



# DETAILED PROJECT REPORT REVISED

## ALUVA- TRIPUNITHURA

November 2018

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## CHAPTER 1

### EXECUTIVE SUMMARY

#### **0.1 INTRODUCTION**

0.1.1 Kochi is the most densely populated city in the state and is part of an extended metropolitan region, which is the largest urban agglomeration in Kerala. Kochi city is part of the Greater Cochin region. Kochi consists of mainland Ernakulam; the islands of Willingdon, Bolghatty and Gundu in the Harbour; Fort Kochi and Mattancherry on the southern peninsula and Vypeen Island, north of Fort Kochi.

Kochi ranks first in the total number of international and domestic tourist arrivals in Kerala. Kochi is home to the Southern Naval Command of the Indian Navy and the state headquarters of the Indian Coast Guard . Commercial maritime facilities of the city include the Port of Kochi, the Cochin Shipyard, offshore SPM of the Kochi Refineries, and the Kochi Marina

0.1.2 Rapid urbanization and intense commercial developments in the recent past have resulted in steep rise in travel demand putting Kochi's transport infrastructure to stress. The increase in capacity of the transport system has not been compatible with transport demand. With ever increasing demand for road space – both for vehicular movement and parking, it is difficult to depend only on road based transport solutions.

0.1.3 The Kochi Metro Rail Project Phase-I was sanctioned at a total cost of Rs. 5181.79 crore with a completion time of 4 years from the date of start of construction works. The project works have started in June 2013 and a stretch of 13 km from Aluva to Palarivattom was commissioned in June 2017. Subsequently, another stretch of 5 km from Palarivattom to Maharajas College was completed in October 2017, thus completing 70% of the works. Kochi Metro is presently having the longest stretch opened for public in the shortest time, compared to any other Indian metros, i.e 0.270 km per month, for the first stretch.

0.1.4 The works in the remaining stretch i.e from Maharajas College to Petta is progressing well with a target to commission the system by end of the year 2019. The delay from Maharajas College to Petta is mainly attributable to the issues in land acquisition due to the implementation of the new land acquisition policies as well as delays caused due to contractual issues in DMRC contracts. On account of various factors including time overrun, the project cost has now been revised to an amount of Rs. 5687.79 crore from the sanctioned cost of Rs. 5181.79 crore mainly due to IDC and DMRC remuneration not included in the original cost.

0.1.5 In the meantime, Government of Kerala had approved an extension for the Phase 1 terminal station Petta to the nearby Junction SN Junction for a length of 2 KM and two stations. Another extension from SN Junction to Tripunithura for 1.2 KM and One station is also proposed in the meantime.

- 0.1.6 With these two essential extensions to take the Kochi metro Phase 1 to the historical township of Trippunithura, the total phase 1 became 28.125 KM with 25 stations. All the technical parameters of the Phase 1 construction remain unchanged in the extended phase 1.
- 0.1.7 "S.N Junction metro station" in the Phase I alignment is located on the Kochi-Dhanushkodi National Highway 85 which is about a Km away from the heart of Tripunithura Town. M/s RITES have already carried out a detailed study on different options available for extending Metro to Tripunithura and found that the most viable option is to connect the Metro alignment to Tripunithura Railway Station which is about 0.968 Kms from S.N Junction Metro Station. The location has its own inherent advantage, as it cater for the traffic from both Eastern & Southern sides of Ernakulam. It is also pertinent to mention here that, Tripunithura Municipality is planning to build a Bus Depot near to the Railway Station which will act as a catalyst to develop the area as a multimodal transport hub of Railway, Metro & Bus Transport, eventually will become the entry point to the city there by increasing the PHPDT of the entire Metro Corridor. The benefits of extending Metro to Tripunithura can only be achieved by extending the network up to Thripunithura Railway Station, which will make it economically viable and technically feasible.

In view of this Kochi Metro Rail Ltd. Intend to revise the DPR submitted by M/s RITES by extending the alignment through the proposed 21m wide road by Thripunithura municipality towards the bus depot planned by them. The proposal is under the consideration of Government of Kerala.

- 0.1.8 Greater Cochin Development Authority (GCDA) and Goshree Islands Development Authority (GIDA) Areas have been considered as the study area to cover the land-use sprawl including existing travel characteristics and future development proposals. The study area comprises Corporation of Cochin along with 9 municipalities and 29 village panchayats spread over an area of about 732 sq km. The population of study area is 20.4 Lakh as per Census 2011 figures.
- 0.1.9 The registered vehicles in Ernakulam have increased significantly over the years. The number has climbed from 8.9 to 17.6 Lakh in six years ( 2009-10 to 2016-17). The share of two wheelers is highest (about 62%). The sharp increase of two-wheelers and cars could be attributed to the improved economic status of people and deficient public transport supply.
- 0.1.10 Various past studies have been reviewed including 'Comprehensive Traffic and Transport Study (CTTS) for Greater Cochin Area' in August 2001 by RITES, 'City Development Plan (CDP) for Kochi' in 2006, 'Traffic and Transportation System Study for Kochi City' in 2007 by NATPAC, 'Development Plan for Kochi City Region – 2031' in 2010 by Department of Town & Country Planning and 'Detailed Project Report on Kochi Metro Phase I by DMRC' in 2005 & 2011.

## 0.2 TRANSPORT DEMAND FORECAST

- 0.2.1 Development Plan for Kochi City Region 2031 gives the likely growth to take place in various areas in the region. The plans also give locations of various land uses such as residential, commercial, industrial uses etc. The total population projection for the year 2021 and 2031 is estimated on the basis of density pattern proposed to be achieved in the Development Plan for Kochi City Region 2031.. The study area is estimated to have population of about 22.7 Lakh in 2015, 26.99 Lakh in 2035 based on CMP prepared in 2017 for Kochi.
- 0.2.2 Traffic demand forecast is taken from Phase 1 Aluva - Tripunithura which is extrapolated to the horizon years 2030,2040 and 2050.**Table 0.1:**

**Table 0.1: Summary of Transport Demand Forecast**

Per Day Ridership Forecast	2023	2030	2040	2050
Aluva – Tripunithura Railway Station	132910	229177	450826	886846

## 0.3 SYSTEM SELECTION

### 0.3.1 PERMANENT WAY

**Choice of Gauge:** Standard Gauge (1435mm) is generally adopted for metro railways world-over. During the last decade, most of the new metros, constructed in various cities of the world have gone for Standard Gauge even though the national gauge for main-lines in some of the cases was different from Standard Gauge. Kochi Metro Phase-I corridor from Aluva to Tripunithura is being implemented with standard gauge.

**Track Structure:** Track on Metro Systems is subjected to intensive usage with very little time for day-to-day maintenance. Thus, it is imperative that the track structure selected for Metro systems should be long lasting and requires minimum maintenance and at the same time, ensure highest level of safety, reliability and comfort, with minimum noise and vibrations. The track structure has been proposed keeping the above philosophy in view with details as under:-

- 60 Kg Head Hardened (HH) 1080 grade rails for main line.
- 60 Kg 90 UTS (non HH) rail for depot.
- Ballastless track for elevated viaduct and underground section of tunnel.
- At grade ballasted track for stabling lines in depot.
- Fastening system conforming to "Performance criteria of fastening system for ballastless track on Metro Railways/MRTS System".
- Turnouts 1 in 9 with lead radius of 190m and speed potential of 30kmph on divergent track.
- Scissor Cross over (1 in 9) is provided for this corridor.
- Flash Butt welds.

### 0.3.2 Rolling Stock

The specifications of the rolling stock and its procurement may be decided on the basis of the project implementation mechanism. The important criteria for selection of rolling stock are as under:

- (i) Proven equipment with high reliability
- (ii) Passenger safety feature
- (iii) Energy efficiency
- (iv) Light weight equipment and coach body
- (v) Optimized scheduled speed
- (vi) Aesthetically pleasing Interior and Exterior
- (vii) Low Life cycle cost
- (viii) Flexibility to meet increase in traffic demand

The controlling criteria are reliability, low energy consumption, lightweight and high efficiency leading to lower annualized cost of service.

### 0.3.3 Traction System

Traditionally, electric traction is used in Metro systems for requirement of high acceleration and pollution-free services in urban areas. There are two standard and proven systems of electric traction for use in suburban and metro lines, viz:- 750V DC third rail, 25kV AC overhead catenary system. All these two systems are presently in use in India (750 V DC third rail in Kolkata & Bangalore Metro, and 25 kV AC catenary in Delhi, Jaipur, Chennai, Hyderabad Metro & Indian Railways).

The 750V DC third rail system is being provided on the phase-I corridor of Kochi Metro.

### 0.3.4 Signalling System

Signaling & Train Control system for Kochi Metro Phase-IB is proposed for design headway of 90 seconds so as to meet sustained train operation at up to 2 minutes interval during peak hours. The proposed system shall be compatible with the existing Phase-I system for seamless operation & maintenance. Therefore, these requirements of the metro are planned to be achieved by adopting a State of art ***Communication based Train Control System***. This will enable running of optimum train services meeting traffic requirements in the most efficient and cost effective way. The Signalling & Train Control system will ensure:

- High level of safety with trains running at close headway ensuring continuous safe train separation.
- Eliminate accidents due to driver passing Signal at Danger by continuous speed monitoring and automatic application of brake in case of disregard of signal / warning by the driver.

- Provide safety and enforces speed limit on section having permanent and temporary speed restrictions.
- Improve capacity with safer and smoother operations. Driver will have continuous display of Target Speed / Distance to Go status in his cab enabling him to optimize the speed potential of the track section.
- Moving block feature shall provide enhancement of headway.
- Improve maintenance of Signaling and telecommunication equipments by monitoring system status of trackside and train born equipments and enabling preventive maintenance.

#### 0.3.5 **Telecommunication**

The telecommunication system acts as the communication backbone for KMRL system and provides telecommunication services to meet operational and administrative requirements of metro network. The proposed system shall be compatible with the existing Kochi Metro Phase-I system for seamless operation & maintenance. The proposed telecom system and transmission media will have following systems:

- Optical Fiber Cable
- Telephone Exchange
- Mobile Radio Communication
- Public Address System
- Centralized Clock System
- Passenger Information System
- Close Circuit Television
- Central Voice Recording System (CVRS) and
- Access control system

#### 0.3.6 **Fare Collection System**

Mass Rapid Transit Systems handle a large number of passengers. Ticket issual and fare collection play a vital role in the efficient and proper operation of the system. To achieve this objective, ticketing system shall be simple, easy to use/operate, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. Automatic fare collection system meets these requirements.

Keeping in view Metro Railways Automatic Fare Collection System and the fact that Contactless card/ QR ticketing technology proves to be cheaper than magnetic technology in life cycle cost due to reduced maintenance as it has less wear and tear and is less prone to dusty environment, it is proposed to provide ***computer based***

*automatic fare collection system with Contactless smart card /QR code type ticketing.*

#### 0.4 CIVIL ENGINEERING

Geometrical design norms are based on international practices adopted for similar metro systems with standard gauge. Design speed is considered as 80 kmph. Horizontal and vertical alignment for elevated section are largely dictated by the geometry of the road.

Tracks are considered to be carried on viaduct superstructure supported by single piers, generally spaced at 25m c/c and located on the median of the road mainly. At few locations special span of more than 25m to avoid placing of piers/ portals in private land has been planned as shown in the alignment and land plans. Tentative spanning arrangement as shown in the Alignment and land plan may be reviewed during interim consultancy stage or execution stage, minimum track centre on the elevated section is kept as 4.2m. Extra clearance on curves as required will be applied on curves. Width of viaduct will depend on design of superstructure as finalized at DDC stage. However, for present DPR, width of superstructure is considered as 10.00. m.

The standards adopted for horizontal and vertical alignments are given in **Table 0.3**

**Table 0.3: Standards for Horizontal and Vertical alignments**

	Radius (Elevated Section)	Radius (Underground Section)
<b>Preferred:</b>	200 m and above	400 m and above
<b>Minimum:</b>	25 m	300m
<b>Absolute minimum:</b>	120m (in exceptional cases)	200m (in exceptional cases)

Minimum curve radius at stations : 1000 m

Maximum permissible cant ( $C_a$ ) : 125 mm

Desirable cant ( $C_a$ ) : 110 mm

Maximum cant deficiency ( $C_d$ ) : 100 mm

Desirable cant deficiency : 85 mm

#### Transition curves

- Minimum length of Transitions of Horizontal curves (m): 0.44 times actual cant or cant deficiency (in mm), whichever is higher.
- Desirable: 0.72 times actual cant or cant deficiency, (in mm) whichever is higher.
- No overlap is allowed between transition curves and vertical curves.
- Minimum straight between two Transition curves: either 25 m or NIL.

- Minimum curve length between two transition curves: 25 m

#### **Vertical alignment at Aluva Station**

The rail level of Phase I corridor at Aluva station is 20.910m. Generally gradient of 2% has been provided except some locations where higher gradient is provided due to site constraint. Change of gradients has been avoided on transition curves or on the locations where turnouts and cross-overs are added.

#### **0.4.1 Aluva-Tripunithura Corridor**

M/s DMRC have conducted the DPR for stretch from Aluva to Petta in which the construction is in progress now. Later M/s RITES have conducted the feasibility report of corridor from Petta To SN Junction for 2 Kms which is currently in the tender stage expected to begin construction by January 2019. M/s RITES have already carried out a detailed study on different options available for extending Metro to Tripunithura and found that the most viable option is to connect the Metro alignment to Tripunithura Railway Station which is about 1.2 Kms from S.N Junction Metro Station. The location has its own inherent advantage, as it cater for the traffic from both Eastern & Southern sides of Ernakulam. It is also pertinent to mention here that, Tripunithura Municipality is planning to build a Bus Depot near to the Railway Station which will act as a catalyst to develop the area as a multimodal transport hub of Railway, Metro & Bus Transport, eventually will become the entry point to the city there by increasing the PHPDT of the entire Metro Corridor. This will make the entire corridor length to 28.125 Kms.

#### **0.4.2 Station Locations & Planning**

Stations have been located so as to serve major passenger destinations and to enable convenient integration with other modes of transport. Effort has been made to keep inter station distances of about one km.

**Table 0.4: : List of stations on Aluva. - Tripunithura corridor**

S.No.	Name of station	Chainage
1	Aluva	98.045
2	Pulinchodu	1826.867
3	Companypady	2795.663
4	Ambattukavu	3779.233
5	Muttom	4716.095
6	Kalamasserry	6768.401
7	CUSAT	8146.910
8	Pathadipalam	9394.189

9	Edappally	10787.412
10	Changampuzha Park	12087.708
11	Palarivattom	13096.523
12	JLN Stadium	14208.595
13	Kaloor	15249.455
14	Lissie	15722.291
15	MG Road	16926.040
16	Maharajas College	18099.557
17	Ernakulam South	18956.309
18	Kadavanthra	20140.774
19	Elamkulam	21295.432
20	Vytilla	22734.060
21	Thaikoodam	23758.272
22	Petta	24881.604
23	Vadakkekotta	26085.692
24	SN Junction	26845.166
25	Tripunithura	27777.702

#### 0.4.3 Land Requirement

All efforts have been made to keep land requirement to the barest minimum and acquisition of private property is minimal. Land is mainly required for route alignment on sharp bends, station buildings, platforms, entry/exit structures, traffic integration, power sub-stations, ventilation shafts, administrative buildings and temporary construction depots / work sites etc.

#### 0.4.4 Viaduct Structure

The Super structure of entire corridor from Aluva to Tripunithura will be consisting of I/U Girder and others at specific locations as per site condition. The precast items(Superstructure & Pier Cap) will be casted at Pre Cast Yard from where it will be transported to site through custom made trailers. The erection of the superstructure is being done through high capacity cranes placed on ground.

### 0.5 TRAIN OPERATION PLAN & ROLLING STOCK

The underlying operation philosophy is to make the MRT System more attractive and economical, the main features being:

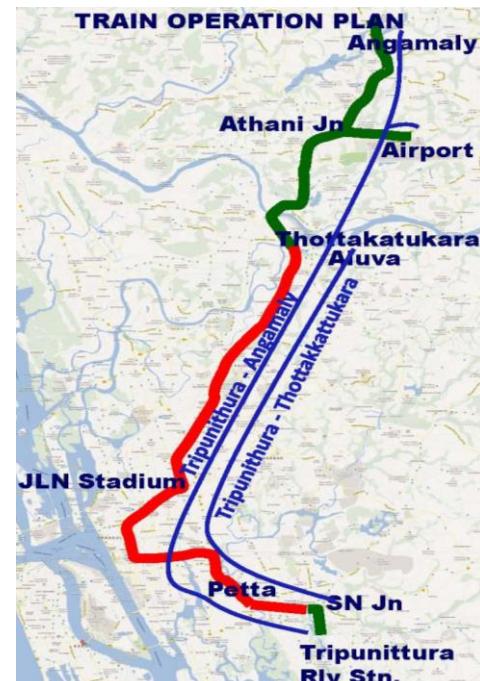
- Selecting the most optimum frequency of Train services to meet sectional capacity requirement during peak hours on most of the sections

- Economical & optimum train service frequency not only during peak period but also during off-peak period.
- A short train consists of 3 coaches with high frequency service.
- Multi-tasking of train operation and maintenance staff.

The salient features of the proposed train operation plan are:

- Running of services for 19 hours of a day (5 AM to Midnight) with a station dwell time of 30 seconds.
- Operation of 3 car rake Rolling stock, similar to Kochi Metro Phase-I
- Two DMC and one TC will form a basic unit capable of independent operation.
- Capacity of 3 car rake is 766 passengers with a seating capacity of 136 and 630 standees @ 6 passengers/ m<sup>2</sup>. The capacity would be 975 passengers with 136 seating and 839 standees @ 8 passengers/ m<sup>2</sup>.
- Scheduled speed of 34 kmph.
- Make up time of 5-10% with 8-12% coasting.
- Adequate services to ensure comfortable journey for commuters even during peak periods.
- Train operation for Tripunithura –(Aluva) – corridor is planned in such a way that during peak hours, out of the total trains originating from Tripunithura, every alternate train will return from mid terminal .
- 

To meet the projected traffic demand, the possibility of running trains with 3 Car train composition has been examined. The basic unit of 3-car train comprising of following configuration has been selected as below -



- DMC : Driving Motor Coach
- TC : Non Driving Trailer Coach
- 3-Car Train Composition: **DMC-TC-DMC**

Every coach should be fully interchangeable with any other coach of same type. ***Two DMC and one TC will form a basic unit*** capable of independent operation.

- **Capacity :**

For the purpose of calculating rake requirement of rolling stock, passenger carrying capacity is considered as below:

- 3 Car Train: 2DMC+1TC= 766 (seating –136, standing – 630@6 passengers/m<sup>2</sup>)  
 $= 975 \text{ (seating -136, standing - 839@8 passengers/ m}^2\text{)}$

Based on the PHPDT demand and above train operation plan, the headway and capacity provided for different sections of the corridor in the horizon years 2020, 2030, 2040 is given in **Table 0.10**.

**Table 0.10: Headway & Number of rakes required**

Year	2020	2030	2040
<b>Headway ( minutes )</b>	8	4	4
<b>No of Cars/Train</b>	3	3	3
<b>Rakes Required</b>	24	28	31
<b>Cars Required</b>	<b>72</b>	<b>84</b>	<b>93</b>

The number of coaches required in the years 2020, 2030, 2040 are indicated in **Table 0.10**.

## 0.6 POWER SUPPLY

The power requirements of a metro system are determined by peak-hour demands of power for traction and auxiliary applications. The broad estimation of auxiliary and traction power demand for the corridor has been made based on the following assumptions:-

- (i) Train operation with **3 car** rake at peak period **headway of 90 seconds**.
- (ii) Specific energy consumption of rolling stock – **65 KWh / 1000 GTKM**
- (iii) Elevated/at grade station load – initially 200KW, which will increase to 250 KW in the year 2033 and 300 kW in 2043/2048
- (iv) Underground station load/ Depot auxiliary load - initially 2000 KW, which will increase to 2500 KW in the year 2031.

Keeping in view of the train operation plan and demand of auxiliary load, power requirement have been worked out for the years 2023,2033, 2043/2048. The calculation of power demand estimation is briefly summarized in table **Table 0.12**.

**Table 0.12: Power Demand Estimation (MVA)\***

Corridor/ Section	Year		
	2023	2033	2043/2048
Aluva - Tripunithura	Traction	0.26	0.41
	Auxiliary	0.22	0.28
	<b>Total (MVA)</b>	<b>0.48</b>	<b>0.69</b>
			<b>1.15</b>

\* Above mentioned demand estimation includes 5% distribution losses

#### 0.6.1 Sources of power supply system

The high voltage power supply network of Kochi has 220kV, 110kV and 66 kV network to cater to various types of demand in vicinity of the proposed corridor. Keeping in view the reliability requirements, it is proposed to avail power supply for traction as well as auxiliary services from the following grid sub-stations of KSEB at 110 kV voltage level through cable feeders for the proposed corridors. Sources of supply are given **Table 0.13.**

**Table 0.13: Sources of Power Supply**

Section/ Feeding Zone	Grid Sub-Station (I/P Voltage)	Location of RSS of Metro Authority	Approx. dist.
Aluva - Tripunithura	Kalamasserry (220 kV) Thaikodam (110kV)	Muttom & Thaikodam (110/33 kV)	Muttom – 3 Km Thykooram-0.2 Km

The summary of expected power demand at various sources is given in **Table 0.14.**

**Table 0.14: Power Demand Projection**

Input Source/ RSS	Peak demand – Normal (MVA)			Peak demand* – Emergency (MVA)		
	Year 2023	Year 2033	Design 2043	Year 2023	Year 2033	2043
<b>Muttom RSS (Feeding Zone Aluva to Palarivattom)</b>						
Traction	9.74	11.51	13.28	19.09	22.56	26.03
Auxiliary	6.18	7.54	7.54	12.97	15.82	15.82
<b>Total</b>	<b>15.91</b>	<b>19.04</b>	<b>20.81</b>	<b>32.05</b>	<b>38.36</b>	<b>41.83</b>
<b>Thaikodam RSS (Feeding Zone Palarivattom to Tripunithura)</b>						
Traction	9.35	11.05	12.75	19.09	22.56	26.03
Auxiliary	6.79	8.28	8.28	12.97	15.82	15.82
<b>Total</b>	<b>16.14</b>	<b>19.32</b>	<b>21.02</b>	<b>32.05</b>	<b>38.36</b>	<b>41.83</b>
* In case of failure of other RSS						

#### Auxiliary Supply Arrangements for Stations & Depot

Auxiliary sub-stations (ASS) are envisaged to be provided at Thripunithura to cater to auxiliary load. The ASS will be located at mezzanine or platform level inside a room. ASS & TSS will be housed together inside a room. The auxiliary load requirements assessed to be about 200kW for elevated / at-grade stations of 33/0.415kV, 500 kVA capacity for elevated/at-grade stations are proposed to be installed. The 33 kV power supply will be stepped down to 415 V, 3 phase for distribution to the consumption points (service utilities) viz. Elevators, Escalators, Light & power sockets, Fire system, HVAC system and Signal & Telecom system etc. For Property Development within the footprints of the station, a provision to add third transformer at a later date may be kept at elevated station.

#### **0.6.2 Standby Power Supply**

In the unlikely event of simultaneous tripping of all the RSSs or grid failure, the power supply to stations as well as to trains will be interrupted. It is therefore proposed to provide standby DG set of 160 KVA capacity at Thripunithura to cater to the following essential services:

- (i) Lift operation
- (ii) Essential lighting
- (iii) Signaling & telecommunications
- (iv) Fire fighting system
- (v) Fare collection system
- (vi) Tunnel ventilation system (for underground stations only)

Silent type of DG sets, which have low noise levels and do not require separate room for installation, are proposed. In addition, UPS with adequate power backup are proposed for the very essential lighting load.

#### **0.6.3 Supervisory Control and Data Acquisition (SCADA) System**

The entire system of power supply (receiving, traction & auxiliary supply) shall be monitored and controlled from a centralized Operation Control Centre (OCC) through SCADA system. Modern SCADA system with intelligent remote terminal units (RTUs) shall be provided. Optical fibre cables provided for telecommunications will be used as communication carrier for SCADA system.

Digital Protection Control System (DPCS) is proposed for providing data acquisition, data processing, overall protection control, interlocking, inter-tripping and monitoring of the entire power supply system consisting of 33kV ac switchgear, transformers, 750V dc switchgear and associated electrical equipment. DPCS will utilize microprocessor-based fast-acting numerical relays & Programmable Logic Controllers (PLCs) having suitable interface with SCADA system.

#### **0.6.4 Energy saving Measures**

Energy charges of any metro system constitute a substantial portion of operation & maintenance (O & M) costs. Therefore, it becomes imperative to incorporate energy saving measures in the system design itself. The auxiliary power consumption of metros is generally more than the traction energy consumed by train movement. The proposed system includes the following energy saving features:

- (i) Modern rolling stock with 3-phase VVVF drive and light-weight stainless steel coaches, which has the benefits of low specific energy consumption and almost unity power factor.
- (ii) Rolling stock has regeneration features and it is expected that 30% of total traction energy will be regenerated and fed back to 750V dc third rail to be consumed by nearby trains.
- (iii) Effective utilization of natural light is proposed. In addition, the lighting system of the stations will be provided with different circuits (33%, 66% & 100%) and the relevant circuits can be switched on based on the requirements (day or night, operation or maintenance hours etc).
- (iv) Machine-roomless type lifts with gearless drive have been proposed with 3-phase VVVF drive. These lifts are highly energy efficient.
- (v) The proposed heavy-duty public service escalators will be provided with 3-phase VVVF drive which gives energy efficiency & improved power factor. Further, the escalators will be provided with infra-red sensors to automatically reduce the speed (to idling speed) when not being used by passengers.
- (vi) The latest state of art and energy efficient electrical equipment (e.g. transformers, motors, light fittings etc) have been incorporated in the system design.
- (vii) Efficient energy management is possible with proposed modern SCADA system by way of maximum demand (MD) and power factor control.
- (viii) Solar power plant may be installed at station to produce electricity which may meet the energy requirement of the station. KMRL has already a Power Purchase Agreement with a private company for installing the Solar Power Plants. The price for solar power is being paid @ Rs. 4.59 per unit.

#### 0.6.5 Electric Power Tariff

The cost of electricity is a significant part of Operation & Maintenance (O&M) charges of a metro system .Therefore, it is the key element for the financial viability of the Project.

The annual energy consumption for the proposed Aluva to Tripunithura section of Kochi Metro Phase-I is about 26 million units, 30 million units, 33 million units, 35 million units in the year 2020, 2030, 2040 and 2050 respectively.

In addition, to keep the energy consumption optimum, it is also necessary that the electric power tariff be kept at minimum in order to contain the O & M costs. Therefore, the power tariff for Kochi Metro should be at effective rate of purchase price (at 110kV or 220kV voltage level) plus nominal administrative charges. This is expected to be in the range of Rs. 5.50-6.50 per unit. It is proposed that Government of Kerala takes necessary steps to fix power tariff for Kochi Metro at “No Profit No Loss” basis.

## **0.7 MAINTENANCE DEPOT**

The Maintenance Depot at Muttom is well equipped to cater entire requirement of Phase I Corridor from Aluva- Tripunithura.

## **0.8 Power Generation Through Renewable energy sources – SOLAR PV System**

As part of its Go-Green initiative, KMRL had planned to install solar power plants of rooftop and ground mounted models in the Metro system. The present rate of the power generated from Solar power plant is less than the rates at which the power is being supplied by the State Electricity authority and hence the measure will support the cost reduction of the Metro Rail Operations.

In Phase I of the Metro, solar power is planned to be generated from the rooftop plants being installed in 22 stations and the Muttom Metro Depot. The planned installed capacity of the rooftop project is 4 MWp. The rooftop project is being implemented through Renewable Energy Service Company (RESCO) model, where the vendor would invest the capital cost and do the operation and maintenance; while KMRL would sign a power purchase agreement and buy the power from the vendor at an agreed rate. Tenders were invited and the first project has been awarded for power production for next 25 years. The plant capacity achieved out of the Muttom depot and of the 14 stations, where it is feasible to install the plant, is about 2671 KWp which has been commissioned.

Further, based on the study conducted, a contract is awarded for installation of ground mounted solar plant of 2.3MWp capacity through Renewable Energy Service Company (RESCO) model, where the vendor would invest the capital cost and do the operation and maintenance; while KMRL would sign a power purchase agreement and buy the power from the vendor at an agreed rate.

Kochi metro Rail Limited has commissioned 2.671MWp solar power plant till March 2018 under RESCO model. KMRL has an ambitious plan of achieving about 40% of energy independence by the end of 2019.



## Chapter 2

### FINANCIAL ANALYSIS, FARE STRUCTURE AND FINANCING

#### 2.1 FINANCIAL ANALYSIS

2.1.1 The financial internal rate of return (FIRR) is calculated after taking the cost estimations under the heads of **capital cost**(i.e. the cost of construction of the corridors, cost of acquiring rolling stock, land cost, cost of support infrastructure like feeder buses, bicycles and development of Footpath), **O&M expenses**, which includes staff, energy and maintenance expenditure, **additional capital cost** comprising the cost incurred on replacement of electrical and S&T equipment and **support vehicles** (feeder buses and bicycles). The capital cost is as given below in **Table 2.1**.

**Table 2.1. Capital Costs**

Sl.No.	Head of expenditure	Phase - 1	Phase - 1A (Revised)	Phase -1B (Revised)	Soft Mobility components	Amount (Rs. In crore)
		AL-Petta	Petta-SN	Petta-Tripunithura	Non Motorised Transport initiatives	Aluva-Tripunithura
1	Land	672.00	97.38	43.23		812.61
	<b>Sub Total(A)</b>	<b>672.00</b>	<b>97.38</b>	<b>43.23</b>	<b>0.00</b>	<b>812.61</b>
2	Civil	2034.75	338.25	150.02		2523.03
3	Track & Electrical	729.67	69.79	45.68		845.14
4	Signalling & telcom	187.20	61.78	20.76		269.75
5	AFC	0.00	0.00	0.00		0.00
6	Rolling Stock	590.07	0.00	30.90		620.97
7	Pedestrianisation				147.32	147.32
8	Public spaces				12.85	12.85
9	Electric mobility	0.00	0.00	0.00	42.37	42.37
	<b>Sub Total (B)</b>	<b>3541.69</b>	<b>469.82</b>	<b>247.37</b>	<b>202.54</b>	<b>4461.42</b>
10	General Charges including design charges & Contingencies	300.92	46.44	24.74		372.09

11	Taxes & Duties	735.00	73.79	40.37	36.46	885.62
12	PMC charges	284.55	23.49	0.00		308.04
	<b>Sub Total ©</b>	<b>1320.47</b>	<b>143.72</b>	<b>65.11</b>	<b>36.46</b>	<b>1565.76</b>
13	IDC	153.63	0.00	0.00		153.63
	<b>Sub Total (D)</b>	<b>153.63</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>153.63</b>
	<b>Grand Total(A+B+C+D)</b>	<b>5687.79</b>	<b>710.92</b>	<b>355.70</b>	<b>239.00</b>	<b>6993.42</b>

(Note : The cost for Soft mobility component is not included in Phase I project cost, but an amount of Rs.9.84 crore and Rs.7.63 crore is included in the project cost of Phase IA and IB for feeder buses and footpath improvement.)

2.1.2 The operation would start from the year 2022-23. It may be mentioned that capital expenditure of the project as mentioned above is at 2019 prices.

2.1.3 Capital costs are also added in the year 2025 and 2035 for addition of Rolling Stock, replacement cost of 25% of the equipment comprising track and electrical and 50% of signaling & telecom after 20 and 30 years of operations. For the purpose of FIRR calculation inflation in capital cost is considered at a rate of 5% per year.

2.1.4 The operation and maintenance cost as shown in **Table 2.2** for the three Scenarios includes the staff cost, maintenance expense and energy charges. The escalation on all the O&M expenditure is taken @5% per annum.

**Table 2.2 Operation & Maintenance Costs**

S.N.	Items of O&M Cost	O&M Cost (in Rs. Crore)		
		2030	2040	2050
1	Staff	92.02	123.66	166.19
2	Maintenance	66.70	71.59	85.20
3	Energy	18.87	22.72	27.45
	<b>Total</b>	<b>177.59</b>	<b>220.97</b>	<b>278.84</b>

2.1.5 The revenue has been estimated for two revenue streams i.e., the fare box revenue and revenue from advertisement and commercial activities and is shown in **Table 2.3**. Fare box revenue has been worked out on the basis of passenger kilometers for the given segment by calculating the average fare per passenger kilometer. The fare structure is taken as per Kochi Metro Phase-I and extended to cover the entire system. The fare is escalated @ 5% in 2025 and @ additional 2.5% every five years thereafter on base price. Revenue from advertisement and commercial activities is estimated on the basis of awarded contracts of Phase I Aluva- Maharajas and contracts projected to be undertaken till 2021 as per **Table 2.7**. The non fare box revenue is escalated @10% per annum from the year 2022 to 2050.

**Table 2.3 Revenue Estimations**

S. No.	Revenue Stream	Revenues (in Rs. Crore)		
		2030	2040	2050
1	Fare box Revenue	214	440	905
2	Revenues from advertisement and Commercial activities	300	769	1985
	<b>Total</b>	<b>514</b>	<b>1209</b>	<b>2890</b>

10.1.7 The FIRR for a project operation period of 38 years is as shown in **Table 2.4** below. The details of project IRR is given in the **Table 2.6**

**Table 2.4 FIRR (with land and taxes )**

FIRR	5.88%
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## 2.2 FINANCING PLAN

**2.2.1** The approach to infrastructure financing is changing rapidly. Basic civic services have been generally considered social goods to be provided by the Government at free or at subsidized costs. In the past the government has been the sole financier of these projects and has often taken responsibility for implementation, operations and maintenance as well. There is a gradual recognition that this may not be best way to execute/finance these projects. This is due to increased focus on cost efficiency, fiscal prudence, and equity allocation considerations.

While the private sector has the potential to provide some of the equity capital and technical/managerial competencies, it appears very likely that the Government itself would have to provide a substantial part of risk capital with banks and capital markets

providing the bulk of the debt finance.

### **2.2.2 Infrastructure Financing**

**2.2.2.1** Due to the inherent characteristics of the infrastructure projects, the capacity to attract capital is limited. The changes necessary for flow of funds in infrastructure projects are needed in diverse areas related to policy matters, legal and regulatory reforms, institutional changes, fiscal incentives, etc. Infrastructure services have the characteristics of being natural monopolies, thereby reducing the role of private sector participation in these projects. Infrastructure projects differ in some very significant ways from manufacturing projects and expansion and modernization projects undertaken by companies.

**Longer Gestation Periods:** The project under consideration would develop capability to repay bulk of its debt only after 3-7 years of dispersion of capital. Therefore, there is a requirement of a higher moratorium period.

**Larger Amounts:** As mentioned earlier there is large initial capital expenditure for the project under consideration.

**Higher Risk:** Since large amounts are typically invested for long periods of time, the underlying risks are also quite high. The risks arise from a variety of factors including demand uncertainty, environmental considerations, technological obsolescence (in some industries) and very importantly, political and policy related uncertainties.

The above mentioned issues underline the need for arranging capital on long-term lending basis, which is not much developed in India. The borrowing in capital and debt market is mostly of short-term duration that favors projects with short payback periods.

### **2.2.3 Financing Plan**

The proposed distribution of capital cost at 2019 prices by various sources is as given in **Table 2.5**

**Table 2.5 Proposed distribution of Capital Cost**

Particulars	Project cost (Amount in Rs.crore)				
	PHASE I	IA	IB	NMT	TOTAL
Equity By GOI	753.73				753.73
Equity By GOK	753.73				753.73
SD for CT by GOI (50%)	248.50				248.50
SD for CT by GOK (50%)	248.50				248.50
Property Development	98.00				98.00
Term loan	842.90				842.90
Pass Through Assistance (PTA)	1327.10			202.54	1529.64
<b>Total</b>	<b>4272.46</b>	<b>0.00</b>		<b>202.54</b>	<b>4475.00</b>
SD by GOK for Land Including R&R cost	672.00	97.38	43.23		812.61
SD by GOK for taxes	237.33	73.79	40.37	36.46	387.95
SD by GOK	352.37	485.78	244.89		1083.04
GOI grant/SD		53.98	27.21		81.19
Interest During Construction (IDC), to be borne by GoK	153.63				153.63
<b>Total</b>	<b>1415.33</b>	<b>710.92</b>	<b>355.70</b>	<b>36.46</b>	<b>2518.42</b>
<b>Grand Total</b>	<b>5687.79</b>	<b>710.92</b>	<b>355.70</b>	<b>239.00</b>	<b>6993.42</b>

**Alternative funding option (IDC not considered as loan shown is in lieu of GoK)**

Particulars	Project cost (Amount in Rs.crore)				
	PHASE I	IA	IB	NMT	TOTAL
Equity By GOI	753.73	0.00	0.00	0.00	753.73
Equity By GOK	753.73	0.00	0.00	0.00	753.73
SD for CT by GOI (50%)	248.50	0.00	0.00	0.00	248.50
SD for CT by GOK (50%)	248.50	0.00	0.00	0.00	248.50
Property Development	98.00	0.00	0.00	0.00	98.00
Term loan	842.90	0.00	0.00	0.00	842.90
Pass Through Assistance (PTA)/Soft loan	1327.10	388.62	195.92	202.54	2114.18
<b>Total</b>	<b>4272.46</b>	<b>388.62</b>	<b>195.92</b>	<b>202.54</b>	<b>5059.54</b>
SD by GOK for Land Including R&R cost	672.00	97.38	43.23	0.00	812.61
SD by GOK for taxes	237.33	73.79	40.37	36.46	387.95
SD by GOK	352.37	97.16	48.98	0.00	498.50
GOI grant/SD	0.00	53.98	27.21	0.00	81.19

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Interest During Construction (IDC), to be borne by GoK	153.63	0.00	0.00	0.00	153.63
<b>Total</b>	<b>1415.33</b>	<b>322.30</b>	<b>159.78</b>	<b>36.46</b>	<b>1933.88</b>
<b>Grand Total</b>	<b>5687.79</b>	<b>710.92</b>	<b>355.70</b>	<b>239.00</b>	<b>6993.42</b>

**Table 2.6 FIRR Analysis (With land and taxes) (in Rs. Crore)**

Year	Capital Cost	Cost (Bus & Cycles)	Staff cost	Maint. Exp.	Energy Charges	Total O & M Cost	Repl. Cost	Total O&M + Replacement Cost	Total Yearly Expenditure	Revenue-Fare box	Non fare box revenue	Total Yearly Revenue	Net Cash Flow
							Rolling stock, electrical and S&T assets						
2012-2013	2.20					0.00		0.00	2.20			0.00	-2.20
2013-2014	674.06					0.00		0.00	674.06			0.00	-674.06
2015-2016	1130.11					0.00		0.00	1130.11			0.00	-1130.11
2016-2017	1013.09					0.00		0.00	1013.09			0.00	-1013.09
2017-2018	888.82	0.00	43.59	21.24	9.12	73.95	0	73.95	962.77	32	12.50	44.67	-918.10
2018-2019	1264.72	0.00	51.91	42.48	10.94	105.33	0	105.33	1370.05	45	45.97	91.08	-1278.97
2019-2020	1294.11	0.00	63.24	58.86	13.99	136.09	0	136.09	1430.20	96	139.92	235.85	-1194.35
2020-2021	191.39	0.00	67.59	59.31	14.80	141.70	0	141.70	333.09	103	174.72	277.36	-55.72
2021-2022	142.28	0.00	69.61	59.78	15.03	144.43	0	144.43	286.71	110	142.20	252.02	-34.69
2022-2023		0.00	74.82	62.41	16.10	153.33	0	153.33	153.33	118	155.97	273.48	120.15
2023-2024		0.00	77.06	62.97	16.49	156.52	0	156.52	156.52	133	171.11	303.69	147.17
2024-2025		2.36	79.37	63.55	16.88	159.80	132.77	292.57	292.57	149	187.76	336.72	44.14
2025-2026		0.00	81.76	64.14	17.28	163.18	0	163.18	163.18	159	206.07	365.45	202.27
2026-2027		0.00	84.21	64.75	17.70	166.66	0	166.66	166.66	171	226.21	396.75	230.09
2027-2028		0.00	86.73	65.38	18.12	170.24	0	170.24	170.24	182	248.36	430.83	260.60
2028-2029		0.00	89.34	66.03	18.56	173.92	0	173.92	173.92	195	272.72	467.97	294.04
2029-2030		0.08	92.02	66.70	18.87	177.59	0	177.59	177.59	214	299.51	513.40	335.81
2030-2031		0.00	94.78	67.39	19.23	181.39	0	181.39	181.39	229	328.97	557.83	376.44
2031-2032		11.52	97.62	68.10	19.59	185.31	0	185.31	185.31	245	361.38	606.26	420.95
2032-2033		0.00	100.55	68.83	19.96	189.34	0.0	189.34	189.34	262	397.02	659.04	469.70
2033-2034		0.00	103.57	69.58	20.34	193.49	0.0	193.49	193.49	280	436.22	716.58	523.09
2034-2035		2.26	106.67	70.35	20.73	197.76	324.4	522.15	522.15	307	479.33	786.30	264.15
2035-2036		0.00	109.87	71.15	21.12	202.15	0.0	202.15	202.15	328	526.75	855.20	653.06
2036-2037		4.12	113.17	71.97	21.52	206.67	0.0	206.67	206.67	351	578.91	930.35	723.69

2037-2038		0.00	116.56	72.82	21.93	211.32	0.0	211.32	211.32	376	636.28	1012.32	801.00
2038-2039		0.00	120.06	73.69	22.35	216.11	0.0	216.11	216.11	402	699.38	1101.75	885.64
2039-2040		0.16	123.66	74.59	22.72	220.97	732.4	953.33	953.33	440	768.78	1209.10	255.77
2040-2041		0.00	127.37	75.52	23.16	226.05	0.0	226.05	226.05	471	845.12	1316.26	1090.22
2041-2042		0.00	131.19	76.47	23.61	231.27	0.0	231.27	231.27	504	929.09	1433.21	1201.94
2042-2043		0.00	135.13	77.45	24.06	236.64	0.0	236.64	236.64	539	1021.45	1560.86	1324.22
2043-2044		20.69	139.18	78.46	24.53	242.17	0.0	242.17	242.17	577	1123.04	1700.21	1458.04
2044-2045		0.20	143.36	79.50	25.03	247.89	155.9	403.74	403.74	631	1234.78	1866.08	1462.34
2045-2046		0.00	147.66	80.57	25.50	253.73	0.0	253.73	253.73	675	1357.70	2033.18	1779.45
2046-2047		0.00	152.09	81.68	25.99	259.75	0.0	259.75	259.75	723	1492.89	2215.67	1955.91
2047-2048		0.00	156.65	82.82	26.31	265.78	0	265.78	265.78	773	1641.61	2414.97	2149.19
2048-2049		0.00	161.35	83.99	27.01	272.35	0	272.35	272.35	828	1805.18	2632.69	2360.34
2049-2050		0.00	166.19	85.20	27.45	278.84	0	278.84	278.84	905	1985.11	2889.79	2610.95
	<b>6600.78</b>	<b>41.39</b>	<b>3507.96</b>	<b>2267.74</b>	<b>666.02</b>	<b>6441.73</b>	<b>1345.37</b>	<b>7787.09</b>	<b>14387.88</b>	<b>11554.93</b>	<b>20932.00</b>	<b>32486.93</b>	<b>18099.05</b>
													<b>5.88%</b>

**Table 2.7 Strategy Plan – Non Fare Box Revenue**

Initiatives	Location	Amount	Remarks	Year
Semi Naming Rights	JLN	1,10,00,000		2018-19
	Changampuzha Park	1,10,00,000		2019-20
	Kalamassery	1,10,00,000		
	South Railway Station	2,00,00,000		
	Palarivattom	1,10,00,000		
	Maharajas	1,10,00,000		
	Vytilla	2,75,00,000		
	Kadavanhara	2,00,00,000		2020-21
Pillars & Medians	Thripunithara	2,75,00,000		
	Maharajas to Thykoodam	3,82,32,000	Rs 177x 80,000 sqft	2019-20
	Aluva to Edapally Addtnl	1,07,23,680	Rs 74.47X12,000 sqft	
ATM in Stations	Thykoodam to Thripunithara	1,04,76,000	Rs 194x 4,500 sqft	2020-21
	Aluva to Maharajas	7,20,000	Rs 20,000per atmX3 nos	2018-19
	Maharajas to Thykoodam	24,00,000	Rs 20,000per atmX10 nos	2019-20
Leasing of space for Telecom Tower	Thykoodam to Thripunithara	14,40,000	Rs 20,000per atmX6nos	2020-21
	Maharajas to Thykoodam	91,59,150	Rs 6206 X 25sqmX 5 station	2019-20
Advertisement inside & outside train	Thykoodam to Thripunithara	80,60,052	Rs 6716X4X25 sqm	2020-21
	Maharajas to Thykoodam	1,26,00,000	Rs 2,10,000 per train X 5 train	2019-20
Advertisement inside & outside station	Thykoodam to Thripunithara	1,76,40,000	Rs 2,10,000 per train X 7 train	2020-21
	Aluva to Maharajas	57,96,000	7000sqftXRs161	2018-19
	Maharajas to Thykoodam	2,65,50,000	12500sqftXRs177	2019-20
	Aluva to Maharajas	1,35,24,000	3000sqftXRs161	
Licensing of commercial space inside station	Thykoodam to Thripunithara	2,32,80,000	10000sqftXRs194	2020-21
	Aluva to Maharajas	97,07,700	Aluva-75sqft-3nos, Edp-65sqft; 2nos; Kmy-2400sqft,Cmp-1800,Pthd-1000,MGR-2400	2018-19
	Maharajas to Thykoodam	74,40,000	SR-1000sqft, Vyt-2000sqft,Kdv-500sqft,elm-500sqft (Rs 155)	2019-20
	Aluva to Maharajas	62,40,000	2000sqftXRS260	
	Aluva to Maharajas	27,85,500	Aluva-75sqft-7nos, Edp-65sqft,4nos; Kmy-2400sqft,MGR-2500	
Office Space	Thykoodam to Thripunithara	1,11,60,000	2000sqft eachXRs155	2020-21
	Aluva	44,92,800	9600sqftXRs39	2018-19
	MG Road	47,04,000	9800sqftXRs40	
	Aluva	1,38,24,000	28800sqftXRs 40	2019-20
	JLN	3,02,40,000	60,000sqftXRs40	
	MG Road	76,56,000	14500sqftXRs44	
	Edapally LHS	1,82,40,000	80,000sqftXRs19	
	ERS	45,00,000	25000sqftX15Rs	2020-21

	Vadakekotta	5,40,00,000	180000sqftXRs25	
<b>Optical Fibre Cable</b>	Aluva to Maharajas	10,80,000	Rs1250perkm for 18km	2018-19
	Aluva to Maharajas	2,48,40,000	RS1250perkmfor18km	2019-20
	Maharajas to Thykoodam	86,40,000	RS1250perkmfor6km	
	Thykoodam to Thripunithara	57,60,000	RS1250perkmfor4km	2020-21
<b>Property Development</b>	Kaloor	1,48,06,800	82000sqftXRs15	2019-20
	Kalamassery	2,69,40,150	149,000sqftXRs15	
	Aluva	1,99,48,050	110,000sqftXRs15	
	Edapally	1,79,73,810	78,000sqftXRs19	
	CUSAT	1,27,50,300	70,000sqftXRs15	2020-21
	Thykoodam	3,33,29,010	2,52,000sqftXRs11	
	Pettah LHS	1,55,33,430	117,000sqftXRs11	
	Pettah RHS	72,38,880	54,000sqftXRs11	
<b>Contracts awarded</b>		42,22,47,708		2018-19
		47,49,67,061		2019-20
		55,28,08,321		2020-21
<b>Total</b>		<b>45,97,48,208</b>		2018-19
		<b>89,92,30,201</b>		2019-20
		<b>1,24,72,39,633</b>	Includes the recurring income generated out of new contracts entered in 2018-19 and 2019-20	2020-21
<b>Property Development Metro City</b>	Kakkanad	2,66,00,00,000	17 Acres of land at Kakkanad	Spread over from 2019-20

### Chapter 3

#### Economic Analysis

- 3.1** The economic appraisal of the Kochi Metro Phase I within the broad framework of Social Cost –Benefit Analysis Technique has been carried out .

In the analysis, the cost and benefit streams arising under the project scenarios have been estimated in terms of market prices and economic values have been computed by converting the former using appropriate shadow prices. The annual streams of project costs and benefit have been compared over the analysis period of 30 years to estimate the net cost/ benefit and to calculate the economic viability of the project in terms of EIRR.

- 3.2** Cost components considered for the purpose of this exercise include:

- Capital cost of infrastructure (civil engineering, land, track, power supply, traction system, signaling and telecommunications, etc.) and rolling stock
- Operating and maintenance cost of metro system

The project cost of the corridors worked out on actual basis for civil costs and incremental for O&M Costs.

- 3.3** The benefits taken into account for this analysis include:

- Capital and operating cost (on present congestion norms) of carrying the total volume of passenger traffic by existing bus system in case metro system project is not taken up.
- Operating cost (on present congestion norms) of carrying the total volume of passenger traffic by existing private vehicles in case metro system project is not taken up.
- Savings in operating costs of all buses and other vehicles due to de-congestion including those that would continue to use the existing transport network even after the metro system is introduced.
- Savings in time of commuters using the metro system over the existing transport modes because of faster speed of metro system
- Savings in time of those passengers continuing on existing modes, because of reduced congestion on roads.
- Savings on account of prevention of pollution with introduction of metro system.

- 3.4** Various assumptions have been made, while assessing the economic benefits to the society on account of various factors after introduction of project. The assumptions

are the same as those adopted in the DPR prepared by DMRC –Phase I and Rites Phase IA.

**Table 3.1 Assumptions for Economic Factor**

S.NO	ITEM	FACTOR
1	Capital Cost	0.85
2	Operations & Maintenance Cost	0.85
3	Savings in Capital & Operating Cost Of Buses	1.00
4	Savings in Operating Cost Of Private Vehicles	1.00
5	Savings in Passenger Time	1.00
6	Savings in VOC	1.00
7	Savings in Pollution Costs	1.00

Considering this, the estimated economic cost and benefits have been worked out for

EIRR analysis is given in **Table 3.2**. The economic internal rate of return (EIRR) comes out to be **16 %** which is above the established cut-off criterion of 14% for the project duration of 30 years of operations for infrastructure projects, implying that the economic benefits accruing out of this project are substantial and will yield high savings to the economy as a whole.

### 3.5 Sensitivity Analysis

A sensitivity analysis of the EIRR with 10% cost overrun and 10% reduction in traffic materialization (separately) has been carried out. The summary of EIRRs with cost and traffic changes are given in **Table 3.2**. EIRR Analysis is given in **Table 3.3, 3.4 and 3.5**.

**Table 3.2 EIRRs - Sensitivity Analysis**

Sensitivity	EIRR (%)
Basic EIRR	15.94
With increase in cost by 10%	14.53
With reduction in traffic materialization by 10%	14.13

Table 3.3 – EIRR

Period	Capital Cost	Support Cost(Feeder Bus & Cycles)	O&M Cost	Addition Cost + Replacement Cost		Total Cost	Total Savings	Net Cash Flow (Rs. in Crore)
				Rolling Stock, Electric and S&T Assets	Feeder Bus & Bicycle			
2012-2013	1.87	0.00		0.00	0.00	1.87	0.00	-1.87
2013-2014	572.95	0.00		0.00	0.00	572.95	0.00	-572.95
2015-2016	960.59	0.00		0.00	0.00	960.59	0.00	-960.59
2016-2017	861.13	0.00		0.00	0.00	861.13	0.00	-861.13
2017-2018	755.50	0.00	62.86	0.00	0.00	818.36	623.07	-195.29
2018-2019	1075.01	0.00	89.53	0.00	0.00	1164.54	681.26	-483.28
2019-2020	1099.99	0.00	115.68	0.00	0.00	1215.67	809.10	-406.57
2020-2021	162.68	0.00	120.44	0.00	0.00	283.12	873.52	590.40
2021-2022	120.94	0.00	122.76	0.00	0.00	243.70	939.40	695.70
2022-2023		0.00	130.33	0.00	0.00	130.33	1011.64	881.31
2023-2024		0.00	133.04	0.00	0.00	133.04	1039.14	906.10
2024-2025		2.01	135.83	112.85	2.01	252.70	1067.24	814.55
2025-2026		0.00	138.70	0.00	0.00	138.70	1096.16	957.46
2026-2027		0.00	141.66	0.00	0.00	141.66	1121.16	979.50
2027-2028		0.00	144.70	0.00	0.00	144.70	1153.39	1008.68
2028-2029		0.00	147.84	0.00	0.00	147.84	1186.85	1039.01

## DPR FOR KOCHI METRO – PHASE I ALUVA-TRIPUNITURA



2029-2030		0.07	150.95	0.00	0.07	151.08	1221.09	1070.00
2030-2031		0.00	154.18	0.00	0.00	154.18	1256.57	1102.38
2031-2032		9.79	157.51	0.00	9.79	177.10	1293.06	1115.96
2032-2033		0.00	160.94	0.00	0.00	160.94	1330.66	1169.72
2033-2034		0.00	164.46	0.00	0.00	164.46	1369.56	1205.09
2034-2035		1.92	168.09	275.73	1.92	447.67	1409.56	961.89
2035-2036		0.00	171.83	0.00	0.00	171.83	1450.70	1278.87
2036-2037		3.50	175.67	0.00	3.50	182.67	1493.36	1310.69
2037-2038		0.00	179.62	0.00	0.00	179.62	1537.36	1357.74
2038-2039		0.00	183.69	0.00	0.00	183.69	1582.61	1398.92
2039-2040		0.14	187.83	622.50	0.14	810.60	1629.41	818.81
2040-2041		0.00	192.14	0.00	0.00	192.14	1677.36	1485.22
2041-2042		0.00	196.58	0.00	0.00	196.58	1727.08	1530.50
2042-2043		0.00	201.15	0.00	0.00	201.15	1778.04	1576.89
	<b>5610.67</b>	<b>17.43</b>	<b>3928.02</b>	<b>1011.09</b>	<b>17.43</b>	<b>10584.62</b>	<b>32358.34</b>	<b>21773.72</b>
							<b>EIRR</b>	<b>15.94%</b>

Table 3.4 -EIRR-10% cost increase

Period	Capital Cost	Support Cost(Feeder Bus & Cycles)	O&M Cost	Addition Cost + Replacement Cost		Total Cost	Total Savings	Net Cash Flow (Rs. in Crore)
				Rolling Stock, Electric and S&T Assets	Feeder Bus & Bicycle			
2012-2013	2.06	0.00		0.00	0.00	2.06	0.00	-2.06
2013-2014	630.25	0.00		0.00	0.00	630.25	0.00	-630.25
2015-2016	1056.65	0.00		0.00	0.00	1056.65	0.00	-1056.65
2016-2017	947.24	0.00		0.00	0.00	947.24	0.00	-947.24
2017-2018	831.05	0.00	62.86	0.00	0.00	893.91	623.07	-270.84
2018-2019	1182.51	0.00	89.53	0.00	0.00	1272.04	681.26	-590.78
2019-2020	1209.99	0.00	115.68	0.00	0.00	1325.67	809.10	-516.57
2020-2021	178.95	0.00	120.44	0.00	0.00	299.39	873.52	574.13
2021-2022	133.03	0.00	122.76	0.00	0.00	255.80	939.40	683.61
2022-2023		0.00	130.33	0.00	0.00	130.33	1011.64	881.31
2023-2024		0.00	133.04	0.00	0.00	133.04	1039.14	906.10
2024-2025		2.01	135.83	112.85	2.01	252.70	1067.24	814.55
2025-2026		0.00	138.70	0.00	0.00	138.70	1096.16	957.46
2026-2027		0.00	141.66	0.00	0.00	141.66	1121.16	979.50
2027-2028		0.00	144.70	0.00	0.00	144.70	1153.39	1008.68
2028-2029		0.00	147.84	0.00	0.00	147.84	1186.85	1039.01

## DPR FOR KOCHI METRO – PHASE I ALUVA-TRIPUNITURA



2029-2030		0.07	150.95	0.00	0.07	151.08	1221.09	1070.00
2030-2031		0.00	154.18	0.00	0.00	154.18	1256.57	1102.38
2031-2032		9.79	157.51	0.00	9.79	177.10	1293.06	1115.96
2032-2033		0.00	160.94	0.00	0.00	160.94	1330.66	1169.72
2033-2034		0.00	164.46	0.00	0.00	164.46	1369.56	1205.09
2034-2035		1.92	168.09	275.73	1.92	447.67	1409.56	961.89
2035-2036		0.00	171.83	0.00	0.00	171.83	1450.70	1278.87
2036-2037		3.50	175.67	0.00	3.50	182.67	1493.36	1310.69
2037-2038		0.00	179.62	0.00	0.00	179.62	1537.36	1357.74
2038-2039		0.00	183.69	0.00	0.00	183.69	1582.61	1398.92
2039-2040		0.14	187.83	622.50	0.14	810.60	1629.41	818.81
2040-2041		0.00	192.14	0.00	0.00	192.14	1677.36	1485.22
2041-2042		0.00	196.58	0.00	0.00	196.58	1727.08	1530.50
2042-2043		0.00	201.15	0.00	0.00	201.15	1778.04	1576.89
	6171.73	17.43	3928.02	1011.09	17.43	11145.69	32358.34	21212.65
							EIRR	<b>14.53%</b>

Table 3.5 -EIRR - 10% traffic increase

Period	Capital Cost	Support Cost(Feeder Bus & Cycles)	O&M Cost	Addition Cost + Replacement Cost		Total Cost	Total Savings	Net Cash Flow (Rs. in Crore)
				Rolling Stock, Electric and S&T Assets	Feeder Bus & Bicycle			
2012-2013	1.87	0.00		0.00	0.00	1.87	0	-1.87
2013-2014	572.95	0.00		0.00	0.00	572.95	0.00	-572.95
2015-2016	960.59	0.00		0.00	0.00	960.59	0.00	-960.59
2016-2017	861.13	0.00		0.00	0.00	861.13	0.00	-861.13
2017-2018	755.50	0.00	62.86	0.00	0.00	818.36	560.76	-257.59
2018-2019	1075.01	0.00	89.53	0.00	0.00	1164.54	613.14	-551.40
2019-2020	1099.99	0.00	115.68	0.00	0.00	1215.67	728.19	-487.48
2020-2021	162.68	0.00	120.44	0.00	0.00	283.12	786.17	503.05
2021-2022	120.94	0.00	122.76	0.00	0.00	243.70	845.46	601.76
2022-2023		0.00	130.33	0.00	0.00	130.33	910.48	780.15
2023-2024		0.00	133.04	0.00	0.00	133.04	935.23	802.18
2024-2025		2.01	135.83	112.85	2.01	252.70	960.52	707.82
2025-2026		0.00	138.70	0.00	0.00	138.70	986.55	847.84
2026-2027		0.00	141.66	0.00	0.00	141.66	1009.04	867.38

2027-2028		0.00	144.70	0.00	0.00	144.70	1038.05	893.35
2028-2029		0.00	147.84	0.00	0.00	147.84	1068.16	920.32
2029-2030		0.07	150.95	0.00	0.07	151.08	1098.98	947.89
2030-2031		0.00	154.18	0.00	0.00	154.18	1130.91	976.73
2031-2032		9.79	157.51	0.00	9.79	177.10	1163.75	986.66
2032-2033		0.00	160.94	0.00	0.00	160.94	1197.59	1036.65
2033-2034		0.00	164.46	0.00	0.00	164.46	1232.60	1068.14
2034-2035		1.92	168.09	275.73	1.92	447.67	1268.60	820.94
2035-2036		0.00	171.83	0.00	0.00	171.83	1305.63	1133.80
2036-2037		3.50	175.67	0.00	3.50	182.67	1344.02	1161.35
2037-2038		0.00	179.62	0.00	0.00	179.62	1383.63	1204.01
2038-2039		0.00	183.69	0.00	0.00	183.69	1424.35	1240.66
2039-2040		0.14	187.83	622.50	0.14	810.60	1466.47	655.86
2040-2041		0.00	192.14	0.00	0.00	192.14	1509.63	1317.49
2041-2042		0.00	196.58	0.00	0.00	196.58	1554.37	1357.79
2042-2043		0.00	201.15	0.00	0.00	201.15	1600.23	1399.09
<b>TOTAL</b>	5610.67	17.43	3928.02	1011.09	17.43	10584.62	29122.51	18537.88
							<b>EIRR</b>	<b>14.13%</b>

**CHAPTER 4**  
**PHASE I ALUVA TO TRIPUNITHURA**  
**SOFT MOBILITY COMPONENTS & NMT INITIATIVE**

### **1. Background**

As envisaged by Kochi Metro Rail Limited, the Non-Motorized Transport Master Plan proposes an integrated network of walkways and cycle paths, (as appropriate), along with related infrastructure and facilities at strategic locations within the study area. It aims to enhance the walking and mobility experience of a pedestrian or a non-motorized vehicle user.

The major components of the project are:

1. NMT Master Plan for the study area of 2 Km on either side of the metro corridor.
2. Public Bicycle Sharing Scheme for appropriate locations within study area.
3. Concept designs for Place Making at selected areas within the study area.

**The NMT Master Plan** focuses on providing safe, comfortable and accessible walking and cycling Infrastructure for easy accessibility of metro stations, other transport stations, public spaces and other destinations.

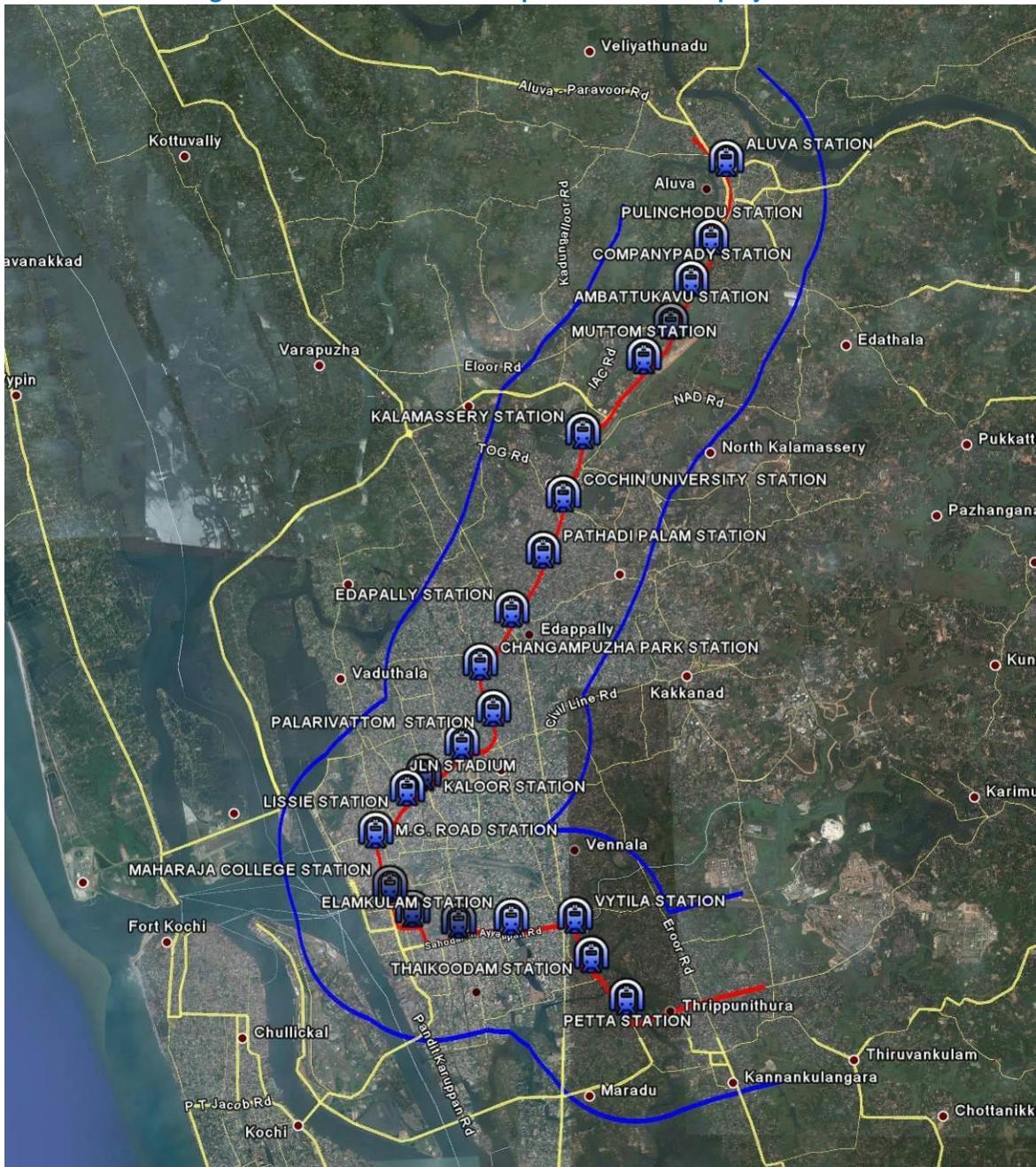
**The Public Bicycle Sharing** scheme recommends requisite infrastructure provisions, operation, and revenue generation strategies to encourage bicycling in Kochi.

The project also identifies areas for **Urban Place making** to improve the quality of urban public realm thereby encouraging people to actively use public spaces of the city.

### **2. NMT area**

Kochi Metro Rail Limited (KMRL) is implementing the Kochi metro rail project from Aluva to Tripunithura along a 28.125 km stretch with 25 stations.

Figure 1: Non-Motorised Transport Master Plan- project Area



### 3. Existing NMT Infrastructure (Ref: - UMTC Study)

All major roads lying within the project area were surveyed to map their physical conditions. The data was mapped to create thematic maps. The thematic maps have formed the basis for preparation of Non Motorised Transport Plan. The following section is a summary of the same survey and the analysis of the collected data.

#### 3.1 Existing road condition mapping

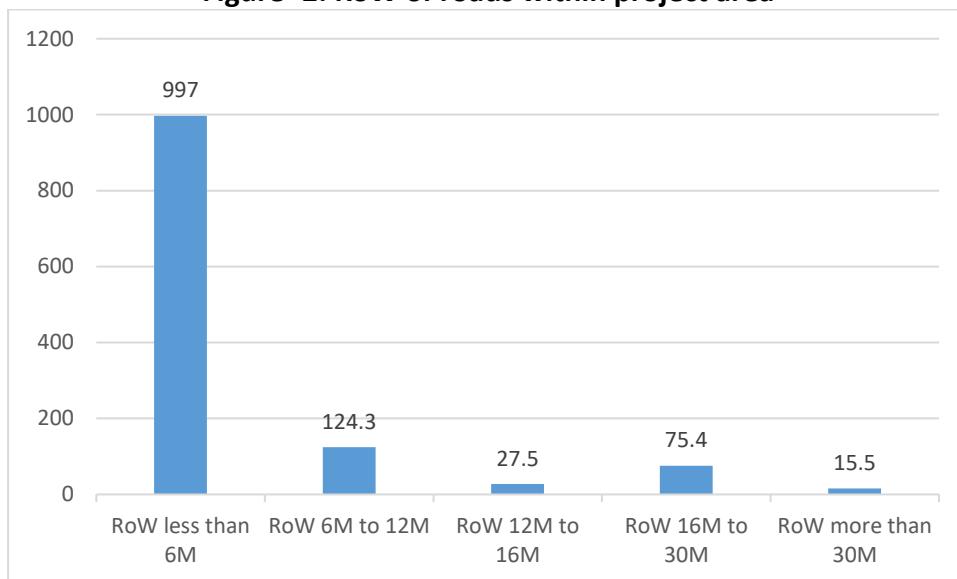
##### Availability of RoW

Kochi has a dense network of narrow roads and lanes. Within the total project area of 125 Sq.Km, the total road length is 1240 Kms. The road length density within the project area is

## NON MOTORISED TRANSPORT INITIATIVE

9.92 Km of roads per Sq.Km. of project area. The same is very close to international benchmark of 10Km of roads per Sq. Km. Also the land area under roads is found to be 7.5%, which is lesser than the benchmark specified in UDPFI Guidelines (10-12% of road space). About 80% of roads within the project area have less than 6m of available RoW. An additional 10% of roads have available RoW between 6m to 12m. All such roads would require road widening in order to accommodate dedicated footpaths or cycle tracks. Remaining roads within the project area have available RoW of more than 16m. Such roads can accommodate dedicated footpaths and cycle tracks as per traffic standards or traffic requirements.

**Figure -2: RoW of roads within project area**



Source: Primary Surveys, 2015

**Table -1: Category of roads based on available road RoW**



Road RoW less than 6M



Road RoW close to 9M



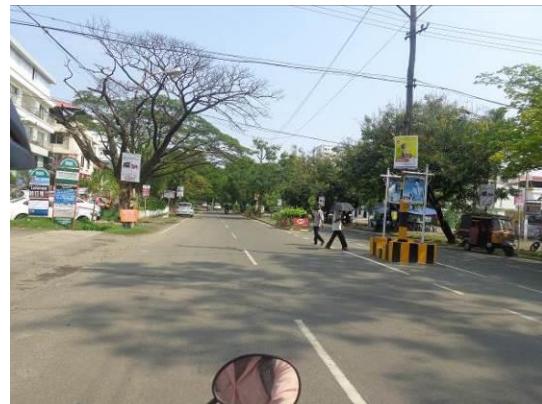
Road RoW close to 12M



Road RoW close to 18M



Road RoW close to 22M



Road RoW close to 33M

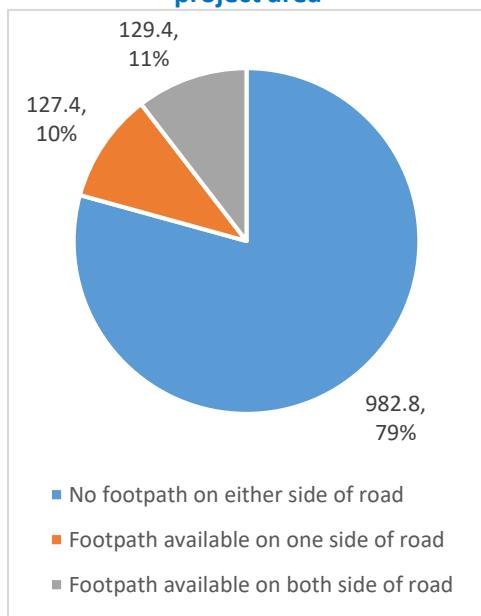


Road RoW more than 33M

### **3.2 Availability of footpath**

Out of the total roads within the project area, 19% of roads have footpaths. These include footpaths of usable and unusable widths.

**Figure -3: Availability of footpaths within project area**



Source: Primary surveys, 2015



No Footpaths available



Footpaths in parts

### 3.3 Usable footpath widths

Within the project area about 3% of roads have usable footpaths on both sides of the roads which are more than 1.2m width. These footpaths have space for accommodating two pedestrians walking along the footpath shoulder to shoulder. 5% of roads have 1.2m wide footpath only along one side of the road. Additional 11% of roads have footpaths with less than 0.9m width on any one side of the road. About 81% of roads have either no footpaths or are less than 0.9m in width making them unusable.

**Figure -4: Unusable footpaths**

Most footpaths are narrow, making them unusable.

### **3.5 Availability of trees within road space**

Only about 20% of roads within the project area have fully grown trees within the road space. This includes 16% of roads which have fully grown trees on either side of the roads.

**Figure -5: Tree lined Panampally Avenue Road**

### 3.6 Availability of services

The utility services like electric and telecommunication cables run through overhead cables. Within the project area only 34Km of roads have underground electric supply lines. This amounts to 3% of the total road length. Transformers and substations generally encroach upon the existing footpaths.

**Figure -6: Overhead electrical and telecommunication cables with poles and substations on footpaths**



Large portions of the city have storm water drains either under footpaths with removable covers or along the roads without any cover. About 14% of roads within the project area do not have storm water drains under footpaths. Major portion, i.e. 86% of roads have storm water drains under the footpaths<sup>1</sup>. Such footpaths in Kochi are found to be unusable by pedestrians due to frequent wear and tear of the drain covers.

**Figure -7: Storm water drains under space for footpaths**



<sup>1</sup> Data source: Primary Surveys, 2015

### 3.7 Availability of street lights

Large parts of the city of Kochi have street lights with very low intensity. Such lights provide very less visibility at night for pedestrians and cyclists. Surveys indicate that 85% of the street lights have an intensity of <4 lux and just 11% with an intensity of  $\geq 8$  lux making it difficult for pedestrians and cyclists to walk or cycle during dark hours. As per IRC Codes road space for NMT usage require lights of intensity 25-30 lux.

**Figure 8: Most street have either no lights or lights with very low intensity**



### 3.8 Project Cost

The identified projects along the corridor with respect to the studies are given below with approximate cost:

NON MOTORISED TRANSPORT - IDENTIFIED WORKS			
Phase I - Works within Reach 1 & Reach 2a of Metro corridor			
Works in Progress - A			
Sl No	NAME OF WORK	Approximate Project Cost	STATUS
1	Junction Improvement- Aluva-Pulinchodu metro station corridor oriented civil work.	8,55,76,910.00	Work in progress
2	Junction Improvement- Edapally junction metro station oriented civil work.	4,20,20,218.00	Completed
3	Station Oriented Development Civil Work - Construction/Improvements to drain and footpath leading to metro stations along metro corridor. Package: 2 (Kalamassery - Pathadipalam)	6,90,61,741.00	Work in final stage
4	Station Oriented Development Civil Work- Construction/Improvements to drain and footpath leading to metro stations along metro corridor. Package: 1 (Companypadi - Muttom)	3,44,18,658.00	Work in progress
5	Landscaping of median below 13 stations and its Entry/Exit structures.	1,69,35,767.00	Completed
6	Street level station underside elastomeric painting works for kochi metro rail stations from aluva to maharajas college (16 stations).	3,47,44,010.00	Completed
7	Consultancy for preparation of Estimates for road works.	12,47,750.00	Completed
8	Electrical Works	2,00,00,000.00	
	<b>Total value of awarded works - A</b>	<b>30,40,05,054.00</b>	
Works to be tendered- B			
Sl No	NAME OF WORK	Approximate Project Cost	STATUS
1	Station Oriented Development Civil Work- Construction/Improvements to drain and footpath leading to metro stations along metro corridor. Package: 3 (Manorama Jn to Vytilla)	5,00,00,000.00	To be tendered.

**NON MOTORISED TRANSPORT INITIATIVE**

2	<b>Station oriented Development Improvements to Arterial roads leading to Metro stations- Package I - Aluva to KLMT</b>	18,00,00,000.00	To be tendered.
3	<b>Station oriented Development Improvements to Arterial roads leading to Metro stations- Package II - CUSAT to Palarivattom</b>	15,00,00,000.00	To be tendered.
4	<b>Station oriented Development Improvements to Arterial roads leading to Metro stations- Package III- JLN Stadium to Maharajas College</b>	15,00,00,000.00	To be tendered.
5	<b>Improvements to Arterial roads leading to Metro stations- Package IV- Ernakulam South - Petta</b>	15,00,00,000.00	To be tendered.
6	Road signages and pedestrian markings - Package I Aluva- Maharajas	3,00,00,000.00	To be tendered.
7	Landscaping below metro stations Reach 2a	1,50,00,000.00	To be tendered.
8	Consultancy for preparation of Estimates for road works. Ernakulam South - Petta	5,00,000.00	To be tendered.
9	PMC for the entire AFD Works including preperation of estimate for the balance work	4,00,00,000.00	To be tendered.
10	Banerjee Road Curve	1,25,00,000.00	To be tendered.
11	Connectivity between Lissie Station & North Railway Station	1,25,00,000.00	To be tendered.
12	Walkway connecting Streetscape & Kadavanthra Metro Station	5,00,00,000.00	To be tendered.
	<b>Expected Value of projects in Tender Stage -B</b>	<b>84,05,00,000.00</b>	
	<b>Projected Fund allotted for Electrical B inclusive- Utility shifting &amp; Lighting - C</b>	<b>20,00,00,000.00</b>	
	<b>Total Value of within Reach 1 &amp; Reach 2a of Metro Corridor - A+B+C</b>	<b>1,34,45,05,054.00</b>	
<b>Phase - Other Non Motorised Transport Initiatives</b>			
1	Jose Junction Curve	1,25,00,000.00	2019 Works

**NON MOTORISED TRANSPORT INITIATIVE**

2	Urban place making projects- Rennovation of Kunnara Park	4,00,00,000.00	
3	Landscaping below metro stations - Ernakulam South to Petta	2,00,00,000.00	
4	Road signages and pedestrian markings - Package II Maharajas to Petta	3,00,00,000.00	
5	Street level <b>station underside elastomeric painting works</b> for kochi metro rail stations from Ernakulam South to Petta (6 stations).	2,00,00,000.00	
6	Arterial Road Improvements Package V	8,29,94,946.00	
7	Utility Shifting & Electrical Works	6,00,00,000.00	
	<b>Total Value of within Reach 2a &amp; Reach 2b of Metro Corridor - D</b>	<b>26,54,94,946.00</b>	
	<b>TOTAL AFD FUND</b>	<b>1,61,00,00,000.00</b>	
<b>Phase I - Extensions</b>			
1	Petta Junction Improvement	10,00,00,000.00	2019-2020 Works
2	Vadakkekkotta Junction Improvement	4,00,00,000.00	
3	SN Junction Improvement	6,00,00,000.00	
4	Footpath Improvement from Petta to SN Junction excl junctions (GoK AS available)	8,00,00,000.00	
	Total Value for Phase I Extension NMT	<b>28,00,00,000.00</b>	
<b>Soft Mobility Components</b>			
1		<b>50,00,00,000.00</b>	
<b>GRAND TOTAL</b>		<b>2,39,00,00,000.00</b>	

All of this projects are expected to complete with the completion of Phase I stretch from Aluva to Tripunithura.

## SALIENT FEATURES

### **Aluva-Tripunithura**

1. **Route Length (From End to End )** : **28.125 Km**
2. **Number of Stations (Ph-I)** : **25**
3. **Traffic forecast**

Per Day Ridership Forecast	2023	2030	2040	2050
Aluva – Tripunithura Railway Station	132910	229177	450826	886846

### **4. TRAIN OPERATION**

<b>Tripunithura – Aluva</b>				
<b>Section</b>	<b>Items</b>	<b>Year</b>		
		<b>2030</b>	<b>2040</b>	
<b>Tripunithura – Aluva</b>	Headway in Min. (Trains/hr)	4	4	
	No : of Cars/ Train	84	93	
	Rakes Required	28	31	
	PHPDT Demand	23834	46886	

\* @8 passengers/ M<sup>2</sup>

### **5. Traction Power Supply**

- (a) Voltage : 750 V DC
- (b) Power Supply source : 110 KV AC - Provided
- (c) No of receiving sub stations : One - Provided
- (d) SCADA system : Provided

### **6. Rolling Stock**

- (a) 2.9 m wide modern rolling stock with stainless steel body, Standard Gauge
- (b) Axle load : 16 T
- (c) Seating arrangement : Longitudinal
- (d) Capacity of 3 coach unit : 766 passengers @ 6 pass/m<sup>2</sup>, 975 @ 8 pass/m<sup>2</sup>

### **7. Maintenance Facilities**

- Maintenance Depot : Current Depot of Phase I at Muttom can cater the requirement for entire Phase I.

### **8. Signaling, Telecommunication & Train Control**

- (a) Type of Signaling : Cab Signalling and continuous Automatic Train Control with Automatic Train Protection (ATP) / CBTC
- (b) Telecommunication : Integrated System with Fibre Optic Transmission

System, Master Clock System, Passenger information display system, Radio system, PA system, Telephony, Central Digital Recording System, Access Control System, Counter communication system etc.

- 9. Fare Collection** : Automatic Fare Collection system with Contactless smart card / QR code type ticketing

**10. Viaduct structure :**

The Super structure of entire corridor from Aluva to Tripunithura will be consisting of I/U Girder and others at specific locations as per site condition. The precast items(Superstructure & Pier Cap) will be casted at Pre Cast Yard from where it will be transported to site through custom made trailers. The erection of the superstructure is being done through high capacity cranes placed on ground.

**11. Total estimated cost at 2019 price level with land cost including all charges and taxes**

Aluva - Tripunithura : Rs 6993.42 Crore

**12. Financial Indices**

**(a) FIRR**

The FIRR for the three alternatives for a project operation period of 30 years is as given below:

Aluva - Thripunithura	
FIRR	5.88%

**(b) EIRR**

The summary of EIRRs under two scenarios of 10% cost over-run and 10% traffic reduction (separately) are given as under.

Sensitivity	EIRR (%)
Basic EIRR	15.94
With increase in cost by 10%	14.53
With reduction in traffic materialization by 10%	14.13



KOCHI METRO RAIL LIMITED

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