Evaluation of Traffic Congestion on Urban Road

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***Abstract*— Traffic congestion is a major phenomenon in most of the cities. Congestion resulting in delays, fuel wastage and money loss. Therefore, the study sought to measure the traffic congestion on the selected road NH-206 in Shivamogga city of Karnataka, India. The study employed an analysis of travel time through the study stretch. This study is to evaluate congestion of urban sub arterial road in terms of travel time indices during peak hours of a working day and non-working day. To do this, various existing travel time reliability indices are considered and are examined. Travel time measures such as Travel Time Index (TTI), Buffer Time Index (BTI) and Congestion Index (CI) are studied. The study revealed that the study stretch considered was under LOS E at present and is under the influence of traffic congestion. And also it was identified that lack of supply with respect to capacity of the road was the main cause of traffic congestion. The study recommends increasing the capacity of the study stretch i.e., to convert present two-lane undivided highway to six lane divided highway to manage traffic congestion in the study stretch as a short-term measure.**

Keywords*— *Urban traffic, Congestion index, Level of service, Heterogeneous traffic.

INTRODUCTION

Traffic congestion condition on road networks occurs as a result of excessive use of road infrastructure beyond capacity, and slower speeds, longer trip hours and increased vehicular queuing characterize it. Traffic congestion is a key issue that is identified in a transportation network from the points of view of both transport users and administrators [1,2,3]. For all methods of transport, travel time is a critical measure for evaluating the level of congestion [4]. Travel Time Index (TTI) represent the comparison and Average Travel Time (ATT) with respect to free flow travel time FFTT and Buffer Time Index compares of 95th percentile travel time with respect to mean travel time [5,6]. Car travel time data were considered for evaluating travel time for representative study segment. This measurement is useful when evaluating network performance under normal daily flow variations. The main advantage of this type of measurement is that, it is useful to the both the transport planners as well as the system users [7]. By considering short term measure, congestion can be reduced by either increasing road capacity (supply) or by reducing traffic (demand). Road capacity can be increased in a number of ways such as adding more capacity over the whole of a route, creating new routes, and improvements in traffic management. Reduction of demand can include, parking restriction, park, and ride, congestion pricing, road space rationing, incentives to use public transport and introduction of carpooling [8].

Chepuri et al. (2018) [9], examined travel time under mixed traffic conditions on urban arterial roads in Indian cities. The study carried out for examining travel time reliability under heterogeneous traffic conditions on three different urban arterial road sections in the cities of Ahmedabad and Surat in India. Travel time reliability was calculated for the selected sections. The study also highlighted the development of the reliability-based Level of Service (LOS). The study results indicated that Buffer Time (BT) and Buffer Time Index (BTI) are the most effective measures that can capture the travel time variations.

Karuppanagounder and Muneera (2017) [10], carried out travel time-based performance evaluation of urban links under heterogeneous traffic condition. Travel time based indices comprising delay, planning time index, congestion index and travel time index were used to evaluate the performance of the urban link. The result of the analysis indicated that link having high value of travel time showed a high values of the performance indicators on urban link, which meant that passengers allocate more time for their trip purposes.

Kumarage (2004) [11], suggested strategies for managing traffic congestion in urban areas. Author categorized the solutions into two categories the Short-Term Strategy: Adding new transport infrastructure capacity- new roads, expressways and railways that can carry more vehicles, Improving existing infrastructure for increasing capacity-adding lanes to the existing roads, Re designing existing infrastructure for increasing capacity- Converting existing road space for high occupancy vehicles either by introducing bus lanes or providing bus ways. In some cities, entire roads have also been converted to pedestrian only streets. Removal of on-street parking, Operational Improvements to existing infrastructure to increase capacity: These include operational changes to increase the capacity of a transport system. These measures include introducing reversible lanes during peak periods. Long-Term Strategy: A Vehicle Ownership strategy compatible with road capacity, A strategy for public transport compatible with population density, A strategy for new modes of public transport compatible with personal incomes. The aim of the present study is to evaluate congestion in terms of travel time indices in one of the traffic congested roads in Shivamogga city, i.e., NH-206 a sub arterial road which passes through Shivamogga city region. However, an attempt has been made to compute the present LOS and LOS for future 15 years by considering vehicle registration data and vehicle growth rate data respectively. This is done as a short-term solution to mitigate congestion on the study road.

STUDY AREA

Shivamogga city is located in Shivamogga district in the central part of the state of Karnataka. It lies on the banks of River Tunga and is the administrative headquarters of the district. The population of Shivamogga is 3,22,428 consisting of 1,61,978 males and 1,60,450 females, as per 2011 census. Males constitute 51% of the population and females 49%. Shivamogga has an average literacy rate of 88.02%, higher than the national average of 59.5%: male literacy is 91.32%, and female literacy is 84.70%. The world famous Jog falls is situated about 100km from the Shivamogga city. Agro based industries Automobile based industries and Engineering based industries are the prominent ones in the district. NH -206, a sub arterial road passing through the city is considered for the present study (Fig.1). Congestion has been observed on the selected road because of the presence of heavy traffic throughout the day and also since it is an undivided road. 3 km stretch of the road is selected to study the travel time through the stretch. The starting point of the stretch is the Shivamogga KSRTC bus terminal, and the end point is Alkola Circle which is 3 km away from the Shivamogga KSRTC bus terminal.

Fig 1. Selected road stretch in Study area, Shivamogga city, Karnataka

DATA COLLECTION AND METHODOLOGY

Secondary Data

The secondary data pertaining to the number of registration of vehicles from Shivamogga Regional Transport Office. Table 1 indicates registered vehicles in Shivamogga city for the last few years. Table 2 indicates the annual traffic growth. This data reveals that city has a maximum strength of 2 wheelers have been registered. The 2 wheelers (bikes, scooters) has increased from 95520 in 1995 to 201781 in 2011 to 2017 with an increase of 13.27 percent, where as the 4 wheelers (cars, jeeps) has increased from 12447 to 29066 with an increase of 15.18 percent and buses has increased from 867 to 1228 with an increase of 5.96 percent. The annual variations of vehicles registration data and traffic growth rate of the Shivamogga city is graphically represented in Fig 2 and Fig 3 respectively.

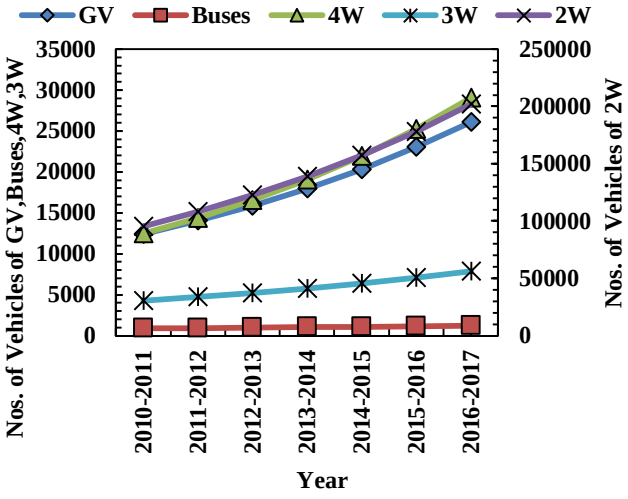

Fig 2. Yearly variation of vehicle registration of Shivamogga city

Table 1. Vehicle registration data of Shivamogga city

Year	GV	Buses	4W	2W	3W
2010-2011	12377	867	12447	95520	4278
2011-2012	14053	918	14332	108218	4715
2012-2013	15855	974	16519	122569	5217
2013-2014	17948	1032	19014	138822	5731
2014-2015	20305	1091	21906	157291	6379
2015-2016	22995	1156	25231	178110	7061
2016-2017	26047	1228	29066	201781	7831

Table 2. Traffic growth rate of Shivamogga city

Year	GV	Buses	4W	2W	3W
2010-2011	13.55	5.83	15.15	13.29	10.22
2011-2012	12.82	6.07	15.26	13.26	10.64
2012-2013	13.2	5.95	15.1	13.2	9.86
2013-2014	13.13	5.75	15.21	13.3	11.31
2014-2015	13.25	5.96	15.18	13.24	10.69
2015-2016	13.27	6.23	15.2	13.29	10.9
Average	**13.20**	**5.97**	**15.18**	**13.26**	**10.60**

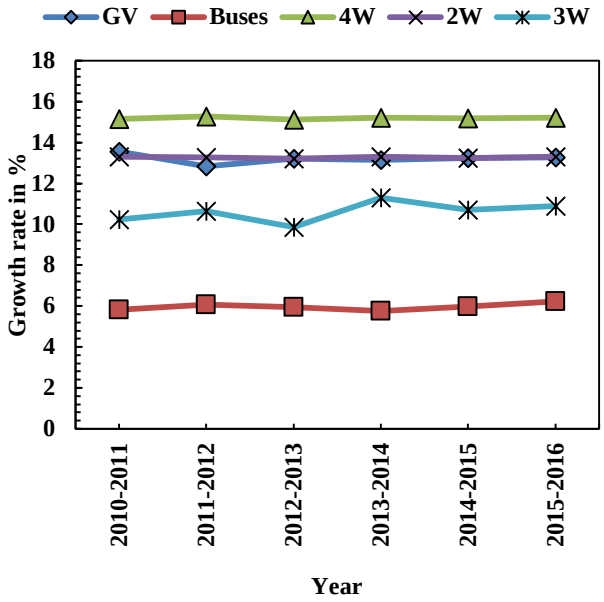

Fig 3. Yearly variation of traffic growth of Shivamogga city

Traffic Data

The video graphic survey was carried out for 8 hours a day on two selected working days and two non-working days (Saturday and Sunday) in a week (total of 32 hours in four days). The study period was included morning hours from 9:00 am to 1:00 pm and evening hours from 4:00 pm to 8:00 pm. Five categories of vehicles were identified during the study period on this corridor. The present study is focused volume of 4W (cars, jeeps), 2W (motorbikes, scooters), 3W (autos), Buses and GV (goods vehicles-trucks, tractors etc) with varying traffic volume and their proportion in the traffic stream. The average vehicular composition is presented in figure 3 and 4. For collecting car travel time data video graphic license plate matching technique was employed. This method consists of collecting vehicle license plate numbers and arrival times at entry and exit points of the section, matching the license plate between entry and exit points and computing travel time from the difference in arrival times. Video cameras were installed at entry and exit locations of the study area to capture the vehicle license plate for all categories of vehicles.

The percentage of 2W composition was observed to be high (46% to 49%), followed by 4W (about 30% to 33%), GV (9% to 11%), 3W (5% to 7%) and Buses (4% to 6%). Fig 4 and Fig 5 represents the morning and evening peak hours traffic composition on the study road stretch respectively for working days. Fig 6 and Fig 7 represents the morning and evening peak hours traffic composition on the study road stretch respectively for non-working days.

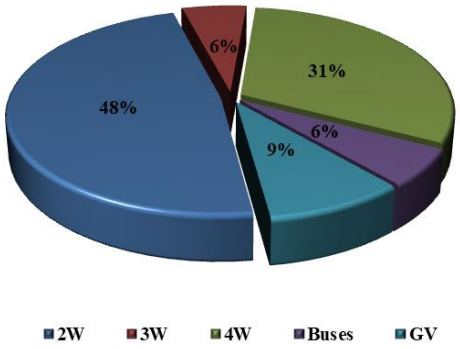

Fig 4. Traffic composition on the study road stretch for morning peak hours (working days)

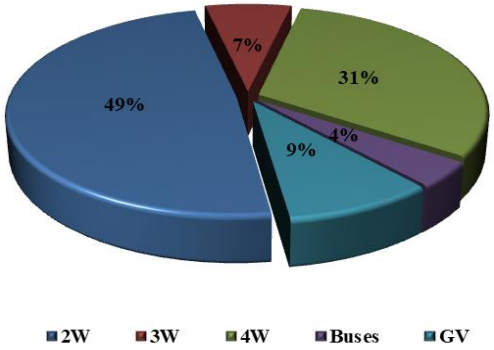

Fig 5. Traffic composition on the study road stretch for evening peak hours (working days)

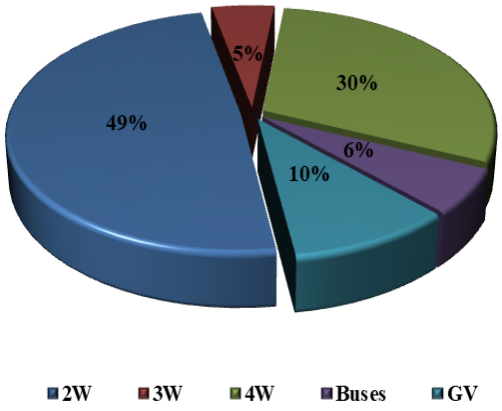

Fig 6. Traffic composition on the study road stretch for morning peak hours (non-working days)

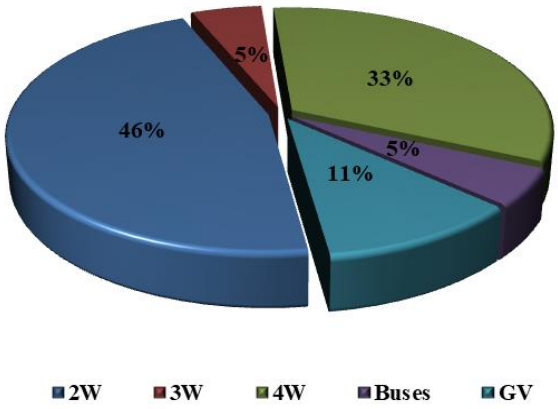

Fig 7. Traffic composition on the study road stretch for evening peak hours (non-working days)

Indices based on travel time

Travel Time Index (TTI) was proposed in the Urban Mobility Repport (Schrank and Lomax, 2005) [12]. Index compares peak period travel time and free flow travel time and is represented by the Eq. (1).

$$TTI = \frac{Peak\ period\ travel\ time}{Free\ flow\ travel\ time} \quad \text{.....(1)}$$

The Buffer Time Index (BTI) is a measure of trip reliability that expresses the amount of extra buffer time needed to be on time for 95th percentile of the trips. This measure allows the traveller to estimate the extra percentage of travel time that the trip may take under prevailing traffic conditions (FHWA Report, 2006) [13]. This is represented by the Eq. (2).

$$BTI = \frac{95th\ percentile\ travel\ time - Average\ travel\ time}{Average\ travel\ time} \quad \text{.....(2)}$$

One of the simple and most widely used congestion measures called CI is used in the present study to depict the congestion level on the study road. The equation for finding the CI is given by Richardson and Taylor (1978) [15]. This is represented by the Eq. (3).

$$CI = \frac{Actual\ travel\ time - Free\ flow\ travel\ time}{Free\ flow\ travel\ time} \quad \text{..... (3)}$$

A study conducted by Taylor et al. (2000) [16], concluded that, a CI value of zero means that the actual travel time and free flow travel time are equal. A value of one means that the actual travel time is twice the free flow travel time. An index greater than two indicates congested condition.

RESULTS AND DISCUSSION

Traffic Growth Rate

The study conducted by Prakash et al. (2018) [17], have showed an exponential increase in traffic distribution (2W) for Mysore city, Karnataka. In the present study, traffic growth is calculated using two methods viz. Cumulative Average Annual Growth Rate method (CAAGR) and Vehicle Registration methods (VRM). For both the methods vehicle registration data is used. First method is manual method whereas second method of calculation is based on IRC: 108-1996 code book [18]. Both the method shows almost same values. Average of result from two methods is adopted. Table 3 represents the values obtained by two different methods adopted for calculation of traffic growth rate. Result shows that growth rate of 4W is higher compared to all other vehicles, with the value of 15.43% followed by 2W, GV, 3W and Buses with the values of 13.57%, 13.54%, 11.05% and 6.23% respectively. From the result it is observed that usage of private vehicles is more in Shivamogga city. And also growth of GV which can be the factor for congestion is high. Growth rate of public transport is very less. This result is used to calculate the volume and LOS on the study road for the future years.

Table 3. Traffic growth rate

Method	GV	Buses	4W	2W	3W
CAAGR	13.2	5.7	15.18	13.26	10.6
VRM	13.88	6.76	15.68	13.88	11.5
Average	13.54	6.23	15.43	13.57	11.05

Evaluation of congestion based on travel time indices

From video graphic method of traffic volume count, morning peak hours and evening peak hours were identified (two hours each in morning and evening time). It was found out to be 9.00 am to 11.00 am in the morning time and 5.00 pm to 7.00 pm in the evening time for working days. Similarly it was 10.30 am to 12.30 pm and 6.00 pm to 8.00 pm for the non-working day. The results extracted for 15 minutes time interval are represented in the Tables 4 and 5. The result shows that the actual travel time during the peak hours varies from 392 seconds to 436 seconds with an average actual peak hours travel time of 415 seconds in the morning hours. Similarly travel time varies from 412 seconds to 451 seconds and average value of 426 seconds during the evening hours. The free flow travel time was found to be 172 seconds during weekdays. Travel time indices obtained for evening hours are more compared to the morning hours. TTI obtained was 2.47 represents the actual travel time on the study road is 2.47 times the free flow travel time. It means that 2.47 times the travel time is wasted due to prevailing traffic congestion. If the road is decongested, the 2.47 times of the travel time can be saved. BTI value of 0.46 was obtained which represents, drivers are taking 46% extra time compared to the 95th percentile travel time on the study road. This indicates that travelers should budget an additional 196 seconds buffer to ensure 95% on time arrival at the destination on study Corridor. Value of CI 1.47 indicates the moderate condition due to prevailing traffic on the road. Similarly it is evaluated for the non-working day. Congestion during weekdays is higher compared to weekends.

Table 4. Travel time indices for working days

Time Segment	ATT(sec)	TTI	BTI	CI
Morning Peak Hours				
9.00 am - 9.15 am	392	2.28	0.39	1.28
9.15 am - 9.30 am	398	2.31	0.41	1.31
9.30 am - 9.45 am	412	2.40	0.33	1.40
9.45 am - 10.00 am	416	2.42	0.44	1.42
10.00 am - 10.15 am	436	2.53	0.47	1.53
10.15 am - 10.30 am	422	2.45	0.52	1.45
10.30 am - 10.45 am	418	2.43	0.36	1.43
10.45 am - 11.00 am	427	2.48	0.38	1.48
Average	**415**	**2.41**	**0.41**	**1.41**
Evening Peak Hours				
5.00 pm - 5.15 pm	412	2.40	0.35	1.40
5.15 pm - 5.30 pm	418	2.43	0.31	1.43
5.30 pm - 5.45 pm	418	2.43	0.43	1.43
5.45 pm - 6.00 pm	416	2.42	0.56	1.42
6.00 pm - 6.15 pm	442	2.57	0.53	1.57
6.15 pm - 6.30 pm	451	2.62	0.43	1.62
6.30 pm - 6.45 pm	419	2.44	0.53	1.44
6.45 pm - 7.00 pm	427	2.48	0.55	1.48
Average	**425**	**2.47**	**0.46**	**1.47**

Table 5. Travel time indices for non-working days

Time Segment	ATT(sec)	TTI	BTI	CI
Morning Peak Hours				
10.30 am - 10.45 am	408	2.29	0.44	1.29
10.45 am - 11.00 am	418	2.35	0.45	1.35
11.00 am - 11.15 am	412	2.31	0.55	1.31
11.15 am - 11.30 am	427	2.40	0.58	1.40
11.30 am - 11.45 am	436	2.45	0.52	1.45
11.45 am - 12.00 pm	425	2.39	0.54	1.39
12.00 pm - 12.15 pm	417	2.34	0.52	1.34
12.15 pm - 12.30 pm	422	2.37	0.44	1.37
Average	**421**	**2.36**	**0.50**	**1.36**
Evening Peak Hours				
6.00 pm - 6.15 pm	417	2.34	0.54	1.34
6.15 pm - 6.30 pm	421	2.37	0.45	1.37
6.30 pm - 6.45 pm	419	2.35	0.49	1.35
6.45 pm - 7.00 pm	428	2.40	0.58	1.40
7.00 pm - 7.15 pm	446	2.51	0.59	1.51
7.15 pm - 7.30 pm	432	2.43	0.57	1.43
7.30 pm - 7.45 pm	429	2.41	0.58	1.41
7.45 pm - 8.00 pm	427	2.40	0.58	1.40
Average	**427**	**2.40**	**0.55**	**1.40**

Calculation of LOS

Increasing the capacity or supply of the road can be done to managing traffic congestion in urban areas as a short term strategy [12]. Considering the prevailing traffic and traffic growth rate, estimation of the future traffic on the road was done. The traffic volume is converted to PCU and capacity of the road is taken by the IRC: 106-1990 code book [19]. The results are shown in the Table 6. Two criteria are proposed i.e., to increase the capacity of the existing undivided 2 lane road to divided 4 lane and 6 lanes road. The result shown that, if the road is converted to 4 lane divided highway, it is estimated to serve for 7 years until year 2025. If the road is converted to 6 lane divided highway, it is estimated to serve for 15 years until year 2031.

CONCLUSIONS

The present study was conducted to understand the traffic congestion on selected road in Shivamogga city, Karnataka, as this place is one of the most traffic congested road in Shivamogga city. Vehicle registration data and traffic growth rate result indicated that, in Shivamogga usage of private vehicles is more compared to public transport which can lead to congestion on the roads of the city. Encouraging and Planning of public transportation system can be done as a long-term strategy to mitigate congestion. Evaluation of the travel time indices shown that there is a moderate congestion exists on the selected road under prevailing traffic condition. And almost 2.5 times the actual free flow time is wasted due to congestion. Solution for the congestion on the study road is proposed in terms of increasing the capacity of the road which is a easy and short term strategy. By converting the existing undivided 2 lane road to 6 lane divided road, the congestion problem can be managed for next 15 years. After this period some other long-term strategies has to be implemented such as parking management, public transport planning and management, diversion of goods vehicle outside the city etc.

Table 6. Result of LOS at different road lanes conditions

Sl. No.	Year	Volume	PCU's	Level of Service for 4-Lane Divided C/W	Level of Service for 6-Lane Divided C/W
1	2017	29251	31531	**Construction Period**	
2	2018	33136	35451		
3	2019	37557	39895	**C**	**B**
4	2020	42591	44936		
5	2021	48322	50656		
6	2022	54851	57152	**D**	
7	2023	62289	64530		**C**
8	2024	70766	72915	**E**	
9	2025	80429	82448		
10	2026	91446	93291	**F**	**D**
11	2027	104011	105629		
12	2028	118344	119673		
13	2029	134696	135664		**E**
14	2030	153355	153878		
15	2031	174653	174632		
16	2032	198965	198286		**F**

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