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Dwell Time Variability at Bus Bays at Six Lane Road of Araniko Highway: Impact of Passenger Attributes and Bus Variation

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ABSTRACT: This paper investigates the variation in dwell time at bus bays along the Araniko Highway's six lanes road section, focusing on the impact of bus variations and passenger characteristics. Dwell time, defines as the duration a bus remains at a station for passenger to board and alight, plays a crucial role in transit effectiveness. Understanding the factors contributing to its variability is essential for optimizing transportation system. The study showed that passenger carrying kids, elderly passengers and children had the longest boarding times. Additionally, the presence of steps at door slows down the boarding and alighting process, resulting longer duration for elderly passenger, passenger carrying small kids and children to alight than for teenager. This study aims to explore the behaviour of the driver concerning the length of stops. The analysis revealed that buses stopping to pick up additional passengers remained stopped for longer period. Compared to the young teenagers, elderly passengers boarded and alighted at a rate that was 17.23% higher. In conclusion, allowing more time for elderly passengers to board and alight is recommend. Similarly, the average rate of boarding and alighting for children and passenger with kids were 7% and 11.5% higher than young teenagers respectively. Multiple regression models were generated for this investigation using alighting and boarding number of passengers. All statistical conclusions were derived with a 95% confidence interval. Based on the R-squared, F-Statistic, and model validation tests, it was determined that the dwell time models developed were statistically significant at a 95% confidence level. In conclusion, this study highlights the significance of impact of passenger attributes and bus variation at the bus bays on the dwell time variability along the Araniko Highway in optimizing bus services reliability and improve overall transit performance.

KEYWORDS: Dwell time; Public Transportation; Passenger's Characteristics; Transporation Mode; Regression Analysis

1. INTRODUCTION

Public transportation (PT) enables people to access jobs, local resources, healthcare, and leisure activities within communities, fostering effective urban mobility. An effective PT optimize urban space while providing affordable, effective mobility and access to places of work, educational institutions, social and recreational venues, and commercial business. Buses, minibuses, and micro buses constitute a commonly crowded form of public transportation. In order to facilitate the movement of people and products while minimizing traffic congestion and environmental effect, efficient public transportation networks are essential parts of modern urban infrastructure. The amount of time passengers spend in bus bays is one of the key requirements that determines how successful public transportation is in terms of both service dependability and customer happiness. The Araniko Highway is a crucial transit route for commuters and travelers, linking Kathmandu, the capital city of Nepal, with other major towns and cities. It is characterized by heavy traffic volumes. For efficient traffic flow and reliable public transportation services, bus bays along this roadway must operate effectively. It is clear that the Kathmandu Valley is investing a lot of money in the development of its public transportation infrastructure. However, the management and operation of public transportation remain largely unchanged from the services that are currently provided by conventional means.

The amount of time a public transportation vehicle stops at specific locations for passengers to board and alight, including door opening and closing, is known as dwell time (DT). Bus stacking and congestion occur when buses remain at bus bays for extended periods of time. This causes the trip to take longer, which raises the overall trip time. When buses deviate from the schedule in any timetable-based operation, it can result in a decline in service reliability, create a bus queue, and cause noticeable delays for passengers. A bus bay's dwell time is typically only a few seconds, but when added up over the course of the trip, it can account for a significant amount of the total trip time. Indeed, dwell time may be the source of variability of the total trip time. To ensure effective and efficient operation, dwell time estimation is crucial. The key for improving bus service levels is having a better understanding of passenger boarding, dwelling, and dwell time. In particular, the effects of passenger characteristics and bus variation will be examined as this study focuses at the variance in dwell time at bus bays along the six lanes of the Araniko Highway. This study aims to uncover significant indicators of dwell time variability and its consequences for transit performance by studying variables such as passenger demographics, boarding and alighting behavior, and bus characteristics. In order to provide efficient and effective public transportation services, a quantitative method to estimate the dwell time of a public bus for serving boarding passengers (BP) and alighting passengers (AP) was developed. Public bus operators or relevant government authority could then take this into consideration to develop transportation planning and management strategies aiming at optimizing the performance of bus bays along the Araniko Highway. This study aims to offer insightful data for transit planners, and transportation experts by a thorough examination of dwell time variance at

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bus bays, incorporating insights from passenger behavior, bus features, and operational dynamics.

2. LITERATURE REVIEW

School buses, charter services, and sightseeing are not considered forms of public transportation; instead, public transportation refers to any form of continuous general or special transportation offered to the general public. Buses, subways, trains, and trolleys are examples of public transportation. With the exception of school buses, charter services, and sightseeing offerings, public transportation offers the general public continuous general or specialized transportation (Tran & Kleiner, 2005). A low capacity bus, like a microbus, can only accommodate a maximum of 14 passengers, including the driver; a minibus can accommodate 15 to 25 passengers, including the driver; and a high capacity bus can accommodate more than 56 passengers, including the driver (DoTM, 2018).

In order to improve the quality of bus transit service, dwell time at stops is one of the most crucial factors to take into account, as it is the main delay that private cars in the network do not experience (Li & Li, 1971). The amount of time that buses spend at stops can range from 9% to 11% of the total trip time. Since passengers suffer negative effects from longer wait times, early or late arrivals at their destinations, and missed connections, which increase their anxiety and discomfort, the reliability of public transportation systems has been considered crucial (Maloney & Boyle, 1999). There is a significant relationship between the primary dwell time and the length of time passengers spend on the bus as well as the number of people who board and exit. It was discovered that passenger demand had the biggest impact on dwell time. Less time would be saved by installing bus priority systems than by reducing dwell time (Rajbhandari, et al., 2003). 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 (Deuker, et al., 2004). 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 (Jaiswal, et al., 2012). Numbers of passengers to be served, doors and door channels available for use, fare payment, bus floor height in relation to platform height, and onboard crowding all have an impact on dwell time. Passenger demand and loading, stop and station spacing, fare payment process, bus type, on-board circulation, and wheelchair and bicycle boarding are some of the factors that affect how long a bus stays in service (Mushule, 2012). The bus dwell time functions play a crucial role in the transit network reliability analysis and the transit assignment models. The bus dwell time was highly uncertain because of the buses' tendency to merge with the traffic in the shoulder lane (Meng & Qu, 2013).

Based on how each person appears, the observer determines whether a passenger is an adult or a senior (more or less than 65 years old). When there is only boarding or only alighting at a stop, the dwell time is considerably less than when there are both boarding and alighting together, 4.95 seconds per passenger (9.07-4.12) and 4.81 seconds per passenger (9.07–4.26), respectively. The boarding time for adults and seniors have, on average, a difference of 1.24 seconds per passenger (6.72-5.48), suggesting that usually older people are slower to board buses. The difference due to age is also observed in alighting; while adults take on average 1.79 seconds per passenger, seniors take 3.54 seconds per passenger, i.e. a difference of 1.75 seconds per passenger. School students are the quickest to alight, as expected (1.35 seconds per passenger) (Tirachini, 2010). Studies were conducted to examine the effects of various passenger characteristics, such as bus types and passenger types, on dwell time. After analyzing 3232 passengers, the longest and shortest boarding times were found for stroller-wielding passengers and typical passengers, respectively (Aydin, et al., 2016). The time required to serve passengers is similar in the morning and evening peak hours, but it takes longer during the midday peak hours. The study also found that departure times were shorter than boarding times (Krarft & Bergen, 1974). Passengers who attempt to board a train while it is almost full are one of the more obvious examples of how passenger behavior affects dwell time duration. Some passengers may use door holding or force in an attempt to board the train quickly (Karekla & Tyler, 2012). Clustered boarding, where a group of passengers waits on the platform when the train arrives, is one of the other situations where passenger behavior affects dwell times. Conceptual model of dwell time, state that boarding and alighting rates are influenced by the number of passengers (LI, et al., 2016). In order to learn more about passengers' preferences for waiting spots on Korean platforms, a survey was administered to them. The vast majority of respondents (77%) said that they do in fact intentionally select where they will wait. Most respondents said they make an effort to cut down on how far they have to walk when they get there (Kim, et al., 2014). The average walking time of passengers at BRT sites is ten times longer than that of passengers at bus stops, according to a bus dwell time methodology specifically designed for BRT stations. (Jaiswal, et al., 2012).

Dwell time needs to be computed in order to model transit assignment, as a more accurate estimate of dwell time will result in a more accurate transit assignment. Having a better understanding of the factors that lead to longer wait times at stops will make it easier to develop strategies to reduce wait times and enhance the effectiveness and reliability of public transportation (Aashtiani & Iravani, 2002). In linear regression analysis, multiple linear regression (MLR) is the most widely used method. Multiple linear regression is a predictive analysis that explains the relationship between one continuous dependent variable and two or more independent variables. The general form of these models is

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

Where,
y = dependent variable i.e. the variable to be estimated
x_1, x_2, x_3,.....x_k = independent variables i.e. observed variables
β_1, β_2, β_3,..... β_k = coefficients;
β_0 is the intercept
ε = random error

The dwell time model for different bus considering number of boarding passenger, number of alighting passenger and number of off bus transaction were developed for Thapathali bus stops (Gupta, 1014). The developed model were

For Thapathali bus stop
For bus
(2) $T_{PD} = 0.145 + 2.80B_p + 2.03A_p + 4.22N_T$
(3) $T_{SD} = 8.148 + 14.34B_s$
For Jumbo micro
(4) $T_{PD} = 1.192 + 2.50B_p\ 2.32A_p + 2.96N_T$
For Micro
(5) $T_{PD} = -0.228 + 4.30B_p + 2.03A_p$

Where,
B_P = Number of primary boarding
A_P = Number of primary alighting
B_S = Number of secondary boarding
N_T = Number of off-bus transactions
T_{PD} = Dwell time for primary passenger

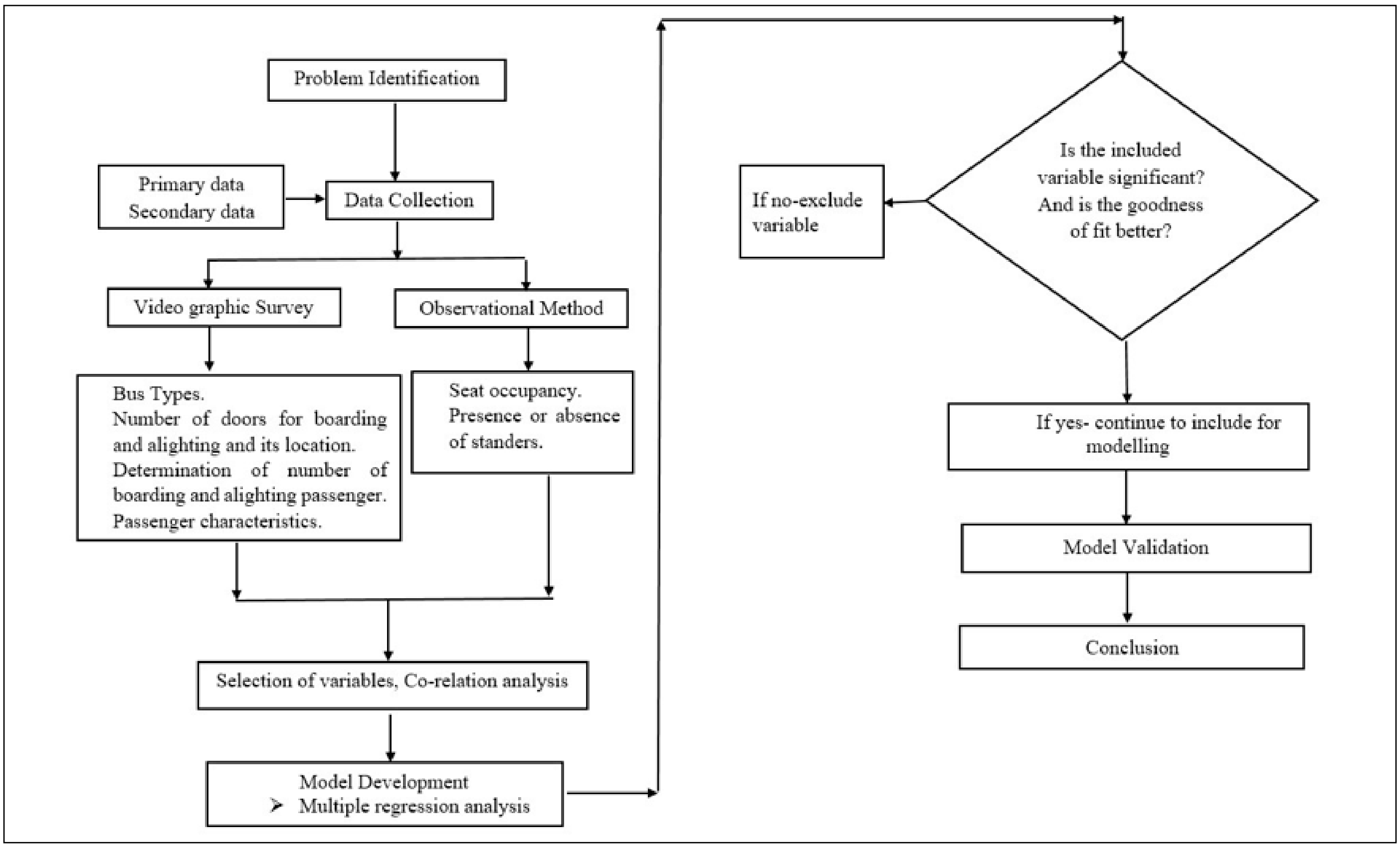

Figure 1. Research Flow Chart.

3. METHODOLOGY

Both quantitative and qualitative analysis formed the basis of this study. The number of doors, dwell time, and passengers getting on and off the bus were all measured and analyzed using a statistical method. Instead of using subjective methods, standard techniques were used to measure the qualitative behavior of drivers and passengers objectively. The detail regarding the methodology is shown in figure 1.

3.1 Study area

The Araniko Highway's Six Lane Road is 6.3 km long and runs from Suryavinayak to Kausaltar. The route has six lanes. The road has been improved and made easier to use with road markings, traffic signals, and signs. Five bus bays that are situated on the Suryavinayak-Kausaltar road section were chosen at random from among the various bus bays in the Suryavinayak-Kausaltar section at the Araniko Highway based on the route that is served by public buses. These included the bus bays at Kausaltar, Gathaghar, Thimi, Suryavinayak, and Sallaghari.

3.2 Data Collection

The video graphic survey and the observation method were the primary data collection techniques used in this study. The study of dwell time at bus bays used journals, books, conference papers, and research papers as secondary sources of data.

3.3 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 three 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. The information that were obtained from the video are shown in table 1.

Bus Types	Door Position	Number passengers	Passenger's Characteristics
Large Buses Mini Buses Micro buses	Front Middle Rear	Number of boarding passenger Number of alighting passenger	Young Passenger, Passenger with kids, Elderly passenger and Children

Table 1. Passenger Attributes and Bus Variability

3.4 Data analysis

Determination of dwell time

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

(6) $t^i = t^i_{depart} - t^i_{arrive}$

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

3.5 Statistical and multiple regression analysis

Multiple regressions were performed using statistical software such as Microsoft Excel/ Statistical Package for the Social Sciences (SPSS). The best regression with highest R-squared value was chosen. The level of significance was taken as 95%.

3.6 Model validation

Following model development, the goodness of fit and significance of the variables tests were used to statistically validate the model. Model validation was done using statistical tests like F- and R-statistics. Using the data that weren't used to create the models, the model was validated.

4. RESULTS AND DISCUSSION

4.1 Passenger related characteristics

Videos recorded at the bus bays in Suryavinayak, Sallaghari, Thimi, and Gathaghar, and Kausaltar provided the passenger details and attributes. Prior to count, the passengers were divided into four categories: young teenagers, passenger with kids, elderly, and children. Based on the participants' physical appearance in the recorded videos, categories were created. Young teenagers are among the passengers who board and exit without any issues. Similarly, Children includes school going passenger, passenger with kids and elderly passenger are passenger who acts slowly in compare to young teenager passenger and generally handling anything for assistance. The detail numbers of types of passenger for each bus bay is shown in figure 2. It was observed that typical passenger were larger in the number than others who made trip through the public buses.

The bus bays selected were used by different types of public bus for the purpose of boarding only, alighting only and both for boarding and alighting. Based on similar characteristic, they have been grouped under similar class of bus as bus, mini bus, micro bus and large bus. The most of bus being operated in the selected area was minibus. The large bus was smallest in the number among all the public buses being operated through Suryavinayak-Kausaltar corridor of Araniko highway. The detail regarding numbers of different types of public buses being operated is shown in the figure 3.

The bus and mini bus have single number of door at the front for boarding and alighting of the passengers. Similarly, the large buses have two number of doors at front and rear end for boarding and alighting of passenger.

The doors in the large bus are of double channel. The micro bus have two number of doors one at front and other at middle for boarding and alighting of passengers. The Mayur yatayat which is large size bus have door at middle of its body part for boarding and alighting of passenger. Similarly, the micro bus have two steps at door, mini bus have three steps at door and buses have three number of steps at door and large bus have four steps at door for getting into and out of bus while boarding and alighting. The detail of door position within the bus that are being operated at selected corridor is shown in figure 4.

The dominance of public buses with front door for boarding and alighting highlight need for infrastructure and boarding system which ensures that passenger flow is smooth and minimizes the boarding time.

4.2 Passenger characteristic affecting dwell time

The characteristics regarding the number of boarding and alighting passenger was studied. As shown in the figure 5, the total numbers of boarding and alighting passengers was observed to be more during morning and evening than in the day time. Therefore, the most of the buss entered the bus bay with seats partially filled and drivers spent more time at bus bay in expectation of getting more boarding passengers.

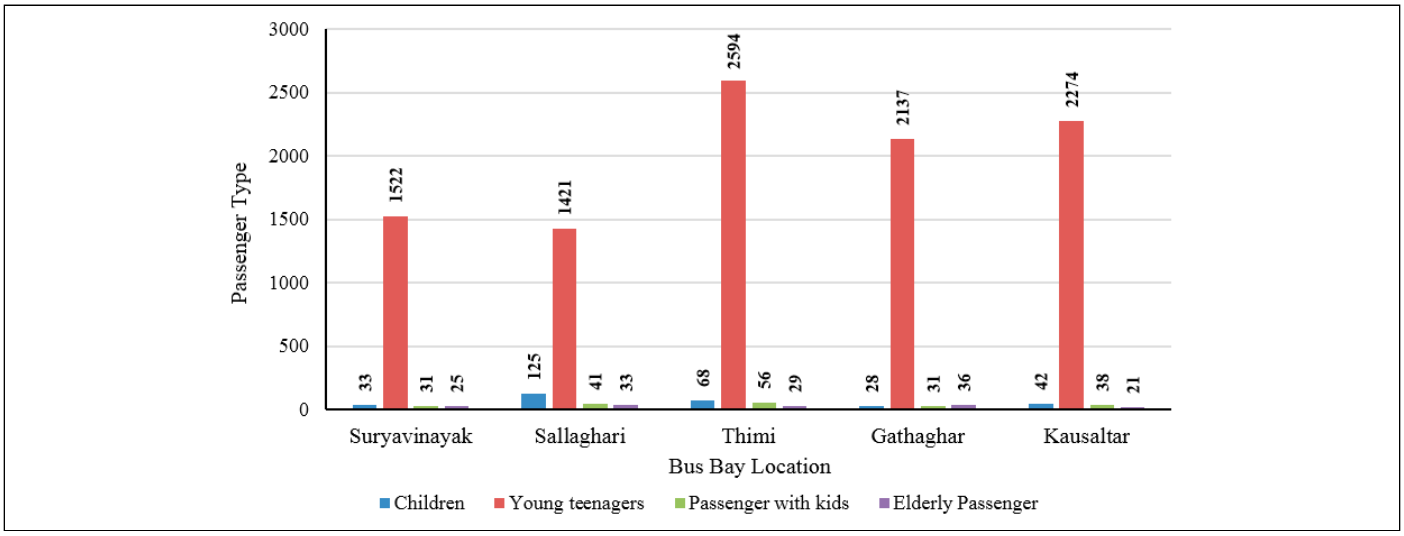

Figure 2. Distribution of Passenger by Type and Location

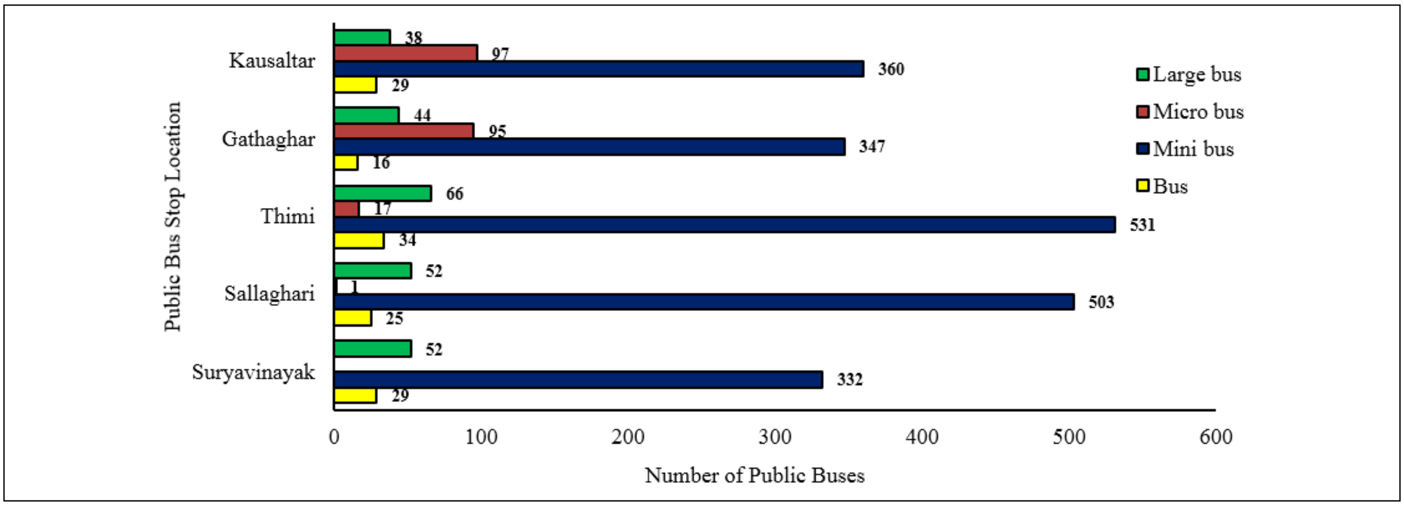

Figure 3. Number of observed public buses by type

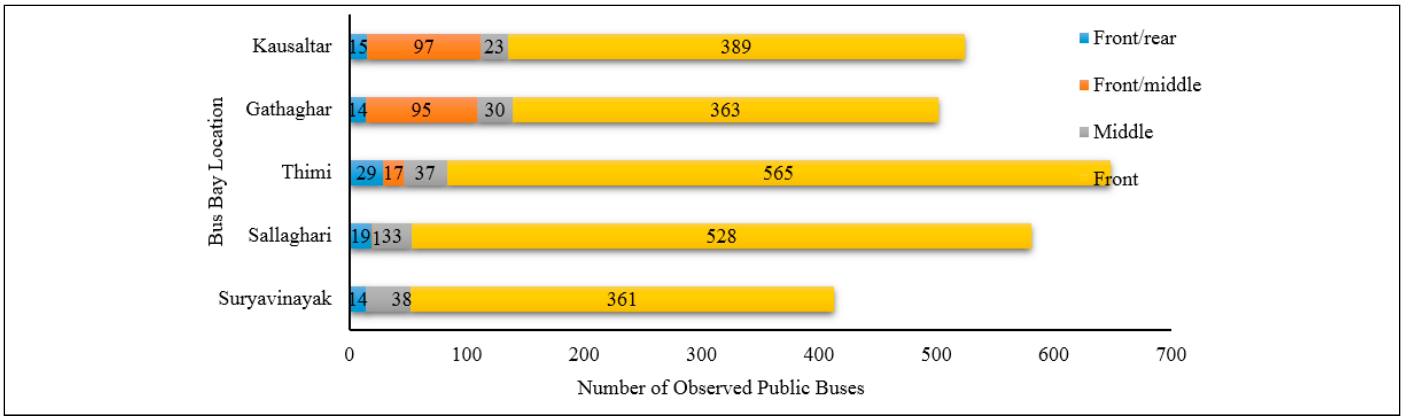

Figure 4. Public buses numbers with different door position at different bus bay

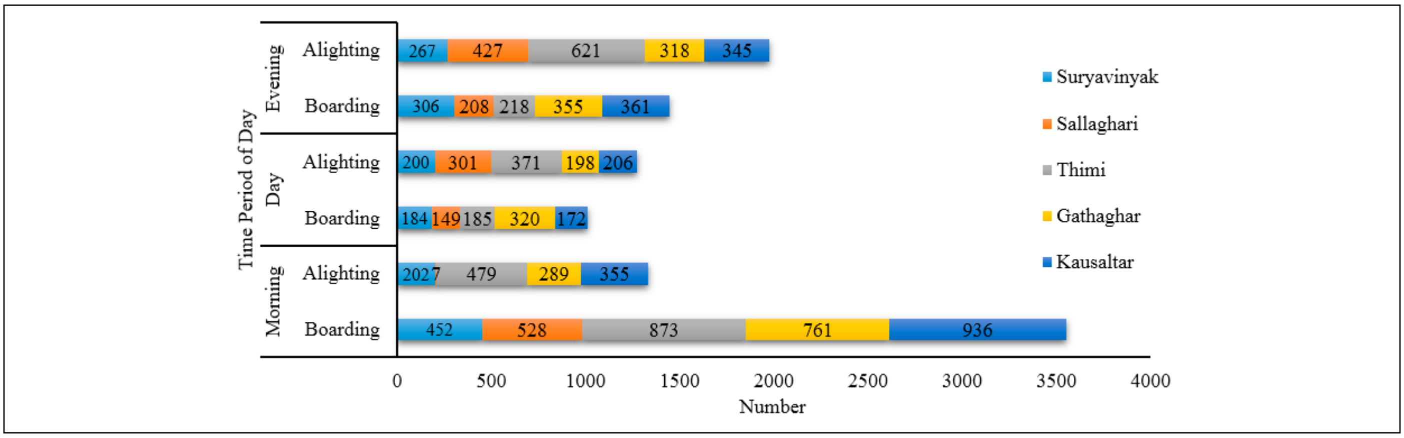

Figure 5. Boarding and alighting passenger number by time of day

The passenger type also affects the rate of boarding and alighting time and as result the dwell time of the public buses at bus bay also changes. In the scope of this study, the length of the boarding and alighting time of the various passenger types were investigated. The results of the data collection and analysis showed that in the public buses serving both typical and other types of passenger that includes children, passenger with child and elder passenger, the rate for boarding and alighting of typical passenger was observed less than the rate of boarding and alighting of passenger other than the typical passengers.

The physical fitness of passenger was observed significant which affected the rate of boarding and alighting. The typical passenger are generally physically strong so the rate for boarding and alighting was found to be less for such passenger at each bus bay under study. The minimum and maximum time for boarding and alighting of typical passenger was 2.97 seconds and 3.24 seconds respectively. The table 2 shows that the rate for boarding and alighting of typical passenger, elderly, children and passenger with child for different bus bays that were under studied during this work.

Children, passenger with child and elderly passenger are slower to board and alight than typical passenger and the contribution of this study is that these differences could be quantified. The maximum and minimum difference in rate of boarding and alighting of typical and other passenger were 0.62 seconds and 0.19 seconds respectively. From the study it was found that the dwell time of public bus in which there were boarding and alighting of typical passenger only was less than the bus in which there were boarding and alighting of typical passenger along with children, passenger with the child and elderly passenger. The detail of dwell time of bus with different passenger types for different bus bay under study is shown figure 6.

Bus bay	Passenger type	Average rate (seconds/Passenger)
Suryavinayak	Young teenagers	3.00
	Children	3.11
	Elder	3.42
	Passenger with kids	3.33
Sallaghari	Young teenagers	3.11
	Children	3.16
	Elder	3.21
	Passenger with kids	3.52
Thimi	Young teenagers	3.24
	Children	3.42
	Elder	3.69
	Passenger with kids	3.31
Gathaghar	Young teenagers	2.97
	Children	3.28
	Elder	3.53
	Passenger with kids	3.68
Kausaltar	Young teenagers	3.23
	Children	3.67
	Elder	4.38
	Passenger with kids	3.50

Table 2. The rate for boarding and alighting by passenger types and time period

Dwell time of buses with other passenger including typical passenger was observed in between 86.05 seconds and 25.78 seconds whereas that for buses with typical passenger was observed in between 64.25 seconds and 19.72 seconds.

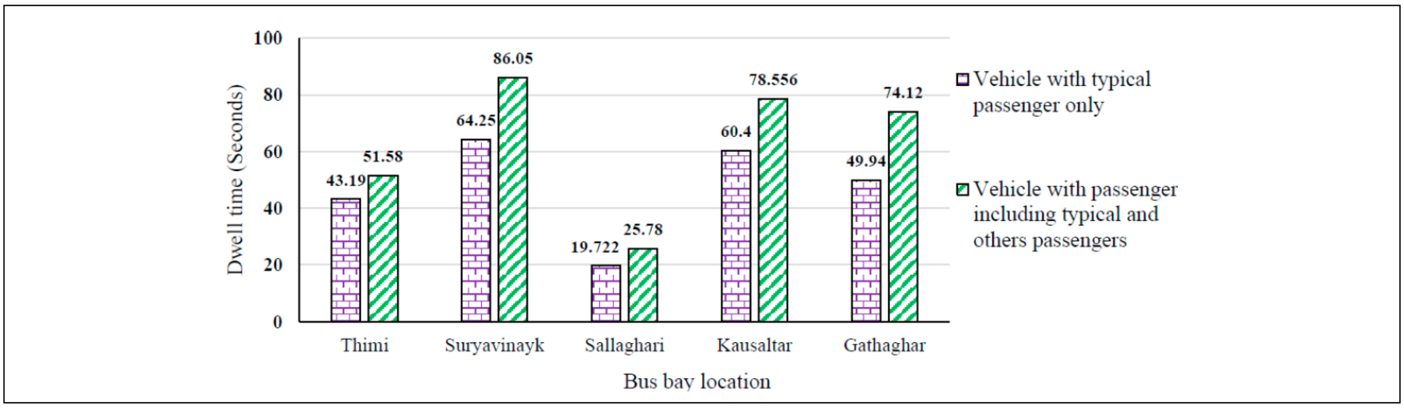

Figure 6. Dwell time of bus with different passenger types.

In average the dwell time of bus with typical passenger only was 47.50 seconds and bus with passenger including both typical and other was 63.22 seconds. Senior passengers are slower to board and alight than younger travelers.

4.3 Dwell time of public buses by its size

The dwell time of large bus was found to be more than bus, mini bus and micro bus. The detail regarding dwell time of the public bus is shown in the figure 7. The dwell time of public buses at bus bay on the basis size of buses depends upon the volume of traffic i.e. the number of people traveling. Smaller buses can provide a higher frequency of service for a given passenger flow. A small bus usually has better acceleration and maneuverability in traffic than a larger bus. Smaller size also means a smaller number of passengers boarding and alighting at each stop, so dwell times at bus bay was less.

The smaller buses have larger rate of boarding and alighting than larger bus. The reason for such trend is due to numbers of alighting and boarding passengers, floor height or number of door and their size. Besides this, mobility within the small buses is not comfortable than large buses. As result, time for boarding or alighting increases and result in higher rate for boarding or alighting. The larger buses have rate for boarding and alighting smaller than the small buses because they have larger space for movement within the bus.

The larger door at both rear and front part as well as middle in incase of large buses helps passenger to get into and out of door quickly for alighting and boarding which reduces rate for alighting and both boarding and alighting combined. The detail regarding boarding and alighting is shown in the figure 8.

4.4 Dwell time of public buses by buses with different steps number at door

The dwell time of the buses with different steps numbers at doors were computed. While climbing the steps, passengers spent extra time due to which the dwell time of the buses increases as buses had to wait till boarding or alighting task was

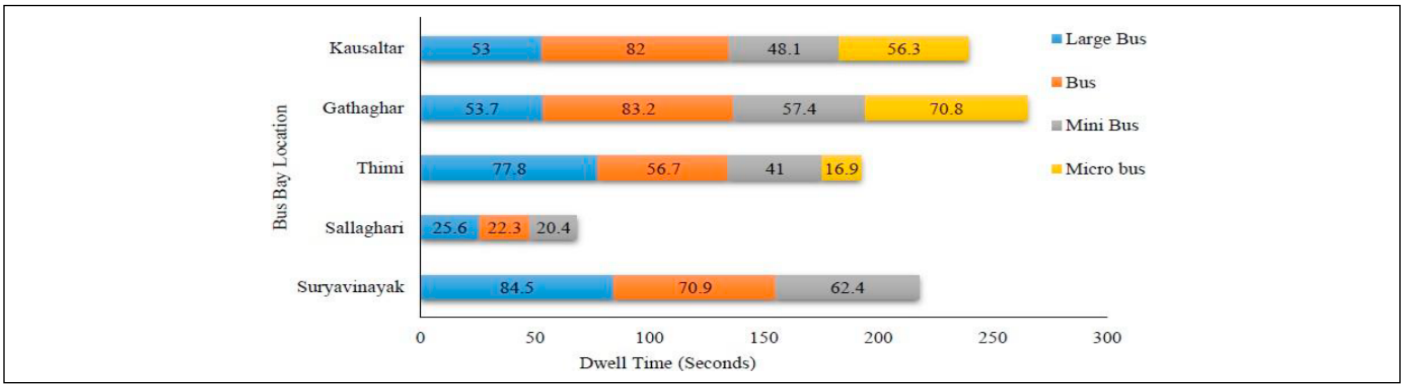

Figure 7. Average dwell time (second) of public bus

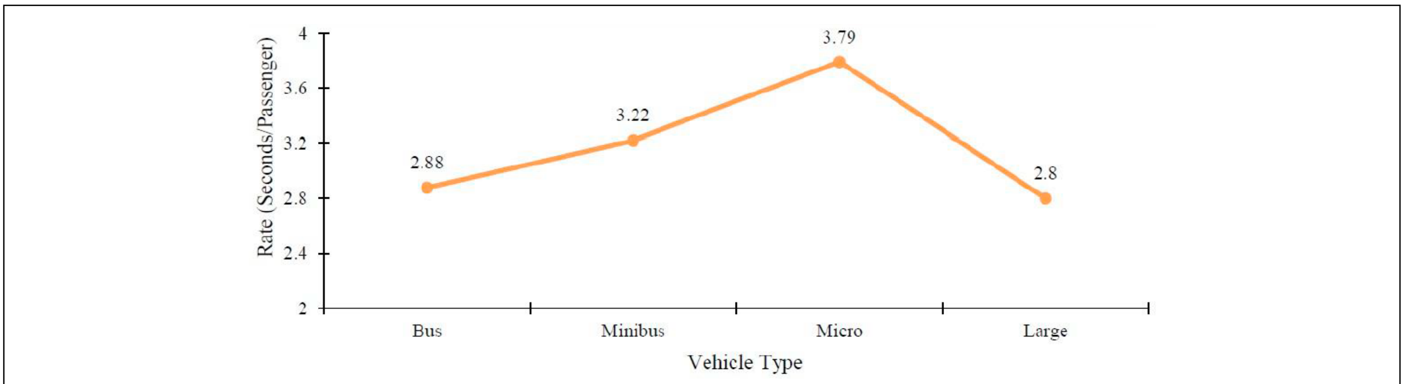

Figure 8. Rate of boarding and alighting

completed. Besides passenger other than typical passenger consumed more time in boarding or alighting the buses. On the other hand, the existence of more steps at the front door makes the boarding process slower, and senior passengers are slower to board and alight than younger travellers. Thus rate of boarding and alighting for such passenger increased and in turn over all dwell time of the buses were increased. The dwell time of the public buses with more number of steps at doors have greater dwell time than lesser number of steps. The detail regarding dwell time of buses with different steps number at doors is shown in figure 9.

4.5 Dwell time of public buses by doors number

As shown in the table 3 the dwell time of the public buses having more than one number of doors was more than those having single door. Micro have two doors but small space at door resulted in delay in completion of boarding and alighting. In the buses having two doors of double channel one at front is for alighting and other at rear, is for boarding. But it was observed that front door was being used for both boarding and alighting which results in crowdness at front doors and dwell time of buses increased. Besides this, the position of buses while it stopped for boarding and alighting played significant role as majority of buses were stopped at entry of door and passenger waiting at waiting shed in the middle of bus bay had to travel extra distance. As result, it took longer time to complete boarding task and the dwell time of the public buses increased. Thus, two numbers of doors in micro was observed to be ineffective to reduce dwell time.

Sn	Time period	Doors numbers	Dwell time-s
			Mean
1	Morning	1	39.9
		2	42.6
2	Day	1	58.8
		2	80.7
3	Evening	1	47.2
		2	64.8

Table 3. Dwell time by doors number

Similarly, the buses having two numbers of doors have larger rate for boarding and alighting than the public buses having single numbers of door for boarding and alighting activities as shown in figure 10.

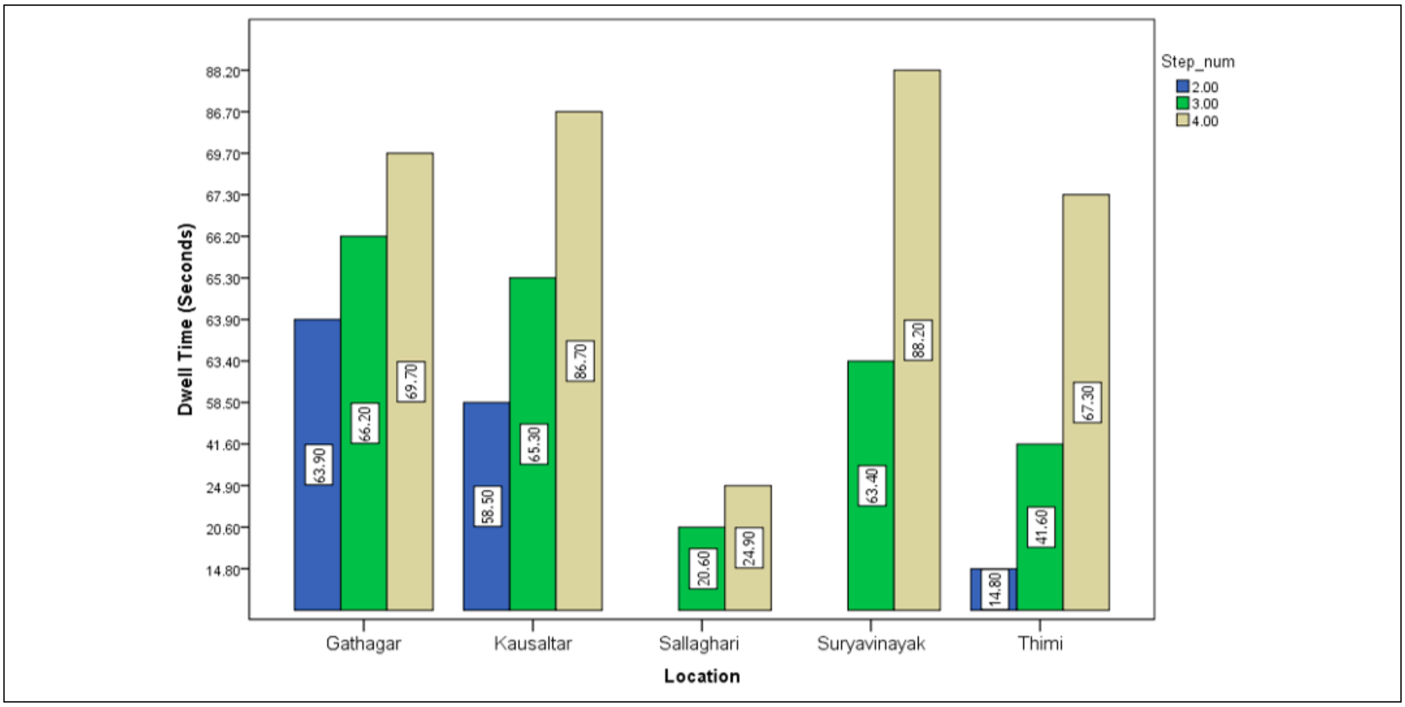

Figure 9. Dwell time with respect to steps number at door.

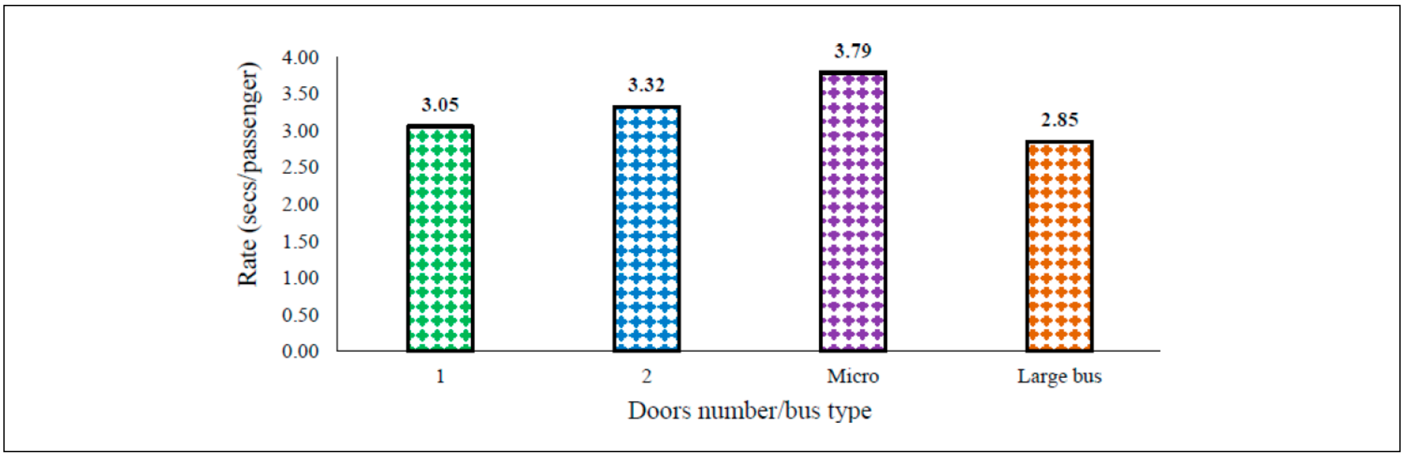

Figure 10. Rate of boarding and alighting for different bus with different door numbers.

From the descriptive statistics the dwell time varies with bus types, doors numbers, and number of boarding and alighting passengers, crowding density of passenger within buses. The dwell time of the large buses was found to be more than small bus since time spent waiting for a gap to pull back into traffic from the bus bay was more. More numbers of steps at door was observed to be ineffective as passenger had to spend more time in climbing the steps. Besides this, the rate for boarding and alighting varied with increase in the steps numbers at doors. Thus, buses sizes, passengers' types, numbers of boarding and alighting, door number for boarding and alighting, steps numbers at door were factors affecting the dwell time of the buses.

4.6 Regression analysis

4.6.1 Correlation between dependent and independent variables

Correlation analysis was performed in order to understand how dwell time is related with others variables at 95% confidence level and 99% confidence level. A correlation coefficient between dependent and independent variables for minibus, bus, large bus and micro bus are shown in the table 4, 5, 6 and 7 respectively

	AP	DN	SO	BPB	BP	DT
AP	1	0.012	-0.018	.050*	-.094**	.511**
DN	0.012	1	-.116**	-.086**	-.046*	-0.026
SO	-0.018	-.116**	1	-.056*	.096**	.075**
BPB	.050*	-.086**	-.056*	1	-.109**	-.052*
BP	-.094**	-.046*	.096**	-.109**	1	.673**
DT	.511**	-0.026	.075*	-.052*	.673**	1

Table 4. Correlation matrix for minibus

	AP	DN	SO	SN	BPB	BP	DT
AP	1	0.020	0.005	-0.060	0.081	-.214*	.389**
DN	0.020	1	0.020	0.017	-0.130	0.104	0.043
SO	0.005	0.020	1	0.167	-0.049	0.038	0.022
SN	-0.060	0.017	0.167	1	-0.066	-0.009	-0.064
BPB	0.081	-0.130	-0.049	-0.066	1	-.273**	-0.095
BP	-.214*	0.104	0.038	-0.009	-.273**	1	.620**
DT	.389**	0.043	0.022	-0.064	-0.095	.620**	1

Table 5. Correlation matrix for bus

	AP	DN	BPB	BP	DT	SO
AP	1	-0.115	0.061	-.238**	.308**	-0.114
DN	-0.115	1	0.032	.267**	.147*	-0.019
BPB	0.061	0.032	1	-0.030	0.017	0.097
BP	-.238**	.267**	-0.030	1	.677**	-0.016
DT	.308**	.147*	0.017	.677**	1	-0.054
SO	-0.114	-0.019	0.097	-0.016	-0.054	1

Table 6. Correlation matrix for large bus

	AP	SO	BPB	BP	DT
AP	1	-0.059	0.046	-0.120	.507**
SO	-0.059	1	-0.103	.202**	.164*
BPB	0.046	-0.103	1	-0.007	0.112
BP	-0.120	.202**	-0.007	1	.620**
DT	.507**	.164*	0.112	.620**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 7. Correlation matrix for large microbus

Where,
AP Alighting passenger number
DN Doors number
SO Seat occupancy
SN Steps number at door
BPB Bus position in bus bay
BP Boarding passenger number
DT Dwell time

At 99% confidence level, correlation coefficient of dwell time with boarding and alighting passenger were 0.620 and 0.389 respectively for buses, correlation coefficient of dwell time with boarding and alighting passenger were 0.673 and 0.511 respectively for mini-buses, correlation coefficient of dwell time with boarding and alighting passenger were 0.677 and 0.308 respectively for large buses and correlation coefficient of dwell time with boarding and alighting passenger were 0.620 and 0.507 respectively for micro buses. There is strong positive correlations of dwell time with both boarding passengers and alighting passenger numbers and other variables appeared to play lesser role and are not important predictor of DT. As the number of boarding and alighting passengers for each types of vehicles increased, dwell time also tends to increase. Hence boarding and alighting number of passenger were only used for developing the dwell time model.

4.6.2 Dwell time model

The main objective of this study is the development of dwell model. The models were developed using multiple regression analysis. The resulting models' regression coefficients were tested at 5% level of significance. Also, each regression model's overall statistical significance was tested using the F-test (ANOVA) at 5% level of significance for each bus stop type, bus type and route of buses operation. Similarly, significance of model coefficient for buses by bus type was calculated and shown in table 8.

Bus type	AP	BP	SO	BB
Minibus	0.000	0.000	0.127	0.890
Bus	0.000	0.000	0.905	0.237
Large bus	0.000	0.000	0.715	0.748
Micro	0.000	0.000	0.067	0.011

AP Number of Alighting Passenger
BP Number of Boarding Passenger
SO Sear Occupancy
BB Bus Position in Bus Bay

Table 8. Significance of model coefficient for bus by size in dwell model

As number of boarding passengers and number of alighting passengers contributes significantly on the dwell time, combine dwell time model for bus types were developed considering boarding numbers and alighting numbers. The regression models and associated statistics are shown in the table 9. The R-square varied from 0.669 to 0.785 for the model generated for bus types.

Types of bus	Dwell Time Models	R-square	Standard error
Mini bus	DT = 1.214 + 2.971BP + 2.531AP	0.785	3.766
Bus	DT = 1.406 + 2.512BP + 2.331AP	0.669	4.031
Large bus	DT = 1.388 +2.709BP + 2.292AP	0.691	4.433
Micro	DT = 1.146 +3.092BP + 2.977AP	0.727	3.671

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

Table 9. Multiple regression models by bus types

4.7 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 minibus was DT = 1.214 + 2.971B + 2.531A.

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

The sum of squares regression (SSR) = 48310.05

The sum of total variation (SST) = SSR + SSE = 48310.05 + 11381.81 = 59691.86

$$R^2 = \frac{SSR}{SST} = \frac{48310.05}{59691.86} = 0.81$$

The results of ANOVA test also showed statistically significant F-statistics (1.1529E-270) ($p<0.05$). R-square is 0.81 which mean there is a significant positive relationship between observed and calculated dwell time for different bus types. The result obtained from the comparison indicates that the model reflects real data in a satisfactory way. The p-value is less than alpha value 0.05 which shows that there is stronger evidence that the null hypothesis should be rejected and alternate hypothesis is more credible. From the results obtained, the proposed model for dwell times are considered valid. The summary of regression statistics R-square, significance F and anova test are shown in the table 10 and table 11.

Types of bus	Dwell Time Models	R-square	Significance F
Mini bus	DT = 1.214 + 2.971BP + 2.531AP	0.8114	1.1529E-270
Bus	DT = 1.406 + 2.512BP + 2.331AP	0.8791	8.37202E-08
Large bus	DT = 1.388 +2.709BP + 2.292AP	0.7644	1.05062E-07
Micro	DT = 1.146 +3.092BP + 2.977AP	0.7643	3.09616E-07

Table 10. Summary of Regression statistics for model validation (combine)

Bus type	SS	MS	F	Significance F
Minibus	48310.05	48310.04	3166.393	1.1529E-270
Bus	2883.176	2883.176	101.7829	8.37202E-08
Large bus	1013.366	1013.366	64.86543	1.05062E-07
Micro	738.82118	738.8211	58.87838	3.09616E-07

Table 11. Anova

R-squared 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 11.

5. CONCLUSION

The statistical analysis show that the dwell time of the buses varied with respects to the number of boarding and alighting passengers, public buses sizes and their frequencies of providing services, doors numbers and their size, floor height

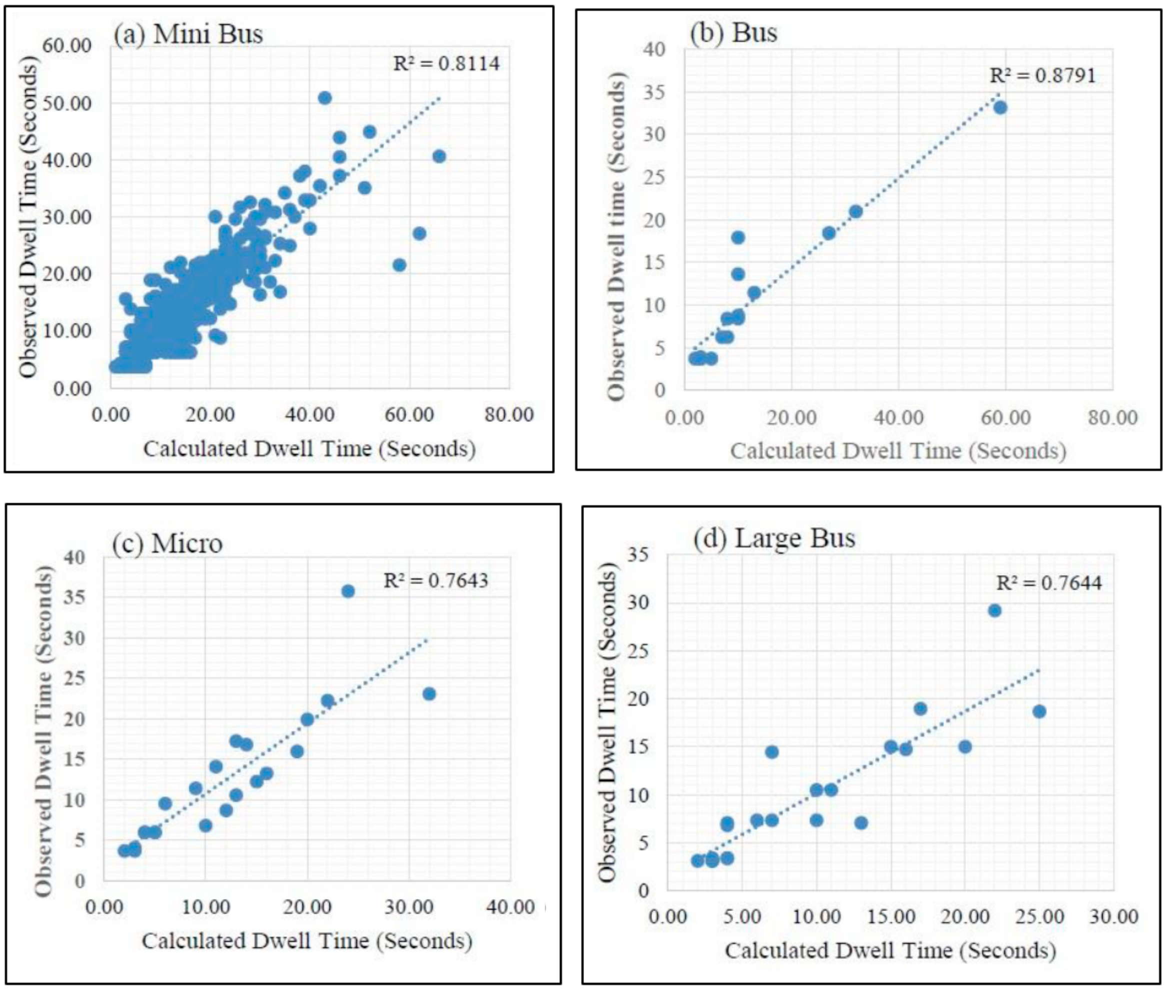

Figure 11. Observed dwell time vs calculated dwell time

and numbers of steps at door, passengers types. Similarly, the public buses with steps numbers greater or equal to 3 at door had more dwell time (average 57.64 seconds) than one having steps less than 3 (average 49.00 seconds) as the passenger took more time either in climbing up the steps or climbing down the steps. The typical passenger had smaller rate of boarding and alighting (average 3.11 seconds) than children, elderly passenger and passenger with child (average 3.3 seconds) which were include in other category. Besides this, passenger type affects rate of boarding and alighting as elders passengers consume more time for climbing up or climbing down the steps. In average the rate of boarding and alighting for typical passenger was 3.11 seconds and that for other types of passenger was 3.36 seconds. The smaller the size of the public buses had higher rate of boarding. Provision of appropriate numbers of large buses with separate double channel doors for boarding and alighting, low floor buses which are comfortable in boarding and alighting to elder and handicapped passengers can reduce rate of boarding/alighting and crowdness inside the buses which in turn reduce dwell time. The models were developed using multiple regression analysis with all statistical inferences at 95% confidence interval. The results of the ANOVA tests also showed statistically significant F-statistics ($p<0.05$). 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. Overall, the results show that dwell time may be reduced and the efficiency and quality of the transportation system can be enhanced by optimizing bus design and operation based on variables such door arrangement, bus size, and passenger demographics.

Based on the finding of statistical analysis of dwell time variability at bus bays, the following recommendation can be made to optimize the transportation system, reduce dwell time variability, and improve the overall efficiency, reliability of the public transportation system.

Bus design and configuration.

From the study, it was observed that buses of appropriate size with fewer steps at the door, buses with low floor which are more accessible and comfortable for boarding and alighting, and buses with separate double-channel doors for boarding and alighting are more effective in boarding and alighting operation. Thus, Department of Transport Management, Nepal should be develop policies to operation large buses with fewer steps at entrance, low floor level and double channel door to facilitate smoother passenger flow.

Frequency and scheduling

The statistical analysis showed that frequency distribution of the public buses at different bus bay under study was not uniform. Thus, transit agencies should increase bus frequencies in morning and evening time during which there is more passenger demand to reduce dwell time and decrease congestion.

Passenger management

Transportation system planner should develop strategies for controlling passenger flow and reducing the amount of time it takes to board and alight taking into consideration implementing priority boarding for elderly and handicapped passengers as the elderly and handicapped had greater boarding and alighting time. Besides this, bus need to be design as elderly and handicapped friendly.

Driver training and behavior.

The transit agencies and government should develop strategies to reward drivers for adhering to their timetables and spending minimum time at bus bays waiting for passengers. Similarly, provision to provide feedback and performance evaluation to driver to promote improvement in operation efficiency need to be initiated.

Infrastructure improvement.

Bus bay infrastructure should be upgraded with sheltered waiting areas and designated boarding zones to increase passenger comfort and accelerate the boarding and alighting process.

REFERENCES

Aashtiani, H. Z., & Iravani, H. (2002). Application of Dwell Time Functions in Transit Assignmnet Model. 88-89.

Aydin, M. M., Yildirim, M. S., Aydin, R., & Arslan, Y. (2016). Effects of different passengers characteristics and bus types on boarding times at bus stops. *Journal of Engineering Researcg and Applied Science*.

Deuker, K. J., Kimpel, T. J., & Strathman, J. G. (2004). Determinants of bus Dwell Time. *Journal of Public Transportation*.

DoTM. (2018). *Bus Building Standard.* KAthmandu: Department of Transport Management.

Gupta, V. (1014). Modelling Dwell Time and Clearance Time of Public Vehicles at Bus Bay Bus Stops of Kathmandu Valley. Kathmandu: Institute of Engineering, Pulchowk Campus.

Jaiswal, S., Bunker, J., & Ferreira, L. (2012). Influence of Platform Walking on BRT Station Bus Dwell Time Estimation. *Journal of Transportation Engineering*, 1173-1179.

Karekla, X., & Tyler, N. (2012). REduced Dwell Time Resulting From Train Platform Improvements: The Costs and Benefits of Improving Passenger Accessibility to Metro Trains. *Trnasportation Planning and Technology*, 525-543.

Kim, H., Kwon, S., Wu, S. K., & Sohn, K. (2014). Why do passenger choose a specific car of a metro train during the morning peak hours? *Transportation Research PArt A: Policy and Practice* , 249-258.

Krarft, W., & Bergen, T. (1974). Evaluation of Passenger Sevices Times for Street Transit Systems. *Transporattion Research Record*(505), 13-20.

LI, D., Daamen, W., & Goverde, R. P. (2016). Estimation of Train Dwell Time at Short Stops Based on Track Occupation Event Data: A Study at a Dutch Railway Station. *Journal of Advanced Transportation*, 877-896.

Li, M. T., & Li, S. C. (1971). *A Simulation Model for Estimating Bus Dwell Time By Simulataneously Considering Numbers of Alighting and Boarding Passengers at Stop Level.* 59-61: Transportatiopn Research Record.

Maloney, M., & Boyle, D. (1999). *Components of Travel Time on The Glendale Beeline Bus Network.* 23-27: Transportation Research Record.

Meng, Q., & Qu, X. (2013). Bus Dwell Time Estimation at Bus Bays: A Probabilistic Approach. *Transportation Research Part C: Emergng Technilogies*, 61-71.

Mushule, N. K. (2012). Bus Bay Performance and its unfluence on the capacity of road Network in Dar Es Salaam. *American Journal of Engineering And Applied Science, 5*(2), 107-113.

Rajbhandari, R., Chien, S. I., & Daniel, J. R. (2003). Estimation of Bus Dwell Time With Automatic Passenbger Counter Informnation. *Journal of The Transportation REsearch Board*(1981), 120-127.

Tirachini, A. (2010). The effect of different fare collection, bus floor level and age of passenger. *Institute of Transport and Logistics Studies, University of Sydney.*

Tran, T., & Kleiner, B. H. (2005). *Managing for Excellence in Public Transportation.* Researchgate.