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Research Article

Statistical Modelling of Dwell Time of the public Buses by Bus Stop Type and Time of Day at Six Lane Road of Araniko Highway

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ABSTRACT

Dwell time (DT) contributes a major portion of the travel time. The deviation of the dwell time largely affects the travel time. In order to increase the effectiveness and efficiency of the public buses, it is important to understand the duration of time it takes to travel between the bus routes end terminals. The study is aimed at determining the dwell time and developing dwell time models for bus bays along Suryavinayk to Kausaltar road section of Araniko Highway taking into the consideration the bus bay types and time of travel. Using video graphic technology, the passengers' boarding and alighting times were recorded. The dwell time of public buses were modeled using regression analysis. The models were validated statistically. The geometry of all the bus bays under consideration were found similar in shape and size. In day-time, the average DT was 73.65 seconds for bus bays located near intersection while 51.65 seconds for mid-block. On the other hand the average dwell time near intersection were 56.15 and 45.24 seconds in morning and evening respectively. Similarly, for mid-block it was 48.06 and 34.21 seconds in evening and morning respectively. The dwell time prediction models were generated using alighting and boarding number of passengers as independent variable. From the model it is found that the effects of boarding on dwell time is 11.38% more than that of alighting. Furthermore, the analysis showed that the models were considered significant based on the type of bus bay and the time of travel. Based on R2, F-statistic and the model validation tests, it was found that the dwell time models were statistically significant at 95% confidence level

Keywords: Dwell Time, Bus Bays, Video Graphic Survey, Boarding and Alighting Number, Regression Analysis

Introduction

Public Transportation (PT) enables more people to make trip together or as single unit along designated routes for the different purposes e.g. for employment, community resources, medical care, education and recreation. Buses, microbuses and minibuses are the most common types of public buses which charge certain amount as fare to passengers and they operate on defined routes. An effective public transportation system makes optimal use of urban space, offers economical, efficient mobility and regular, scheduled access to places of employment, educational institutions, social gatherings, and recreational opportunities. Informal public transportation services are provided by private citizens or small enterprises in many developing nations when the government is not strongly dedicated to provide an effective formal public transportation system. These private operators are motivated for generating profits rather than providing economical and effective public service.

Dwell Time (DT) is duration a public transports stops at the particular locations to let passenger board and exit of the vehicles including the time it takes to open and close doors. The dwell time for public transport observed to be varied among means of transports, time of travel and the area it stopped for the boarding and alighting the passengers. A bus bay is a specific location where buses stop so that people can board or get off. There are three primary types of stops that are used for operations.

The travel demand has increased with increased in the population along Suryavinayak- Kausaltar Araniko road section. Even the entire area of the bus bays seems to be randomly used for boarding and alighting resulting into traffic congestion within bus bays. The most of trip time was spent at bus stop. Public transportation vehicles wait longer at Bus Bays (BB), which causes bus stacking and traffic jams. Even though the Dwell Time (DT) at each bus bay is typically only a few seconds, when added up over the course of the trip, it can account for a significant amount of the total travel time. Since dwell time accounts for a significant amount of trip time, deviations in dwell time have a substantial impact on both trip time and service reliability. Therefore, the first step to improve the public transit performance is by reducing dwell time and for effective trip assignments, in depth information on dwell time at bus bay is required. The understanding of boarding and dwelling of passenger and its impact on dwell time is the most significant for improving bus service levels. Therefore, a quantitative approach to estimate dwell time of public bus for serving Boarding Passenger (BP) and alighting passenger (AP) was developed that could be considered by public bus operator or concern government authority to provide efficient and effective public transport services.

Literature Review

School buses, charter services and sightseeing are not considered forms of public transportation; instead public transportation refers to any form of regular or special transportation offered to the general public. Public transportation consists of trolleys, trains, buses, and subways.[1] Effective public transportation utilizes urban space effectively, offers economical and efficient mobility and facilitates access to jobs, educational institutions, social, recreational, and commercial activities. Bus bays are a specially constructed space separated from the traffic lanes that provides space for the loading and unloading of passengers.

The transit capacity and quality of service manual[2] the bus stop is classified into three types based on the location namely far side bus stop, near side bus stop and midblock bus stop. Far side bus stop is bus stop immediately after passing through intersection. By permitting traffic to utilize the curb lane, it improves the capacity for right turns. When buses stop at this sort of bay, the intersection may become blocked during peak hours. A near-side bus stop is one that is located just before an intersection. This bus bay allows passenger to get in and out of buses while the bus is at a red signal. It gives the driver a chance to look for incoming traffic, including other buses that might contain passengers. Mid-block bus stop is bus stop within the block. This type of bus bay reduces sight distance problem for bus and pedestrians. The walking distance for pedestrian crossing intersections is increased by this kind of bus bay. Midblock bus bay encourage pedestrian crossing at midblock. The focus on present dwell time models is primarily on the quantity of passengers boarding and exiting. According to a bus dwell time methodology developed especially for BRT stations, passengers' average walking times at BRT sites are ten times longer than those at bus stops.[3]

In the transit network reliability analysis and transit assignment models, the bus dwell time functions are essential. Due to the buses' tendency to merge with the traffic in the shoulder lane, the bus dwell time had a high degree of uncertainty.[4] In order to model transit assignment, dwell time must be calculated since a precise dwell time estimate will produce a more precise transit assignment. More knowledge of the causes and consequences of factors that contribute to longer wait times at stops will facilitate the development of strategies to shorten wait times and improve the efficiency and dependability of public transportation.[5] As the primary delay that private vehicles in the network do not experience, dwell time is one of the most important variables that should be taken into account while upgrading the quality of bus transit services.[6] Up to 9%–11% of the total bus travel time can be attributed to bus dwell time. Public transportation systems'

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dependability has been considered crucial since passengers suffer negative effects from longer wait times, early or late arrivals at their destinations, and skipped connections, each of which intensify their discomfort and anxiety.[7]

Only small amounts of manually gathered data sets were used in earlier research on dwell time and time lost during serving stops in order to correlate dwell time. The use of automatic bus location and automatic passenger counter provides a rich set of dwell time for determination of dwell time. In addition large data helps in analysis of lift operation.[8] The amount of time spent on the bus and the number of passengers getting on and off has a strong correlation with the primary dwell time. It was found that dwell time was primarily influenced by passenger demand. Installing bus priority systems would not save as much time as lowering dwell time.[9] The rate of boarding and alighting of different types of bus shows that smaller the size of bus, higher is the time required to board and alight passenger. There is a significant correlation between the number of boarding, alighting, and off-bus transactions and the total dwell time.[10]

DT was measured three times a day, in the morning, midday, and evening. The analysis of the data for bus stops situated at mid-blocks revealed that the peak mid-day period had the highest average DT of 22.1 seconds. DT was typically 22.7 seconds in the morning, 32.5 seconds in the middle of the day, and 31.2 seconds in the evening for bus stops that were at intersections. Using simple ordinary least squares methods techniques with statistical inferences at a 95% confidence interval, the dwell time model for bus stops close to the intersection and mid-block was developed. Bus stops located at intersections have average dwell times are 22.7 seconds in the morning, 32.5 seconds in the middle of the day, and 31.2 seconds at evening. Additionally, the analysis showed that the models differed significantly depending on the type of bus stop and the time of day.[11]

During morning and evening peak hours, the amount of time needed to serve passengers is comparable, but during midday peak hours, more time is needed. It was also determined by the study that boarding times were longer than departure times.[12]

The most popular type of linear regression analysis is multiple linear regression. To explain the relationship between one continuous dependent variable and two or more independent variables, multiple linear regression is used as a predictive analysis. By fitting a linear equation to observed data, multiple linear regression (MLR) attempts to describe the relationship between two or more explanatory variables and a response variable. Due to its ability to explicitly control for numerous other factors that continuously affect the dependent variable, multiple regression is more suitable to analysis. In short, regression focuses at the relationship between the variables. In other word, it forecasts whether a significant relationship exists between the independent and dependent variables. The regression models are developed to predict the other points. The general form of these models is

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots\ldots + \beta_k x_k + \varepsilon \quad \ldots\ldots(1)$$

Where,

y = dependent variable i.e. the variable to be estimated

x1, x2, x3,.....xk = independent variables i.e. observed variables

β1, β2, β3, ..., βk = coefficients;

β0 is the intercept and other coefficients are regression coefficients

ε = random error

R-squared is a statistical metric that quantifies the extent to which variation in the independent variables can account for variation in the outcome. Even though additional predictors may not be associated to the outcome variable, R-squared always rises as they are added to the MLR model.

Therefore, it is not possible to determine which predictors should be included in a model and which should be excluded using R-squared alone. R^2 can only have a value between 0 and 1, where 0 means that none of the independent variables can predict the outcome and 1 means that all of the independent variables can predict the outcome accurately.

Generalized regression model for dwell time for bus stops situated near the intersection and at mid-block time period of day[11]

$$DT_{am} = 1.13P_a + 3.34P_b \quad \ldots\ldots(2)$$

$$DT_{mid} = 1.89P_a + 5.48P_b \quad \ldots\ldots(3)$$

$$DT_{pm} = 12.61P_a + 4.29P_b \quad \ldots\ldots(4)$$

Where,

DT_{am} = Dwell time at morning

DT_{mid} = Dwell time at mid of day

DT_{pm} = Dwell time at evening

P_a = Numbers of alighting passengers

P_b = Numbers of boarding passengers

A simple regression methodology was used to analyses and forecast bus dwell time for bus stops across US cities[13]

The dwell time was calculated as

DT = 5.0 + 2.75 N..........(5)

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Where,

DT = Total dwell time

N = The summation of boarding and alighting passengers

A simple linear equation was developed using boarding and alighting numbers for predicting dwell time [14]

DT = 1.31 + 2.573*BA...(6)

Where

BA = number of boarding and alighting at a bus stop.

Methodology

This research was based on quantitative and qualitative analysis. The numbers of boarding and alighting passengers number of doors in bus and dwell time were measured and were analyzed using statistical procedure. Passenger and driver behavior were qualitative but they were measured objectively rather than the subjective using standard techniques.

Study Area

The Suryavinayak-Kausaltar road, 6.3 km in length is part of Araniko Highway. The road is of six lane. The road is upgraded and facilitated with traffic sign and signal and road marking. Among different bus bays in section from Suryavinayak-Kausaltar at Araniko Highway, five bus bays were selected randomly which are located on the Suryavinyak Kausaltar road section on the basis of route being covered by public buses. They were Suryavinayak bus bay, Sallaghari bus bay, Thimi bus bay, Gathaghar bus stop and Kausaltar bus bay.

Suryavinayak bus stop serves the public buses and passengers along more than 9 routes. Public buses which operate along different routes make their stop here. The bus bay is trapezoidal in shape. It is located nearby intersection and overhead bridge. Sallaghari bus bay serves the public buses and passengers along more than 9 routes from Bhaktapur to Kathmandu, Lalitpur and Kavrepalanchok district. All types of public buses which operate along different routes make their stop here. It is located adjacent to six lane road and is nearby intersection and overhead bridge. The overhead bridge is located at the end of bus bay. Thimi bus bay serves the public buses and passengers along more than 9 routes from Bhaktapur to Kathmandu, Lalitpur. It is located in the vicinity of residential area, institutional and commercial area. From this location mini buses are operated to rural area of Thimi. All types of public buses which operate along different routes make their stop here for the boarding and alighting passenger. It is located adjacent to six lane road and overhead bridge. It is near to intersection at both end i.e. at entry and exit of bus bay. Gathaghar bus bay serves the public bus and passengers along more than 11 routes from Bhaktapur to Kathmandu, Lalitpur. It is located adjacent to six lane road. It is of trapezoidal shape. This bus bays is located nearby intersection. Kausaltar bus bay serves the public bus and passengers along more than 12 routes from Bhaktapur to Kathmandu, Lalitpur. It is located adjacent to six lane road near by intersection and fly over bridge. It is of trapezoidal shape. It is located nearby intersection.

Data Collection

Primary and secondary data were used in studying dwell time. The methods of primary data collection that was used for the collection of data in this study were video graphic survey and observation method. The secondary source of data were used for study of dwell time at bus bays and they were Journals, Books, Thesis papers and Conference Papers.

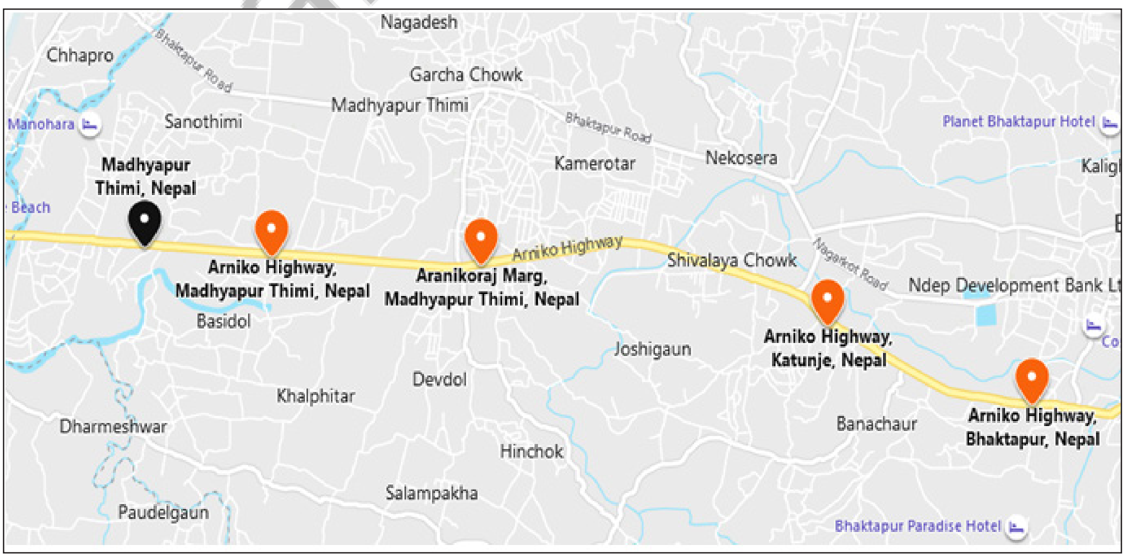

Figure 1.Detail map of study area

(Source: Google,2023)

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Video Graphic Survey

The videos were recorded between 9 am to 10 am, 1 pm to 2 pm and 5 pm to 6 pm for 3 days at each bus bays for weekdays. The observer with cameras positioned on the top of overhead bridge ensuring that he won't be noticed by driver, conductor and passengers boarding and alighting. The observer with camera stood in overhead bridge in such way that the public buses and passengers boarding and alighting were clearly visible. From the video following information were obtained.

- Boarding and alighting passengers number

There are two sorts of passengers recorded during video graphic and they are

- Primary boarding and alighting passengers

Primary boarding passengers are passenger who get into the buses after the buses stopped at bus bay and alighting passengers are passengers who get out of the buses as the buses stopped at the bus bays.

- Secondary passengers

They are one who enter into the bus after certain time the bus have stopped at bus bay and completed primary boarding and alighting.

Seat occupancy before buses enter the bus bay for boarding and alighting.

- Location of bus within bus stop for boarding and alighting passenger

The number of buses that stop in bus bay and shoulder near to bus bay at

- Entry of bus bay
- Middle of bus bay.
- Exit of bus bay

Data Analysis

Determination of dwell time

The dwell time was noted during data collection. The dwell time was calculated as

$$t^i = t^i_{depart} - t^i_{arrive} \quad \text{...(7)}$$

Where,

t^i = dwell time for bus i

t^i_{depart} = time bus i depart from stop

t^i_{arrive} = time bus i arrives at stop

Statistical and Multiple Regression Analysis

The method of multiple regression analysis was used to look into the variables affecting the public bus's dwell time. Dwell time was the dependent variable, and the independent variables were the type of bus, dwell time, crowding on the platform and inside the bus, and the number of passengers who boarded or alighted. The general form of model was

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots\cdots + \beta_k x_k + \varepsilon \quad \text{.................(8)}$$

Where,

y = dependent variable i.e. the variable to be estimated

$x_1, x_2, x_3, \ldots x_k$ = independent variables i.e. observed variables

$\beta_1, \beta_2, \beta_3, \ldots, \beta_k$ = coefficients;

β_0 is the intercept

ε = random error

Multiple regressions were performed by means of statistical software such as Microsoft Excel/ Statistical Package for the Social Sciences (SPSS). The best regression with highest R^2 value was selected. The level of significance was taken as 95%.

Model Validation

After development of the model, the model was statistically validated based on the test of significance of variables and test of goodness of fit. Statistical tests such R-square and F-statistics were carried out for model validation. The model was validated by using the data that were not used in generating models. Approximately 10% data were used for model validation.

Results and Discussion

Video graphic records were studied to find the quantity of boarding and alighting passengers. The detail regarding numbers of boarding and alighting passenger is shown in figure 2.

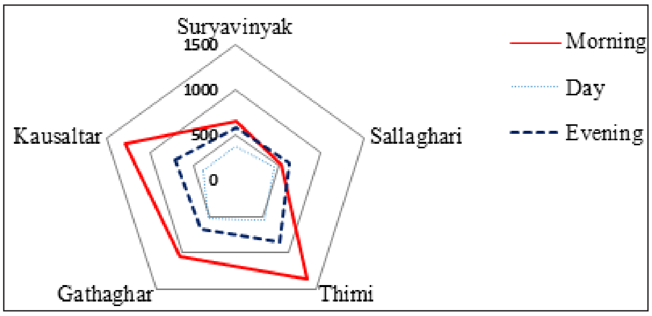

Figure 2.Number of boarding and alighting passengers by time period

From the analysis, it was observed that the total numbers of boarding and alighting passengers was greater during morning and evening than day time.

Dwell Time of Public Buses by Time Period

The dwell time of buses were observed for three different time period i.e. morning, day and evening at different bus bay under study area for 9 hours for each bus bays with help of video graphic survey. The time period once it entered the bus bay and after it left were noted down

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to calculate the dwell time. Similarly, the time for primary boarding and alighting was also ascertained from the video captured at different bus bay. The statistical analysis was carried out and the average dwell time was observed more during day time. The detail regarding dwell time of buses is shown in the table 1.

It was observed that the dwell time for bus bay was more during day time than during morning and evening. The dwell time of the buses varied from 18.9 to 52.7 seconds during morning time period while it varied from 24.1 to 86.2 seconds at day time and 20.4 to 75.7 seconds at evening time period. The possible influences of traffic, signal operations, pedestrian crossings, congestion, and parking maneuvers could be the cause of this.

Dwell Time of Public Buses by Bus Bay Types and Time of Day.

As shown in figure 3, dwell time of buses was observed to be more during day time than morning and evening since the buses were partially full and drivers stopped for more duration at bus bays waiting for more boarding passengers. Similarly, signal delay and bus stop failure in case of near end types of bus bay and queuing of buses behind entry point of bus bay in case of far end type of bus bay causes traffic congestion in traffic stream and contribute for increase dwell time.

Table 1.Dwell time of public bus

Sn	Location	Time period	Dwell time (Seconds)	
			Mean	Standard Deviation
1	Suryavinayak	Morning	49.7	55.9
		Day	79.2	83.6
		Evening	75.7	80.0
2	Sallaghari	Morning	18.9	12.9
		Day	24.1	27.1
		Evening	20.4	14.7
3	Thimi	Morning	42.1	45.5
		Day	51.1	61.9
		Evening	41.8	52.8
4	Gathagar	Morning	40.9	181.8
		Day	86.2	61.4
		Evening	61.4	51.2
5	Kausaltar	Morning	52.7	41.7
		Day	83.7	72.2
		Evening	65.3	56.5

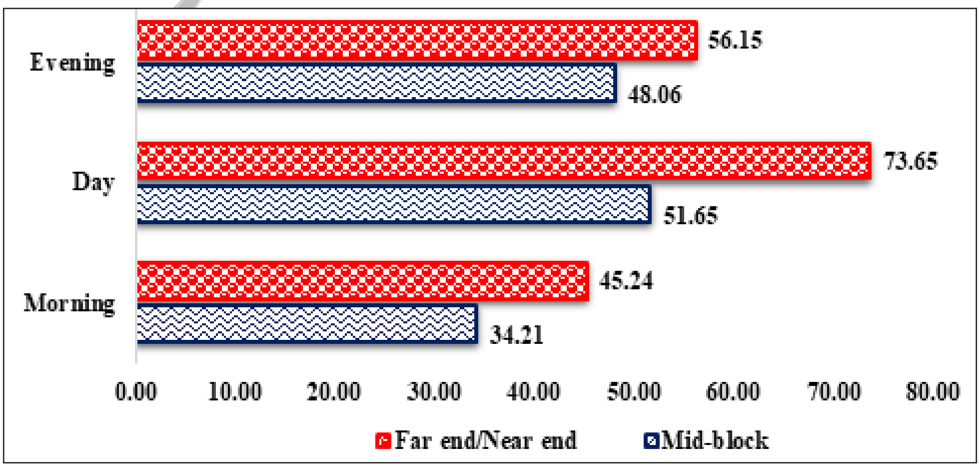

Figure 3 Average dwell time (second) of bus bay by location and by time of day

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For the bus bay situated at mid-block, the mean dwell time during mid-day was 51.65 second which was greater than average dwell time for mid-block bus bay observed at evening and morning time. It was observed that average dwell time for midblock bus bay was lower than that for far end and near end intersection as shown in the figure 3. Similarly, the average dwell time for far and near end bus bay was observed greater at day time i.e. 73.65 seconds than that was observed at evening and morning time. The average dwell time for far and near end bus bay was 56.15 seconds and 45.24 seconds at evening and morning time respectively. From the analysis results, it can be determined that DT's differ based on the bus bay location and time of day and was lower for the mid-block type of bus bay than far end and near end type of bus. The possible influences of traffic, signal operations, pedestrian crossings, congestion, and parking maneuvers could be the cause of this, which are more at near end and far end type of bus bays than mid-block types of bus bays.

Dwell Time of Observed Bus by Position in Bus Bay

The detail regarding the dwell time by position within the bus bay for the purpose of boarding and alighting the passengers are shown below figure 4.

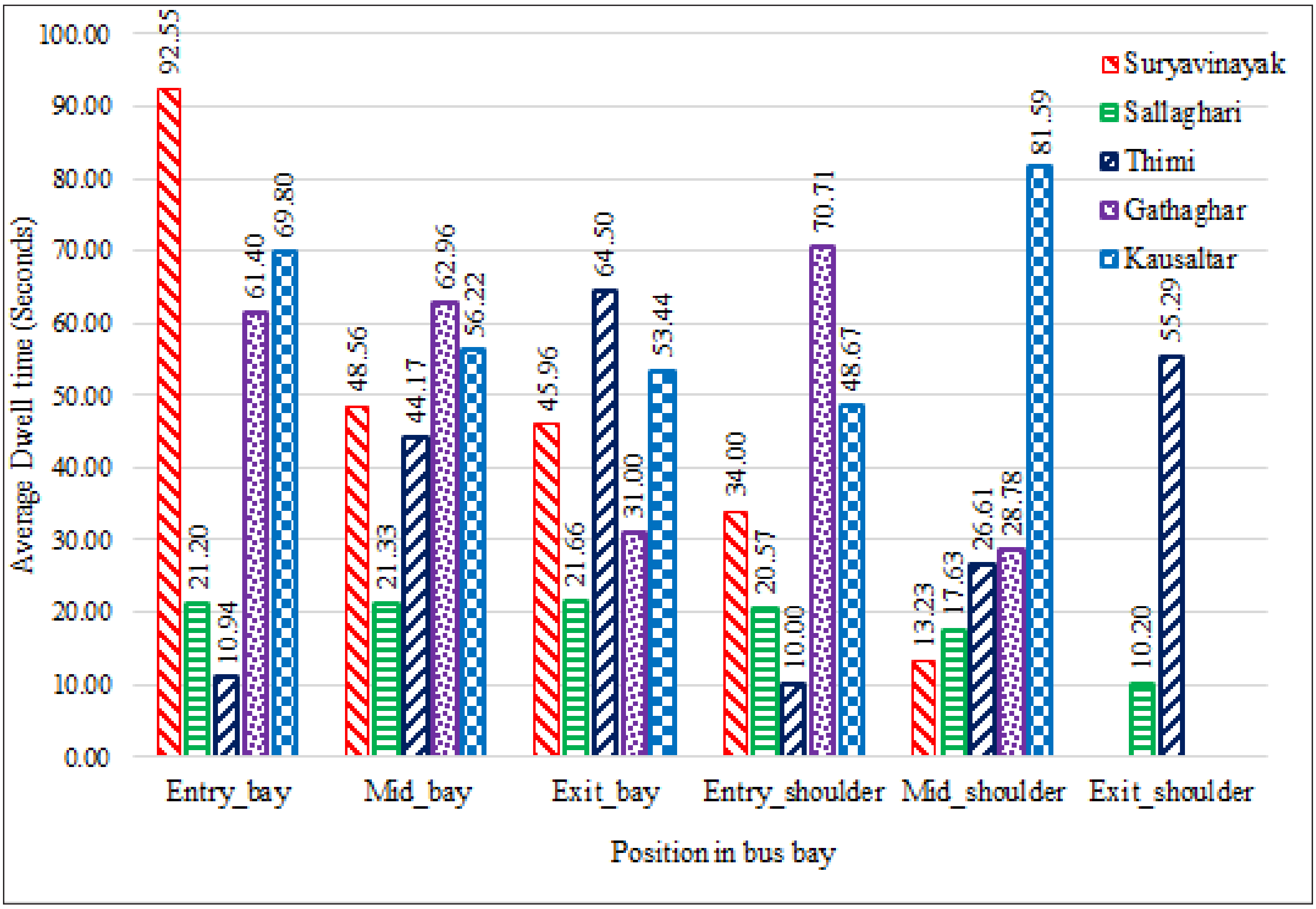

Figure 4. Average Dwell time by position within bus bay

Far-Side Type Bus Bay

The detail regarding average dwell time by position within bus bay for far side bus bay is shown in the table 2.

This type of bus bay includes Kausaltar bus bay and Gathaghar bus bay. At far-side type of bus bay the dwell time at entry of bay was observed to be 65.60 seconds in average which was larger than dwell time when the bus was stopped at different location within the bus bay. In this context, when a bus stops at an entry, it causes traffic to back up into the intersection because the bus is stooped in the travel lane. Besides this, passengers had to walk extra distance which in turn increased the dwell time of buses.

Near Side Type Bus Bay

This type of bus bay includes Thimi bus bay. The dwell time of public buses that stopped for the purpose of boarding and alighting by the position within the bus bay was analyzed and shown in the table 3.

Table 2 Average dwell time by position within bus bay

Position in bay	Average Dwell time (seconds)
Entry bay	65.60
Mid-day	59.59
Exit bay	42.22
Entry shoulder	59.69
Mid shoulder	55.18
Exit shoulder	0.00

Table 3 Average dwell time by position within bus bay

Position in bay	Average Dwell time (seconds)
Entry bay	10.94
Mid-day	44.17
Exit bay	64.50
Entry shoulder	10.00
Mid shoulder	26.61
Exit shoulder	55.29

The dwell time at exit of bay in the case of near side type of bus bay was observed larger than in other position within the bus bay. As the exit is immediately prior to an intersection, this bus bay allow the boarding and alighting passenger to board and alight while the bus is at a red signal. It results in a longer dwell time and gives the driver the chance to look for incoming traffic, including other buses carrying possible passengers.

Mid Block Bus Bay

This type of bus bay includes the Suryavinayak bus bay and Sallaghari bus bay of study area. The detail regarding dwell time is shown below in the table 4.

Table 4.Average dwell time by position within bus bay

Position in bay	Average Dwell time (seconds)
Entry bay	56.87
Mid-bay	34.94
Exit bay	33.81
Entry shoulder	27.29
Mid shoulder	15.43
Exit shoulder	5.10

At midblock type bus bay the dwell time at entry of bay was observed to be 56.87 seconds in average which was larger than dwell time when the bus was stopped at location other than entry within the bus bay. In this context, the passenger walking distance is increased as the public buses were queued behind entry of bus bay. As a result the dwell time of the public buses being stopped at entry for boarding and alighting of passengers is increased. From the analysis it was observed that the driver's choice of preferring location within the bus bay varied with types of bus bay and the dwell time of the bus also varied accordingly. The mid-block type of bus bay have the minimum dwell time in comparison to two remaining type of the bus bay. Therefore, it is recommended to prefer mid-block type of bus bay for boarding and alighting the passengers.

Regression Analysis

The main objective of this study is the development of dwell model. The models were developed using multiple regression analysis. The regression coefficients of the final models were examined at the 5% significance level. Additionally, the F-test (ANOVA) was used to test the overall statistical significance of each regression model for each type of bus stop, with a 5% significance level.

Table 5.Significance of model coefficient for bus at far end

Variables	DT_m	DT_d	DT_e
AP	0.000	0.000	0.000
BP	0.00	0.000	0.000
SO	0.684	0.802	0.237
BB	0.728	0.213	0.002
ST	0.190	0.455	0.327
DN	0.680	0.634	0.628

Table 6.Significance of model coefficient for bus bay of near end

Variables	DT_m	DT_d	DT_e
AP	0.000	0.000	0.000
BP	0.00	0.000	0.000
SO	0.257	0.759	0.016
BB	0.431	0.664	0.266
ST	0.002	0.507	0.886
DN	0.281	0.925	0.407

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Table 7.Significance of model coefficient for bus bay of mid-block type

Variables	DT_m	DT_d	DT_e
AP	0.000	0.000	0.000
BP	0.000	0.000	0.000
SO	0.993	0.156	0.863
BB	0.175	0.438	0.797
ST	0.041	0.004	0.001
DN	0.442	0.800	0.158

AP Alighting passenger numbers

BP Boarding passenger numbers

SO Seat occupancy

BB Bus position in bus bay

ST Steps numbers

DN Doors numbers

DT Dwell Time

The results presented in the table 5, 6 and 7 shows that boarding numbers of passenger and alighting number of passenger contribute significantly to the prediction of dwell time. Considering correlation is significant at 0.01 level, the number of boarding and alighting passengers contribute significantly to the prediction of dwell time. Hence, primary boarding passenger number and alighting passenger number are only used for developing the dwell time model. The dwell time was used as the dependent variables and numbers of boarding and alighting passenger used as independent variables. Based on this, the regression models and related statistics are shown in the table 8, 9 and 10.

Table 8.Multiple regression models by bus bay type and time

Types of bus	Time period	Dwell time models	R-square	Standard Error
Far end	Morning	DT = 0.978 + 3.320BP + 3.142AP	0.741	5.369
	Day	DT = 0.632 + 2.642BP + 2.638AP	0.756	2.778
	Evening	DT = 0.342 + 3.401BP + 2.920AP	0.76	4.374

Table 9.Multiple regression models by bus bay type and time

Types of bus	Time period	Dwell time models	R-square	Standard Error
Near end	Morning	DT = 0.992 + 3.317BP + 3.254AP	0.759	5.965
	Day	DT = 1.573 + 2.482BP + 2.281AP	0.618	3.251
	Evening	DT = 1.717 + 2.224BP + 2.093AP	0.678	3.927

Table 10.Mulqwtiple regression models by bus bay type and time

Types of bus	Time period	Dwell time models	R-square	Standard Error
Mid-Block	Morning	DT = 0.873 + 2.736BP + 2.634AP	0.846	3.139
	Day	DT = 0.942 + 2.823BP + 2.787AP	0.773	2.773
	Evening	DT = 0.939 + 2.745BP + 2.510AP	0.794	3.154

DT = Dwell Time AP = Alighting Passenger number BP = Boarding Passenger Number

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Model Validation

Statistical tests such R-square and F-statistics were carried out for model validation. A comparison between observed dwell time and calculated dwell time from the model was made.

Dwell time model for far end type bus bay during morning was

DT = 0.978 + 3.320B + 3.142A.

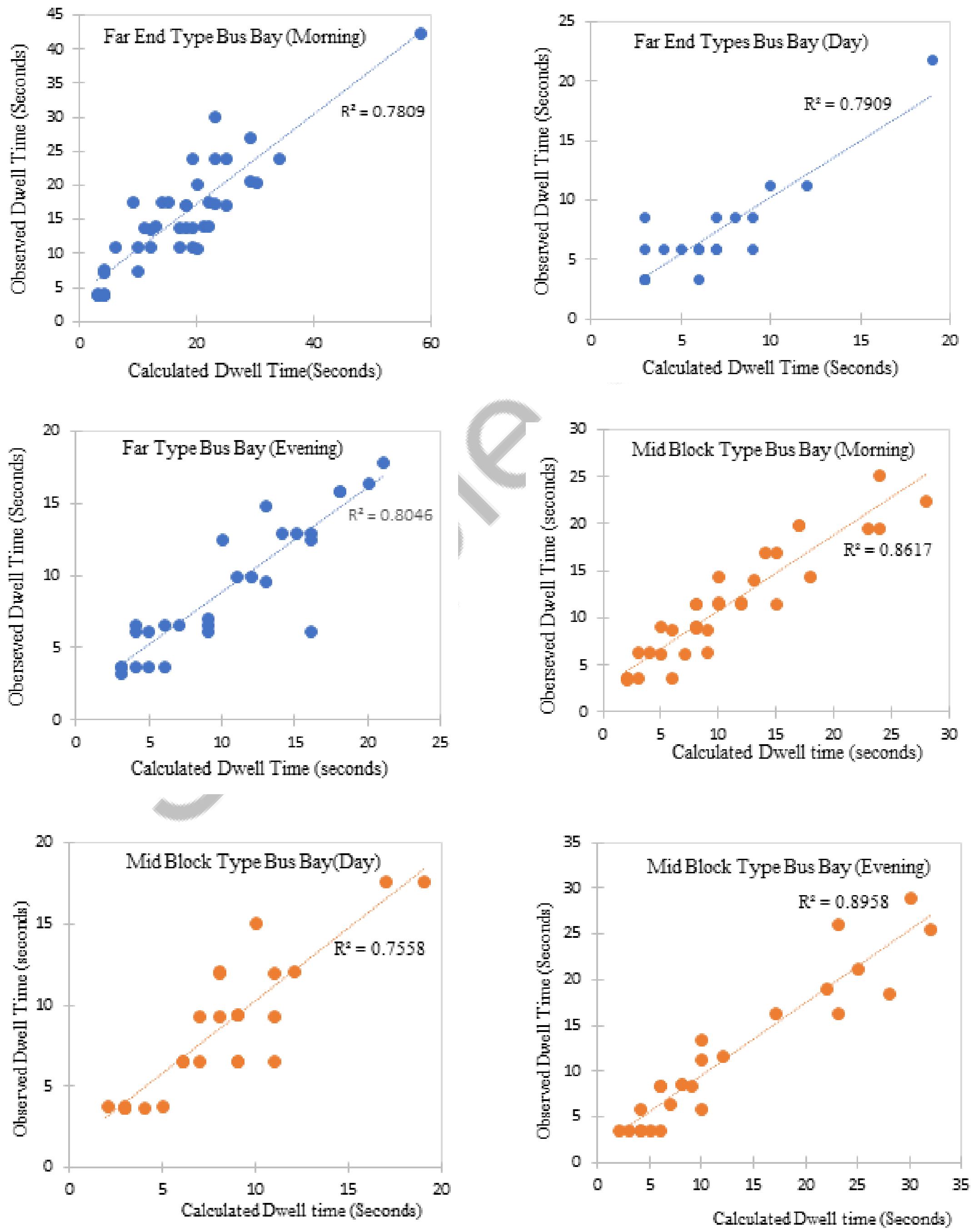
The dwell time was calculated from model above and regression line was made.

The sum of squares regression (SSR) = 3585.838

The sum of total variation (SST) = SSR + SSE = 3585.838+ 1005.967 = 4591.805

$$R^2 = \frac{SSR}{SST} = \frac{3585.838}{1005.967} = 0.781$$

Similarly, Statistical tests such R-square and F-statistics were carried for near end and mid-block type bus bay. R^2 obtained from linear regression between observed dwell time and calculated dwell time for three different time of day i.e. morning, day and evening are shown figure 5.



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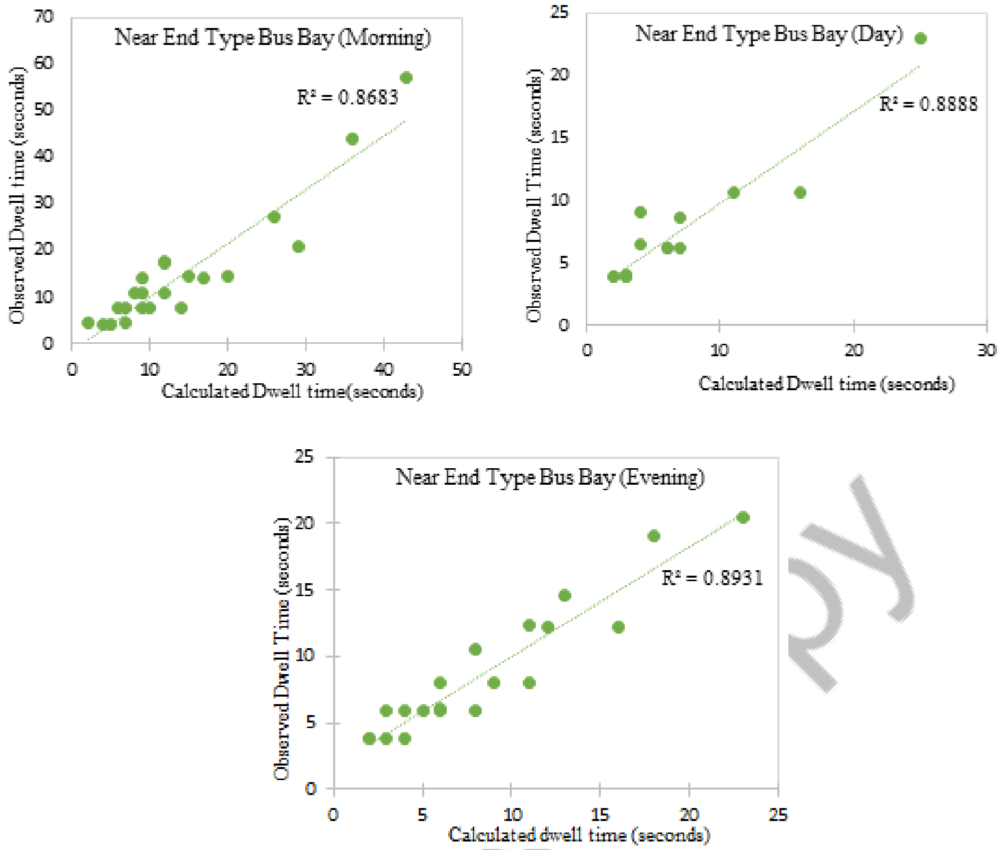

Figure 5.Plot of Observed Dwell Time vs Calculated Dwell time for different bus bay at different time of day

The results of ANOVA test also displayed statistically significant F-statistics (1.98E-14) ($p<0.05$). The regression statistics and ANOVA test for model validation is shown table 11 and table 12.

Table 11.Regression statistics for model validation for bus bay type

Types of bus bay	Regression Statistics	Morning	Day	Evening
Far end	Multiple R	0.883697	0.889327	0.897003
	R Square	0.780921	0.790902	0.804615
	Adjusted R Square	0.775304	0.779286	0.7971
	Standard Error	5.078782	1.856039	2.551674
Mid-Block	Multiple R	0.928268	0.869346	0.946445
	R Square	0.861682	0.755763	0.895757
	Adjusted R Square	0.85736	0.744661	0.891225
	Standard Error	2.588905	2.101905	3.096941
Near End	Multiple R	0.931814	0.942756	0.945031
	R Square	0.868277	0.888789	0.893084
	Adjusted R Square	0.861691	0.879521	0.887144
	Standard Error	3.9469	2.234853	1.91748

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Table 12 Anova

Location		SS	MS	F	Significance F
Far End	Morning	3585.838	3585.838	139.0181	1.98E-14
	Day	234.5421	234.5421	68.08423	1.57E-07
	Evening	697.1416	697.1416	107.0707	1.04E-10
Mid-block	Morning	1336.14	1336.14	199.3515	2.69E-15
	Day	300.7622	300.7622	68.07649	3.52E-08
	Evening	1895.566	1895.566	197.6392	8.83E-13
Near end	Morning	2053.712	2053.712	131.8339	2.95E-10
	Day	478.9938	478.9938	95.90298	4.49E-07
	Evening	552.8188	552.8188	150.3561	3.56E-10

The R-square is 0.781 for far end (morning) which specifies that there is a significant positive relationship between observed and calculated dwell time during morning time i.e. 78.1 % data were closed fitted to best regression line. The comparative analysis's outcome shows that the model satisfactorily represents actual data.

The calculated dwell time and the observed dwell time were closely fitted to the best regression line, supporting the alternate hypothesis that should be accepted more strongly than the null hypothesis, as indicated by the p-value being less than alpha value 0.05. The suggested model for dwell times in the bus bay is considered valid based on the obtained results.

The summary of regression statistics R-square and significance F is shown in the table 13.

Table 13.Summary of Regression statistics for model validation (bus bay type)

Types of bus	Time period	Dwell time models	R-square	Significance F
Far End	Morning	DT = 0.978 + 3.320BP + 3.142AP	0.781	1.98E-14
	Day	DT = 0.632 + 2.642BP + 2.638AP	0.791	1.57E-07
	Evening	DT = 0.342 + 3.401BP + 2.920AP	0.804	1.04E-10
Near end	Morning	DT = 0.992 + 3.317BP + 3.254AP	0.868	2.95E-10
	Day	DT = 1.573 + 2.482BP + 2.281AP	0.889	4.49E-07
	Evening	DT = 1.717 + 2.224BP + 2.093AP	0.893	3.56E-10
Near end	Morning	DT = 0.873 + 2.736BP + 2.634AP	0.862	2.69E-15
	Day	DT = 0.942 + 2.823BP + 2.787AP	0.756	3.52E-08
	Evening	DT = 0.939 + 2.745BP + 2.510AP	0.896	8.83E-13

DT = Dwell Time AP = Alighting Passenger Number BP = Boarding Passenger Number

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Conclusion and Recommendation

The dwell time of the public buses was found to be more during mid of the day. For bus bay located at intersection, the average dwell time were 56.15 seconds in the evening, 45.24 seconds in the morning and 73.65 seconds during the day time. Similarly, the average dwell time of mid-block bus bay were 48.06 seconds on the evening, 51.65 seconds on the mid-day and 34.21 seconds during morning. The dwell time of the public buses was affected by position where the driver prefer to stop the bus with bus bay. A very huge proportion of buses were stopped at entry and exit of bus bay. From the study, it was observed that about 45.4% buses were stopped at mid of bus bay which results in underutilization of other space of bus bay. This results in accumulation of the buses at entry and exit of bus bay and passenger had to walk further from waiting area to board in the buses. At midblock type bus bay, the dwell time at entry of bay (in average 58.87 seconds) was larger than the buses stopped at different location. Similarly, at far-side type of bus bay, the dwell time at entry of bay (in average 65.60 seconds) was larger than the buses stopped at different location. The dwell time at exit of bay (in average 64.50 seconds) in the case of near side type of bus bay, was observed larger than in other position within the bus bay. The possible impact of intersection interactions, including traffic, signals, pedestrian crossings, parking, etc., can be attributed for it.

Multiple regression analysis was used for developing the models, and all the statistical findings were drawn with a 95% confidence interval. The results of the ANOVA tests also showed statistically significant F-statistics ($p<0.05$). The dwell models generated for bus bay types revealed that number of boarding passengers affected dwell time of bus more than number of alighting passengers. It was observed from model for bus, effects of number of boarding passenger on dwell time was in average 11.38% more than number of alighting passengers in. It was observed from model for route, effects of number of boarding passenger on dwell time was in average 19.74% more than number of alighting passengers. Similarly, it was observed boarding number affects 7.62%, 5.37% and 4.70% more than alighting number of passenger from dwell time models for far, near and end type bus bay respectively.

Recommendation

With effort to study dwell time and dwell time models as the main objectives through this research, its scope would be widened to enhance the performance characteristics of the public buses with following recommendations.

Department of Transport Management can work out on provision for replacing small sizes buses by low floor large buses with appropriate double channel based on passenger demand for boarding and alighting which are more user friendly and helpful to reduce dwell time. These models can be implemented by the concerned authorities in order to shorten the dwell time at bus bays along at highway.

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