



## CASE REPORT

# Traffic Characteristics Evaluation and Traffic Management Measures: A Case study of Dharwad City

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**Abstract:** Traffic problems in the urban areas are increasing at a rapid rate. Engineers, planners or the policymakers are having a tough time in dealing with their multiple constraints for getting the desired solution. Some of the main transportation planning problems are mixed traffic plying on the roads, inadequate parking areas, increasing number of vehicles and road users, the unbalanced pattern of land use with obsolete road system, increasing number of road facilities and environmental pollution. Since in India most of the cities are unplanned, we are only left with an option management of existing infrastructure. In this paper, one such case study is presented in which a detailed traffic management for the city of Dharwad is carried out.

**Keywords:** Dharwad, Traffic management, Speed and delay, Spot speed, Vehicle growth, Length growth.

## 1. INTRODUCTION

The population of India which is growing at a tremendous rate coupled with the growing cities has resulted in the increased individual distance travelled for their daily commuting. Also, the lack of public transportation forced the increase in private mode for travel needs to result in an increase in privately owned vehicles. Unfortunately, the road development has not kept in pace with the increased traffic. The total road length in India is around 5.47 million kilometres (as in 2015) against 0.39 million in 1951 [1]. As per the Basic road statistics of India, the number of registered motor vehicles has grown at a CAGR of 10.6 percent between 1951 and 2011, while the growth in the road network during the same period was 4.2 percent [2]. Table 1 shows the Percentage vehicular growth versus road length growth.

**Table 1. Percentage vehicular growth versus road length growth.**

Period	Percentage Vehicular Growth	Percentage Road Length Growth
1951-1961	8.1	2.7
1961-1971	10.9	5.7
1971-1981	11.2	5
1981-1991	14.8	4.6
1991-2001	9.9	3.8
2001-2011	9.9	3.4
<b>1951-2011</b>	<b>10.6</b>	<b>4.2</b>

Source [2]: Basic road statistics in India 2008-09, 2009-10 & 2010-11 (Published by Ministry of Road Transport and highway, India)

Traffic management is the process of utilising the existing infrastructure to maximise the effectiveness of the system

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in order to ensure safe and reliable operation of traffic. Most of the Indian cities are unplanned and due to the catastrophic increase in the vehicle growth, it is very essential for transport planners to manage the traffic with the existing infrastructure with minimum cost.

The wide variety of traffic units with their great disparity in size and speed creates a number of problems viz., delay, congestion, accidents and areas of conflicts. Due to the mixing up of different classes of vehicles, the journey speed is considerably reduced and the capacity of the roads is adversely affected and severe congestion has been found to be occurring frequently in the CBD area. Constants stoppages, acceleration and deceleration and movement in low gears increase operational costs and wear and tear of vehicles. The conflicts, confusion and irritation caused by mixed traffic result in accidents.

Studies were carried out to calculate the traffic conditions in speeds at midblock, space mean speed and time mean speed and the delays for a particular stretch [3, 4]. Studies on speed and delays were used to calculate the delays and further find the relationship between speeds of different types of vehicles [5]. Volume counts at intersections and on mid-block help to evaluate the level of service at which the section of road is under operation [6].

Traffic management involves monitoring the actual traffic situation (speed and volume counts) and controlling the flow in order to ease the traffic movement without congestion and to increase the safety of the road users. Traffic management involves signals re/designing, speed studies, parking and pedestrian studies. In this paper, a detailed traffic study with existing and proposed measures is presented for the city of Dharwad.

## 2. STUDY AREA

Dharwad is situated on the edge of Western Ghats and hence is a hilly town. Spread over seven small hills at an average altitude of 750 meters above sea level, the city enjoys a 14 salubrious climate amidst thick vegetation, with coordinates of 15°27'N 75°00'E 15.45°N 75.0°E. Dharwad along with Hubli is major cities of Karnataka with a population of 943,788 as per 2011 census and it is estimated to be more than 1 million now. Hubli is situated at a distance of 20 km from Dharwad.

Indian cities are developed as a radial pattern. The city has a Central Business District (CBD) and the surrounding residential and community utilities. The major traffic problem occurs in the CBD area. The study area is selected which has a major traffic problem. So to carry out the traffic management study, we have taken the study area starting from the entrance of Dharwad city *i.e.* from Toll Naka intersection in the east to the DHO (Old DSP) office junction in the west and Shivaji circle in the north to KCD circle in the south, covering all major intersections and the CBD area. Fig. (1) shows the road network of Dharwad City, the area under the circle is considered for the study.

## 3. METHODOLOGY

The objective of this study is to obtain the traffic characteristics like spot speed, Speed and delay of the particular stretch road and the volume counts at the intersections of Dharwad city. The data is used to determine the level of service, amount of congestion and the measures that need to be taken in order to ease the situation.

### 3.1. Spot Speed Study

For the spot speed study, the spot watch method is used. This is one of the simplest methods for spot speed determination. Two reference points are marked on the pavement at a suitable distance apart and an observer starts and stops watch as a vehicle crosses these two marks. From the known distance and the measured time intervals speed are calculated. But this is the least accurate method, therefore in order to check the accuracy of the measure few samples are collected using radar meter. A classified count was conducted between 9.00AM to 12.00PM and 4.00PM to 7.00PM on working day.

The spot data is used to calculate the average speed of traffic stream and the safe speed on the stretch. The 50<sup>th</sup> percentile speed refers to the average speed and the 85<sup>th</sup> percentile speed refers to the safe speed. The frequency distribution table is the convenient method to find the percentile speed.



**Fig. (1).** Road network of Dharwad city.

### 3.2. Speed and Delay Study

To carry out the speed and delay study, the most convenient method is the Moving car method. In this method, the speed and flow can be obtained by travelling in a car against and with the flow and noting down the journey times, delays, the number of vehicles met with from the opposite direction, a number of vehicles overtaking the test vehicle and number of vehicles overtaken by the test vehicle.

1. To conduct a Travel Time and Delay Study, one must first define the study area by selecting all control points before beginning the study. The time periods recommended for studies are A.M. and P.M. peak hours as well as off-peak hours in the direction of heaviest traffic movements. An average of six round ensures the accuracy in the results [7].
2. These studies should be made during reasonably good weather so that unusual conditions do not influence the study, such as crashes or other unusual delays will produce erroneous results, any runs made during such an occurrence should be terminated and another run conducted. These studies should be conducted during average or typical weekday traffic conditions.

Keeping in view of the above things, the study was conducted in morning peak from 9.00am to 11.00am, evening peak from 5.00pm to 7.00pm and off-peak from 1.00pm to 3.00 pm. The collected will be used to know the running speed and the journey speed of the different corridors. The details of the data and the analysis are given in the next section.

### 3.3. Traffic Volume Counts for the Design of Road Junctions

For the requirement of road design, it is necessary to know the directional movement of traffic in peak hour. The survey is conducted using stationary enumerators at each arm of the junction to note down the vehicles entering and direction of the exit. Mechanical counters are used to note down the different categories of vehicles. It is sufficient to note down two hours of morning and evening peak [7]. But in order to get the exact peak hour, we took 4 hours in the

morning from 8.00am to 12.00pm and evening 4.00pm to 8.00pm to analyze the existing turning movement pattern and to plan the required improvements at the junctions.

The main objective of traffic volume counts is to evaluate the Level Of Service (LOS) at the intersection and at midblock. LOS represents the ease at which the traffic is moving at that particular point. In order to evaluate the LOS, the following data was collected; design hour turning movement volume, vehicle classification for design hour, peak hour factor, prevailing speed, number of lanes on major and minor streets, type of control on minor streets and other geometries of the intersections.

#### 4. DATA AND ANALYSIS

Dharwad city traffic has heterogeneous traffic with a mixture of fast-moving motor traffic and slow moving traffic. Even extremely slow traffic such as animal-drawn vehicles can be seen on the roads of Dharwad. Motor traffic consists mainly of a two-wheeler, cars and commercial vehicles. Pedestrian traffic is found to be very heavy in the CBD areas of the city. Fig. (2) shows the traffic composition of Dharwad.

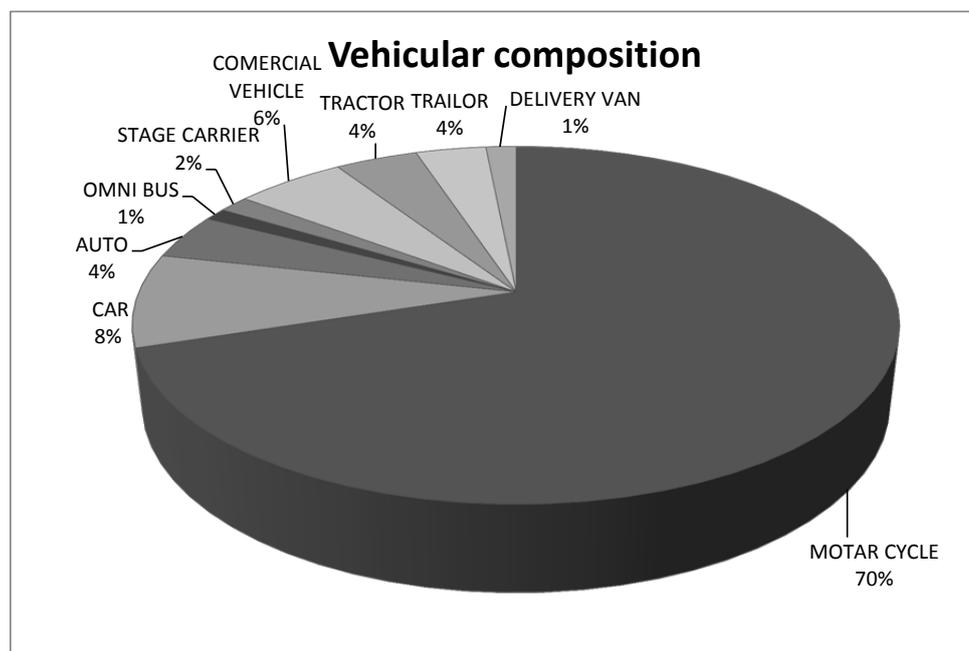


Fig. (2). Traffic composition.

##### 4.1. Spot Speed Study

Three roads were selected to carry out the speed studies, Old PB road, Dandeli road and Saudathi road. These three road pass through the centre of the city and intersect at the Jubilee Circle. Seven locations selected on these three roads are as below along with average spot speeds. L1 and L2 are on Old PB road, L2 and L4 are on Dandeli road, L5, L6 and L7 are on Saudathi road.

- L1- Between Jubilee Circle and DHO Circle
- L2- Between Jubilee Circle and Court Circle
- L3- Dandeli road near KCD
- L4- Dandeli road near Jubilee Circle
- L5- In front of Corporation office
- L6- In front of Azad Park
- L7- Between Corporation Circle And CBT circle

Table 2. Spot speeds on selected roads.

Vehicle type	SPEEDS IN kmph						
	L1	L2	L3	L4	L5	L6	L7
Two wheeler	34	31	34	36	29	26	28
Auto	28	27	27	31	24	24	23
Car	33	30	36	35	26	24	26
Bus	30	29	31	31	24	22	24
Truck	29	27	-	-	-	-	-

The average speed of vehicles on Old PB road towards Belgaum is found to be 31 kmph, towards Bangalore, it is found to be 29 kmph. The speed average speed measured on Dandeli road is 32 kmph, and on Saudathi, road is around 25 kmph. On all the roads, it is observed that speeds of two-wheeler and cars are high, in the range of 30-40kmph. Whereas auto, buses and truck speed is in the range of 25-30 kmph.

The speed of more than 500 vehicles in each direction was found and the tally sheet for the same is given in Tables 3 and 4 represents the frequency distribution table for the three routes are calculated separately to calculate the 15<sup>th</sup>, 50<sup>th</sup>, 85<sup>th</sup> and 90<sup>th</sup> percentile speed.

Table 3. Vehicle tally sheet.

Speed in kmph	Two-Wheeler			Auto			Car			Bus			Truck		
	Old PB Road	Dandeli Road	Saudathi Road	Old PB Road	Dandeli Road	Saudathi Road	Old PB Road	Dandeli Road	Saudathi Road	Old PB Road	Dandeli Road	Saudathi Road	Old PB Road	Dandeli Road	Saudathi Road
10--19.9	2	5	9	2	20	22	1	2	14	0	3	29	4	0	0
20--29.9	56	34	82	87	67	88	54	32	83	67	65	83	49	0	0
30--39.9	80	81	28	29	62	7	57	86	22	51	81	8	27	0	0
40--49.9	20	34	1	0	10	0	7	33	1	2	10	0	0	0	0
50--59.9	2	2	0	0	1	0	1	3	0	0	1	0	0	0	0
60--69.9	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0

Table 4. Frequency Distribution table of Spot speed data.

Speed Class (kmph)	Median	Class Frequency (f <sub>i</sub> )	f <sub>wi</sub> = i*f <sub>i</sub>	Percentage of Observation in Class	Cumulative Percentage Observation	-
<b>For Route 1 (Old PB Road)</b>						
15-19.9	17.5	10	175.0	1.67	1.67	-
20-24.9	22.5	80	1800.0	13.33	15.00	} 50 <sup>th</sup> percentile
25-29.9	27.5	234	6435.0	39.00	54.00	
30-34.9	32.5	188	6110.0	31.33	85.33	-
35-39.9	37.5	56	2100.0	9.33	94.67	-
40-44.9	42.5	19	807.5	3.17	97.83	-
45-49.9	47.5	10	475.0	1.67	99.50	-
50-54.9	52.5	2	105.0	0.33	99.83	-
55-59.9	57.5	1	57.5	0.17	100.00	-
Total		600.000				-
<b>For Route 2 (Dandeli Road)</b>						
10-14.9	12.5	1	12.5	0.156	0.156	-
15-19.9	17.5	29	507.5	4.531	4.688	-
20-24.9	22.5	68	1530.0	10.625	15.313	} 50 <sup>th</sup> percentile
25-29.9	27.5	134	3685.0	20.938	36.250	
30-34.9	32.5	177	5752.5	27.656	63.906	

(Table 4) contd....

Speed Class (kmph)	Median	Class Frequency (f <sub>i</sub> )	f <sub>wi</sub> = i*f <sub>i</sub>	Percentage of Observation in Class	Cumulative Percentage Observation	-
35-39.9	37.5	133	4987.5	20.781	84.688	-
40-44.9	42.5	56	2380.0	8.750	93.438	-
45-49.9	47.5	31	1472.5	4.844	98.281	-
50-54.9	52.5	4	210.0	0.625	98.906	-
55-59.9	57.5	3	172.5	0.469	99.375	-
60-64.9	62.5	3	187.5	0.469	99.844	-
65-69.9	67.5	1	67.5	0.156	100.000	-
Total		640.000				-
<b>For Route 3 (Saudathi Road)</b>						
10-14.9	12.5	10	125.0	2.083	2.083	-
15-19.9	17.5	67	1172.5	13.958	16.042	-
20-24.9	22.5	170	3825.0	35.417	51.458	-
25-29.9	27.5	166	4565.0	34.583	86.042	-
30-34.9	32.5	51	1657.5	10.625	96.667	-
35-39.9	37.5	14	525.0	2.917	99.583	-
40-44.9	42.5	1	42.5	0.208	99.792	} 50 <sup>th</sup> percentile } 85 <sup>th</sup> percentile
45-49.9	47.5	2	47.5	0.208	100.000	-
Total		480				-

As it can be observed from Table 4 the exact 15<sup>th</sup>, 50<sup>th</sup>, 85<sup>th</sup> and 95<sup>th</sup> percentile speed is not found. Therefore the following method is used to calculate the exact speeds.

$$S_D = \frac{P_D - P_{min}}{P_{max} - P_{min}} (S_{max} - S_{min}) + S_{min}$$

Where:

S<sub>D</sub>= Speed at P<sub>D</sub>, P<sub>D</sub>= percentile desired, P<sub>max</sub> = higher cumulative percent, P<sub>min</sub> = lower cumulative percent, S<sub>max</sub> = higher speed and S<sub>min</sub> = higher speed

Therefore, the exact 15<sup>th</sup>, 50<sup>th</sup>, 85<sup>th</sup> and 95<sup>th</sup> percentile speed for the three routes are as follows,

For Route 1:

$$S_{15} = = 22.5 \text{ kmph}$$

$$S_{50} = \frac{50-15}{54-15} (27.5-22.5) + 22.5 = 26.98 \text{ kmph}$$

$$S_{85} = \frac{85-54}{85.33-54} (32.5-27.5) + 27.5 = 32.44 \text{ kmph}$$

$$S_{95} = \frac{95-94.67}{97.83-94.67} (42.5-37.5) + 37.5 = 38.02 \text{ kmph}$$

For Route 2:

$$S_{15} = \frac{15 - 4.68}{15.313 - 4.68} (22.5 - 17.5) + 17.5 = 22.35 \text{ kmph}$$

$$S_{50} = \frac{50 - 36.25}{63.91 - 36.25} (32.5 - 27.5) + 27.5 = 29.98 \text{ kmph}$$

$$S_{85} = \frac{85 - 84.69}{93.44 - 84.69} (42.5 - 37.5) + 37.5 = 37.67 \text{ kmph}$$

$$S_{95} = \frac{95 - 93.438}{98.281 - 93.438} (47.5 - 42.5) + 42.5 = 44.11 \text{ kmph}$$

For Route 3:

$$S_{15} = \frac{15 - 2.083}{16.042 - 2.083} (17.5 - 12.5) + 12.5 = 17.12 \text{ kmph}$$

$$S_{50} = \frac{50 - 16.04}{51.49 - 16.04} (22.5 - 17.5) + 17.5 = 22.28 \text{ kmph}$$

$$S_{85} = \frac{85 - 51.49}{86.04 - 51.49} (27.5 - 22.5) + 22.5 = 27.35 \text{ kmph}$$

$$S_{95} = \frac{95 - 86.042}{96.667 - 86.042} (32.5 - 27.5) + 27.5 = 31.71 \text{ kmph}$$

15<sup>th</sup> percentile speed is the lower speed limit at which the vehicle can move, 50<sup>th</sup> percentile speed is the average speed of the traffic stream, 85<sup>th</sup> percentile speed is the safe speed and 95<sup>th</sup> percentile speed is the design speed for the road section.

The average speed for the first route is around 27 kmph and the safe speed found to be 32.44 kmph. For the second route, the average speed is 30 kmph and the design speed is 37.67 kmph. The first route is the old PB road which has a relatively higher volume compared to Dandeli road in route 2 as seen from the results.

Similarly, the third route passes through the CBD, and the average speed and the safe speed will be much lower than the other two roads *i.e.* 22.28 kmph and 27.35 kmph, respectively.

#### 4.2. Speed And Delay Study

Journey time studies on a road network in a town are used to evaluate congestion, capacity, level of service and need for improvements. The study was conducted using a moving car technique. Three routes were selected which include all major roads connected to the city *i.e.* Old PB road, Dandeli road and Saudathi road. The study also covers the CBD area of the city. Route 1 starts from Toll Naka to Shivaji Circle via DHO circle, Route 2 starts from KCD circle to Shivaji circle via Kalabhavan circle and Route 3 covers the market area, *i.e.* from Lakshmi theatre to NTT via Hanuman temple and Gandhi Chowk. The three routes are shown in Figure 3. The survey data has been analysed to obtain.

- Journey time and journey speed
- Duration, location and cause for delay.
- Running time and running speed.

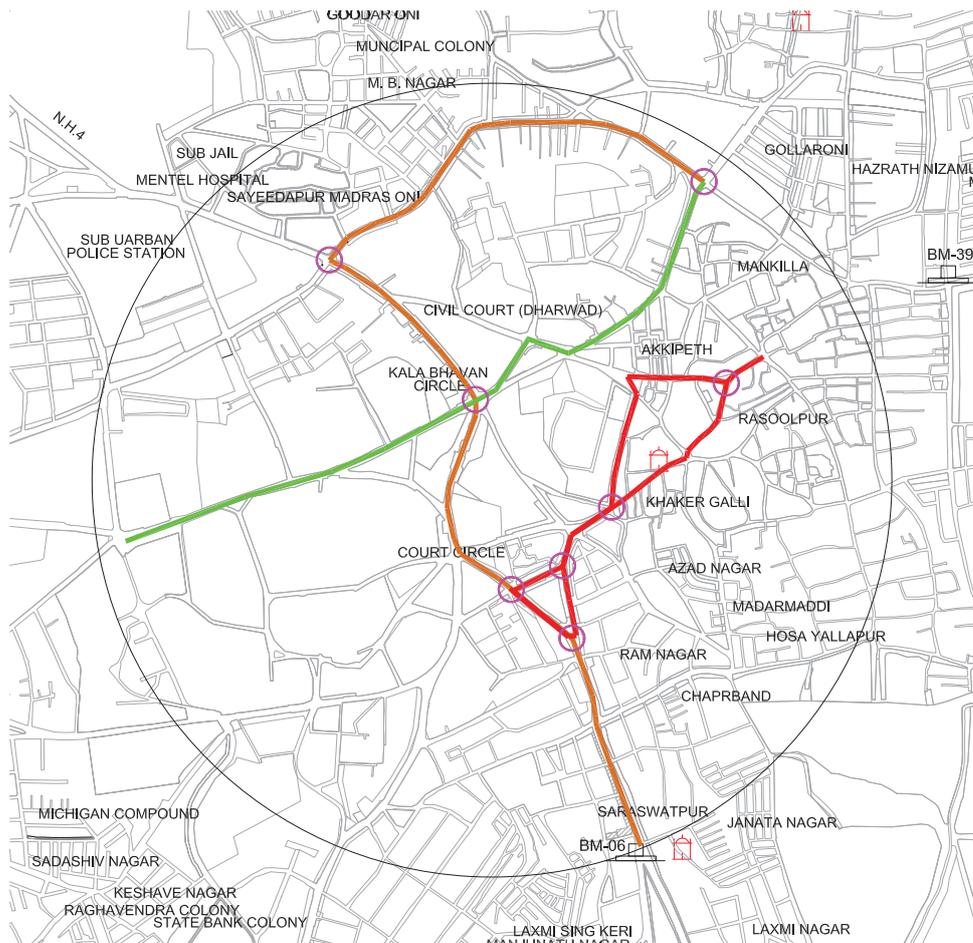


Fig. (3). Routes selected for speed and delay study.

The results of the study are given in Table 5. The study reveals that the on the major corridor, the delay was at junctions and due to bus stops, and on CBD area, the delay was due to congestion, pedestrian movements and bus stand. The maximum running speed of 31 kmph is observed between Jubilee circle and DHO junction and the minimum of 11 kmph between Gandhi Chowk and CBT circle. On the main road, the average overall journey speed is around 21 kmph, and on CBD area, the speed is around 15 kmph, which means that these two corridors are approaching unstable flow, with tolerable delay *i.e.* the level of service is D.

Table 5. Summary of Speed and Delay study Results.

NAME OF THE SECTION	AVERAGE JOURNEY SPEED (km/h)						AVERAGE RUNNING SPEED (km/h)						REASONS FOR DELAYS
	Off-peak		Morning Peak		Evening Peak		Off-peak		Morning Peak		Evening Peak		
	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	
<b>ROUTE NO:1</b>													
Toll naka-Lakshmi theatre	24	23	22	19	19	18	26	26	24	21	22	20	Intersection
Lakshmi treatre-Jubilee circle	20	18	20	21	19	17	23	21	20	22	21	20	Intersection
Jubilee circle-DHO office	26	25	19	21	29	28	30	30	20	25	31	29	Intersection
DHO office- Shivaji circle	17	14	15	16	18	15	17	17	15	16	18	18	Intesection & congestion
<b>ROUTE NO:2</b>													
KCD circle-Jubilee circle	24	23	22	21	24	23	24	22	22	21	23	22	
Jubilee circle-Regal Theatre	18	17	18	18	16	15	15	15	16	16	13	13	Intesection & congestion
Regal theatre-Shivaji circle	13	16	18	15	15	17	14	17	18	15	15	17	congestion

(Table 5) contd....

NAME OF THE SECTION	AVERAGE JOURNEY SPEED (km/h)						AVERAGE RUNNING SPEED (km/h)						REASONS FOR DELAYS
	Off-peak		Morning Peak		Evening Peak		Off-peak		Morning Peak		Evening Peak		
	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	UP	DOWN	
<b>ROUTE NO:3</b>													
Lakshmi theatre- Bosappa circle	21	21	18	17	15	16	21	21	18	19	16	16	
Bosappa circle-Gandhi Circle	18	24	17	15	13	14	19	24	17	15	13	17	congestion
Gandhi circle-CBT Circle	11	19	11	13	11	10	12	20	15	14	11	11	congestion
CBT Circle- Hanuman Temple	16	14	10	13	13	15	16	14	14	15	14	15	
Hanuman Temple-NTTF	21	21	18	18	18	19	23	21	19	18	18	19	congestion
NTTF-Lakshmi theatre	23	21	21	20	18	22	23	21	21	21	19	22	

The following are the main reasons for greater travel time:

1. On main roads, the delays are due to the intersections.
2. Pedestrians using the carriageway for movement since there are no proper footpaths.
3. Unscientific location of bus stops causing the blockage of narrow carriageways.
4. Presence of crossroads connecting mainstream causing congestion.
5. In the CBD area, the CBT bus stand and old bus stand causes long delays.

#### 4.3. Volume Counts

Classified traffic volume counts are carried out to know traffic characteristics, directional split and hourly variation. A traffic volume count indirectly indicates the capacity utilization. If the traffic is heavy, the road suffers from congestion with consequent loss in journey speeds. Lower speed cause economic loss to the community due to time lost by the occupants of volume counts are, therefore, indicators of the need to improve the transport facilities and is an invaluable tool in the hands of transport planner. A classified count was conducted from 8.00AM to 12.00PM and 4.PM to 8.00PM on working day.

Urban roads are characterized by mixed traffic conditions resulting in complex interaction between various kinds of vehicles. To cater to this, it is usual to express the capacity of urban roads in terms of a common unit. The unit generally employed is the Passenger Car Unit (PCU). PCU values are adopted for different classes of vehicles depending open the percentage of vehicle category as per IRC 106-1990 [8].

Eleven major intersections were selected for the study. The intersections were chosen based on the study area. These intersections lie on the three roads that pass through the city. The peak hour tuning movement for one of the major junction is given in Fig. (4A and B). The consolidated peak hour volume for all the intersections was obtained and is presented in (Table 6).

**Table 6. Consolidated Peak hour traffic for all the intersection.**

Name of the Intersection	Morning		Evening	
	Peak Hour	volume	Peak Hour	Volume
Toll Naka	10.15-11.15	3163	17.30-18.30	2966
Bagalkot petrol pump	10.45-11.45	3307	18.15-19.15	3959
NTTF	10.45-11.45	3460	18.45-19.45	3929
Lakshmi theatre	10.15-11.15	3402	18.45-19.45	3668
Court circle	10.45-11.45	3845	18.45-19.45	4152
Jubilee circle/ Kalabhavan circle	11.00-12.00	5045	19.00-20.00	5139
DHO circle	10.45-11.45	3026	17.45-18.45	2876
CBT circle	10.30-11.30	4443	18.30-19.30	4275
Shivaji circle	10.15-11.15	1922	18.00-19.00	1904
KCD circle	10.30-11.30	1800	17.30-18.30	1974
Shiva sagar hotel	11.00-12.00	1968	19.00-20.00	3218

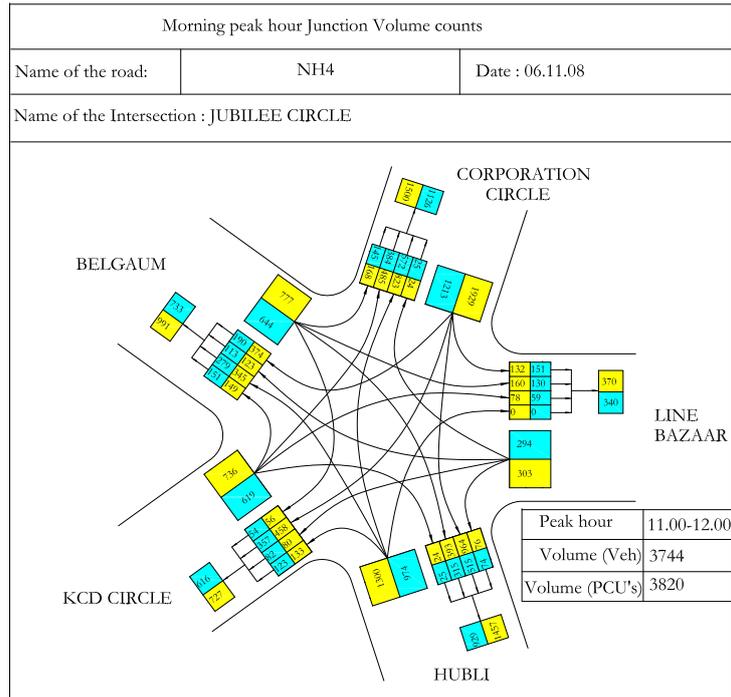


Fig. (4A). Morning peak turning movement at Jubilee circle.

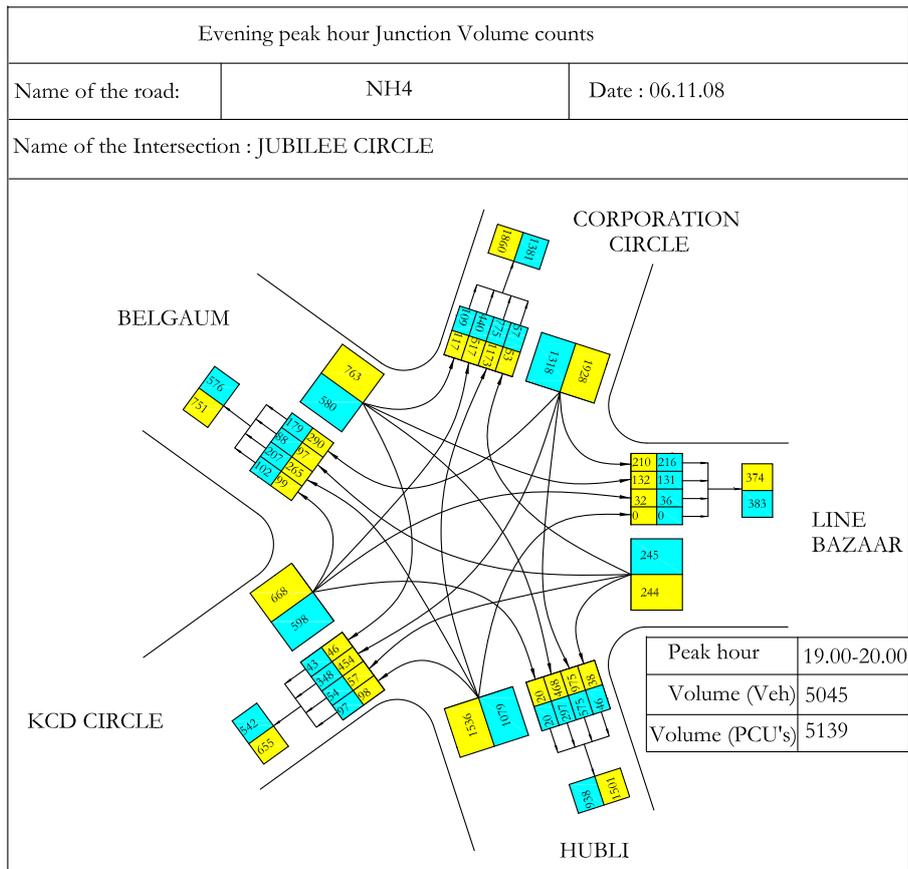


Fig. (4B). Evening peak turning movement at Jubilee circle.

### 4.3.1. Level of Service

The main objective of traffic volume counts is to calculate the level of service for that intersection. Level of service is defined as a qualitative measure describing operational conditions within a traffic stream and their perception by drivers/passengers. Level of service definition generally describes these conditions in terms of factors such as speed and travel time, freedom of maneuver, traffic interruption, comfort, convenience and safety. The level of service of an intersection is determined using IRC SP-41 [9]. The data was obtained in 2008, keeping the design period as 10 years, the volume count was extrapolated with a growth rate of 9% which is obtained by the local road transport authority.

Similarly, the LOS for the midblock is calculated for different legs of the intersection. For the intersections, the LOS is based on the reserve capacity and it shows the expected delay to minor street traffic, whereas for the mid-block, LOS is based on the volume to capacity (V/C) ratio. *i.e.* the LOS for the minor roads at intersections may be F, which means Stop and Proceed, which is true whereas the LOS based on V/C ratio for the same leg at mid-block is comparatively good which shows that the volume is less than the capacity.

The analysis is carried out to evaluate the LOS for all the intersections both at midblock and at the intersection. The analysis is done for present and the design period and is given in (Table 7).

**Table 7. Level of Service for base and design period.**

S NO.	NAME OF THE INTERSECTION	NAME OF THE LEG	2008		2018	
			At Intersection	At midblock	At Intersection	At midblock
1	TOLL NAKA	Dharwad	E	F	F	F
		Hubli	E	F	F	F
		Bypass	F	B	F	F
2	BAGALKOT PETROL PUMP JUNCTION	Dharwad	D	F	E	F
		Hubli	B	F	E	F
		Malmaddi	F	B	F	F
		Hosayellapur	F	A	F	A
3	NTTF JUNCTION	Jubilee circle	E	F	F	F
		Hubli	E	F	F	F
		Line bazaar	F	E	F	F
4	LAKSHMI THEATRE JUNCTION	Jubilee circle	C	F	D	F
		Hubli	A	F	A	F
		Taluk office	F	B	F	F
		Line bazaar	F	A	F	E
5	COURT JUNCTION	Jubilee circle	A	F	D	F
		Hubli	D	F	F	F
		Railway Station	F	A	F	B
		Line bazaar	E	A	E	A
		DC Compound	A	A	A	A
6	KALABHAVAN (JUBILEE) JUNCTION	Belgaum road	A	C	F	F
		Hubli road	A	F	B	F
		KCD	F	A	F	B
		Line bazaar	F	A	F	C
		CBT Circle	F	B	F	F
7	DHO (OLD DSP) OFFICE JUNCTION	Belgaum	C	D	F	F
		Hubli	D	F	F	F
		KCD	E	D	F	F
		Shivaji circle	F	C	F	F
8	CBT CIRCLE	Jubilee circle	A	D	B	F
		Corporation office	F	D	F	F
		Shivaji circle	A	F	A	F
		Vivekananda circle	F	F	F	F

(Table 7) contd.....

S NO.	NAME OF THE INTERSECTION	NAME OF THE LEG	2008		2018	
			At Intersection	At midblock	At Intersection	At midblock
9	KCD CIRCLE	Jubilee circle	B	A	C	D
		KCD	A	A	B	A
		AIR	A	A	B	C
		Dasankoppa	A	B	B	F
		KUD	A	A	B	F
10	SHIVAJI CIRCLE	DHO Office	F	A	F	D
		Regal theatre	A	D	A	F
		Soudhatti	A	B	C	F
		Navalgunda	C	A	F	A
11	SHIVA SAGAR JUNCTION	Tikare road	C	F	F	F
		Subhas road	E	F	F	F
		Jakkanbhavi	F	F	F	F
		Bus stand	F	F	F	F

In order to have free movement of the vehicle, the maximum allowable LOS is C, anything above this will result in the decreased capacity. From Table 7, it can be noted that for the design period, one intersection (KCD) has the LOS B and C for all the legs. Therefore, in order to have desired LOS, some of the traffic management measures were proposed as per IRC SP: 43-1994 [10].

4.3.2. Junction Improvements

Intersections are to be redesigned to cater to the present day and future traffic and pedestrian volume. Channelising island has to be included to reduce the area of possible conflicts between traffic streams. Establish the desired angle of crossing and merging and serve as pedestrian refuges. The intersections are to be designed considering appropriate turning radius, adequate lanes, appropriate road markings and signboards.

The geometric of all eleven intersections were redesigned by providing necessary elements such as proper median, channelising islands, turning radius, etc, as per IRC SP:41-1994 [9]. Along with this, some of the major roads are proposed for widening from existing two lanes to four lanes. Figs. (5A and B) show the geometries of the junction (DHO) before and after the proposed improvements. As a result, the Shivaji, KCD, CBT and Lakshmi Theater junctions have reached the required LOS. Further, in order to bring all the intersection to the desired LOS, some of the restrictions are proposed.

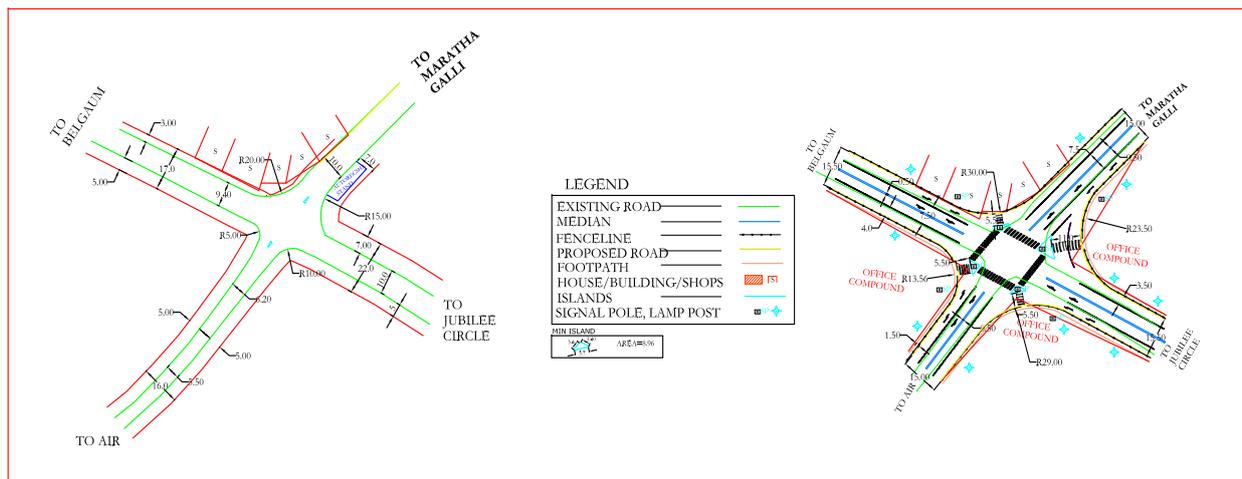


Fig. (5a). Existing DHO Junction Fig. (5b): Redesigned DHO Junction.

4.3.3. Traffic Management Techniques

Restriction of long route buses from entering old bus stand

There is a bus stand at the centre of CBD area in the city of Dharwad. Buses including Hubli-Dharwad intercity

services, Mofussil services and also intracity services of Dharwad visit this bus stand. As a result, the entire CBT area will be jam packed by the buses itself. The first proposal is to shift the bus stand completely to the newly constructed bus stand which is away from the CBD area. HDMC should take action in restriction of long route buses to enter into the old bus stand. The following are the advantages of shifting the bus stand:

1. Reduce congestion in the CBD area.
2. Creates extra space for the local buses.
3. The CBT bus stand which is vacant can be used for a parking lot.

Restriction on TRUCKS entering the city from 9.00am to 9.00pm

The second proposal is to put a restriction on trucks and heavy vehicles on entering into the city from 9.00am to 9.00pm. Majority of cities have already implemented restrictions. HDMC should take action in restriction of trucks and heavy vehicles in to enter into the city. The following are the advantages of the restrictions.

1. Reduce congestion in the CBD area.
2. It prevents curbside loading and offloading.
3. It improves the capacity of roads.
4. It improves the speeds.

Restriction on traffic entering from crossroads.

There are many crossroads along the old PB road intersect the main traffic flow. Traffic regulation by allowing the cross flow at a particular point will increase the capacity of the main road.

With these modifications, the final LOS obtained for the different intersections was obtained and given in Table 8. The result shows that except Shiva Sagar junction, all other intersections have reached the required LOS. The lesser LOS in Table 8 is the roads with minor traffic flow and which means Stop and Proceed for those movements as explained earlier.

**Table 8. Level of Service after the final proposal.**

S NO.	NAME OF THE INTERSECTION	NAME OF THE LEG	LOS
1	TOLL NAKA	Dharwad	D
		Hubli	D
		Bypass	F
2	BAGALKOT PETROL PUMP JUNCTION	Dharwad	C
		Hosayellapur	F
		Hubli	D
		Malmaddi	F
3	NTTF JUNCTION	Jubilee circle	A
		Hubli	A
		Line bazaar	E
4	LAKSHMI THEATRE JUNCTION	Jubilee circle	D
		Hubli	A
		Taluk office	F
		Line bazaar	F
5	COURT JUNCTION	Railway Station	E
		Line bazaar	A
		Hubli	D
		DC Compound	A
		CBT Circle	D
6	KALABHAVAN (JUBILEE) JUNCTION	KCD	C
		Line bazaar	A
		Hubli	D
		Belgaum	C
		CBT Circle	D

(Table 8) contd.....

S NO.	NAME OF THE INTERSECTION	NAME OF THE LEG	LOS
7	DHO (OLD DSP) OFFICE JUNCTION	Belgaum	B
		Hubli	D
		Shivaji circle	F
		KCD	B
8	CBT CIRCLE	Jubilee circle	C
		Corporation office	F
		Shivaji circle	A
		Vivekananda circle	F
9	KCD CIRCLE	Jubilee circle	C
		KUD	A
		AIR	A
		Dasankoppa	F
		KCD College	A
10	SHIVAJI CIRCLE	DHO Office	F
		Regal theatre	A
		Soudhatti	C
		Navalgunda	F
11	SHIVA SAGAR JUNCTION	Tikare road	F
		Subhas road	F
		Jakkanbhavi	F
		Bus stand	F

## CONCLUSION

Traffic management measures normally involve traffic engineering improvements, regulation and control of the movement of a different category of vehicles on the road system to ensure safe and efficient movement of traffic. The problem of delay, congestion and accidents can be decreased to some extent by controlling the traffic, imposing regulatory measures and enforcing proper management of road space so as to make the most economical use of the roads. Due to the movement of a heavy volume of traffic, many of the narrow roads get choked thereby needing the enforcement of traffic management measures such as one-way streets, restriction on commercial vehicles within the city, restriction on turning movements and closing side streets. Heavy commercial vehicles occupy considerable road space and cause serious impediments to traffic. Closing the busy roads for commercial vehicles will preserve the utility of the roads, improve the speed, safety and comfort of other road user. Traffic management measures proposed are based on the findings of the study carried out in Dharwad city.

## CONSENT FOR PUBLICATION

Not applicable.

## CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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