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INTEGRATED TRANSPORTATION AND LAND USE PLANNING FOR DECREASING TRAFFIC CONGESTION IN KOCHI CITY

Anju Sebastian[1], Sangeeth K[2]

[1]*M.Plan Student (Urban Planning), Dept. of Architecture, TKM College of Engineering, Kollam, India*
[2]*Assistant Professor, Dept. of Architecture, TKM College of Engineering, Kollam, India*

Abstract – *Transportation planning is a major component which decides the growth of the city. Integrating transportation and land use is much wanted in urban areas and it will be a best solution for decreasing traffic congestion in developing countries. Integrated Transportation and Land Use Package is composed of a land use allocation, employment allocation and a travel demand model. This integration method helps to decrease the traffic congestion in urban areas. This study aims to prepare a solution for the traffic congestion in Kochi city, Kerala by preparing a traffic management plan by integrating land use and transportation.*

Key Words: **Transportation, Land use, Traffic congestion, Planning, Urban areas**

1. INTRODUCTION

Kochi city faces a high level of traffic congestion compared to other states of Kerala. Controlling traffic congestion in urban areas like Kochi is much wanted to attain a sustainable transport system in future. Kochi experiences world class planning for transportation infrastructure but still the city faces traffic related problems. Traffic congestion in the city shows that there is no interaction with transportation and land use. When land use and social infrastructure components are compared the allocation of job centres, institutions, commercial areas, industrial areas etc does not suit the transport facilities. So both the land use and transportation has to be interlinked for a congestion free mobility. When the needs are accessible at walkable distance then the number of vehicles can be decreased and gradually people will depend on public transport facilities also.

So for this small cities or places with high potential in Kochi City have to be identified and those cities have to be connected to the CBD area. Infrastructural facilities in those small/sub cities have to be improved. Relocation of major hubs is also a part of integration which helps to decrease traffic congestion.

2. AIM & OBJECTIVE

Aim is:
To manage traffic congestion by improving accessibility by integrating land use and transportation.

Objectives are:

- To identify the area with high development potential delineate the area using GIS.
- To identify the areas with high traffic volume and to study the factors responsible for congestion in the study area.
- To make a micro level analysis for the land use pattern and transport services and to analyse the traffic based on existing infrastructure.
- To prepare a Traffic Management Plan by integrating transportation and land use.

3. STUDY AREA

Kochi City is known as the Commercial Capital of Kerala state, India. Kochi city is surrounded by the Arabian Sea and backwaters. It comprises of two distinct areas, they are the old Kochi City and the mainland, Ernakulam.

Table -1: Details of Kochi City

District	ERNAKULAM
Corporation Area	94.88 km²
Population	6.77 Lakhs (2011 census)
Population Density	7139/km² (Most densely populated city corporation in the state)

Average annual population growth rate is 1.28 percent (natpac, 2019). There is a drastic increase seen in the population. This is because of the employment opportunities, development and quality infrastructural services.

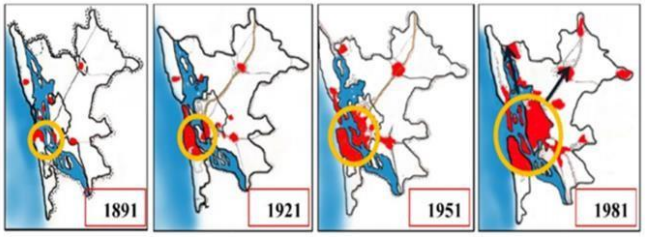


Fig -1: Growth pattern of Kochi city
Source: A study on inland water transportation in Kochi City Region, 2012

Based on the growth pattern, Kochi city faces a drastic growth in the city centre and spreading outwards. Kochi Corporation is considered as the major functional area based on the growth pattern.

Kochi urban area is the most economically active region in the State. This urban region significantly contributes to the economy of the State. City level activities, residential, commercial and industrial, overspill to the outskirts often causing unplanned urban sprawl. The increasing population and its resultant impacts on the land cause concerns related to land use, environment and economy (Department of Town and Country Planning, 2010).

Kochi is located on the southwest coast of India, between 9.48° and 10.50° latitude and 76.5° and 76.58° E longitude. The Kochi City has a flat topography.

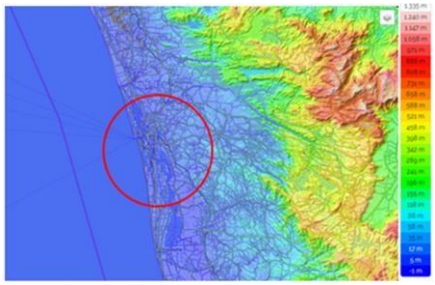
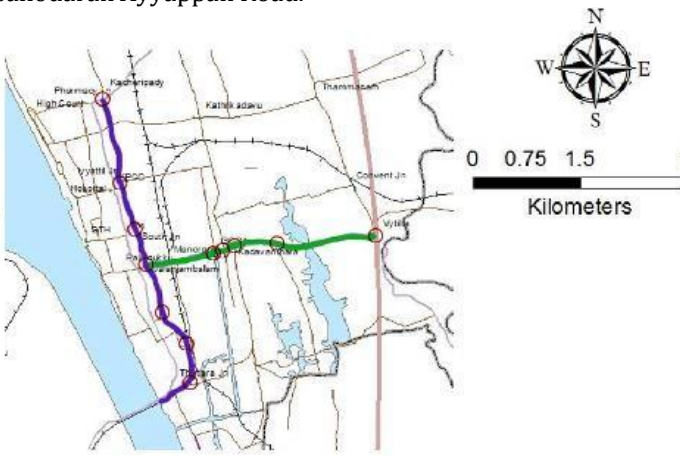


Fig -2: Topography of the city
Source: Author generated using GIS

4. AREA DELINEATION

The areas selected are two road stretches in Kochi Corporation. They are Mahathma Gandhi Road and Sahodaran Ayyappan Road.



Route	From Node	To Node	Road Name
	Madhava Pharmacy Junction	Vikranth – Venduruthy Bridge	Mahatma Gandh Road
	Pallimukku Junction	Vyttila Junction	Sahodaran Ayyappan Road

Fig -3: Stretches taken for study

4.1 Importance of the study area

- Mahatma Gandhi (MG) Road stretch is considered as the CBD area of Kochi City andSahodaran Ayyappan (SA) is the second main road of CBD area.
- SA road starts from MG road and ends at Vyttila which connects the Bypass NH66 with the CBD area.
- Metro line passes through MG Road- SA Road-Vyttila.
- Vyttila is an area with high potential both in case of infrastructural development and ease of connectivity.
- Vyttila Mobility Hub is an integrated transit terminal designed as a converging point of various forms of public transportation, such as local and long distance buses, metro rail and inland water transport.
- MG Road and SA Road in Ernakulam are the main arterial roads of the city.
- These roads are constructed in 1925 & 1962 respectively, which run parallel and perpendicular to the coast and having the Metro Rail connectivity.
- Other major roads in Kochi city includes Chittoor Road (Sub-arterial road), Kaloor- Kadavanthara Road (Sub-arterial road), Park Avenue etc which all comes under the study area.

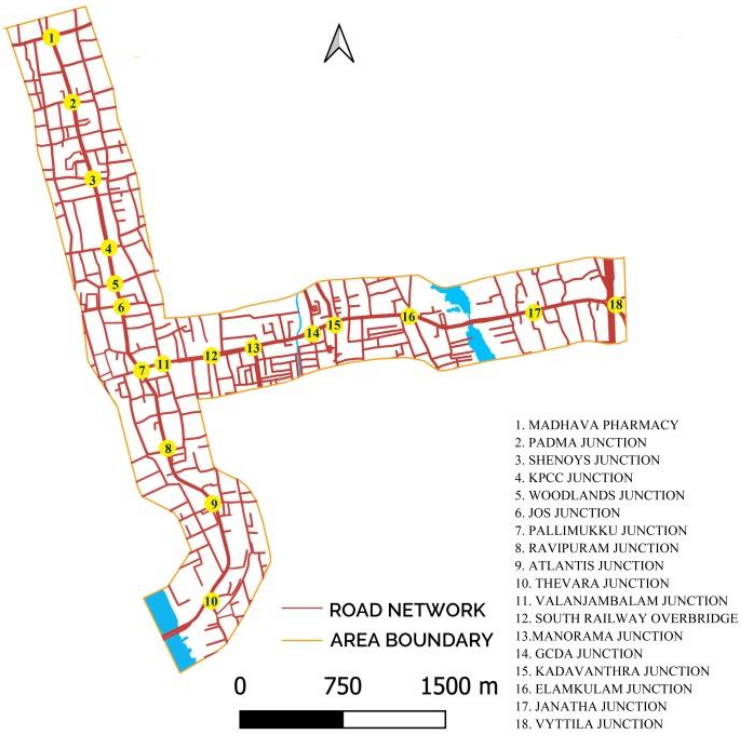


Fig -4: Major Junctions of the study area
Source: Author generated using GIS

4.2 Characteristics and Nature of MG Road

- MG Road has many premium brand stores, leading shops and boutiques.
- Large numbers of shops are available for dress and fabrics in MG Road.
- The Ernakulam South railway station is on Chittoor road.
- There are many bookstores in Convent road. Ernakulam public library is situated in Convent road.
- Hospital road in KPCC Junction is known for medical facilities and shops.
- Kochi is famous for gold, diamond, silver and platinum jewelry. Most of them are concentrated at Jewel Junction (Woodland Junction), on MG Road.
- Medical Trust Hospital in Pallimukku is one of the top hospitals in Kerala.
- Govt higher secondary school for girls is also on the Chittoor road.
- Cochin Shipyard and National Institute of Fisheries Post Harvest Technology and Training are between Pallimukku and Thevara Junction.

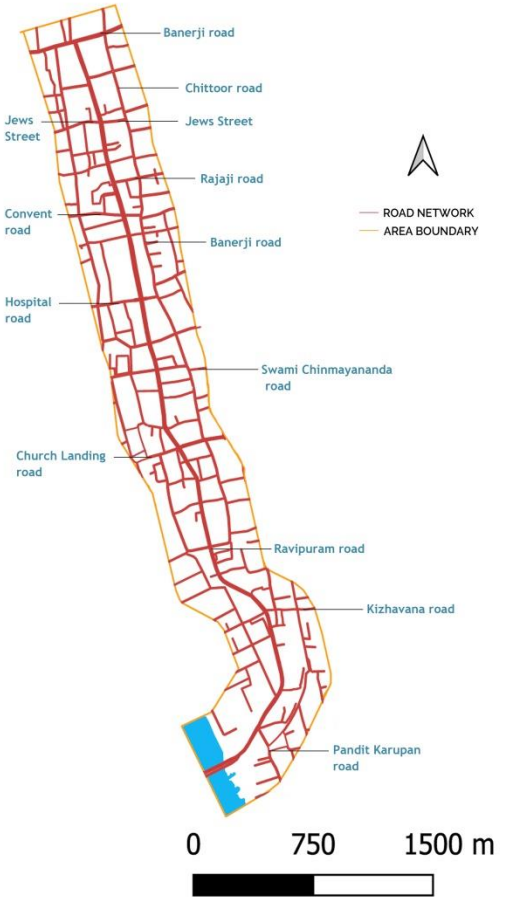


Fig -5: Road network of MG Road
Source: Author generated using GIS

Table -2: Details of MG Road

NODES		LENGTH (Km)	NO OF LANES	ONE WAY/ TWO WAY	CARRIAGEWAY (m)			SHOULDER (m)		FOOTPATH (m)		DRAIN (m)		ROW(M)	LAND USE		HIERARCHY OF ROADS
FROM NODE	TO NODE				LHS	MEDIAN	RHS	LHS	RHS	LHS	RHS	LHS	RHS		LHS	RHS	
Thevara Jn to Madhava Pharmacy Jn																	
Thevara	Ravipuram	1.3	4	2	7.5	0.5	7.5	1	1	1	1	1	1	19.5	C	C	Arterial
Ravipuram	Pallimukku	0.65	4	2	7.5	0.5	7.5	1	1	1.25	1	1	1	19.5	C	C	Arterial
Pallimukku	JOS	0.50	4	2	7.5	0.5	7.5	1	1	1	1	1	1	19.5	C	C	Arterial
JOS	KPCC	0.45	4	2	7.5	0.5	7.5	1	1	1	1	1	1	19.5	C	C	Arterial
KPCC	Madhava Pharmacy	1.60	4	2	7.5	0.5	7.5	1	1	1	1	1	1	19.5	C	C	Arterial
JOS Jn to BTH																	
JOS	BTH	0.55	4	2	8			1	1		1	1	1	12	C	C	Sub-Arterial
Atlantis Road																	
Kizhavana Road		0.60	4	2	6					1	1			6	R/C	R/C	Tertiary
Chittoor Road																	
Ravipuram	Valanjambalam	0.50	2	2	6			1	1			1	1	10	C	C	Sub - Arterial
Valanjambalam	South	0.45	2	2	6							1	1	9	C	C	Sub - Arterial
South	Iyyattil	0.45	2	2	7							1	1	9	C	C	Sub - Arterial
Iyyattil	Rajaji	0.70	2	2	7							1	1	9	R/C	R/C	Sub - Arterial

Source: natpac, 2021

4.3 Characteristics and Nature of SA Road

- SA Road is also known as Ettomannor- Ernakulam road
- Panampilly Nagar has many premium exclusive designer boutiques
- SBI is in manorama junction in SA Road
- Urban primary health centre one of the top hospital in Elamkulam junction
- Panampilly nagar Central park is in Panampilly Ave road and there are many shopping malls near to the park.

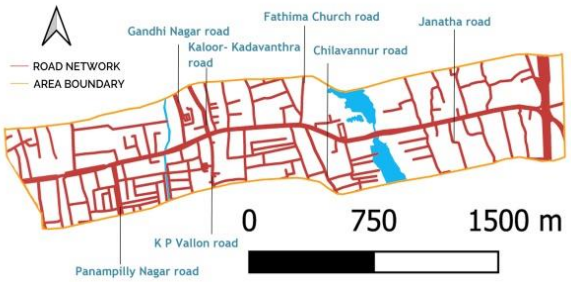


Fig -6: Road network of SA Road
Source: Author generated using GIS

Table -3: Details of SA Road

NODES		LENGTH (Km)	NO OF LANES	ONE WAY/ TWO WAY	CARRIAGEWAY (m)			SHOULDER (m)		FOOTPATH (m)		DRAIN (m)		ROW (m)	LAND USE		HIERARCHY OF ROADS
FROM NODE	TO NODE				LHS	MEDIAN	RHS	LHS	RHS	LHS	RHS	LHS	RHS		LHS	RHS	
Kaloor- Kadavanthara road																	
Kadavanthara	Subhash Road	0.40	4	2	7.5	0.8	7.5	0.5	0.5			1	1	18.8	R/C	R/C	Sub - Arterial
Panampilly Nagar Road																	
Ambedkar mark	Manorama	1.50	4	2	7.5	0.5	7.5	3	3	1.5	1.5	1	1	23.5	C	C	Tertiary
GCDA- Gandhi Nagar Road																	
GCDA	Subhash Road	0.35	2	2	7.5			1	1			1	1	11.5	C	C	Tertiary
Subhash Road	Gandhi Nagar	1	2	2	7.5			1	1			1	1	11.5	C	C	Tertiary
SA Road																	
Pallimukku	Valamjambalam	0.16	4	2	7.5	0.3	7.5	1	1	1.5	1.5	1.5	1.5	20.3	C	C	Arterial
Valamjambalam	Manorama	0.65	4	2	7.5	2	7.5			1.5	1.5	1.5	1.5	20	C	C	Arterial
Manorama	GCDA	0.45	4	2	7.5	2	7.5			1.5	1.5	1.5	1.5	20	C	C	Arterial
GCDA	Kadavanthara	0.15	4	2	7.5	2	7.5			1.5	1.5	1.5	1.5	20	C	C	Arterial
Kadavanthara	Vyttila	0.55	4	2	7.5	2	7.5	1	1			1	1	21	C	C	Arterial
Vyttila	Pettah(Border)	2.70	2		10									10	C	C	Arterial
Other roads																	
JOS Jun to South Jn		0.18	2	2	7							1	1	9	C	C	Tertiary
South Jn to Ernakulam Jn Railway Station		030	2	2	7							1	1	9	C	C	Tertiary
Vyttila Mobility Hub road(Mathur Jn to Vyttila Jn)		2.20	1	2	5							1		6	R	R	Tertiary

Source: natpac, 2021

5. STUDY AND ANALYSIS OF STUDY AREA

Traffic volume, transportation facilities, land use pattern and transport and land use projection has to be analysed and a comparison has to be made for determining the problems.

5.1 Peak hour traffic volume observed at major intersections and road stretch in Kochi City

Thevara Junction, Madhava Pharmacy and Vyttila carry more than 7,000 PCU per hour. Kadavanthara and Pallimukku hands peak hour traffic volume between 6,000 and 7,000 PCU.

Table -4: Peak hour volume in junctions

NAME OF JUNCTION	NO. OF ARMS	PEAK HOUR VOLUME (PCU)	PEAK HOUR
Thevara Jn	3	7737	8.45-9.45
Pallimukku Jn	3	6700	8.30-9.30
Jos Jn	4	3906	16.45-17.45
KPCC Jn	4	4348	9.30-10.30
Madhava Pharmacy	3	7200	17.15-18.15
South Jn	4	2215	9.45-10.45
Iyyattil	3	1511	9.45-10.45
Manorama	3	7969	9.15-10.15
GCDA	3	4811	18.00-19.00
Kadavanthara	4	6820	16.15-17.15
Vyttila	5	7139	8.30-9.30

Source: natpac, 2021

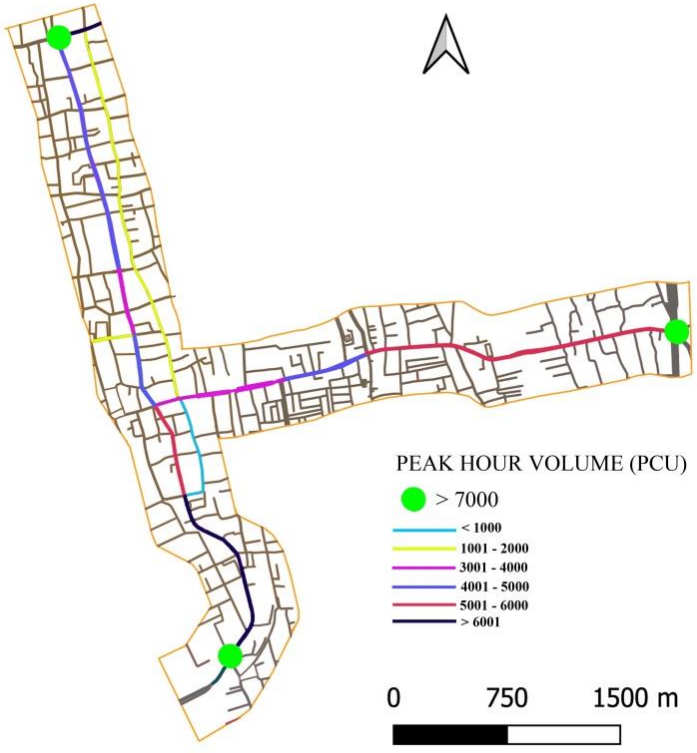


Fig -7: Traffic volume observed at the major intersections and road stretches

Source: Author generated using GIS

Table -5: Peak hour volume in road stretch

ROAD NAME	TOTAL (No)	TOTAL (PCU)	PEAK HOUR
Cochin Port Jn- Madhava Pharmacy			
Willingdon Island Hotel Jn to Thevara Jn	6224	6443	8.45-9.45
Thevara Jn to Ravipuram Jn	6975	7148	8.45-9.45
Ravipuram Jn to Pallimukku Jn	6001	5171	8.30-9.30
Pallimukku Jn to Jos Jn	4400	4515	8.30-9.30
Jos Jn to KPCC Jn	3304	3273	9.30-10.30
KPCC Jn to Madhava Pharmacy	4415	4279	17.15-18.15
Thevara Ferry Road			
Thevara Jn to Santhi Nagar	1979	1884	8.45-9.45
Ravipuram – BTH Road			
Ravipuram to Pallimukku Jn	1147	950	17.30-18.30
Jos Jn to BTH			
Jos Jn to BTH	2145	1696	17.30-18.30
Panampilly Nagar Road			
Ambedkar Mark to Manorama	2632	2394	9.1510.15-
GCDA – Gandhi Nagar Road			
GCDA to Subhash Road Jn	2651	2215	18.00-19.00
Kaloor – Kadavanthra Road			
Kadavanthra to Subhash Road Jn	2782	3054	16.15-17.15
SA Road (Pallimukku to Petta)			
Pallimukku to Valanjambalam	4740	3579	8.30-9.30
Valanjambalam to Manorama	4129	3294	9.15-10.15
Manorama to GCDA	4741	3729	18.00-19.00
GCDA to Kadavanthra	4229	4071	16.15-17.15
Kadavanthra to Vyttila Jn	5003	5176	16.15-17.15
Vyttila Jn to Petta (Border)	3754	3254	17.15-18.15
Hospital Jn to KPCC Jn to Iyyattil Jn			
Hospital Jn to KPCC Jn	1103	1190	9.30-10.30
KPCC Jn to Iyyattil Jn	871	857	9.30-10.30
Other Roads			
Jos Jn to South Jn	319	254	9.45-10.45
South Jn to Ernakulam Jn Railway Station	733	636	9.45-10.45
Vyttilla Mobility Hub Road	531	739	9.45-10.45

Source: natpac, 2021

The traffic volume ranges between 3,000 and 7,000 PCU on the major travel corridor of the city, namely MG road between Thevara and Madhava Pharmacy. The highest peak hour traffic volume was observed between Thevara and Ravipuram on MG road with more than 7,000 PCU this is because this road connects to the Willingdon Island and Fort Kochi.

Between Pallimukku and Thykkoodam Junction on SA road, the peak hour traffic volume was found to be varying from 3,200 PCU on Vyttila-Petta section to 5,300 PCU on Kadavanthara - Vyttila section. Traffic volume ranges between 3,000 and 3,500 PCU on Kaloor - Kadavanthara road. On the Chittoor road the range is between 1,000 and 2,000 PCU.

5.2 Speed and delay characteristics

SA road from Pallimukku to Vyttila clocked 22 kmph in spite of poor road condition and signal delay. With the construction of flyover at Kundannoor, Vyttila and Palarivattam, the travel speed could reach an optimal speed of about 45 kmph. Kaloor - Kadavanthara road is another sub arterial road where traffic flew at a very low speed of 15kmph due to traffic congestion at Kumaranasan and Kathrikadavu Junction (natpac, 2021).

Table -6: Speed and delay in road stretch

ROAD NO/ NAME OF ROAD	DISTANCE (m)	JOURNEY TIME (sec)	DELAY (sec)	SPEED (Kmph)	REASON FOR DELAY
Cochin Port Junction- Madhava Pharmacy	**6600**	**1133**	**154**	**20.97**	
Cochin Port Jn-Thevara Jn	2775	377	20	26.53	Bus stop delay
Thevara Jn- Ravipuram Jn	973	263	91	13.32	
Ravipuram- Pallimukku Jn	755	180	3	15.10	Intersection and signal delay
Pallimukku Jn- Jos Jn	837	79		37.97	
Jos Jn- KPCC Jn	270	72	23	13.59	
KPCC Jn- Madhava Pharmacy	990	163	17	21.93	Signal Delay
Ravipuram-BTH Road	**1700**	**235**	**54**	**26.04**	
Ravipuram-Palimukku Road Jn	750	111		24.32	
Pallimukku Road Jn- Fine arts club	450	48		33.6.72	
Chittoor road	**7520**	**1665**	**167**	**20.35**	
Ravipuram Jn-Valanjambalam	500	90		20.00	
Valanjambalam- South	450	80		20.25	
South- Iyyattil Jn	450	102		15.88	
Iyyattil Jn-Rajaji Jn	720	97		26.72	
SA Road(Pallimukku to Petta)	**6469**	**998**	**120**	**23.34**	
Pallimukku-Valanjambalam	750	131		20.61	
Valanjambalam- Manorama	650	148	99	15.81	Signal Delay
Manorama-GCDA	729	133	21	19.73	
GCDA-Kavanthara	350	57		22.11	
Kadavanthara- Vyttila Jn	1270	166		27.54	
Vyttila Jn-Petta(Boarder)	2720	363		26.98	
Kaloor-Kadavanthra Road	**3320**	**744**	**124**	**16.08**	
Kadavanthra- Subhash Road Jn	470	103		16.43	
Subhash Road Jn-Kumaranasan Jn	850	115		26.61	

Source: natpac, 2021

Fig -8: Speed and delay along the road stretches
Source: Author generated using GIS

5.3 Major parking streets according to parking accumulation

Vyttila to Kadavanthara is having higher number of on street parkings this is because of the mobility hub and bus stand in the Vyttila Junction. Ravipuram to Thevara is also having higher number of on street parking this is becauseof the connectivity towards the Willington Island and Fort Kochi. Parking in Panampilly Nagar Ave can be due to the park, shopping complex etc.

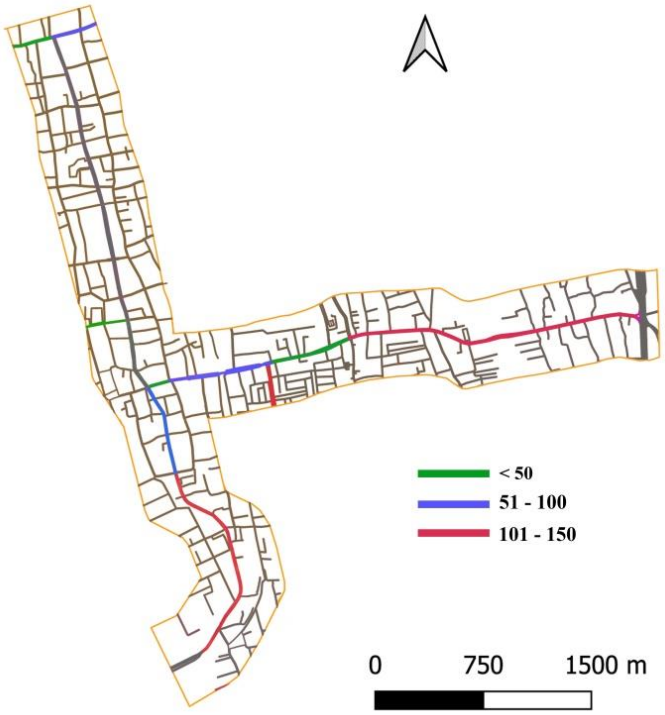


Fig -9: Major parking streets
Source: Author generated using GIS

5.4 Accident Prone Areas

Vyttila stands second with 66 reported accidents after Palarivattam with 80 during the year 2018. Vyttila is a major bus station and developing as a mobility hub. SA Road connects Vyttila with the NH 66. Atlantis Junction is also an accident prone area.

Table -7: Accident prone areas in the study area

ACCIDENT PRONE LOCATION	NO. OF ACCIDENTS					NO. OF ACCIDENTS			
	GREVLOUS INJURY	NON INJURY	MINOR INJURY	FATAL	TOTAL	DEATH	GRIEVOUS	MINOR	TOTAL
Vyttila	30	24	9	3	66	34	11	110	155155
Atlantis	9		1		10	9	1	18	28

Source: natpac, 2021

5.5 Intense pedestrian movements

Peak hour pedestrian movements as per the study conducted by the natpac are as follows:
Locations observed to be between 1,000 and 2,000 are
(i) Kacherippady (1,900)
(ii) Hospital Jn (1,865) - Study Area
(iii) Jos (1,614) - Study Area
(iv) Town Hall Jn (1,400)
(v) Kadavanthara (1,300) - Study Area

(vi) KPCC Jn (1,091) - Study Area
At other pedestrian locations, the peak cross movements were below 1,000 per hour.

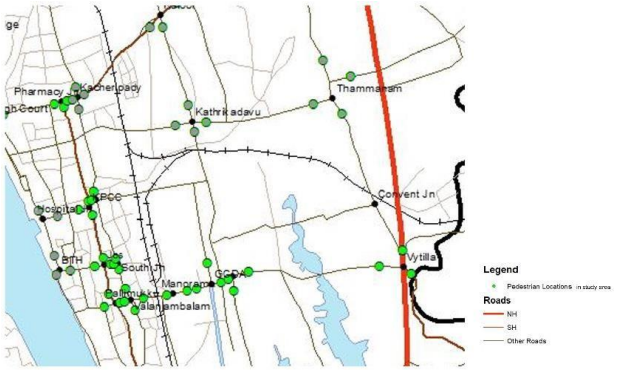


Fig -10: Pedestrian flow
Source: natpac, 2021

5.6 Level of pedestrian vehicle conflicts on major roads

Pedestrian vehicle is high in Pallimukku to Kadavanthara and in Vyttila Junction. Pallimukku to Vyttila Junction (SA Road) is having higher social infrastructural facilities so people will move towards these areas for buying needs.

Fig -11: Pedestrian vehicle conflicts
Source: natpac, 2021

5.7 Public Transport Facilities

A large number of inter-city passengers travel to and from the city from South and North Railway stations in Kochi City. The average daily originating passenger traffic during the year 2018-19 was found to be 25,587 from Ernakulam south station. Eranakulam South station handles about 70% of traffic generated from the city. The South station is one of the busiest railway stations in South India, with more than 128 scheduled train services daily (natpac, 2021) .

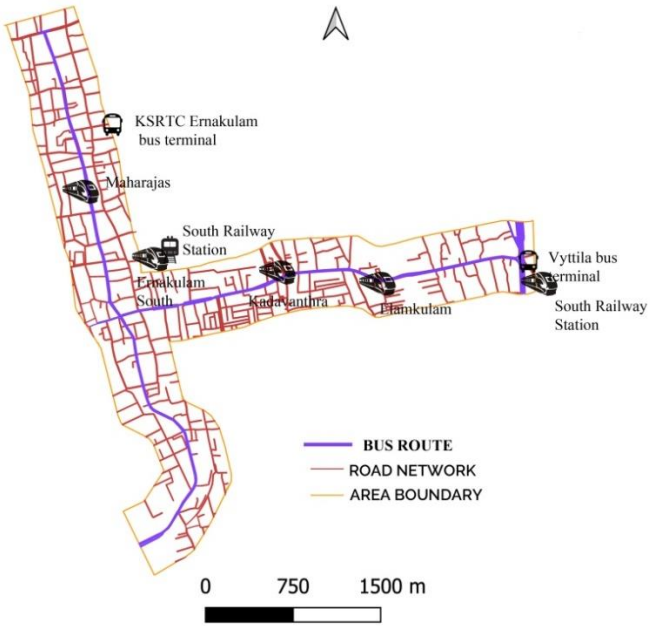


Fig -12: Major Public Transport Stations
Source: Author generated using GIS

Most of the city bus services will get converged on MG road, Bannerji road and SA road thus making them the most congested travel corridors. MG road corridor between Thevara and KPCC Junction had bus passenger volume ranging between 5,000 and 10,000. Similar volume of bus passengers are seen between Pallimukku and Vyttila Junction. This shows the importance of the area.

5.8 Density of Bus Passengers

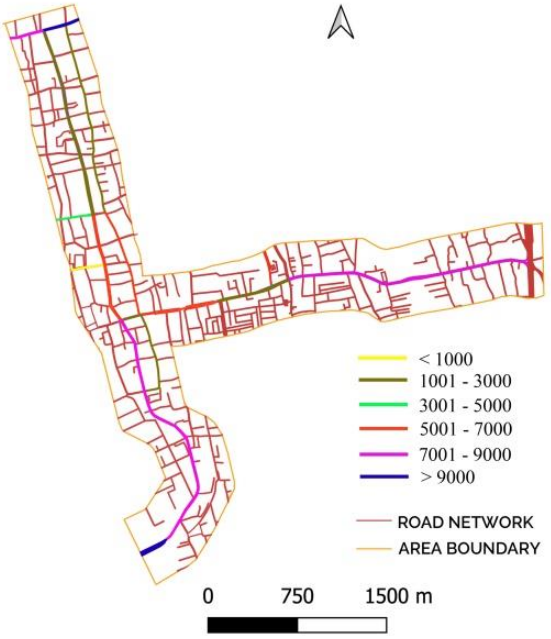


Fig -13: Bus passenger density along road stretches
Source: Author generated using GIS

Around 2,000 bus trips were handled at Vyttila mobility hub between 7.00 am and 8.00pm which is very high and 351 at KSRTC bus station. Major services are operated at Chittoor also with 13 trips. Some of the corridors along SA road carried less bus passengers because the buses get diverted along other parallel roads. Other major bus corridors are Bannerji road from High Court Junction to Madhava Pharmacy and Vyppin road, Shanmugam Road between Hospital Junction and High Court Junction. All these corridors carry bus passengers above 5,000 and also most of these corridors are served by Kochi metro.

5.9 Vyttila Mobility Hub

The integrated transit terminal at Vyttila is under 2nd phase of construction. It acts as a hub for long distance bus services far away from the city centre and it also acts as a converging point for different modes of public transport such as local and long distance buses, inland water transport and metro rail. It is spread over an area of 37 acres adjacent to NH bypass. The mobility hub connects Edappally, Kundannoor, Palarivattam, Vyttila junction through Kochi Bypass and exit road links with Ettumanoor road connecting it with Thrippunithura, Petta, Ambalamugal etc.

Being a multi modal mobility hub, it is connected to Kochi Metro and Kochi Water Metro also. Vyttila Mobility Hub is connected to Vyttila Metro Station of Kochi Metro Line 1(Aluva to Thykkoodam). It is a 160 metres walk to the metro station by Vyttila Mobility Hub Road. Ferry terminal is on the east side of the mobility hub. It is located by Kaniyampuzha river. It is a 76 metres walk to the ferry terminal by Vyttila Boat Jetty Walkway (natpac, 2021).

Fig -14: Proposed Vyttila Mobility Hub
Source: kochimetro.org

Impact of Vyttila Mobility Hub

Vyttila Flyover helps to decrease the delay and increases the speed. Traffic congestion and accidents in Vyttila junction will get decreased. SA Road and NH66 will get developed due to the Vyttila Mobility Hub.

5.10 Metro Facility

Metro passes through MG Road - Elamkulam Junction - SA Road. Maharaja's stands third with 5,635 passengers after Edappally station and Aluva station. MG Road station stands fourth with 4,133 passengers. Other stations handled less than 4,000 passengers per day.

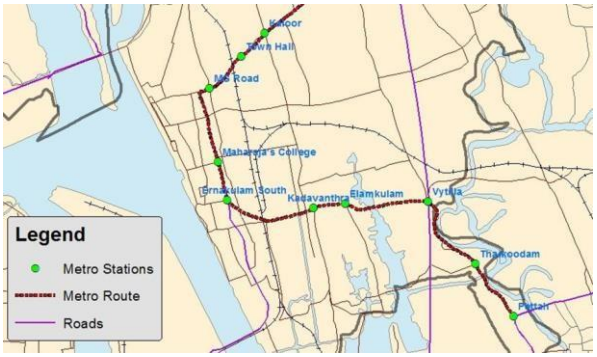


Fig -15: Metro stations
Source: natpac, 2021

Impact of Metro

There is a traffic reduction seen in Bannerji road, MG road and SA road over which the Kochi Metro passes with 4.7%, 1.5% and 2.6% reduction respectively. Other roads like NH 66, Kaloor-Kadavunthara road and Chittoor road also had traffic reduction of 2.1%, 1.7% and 4.0 in the order. Even there is Kochi metro facility MG road and other north south corridors, Chittoor road and Shanmugham road remain still highly congested.

Table -8: Traffic volume with and without metro

METRO CORRIDOR	TRAFFIC VOLUME WITHOUT METRO		TRAFFIC VOLUME WITH METRO		VARIATION (%)
	TOTAL (No)	TOTAL (PCU)	TOTAL (No)	TOTAL (PCU)	
Cochin Port Jn- Madhava Pharmacy					1.5
Jos Jn to KPCC Jn	3361	3320	3304	3273	1.4
KPCC Jn to Madhava Pharmacy	4494	4345	4415	4279	1.5
Madhava Pharmacy- Edappally Jn					4.7
Madhava Pharmacy to Kacherippadi Jn	7517	6389	7431	6275	1.8
Jos Jn- BTH					1.3
JOS Jn to BTH	2156	1728	2145	1696	1.9
Chittoor Road					4
Valanjambalam to South	1882	1819	1871	1787	1.8
South to Iyyattil	1912	1839	1839	1753	4.7
Iyyattil to Rajaji Jn	1352	1094	1290	1041	4.9
Kaloor-Kadavanthra Road					2.1
Kadavanthra to Subhash Road Jn	2842	3105	2782	3054	1.6
SA (Pallimukku to Petta Border)					2.6
Pallimukku to Valanjambalam	4759	3596	4740	3579	0.5
Valanjambalam to Manorama	4253	3441	4129	3294	4.3
Manorama to GCDA	4868	3877	4741	3729	3.8
GCDA to Kadavanthra	4356	4219	4229	4071	3.5
Kadavanthra to Vyttila	5166	5345	5003	5176	3.2
Vyttila to Petta	3764	3266	3754	3254	0.4
Hospital Jn - KPCC Jn – Iyyattil					3.1
Hospital Jn to KPCC Jn	1114	1222	1103	1190	2.7
KPCC Jn to Iyyattil Jn	882	889	871	857	3.6

Source: natpac, 2021

5.11 Water Transport

Kochi has a good network of inland waterway system. It consists of backwaters, canals, lagoons and estuaries. The city alone has about 1,100 km of waterways or canals and out of this, around 40 km of rivers and canals are navigable by motorized crafts. The waterway network is more or less of a grid iron pattern and only a few links are missing. The main routes for water transport in the city are Eranakulam-Fort Kochi, Eranakulam- Mulavukadu, Eranakulam-Varapuzha, Eranakulam- Mattancherry, Eranakulam- Vyppin, Vyttila- Kakkanad and High Court– Mulavukadu.

Proposed development scheme for Water Transport

The proposed water transport passes perpendicular through SA Road.

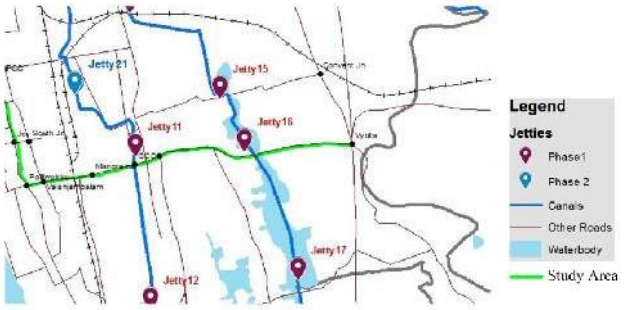


Fig -16: Water transport path
Source: natpac, 2021

Water Metro

The study area has proposed water metro route. It touches Thevara and Vtyyila of the study area.

Fig -17: Water Metro Path
Source: natpac, 2021

The study area has proposed water metro route. It touches Thevara and Vtyyila of the study area.

Fig -18: Vyttila water metro station
Source: watermetro

5.12 Land Use

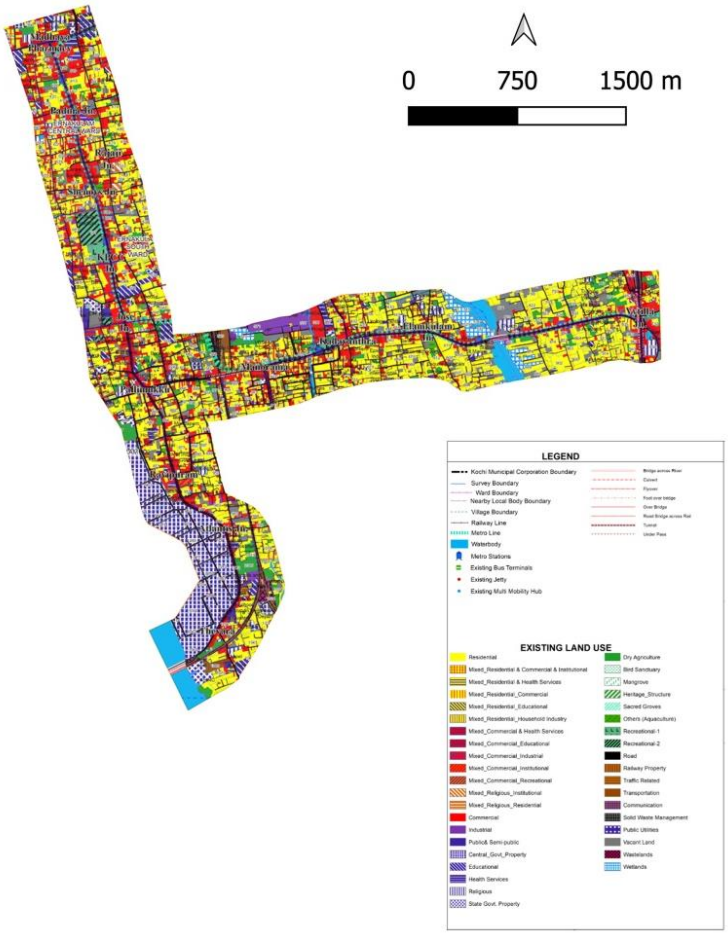


Fig -19: Land use map, 2020
Source: rtp, 2020

- Madhava Pharmacy and Vyttila junction is concentrated with commercial activities.
- In MG Road, Commercial area is mainly concentrated along the road network with 200m buffer. Remaining is the residential area.

- But in SA Road, commercial area is mainly seen till Kadavanthra and then residential area is seen till Vyttila.
- Educational institutions area mainly seen on Madhava Pharmacy Junction and also in SRV Road in Woodlands Junction which is the school area.
- Area near to the south railway station is considered as industrial area.
- Health Service area is seen in hospital road in KPCC Junction.
- Ravipuram - Atlantis - Thevara road is mainly a residential area and also most of the areas area central government property.
- State Government property is seen in Jos Junction and Thevara near the Vikranth - Venduruthy Bridge.

5.13 Land Use Changes

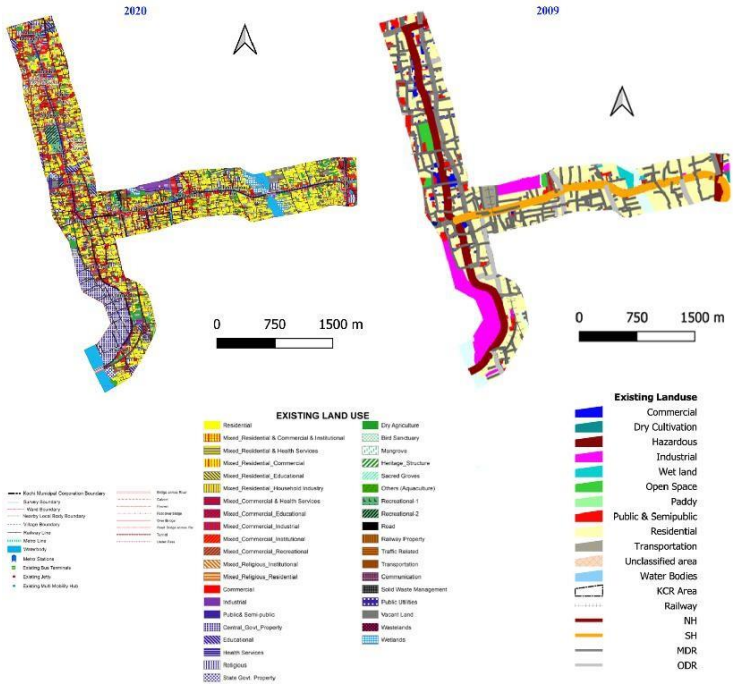


Fig -20: Land use map of 2020 and 2009
Source: rtp 2020 , rtp 2009

In 2020 the 100 - 200m buffer area is fully occupied as commercial area. Residential area is very low compared to 2009. SA Road is having higher residential area. The industrial area in Ravipuram - Thevara Road is same. Cochin Shipyard is in this area.

In 2009 the study area was filled with residential area. Commercial area was very low. In MG Road there were some commercial areas but in SA Road commercial area was very low.

5.14 Comparing Traffic Volume with Land Use

Fig -21: Land use and traffic volume analysis
Source: Author generated using GIS

Ravipuram to Thevara road is having higher traffic volume with more than 6001. This area is central government property. Cochin shipyard is located in this area. This area carries heavy traffic because people travel for job and also this route connects to the Willington Island and Fort Kochi.

Pallimukku Junction to Ravipuram and Kadavanthra to Vyttila Junction has traffic volume ranging between 5001 - 6000. Kadavathra to Vyttila Junction is residential area and also this area connects to NH66 and Kaloor - Kadavanthra road connects to the Banerji Road. Pallimukku to Ravipuram Junction also comes under central government property. National Institute of Fisheries Post Harvest Technology and Training is situated here. This area is also an employment hub.

Pallimukku to JOS Junction, KPCC to Madhava Pharmacy and Manorama to Kadavanthra ranges from 4001 to 5000. In Pallimukku to JOS Junction and KPCC to Madhava Pharmacy the stores are congested on the road side. Metro passengers from Madhava Pharmacy to Maharaja's college are more which helps to decrease the road traffic. But Manorama to Kadavanthra Junction is fully occupied with houses.

JOS to KPCC Junction and Pallimukku to Manorama Junction range 3001 to 4000.

JOS to KPCC Junction has maily educational institutions, Hospitals, Religious place and some portion is state government property. Pallimukku to Manorama Junction is a residential area.

Chittoor Road connects North Kochi to Valanjambalam in SA

Road having a low traffic volume of 1001 to 2000.

Valanjambalam to Ravipuram Junction is having a very low traffic volume of below 1000.

5.15 Traffic Projection

Growth in traffic volume between 2005 and 2019

Table -9: Growth in traffic volume

NAME OF INTERSECTION	TRAFFIC VOLUME		GROWTH (%)
	2005	2019	
Thevara	3525	7737	5.78
Pallimukku	4847	6699	2.34
Jos	5395	3906	(2.28)
Maharaja	5386	4347	(1.52)
Madhava Pharmacy	3934	7200	4.41
South	4541	2214	(5.00)
Valanjambalam	4015	4213	0.35
Manorama	6098	7969	1.93
GCDA	4906	4810	(0.14)
Kadavanthra	3959	6820	3.96
Vyttilla	8721	7138	(1.42)

Source: natpac, 2021

In MG Road Madhava Pharmacy Pallimukku Thevara experience an increase in traffic volume. Out of these Thevera experience drastic growth in traffic which shows that people traveling to and from Willington or Fort Kochi is increasing.

In case of SA Road only Kadavanthara experience growth in traffic volume this is because shops are concentrated in Kadavanthara and also it is near to NH66.

Projected Traffic Volume for 2030 and 2040

Table -10: Projected traffic volume

ROAD NAME	CAPACITY (PCU)	2020		2030		2040	
		PEAK HOUR TRAFFIC VOLUME (PCU)	VOLUME TO CAPACITY (V/C)	PEAK HOUR TRAFFIC VOLUME (PCU)	VOLUME TO CAPACITY (V/C)	PEAK HOUR TRAFFIC VOLUME (PCU)	VOLUME TO CAPACITY (V/C)
Cochin Port Jn- Madhava Pharmacy							
Willingdon Island hotel Jn to Thevara Jn	1500	6443	4.30	10494	7	15534	10.36
Thevara to Ravipuram Jn	3600	7148	1.99	11101	3.08	15659	4.35
Ravipuram to Pallimukku Jn	3600	5171	1.44	8030	2.23	11327	3.15
Pallimukku to Jos Jn	3600	4515	1.25	7012	1.95	9891	2.75
Jos Jn to KPCC Jn	3600	3273	0.91	5012	1.39	6921	1.92
KPCC Jn to Madhava Pharmacy	3600	4279	1.19	6543	1.82	9017	2.50
Ravipuram- BTH Road							
Ravipuram to Pallimukku Jn	900	950	1.06	1216	1.35	1411	1.57
Jos Jn- BTH							
Jos Jn to BTH	1200	1696	1.41	2347	1.96	2920	2.43
Chittoor Road							
Ravipuram Jn to Valanjambalam	1200	811	0.68	1143	0.95	1464	1.22
Valanjambalam to South	1200	1787	1.49	2475	2.06	3084	2.57
South to Iyyattil Jn	1200	1753	1.46	2357	1.96	2805	2.34
Iyyattil Jn to Rajali Jn	1200	1041	0.87	1396	1.16	1655	1.38
Panampally Nagar Road							
Ambedkar Mark to Manorama	2900	2394	0.83	3544	1.22	4762	1.64
GCDA- Gandhi Nagar Road							
GCDA to Subhash Road Jn	900	2215	2.46	2835	3.15	3290	3.66
Kaloor- Kadavanthra Road							
Kadavanthra to Subhash Road Jn	2900	3054	1.05	4237	1.46	5291	1.82
Atlantis- Thykkoodam Road							
Kizhavana Road	900	900	1	1210	1.34	1474	1.64
SA Road (Pallimukku to Petta)							
Pallimukku to Valanjambalam	3600	3600	1	5564	1.55	7794	2.17
Valanjambalam to Manorama	3600	3600	1	5353	1.49	7068	1.96
Manorama to GCDA	3600	3600	1	5377	1.49	7150	1.99
GCDA to Kadavanthra	3600	3600	1	5394	1.50	7208	2
Kadavanthra to Vyttila	3600	3600	1	5954	1.65	8807	2.45
Vyttila to Petta (Border)	1500	1500	1	2553	1.70	3942	2.63
Hospital Jn - KPCC Jn - Iyyattil Jn							
Hospital Jn to KPCC Jn	1200	1200	1	1648	1.37	2028	1.69
KPCC Jn to Iyyattil Jn	1200	1200	1	1631	1.36	1974	1.64
Other Roads							
Jos Jn to South Jn	900	254	0.28	325	0.36	377	0.42
South Jn to Ernakulam Railway Station	900	636	071	814	0.90	945	1.05
Vyttila Mobility Hub Road	900	739	0.82	993	1.10	1211	1.35

Source: natpac, 2021

Peak Hour Traffic Volume and Volume to Capacity Ratio in MG Road shows drastic increase. This shows that the demand for CBD area will increase in the coming years but still there is no improvement in the road nature. SA Road also shows increase in the traffic but NH66 road area is under high speed development which will increases the demand for SA road connecting Bypass and CBD area.

Projected Traffic Growth Rates for 2030 and 2040

Table -11: Projected traffic growth rate

ROAD NAME	CATEGORY OF ROAD	LOCATION	GROWTH RATE ADOPTED	
			2030	2040
Cochin Port Jn- Madhava Pharmacy				
Thevara to Ravipuram Jn	Arterial	CBD	4.5	3.5
Ravipuram to Pallimukku Jn	Arterial	CBD	4.5	3.5
Pallimukku to Jos Jn	Arterial	CBD	4.5	3.5
Jos Jn to KPCC Jn	Arterial	CBD	4.5	3.5
KPCC Jn to Madhava Pharmacy	Arterial	CBD	4.5	3.5
Ravipuram- BTH Road				
Ravipuram to Pallimukku Jn	Tertiary	CBD	2.5	1.5
Jos Jn- BTH				
Jos Jn to BTH	Sub- arterial	CBD	3.5	2.5
Chittoor Road				
South to Iyyattil Jn	Sub- arterial	CBD	3.5	2.5
Iyyattil Jn to Rajali Jn	Sub- arterial	CBD	3.5	2.5
Panampally Nagar Road				
Ambedkar Mark to Manorama	Sub- arterial		4	3
GCDA- Gandhi Nagar Road				
GCDA to Subhash Road Jn	Tertiary	CBD	2.5	1.5
Atlantis- Thykkoodam Road				
Kizhavana Road	Tertiary		3	2
SA Road (Pallimukku to Petta)				
Pallimukku to Valanjambalam	Arterial	CBD	4.5	3.5
Valanjambalam to Manorama	Arterial	CBD	4.5	3.5
Manorama to GCDA	Arterial	CBD	4.5	3.5
GCDA to Kadavanthra	Arterial	CBD	4.5	3.5
Kadavanthra to Vyttila	Arterial		5.5	4.5
Vyttila to Petta (Border)	Arterial		5.5	4.5
Other Roads				
Jos Jn to South Jn	Tertiary	CBD	2.5	1.5
South Jn to Ernakulam Railway Station	Tertiary	CBD	2.5	1.5
Vyttila Mobility Hub Road	Tertiary		3	2

Source: natpac, 2021

Traffic growth rate shows decline by 2040. Traffic growth will increase in 2030 and there will be traffic congestion.

Projected Traffic Reduction due to Impact of Metro for 2030 and 2040

Table -12: Projected traffic reduction due to metro

ROAD NAME	CATEGORY OF ROAD	LOCATION	TRAFFIC REDUCTION DUE TO IMPACT OF METRO		
			PRESENT	2030	2040
Cochin Port Jn- Madhava Pharmacy					
Thevara to Ravipuram Jn	Arterial	CBD		0%	0%
Ravipuram to Pallimukku Jn	Arterial	CBD		0%	0%
Pallimukku to Jos Jn	Arterial	CBD		0%	0%
Jos Jn to KPCC Jn	Arterial	CBD	1.4%	1.4%	2.1%
KPCC Jn to Madhava Pharmacy	Arterial	CBD	1.5%	1.5%	2.3%
Ravipuram- BTH Road				0%	0%
Ravipuram to Pallimukku Jn	Tertiary	CBD		0%	0%
Jos Jn- BTH					
Jos Jn to BTH	Sub- arterial	CBD	1.9%	1.9%	2.8%
Chittoor Road					
South to Iyyattil Jn	Sub- arterial	CBD	4.7%	4.7%	7%
Iyyattil Jn to Rajali Jn	Sub- arterial	CBD	4.9%	4.9%	7.4%
Panampally Nagar Road					
Ambedkar Mark to Manorama	Sub- arterial			0%	0%
GCDA- Gandhi Nagar Road					
GCDA to Subhash Road Jn	Tertiary	CBD		0%	0%
Atlantis- Thykkoodam Road					
Kizhavana Road	Tertiary			0%	0%
SA Road (Pallimukku to Petta)					
Pallimukku to Valanjambalam	Arterial	CBD	0.5%	0.5%	0.7%
Valanjambalam to Manorama	Arterial	CBD	4.3%	4.3%	6.4%
Manorama to GCDA	Arterial	CBD	3.8%	3.8%	57%
GCDA to Kadavanthra	Arterial	CBD	3.5%	3.5%	5.3%
Kadavanthra to Vyttila	Arterial		3.2%	3.2%	4.8%
Vyttila to Petta (Border)	Arterial		0.4%	0.4%	0.6%
Other Roads					
Jos Jn to South Jn	Tertiary	CBD		0%	0%
South Jn to Ernakulam Railway Station	Tertiary	CBD		0%	0%
Vyttila Mobility Hub Road	Tertiary			0%	0%

Source: natpac, 2021

Valanjambalam to Vyttila Junction in SA Road shows drastic decrease in traffic due to metro which helps to decrease theincreased statistics of projected traffic volume in 2030 and2040.

6. PROBLEM IDENTIFICATION

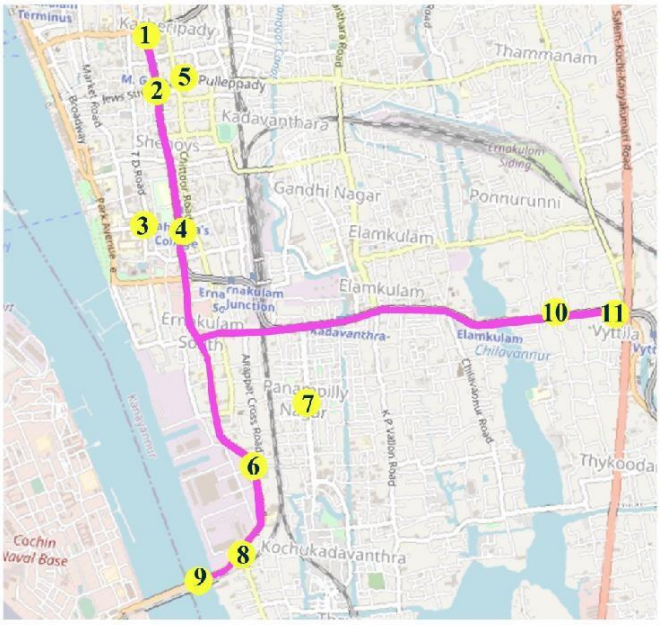


Fig -22: Location of problems identified
Source: Author generated using GIS

1. Madhava Pharmacy Junction
   - High traffic

2. Between Madhava Pharmacy Junction and ShenoysJunction
   - Shops along both sides of the road
   - Commercial area is high

3. Hospital road
   - Faces very high Pedestrian flow
   - Between Ernakulam general hospital andMaharaja's college
   - Vehicles parks on the walkway on hospitalroad

4. From KPCC Junction to Woodslands Junction
   - Maharaja's college and SRV Govt Hss school
   - Educational Institution area
   - Pedestrian Movement is high

5. Chittoor road
   - Speed delay
   - Residential area
   - Connects to the Ernakulam South RailwayStation

6. Thevara to Ravipuram Junction
   - High traffic congestion

- Employment centre, Educational institutions on west and residential area oneast side
- Speed delay due to bus stop
- Bus passenger is high
- Onstreet parking is high due to employment centre

7. Panampilly Nagar Ave
   - Onstreet parking is high
   - Panampilly Nagar Central Park and the markets and shops nearby is the reason for parking
   - Residential- commercial area

8. Thevara Junction
   - High traffic
   - Speed delay due to bus stop delay

9. Vikranth- Venduruthy Bridge
   - Bus passenger density is high

10. Kadavanthara Junction to Vyttila Junction
    - Faces high traffic congestion because vehicle entering from Vyttila is very high and then diverted to panampally Nagar Avefrom Manorama Junction.
    - Onstreet Parking is high
    - Mainly residential area

11. Vyttila Junction
    - High traffic
    - Accident prone area

7. GUIDELINES AND STANDARDS

Guidelines and standards are to be considered while planning. The required standards recommended by IRC are as following:

7.1 Road Design

Width of carriageway standards

The width of the carriageway recommended by IRC:

Table -13: Standard width of various roads

	CLASS OF ROAD	WIDTH OF CARRIAGEWAY (m)
i.	Single Lane Road	3.75
ii.	Two lanes, without raised kerbs	7.0
iii.	Two lanes, with raised kerbs	7.5
iv.	Intermediate carriageway(expect on important roads)	5.5
v.	Multi-lane pavements	3.5 per lane

Source: Code of Practice (Part -1), 2012

Typical Cross Section

The cross section has a 3.5m width carriageway each and 2.5m width median. The space for cycling and pedestrian movement is also given.

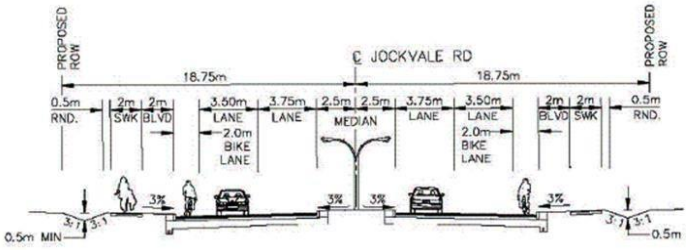


Fig -23: Typical 4 lane urban divided cross section DesignComponents of Road
Source: googleimage

The components to be considered for designing road are light weight and heavy weight vehicles, cycling and walkability.

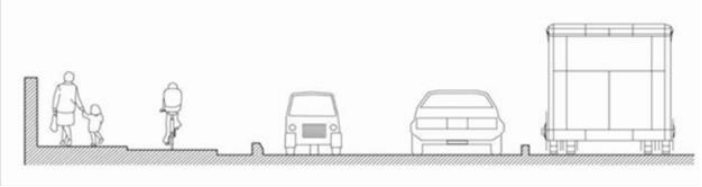


Fig -24: Design components of road
Source: Code of Practice (Part -1), 2012

Land Use - Transportation Plan

The design shows the elements to be considered for land use and transport plan.

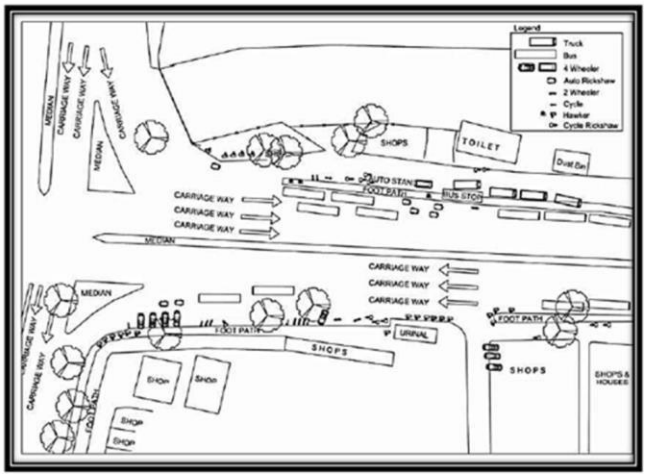


Fig -25: Land use and transport design
Source: Code of Practice (Part -1), 2012

Design Speed

Design speed for different road classification is as follows:

Table -14: Standard design speed for various roads

	ARTERIAL ROAD	SUB ARTERIAL ROAD	COLLECTOR ROAD	LOCAL STREET	URBAN EXPRESSWAY
Plain	60	60	40	30	80
Rolling	50	50	40	30	70
Mountains	40	40	30	20	60
Steep	40	40	30	20	60

Source: IRC 2012

Intersection - Turning Radius

Arterial, Sub arterial and Collector streets shall not exceed 9m. For Local Streets, shall not exceed 4m.

Median

Median provides a safe and easy journey. It helps to decrease the accidents. Median width can be 1.2 m but preferably 2m.

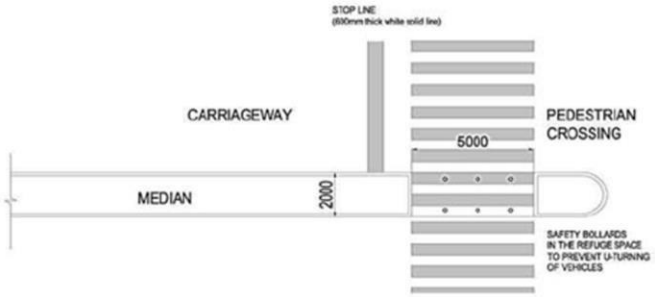


Fig -26: Design of median
Source: IRC 2012

7.2 Pedestrian Facilities Design Standards

1. The minimum 1.8m (width) x 2.2m (Height) walking zoneshould be clear of all obstructions - both horizontally and vertically.

2. No utility ducts, utility poles, electric, water or telecom boxes, trees, signage or any kind of obstruction should be placed within the 'Walking Zone'.

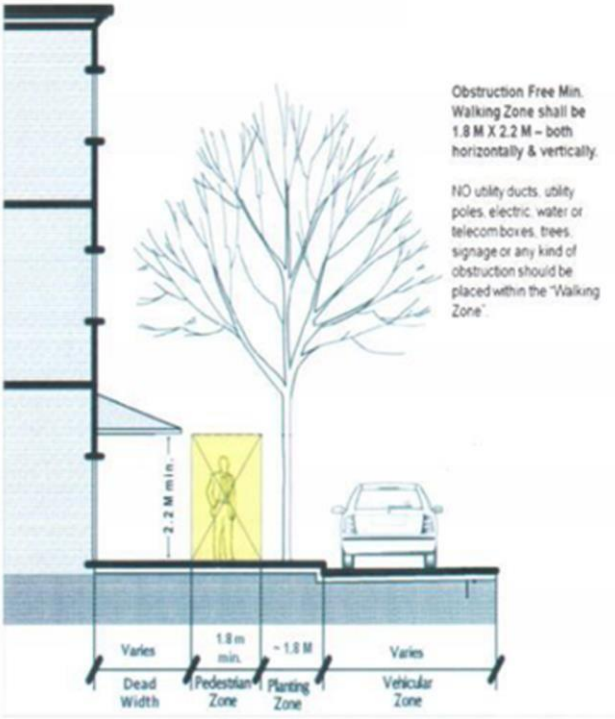


Fig -27: Design of Pedestrian path
Source: IRC 2012

Table -15: Standard width for pedestrian path for different land use

Minimum obstacle free walkway width and Residential/ Mixed Use Areas	1.8 m
Commercial/ Mixed Use Areas	2.05 m
Shopping frontages	3.5 to 4.5 m
Bus stops	3 m
High Intensity Commercial Areas	4 m

Source: Code of Practice (Part -1), 2012

Table -16: Standards for pedestrian path

A. WALKABLE AREA WITHIN THE TRANSIT AREA
The permissible walking distance in transit area is 400m & the sufficient area for pedestrian to be aware of other pedestrian in transit area is required to be 1.9 – 3.3 sq m/person.
The maximum flow of pedestrian for public transit occurs when transit stops are within a 10 minute walking distance from source.
B. PEDESTRIAN FACILITIES IN TRANSIT AREAS –WALKWAYS
Pedestrian walkways should be planned with minimum width of 2 m with accessible grace changes.
Pedestrian should not have to walk more than 200 m to ramp or elevators to change floor level to access transit.
C. FOOTPATH
1.8 – 2 m footpath for light pedestrian traffic.
5 m footpaths for heavy pedestrian traffic.
To allow walking at near normal speeds, the foot path must provide continuity without any obstacles.
D. CROSSWALKS
The crosswalks should be provided at every 30 m on the pedestrian streets.
At the zebra crossing, width of zebra crossing should be within the range of 2 – 4 m.
The minimum island size should be 15 sq m.
The radii at the corner of the streets varies from 0.7 m to 1.7 m and with curbside parking it can vary from 1.7 to 3.5 m.
In case of raised median, being used as pedestrian refuge, such portion could be suitable depressed with curb height not exceeding 150 mm.
E. RAMPS
Ramps must have maximum slope of 1:20. A level walking space should be provided at the top of the ramp.
The ramps and landings are required where the slope exceeds 5 per cent.
For ramps maximum permissible slope is 8.33% with minimum width of 1 m.
The hand rails should be installed along the side of the ramp, more than 0.15 m or the length should be greater than 2 m.
The diameter of the hand rail should be not more than 35 mm for proper gripping.
F. OTHER PEDESTRIAN FACILITIES IN TRANSITAREAS
Signage can add several pedestrian qualities to the streets.
Use of special paving to break up an expense or to link pedestrian path with the transit stop restricting pedestrian and vehicular conflicts.
Street trees should be placed less than 30 m apart.

Pedestrian Guard Rail

1. Preferably, the guard rails should be set back from edge of the carriageway by at least 150 mm.

2. To be clearly detectable, guardrails should be 1100mm high from the median level and painted to contrast clearly with the surroundings preferably in canary yellow colour.

Fig -28: Design of Pedestrian guard rail
Source: IRC, 2012

7.3 Cycle Path

The minimum width to be provided for cycle path is as follows:

Table -17: Standard width for cycle path

	ARTERIAL ROADS	SUB ARTERIAL ROADS	DISTRIBUTORY ROADS	ACCESS ROADS
Minimum Width	2.5 for a two lane cycle track and 1.9 m for a common cycle track and footpath	2.0 for a two lane cycle track and 1.7 m for a common cycle track and footpath	1.5 m	1 m (painted)

Source: Code of Practice (Part -1), 2012

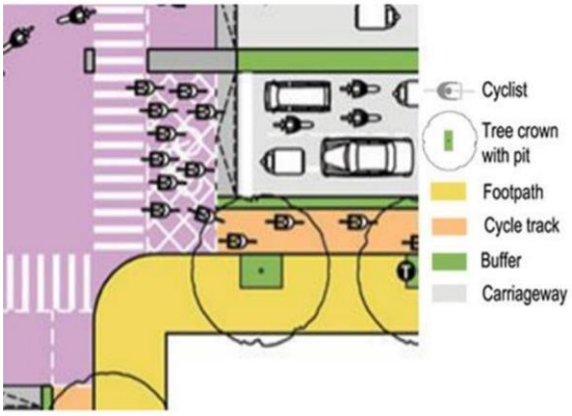


Fig -29: Design of Cycle path at intersection
Source: Code of Practice (Part -1), 2012

7.4 Bus Stop

1. Bus stop should not be placed at the Junction or Intersection point.

2. In Kerala, Bus stops are placed 50 -70 m away from the intersection point.

3. The distance between the bus stops should not exceed more than 1Km.

7.5 Zebra Crossing

1. Mid-Block crossings must be provided for people to cross the street safely between building entries or bus stop locations or active land uses on opposite sides of the street.

2. Crossings must be provided at all T- Junctions.

3. The width of zebra crossing lies within a range of 2-4m.

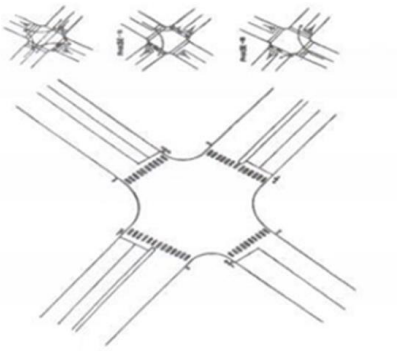


Fig -30: Design of Zebra cross at intersection
Source: IRC, 2012

Cycle Crossing

Minimum 2.5 m wide cycle crossing must be provided at all road crossings.

Traffic Signal

For a 7.5m crossing, the red phase should keep traffic stopped for minimum 12 seconds to allow disabled pedestrian to complete their crossings.

Refuge Island

1. It is mandatory on all roads with four lanes or more.

2. Recommended width is 2 m.

7.6 Parking

1. No parking on arterial roads where available carriageway width is less than 7.25m (individually in 4 lanes).

2. No parking on sub-arterial roads where available carriageway width is less than 7.5 m.

3. No parking on collector streets where available carriageway width is less than 5.5 m.

4. Parking on one side on local streets where available carriageway is not less than 5.5 m and both sides where carriageway is more than 10.5 m.

7.7 Skywalk

1. Shall be provided within a distance of 200 m from a school or hospital or factory/ industrial area.

2. Minimum width should be 1800 mm.

3. A hand rail set 760 mm- 900 mm above the walking surface should be provided.

8. PROPOSALS

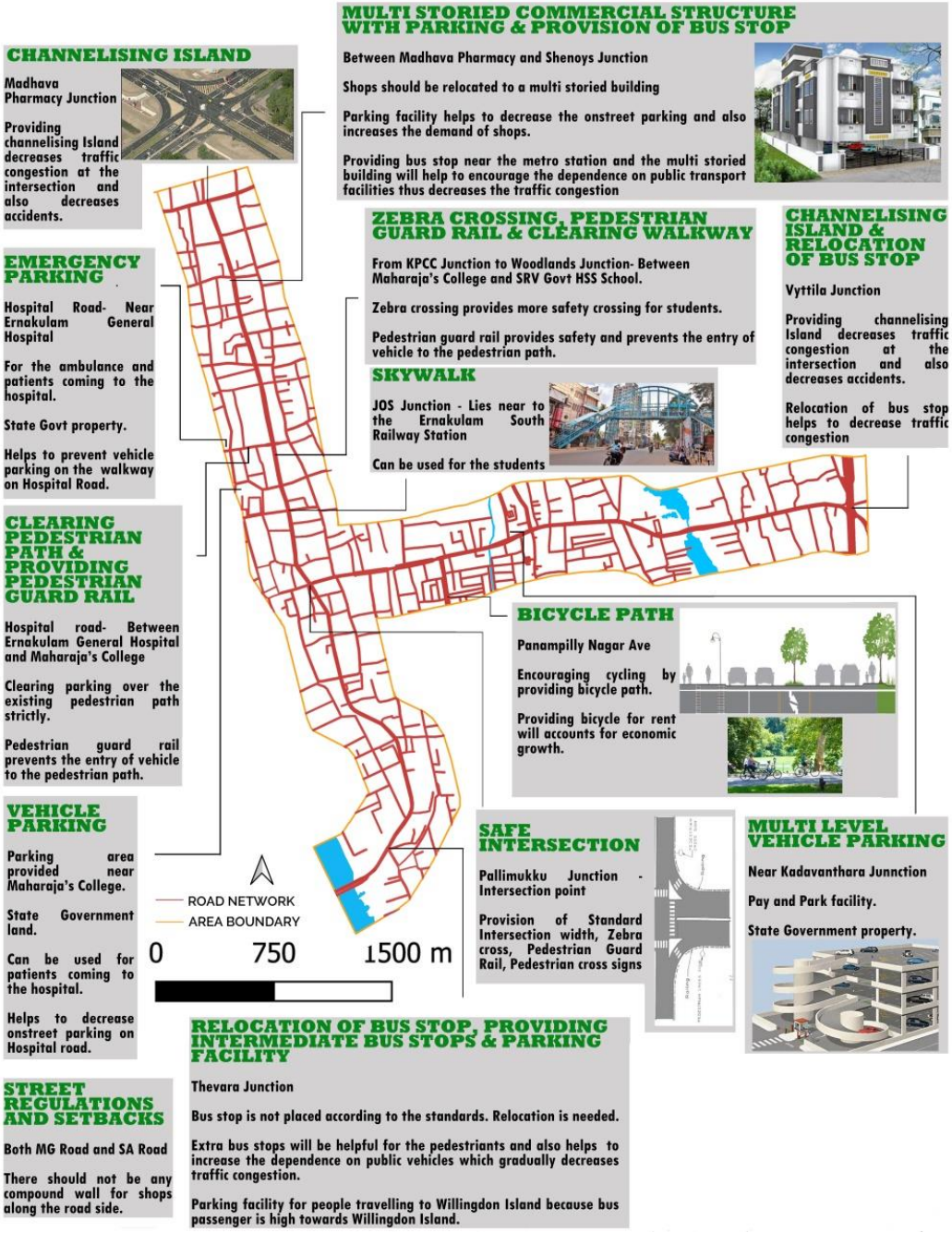


Fig- 31: Proposed Plan

9. CONCLUSION

Integration was done by analysing the study area in a micro level. In the case of Kochi, the reason for traffic congestion at each junction is due to different factors. The problem identification comparing land use and transportation helps to provide a traffic management plan for decreasing traffic congestion. In Kochi, the possible change that can be made is to modify the existing land use and infrastructure. A traffic management plan has been given as the proposal and the proposals are based on the guidelines and standards. Proposals such as mixed land use, public transport facility, walkability, cycling, parking facility etc has been provided as a solution based on the land use and transport interaction. When the travel demand and travel length decreases then the traffic congestion also decreases.

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