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IMPACT OF ROAD SIDE BUS STOPS ON CAPACITY OF ROADWAY

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ABSTRACT

The total number of vehicles travelling on Shimoga city has rapidly increased now a days resulting in an increase in traffic congestion and a decrease in the operational integrity of the transportation system. Urban transport is a nightmare in India though most urban residents take it as a fait accompli. Indian cities, of all sizes, face a crisis of urban transport. Despite investments in road infrastructure, and plans for land use and transport development, all cities face the ever increasing problems of congestion, traffic accidents, air, and noise pollution. Traffic congestion at bus stops in Shimoga city is on rise with increasing private automobiles on the roadways competing with public transports for the limited roadway spaces. The efficiency of public transportation buses are declining considerably. Commuters have to waste a lot of time at bus stops and also in the bus in order to get their destination. The purpose of this project is to determine the roadway capacity loss at bus stops due to limited road width.

Field data were collected for urban roads of Shimoga city. The roadway was divided into two sections (A - Before bus stops, B - At bus stops). Based on bus arriving frequency bus stop capacity has been defined. Results & analysis showed significant loss in roadway capacity for on-street bus stops.

Key Words: Bus Stop, Capacity, Congestion, and Speed.

I. INTRODUCTION

1.1General

Transportation infrastructure is one of the back bones of any country. For sustainable development, an economy has to ensure proper supply of transportation facilities. One of such facility is the public transportation system of the city. More efficient use of urban spaces, and space allocated to transport in particular can improve operational conditions for public transport. To give priority to buses in congested cities proves to be a very effective strategy. In its simplest form, a bus lane can be implemented only on a short stretch of road, as a through route - or bypass - for a congested zone.Bus stops have a significant influence on the capacity of curb lanes because they interfere with passing vehicles primarily while buses maneuver to pull into and out of the bus stops.[1] .Roadway capacity is defined as the maximum hourly rate at which vehicles can reasonably be expected to traverse a point or uniform section of a carriageway lane per time period under prevailing roadway, traffic and ambient conditions. In this project, primary concern is bus stop locations on the urban roads and the consequences for traffic stream properties. On - street bus stops is the location selected for the study. A bus stop is a designated place where buses stop for passengers to board or alight the bus. The number and type of bus stops provided on a road significantly influence the flow characteristics of traffic on the road. So it can be

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postulated that any change to the prevailing location of a bus stop could trigger a change in the capacity of the road section. Bus stops primarily conflict with other passing vehicles when buses maneuver to pull into and out of the stop. Roadway capacity is a quantitative assessment of traffic stream properties. It is based on relationship between flow, speed and density [2]. A bus stop is a designated place where buses stop for passengers to board or alight. Bus stops are normally positioned on the highway and the bays are either located on or off the road carriageway lane to reflect the level of usage.

When bus stops located on the carriageway, buses blocking the curbside traffic lane during their occupancy period or dwell period due to reduced width of the roadway or due to erratic behavior of driver. This bus stop also creates problems when attempting to re-enter the traffic, especially during the peak-hour period of high roadway traffic volumes.

1.2 Objectives and Scope of the Study

In this project, the primary concern is bus stop locations on the highways and the consequences for traffic stream properties. The location of bus stops along a road carriageway lane is the main condition in this study. A bus stop is a designated place where buses stop for passengers to board or leave a bus. The number and type of bus stops provided on a road significantly influence the flow characteristics of traffic on the road. So, it can be postulated that any change to the prevailing location of a bus stop could trigger a change in the capacity of the highway.

The main objectives of the proposed study are summarized as follows:

- To determine roadway capacity as per IRC-106-1990.
- To determine capacity loss at bus stops as per HCM - 2000.
- To determine spot speed measurement at both sections i.e., before bus stop & at bus stop.
- To provide free flow movements at bus stops by providing separate bus bays.

1.3 Need for the Study

The road traffic on Indian cities is highly heterogeneous comprising vehicles of wide rangingstatic and dynamic characteristics. Under the heterogeneous traffic flow conditions, the buses, being relatively larger vehicles, find it difficult to maneuver through the mixed traffic and are subjected to frequent acceleration and deceleration leading to lower speed and discomfort to both the driver and passengers. This also results in enormous delay and uncertainty of travel time to bus passengers. The level of service of bus transit systems in Indian cities is gradually declining due to inadequate capacity and managerial and financial problems, making bus, a less attractive mode of transport. In the absence of an adequate and efficient bus transit system, the potential bus users shift to personal vehicles. This requires an increase, both in quantity as well as quality of bus transport service and effective application of demand as well as supply-side management measures. This goal can be attained by encouraging bus transport by assigning priority to it. One of the common bus preferential treatments is provision of bus bay on major urban roads, to facilitate faster movement of buses, which will make the mode more attractive.

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II. STUDY METHODOLOGY, DATA COLLECTION AND ANALYSIS

2.1 Introduction

Collection and analysis of data play a pivotal role in the development of successful results. Field data should be gathered covering the ranges of anticipated roadway and traffic flow conditions. The required traffic data were collected by observing traffic flow near the bus stop. The collected data were used for the analysis of capacity, level of service as per IRC. At each bus stop parameters such as dwell time, clearance time, dwell time variability and failure rate were collected. These parameters were used to calculate the capacity of each bus bay stop.

2.2 Methodology

A methodology based on technically sound information will have to be formulated before collecting the data and its analysis. The various stages are presented below.

Stage 1 Reconnaissance survey

Stage 2 Road inventory survey

Stage 3 Traffic survey and data collection

Stage 4 Spot speed Survey

Stage 5 Analysis

Stage 1: Reconnaissance survey

- To plan the study methodology, data collection.
- Carry out reconnaissance survey for bus stop selection.

Stage 2: Road inventory survey

Before carrying out any improvement measure like bus bay facility, there is a need to obtain road width, surrounding features, obstructions if any in the alignment and other important information which helps in planning and design.

Stage 3: Traffic survey and data collection

Classified Traffic Volume Count has been done manually to carry out analysis part. The Roadway section was divided into two sections, (Before Bus Stops &At Bus Stops).traffic count was done simultaneously at both section. In addition, bus arrival frequency was also studied at the same bus stops and same time. This was done by counting the buses that arrived within 15 min period. Subsequently, the maximum flow rate was then determined by considering the highest number of buses which arrived in any 15 min duration converted into equivalent hourly rate.

Stage 4: Spot speed Survey

Spot speed study carried at both sections and compared. Speed at the bus stops reduces due to presence of bus stop on the street lane. When the buses stops on the on-street bus stops in order to board or alight the passengers, following vehicles are forced to slow down their speed due to decreased lane width. By this speed reduces as well as number of vehicles passing also reduces & hence capacity reduces significantly.

Stage 5 Analysis of data

1. Calculation of PCU values of different classes of vehicle and defining LOS.
2. Defining LOS base on Speed data.
3. Determining Bus Stop Capacity.

2.3 Selection of Study Area

The study area selected for the analysis is Shimoga city. Shimoga is a developing city with wide spread of commercial, industrial, government, private and other activities and having a good road network around the city with well-conditioned roads. Frequently people using city buses instead of auto rickshaws for their daily purpose. In order to study the effect of these city buses on traffic we selected Shimoga as a place of interest. In this project we can study the influence of bus stop on traffic flow and by suitable measures we can ensure a smooth flow of traffic.

Following five bus stops were selected for the traffic study,

1. Court Circle Bus stop
2. Gandhi Park Bus stop
3. Kamala Nursing Home Bus stop
4. Milaghatta Bus stop
5. Sandal Colony Bus stop.

Fig.(1) Location of Bus Stops.

2.4 Data Collection

Data from study area were collected during the period of February and March 2013. Five major bus stops are selected in Shimoga city for the analysis. The following data have been collected.

1. Traffic volume survey.(Before bus stop, At bus stop)
2. Speed data. (Before bus stop, At bus stop)
3. Bus arrival frequency. (Dwell time, Clearance time).

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On urban roads, the Level of Service is affected strongly by factors like the heterogeneity of traffic, speed regulations, frequency of intersections, and presence of bus stops, on-street parking, road side commercial activities and pedestrian volume.

III, CALCULATIONS AND RESULTS

3.1 LOS based on Traffic Volume Count.

Traffic count was converted into equivalent PCU values as per IRC code and the capacity was tabulated for each bus stops. Capacity loss is shown in below tables. Level of Service is based on traffic count as per IRC 106: 1990.

3.1.1 Court Circle Bus Stop

Basic capacity - 2900

Lane width - 6.3 m.

Table 3.8 - Level of service based on traffic count

Description	Day	Before Bus Stop		At Bus Stop			Capacity Loss (%)
		V (PCU/hr)	V/C	V (PCU/hr)	V/C	L O S	
Sub – arterial road with frontage access with side roads, bus stops but no standing vehicles, and high capacity intersections.	1	916	0.32	1132	0.39	B	19.08
	2	903	0.31	1124	0.39	B	19.66
	3	928	0.32	1122	0.39	B	17.29
	4	925	0.32	1150	0.40	B	19.57
	5	949	0.33	1186	0.41	B	19.98
	6	934	0.32	1185	0.41	B	21.18

3.1.2 Gandhi Park Bus Stop

Basic capacity - 2900

Lane width - 6.3 m.

Description	Day	Before Bus Stop		At Bus Stop			Capacity Loss (%)
		V (PCU/hr)	V/C	V (PCU/hr)	V/C	L O S	
Sub – arterial road with frontage access with side roads, bus stops but no standing vehicles, and high capacity intersections.	1	1041	0.36	1303	0.45	B	20.11
	2	1008	0.35	1209	0.42	B	16.63
	3	1001	0.35	1290	0.44	B	22.40
	4	1023	0.35	1307	0.45	B	21.73
	5	992	0.34	1284	0.44	B	22.74
	6	1003	0.35	1285	0.44	B	21.95

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3.1.3 Kamala Nursing Home Bos Stop

Basic capacity - 2900

Lane width - 6.7 m.

Description	Day	Before Bus Stop		At Bus Stop			Capacity Loss (%)
		V (PCU/hr)	V/C	V (PCU/hr)	V/C	L O S	
Sub – arterial road with frontage access with side roads, bus stops but no standing vehicles, and high capacity intersections.	1	942	0.32	1216	0.42	B	22.53
	2	922	0.32	1196	0.41	B	22.91
	3	887	0.31	1109	0.38	B	20.02
	4	875	0.30	1145	0.39	B	23.58
	5	859	0.30	1147	0.40	B	25.11
	6	887	0.31	1129	0.39	B	21.43

3.1.4 Milaghatta Bus Stop

Basic capacity - 900

Lane width - 6.3 m.

Description	Day	Before Bus Stop		At Bus Stop			Capacity Loss (%)
		V (PCU/hr)	V/C	V (PCU/hr)	V/C	L O S	
Collector road with frontage access with side roads, bus stops, parked vehicles, and heavy cross traffic.	1	479	0.53	612	0.68	D	21.73
	2	474	0.53	642	0.71	D	26.17
	3	458	0.51	634	0.70	D	27.76
	4	441	0.49	661	0.73	D	33.28
	5	445	0.49	704	0.78	D	36.79
	6	454	0.50	673	0.75	D	32.54

3.1.5 Sandal Colony Bus Stop

Basic capacity - 1200

Lane width – 7.3 m.

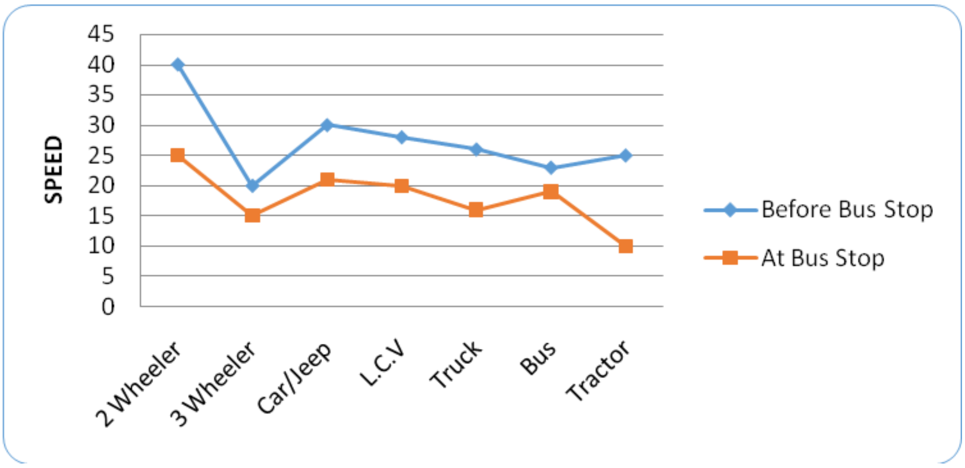
Description	Day	Before Bus Stop		At Bus Stop			Capacity Loss (%)
		V (PCU/hr)	V/C	V (PCU/hr)	V/C	L O S	
Sub – arterial road with frontage access with side roads, bus stops but no standing vehicles, and high capacity intersections.	1	792	0.66	956	0.80	D	17.15
	2	660	0.55	898	0.75	D	26.50
	3	585	0.49	771	0.64	D	24.12
	4	637	0.53	880	0.73	D	27.61
	5	627	0.52	894	0.75	D	29.87
	6	622	0.52	837	0.70	D	25.69

3.2 LOS Based on Speed Data.

Bus operations present impediments to the traffic flow. Average speed measured from two sections i.e., Before Bus Stop and At Bus Stop were compared. As per HCM recommendation Level of Service was defined based on speed data.

Table 3.9 - Level of Service Based on Speed Data.

Location	Section	2 Wheeler	3 Wheeler	Car/ Jeep	L.C.V	Truck	Bus	Tractor	Avg. Speed	LOS
Court Circle bus stop	Before	38	27	43	40	36	33	30	35.3	C
	At	36	24	37	33	27	27.5	18	28.9	D
Gandhi Park bus stop	Before	43	38	40	45	40	35	33	39.1	C
	At	40	27	38	38	25	27	20	30.7	C
Kamala Nursing home bus stop	Before	42	25	45	39	38	33	26	35.4	C
	At	32	19	29	31	26	22	13	24.6	E
Milaghatta bus stop	Before	40	20	30	28	26	23	25	27.4	D
	At	25	15	21	20	16	19	10	18	F
Sandal Colony bus stop	Before	40	29	42	42	33.4	38	29	36.2	C
	At	36	22	39	32	27	25	12.5	27.6	D



Figure(1) Graph showing Variation of Speed.

3.3 LOS based on Density

Density is the number of vehicles occupying a given length of a lane or roadway at a particular instant. Density is usually expressed as vehicles per kilometer (veh/km).[3]

Density is determined from the average travel speed and flow rate as per below equation,

$$D = v / S$$

Where, v = flow rate (veh/h)

S = average travel speed (km/h)

D = density (veh/km)

Table 3.10 - LOS based on Density as per HCM 2000[3]

	(LOS) A	(LOS) B	(LOS) C	(LOS) D	(LOS) E
Density(veh/km)	7	11	16	22	25

Source: HCM 2000

Table 3.21 Describes tabulated density of all the bus stops and LOS as per HCM 2000.

Table 3.11 - Tabulated Density and LOS as per HCM 2000[3]

Location	Section	Density	LOS
Court Circle bus stop	Before	13	C
	At	20	D
Gandhi Park bus stop	Before	18	D
	At	25	E
Kamala Nursing home bus stop	Before	14	C
	At	22	D
Milaghatta bus stop	Before	17	D
	At	24	E
Sandal Colony bus stop	Before	18	D
	At	24	E

3.4 Determining Loading Area Capacity [3]

The maximum number of buses per loading area per hour (B_{bb}) is calculated by Equation (1) as per HCM.

$$B_{bb} = \frac{3600(g/C)}{t_c + (g/C)t_d + Z_a c_v t_d} \quad \text{...Equation (1)}$$

where:

B_{bb}= maximum number of buses per loading area per hour

g/C= ratio of effective green time to total traffic signal cycle length (1.0 for a stop not at a signalized intersection)

t_c= clearance time between successive buses (s)

t_d= average dwell time (s)

Z_a= one-tail normal variate corresponding to the probability that queues will not form behind the bus stop, and

c_v= coefficient of variation of dwell times.

3.5 Bus Stop Capacity

The vehicle capacity of a bus stop in buses per hour is given by Equation (2),

$$B_s = N_{eb}B_{bb} = N_{eb}\frac{3600(g/C)}{t_c + (g/C)t_d + Z_a c_v t_d} \quad \text{...Equation (2)}$$

where:

B_s= maximum

N_{eb}= number of effective loading areas.

Table 3.14 - Bus Stop Capacity

Parameters considered	Location				
	Court Circle Bus Stop	Gandhi Park Bus Stop	Milaghatta Bus Stop	Kamala Nursing Home Bus Stop	Sandal Colony Bus Stop
Dwell time (s)	26	32	50	25	33
Coefficient of variation of dwell times	60%	60%	60%	60%	60%
Failure rate	2.5%	2.5%	2.5%	2.5%	2.5%
Z_a	1.96	1.96	1.96	1.96	1.96
g/C ratio	1.00	1.00	1.00	1.00	1.00
On-street/Off-street	On-street	On-street	On-street	On-street	On-street
Clearance time (s)	87	35	75	45	44
Bus Stop Capacity (bus/h)	25	34	20	36	31
Actual Bus Arriving (bus/h)	**32**	**41**	**25**	**39**	**43**

IV. CONCLUSION & DISCUSSIONS

From the analysis of data we can judge that On-street bus stops will interfere with vehicles movement if bus demand exceeds the bus stop capacity, resulting in some buses queuing and congestion. To overcome this condition, we are suggesting following proposals. By implementing these proposals we can ensure orderly movement of through traffic and increase in bus stop capacity.

All the bus stops are on-street bus stops which are heavily congested during peak hour. These bus stops primarily conflict with other passing vehicles when buses maneuver to pull into and out of the stop, resulting in capacity loss. Presence of pot hole, inadequate footpath, inadequate drainage facility resulting in decrease in bus stop capacity. Presence of stopped buses blocking the running lane and resulting in a “bottleneck” (reduction in lane width) and reducing road capacity. By adopting following measures capacity can be increased.

- Provide Bus Bay of suitable design with two loading area.
- Ordinarily no structure other than sheds for passengers should be permitted at the bus stops. The shed should be structurally safe and aesthetic in appearance, while also being functional so as to protect the

waiting passengers adequately from sun, wind and rain. The sheds should be set back from the kerb line by at least 0.25 meters. (IRC: 80-1981)

- Pavement marking should be provided with the word 'BUS' written prominently on the pavement. Pedestrian crossings should be marked slightly behind the standing position of the buses in order to reduce pedestrian conflicts. The kerbs should be marked with continuous yellow line to indicate no parking. These Markings should be kept maintained regularly. As per IRC: 35- 1997.
- Bus stops should be provided on the both sides of road for each direction of travel independently so that the buses do not have to cut across the road. Bus stops on opposite sides should be staggered to a certain extent as shown in Fig.4 to avoid undue congestion on the road.
- The pavement in the bus bay area should have adequate crust with respect to the wheel load expected. The surfacing should be strong enough to withstand forces due to frequent breaking and acceleration by the buses. The colour and texture of the bus bay surfacing should be preferably distinctive from that of main carriageway.
- Shoulders close to the bus stop should be paved to facilitate drainage. Brick – on edge, lean cement concrete, lean cement- fly ash concrete, precast tiles, stone slabs/blocks, water bound macadam with surface dressing etc., are some of the materials to be considered for this purpose. Paved shoulders should be flush with the surface of the adjoining carriageway and slope away from it to enable drainage.
- Provide proper cross slope to drain off the excess water. No water which is likely to splash on the waiting passengers should be allowed to collect near the bus shelters.
- Along all kerbed edges provide a suitable kerb-gutter section with requisite longitudinal slope and outlets at intervals to ensure quick disposal of water.
- Curbs should be extended in order to

➢ Reduce delay due to merging back into traffic
➢ Increase riding comfort because buses don't need to pull in and out of stops
➢ Increase on-street parking by eliminating need for taper associated with bus pullouts
➢ Increase space for bus stop amenities
➢ Reduce pedestrian street crossing distances

- Parking for other vehicles should be restricted on both opposite side bus stops, enforcing by the laws and orders of the duty police.

Given the fact that there is not much space available to expand existing roads, the future mobility needs can only be met by increasing the capacity of the existing road network. This can only be achieved by encouraging modes that are more efficient in terms of space utilization.

Private operators are the preferred option wherever possible. However, these operators must be subject to the following:

➢ No competition among them for attracting passengers.
➢ There can be several large operators but using state infrastructure.
➢ A regulatory authority that decides routes, fare structure, quality of buses, etc, must manage the operators.

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