Economic Evaluation of Traffic Congestion at Intersection: Case Study from Ernakulam City

Prof. Leni Stephen[1], Ashna P B[2], Fathima S[2], Shamnath M[2], Swathy S Thilakan[2]

[1]*Professor, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India*
[2]*Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India*

Abstract – *Traffic congestion is a condition in transport that is characterised by slower speeds, longer trip times, and increased vehicular queueing, which causes negative impacts in transportation and it may cause huge loss in the economic part. resulting increase in delay, vehicular growth, unnecessary journeys etc create more economic loss. Congestion cost evaluation helps to identify the economic loss and we can identify the necessary steps we have to put forward to reduce this much drastic loss. This study evaluates the traffic congestion cost at signalized intersections located at Ernakulam city, with heterogeneous traffic conditions. Congestion cost evaluation is done by using different factors such as delay, traffic volume, passenger occupancy, and value of travel time of different vehicle types. The annual congestion cost of each approach is also estimated to identify the need of any flyovers, metros, in that area and thereby we can understand the importance of traffic less junctions. Therefore, it is important to use public transport vehicles instead of private transport vehicles to reduce these huge amounts of economic loss.*

Key Words: **delay, traffic volume, value of travel time, passenger occupancy, cost estimation, strategies to mitigate congestion**

1.INTRODUCTION

Traffic congestion has a direct effect on our quality of life. Traffic congestion on road networks is a fact of life in the modern world. It affects the quality of life directly or indirectly. Rising traffic congestion is an inescapable condition in large and growing metropolitan areas across the world. Peak hour traffic congestion is an inherent result of the way in which modern societies operate. Traffic jams can cause delays in many areas of our life and that delayed time may cause so much inconvenience to people. Other negative effects of traffic jams are additional pollution, more fuel expenditure and delay in the delivery of goods. Traffic congestion is the most outstanding performance of the negative externalities of urban road traffic, which is characterised by the negative effects of time delay, energy waste, air pollution and many other impacts. These will also have a bad impact on the entire market economy.

Traffic Delay is the additional travel time experienced by a driver, passenger or pedestrian due to circumstances that impede the desirable movement of traffic.

Passenger Occupancy is the total number of people carried by the vehicle, usually an average or typical number for a specific set of conditions.

Value of travel time refers to the cost of time spent on transport. It includes the cost to businesses of the time their employees and vehicles spend on travel, and costs to consumers of personal time spent on travel.

Traffic volume is defined as the number of vehicles crossing a section of road per unit time at any selected period.

Delay, the performance measure that is used for the operational evaluation of the intersection and is estimated as the extra time consumed by the vehicles in traversing the intersection.

$$d_{intersection}=\sum_{i=1}^{n}\sum_{m=1}^{k} delay_{i,m} v_{i,m} vot_{i,m} o \qquad (1)$$

Where delay is the delay of the vehicle, v is the traffic volume, o is the occupancy, vot is the value of travel time, i is the different approaches and m is the vehicle type for an intersection.

Traffic congestion causes severe impacts on economic loss. Metropolitan cities experience more economic loss. To reduce this huge loss necessary steps, have to be taken and these steps have to be followed. Considering these facts, sites with major congestion in Ernakulam city are selected for cost estimation.

2. STUDY AREA

The study area selected is Ernakulam city. Ernakulam city is the second most heavy traffic city in Kerala, which has a large amount of traffic volume and signalised intersections are provided to divert the vehicle in proper directions and thereby we can reduce the traffic jam. These four intersections are operating under heterogeneous traffic conditions, which may or may not permit left turn, because in some points on the road, some diversion points are provided to divert buses into that road and thereby reduce congestion in that intersection. The intersections are provided with signal operations, according to the traffic demand in some of the intersections and others are having fixed time continuous

cycle operations. The four intersections are Pallimukku, Jos junction, DCC junction and Kaloor.

.

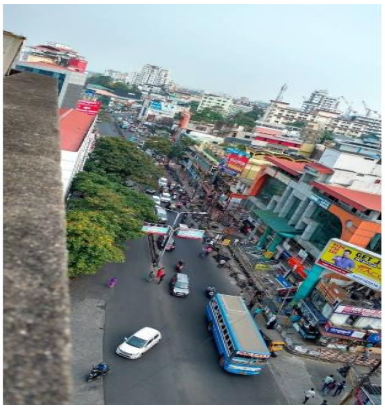

Figure 1. Pallimukku junction

Figure 2. Jose junction

Figure 3. DCC junction

Figure 4. Kaloor junction

Name of intersection	Approach name	Approach width (m)	Green time (sec)	Cycle length(sec)
Pallimukku	Approach 1 (from Shipyard junction)	14.18	43	150
	Approach 2(from Jos junction)	14.18	75	150
	Approach 3 (from Foreshore Road)	5.5	0	0
	Approach 4 (from Valanjambalam)	16.1	70	150
Jos junction	Approach 1 (from Pallimukku)	14.18	50	120
	Approach 2 (from DCC junction)	14.18	50	120
	Approach 3 (from TD junction)	7.6	10	120
	Approach 4 (from Chittoor Road)	5.8	33	120
DCC Junction	Approach 1 (from Jos junction)	14.18	58	120
	Approach 2 (from Kacherippady)	14.18	55	120
	Approach 3 (from Maharajas)	10.2	10	120

	Approach 4 (from Chittoor Road)	9.6	34	120
Kaloor junction	Approach 1 (from Kadavanthara)	22	30	180
	Approach 2 (from Elamakkara)	7.2	18	180
	Approach 3 (from Ernakulam)	22	101	180
	Approach 4 (from Aluva)	22	92	180

Table 1. Salient features of signalised intersection

3. DATA COLLECTION

3.1 Delay

Delayed data collections were carried out manually. Entry and exit points were selected for measuring the delay, in such a way that entry point is the queue arrival of vehicles and exit point is the discharges at each approach. Travel time required for the vehicles in the absence of signal operating conditions is also estimated by manual observation. The average value is taken as the delay. Table 2 represents the range of observed delay values in each approach.

Name of intersection	Approach	Traffic delay (sec)
Pallimukku junction	Approach 1	51
	Approach 2	32.5
	Approach 3	50
	Approach 4	34
Jos junction	Approach 1	41
	Approach 2	44
	Approach 3	68
	Approach 4	51
DCC junction	Approach 1	50
	Approach 2	44
	Approach 3	62
	Approach 4	57
Kaloor junction	Approach 1	86
	Approach 2	82
	Approach 3	57
	Approach 4	61

Table 2. traffic delay

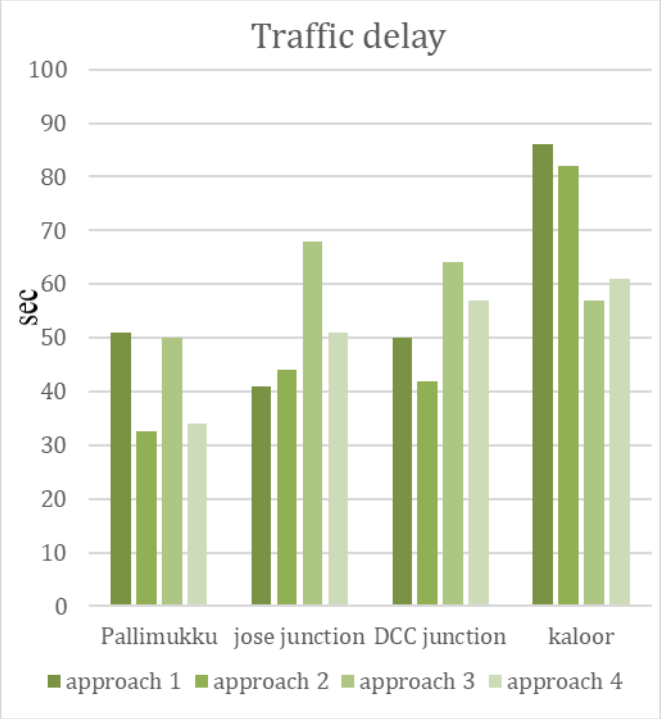

Figure 5. Observed delay in the study stretches

3.2 Traffic volume

For traffic volume data collection, CCTV footage of each intersection were collected. And by clean observation we counted the number of vehicles in every intersection. For the collection of traffic footage at each intersection, proper permission was obtained from "THE COMMISSIONERATE, KOCHI". Data collected on a typical day from 7.00 AM to 11.00 AM and 3.30 PM to 6.30 PM for traffic volume. Traffic volume is counted in terms of number of vehicles. Traffic volume of four junctions is given below

	Time	7:00-8:00 AM	8:00-9:00 AM	9:00-10:00 AM	10:00-11:00 AM	3:30-4:30 PM	4:30-5:30 PM	5:30-6:30 PM
Approach 1(from Shipyard junction)	Bus	12	16	17	13	15	17	20
	Car	416	437	445	429	435	450	468
	Auto-rikshaw	71	74	79	75	80	83	88
	Two-	58	59	62	615	63	64	67

	wheeler	8	5	3		0	8	1
Approach 2(from Jos junction)	Bus	60	62	65	60	64	67	68
	Car	422	441	438	434	439	462	470
	Auto-rikshaw	68	72	76	73	78	80	85
	Two-wheeler	591	599	628	620	634	641	680
Approach 3(from foreshore road)	Bus	0	0	0	0	0	0	0
	Car	68	72	77	74	75	80	83
	Auto-rikshaw	14	16	19	15	17	20	23
	Two-wheeler	113	124	129	119	115	127	132
Approach 4(from Valanjambalam)	Bus	0	0	0	0	0	0	0
	Car	420	438	441	437	438	458	465
	Auto-rikshaw	70	72	78	76	81	84	89
	Two-wheeler	600	618	625	632	640	648	650

Table 3. Traffic volume of Pallimukku junction

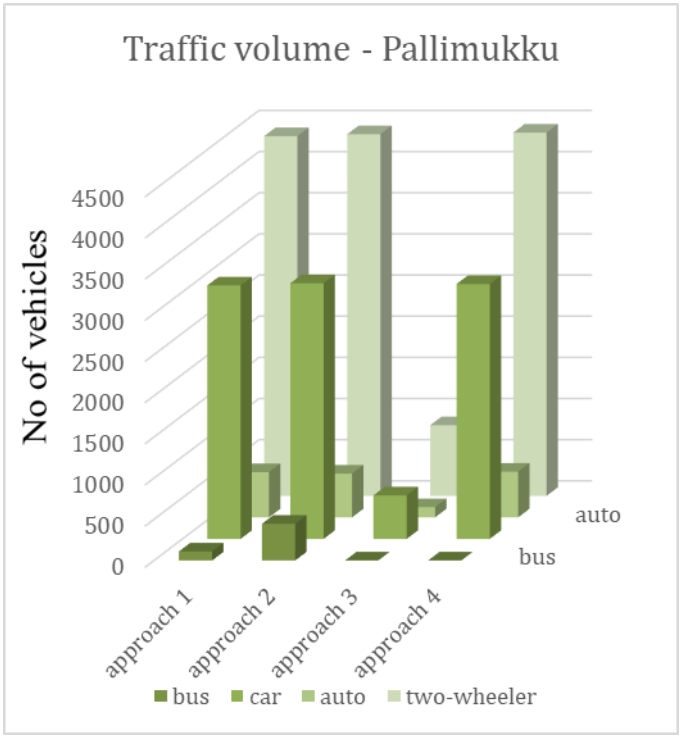

Figure 6. Traffic volume – Pallimukku junction

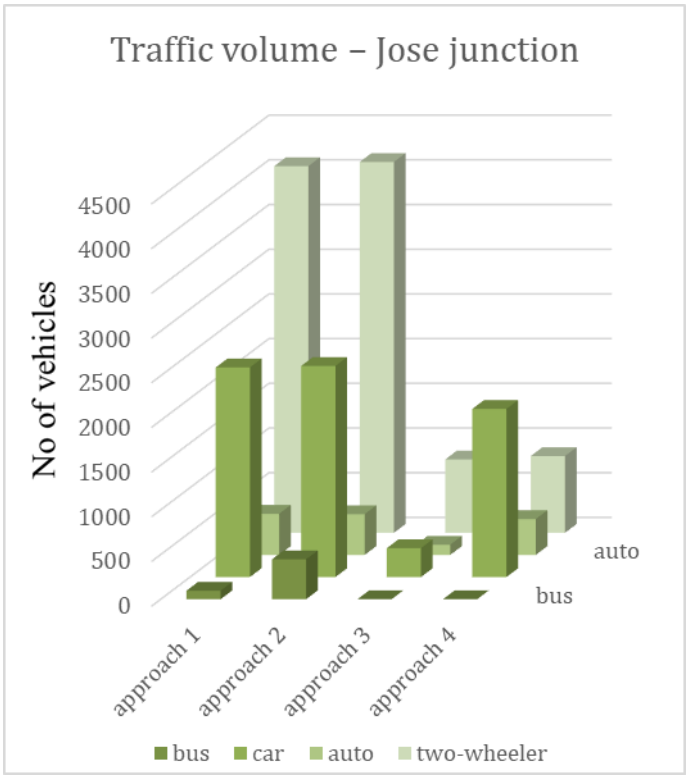

Figure 7. Traffic volume – Jose junction

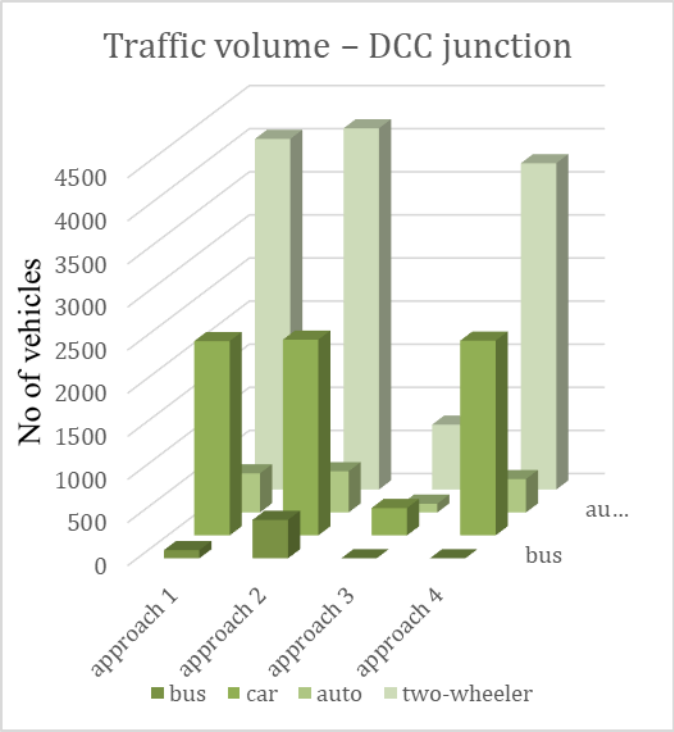

Figure 8. Traffic volume – DCC junction

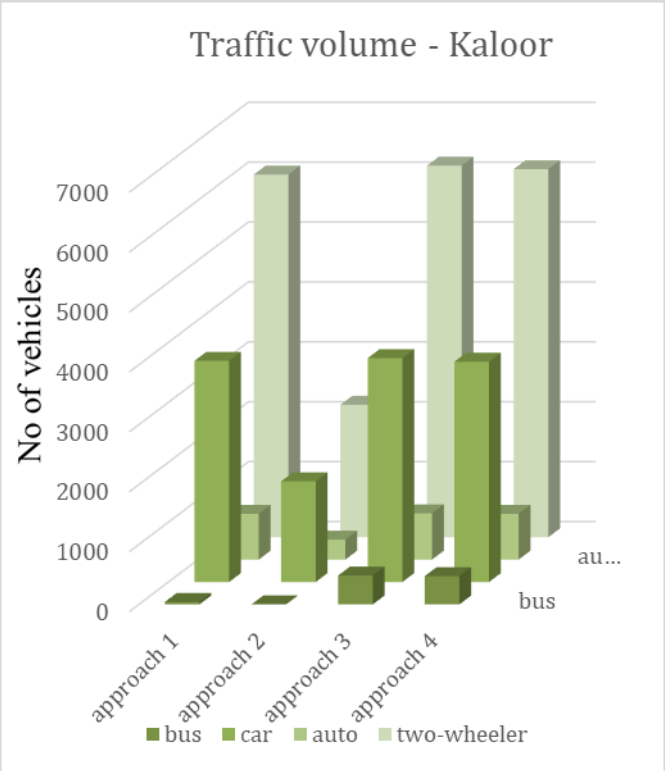

Figure 9. Traffic volume - kaloor

3.3 Value of travel time (VOT)

Value of travel time is the maximum amount of money that people are willing to sacrifice to save one unit of time. Value of travel time mainly depends upon travel time and travel cost. Value of travel time also depends upon the socio-economic characteristics including age, gender, marital status, education, personal income etc. It is also associated with work trips which are higher in high income groups. Trip length also has a positive influence on the value of travel time. For the same trip length value travel time will be different for different income groups. The different values which are taken for different modes of transport are given below in table 4.

Vehicle	Value of travel time (Rs/hr)
Car	240
Two-wheeler	180
Auto-rickshaw	150
Bus	60

Table 4. value of travel time

3.4 Passenger occupancy

Passenger occupancy of the vehicle is done by manual observations. For finding passenger occupancy, a survey was conducted at four selected intersections. By manual observation we counted the number of passengers in each mode of transport of vehicles such as car, two-wheeler, auto rickshaw and bus. Ten numbers of vehicles were randomly selected in each intersection and the number of passengers were counted. Its average value is taken as passenger occupancy.

Vehicle	Passenger occupancy
Car	2.1
Two-wheeler	1.42
Auto-rikshaw	1.88
Bus	50

Table 5. passenger occupancy

3.5 Cost estimation

Total cost estimation is done by adding the cost for different types of vehicles. Congestion cost is calculated separately for each mode and aggregated for each approach

$$d_{intersection}=\sum_{i=1}^{n}\sum_{m=1}^{k} delay_{i,m} v_{i,m} vot_{i,m}$$

Intersection	Approach	Modes	VOT	Occupancy	Delay	Volume	Delay Cost (Day)	Annual delay cost (Rs)
Pallimukku	Approach 1(from Shipyard junction)	Bus	60	50	51.8	110	4748	1733141
		Car	240	2.1	51.6	3080	22250	8121220
		Auto	150	1.88	51.5	550	2218	809858
		Two-wheeler	180	1.42	51.4	4370	15947	5820975
	Approach 2(from Jos junction)	Bus	60	50	32.6	446	12116	4422461
		Car	240	2.1	32.4	3106	14089	5142417
		Auto	150	1.88	32.3	532	1355	494583
		Two-wheeler	180	1.42	32.2	4393	10043	3665796
	Approach 3(from Foreshore Road)	Bus	60	50	0	0	0	0
		Car	240	2.1	34.5	529	2555	932601
		Auto	150	1.88	34.3	124	333	121606
		Two-wheeler	180	1.42	34.1	859	2080	759100
	Approach 4(from Valanjambalam)	Bus	60	50	50.6	0	0	0
		Car	240	2.1	50.4	3097	21852	7976138
		Auto	150	1.88	50.2	550	13667	4988437
		Two-wheeler	180	1.42	50.1	4413	15697	5729581
Total								50717914

Table 6. Cost estimation at Pallimukku junction

Intersection	Approach	Modes	VOT	Occupancy	Delay	Volume	Delay Cost (Day)	Annual delay cost (Rs)
Jos junction	Approach 1 (from Pallimukku)	Bus	60	50	41.9	95	3317	1210735
		Car	240	2.1	41.7	2345	13690	4996890
		Auto	150	1.88	41.6	460	1127	411271
		Two-wheeler	180	1.42	41.4	4102	12057	4400958
	Approach 2(from DCC junction)	Bus	60	50	44.5	446	16539	6036796
		Car	240	2.1	44.3	2362	14649	5346930
		Auto	150	1.88	44.2	456	1579	576270
		Two-wheeler	180	1.42	44	4149	12961	4730938
	Approach 3(from TD Junction)	Bus	60	50	68.3	0	0	0
		Car	240	2.1	68.1	323	3079	1124010
		Auto	150	1.88	68	114	607	221643
		Two-wheeler	180	1.42	67.9	821	3958	1444655
	Approach 4 (from Chittoor Road)	Bus	60	50	51.1	0	0	0
		Car	240	2.1	50.9	1881	13404	4892462
		Auto	150	1.88	50.8	401	1596	582435
		Two-wheeler	180	1.42	50.7	3785	13625	497307
Total								36473300

Table 7. Cost estimation at Jose junction

Intersection	Approach	Modes	VOT	Occupancy	Delay	Volume	Delay Cost (Day)	Annual delay cost (Rs)
DCC junction	Approach 1(from Jose junction)	Bus	60	50	50.9	95	4030	1470798
		Car	240	2.1	50.8	2254	16030	5851114
		Auto	150	1.88	50.7	453	1799	656668
		Two-wheeler	180	1.42	50.5	4067	14582	5322513
	Approach 2(from Kacherippady)	Bus	60	50	44.7	446	16614	6063928
		Car	240	2.1	44.6	2270	14174	5173466
		Auto	150	1.88	44.4	477	1659	605537
		Two-wheeler	180	1.42	44.3	4190	13179	4810265
	Approach 3 (from Maharajas)	Bus	60	50	62.4	0	0	0
		Car	240	2.1	62.3	317	2765	9953546
		Auto	150	1.88	62.1	101	491	179330
		Two-wheeler	180	1.42	62	753	3315	1209868
	Approach 4(from Chittoor Road)	Bus	60	50	57.5	0	0	0
		Car	240	2.1	57.4	2259	18153	6625963
		Auto	150	1.88	57.2	387	1734	632917
		Two-wheeler	180	1.42	57.1	3583	14526	5301932
Total								53857845

Table 8. Cost estimation at DCC junction

Intersection	Approach	Modes	VOT	Occupancy	Delay	Volume	Delay Cost (Day)	Annual delay cost (Rs)
Kaloor	Approach 1(from Kadavanthara)	Bus	60	50	86.7	41	60	1081221
		Car	240	2.1	86.5	3692	240	16319194
		Auto	150	1.88	86.3	764	150	1885140
		Two-wheeler	180	1.42	86.2	6053	180	13521633
	Approach 2(from Elamakkara)	Bus	60	50	0	0	60	0
		Car	240	2.1	82.5	1680	240	7082460
		Auto	150	1.88	82.3	334	150	785933
		Two-wheeler	180	1.42	82	2210	180	4696316
	Approach 3(from Ernakulam)	Bus	60	50	57.9	482	60	8488623
		Car	240	2.1	57.6	3738	240	11002280
		Auto	150	1.88	57.4	773	150	1268618
		Two-wheeler	180	1.42	57.3	6202	180	9209533
	Approach 4 (from Aluva)	Bus	60	50	61.5	473	60	8848056
		Car	240	2.1	61.4	3677	240	11536734
		Auto	150	1.88	61.2	765	150	1338604
		Two-wheeler	180	1.42	61	6143	180	9710946
Total								106775291

Table 9. Cost estimation at Kaloor junction

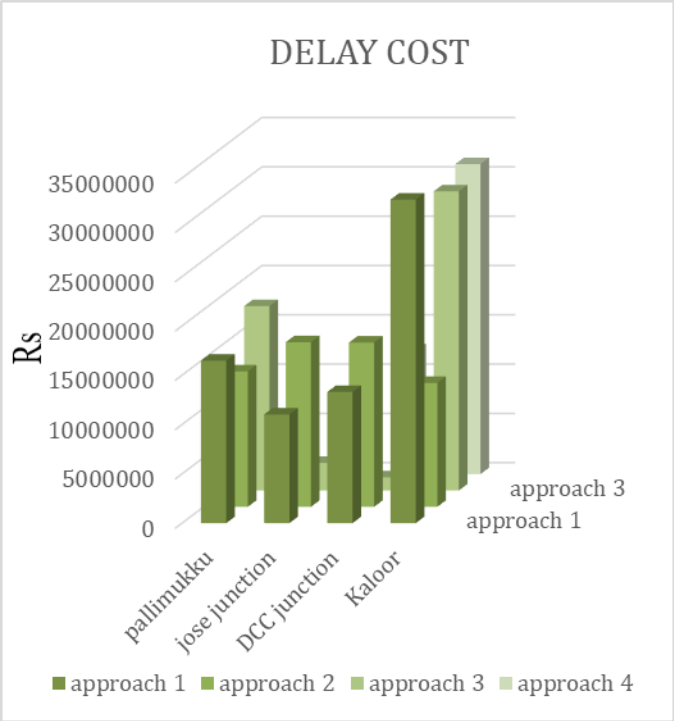

Figure 10. Delay cost for different intersection

3.6 Strategies to mitigate congestion

There are several methods which can be utilized to reduce traffic congestion and thereby reduce the economic loss. Since vehicular growth is increasing day by day, the need of taking necessary steps to reduce traffic congestion reducing measures is very much important. Some of them are given below.

3.6.1 Improved Public Transport System:

Improved public transport systems can help to enhance usage of public transport vehicles and thereby we can reduce the number of private vehicles on the road. The main reasons for avoiding public transport vehicles may be inefficiency, non-cleanliness, slower speeds etc. The improved transport system such as metro rails can be highly incorporated for travel purposes which will also help to reduce congestion cost.

3.6.2 Congestion Charging:

Congestion charges refers to money motorists must pay in order to drive in some areas. These charges are intended to reduce traffic within those areas. Congestion charging is the most favourable method to reduce traffic congestion. Some of the cities around the world have introduced this scheme to reduce traffic congestion which helps to reduce unnecessary journeys and increase the usage of public transport vehicles, which has the lowest value of travel time.

3.6.3. Proper footpaths for pedestrians:

In the absence of a proper way for pedestrians, they will get into the roads, which may cause accidents and congestion. If we are provided with proper ways for pedestrians, we can reduce the pedestrian overflow. And it is important to provide necessary footpaths and subways.

3.6.4 Improved Traffic Management:

By providing traffic volume, identifying sensors at different intersections may also help to reduce economic loss. By providing these kinds of sensors we can vary the signal time according to the traffic demand and thereby we can reduce the traffic delay in each approach.

4. CONCLUSIONS

The main objective of the study was to determine the overall economic loss due to traffic congestion of four signalized intersections at Ernakulam city. Traffic flow slows down when the number of vehicles traveling on the road increases or the roadway capacity decreases due to various reasons. Traffic congestion is a serious issue in every big city and that causes several problems for common people. Traffic congestion affects travel costs, travel time, mobility, accessibility, productivity and also impacts on the environment such as air pollution and global warming. To overcome these serious issues, responsible authorities should take proper measures such as providing exclusive lanes for public transport, use regulations and traffic email to control traffic, and use innovative ideas to reduce traffic impacts on public transport. We, common people also should be concerned to reduce traffic congestion, that is by promoting the use of public transport. Development of the public transport network at economical rates is essential. This study proposes a demand side policy to the Indian city along with the congestion cost estimation at signalized intersections. This study also points out ways to reduce private vehicles and promote the usage of public vehicles and to get to know about the importance of flyovers, metros and traffic less junctions.

REFERENCES

[1] Krishnamurthy K, Muneera, Transportation Research Procedia 48 (2020) 1766–1777. Economic Evaluation of Traffic Congestion at Intersection: Case study from an Indian City

[2] Wan- Xing Wang and Jing Yu, Advances in Mechanical Engineering 2018 vol 10 (6) 1- 8’ Research on road traffic congestion index based on comprehensive parameters: Taking Dalian city as an example

[3] E Prahara, IOP Conf series 196 (2018) The evaluation of traffic characteristic analyzed by vissim (case study: underpass construction at Metro Pondok Indah Road)

[4] Devaraj Hanumappa, Raviraj H. Mulangi and Nityanand S. Kudachimath, Open Transportation Journal 2018, Vol 12. Traffic Characteristics Evaluation and Traffic Management Measures: A Case study of Dharwad City

[5] Krishnamurthy K, European Transport Journal 2018 Issue 68. Economic evaluation of traffic congestion- challenges.

[6] Dr YP Joshy, Mrityunjay Singh, International Research Journal of Engineering and Technology 2017 Vol 4 Issue 7 Evaluation of Traffic Characteristics: a Case Study on NH-12, Near Barkatullah University, Bhopal (M.P.)

[7] D Aniketh Goud, Gillela. Naresh Kumar Reddy International Journal of Advance Research in Science and Engineering, 2016, Vol 5, Issue 10 EVALUATION OF TRAFFIC CHARACTERISTICS

[8] Bivina GR, Vishrut Landgeb & Sanjay Kumar VS, Transportation Research Procedia 17 (2016) Socio Economic Valuation of Traffic Delays

[9] Liang Ye, Ying Hui, Dongyuan Yang, J Mod Transport 2013 Road traffic congestion measurement considering impacts on travelers

[10] Mahmood Nesheli, Arash Moradkhani Roshandeh, Che Puan, International Journal of Recent Trends in Engineering, Vol 1, No 6, 200 Evaluation of Traffic Characteristics: A Case Study