Planning of Bus Stops for Safe and Effecient Passenger Boarding and Alighting

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***Abstract*— The bus stop is the first point of contact between the passenger and the bus service. To improve the quality of bus services bus stop is recognized as a crucial element. Bus stop layout should enable safe and smooth flow of bus and passengers. Most bus stops in Chennai are along the public sidewalk, with signage marking, and in some cases, with a bench or small shelter. It is observed that congestion occurs at bus stops due to deceleration, stopping and acceleration of buses on the carriageway and accidents occur due to lack of facilities for safe passenger movements at bus stops. This study is planned to identify planning aspects for ideal location of bus stop to increase accessibility, to suggest optimal layout of bus stops, and to examine the impacts of the interactions between buses, passengers and traffic on delays and capacity at bus stops. The passenger service time, dwell time of buses, arrival pattern of buses and passengers at bus stops, stop delays are analyzed. This suggests the necessity of microscopic simulation to study the capacity of bus stops. Results indicate that it is important not to underestimate the real situation found at bus stops, as designing for ideal conditions will be insufficient if the reality is different. Application of these results will improve the performance of the bus system as a result of a better understanding of its operation leading to simple changes in the design of infrastructure.**

Keywords*— *Congestion, Microscopic Simulation, Dwell Time

I. INTRODUCTION

The bus stop is the first point of contact between the passenger and the bus service. To improve the quality of bus services bus stop is recognized as a crucial element. Bus stops should provide required facilities for safe boarding and alighting of passengers. Accessibility of a bus stop is a critical element in deciding the bus transport ridership. The location of bus stops significantly influence bus transit system performance and customer satisfaction. The choice of location is primarily related to the operational performance of the bus route and traffic, but can also be influenced by the adjacent land uses and opportunities for easy transfer to crossing bus routes. Bus stop layout should enable safe and smooth flow of bus and passengers. A well-designed layout of bus stop can allow passengers to board and alight without the bus significantly impeding or delaying adjacent traffic. A lack of regional co-ordination has resulted in inconsistencies in bus stop layout and provision across the region. Most bus stops in Chennai are along the public sidewalk, with signage to mark the bus stop, and in some cases, with a bench or small shelter. This lack of consistency and the often poor bus stop infrastructure planning of location and layout impacts not only on the customer's perceptions, experiences and views of the passenger transport network, but importantly on the operational effectiveness of the buses and therefore on the ability of bus operators to operate efficient and reliable services. This Study is planned to identify planning aspects for ideal location of bus stop to increase accessibility, to reduce the number of transfer time, necessary to make a trip and also to suggest optimal layout to reduce the congestion and accidents occurring at bus stops.

A. NEED FOR THE STUDY

A bus operating in mixed traffic situation is the most common operating scenario in India. Mixed traffic operation complicates capacity calculations for both bus and automobile flow since it exposes buses to automobile traffic condition and slows automobiles as buses to serve passenger. The bus facilities are based on the critical bus capacity and the operational procedure. Urban development should satisfy the bus stop facilities and its operation. Planning of proper bus stop location and layouts are missing in our condition. In present situation bus stops also act as a dropping and pick up points of auto rickshaws and two wheelers. Expansion of the cities should be linked with the planning. Planning components should improve the existing facilities. Because of the improper planning of bus stop layout and bad location, results in the congestion and accidents at the bus stops. The congestion of the bus stop affects the existing traffic flow.

The study is needed to concentrate identifying the planning aspects for the location and layout of bus stops. Capacity evaluation will be taken into account to decide the layout of bus stops at the planning stage.

B. OBJECTIVES

The important objectives of this present study are

- To understand the activities of bus and passenger movements at bus stops and to assess the existing facilities in selected corridors
- To review the location of bus stops on selection corridor with respect to desirable planning parameters (accessibility)
- To evaluate the capacity of bus stops considering the bus operations and bus routes for present and future period

II. LITERATURE REVIEW

The scope of the review is to exhibit an overview of various studies done so far in this field. The reviews of literature of the past studies in the areas are as grouped as follows

i. Planning of location of bus stops
ii. Planning of layout of bus stops
iii. Bus Stop Modeling and Simulation

A. Planning Of Location of Bus Stops

Guidelines for the Location and Design of Bus Stops, prepared by Transportation Research Board National Research, Report-19. These guidelines can assist transit agencies, local governments, and other public bodies in locating and designing bus stops that consider bus patrons' convenience, safety, and access to sites, as well as safe transit operations and traffic flow. The guidelines include a compilation of information necessary for locating and designing bus stops, as well as checklists of factors that must be taken into consideration. The guidelines list the advantages and disadvantages of various bus stop treatments and discuss the trade-offs among different alternatives. These guidelines also provide an approach to integrating transit and development. By assembling the information into a single document, public agencies and developers can more easily incorporate. Transit needs into the design and operations of streets and highways, as well as in land development. Finally, these guidelines should help transit, state, and local agencies in selecting bus stop amenities.

Peter G. Furth et.al. (2007) Geographic databases and computing tools present an opportunity for improved analysis of bus stop location or spacing changes. Changes in stop location affecting walking, riding, and operating cost; of these, walking impact is the most important and complex. Traditional models and stop spacing design rules model walking impacts very roughly, as they assumed uniform demand density and unobstructed walking paths. They developed an analysis procedure based using a parcel-level geographic database (supplied by a local government body such as the city tax assessor) and the street network. Walking paths and stop service area boundaries were based on shortest path and Voronoi diagram methods applied to the street network. Data on each parcel’s land use and development intensity were used to distribute historic on / off counts, thus estimating the demand arising in each parcel. Then for alternative stop sets, demand at each stop, walking distance, riding time, and operating cost impacts can be determined. Case studies on Boston and Albany transit routes demonstrate the method’s practicality. Results confirm the benefits of a recent stop rationalization effort in Boston, and show how proposed stop elimination / relocation plans can be adjusted to yield a greater net benefit to society.

Bus Routing and Coverage, prepared by Transportation Research Board National Research, Report 95. Bus routing and coverage included the routing changes at the individual route and system level, new bus systems and system closures, bus system expansion and retrenchment, increases and decreases in geographic coverage, and routing and coverage changes made together with fare changes. Routing and coverage changes may improve transit system efficiency, effectiveness, or reach through the adjustment, extension or creation of bus routes. Types of bus routing and coverage changes include New Bus Transit Systems, Comprehensive Service Expansion, and Service Changes with Fare Changes, Service Restructuring, Changed Urban Coverage, and Feeder Routes. The response of transit ridership to aggregate changes in amount of transit service is the one aspect of bus routing and coverage, and related service changes, that lends it well to quantification on the basis of actual experience as expressed in the data typically collected by transit agencies. Confounding analysis of any situation where transit routing changes increase or decrease the need for passengers to transfer, such as conversion to or away from a hub and spoke or timed transfer route structure, was the “unlinked-trip” method of tracking ridership.

B. Planning of Layout of Bus Stops

Bus Stop Infrastructure Design Guidelines, May 2009, prepared by The Auckland Regional Transport Authority, Auckland, New Zealand. The purpose of these guidelines is to assist practitioners in the development of bus stops that meet the objectives. These guidelines outline best practice planning and design principles for optimal bus stop layout. They provide a framework for promoting consistency in design and in the provision of bus stop amenities. Adhering to these guidelines they found that it improves the visibility of stops, making them easier to identify, and better suited for their use, location and potential for attracting users. Ultimately, the over-arching aim of these guidelines was to ensure that bus stops contribute towards the provision of a high-quality, attractive and accessible bus passenger transport system so that Aucklanders genuinely felt that they had a real passenger transport alternative to the private car.

Shashi K. Sathisan and nanda srinivasan had done their work in A basic function of any transportation facility is to provide accessibility and mobility to the end user. Accessibility in general terms refered to the capability of being reached, and mobility refered to the ease with which a movement can take place. Accessibility had traditionally been estimated using proximity of people, places, or services to the transportation system. Proximity was measured using travel time, travel distance, or a generalized travel cost function. Transportation demand models had also used some measure of accessibility to estimate the trips that can theoretically be made between two locations based on some relative attractiveness measures. It can, therefore, be observed that quantifying accessibility helps in three ways: System evaluation to monitor changes in the urban system, regardless of whether such changes are planned or unplanned; Travel demand modeling as input variables in modeling travel choice situations; and urban development models in order to model urban form.

C. Bus Stop Modeling and Simulation

Danas. A (2000) Arrivals of passengers and buses at two London bus-stops, this study deals the problem of estimating the average passenger waiting time not only using bus data but also consider the long-term variations in the passenger arrival rate and the fact that it was not always possible foe a passenger to get on the first bus to come, especially during peak period. Observation of two London Transport bus services had been made at two bus-stops, the first served by route w3 and the second by route 159, in north and North West London respectively. The data collected were passenger arrival time, the number of passengers left behind each bus, bus arrival and departure time. Data from both bus stops had been checked against any significant variation in the arrival rate within the different week days and the different time of the day. The arrival pattern characterized by two different types of variation (i) on a microscopic level there was the long-term variation of the average passenger flow, which was mainly related to the time of the day and (ii) on a macroscopic level, even when the average level of passenger arrivals remains constant, there are still the random variations of the minute to minute arrivals.

Paulo C M Silva (2000) Simulating bus stops in mixed traffic, the design of bus stops to satisfy at least two requirements. The paper justifies and describes the changes implemented into SIGSIM and reports the practical exercise undertaken in east London, where some bus stops are redesigned. Simulation models usually represent buses and their interactions in a simplistic way. They either (a) are designed to assess the effect of segregation between buses and other traffic. (b) Simply the behavioral of buses, representing that merely as large cars. Macroscopic models make this more evident than their microscopic equivalents.

Julian Laufer, The VISSIM micro simulation software package is primarily applied to traffic and transport simulation modelling to understand the complexity of traffic operations. The micro simulation modelling assessed the variation in flow volumes between a series of design plans, and adjustments to bay layouts. The VISSIM modelling was undertaken to determine how many buses could enter the station. Schedules, there was potential for unutilised time within the peak hour. Therefore, an arrival pattern based on schedules may not represent the true capacity of the bus station. As a sensitivity analysis to the VISSIM micro simulation modeling to identify potential throughput of buses, a series of dwell times were incorporated into the station designs. This action assessed the risk that the model could overstate or understate the time that buses are stationary for passenger boarding and alighting. A number of variations in the layout of the bus bays were assessed. The potential throughout of six designs were modeled.

III. STUDY METHODOLOGY

The methodology employed, first to identification of the problem in bus stop design in the study area. Second formulation of the objectives to eliminate the problem in the study area. The collection of literature review related to Bus Stop Infrastructure Design, Location and design, Bus Route Coverage, Arrivals of passenger at bus stops, Bus stop modeling, and Bus stop simulation. The required data will be collected to design the bus stop. The data are related to passenger waiting time, delay of bus due to passenger and queuing, actual spacing between the bus stops and actual frequency of buses. Analysis the bus stops by using network analysis. The design of bus stops provides approach to integrating bus stop development. Finally findings and recommendations will arrive from the study of bus stop planning of location and layout.

A. Formulation of Objectives

The objectives are formulated based on the problem identification. The derived objectives should satisfy the need of the problem. The initial point in the objective is to understand the activities of bus and passenger movements at bus stops and to assess the existing facilities in selected corridors. The layout aspects are considered with respect to movement of bus and passenger. Finally to evaluate the capacity of bus stops considering the bus operations and bus routes for present and future period.

B. Literature Review

The literature review is to explicitly give an overview of various studies done so far in this field. The reviews of literature of the past studies in the areas are clustered into to three groups are

i. Planning of location of bus stops
ii. Planning of layout of bus stops
iii. Bus Stop Modeling and Simulation

C. Selection of Study Area

The study area considers the location of bus stops at different routes.

The following location of bus stops are consider for this study

i. LIC
ii. TVS

The location of the bus stops and its information in the selected study area is explained as follows

i. LIC

LIC bus stop is located at Mount Road. Mount Road is having six lane divided road and three lane for both direction. This is highly commercial area where the usage of private vehicle is more. The adjacent land use is consists of commercial as well as government offices. *Fig 1* shows a snap shot of LIC bus stop. The lane classifications are

Two wheeler and Auto lane	- 1.5 m
Car lane	- 2.0 m
Bus Lane	- 3.5 m

Fig 1 LIC bus stop

ii. TVS

TVS bus stop is located at Anna Salai Road. Anna Salai Road is having six lane divided road. Exclusive bus bay is provided in this location. The adjacent land use is consists of commercial area. *Fig 2* shows a snap shot of TVS bus stop.

Fig 2 TVS Bus Stop

D. Data Collection

The data collection process is divided into two parts

- Primary Data
- Secondary Data
- Primary Data

Primary data collected from the following

a) Number of passengers

Numbers of passenger boarding and alighting will be counted all the location in the study area. The count data will be entered into a spreadsheet and then analyzed the data by route, time, and location. The data were also geocoded into a Geographic Information System in order to perform a spatial analysis.

b) Passenger waiting time

The way how passengers are waiting at bus stops and what kind of activities they engage in while waiting can affect the value of waiting time at bus stops will be measured.

c) Dwell Time

Dwell times may be governed by boarding demand by alighting demand, or by total interchanging passenger demand. In all cases, dwell time is proportional to the boarding and/or alighting volumes and the amount of time required serving each passenger.

Secondary Data collected from the following

d) Spacing between bus stops

Bus stop spacing has a major impact on different type of buses and bus stop performance. Stop spacing also affects overall travel time, and therefore, demand for bus stop. The determination of bus stop spacing is frequently subdivided by development type, such as residential area, commercial, and/or a central business district (CBD).

e) Frequency of buses

The frequency of buses at bus stops are influencing the waiting time of the passengers at bus stops. Minimizing the frequency of buses is decrease the passenger waiting time. The frequency of buses can be measures from the observation survey.

f) Land use pattern

Land use pattern is one of the main concepts for planning and designing the bus stop. The characteristics of the land use pattern influencing the location of bus stops and also influence the passenger arrival pattern. The different types of land use patterns are commercial, residential, institutional, central business district and industrial areas.

E. Study of Existing Bus Stops

The existing location of the bus stops will be studied based on the locational aspects and also considering accessibility. The existing layout of bus stops will be studied and the standard specifications will be arrived.

F. Modeling and Simulation of Bus stop

The bus stop model will be formed based on the Highway Capacity Manual model 2000. The simulation of bus movements, pedestrian & passenger movements for various layouts to be carried to identify the best layout. Modeling & Simulation of bus arrival, berthing at bus stop and pedestrian, passenger movement at bus stop for various derived lay out are also to be carried out in this stage. The modeling and simulation of bus stop will be carried out by using traffic simulation software Verkehr in Stadten – Simulation (VISSIM).

Verkehr in Stadten – Simulation (VISSIM)

VISSIM is a microscopic, time step and behavior based simulation model developed to model urban traffic and public transit operations. The program can analyze traffic and transit operations under constraints such as lane configuration, traffic composition, traffic signals, transit stops, etc., thus making it a useful tool for the evaluation of various alternatives based on transportation engineering and planning measures of effectiveness. The following list gives a selective overview of applications of VISSIM:

- VISSIM is used to evaluate the feasibility and impact of integrating bus system into urban street networks.
- VISSIM is applied to the analysis of slow speed weaving and merging areas.
- Capacity and operations analyses of complex station layouts for bus systems have been analyzed with VISSIM.

i. A simulation model called VISSIM version 5.3 was used as part of the study of planning of bus stops for safe and efficient passenger boarding and alighting. A simulation program is used to model the complex interactions influencing capacity and delay at congested bus stops. The program has been called VISSIM is used for calculating capacity of bus stop and queuing behavior at bus stops.

G. Structure of the model

The bus module generates arrivals and characteristics of buses. Any arrival pattern can be reproduced in VISSIM, such as regular headways, random headways following certain distribution, scheduled arrivals, and combination of several lines with different frequencies, batch arrivals or actual arrivals from field data. Some of these arrival patterns can be generated from statistical distributions, but other should be directly enter into the input file. Other characteristics of buses are also provided in the bus module. These are the number of the route, the amount of alighting passengers from each arriving bus, the mean alighting time per passenger for each route, the spare capacity of each arriving bus, and any blocking time for each bus to leave the stop area.

The passenger module generates the arrival and characteristics of passengers. As in the case of buses, any inter-arrival pattern can be produced by either using statistical distributions or spreadsheet facilities. Similarly, in this module the route of the passenger and its particular boarding time is entered.

VISSIM version 5.3 responds to a number of design and operating features including:

i. Bus stop area design: number of berths, mandatory or request stop, FIFO or OA queue discipline

ii. Bus arrivals are according to fixed intervals or following a poisson distribution

iii. Buses may be single or multiple, non-stopping buses mayor may not be forced to pass through the bus stop area

iv. Stops may be made at any berth , or (at single stops) at the berth closest to the exit buses may stop for just boarding, alighting or bi-functional operations

v. Types of bus in terms of number of passengers boarding and alighting per hour and bus flows

Calculation of Bus Stop Capacity Using VISSIM

Buses can operate in mixed traffic as well as on dedicated roads. They are defined separately from all other traffic. Data input for bus occurs in two steps:

Step 1: Definition of bus stops.

Step 2: Definition of routes including served bus stops and schedules.

a) Bus Stops

Bus stops can be created on or adjacent to an existing link. There are two types of stops:

i. On Street stop (curbside stop): A bus stops on a user defined travel lane of the selected link

ii. Bus lay-by (turnout): A bus stops on a special link next to the slow lane of the selected link

IV. RESULTS AND DISCUSSIONS

The Highway Capacity Manual Model 2000 is used for calculating bus stop capacity and dwell time of buses. VISSIM version 5.3 is used for the simulation of bus stop. Queuing behavior at bus stops are studied by formulation of scenarios.

A. BUS ARRIVING PATTERN

Figure and shows the minute to minute bus arrivals for a typical data at LIC and TVS bus stops. It can be observed that the number of buses arriving at the bus stops does not remains constant throughout the observation period. *Fig* 3 & 4 shows the Arrival Time of Buses at LIC & TVS bus stop.

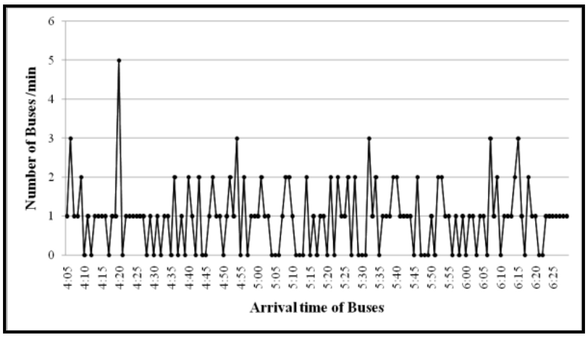

Fig 3 Arrival Time of Buses at LIC Bus stop

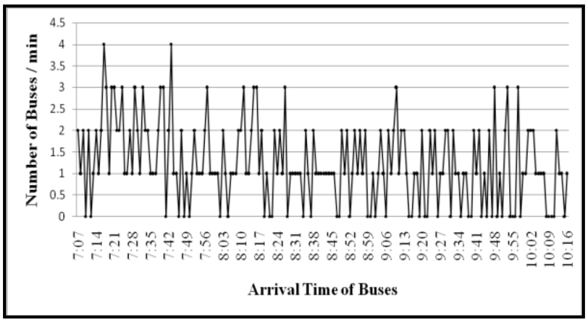

Fig 4 Arrival Time of Buses at TVS Bus stop

B. PASSENGER ARRIVING PATTERN

Data from both bus stops have been checked against significant variation in the arrival rate within the observation period.

Fig 5 & 6 shows the minute to minute passenger arrivals for a typical data day at LIC and TVS bus stops. It can be observed that the number of passengers arriving at the bus stops does not remain constant throughout the observation period. Minute to minute variations are due to the fact that passenger arrivals at a bus stop are approximately random event. Furthermore, when passengers see a bus coming, they run to the bus stop to catch it, thus affecting the passenger arrival rate**.**

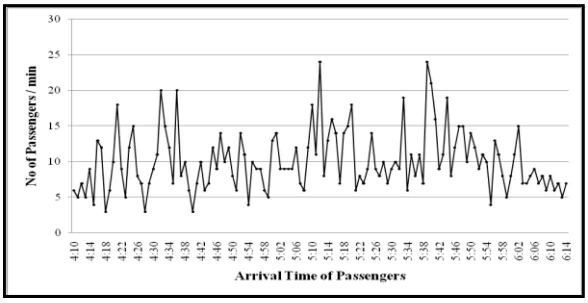

Fig 5 Arrival Time of Passengers at LIC Bus stop

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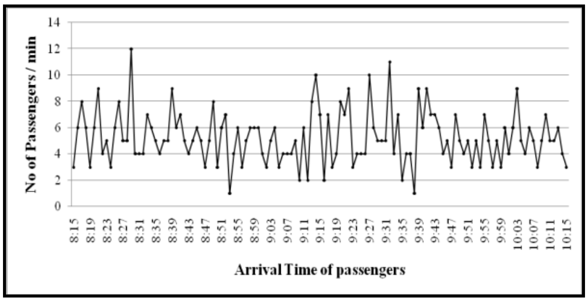

Fig 6 Arrival Time of Passengers at TVS Bus stop

Seedon and Day have suggested that, for bus services with headway of less than 10 min., random arrival of passenger at the bus stop is the reasonable assumption. This assumption appears to hold the all observation period, although the mean headway recorded is 64 sec and 47 sec for LIC and TVS bus stops respectively.

C. PASSENGER WAITING TIME

Bus data have been analyzed in relation to the departure time, since it is the departure time rather than the bus arrival time which is associated with the passenger waiting time. Bus headway seems to follow an exponential distribution. As the headways of successive buses seem to be independent, it can be concluded that buses arrival at random following the Poisson process at both bus stop.

The expected waiting time, assuming random arrival of passengers, was calculated using a formula given by Welding:

$$\overline{w}_{ran} = \frac{\overline{h}}{2}\left[1+\left(\frac{\sigma}{\overline{h}}\right)^2\right] \qquad (1)$$

From bus data only: $\overline{h}$ is the mean, σ is the standard deviation of the observed bus headway. These values exceed the average passenger waiting time w'_{avg} calculated from passenger arrival and bus arrival data assuming that passenger boarding the first bus to come. Table 5.1 describes the bus data and passenger waiting time.

Table 1 Bus data and Passenger Waiting Time

Bus Stop	Average Bus Headway ($\overline{h}$) (sec)	St.dev. of headways (σ) (sec)	Coeff.of variation $\frac{\sigma}{\overline{h}}$	$\overline{w}_{ran}$ (min)	$\overline{w}'_{act}$ (min)	$\frac{\overline{w}'_{act}}{\overline{w}_{ran}}$
LIC	64	55	0.86	6.04	5.15	0.85
TVS	47	42	0.89	12.11	10.08	0.83

Average waiting time assuming random arrivals $\overline{w}_{ran}$ has been found to be 17% more than $\overline{w}'_{act}$ at LIC bus stop.

Average waiting time assuming random arrivals $\overline{w}_{ran}$ has been found to be 20% more than $\overline{w}'_{act}$ at TVS bus stop.

D. DWELL TIME MODEL (HCM MODEL)

Dwell times may be governed by boarding demand by alighting demand, or by total interchanging passenger demand. In all cases, dwell time is proportional to the boarding and/or alighting volumes and the amount of time required serving each passenger. Dwell time at bus stops is measured by manually.

The dwell time is the time required to serve passengers at the busiest door, plus the time required to open and close the doors. A value of 2 to 5 seconds for door opening and closing is reasonable for normal operations.

$$t_d = P_a t_a + P_b t_b \qquad (2)$$

Where:

t_d = average dwell time (s);

P_a = alighting passengers per bus through the busiest door (p);

t_a = alighting passenger service time (s/p);

P_b = boarding passengers per bus through the busiest door (p);

t_b = boarding passenger service time (s/p);

From the collected data at LIC Bus stop the findings are tabulated as follows:

Table 2 Dwell Time Results at LIC Bus stop

Average dwell time	40.25 sec
Standard Deviation of dwell time	22.25
Coefficient of variance of dwell time	0.55
Number of Passenger Boarding	7 pass/min
Number of Passenger Alighting	3 pass/min
Average Clearance time	4 sec

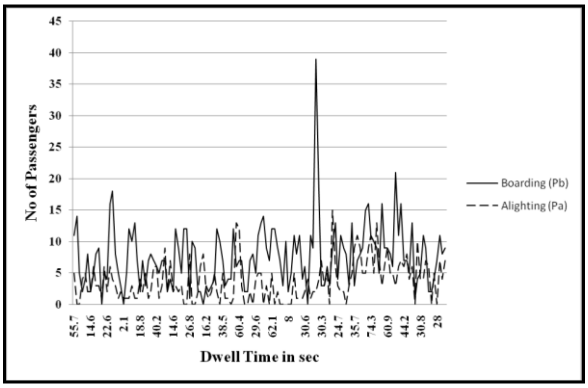

Fig 7 Dwell Time vs. Passenger Boarding & Alighting (LIC)

From the collected data at TVS Bus stop the findings are tabulated as follows:

Table 3 Dwell Time Results at TVS Bus stop

Average dwell time	37.77 sec
Standard Deviation of dwell time	15.87
Coefficient of variance of dwell time	0.42
Number of Passenger Boarding	3 pass/min
Number of Passenger Alighting	12 pass/min
Average Clearance time	7 sec

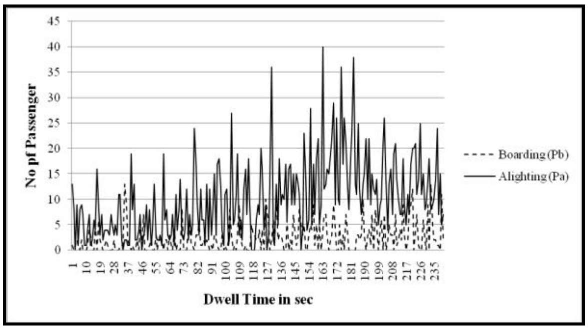

Fig 8 Dwell Time vs. Passenger Boarding & Alighting (TVS)

E. Regression Analysis

The regression selected for analysis is Multiple Linear Regression. This analysis is based on the dwell time and number of passenger boarding and alighting. The equation is formulated based on the variables. The dependent variable is selected for analysis is dwell time and independent variable is number of passenger boarding and alighting.

$$y = a_1 x_1 + a_2 x_2 + a_3 \tag{3}$$

Here,

y = dependent variable

x_1, x_2 = independent variable

a_3 = coefficient

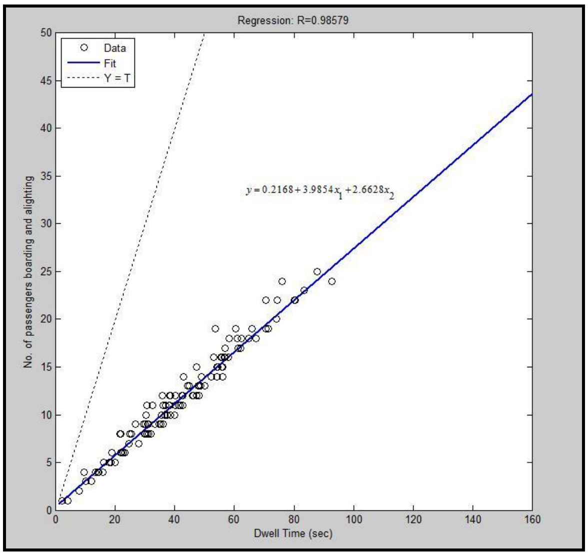

Fig 9 Regression analysis of LIC Bus stop

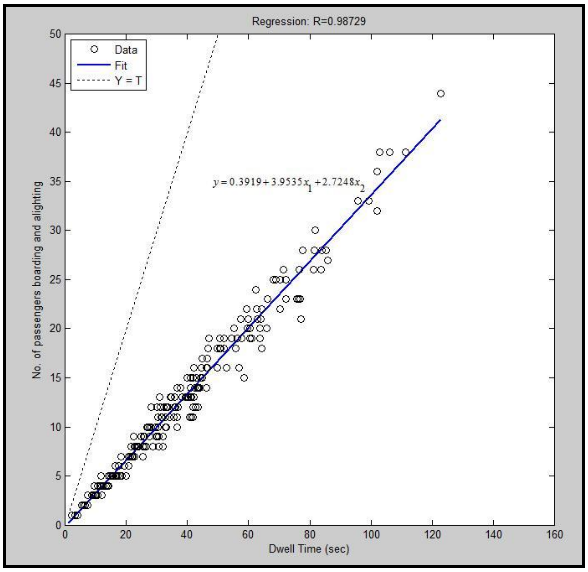

Fig 10 Regression analysis of TVS Bus stop

F. ESTIMATION OF BUS STOP CAPACITY

Estimation of bus stop capacity is now a well-researched field. There are various mathematical models available for estimating bus stop capacity. The theoretical basis for estimating bus stop capacity is briefly explained below. The simplest possible theoretical model for estimating bus stop capacity may be given as:

$$Q_c = \frac{3600}{t_{dwell} + t_{clear}} (buses/hr) \tag{4}$$

The degree of saturation, which is a key performance mea- sure of a bus stop defined as the ratio of flow to the theoretical capacity can be found as:

Saturation = (Q/Qc) x 100 (%), where Q is the observed bus flow.

Table 4 Theoretical Bus Stop Calculation

Name of Bus Stop	Theoretical Bus Stop Capacity (buses/hr)	Degree of Saturation (%)
LIC	81	196.29
TVS	80.44	228

1) The Highway Capacity Manual (HCM) 2000 Model

The HCM 2000 Model (TRB, 2000) introduces a new concept of using failure rate. Failure rate, which is derived from basic statistics, is the probability that a queue of buses will not be formed behind a bus stop. Z_a represents the area under one tail of the normal curve beyond the acceptable levels of pro ability that a queue will form at a bus stop. Typical values of Z_a are obtained from standard tables. Suggested values of Z_a for CBD stops range from 1.44 to 1.04 resulting in probabilities of 7.5% to 15.0%, respectively that queues will develop. For outlying stops, 1.96 is suggested as the value of Z_a resulting in queues beyond bus stops only 2.5% of the times. However, in general, Z_a values of 1.44 (representing 7.5% probability) are acceptable. The theoretical capacity of the berth is then given as:

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$$B_S = N_{el} B_j = \frac{3600\,(g/c)}{t_c + t_d (g/c) + Z c_v t_d} \qquad (5)$$

Where,

B_s = bus stop bus capacity (bus/h);

B_j = individual loading area bus capacity (bus/h);

N_{el} = number of effective loading areas,

3,600 = number of seconds in 1 hour;

g/C = green time ratio (the ratio of effective green time to total traffic signal cycle length, equals 1.0 for unsignalized streets and bus facilities);

t_c = clearance time (s);

t_d = average (mean) dwell time (s);

Z = standard normal variable corresponding to a desired failure rate; and

c_v = coefficient of variation of dwell times.

From the collected data capacity of bus stops by using HCM manual model 2000 is tabulated as follows

Table 5 Bus Stop Capacity using HCM Model 2000

Name of Bus Stops	Capacity of Bus Stops using HCM Model 2000 (buses/hr)
LIC	123
TVS	163

G. *A MICEROSCOPIC SIMULATION APPROACH*

1) VISSIM Model Coding

Coding data for input into the VISSIM model is accomplished within the graphical user interface of the program. To facilitate drawing the links that form the roadway segments, it is possible to display a bitmap (.bmp) in the background of the workspace. Either roadway design files (converted to bitmaps) or aerial photography can be used, and result in a scaled model being constructed within VISSIM. As with most traffic models, the primary input data for VISSIM is composed of roadway geometric information (lengths of roadway, number of lanes, lane use, turn bays, etc.), traffic volume data (peak-hour volume, intersection turning movement counts, traffic composition, vehicle occupancy, etc.), and traffic control information (signal presence and timing, signing, rules of the road, etc.). The following sections describe the source for data included in the managed lanes modeling and the process used to convert the managed lane and freeway design details and other information into VISSIM input files.

2) VISSIM 5.3 Simulation Results

The simulation results for LIC and TVS bus stops are tabulated as follows:

Table 6 Simulation Results for LIC and TVS Bus Stop

Output	LIC Bus Stop	TVS Bus Stop
Mean pas waiting time	1.63 min (max 6.12 sd: 1.46)	2.41 min (max 2.42 sd: 1.02)
Mean pas on platform	17.79 pass (max: 49)	13.26 pass (max: 24)
Mean bus pad delay	37.11 s/bus (max: 99.34 sd:29.44)	29.18 s/bus (max: 67.42 sd: 19.31)
Mean bus extra delay	37.34 sec sec	20.12 sec
Mean bus queue delay	7.62 s/bus (max: 69.42 sd: 17.66)	6.89 s/bus (max: 61.02 sd: 13.75)
Mean bus total delay	82.07 s/bus (max:104.34 sd:31.24)	56.19 s/bus (max: 98.41 sd: 22.64)
Bus Stop Capacity	85.38 bus /h	95.53 bus /h
Mead bus queue length	0.03 buses (max:1.00)	0.09 buses (max: 1.00)
Exit time deviation	154.24s	103.74s
Probability of developing queue	47%	39%

H. *Scenario Formation for the Bus Stop Queuing*

This specifies the physical setup of the queue, which combines two main factors: the number of servers and lines available. Scenario created for queuing at bus stops under this category:

1) Scenario 1: Single line and multiple servers

In this situation, buses enter the system and line up in a single queue based on their arrival. However, there are multiple servers available in this case, where each of the buses is served by the next available server among all.

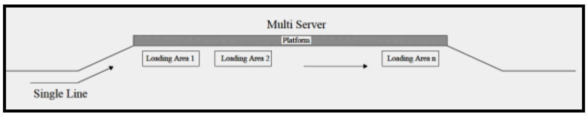

Fig 11 Single line and multiple servers

2) Scenario 2: Multiple lines and multiple servers

This is the case involving multiple servers and multiple waiting lines, in which each line is served by a single server. The buses arriving at the system join in one of the waiting lines and wait until they move towards the front of their chosen line.

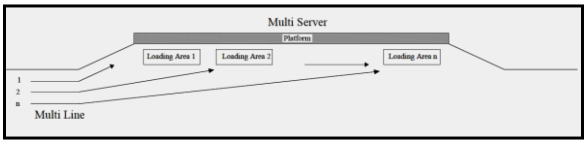

Fig 12 Multi line and multiple servers

Table 7 Queuing output for LIC and TVS Bus Stop

Output	LIC Bus Stop		TVS Bus Stop	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Average Queue Length (m)	4.3	2.7	6.4	5.4
Maximum Queue Length (m)	13.1	11.88	16.45	12.5
Number of Stop within the queue	4.5	3.7	10.7	6.4

V. CONCLUSION

In this study a new model for capacity of bus stop, and queuing behavior at bus stops was described. It was argued that, for the characteristics of the system under investigation, a fundamental model like this is enough to study the main interactions at bus stops. This suggests that, before to attempt the study of bus stops, it is necessary to have a better description of the microscopic short-term dynamic simulation for bus stops. In addition, it was demonstrated by means of simple experiments that this model is able to answer some relevant questions about the operations of bus stops. In particular, the effect of arrival pattern of buses and passengers, obstructions to pull out from the berth, marginal boarding times, and bus capacities seem to be important factors for bus operations.

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