location and depth) has not been recorded well.

Therefore, working group for utility relocations will be appointed to address utilities relocation in advance of construction stage. During the construction, the Contractor will be directed by the Engineer to identify the utilities in more detail with the help of the area officers (e.g. Technical Officers) of the relevant line agencies. Immediate action will be taken during construction to provide the usual utility services such as electricity, water supply and telecommunication uninterrupted as much as possible.

Disturbance to water lines is a very common impact and such impact will be mitigated by the provision of water supply bypass lines to maintain an uninterrupted water supply. Suitable liaising arrangement with the line agencies such as, NWS&DB and SLT will be maintained with the support of the area offices and the PMU. Some agencies such as NWS&DB and CMC have provided the existing utility plan. Some of the available and presentable utility plans are given in **Annex G**.

The project requires temporary adjustments in the infrastructure facilities to proceed with its construction work as scheduled. The transmission lines, telecommunication and water supply lines may be temporarily closed and shifted as a result. Such activities would be carried out with the following mitigation measures.

1) Any change in the infrastructure facilities will be done with the co-ordination of the authorities responsible for the installation and maintenance of utilities.

2) Adoption of schedules for the shifting and temporary termination of infrastructure service supply and making the public aware of them in advance to prevent ad hoc activities and the resulting negative impact on people and the work force.

3) Making all the payments timely, as agreed upon at the beginning of the project to enhance the efficiency of shifting of infrastructure facilities. The delay of payment tends to prolong the period of restoring the disturbed infrastructure facilities and such disturbances will affect the day to day activities of the people. The Project Proponent being alive to such issues will avoid the delay of the completion of the shifting of infrastructure facilities.

4) The Project Proponent will assist the service provider to complete the shifting of such facilities and it will not allow any informal or unauthorized shifting of any infrastructure facility, which would be harmful to the work force and the people in the area.

5) Although utility plans are available there could be unexpected situations when the ground is opened. Such situations will be anticipated, and necessary advices will be obtained from other ongoing projects (e.g. Colombo sewerage project).

5.7.2 Disruption to Overhead Utilities

The common overheads utilities are telephone lines and electricity lines. The Project Proponent will liaise with CEB and SLT to make the necessary changes to utilities as outlined under Underground Utilities.

5.8 Mitigation Measures for Land Acquisition Impacts

5.8.1 Mitigation measures due to impacts on land acquisition and resettlement of people and / or relocation of structures/buildings etc. (if any)

The proposed LRT trace was planned to traverse along existing roads to minimize land acquisition. Further, the design alternatives also have been considered to avoid residential and commercial places. These are mitigation-by-design actions. However, the project would still need to acquire land, residential and commercial structures to a limited extent.

A Resettlement Action Plan (RAP) is ongoing to identify these affected places exactly and to carry out consultation with owners of these affected properties to decide on the compensation that will be provided. The RAP will provide guidance to relocate affected people with compensation and required support and assistance to reestablish the affected income and livelihood.

The Project Proponent has already taken cabinet approval for Land Acquisition and Resettlement Committee (LARC) system to be used to pay compensation for the affected parties. The relevant Gazette is attached in **Annex I.** The LAA system was abolished after introducing 2008 regulations for payment of compensation. However, the Ministry of Land reintroduced the LARC system to 18 projects through gazette notification no. 1837/47 dated 22nd of November 2013. LARC is used to compliment undervalued properties through a consultative process with the participation of affected persons at community level and at national level, if the concerned affected person is not satisfied with the decision at community level LARC, the person can appeal for Super LARC.

5.8.2 Mitigating impacts to Government Institutions and properties

The Project proponent will discuss with relevant government organizations and will provide necessary assistance to relocate the affected parties. The Project Proponent has already started discussions with relevant ministries in this regard.

5.8.3 Socio Economic Benefits During Operation

This is a positive impact for which mitigation measures are not necessary.

5.9 Mitigation Measures for Neighboring Land Users Related Impacts

5.9.1 Mitigation Measures for impact on neighboring land uses

No significant impact is expected since LRT route goes at the center of the existing road, while providing roadside buildings with adequate space for light and ventilation. Therefore, no mitigation measure is required.

5.10 Mitigation Measures for Impacts due to Solid Waste

5.10.1 Mitigation measure for erosion of excavated materials, spoil and other waste construction materials etc.

Following objects which consist of construction material will be subject to erosion;

1) Temporary non-compacted soil mounds formed from excavated earth of foundation trenches ready to be transported for pilot road construction in flood plains as it is prudent to use such material for the pilot roads on the flood plains which have a limited length.
2) Sand stockpiles used for concrete in the batching plant site

To mitigate the erosion impacts following mitigation measures will be adopted.

1) Loose earth will not be kept by the road side even within the construction site for a long time without transportation to the pilot road. If such soil is kept temporarily such soil mounds will be covered by a polythene sheet and weights will be placed on sides to avoid the cover getting off soil mound.
2) Sand stockpiles will be haunched and compacted slightly to avoid ready erosion from rain.
3) Temporary drainage provisions will be provided around the sand stockpiles.

As only excavations are limited to 6mx6m trenches for column foundations not much spoil will be generated. Such spoil after checking the suitability will be used for the pilot road construction on the flood plain.

Temporary storage areas will be identified prior to construction. Sensitive areas such the protected areas (e.g. Thalangama EPA, Sri Jawardenapura Bird Sanctuary, wetlands) will be avoided. Wastes will be segregated and disposed accordingly.

Building rubble, excavated soil, and construction wastes will be used for necessary pilot roads and temporary filling. Once construction is over, these will be disposed at the Waste Management Park development area at Kerawalapitiya, located approximately 15km north from the LRT route. The consent letter on the disposal of construction waste at the above disposal site is obtained from SLLRDC (See Annex B).

Recyclable materials (e.g. paper, glass) will be handed to registered recyclers. Non-hazardous waste (Non-Scheduled Waste) will be disposed to in accordance with relevant local regulations (e.g. disposal to designated disposal sites through the Local Authority). Wastes will be collected and disposed regularly to prevent accumulation, which may cause pollution and safety risks.

Scheduled wastes (e.g. oil) will be collected and carefully stored. Treatment and disposal of these wastes will be contracted out to a registered industrial waste company.

Any metal solid waste generated from construction activities will be handed over for recycling. Any other waste such as chemicals residues or any other Scheduled Waste will be handed over to the Lafrage Hocim Geocycle process for burning in the cement manufacturing plant Puttlam.

5.10.2 Mitigation measure for waste generated from Depot during the Operation Stage

During operational stage, lubricant oil, sludge, brake shoe, metal scraps and rubber tube will be generated as waste from the Depot. Metal scraps can be recycled. If available, these will be handed to a registered recycling company. On the other hand, hazardous wastes (e.g. lubricant oil, sludge) and other industrial wastes (e.g. rubber tube, brake shoe) will be collected and stored at designated area. Treatment and disposal of these wastes will be contracted out to a registered industrial waste company. With implementation of proper waste management practice, the likelihood of an accident such as spillage and leakage of wastes streams will be minimal. Currently, Ecocycle (waste management company) is identified as candidate company in charge of the disposal of these wastes. (See Annex B).

5.10.3 Mitigation measure for waste generated from Stations during the Operation Stage

Domestic solid waste will be generated from the stations and from the depot during the operational stage. Such solid waste will be separated to bins for bio degradable and non-degradable waste and such waste will be handed over to Colombo Municipal Council and relevant Pradesheeya Sabhas for disposal.

Any wastes generated will be collected according to the type of waste by registered waste contractor and treated through a registered waste disposal facility such as the "Ecocycle" facility in Puttlam Cement Factory. Recyclable waste will be handed over for recycling.

5.11 Mitigation Measures for Impacts on Surface and Groundwater Quality

5.11.1 Mitigation Measures for Surface Water Quality Degradation during Construction

There are possibilities of surface water quality degradation during the construction of piers for Diyawanna Lake crossing and the depot. Water turbidity and alkalinity could increase. This impact is temporary and limited to the construction stage. As Diyawanna Lake is a large waterbody the increase of alkalinity will not be significantly felt. Water quality in Diyawanna Lake near the construction site will be monitored to detect abnormal water quality changes.

5.11.2 Groundwater Quality Degradation during Construction

The potential impact on groundwater is very limited because alkaline substances will not dissolve in the water. Once built, the foundation structures will have negligible impact on groundwater quality. Hence no special mitigation measures are necessary. However, the groundwater monitoring will be conducted near the Depot area to confirm the potential contamination.

5.12 Mitigation measures due to impacts on culturally and Historically Important aspects during Construction

5.12.1 Mitigation measure for Bo trees and shrines

There are total 14 Bo trees (with and without shrine) along the LRT route. Careful consideration has been taken to avoid and minimize the impact on Bo trees since the initial stage of feasibility study. The route will be further adjusted to minimize the impact on Bo trees during detailed design stage.

In case trimming or cutting down of branches is required, religious rituals and communication with relevant stakeholders (Monks and devotees) will be carried out before the commencement of construction activities.

Access to religious and culturally important sites may be impaired temporarily. Therefore, a traffic management plan will be developed considering alternative access roads to religious and culturally important sites.

5.12.2 Mitigation measure for Archeological buildings

Based on the preliminary archaeological survey conducted by the Department of Archeology, there are two buildings along the trace that are potentially significant, but these are not designated as archeologically important. However, there are listed archeologically important buildings close to Lipton Circle (eg: Hospital Building).

The LRT route was designed to avoid the direct impact on these buildings. Also, "archeological effect evaluation application" was submitted to the Department of Archeology and further study may be conducted as per the guidance from the Department. Refer to **Annex B** for the submitted application form.

5.13 Mitigation Measures for Wastewater Impacts

5.13.1 Disposal of waste/waste water generated from workers camp (depot area) and Construction Site during Construction Stage

Since no workers camp is needed for the construction activity, there will be no domestic waste or sewage generated during this period. However, limited number of construction workers may live on the Depot site, therefore, adequate facilities will be provided, such as sanitary latrines.

In addition, at construction sites, cylindrical septic tank or temporary toilet**Error! Reference source not found.** Will be installed. Septage will be collected by authorized sewage waste management company.

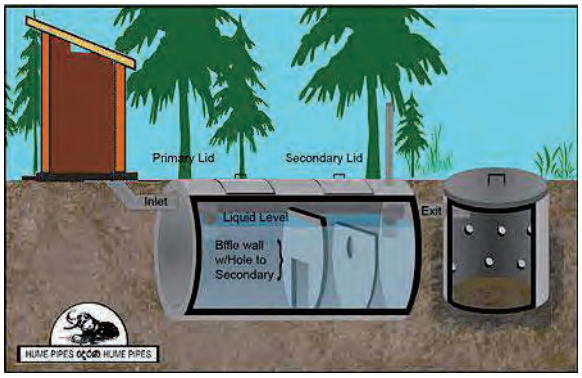


Figure 5.1 Example of Cylindrical Septic Tank (Left) and Temporary Toilet (Right)

5.13.2 Mitigation Measures for Spillage, Leak and Accidental Discharge of Fossil Oil Generated from Construction and operation stages

Construction Stage

The risk of spillage, leak and accidental discharge of fuels from construction equipment can be reduced and manage with proper spill prevention measures. Following mitigation measures will be implemented during construction stage.

1) Good use and maintenance of construction machines and heavy vehicles
2) Install oil and grease traps in the drainage system
3) Establish and implement emergency and contingency plan in case of spills

Operational Stage

LRT is an electrically operated transport mode and fossil fuel will not be used for train operation. However, fuel oil or lubricant oil will be stored and handled at Depot area. In order to prevent leakages/spillage, the following mitigation measures will be conducted:

1) Secondary containers will be placed in storage areas
2) Spill kits will be provided
3) Areas which have risks to spill/leakage will be provided with a drainage that is directed to the oil separator (particularly for the depot area)

5.13.3 Mitigation Measures for Disposal of Wastewater Generated from Depot (Terminal Buildings, Rolling Stocks, Maintenance, Washing, serving etc.) during the Operation

Wastewater from Depot

Wastewater from maintenance yard

Wastewater generated from maintenance yard for LRT system will be treated in series of wastewater treatment system to treat the wastewater to meet required standard It is expected that type of

wastewater treatment system to be installed includes Holding tank, Oil Separator, Dissolved air floatation, dehydrator and filtration as shown in Figure 5.2. Treated wastewater will be discharged to the public sewage system.

Wastewater from administration building

In addition, wastewater will be generated from administration building, such as from toilet and kitchen. These wastewaters will be treated through Oil Separator as minimum treatment process, then discharged to the public sewage system as shown in Figure 5.2.

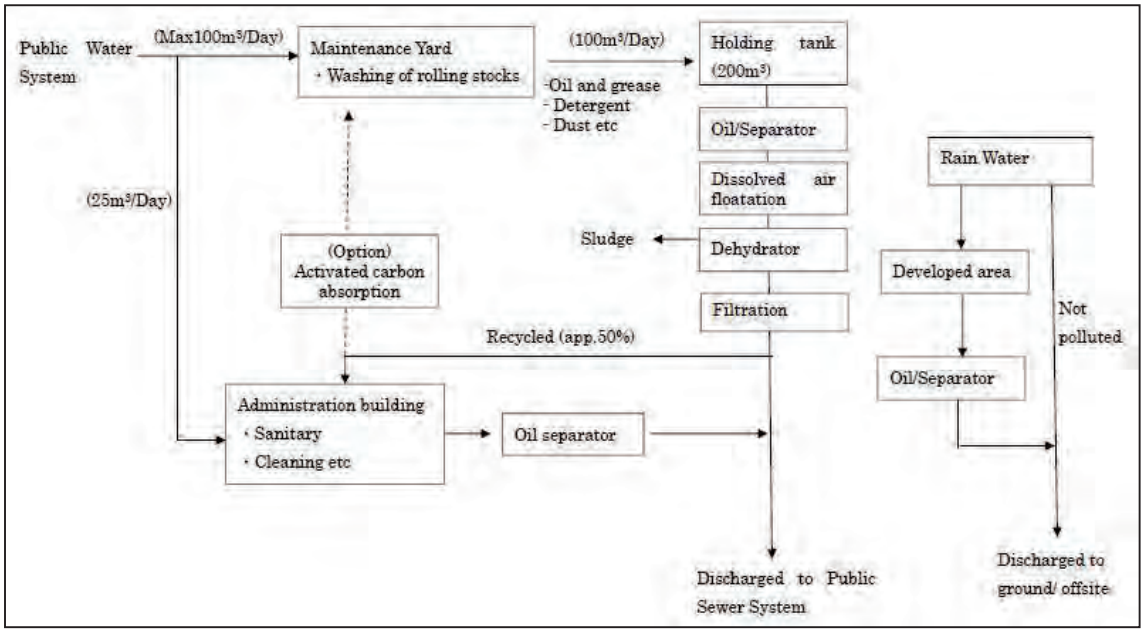


Figure 5.2 Proposed Wastewater Treatment System for Depot

It is intended that the treated wastewater from maintenance yard will be reused in administrative building as well as maintenance yard as reasonable as possible. The necessity of implementation of activated carbon absorption will be considered during the detailed design stage once the characteristic of wastewater quality as well as requirement of water quality for maintenance yard is confirmed.

It is noted that no public sewage system is currently developed around the proposed Depot location. However, there is a plan of the sewage system development around Si Jayawardanapura Kotte area. The study of this project has been conducted by National Water Supply and Drainage Board, supported by JICA. Under the current proposal, the public sewage system is planned to be extended up to the area of Koswatta Junction, which is approximately 3km from the proposed Depot area. The wastewater pipeline from the Depot will be connected to the proposed public sewage system. (See Annex B). The wastewater can be transported through the pipeline (diameter could be around 20cm) which would be hooked along the elevated structure and connected to their proposed treatment plant, located in Battaramulla. The consent letter from NWS&DB regarding to the acceptance of the wastewater generated from the LRT project has been obtained and attached in Annex B.

In case that the implementation of the proposed public sewage system is delayed, the following temporary mitigation measures will be implemented until the proposed sewage system is implemented.

1. Wastewater generated from the maintenance yard.

Mediwela canal is running west of proposed depot adjacent to the road, which connects Thalangama Tank and Kelani River. Total length of the canal is approximately 7km and proposed discharge point is located about half point. Main source of the water in the canal is Thalangama tanks. In case wastewater is discharged to Madiwela canal, the wastewater will be treated to the meet CEA standard (SCHEDULE 1, LIST1, General standards and criteria for the discharge of industrial effluents into inland surface waters).

2. Wastewater generated from the administrative building.

The wastewater from administrative building will be collected in Septic Tank, then the sewage will be collected by gully sucker by licensed contractor or local authority for final disposal.

5.13.4 Mitigation Measures for Disposal of Wastewater Generated from Stations during the Operational Stage

The wastewater generated from the station is sewage from the toilet facility. Sewage will be sent to public sewage system. The stations located within CMC area (6 stations) will be connected to the existing public sewage network system. For remaining stations, the sewage pipeline will be connected to the proposed public sewage system as described in above.

In case that the implementation of the proposed public sewage system is delayed, the sewage will be collected in Septic Tank which will be installed within the elevated station structure or underground under the station structure, then collected by gully sucker by licensed contractor or local authority for final disposal.

5.14 Mitigation Measures for Impacts on Water Courses

5.14.1 Mitigation Measures for Backwater at Lake Crossings during Construction and Operation

Construction Stage

1) Using a two-dimensional flood model with a possible tentative blocking arrangement for construction rigs within the Diyawanna Lake possible backwater from 100 year will be controlled to an insignificant level. The entire cross section of the lake across the LRT trace will not be blocked substantially for construction work. Blocking of the lake cross section will be done part by part.

2) Construction of the foundation of LRT structure within the lake will be strictly limited to dry season and critical monsoon periods such as April- June and September to November will be avoided using the rain forecasts from the Department of Meteorology and other international

weather information sources.

3) Temporary blocking of the lake section will be carried out according to the instructions of SLLRDC and the model will be re-run depending on the site-specific construction arrangements.

4) In case of a flood a suitable pumping arrangement will be made to speed up the flow through the blocked sections to minimize backwater and such pumps will be kept in reserve at the construction site.

5) If in the opinion of the Engineer that flooding is aggravated because of temporary construction blocks such blocks will be temporarily removed until the flood subsides.

Operational Stage

The model studies show that the backwater impact because of LRT piers is not significant and no mitigation measures are needed as the mitigation by design has been effected.

5.14.2 Mitigation for Pocket Flooding Locations

The contractor will be cautioned about the pocket flooding places. Drainage paths over the road will be kept undisturbed as far as possible. During construction if necessary temporary drainage paths will be created from the construction sites to the nearest drain. Construction equipment will be removed from site if inundation occurs.

5.14.3 Mitigation Measure for Backwater on Flood Plains

Mitigation Measures for Flood Aggravation in Depot Area

It was inferred that the flood impact will be around 6cm because of the temporary filling for the depot and the low-lying area from Chandrika Kumarathunga Mawatha to depot. The flood level rise for a construction stage flood of 10-year return period will be 12 cm. To mitigate the flood impact the following mitigation measures will be adopted.

Depot Area

1) Provide a 3m wide canal right round the fill area to reduce the net water level rise to 5cm and this result was confirmed through model studies conducted by SLLRDC.

2) The entire area demarcated for the depot will not be filled at once even temporarily. Filling and construction will be in parts. Once the construction of a part of the depot is over the temporary filling will be removed and temporary filling in another sub area could be started.

3) Height of fill will be controlled and water overtopping over the fill will be allowed.

4) It is also proposed to improve the existing drainage canals in the low-lying paddy by desilting them. The desilting of the drainage canals will be undertaken under the supervision of SLLRDC and Provincial Irrigation Department, Western Province.

5) Direct drainage connection will be established between these canals and main canal.

6) Culverts connecting paddy area and Madiwela canal are closed by gates and these gates are not

functional. During a flood, these culvert gates will be opened.

7) Existing drainages will not be blocked by temporary fillings.

8) The overall model will be refined adding the sub streams of the sub catchment on which the proposed depot will be constructed. Lower part (part occupied by the proposed depot) of this sub catchment will be modelled as a hydro dynamic model to represent the existing drainages and internal road culverts.

9) Filling will be breached at strategic locations in case of a flood if there is a backwater build up.

Pilot Road in the Low-Lying Areas Adjacent to Chandrika Bandaranayaka Kumaranathunga Mawatha

1) Height and width of the pilot road will be minimized to a height of 0.6m to allow floods of higher (greater than 10 years) return periods to overtop the pilot road.

2) Temporary culverts will be provided to all drainage paths and at places of the flood plain (where flow balancing is required) crossing the pilot road.

3) Filling will be breached at strategic locations in case of a flood if there is a backwater build up.

4) Pilot road will be again tested using the flood model of SLLRDC to represent site specific conditions accurately with openings.

Bridge crossing

In case of heavy floods, if necessary if there are coffer dam, they will be breached. Approval from SLLRDC will be obtained for the coffer dam

5.15 Mitigation Measures for Impacts on Air Quality

5.15.1 Air Quality Degradation During Construction Stage

Usually air quality could be impacted by dust as well as vehicular emissions. Several mitigation measures will require to be adopted during the construction phase to reduce dust generation. This includes the water spraying of surfaces which are prone to dust emission. It is also important to ensure that vehicles transporting construction material such as sand, metal and cement are covered adequately to reduce dust generation. The dust levels will be monitored periodically to ensure that the levels are not too high. To prevent adverse impacts on air quality from heavy vehicles these vehicles will be maintained in optimum condition always.

Dust-Wetting and water spraying of exposed surfaces to control dust. Soil compaction and timely debris removal. Cover exposed earth with gunny bags, black polythene etc. Covering of material transport vehicles. Limiting speed of construction vehicles to 10km/h. erect speed limiting sign boards. Careful stockpiling of cement and even spoil away from sensitive receptors (temples, schools etc.) and wind vulnerable areas. Road usage for material transport to be meticulous and will be free from spills from vehicles or tires. Assembling, dismantling of machines or other construction components will be carried out with minimum dust emission. Siting of crushing plans away from schools, temples etc. - upwind 500m and downwind 100m. Dust generation from crusher plants will be controlled by covering using wetted fabrics. Wetting the materials (e.g. aggregate) earmarked to be loaded, to avoid dust stir.


Site Wetting

Emissions – Keep all vehicles and equipment in good service (with emission certificates). Siting cement mixing places and batching plants away from sensitive receptors and avoid operations during windy conditions. Provide quarry, batching plant and construction workers with dust masks and safety goggles. Wetting of quarry site before blasting without causing misfires.


Dust Mask

Dust and emissions will be prevented, suppressed and contain exposure of workers, public or sensitive receptors. Prepare of a schedule for dust/emission generation activities and inform public in the environs regarding such activities.

Dust barriers will be installed near sensitive receptors or residential areas if the need arise. Site wetting will be continually carried out and dust monitoring will be an inherent activity of the Contractor's /Consultant's Environmental Officers.

5.15.2 Air Quality Improvement during Operational Stage

LRT will be electrically driven, and it is an emission free operation and the impact on emissions has already mitigated by the design itself. No further mitigation measures are warranted.

5.16 Mitigation Measures for Urbanization Impacts

5.16.1 Mitigation measures for impacts of increased urbanization

The LRT project will provide a positive impact, on resolving the issues which Colombo Urban Area has been undergoing, including spread of urban population, lack of high-quality public transport system and losing competitiveness in the region. No mitigation measure is required.

For the conversion of green areas and paddy fields to expansion of train station facilities and residential/commercial buildings, PMU will coordinate with relevant agencies regarding possible alternatives.

5.17 Mitigation Measures for Contingency Impacts

5.17.1 Mitigation Measures for Unexpected Events such as accidents, fire, natural hazards

Mitigation Measures Implemented

In order to address risks of unexpected events such as accidents and natural hazards, the following mitigation measures will be implemented.

1) Compliance with applicable performance specification, design standards and codes, health and safety regulations
2) Provision of firefighting system (firewater retention pond, fire hydrants, fire extinguishers) will be implemented as per applicable industrial standard
3) Development of an emergency response plan for both construction and operation phases.

Emergency Response Plan Policy

An emergency is an unplanned event when a project operation loses control, or could lose control, of a situation that may result in risks to human health, property, or the environment, either within the facility or in the local community. Emergencies do not normally include safe work practices for frequent upsets or events that are covered by occupational health and safety.

During the detailed design stage, PMU and EPC contractor will develop an emergency response plan for construction stage. During operational stage, O&M company will also prepare a specific emergency response plan for operational stage. The emergency response plan will be developed to address, as a minimum, the following categories:

- ≠ Fire due to extreme hot weather, equipment failure and accident
- ≠ Impact due to flooding
- ≠ Failure of rail component and structure/train accident

Emergency response plan will include following elements;

- ≠ Administration (policy, purpose, distribution, definitions, etc.)
- ≠ Organization of emergency areas (command centers, medical stations, etc.)
- ≠ Roles and responsibilities
- ≠ Communication and reporting systems
- ≠ Emergency response procedures
- ≠ Emergency resources

≠ Training and updating

≠ Checklists (role and action list and equipment checklist)

≠ Business Continuity and Contingency

Emergency Response Procedures

Emergency response procedure for each potential hazard will be prepared. A simplified set of emergency procedures for each potential hazard is presented below. There is a need to develop in situ specific response strategies once project details and corresponding hazards and risks have been identified.

1) Fire

≠ The Emergency Response Coordinator must be notified.

≠ Personnel in the immediate vicinity of the fire, including the designated Evacuation personnel must be immediately notified.

≠ All persons located in the area where fire is located must be evacuated. Evacuation must be carried out as per the Evacuation Procedure.

≠ All doors and windows of buildings and vehicles that are in the immediate vicinity of the fire must be closed.

≠ The fire must be contained with the correct extinguisher only by trained staff.

≠ Those requiring assistance must be assisted and first aid must be rendered only by trained staff.

≠ Those confined to an area where there is smoke, must move under the level of the smoke and cover their nose/mouth.

2) Flood

≠ Identify flood hazards of project components located in low-lying areas.

≠ The weather forecast in flood-prone areas must be constantly monitored, especially during the rainy season.

≠ All key equipment must be raised above (or away) expected flood levels.

≠ Construction of bund and water channels to divert flood water to safe areas.

3) Failure of rail component and structure/train accident

≠ Operational control center shall play important role in initial stage of emergency response. Following shall be included in the plan.

✓ The general roles and responsibilities of key personnel during emergencies

✓ The roles and responsibilities of the control centre in the incident notification,

evaluation and documentation processes

- ✓ The location of emergency plans and procedures
- ✓ The policies for coordinating with incident command

≠ Procedure for notifying key parties of emergency situations and incidents must be developed. Following shall be included.

- ✓ Guidelines on what information to obtain from employees, passengers or other individuals first reporting emergencies to the RTS
- ✓ Guidelines for what people/departments are to be contacted at what stage of the process
- ✓ Policy for reporting emergencies within the RTS
- ✓ Guidelines for disseminating appropriate information to customers
- ✓ Inter-agency policy for broadcasting system status information to the public
- ✓ Instructions and policy for contacting outside agencies
- ✓ Instructions and policy for media notification.

≠ Training for emergency response crew for the operation stage will be programmed. This would include training programs:

- ✓ Evacuation of passengers from train, to a point of safety
- ✓ Evacuation of passengers from stations (surface and underground)
- ✓ Emergency procedures to be controlled from the Depot control center, including co-ordination of participating agencies such as fire service, police, ambulance, public works and utility companies, etc.

≠ Coordination with other agencies shall be arranged for emergency situation, including

- ✓ Medical services
- ✓ Building department
- ✓ Fire department
- ✓ Police department
- ✓ Utility companies
- ✓ Other transportation agencies