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Effect of Secondary Factors (fare type, crowding, door location) on Dwell Time of Public Buses in Kathmandu Valley

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Abstract

Dwell time, the additional delay that the public transport mode user has to suffer in comparison to that of private mode user and covered greater portion of travel time. Variability of which greatly influences punctuality of public transport mode and ultimately hindered the public transportation system reliability pushing public mode users toward private mode. Therefore, development of accurate dwell time estimation model and analysis of different contributing factors for longer dwell time becomes necessary. With the help of multiple linear regression model and using collected video recording data, model estimation for public bus as well as impact of contributing factors of dwell time such as cash fare payment, in-vehicle crowding condition and vehicle door position were able to establish. Cash fare payment has found to be increased both boarding and alighting time by 1.392 s/pax and 1.177 s/pax respectively in comparison to pre-paid fare. Similarly, both boarding and alighting time has found to be gradually increased as the in-vehicle crowding condition increases. Large bus with central door position was found to be more efficient than front door for the purpose of dwelling.

Keywords

Dwell time, public bus, multiple linear regression, cash fare payment, in-vehicle crowding, door position

1. Introduction

Rapid rise in population of Kathmandu in recent years, demands increased mobility imposing pressure to the existing transportation system inherited with various ill effects such as congestion, overcrowding, delays etc. The existing urban public transport route network in Kathmandu is labyrinth. There are more than 150 routes, which have been developed over the several years without proper prospect. Many routes have terminated in the central area of the city, resulting in congestion caused by large numbers of vehicles standing between trips.

As the reliability of public transportation system has been uncertain due to delays, public transport users tend to shift to private mode in search of a better one. Systematic corruption on the regulation, syndicate, road condition, traffic mismanagement and congestion, dwelling time and improper activities of the operators has caused the delays in public transportation system. Out of many causes of delay most of the people are irritated by the dwell time (being the additional delay in comparison to private mode) of public transportation rather than the traffic congestion as later is same for the both private and public transport mode.Longer dwell time is caused by number of passenger boarding and alighting, waiting time for passenger at bus stop, fare collection system, overcrowding, vehicle configuration etc. Prolonging the dwell time by fare collection being on board cash payment system is also supported by A. Tirachini results from the simulations which shows that substantial time savings are possible if payment methods are upgraded from slow techniques, such as cash transactions to the fastest one (off board fare payment), while intermediate technologies such as prepaid cards to be validated inside buses fall in between [1]. Thus study on factors causing longer dwell time is significant for management of public transportation system.

2. Methodology

2.1 Research Design

The methodology adopted for research work has been represented in flowchart in figure 1.

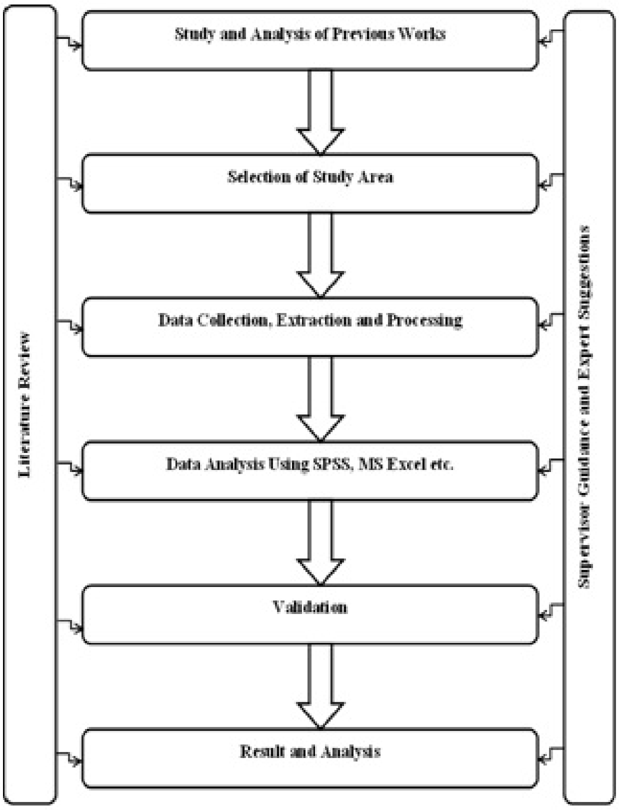

Figure 1: Methodology for Research Work

2.1.1 Sampling and Sample Size

Simple random sampling was used for the sampling. Minimum sample size for each bus stops is estimated by rule of thumb n ≥50+8m for multiple regression suggested by (Green, 1991) [2].
where,
n is sample size
m is number of independent variable

2.1.2 Data Collection

Video recording was used to collect the data during morning off peak time (8:00 am to 9:00 am), morning peak time (9:00 am to 10:00 am) and evening peak time (16:30 to 17:30) for two weeks following the guidelines of TCQSM [3][4].

2.1.3 Data Extraction

Video recordings of the collected data were analysed repeatedly in media player and extraction of data related to each variable was completed.

2.2 Study Area

According to TCQSM to determine passenger service times for use in evaluating the differences between systems (such as door position or alternate fare collection systems), data collection should be done only at high-volume stops [3][4]. Thus Kalanki, Tripureshwor,Thapathali, Babarmahal and Tinkune bus stops were selected for study, which starts from one entry point of ring road and end to the other entry point of the same passing through the core business area of Kathmandu valley with length of about 7.7Km. Map of study area has been shown in figure 2.

Figure 2: Map of Study Area

2.3 Data Analysis

SPSS software was used to analyze the data. In SPSS multiple regression analysis was done and completed in three steps, namely model formulation, model estimation and model validation.

2.3.1 Model Formulation

The generalized multiple regression models adopted for the analysis is shown in equation no 1.

$$D_t = \beta + a_b N_b + a_a N_a + a_{ac} N_{ac} + a_o V_o + a_t T_w + \varepsilon \quad (1)$$

where,
D_t: Dwell time (s)
N_b: Number of passengers boarding
N_a: Number of pre-paid fare alighting passengers (s)
N_{ac} :Number of alighting passengers with cash fare transaction(s)
V_o: Vehicle occupancy (%)
T_w: Waiting time for passengers (s)
$a_b, a_a, a_{ac}, a_o, a_t$ are respective independent variable regression coefficients
β- D_t-intercept, i.e., the value of D_t when all independent variables are 0
ε- Residual error

2.3.2 Model Estimation

The coefficient for each of the independent variable was estimated by best fitting the data to the model.

2.3.3 Model Validation

Developed model was validated with the new data set that was not used in the development of the model. Thereafter, validity of model was evaluated by comparing similarities in the predicted and observed dwell time.

3. Results and Discussion

3.1 Public Bus Characteristics

About one third of the passenger motor vehicle was found to be mini buses and remaining buses. Classification of buses for this study is based on the Motor Vehicles and Transport Management Rules, 2054 (1997) [5].

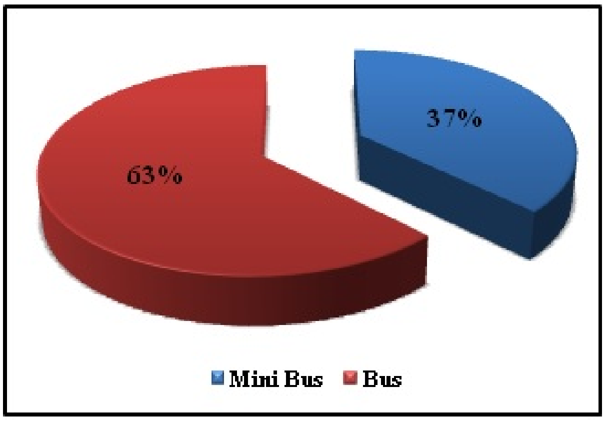

Figure 3: Category of Passenger Motor Vehicle

In sample observed there were no buses with two doors, negligible proportion with center door position in mini bus category. Front door was dominant in most of the buses followed by center door while two doors were nominal.

3.2 Average Boarding and Alighting Passengers

Among the observed stations, average alighting is found to be more in core area bus stop (Tripureshwor and Thapathali) while boarding is more in Kalanki and Babarmahal.

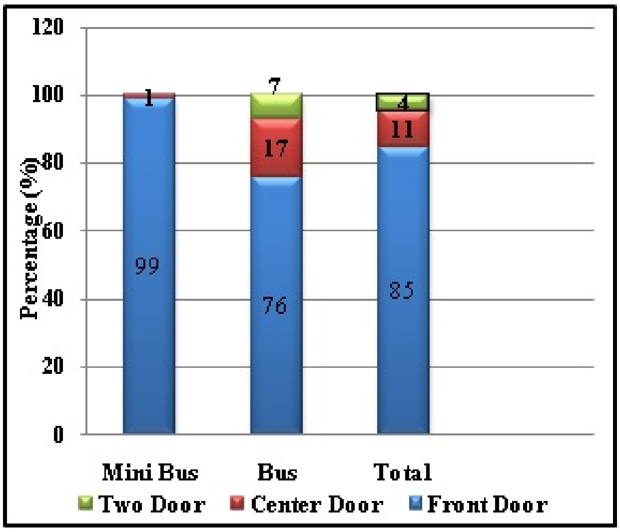

Figure 4: Door Position Characteristics

3.3 Average Boarding and Alighting Time

Average per passenger alighting time with cash fare per passenger is found to be approximately double or more than average per passenger alighting time of pre-paid fare.

3.4 Pre-Paid Fare versus Cash Fare Alighting Passengers

Pre-Paid fare alighting passenger is almost double of cash fare alighting passenger although average alighting time with cash fare per passenger is found to be approximately double or more than average alighting time of pre-paid fare.

3.5 Passenger Service Time versus Waiting Time

Almost all buses are of waiting nature, no matter of time whether that is peak or off-peak. However, waiting time is negligible in core bus stops.

Waiting time is more in Kalanki and Babarmahal stops, comparable in Tinkune stops and negligible in core bus stops (Tripureshwor and Thapathali).

From figure 9 and figure 10 it can be concluded that off peak waiting time is exceptionally high than peak waiting time except in core bus stop.

3.6 Vehicle Occupancy

In an average mini buses run with full capacity all the time and exceed occupancy up to about one-fifth of its full capacity. While in an average, buses has found

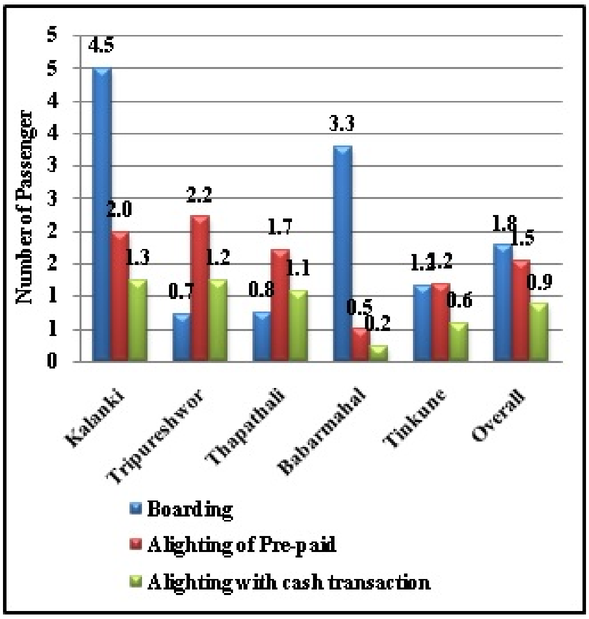

Figure 5: Average Number of Passenger Boarding and Alighting

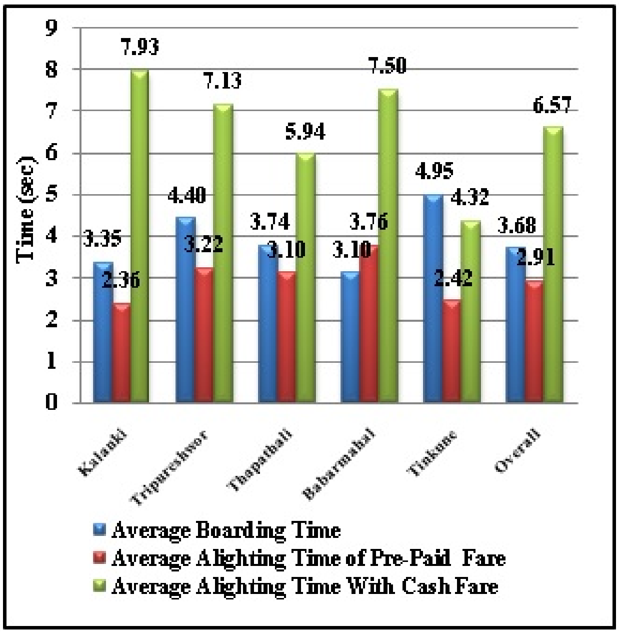

Figure 6: Average Boarding and Alighting Time

to operate below the full capacity, and hardly reached their full capacity even during peak hours.

3.7 Waiting Time

Average waiting time of all mini buses is almost same while average waiting time of buses are approximately 50% more in off-peak than in peak time. Also from figure 11 the occupancy of mini buses is almost full at both peak and off peak so waiting time for them is invariable with the time while buses is about 76% full at off peak and almost full at the peak time validating the point that buses have almost 50 % more waiting time in off peak than in peak time.

3.8 Model Estimation

Following regression models estimation were done in research.

3.8.1 Dwell Time (D_t) Model Estimation for Study Area

Regression model coefficient of each independent variable is estimated using SPSS to estimate the dependent variable (Dwell Time) as shown in table 1. For this model estimation, the sample size considered is 454(greater than n $\geq$50+8m), average number of boarding passenger is 1.77, average number of pre-paid fare alighting passenger is 1.54, average number of cash fare transaction alighting passenger is 0.87, average vehicle occupancy is 95.94% and average time taken for passenger waiting is 13.93 sec. Dwell time model estimation for all category of buses in this study area is as per equation 2.

$$D_t = 2.718 * N_b + 2.240 * N_a + 4.277 * N_a c + 0.065 * V_o + 1.047 * T_w \quad (2)$$

Table 1: D_t Model for Study Area (Model I)

Dwell time	Coefficient	Standard Error	t	Sig.
N_b	2.718	0.158	17.154	0.000
N_a	2.240	0.262	8.545	0.000
N_{ac}	4.277	0.289	14.782	0.000
V_o	0.065	0.007	8.907	0.000
T_w	1.047	0.015	69.847	0.000
Adjusted R^2=0.963				

3.8.2 Dwell Time Model Estimation During Off-Peak

For this model estimation, sample size considered is 188. Average number of boarding passenger is 1.48, average number of pre-paid fare alighting passenger is 1.4, average number of cash fare transaction alighting passenger is 0.77, average vehicle occupancy is 84.39% and average time taken for passenger waiting is 16.48 sec. Dwell time model estimation during off-peak houris as per equation 3.

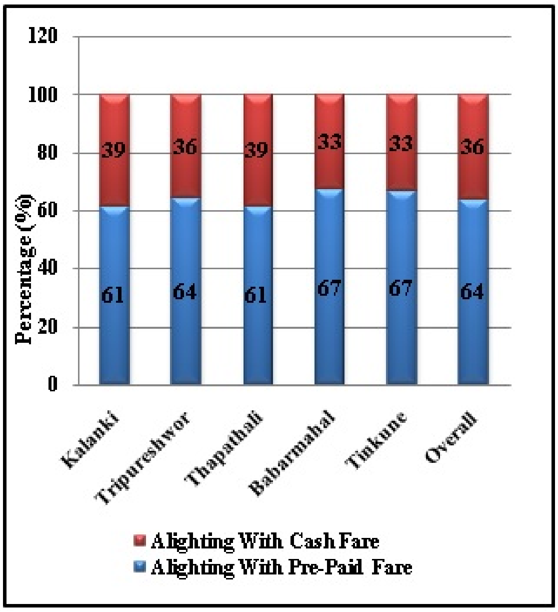

Figure 7: Pre-Paid vs Cash Transaction of Alighting Passenger

$$D_t = 3.239 * N_b + 2.350 * N_a + 5.343 * N_{ac} + 0.054 * V_o + 1.039 * T_w \quad (3)$$

Table 2: D_t Model Estimation During Off-Peak (Model II)

Dwell time	Coefficient	Standard Error	t	Sig.
N_b	3.239	0.272	11.909	0.000
N_a	2.350	0.341	6.897	0.000
N_{ac}	5.343	0.370	14.443	0.000
V_o	0.054	0.010	5.420	0.000
T_w	1.039	0.016	63.811	0.000
Adjusted R^2=0.984				

3.8.3 Dwell Time Model Estimation During Peak

For this model estimation, sample size considered is 266.Average number of boarding passenger is 1.98, average number of pre-paid fare alighting passenger is 1.64, average number of cash fare transaction alighting passenger is 0.94, average vehicle occupancy is 104.1% and average time taken for passenger waiting is 12.12 sec. Dwell time model estimation during off-peak hour is as per equation 4.

$$D_t = 2.626 * N_b + 2.257 * N_a + 3.659 * N_{ac} + 0.072 * V_o + 1.012 * T_w \quad (4)$$

On comparison between Model II and Model III,

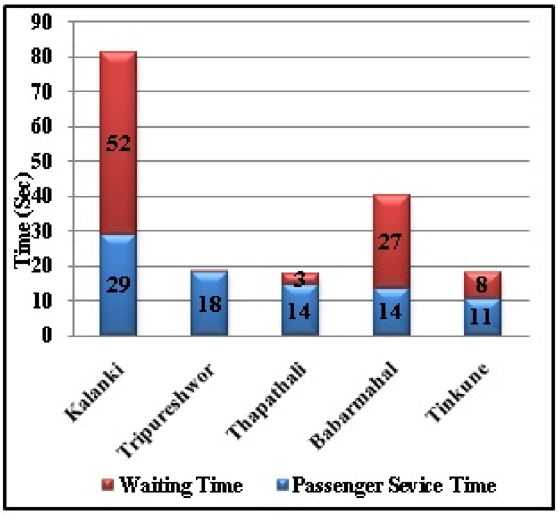

Figure 8: Passenger Service Time versus Waiting Time (Average)

Table 3: D_t Model Estimation During Peak (Model III)

Dwell time	Coefficient	Standard Error	t	Sig.
N_b	2.626	0.199	13.169	0.000
N_a	2.257	0.369	6.115	0.000
N_{ac}	3.659	0.409	8.938	0.000
V_o	0.072	0.010	7.041	0.000
T_w	1.012	0.030	33.303	0.000
Adjusted R^2=0.934				

average per passenger boarding time during off-peak hour is almost 23.34% higher than average per passenger boarding time during peak hour which may be due rush in work during peak hour.

3.9 Model Validation

The dwell time model estimation for study area is validated with the different set of data that has not been used in model development in order to check the predictability of the developed model. For the validation process predicted dwell time defined by the equation 2 is plotted against the observed dwell time in the field as shown in figure 13. The R square value was found to be 0.982 which indicates that 98.2 percentage of variance in predicted dwell time is explained by observed dwell time.

Predicted observed-predicted D_t= 1.035* Observed dwell time (5)

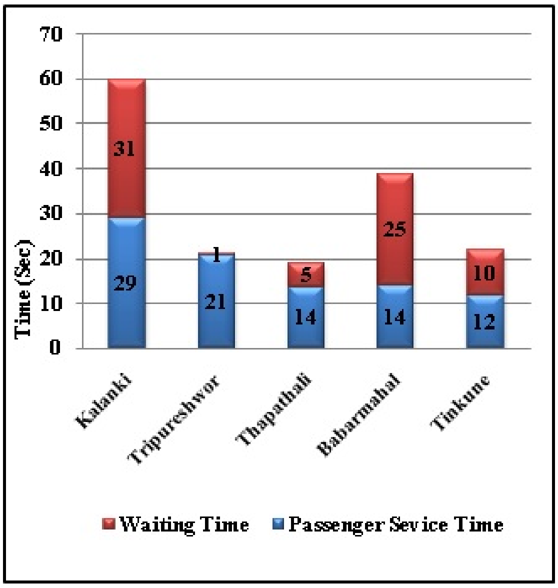

Figure 9: Passenger Service Time versus Waiting Time in Peak Hour

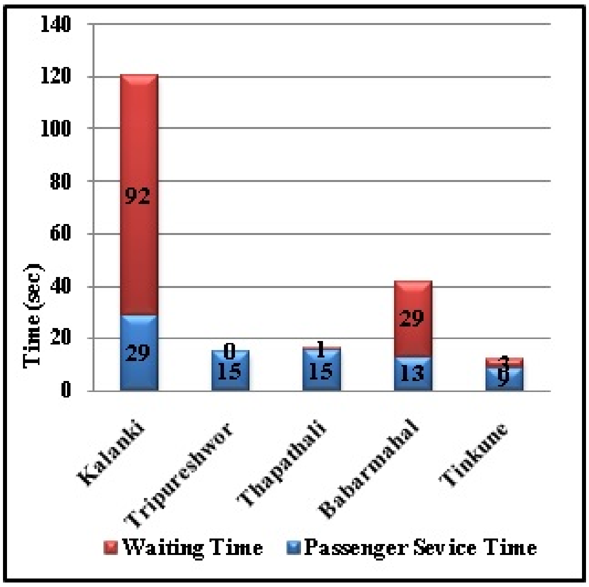

Figure 10: Passenger Service Time versus Waiting Time in Off-Peak Hour

3.10 Study of Different Factors on Dwell Time

3.10.1 Impact of Cash Fare Payment

On comparison of regression coefficients of number of passengers alighting with pre-paid fare (N_a) and number of passengers alighting with cash fare transaction (N_{ac}) of equation 2, it has found that the average per passenger alighting time with cash fare transaction is 2.037 sec more than average per passenger alighting time with pre-paid fare.

3.10.2 Impact of Crowding

Similarly, regression coefficient of vehicle occupancy (V_o) in equation 2 indicates that crowding condition inside the vehicle lengthened the dwell time by 6.5 sec per hundred percent increase in vehicle occupancy.

3.10.3 Impact of Door Position

For this two models estimation were done, one for front door position and another for center door position. The model estimation for front door position is illustrated in table 4. For this model estimation, the sample size considered is 303 (greater than n≥50+8m, m being number of independent variable considered in model estimation), average number of boarding passenger is 2.37, average number of pre-paid fare alighting passenger is 1.27, average number of cash fare transaction alighting passenger is 0.58, average vehicle occupancy is 87.11% and average time taken for passenger waiting is 16.48 sec.Dwell time model estimation for front door position is as per equation 6.

$$D_t = 3.042 * N_b + 2.469 * N_a + 5.530 * N_{ac} + 0.049 * V_o + 1.026 * T_w \quad (6)$$

Table 4: D_t Model Estimation for Front Door Position (Model IV)

Dwell time	Coefficient	Standard Error	t	Sig.
N_b	3.042	0.189	16.069	0.000
N_a	2.469	0.297	8.305	0.000
N_{ac}	5.530	0.367	15.065	0.000
V_o	0.049	0.009	5.520	0.000
T_w	1.026	0.014	75.097	0.000
Adjusted R^2=0.977				

Similarly, dwell time model estimation for center door position is illustrated in table 5. For this model estimation, the sample size considered is 68, average number of boarding passenger is 2.53, average number of pre-paid fare alighting passenger is 2.21, average number of cash fare transaction alighting passenger is 0.81, average vehicle occupancy is 96.54% and average time taken for passenger waiting is 14.32 sec. Dwell time model estimation for center door position is as per equation 7.

$$D_t = 5.916 + 2.118 * N_b + 1.252 * N_a + 4.032 * N_{ac} + 1.109 * T_w \quad (7)$$

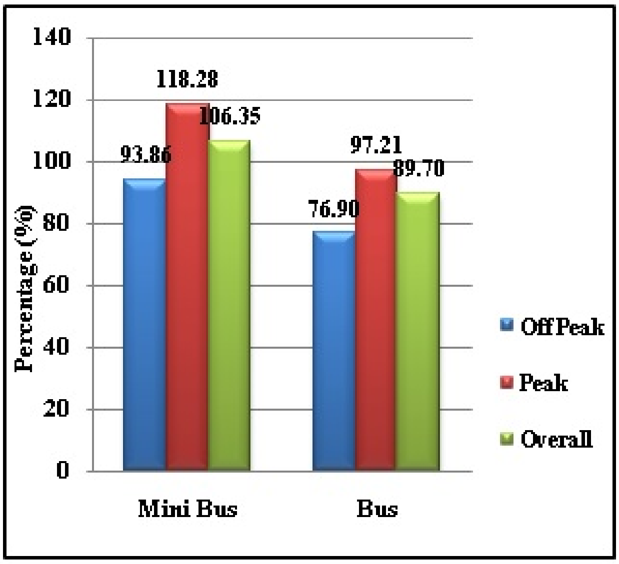

Figure 11: Vehicle Occupancy versus Bus Category in Peak and Off Peak

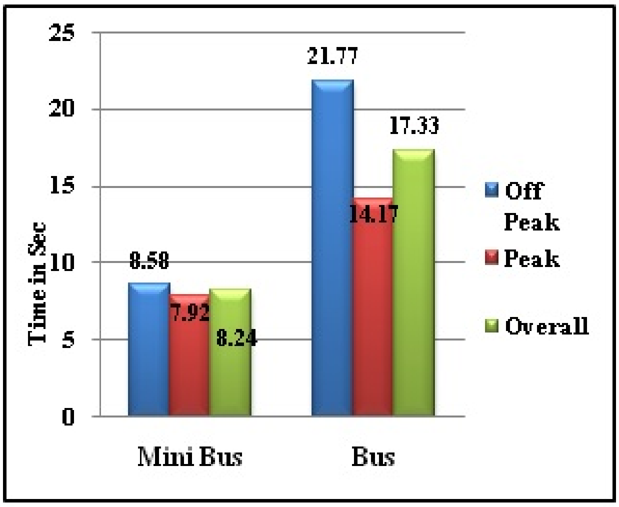

Figure 12: Waiting Time versus Bus Category in Peak and Off Peak

On comparison of Model IV and Model V, both the average per passenger boarding time and average per passenger alighting time of pre-paid fare is found to be lesser in center door position by 0.924 sec and 1.217 sec respectively.

4. Conclusion

The following conclusions were drawn from this research study:

• Average per passenger alighting time with cash fare transaction is 2.037 sec more than average per passenger alighting time with pre-paid fare for the study area.

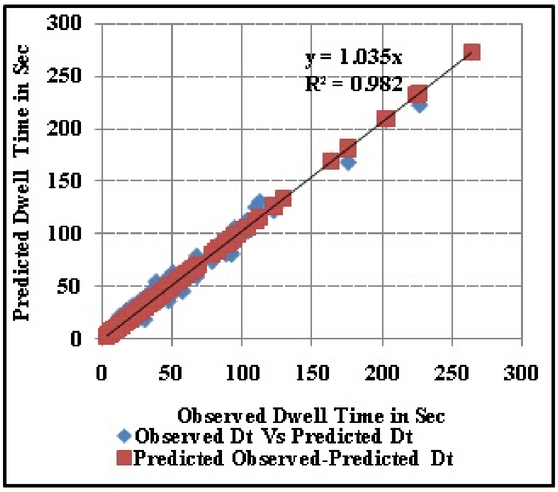

Figure 13: Validation of D_t Model of Study Area

Table 5: D_t Model Estimation for Center Door Position (Model V)

Dwell time	Coefficient	Standard Error	t	Sig.
Constant	5.916	1.424	4.155	0.000
N_b	2.118	0.160	13.271	0.000
N_a	1.252	0.392	3.193	0.002
N_{ac}	4.032	0.561	7.192	0.000
T_w	1.109	0.032	34.258	0.000
Adjusted R^2=0.962				

• Average per passenger boarding time during off-peak hours is almost 23.34% (0.613 sec) higher than average per passenger boarding time during peak hours which may be due to rush in work during peak hours.

• Average per passenger alighting time with pre-paid fare is comparable in both peak (2.257 sec) and off-peak hours (2.350 sec).

• Crowding condition inside the vehicle increased the dwell time by 6.5 sec per hundred percent increase in vehicle occupancy in the study area considered.

• Average boarding time per passenger and average alighting time per passenger was found to be lesser in center door position by 0.924 sec and 1.217 sec respectively.

5. Recommendation

Based on the study following is recommended for future works.

1. Research can be carried out to study dwell time on all public passenger motor vehicles defined by Motor

Vehicles and Transport Management Rules, 2054 (1997) [5].
2. The study can be carried out with multiple route in Kathmandu Valley.
3. The study can be carried out with sample from both direction bus stops.
4. The study can also be done on other contributing factor on dwell time like door width, number of doors, age of passengers etc.
5. The study can be done separately considering waiting time only in multiple routes.

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