International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:11, No:10, 2017

Exploratory Data Analysis of Passenger Movement on Delhi Urban Bus Route

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Abstract**—**Intelligent Transportation System is an integrated application of communication, control and monitoring and display process technologies for developing a user–friendly transportation system for urban areas in developing countries. In fact, the development of a country and the progress of its transportation system are complementary to each other. Urban traffic has been growing vigorously due to population growth as well as escalation of vehicle ownership causing congestion, delays, pollution, accidents, high-energy consumption and low productivity of resources. The development and management of urban transport in developing countries like India however, is at tryout stage with very few accumulations. Under the umbrella of ITS, urban corridor management strategy have proven to be one of the most successful system in accomplishing these objectives. The present study interprets and figures out the performance of the 27.4 km long Urban Bus route having six intersections, five flyovers and 29 bus stops that covers significant area of the city by causality analysis. Performance interpretations incorporate Passenger Boarding and Alighting, Dwell time, Distance between Bus Stops and Total trip time taken by bus on selected urban route.

Keywords**—**Congestion, Dwell time, delay, passengers boarding alighting, travel time.

I. Introduction

IN recent years, the traffic congestion on urban corridors results from the exponential growth of private vehicles with corresponding increase in trip lengths. In order to develop a sustainable transportation system and to reduce traffic congestion, the focus shifted from building new infrastructure or mending aging infrastructure to Intelligent Transportation System (ITS). To monitor traffic congestions and traffic flows on urban route, an Urban Transportation Information System (UTIS) for the Guangzhou city of China has been developed that integrates traffic information with GPS [4]. In 2014, an attempt has also been made as part of ITS technology to model the distribution of travel time using traffic volume on the Hanshin Expressway [3].

Dwell time is an important aspect in the predication of travel time of buses on urban roads. One of the most important considerations in measuring dwell time is passenger activity, which is used to analyze various factors like lift operation, low floor buses, time of day and types of urban bus route such as arterials or sub arterials routes [6]. An analysis has been done by Bertini and El-Geneidy in 2004 to model dwell time of morning peak hours for a single inbound radial route and integrate the results of the dwell time analysis directly into the trip time model by estimating the parameters for number of passengers boarding and alighting [2]. A dwell time model has also been developed for buses to estimate the capacity of the busway stations. Finally, it is concluded that boarding at busway station predominantly increasing the span of passenger – bus interface that results increasing in lost time as well as dwell time for buses [8]. The effect of low floor and articulated buses on dwell and running time is different. Operation of articulated buses resulted in saving dwell time, especially with high passenger activity [7].

Accurate forecasting of bus travel time is essential to improve the quality of bus services on urban bus routes as it attracts more commuters and enhance their satisfaction [9]. A regression model can be used to determine the arrival time of the bus by using various independent variables such as number of bus stops, distance between stops, number of passengers boarding and alighting and dwell time [10]. Regression models generally used the values of independent variables to estimate the values of dependent variables. Regression model not only tell about the important input variables needed for travel time prediction but also can work under changeable traffic condition. A linear and nonlinear regression model can be used to predict bus delay time during the blockage of one traffic lane under normal traffic condition [1]. In 2013 Zhang et al. developed a GPS based multiple linear regression model to predict bus travel time. It is also determined that the parameters such as dwell time at bus stops and delays at intersection are less associated and hence not recognized for the development of regression model [12]. In order to solve nonlinear problem having complex data Artificial Neural Network (ANN) can be used. The ANN model can be invoked by either recalling phase or learning phase. In the learning phase the weights are assigned to train the model, while on the other hand, the recalling phase implements the weights selected in the course of learning phase. ANN model can be used to predict the real travel time or arrival time of the bus at any bus stop. CORSIM can be used for simulation by using traffic volume and passenger demand data [5]. A back propagation model based on ANN can be used to forecast traffic flow for Intelligent Vehicle Highway System (IVHS) [11].

The following sections of this article are organized as follows. The second section discusses the methodology adopted during the study. The third section demonstrates the types of data collected and their classification. The fourth

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section gives the outcomes obtained from Exploratory Data Analysis of distance between bus stops, dwell time and passenger boarding and alighting on selected urban route during the study.

II. Methodology

The methodology used for the operational study of urban bus route in Delhi area, shown in Fig. 1, involved the steps like Selection of urban bus route, data collection which can be further categorized as primary data and secondary data and the last step is data analysis which involves Exploratory Data Analysis of different parameters considered during the study.

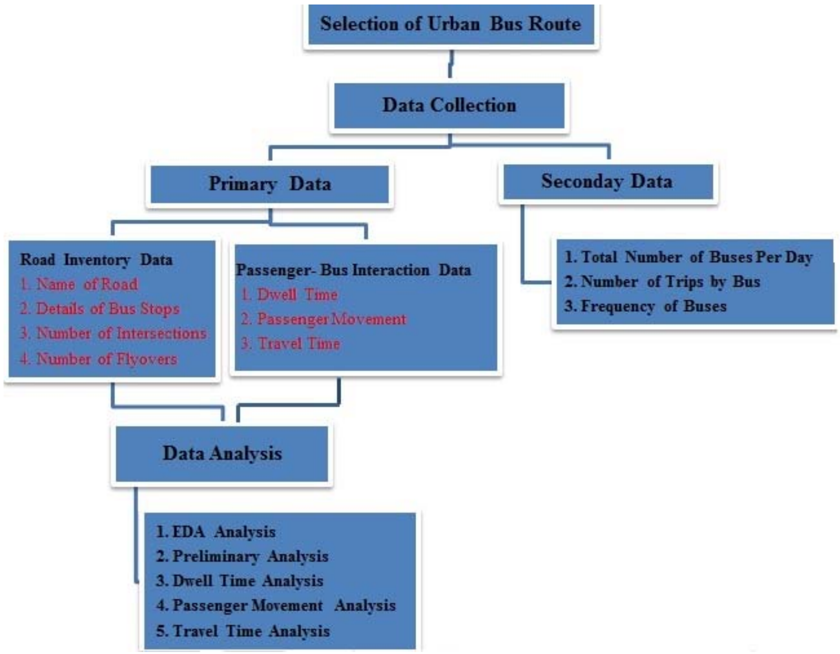

Fig. 1 Methodology

TABLE I
NAME OF BUS STOPS AND REFERENCE ID

Bus Stop Reference ID	Name of Bus Stop	Bus Stop Reference ID	Name of Bus Stop
1	ISBT Kashmiri Gate	16	South Extension
2	Raj Ghat	17	AIIMS -1
3	IG Stadium	18	AIIMS-2
4	IP Power Station	19	Yusuf Sarai
5	IP Depot	20	Green Park
6	Railway Road Bridge	21	Hauz Khas
7	Nizamuddin Road Bridge	22	Padmini Enclave
8	Sarai Kale Khan	23	IIT Gate
9	Gurudwara Bala Sahib	24	Adchini Village
10	Maharani Bagh	25	MMTC
11	Nehru Nagar	26	PTS
12	Sri Niwas Puri	27	DDF Flats Lado Sarai
13	Lajpat Nagar	28	Qutub Minar
14	Gupta Market	29	Mehrauli Terminal
15	Andrew Ganj		

III. Selection of Urban Bus Route

Delhi being the capital city of India covers an urban area of 700 km^2. Delhi has the highest road densities in India but due to interminable expansion in population and number of vehicles, there is a consistent increase in demand of infrastructure over the years. This has led to severe traffic problems of congestion, delays, safety and pollution on Delhi's roads. Thus, it is essential to assess the transportation problem and assimilate possible solutions.

The urban corridor selected for the study has a length of 27.4 km, covering six intersections, five flyovers and 29 bus stops. This corridor consisting of six lanes as well as an eight lane divided road network that covers significant areas of the city. It starts from the Kashmiri Gate Interstate Bus Terminal (ISBT) and passing through inner ring road and then through Sri Aurobindo Marg ending at Mehrauli Terminal. Study area road network is shown in Fig. 2.

IV. Data Collection

Data collection has been conducted from May 28, 2016 to May 31, 2016 on urban bus route. During Data collection the following types of data has been collected to determine which locations in the selected urban corridor have the greatest transit demand. Data were collected for each run on the route. Therefore the total runs were 20 around 5 runs per day.

A. Primary Data

The primary data has been collected through field survey which includes the following:

1. Road Inventory Data

The road inventory data for the selected urban bus route has been collected through visual inspection. The data includes geometric details of the route, name of bus stops, distance between them and time taken by the bus in making one trip during the weekend and weekday, as shown in Table II.

TABLE II
ROAD INVENTORY DATA

S. No.	Details of Bus Route	ISBT to Mehrauli Terminal	
		Weekend	Weekday
1	Length	27.4 km	27.4 km
2	Travel Time	45 min to 1 hr 30 min	55 min to 1 hr 30 min
3	Number of Bus Stops	29	29
4	Number of Intersections	6	6
5	Number of Flyovers	5	5

2. Passenger - Bus Interaction Data

Passenger – Bus interaction data has been collected through site visit. For collecting the data the location was inside the bus for all the stops located along the bus route. Passenger – Bus interaction data discussed below includes bus arrival time and departure time, number of passenger boarding and alighting at each bus stop and the total trip time of bus.

a. Dwell Time Analysis

Dwell time is an important constituent of travel time because as it affects the quality of transit service. Calculation of dwell time at each stop is done by using Arrival and departure time. Dwell time at any stop (k) for a journey (j) is defined as difference between the departure time at stop k and arrival time at stop k as shown in (1):

$$DT_k = TD_k - TA_k \tag{1}$$

where, DT_k = bus dwell time at stop k, TD_k = bus departure time at stop k, TA_k = bus arrival time at stop k.

The average dwell time for all stops is shown in Figs. 3 (a)-(d). The figures show the average dwell time on 29 bus stops in upstream direction for weekend and weekday with peak and non peak hours. It is observed that Sarai Kale Khan bus stop has maximum dwell time in both peak and non peak hours.

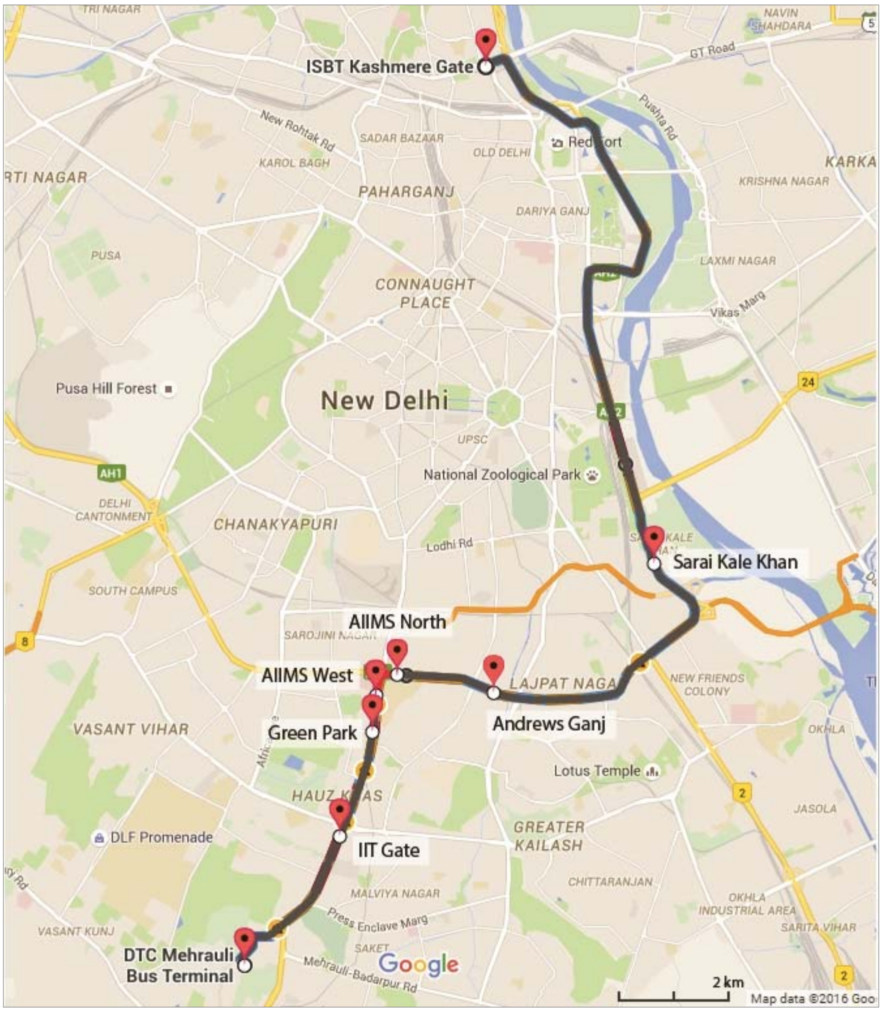

Fig. 2 Urban Corridor Selected for Study

b. Passenger Movement Analysis

Passenger's activity consists of two actions, i.e., Passengers Alighting (PA) and Passengers Boarding (PB). From the Figs. 3 (a)-(d) it is concluded that at maximum stops passenger boarding and alighting are in the range of one to 32 passengers and at some stops there is no passenger movement.

c. Travel Time Analysis

Travel Time is an important constituent of transportation system because it influences the efficiency of system and service fascination. Befitting of travel time attracts more number of commuters along the route and also augments their satisfaction. Travel time between any two stops k and k+1 for a journey j is defined as difference between the arrival time and departure time at stop k as shown in (2):

$$T_{k-k+1} = TA_{k+1} - TD_k \tag{2}$$

where, $T_{k\text{-}k+1}$ = travel between stop k and stop k+1 for journey j, TA_{k+1} = bus arrival time at stop k+1, TD_k = bus departure time at stop k.

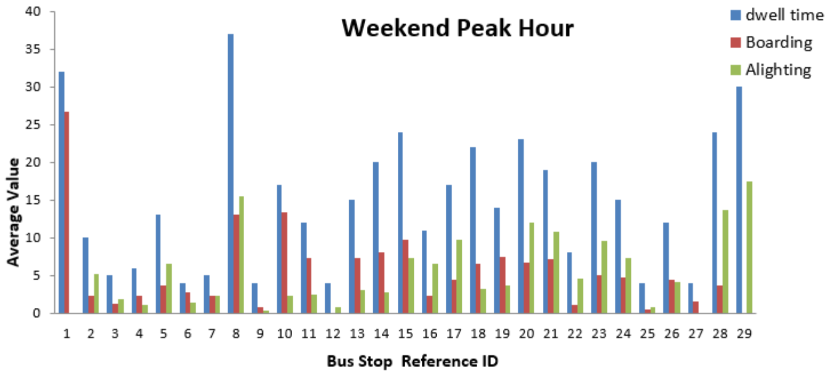

Fig. 3 (a) Dwell Time and Passenger Movement Analysis for Weekend Peak Hour

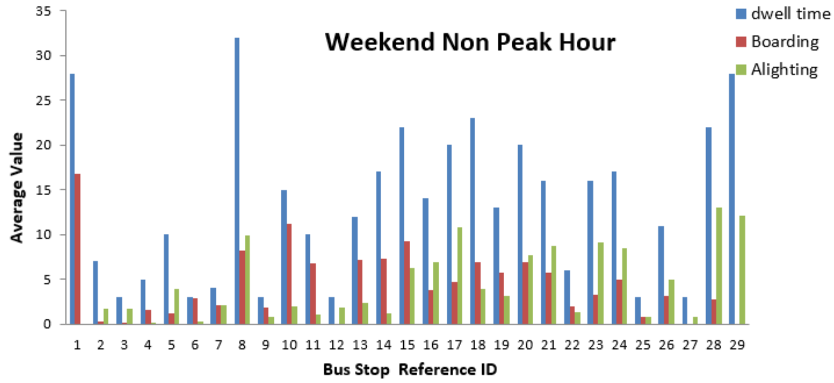

Fig. 3 (b) Dwell Time and Passenger Movement Analysis for Weekend Non Peak Hour

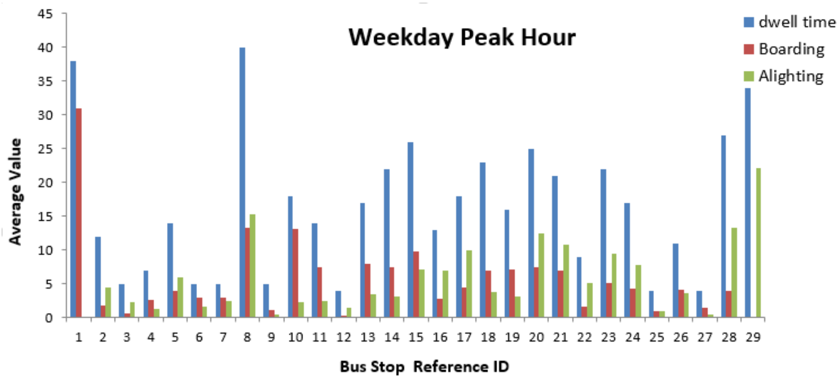

Fig. 3 (c) Dwell Time and Passenger Movement Analysis for Weekday Peak Hour

International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:11, No:10, 2017

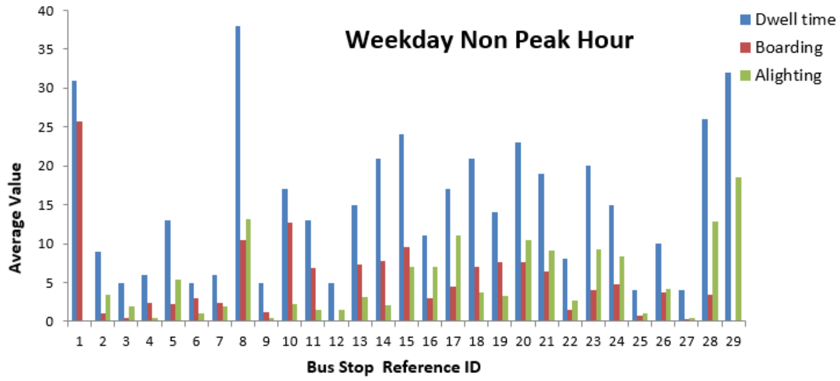

Fig. 3 (d) Dwell Time and Passenger Movement Analysis for Weekday Non Peak Hour

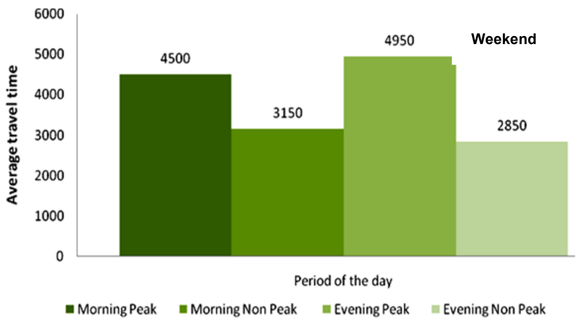

Fig. 4 (a) Average Travel Time Variations during Weekend

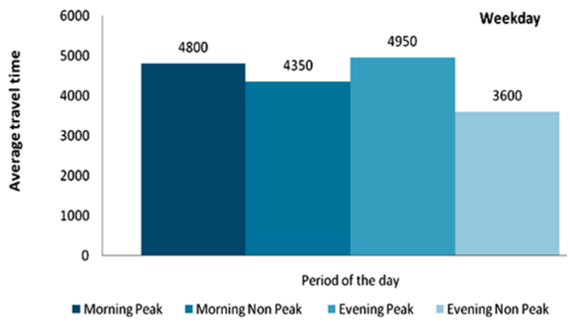

Fig. 4 (b) Average Travel Time Variations during Weekday

Figs. 4 (a) and (b) show the plot of average travel time variation for weekend and weekday during morning peak, morning off peak, evening peak and evening off-peak hours. From the figures, it is depicted that average travel time is generally higher during weekday and weekend evening peak hours and it also seems that pattern is intermittent in nature.

B. Secondary Data

The data are collected from sources like bus operating agency, Delhi Transport Corporation (DTC) and Delhi Master Plan 2021. The data collected were:

(i) Operation details of bus such as fleet size, frequency, operation and maintenance cost, etc.
(ii) Bus route map for the routes operated by DTC.
(iii) Location of bus stops.
(iv) Fare structure of bus.
(v) Future strategies for bus operation.

V. Data Analysis

A. Road Inventory Data Analysis

Exploratory Data Analysis (EDA) of road inventory data was done to describe the basic features of distance between the bus stops (in meters). Resultant from the analysis is shown in Table III.

B. Dwell Time Data Analysis

From the study it is identified that maximum stops are having dwell time between 3 to 40 seconds. Exploratory Data Analysis (EDA) was done to describe the basic features of dwell time and resultants from the analysis are shown in Table IV.

TABLE III
EDA Analysis of Distance between Bus Stops

Route	Statistics of Data				
	Minimum	**Maximum**	**Mean**	**Variance**	**Standard Deviation**
ISBT to Mehrauli Terminal	300	3900	969.64	534507.28	731.10

TABLE IV
EDA Analysis for Dwell Time

Route	Statistics of Data				
	Minimum	**Maximum**	**Mean**	**Variance**	**Standard Deviation**
ISBT to Mehrauli Terminal	3	40	14.91	85.37	9.24

C. Passenger Movement Analysis

EDA was done to describe the basic characteristics of passenger boarding and alighting and outcomes from the analysis, as shown in Tables V and VI, respectively.

TABLE V
EDA Analysis for Passenger Boarding

Route	Statistics of Data				
	Minimum	**Maximum**	**Mean**	**Variance**	**Standard Deviation**
ISBT to Mehrauli Terminal	0	31	5.00	26.30	5.13

TABLE VI
EDA ANALYSIS FOR PASSENGER ALIGHTING

Route	Statistics of Data				
	Minimum	**Maximum**	**Mean**	**Variance**	**Standard Deviation**
ISBT to Mehrauli Terminal	0	22	5.13	21.68	4.66

VI. CONCLUSIONS

This paper presents an approach which can be used to analyze the parameters affecting service time of the buses running on an urban route. The data collected can be further used to develop a generalized service time model for upstream direction of the bus. It is concluded that service time can be expressed in terms of alighting and boarding of passengers with others factors can also be taken into consideration. Using the above data analysis, parameters which are illustrated can be used as independent variables for developing a Speed Model for an urban bus route system. The models developed in future by the study conducted can be useful to transport engineer for planning day to day operation management, which can make the public transport service system effective and appealing in terms of faster travel time.

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