Behavior of Public Vehicles at Bus Bay Bus Stops of Kathmandu: A case study of Bus Bay at Thapathali

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Abstract: This paper investigates behavior of different types of public vehicles in the bus bay. Understanding the behavior of different vehicles in the bus bay is necessary to determine the inefficiencies and safety issues associated with the current operations at the bus stops. This includes location where they stop, duration of their stopping, activities during the stopping and time taken to clear the bay. This paper tries to investigate these behavior and factors that leads to the delays in the bus stop. This paper shows that the rate of boarding and alighting for different types of vehicles and buses of different routes/operators is different. Further, the reason for their variation is also explored. The factors affecting the dwell time is investigated and quantified. The extent of crowding that exists is also considered and its possible effects accounted for. The models developed for dwell time shows strong relation of the dwell time with the number of passengers boarding and alighting, and number of off-vehicle transactions. This paper also suggests that the traffic flow in the adjacent lanes has no effect on the normal bus bay operations except when breakdown occurs due to traffic jam in the upstream of the bus bay.

Keywords: bus bay bus stop; dwell time; clearance time; public transit; regression model; boarding rate; alighting rate; crowding effect

1. Introduction

Bus stop is an area where one or more buses load or unload passengers. It consists of one or more loading areas and may be on-line or off-line (Transport Research Board, 2000). The bus bay allows the public vehicles to stop off the line of flow and allow the thorough traffic to flow without obstruction by the stopping vehicles. In case of Kathmandu, the bus stop area is used by buses, micro-buses, small van and 3 wheelers. Bus dwell time at a bus stop is defined as the time spent by a bus at the bus stop for passenger alighting and boarding, including time of opening and closing bus doors (Jaiswal, Bunker, & Ferreira, 2010). Once a bus closes its doors and prepares to depart a stop, there is an additional time called the clearance time, when the loading area is not yet available for the use by next bus. Part of this time is fixed, consisting of the time for a bus to start up and travel its own length, clearing the stop (Mushule, 2012). In case of off-line bus bay bus stop, there is an additional component to clearance time- the time required for a suitable gap in traffic to allow the bus to re-enter the street. This re-entry delay depends on traffic volume in the curb lane and upstream traffic signal (Mushule, 2012).

Each stop that a bus makes along its route requires time, which affects how fast the route operates, which influences how many buses are required to operate the route, which in turn sets the cost of operating the route (TRB, 2013). According to the highway capacity and quality of service manual (2013), the bus dwell time depends upon the time for opening and closing of the door, passenger demand, fare payment, vehicle configuration, passenger load, door usage and platform configuration.

Population growth on one hand and physical limitations of resources and constraints on the other hand have hindered further expansion of road network systems of cities around the world (Aashtiani & Iravani, 2002). Proper understanding and estimation of dwell time and clearance time helps to accurately predict and thus schedule public transit. The calculation of dwell time is necessary in modeling transit assignment because an accurate estimation of dwell time will lead to more precise transit assignment results(Aashtiani & Iravani, 2002). Further, understanding of factors and their effects that lead to increased delay at stops will help to develop measures to reduce the delays and make the public transit more reliable and efficient. Lack of reliability in public transport results in uncertainty and delays aggravating anxiety and discomfort for the passengers, and increases costs due to lost mileage and lower fleet utilization for the operators(Liu & Sinha, 2008).

Bus dwell time is of great importance to estimate capacity of a bus station. It is also a major component of bus travel time. In addition, the bus dwell time functions play a vital role in the transit assignment models and reliability analysis of the transit network (Meng & Qu, 2013). Dwell time at stops is one of the most important factors that should be considered in improving bus transit service quality as it is the major delay that is not encountered by the private cars in the network (Li & Li, 1971). A significant portion of journey time is spent in bus stops as dwell time and clearance time. A cross section study conducted by Levinson (1983) in cities of U.S. stated that nearly 26% of total bus travel time is contributed exclusively by bus dwell time. According to Maloney and Boyle (1999) bus dwell time at stops can contribute 9% - 11% of the total bus travel time.

Reliability of public transport systems has been considered critically important by most public transport users because passengers are adversely affected by the consequences associated with unreliability such as additional waiting time, late or early arrival at destinations and missed connections, which increases their anxiety and discomfort (Bates J., Polak, Jones, & Cook, 2001). In theory, improving transit service reliability has been linked to increases in transit demand for particular routes and also should increase service productivity, given accurate schedules (El-Geneidy, Horning, & Krizek, 2010). For a given limited travel time budget, higher delays at bus stops results in reduced coverage by the service and thus the accessibility. Different approaches promote faster transit speed and greater geographical coverage for a given travel time budget to enhance accessibility (Murray & Wu, 2003).

1.1 Background

The rate of increase in population of Kathmandu Valley (4.86% per annum for Kathmandu district, 3.29% per annum for Lalitpur district and 3.04% per annum for Bhaktapur district) is more than double the country's growth rate (1.4% per annum) (CBS Nepal, 2001-2011).

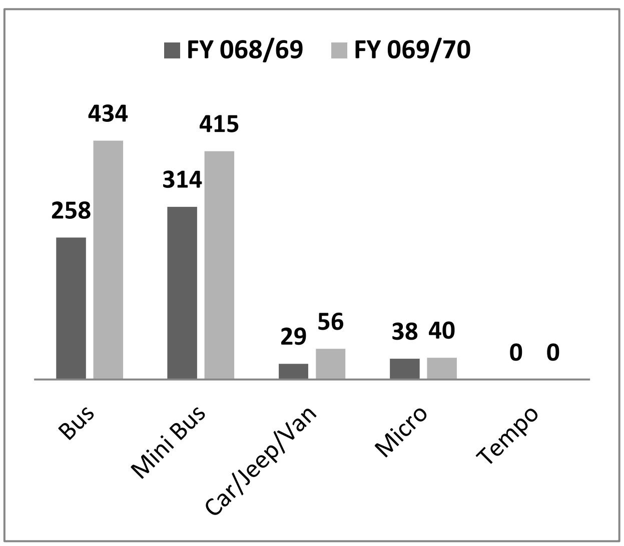

Figure 1: Number of public vehicles registered in Bagmati zone (Source: MoPIT, DoTM)

The rise in population directly increases the demand to mobility in terms of service required. During the time period of 1991 to 2011 the mode share of buses for travel has slightly increased from 27.2% to 27.6% (MoPIT Report, 2012). This share of travel by bus is nearly half of the total motorized travel mode share. The share seems to be stable but due to high population rise, the demand, in terms of number, is ever increasing. The increase in demand can be visualized by the increasing number of public vehicles being registered.

To cope with the rise in demand, there has been an extensive road expansion projects in Kathmandu Valley and every year large number of public vehicles is added to the service. During the fiscal year 069/70, 849 public buses and mini-buses were registered in Bagmati zone. Despite the addition of large number of vehicles to the service every year, the supply seems deficit as passengers are forced to make uncomfortable, unreliable and risky trips. Recently, KMC has initiated installation of modern bus-stop furniture along major corridors in the urban area.

Though there is large investment being made on infrastructure development in Kathmandu Valley, no significant change in public transit operation and management is implemented in the conventionally run services. Apart from the introduction of high capacity *Sajha Yatayat* buses with two doors (front and rear) into service and construction of bus bay bus stops, the method of operation and management in Kathmandu Valley is still same as before. The road expansion has reduced the congestion, but with the increasing motorization the problem will only be temporarily absent. A long term change in terms of policy and operation of public transit is very much necessary. For the policy to be realistic, it should be backed with proper data and research findings.

A reliable public transit service is one with reliable accessibility and journey time. Study to identify the causes of delay and the extent of impact they have on the journey time will enlighten the neglected issues. Proper estimation helps to schedule a reliable time table for the transit.

1.2 Objectives

- To investigate the factors that affects dwell time and clearance time of public transit vehicles at bus bay bus stops.
- To develop model of dwell time of public vehicles at bus bay bus stops of Kathmandu Valley.
- To investigate different public vehicle behavior at bus stop and their interaction with the passengers.

1.3 Limitations

- The data was collected only for 2 days (9 hours) which was not be sufficient to generate required number of data for detail analysis of few parameters.
- Limitation posed by technology available and time available to conventionally collect and extract data, factors such as crowding in and off the vehicle, vehicle internal clearance height, density of the passengers at the stop, boarding lost time, etc which may be contributing to the dwell time could not be quantified.

2. Methodology

The bus stop under study is Thapathali bus stop. It is located in front of the central bureau of statistics. It is trapezoidal shape with dimension of parallel sides as 39 meters and 65 meters. Other sides are 14 meters and 15 meters in length. It is used by different types of public vehicles serving more than 15 routes.

This study involves analysis of dwell time and clearance time at Thapathali bus bay bus stop. The data collected for this study was primary source data. All the required information was collected via video-graphic recording. Other necessary information was recorded on field sheets. No any secondary data was used in this study.

2.1 Data collection

The data was collected via video recording for 2 days; 4.5 hours each day (1.5 hour morning peak, 1.5 hours evening peak and 1.5 hours off-peak). The camera was placed on the roof of the Rastriya Banijya Bank Building. The crowding effect was of interest but was not possible to quantify it from the video recorded, so a separate sampling survey was done to check the significance of crowding on the dwell time. Sampling was also done for 2 days, 4.5 hours on each day.

2.2 Data extraction

The video footage captured at site was replayed in the laboratory and following information was noted in excel sheets along with other manually collected data.

- Vehicle characteristics such as number plate, type of vehicle and route served by each vehicle that pull-over at the bus stop.
  - The time when the bus arrives and comes to complete halt.
  - The number of passengers that board and get off the vehicle.
  - Possible reasons for delay such as overcrowding of the passengers inside the vehicle or on the stop platform.
  - Fare collection: off the vehicle after alighting.
  - The time when the bus doors are closed and the bus starts to depart.
  - The time it takes to get accepted into the main flow traffic.
  - Speed of the traffic in the main flow stream.

2.2 Method of analysis

All the data was stored in a excel sheet and different parameters of interest were calculated from it. Multiple regression modeling was adopted to investigate the extent of factors influencing the dwell time of the public vehicles. The dependent variable is dwell time; and the independent variables are number of passengers who alight or board the vehicle, crowding in vehicle, and door opening and closing time for dwell time. Stepwise multiple regressions were done using statistical software such as Microsoft Excel. The best regression with highest R^2 value was chosen. A level of significance of 95% was assumed for regression modeling.

3. Findings

3.1 Vehicles stopping details

During the specified time, a total of 899 vehicles stopped in the specified bus bay area. The details of these and other public vehicles are tabulated below:

Table 1: Public vehicle behavior at the bus stop

Type of Vehicle	Vehicles stopped in the bay	Vehicles not stopped	Vehicles stopped off the bay	Failure
Bus	348	88	34	49
Jumbo Micro	201	121	10	41
Micro	112	77	2	21
Tempo	175	209	8	19
Van	63	50	3	3
Sum	899	545	57	133
% of total	57.37	34.78	3.64	8.49

The vehicles that stopped in the bay were observed in detail for analyzing and modeling purpose. Of all the vehicles that stopped inside the bus bay, nearly 50% stopped in the first quarter of the bay as shown in figure 2.a. Similarly, the inner edge of the vehicles, for nearly 84% of the vehicles, was in middle half of the bay as shown in figure 2.b.

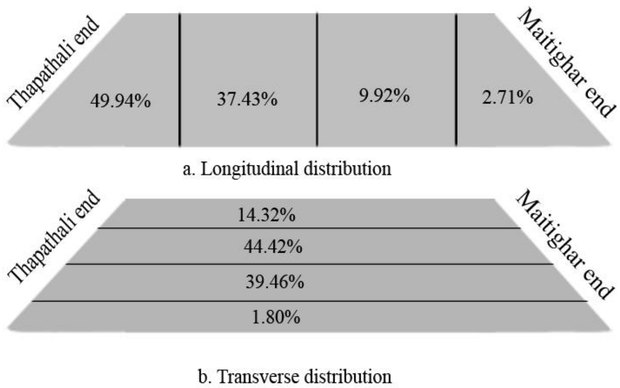

Figure 2: Distribution of stopped vehicles in space

3.2 Boarding and alighting

Boarding and alighting of the passengers is the main reason for the stopping of the vehicles at the stop. During the study, a total of 897 passengers boarded and 956 passengers got-off of different public vehicles at Thapathali bus stop. For the modeling purpose the boarding and alighting was further classified into primary and secondary. The primary being the immediate boarding and alighting of the passengers after the vehicle stops in the bay in. After the primary boarding and alighting the vehicle waits for some time for other passenger, this extra time is taken as secondary dwell time and the boarding and alighting taking place during this time as secondary boarding and alighting. The primary dwell time includes the time taken for off-vehicle fare payment by the passengers alighting primarily.

Table 2: Number of passengers alighting and boarding summary

Type of Vehicle	Number of boarding passengers		Number of alighting passengers	
	Primary	Secondary	Primary	Secondary
Bus	454	129	403	22
Jumbo Micro	107	38	230	5
Micro	59	15	56	3
Tempo	67	14	108	8
Van	12	2	114	7
Total	699	198	911	45

Table 3: Passenger boarding an alighting detail

Type of Vehicle	Primary Boarding	Number of vehicles	Primary Alighting	Number of vehicles	Secondary boarding	Number of vehicles	Number of off-vehicle Transaction	Number of vehicles
Bus	454	184	403	166	129	52	61	38
Jumbo Micro	107	61	230	123	38	21	12	9
Micro	59	39	56	40	15	12	9	6
Tempo	67	50	108	75	14	10	40	35
Van	12	9	114	49	2	2	40	22

The rate of boarding and alighting is of great importance to determine the required dwell time at any bus stop. It is the time required for boarding and alighting each passenger. These vary according to the type of vehicle (dimensions) and the crowding conditions. The average boarding and alighting rates are for different types of vehicles and different operator buses are summarized in the figures below.

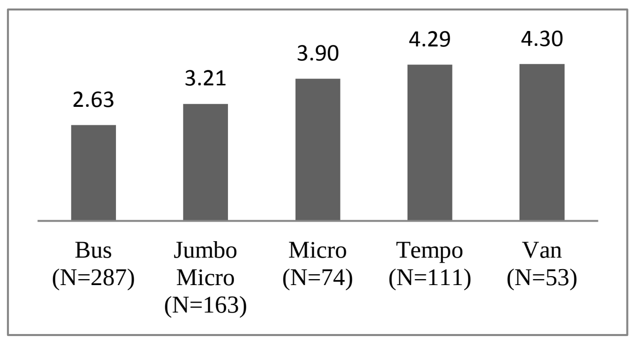

Figure 3: Rate of boarding and alighting (combined) of different types of vehicles (in sec)

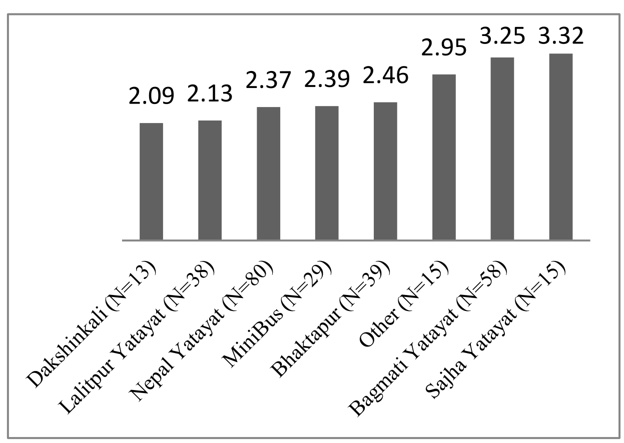

Figure 4: Rate of boarding and alighting (combined) of different route-operator buses (in sec)

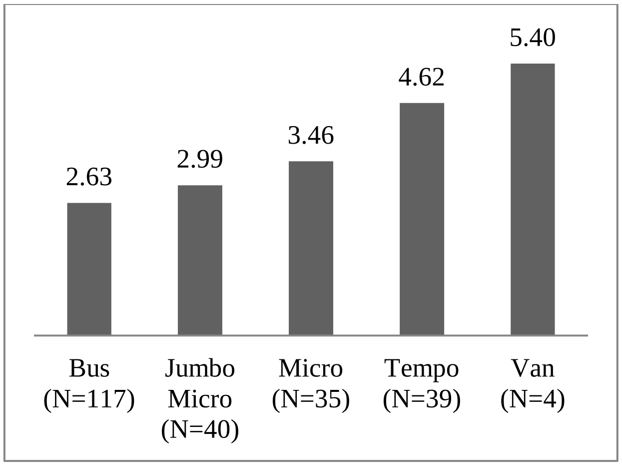

Figure 5: Rate of boarding of different types of vehicles (in sec)

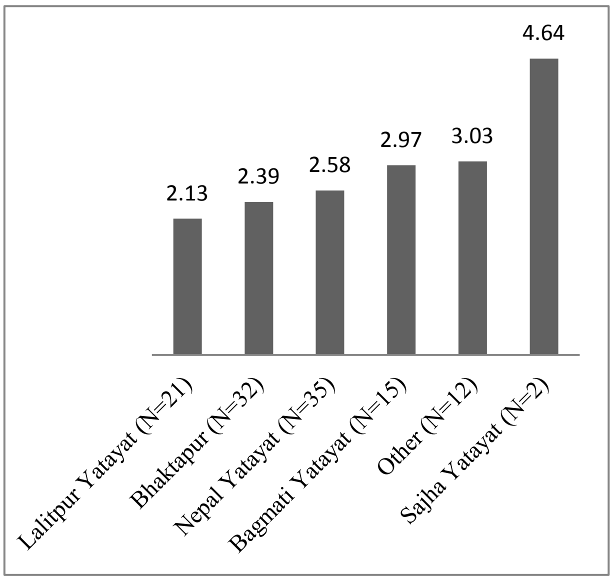

Figure 6: Rate of boarding of different route-operator buses (in sec)

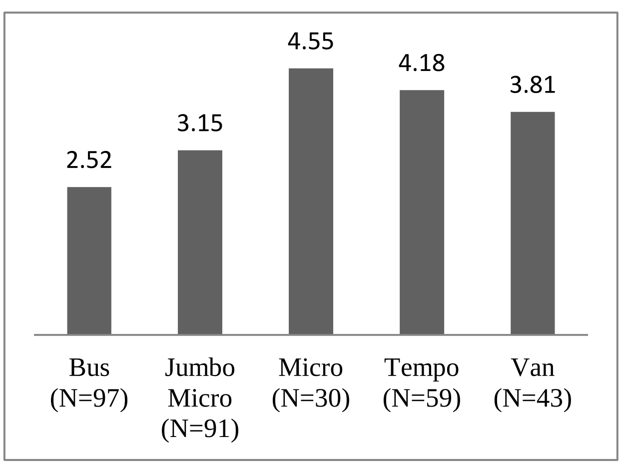

Figure 7: Rate of alighting of different types of vehicles (in sec)

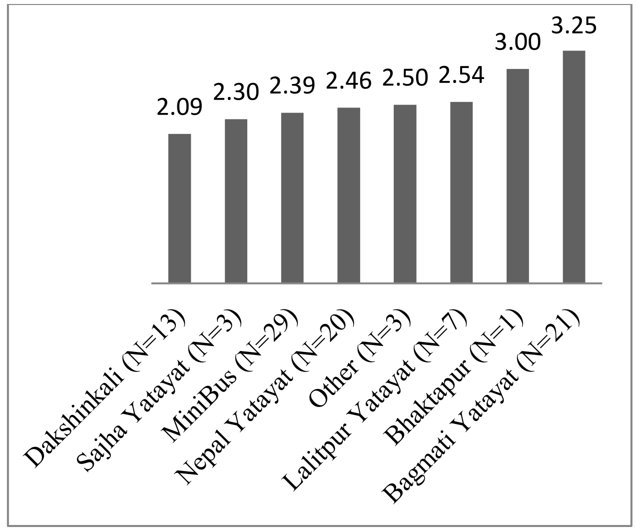

Figure 8: Rate of alighting of different route-operator buses (in sec)

The rate of boarding alighting, individual and combined is in increasing order from buses to van through jumbo micro, micro and tempo; except for alighting rate of micro. It can be seen that the rate is very high in case of tempo (3-wheelers) and small van. This clearly shows that there is a direct link of the vehicle dimension and its seat arrangement with the rate of boarding and alighting.

Further classification of buses revels that even though the dimension and seat arrangement of buses of Bhaktapur and Dakshinkali routes, *Lalitpur Yatayat*, *Bagmati Yatayat* and *Nepal Yatayat* are similar there is a variation in the boarding and alighting rate. This variation may be attributed to the crowding condition of these different route-operator buses as seen from the random sampling of the vehicles.

Further, the values for rate in case of *Sajha Yatayat* are also very high. But because the number of data observed is very few, these figures can only be used as indicative values. The high boarding and alighting (combined) rate and boarding only rate of may be due to confusion as to which door to use to board as seen during the observation and delay in opening of the back door. Also, when the vehicle is highly crowded, boarding was done from the front door after all the alighting took place. Payment of fare inside the bus, at the bus stop while the bus is at halt also contributes high rate of boarding and alighting.

3.3 Crowding

To see the contribution of crowding, a separate sample data was manually collected from the bus stop. Crowding condition was observed in 47.59% of buses and 14.93% of jumbo micro buses.

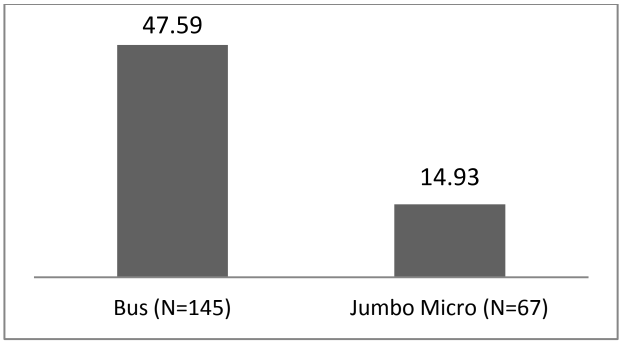

Figure 9: Percentage of vehicles with crowding

Among above mentioned operators, the rate of boarding and alighting is highest for *Bagmati Yatayat* vehicles, and from the sample data it is seen that all the vehicles operating in this specific route are crowded.

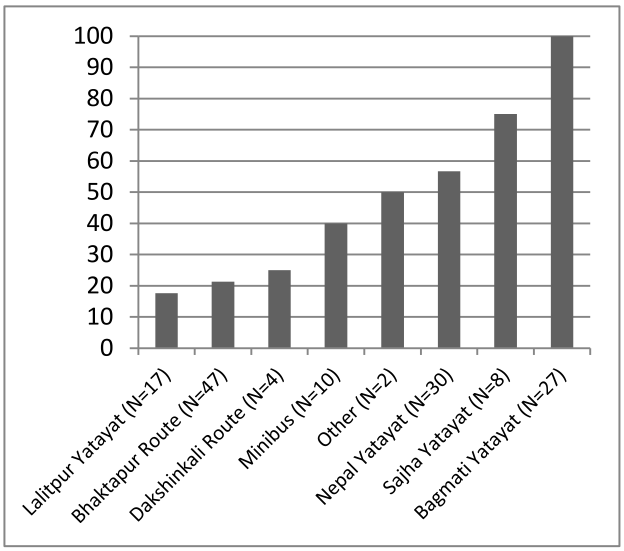

Figure 10: Percentage of crowded vehicles of each route-operator

The crowding condition affects the rate of boarding and alighting. Its effects can be visualized from the following figures:

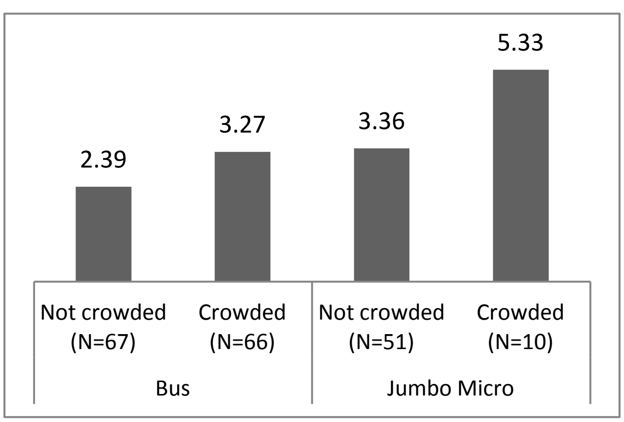

Figure 11: Rate of boarding and alighting for crowded and not crowded condition (in sec)

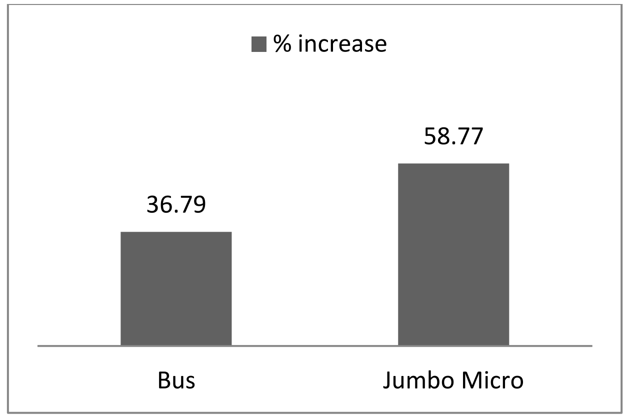

Figure 12: Change in boarding and alighting rate due to crowding

The increase in rate of boarding and alighting is maximum for *Lalitpur Yatayat* buses (increase by 68.42%) while the increase is minimum for buses in route to Bhaktapur (increase by 4.43%).

3.4 Door operation

The time for opening and closing the vehicle door is also a component of the vehicle dwell time. Proper bus bay use does not allow the movement of vehicle with open doors. So, the doors should be opened only after the vehicle comes to complete halt and the vehicle should close the doors before moving out. This procedure was followed by only two vehicles; a micro and a small van. Other twelve vehicles only opened the door after stopping while only 3 other vehicles started to move after closing the doors. This procedure omits the time for opening and closing the door from the dwell time equation. But it is unacceptable from the safety point of view. The door opening time varied from 2 to 4 seconds while the door closing time varied from 1 to 3 seconds for different vehicles.

3.5 Clearance time

Clearance time is the time taken by a vehicle to enter the curb lane flow after stopping in the bay. It can be divided into time for in-bay movement to the edge of the bay and time to get accepted in the curb lane flow. The data suggest that the clearance time is not affected by the flow characteristic in the adjacent curb lane. Out of all 899 vehicles only 102 vehicles' interacted with flow in the curb lane. This is because the flow in the main road is concentrated to the inner lane. Slow moving public vehicles at the entry of the bus bay forces other vehicles to take the inner lane, which ultimately results in very low traffic in the curb lane along the bus bay and at the exit of the bus bay.

As seen from figures above, more than 87% of the vehicles that stops in the bay stop in the first half of the bay. So, while clearing the bus bay the vehicles tend to move slowly to the other half looking for more passengers. While exiting, more than 65% exited from the latter half of the bus bay. This contributes to further delay at the bus bay. Time for acceptance with and without interaction with flow lane traffic does not vary. The range of time taken by different vehicles while encountering flow in curb lane falls almost within the range of time taken to enter the flow lane without vehicles in the flow lane.

Table 4: Acceptance time for different type of vehicles with and without flow in the curb lane

Type of vehicle	Acceptance time (with flow in curb lane), sec	Acceptance time (without flow in curb lane), sec
Bus	3 to 14	1 to 15
Jumbo Micro	3 to 17	2 to 14
Micro	3 to 7	1 to 15
Tempo	2 to 14	1 to13
Van	4 to 8	1 to 14

3.6 Modeling dwell time

For the purpose of modeling, the dwell time is theoretically divided into time for opening and closing of door, primary dwell time and secondary dwell time. The total dwell time is expressed as follows:

$$T_D = T_{door} + T_{PD} + T_{SD}$$

Where,
T_D = Total dwell time

T_{door} = Time for opening and closing of the door/s

T_{PD} = Primary dwell time

T_{SD} = Secondary dwell time

Modeling of the primary dwell time and secondary dwell time was done separately. The independent variables for primary dwell time are number of primary boarding and alighting and number of off-vehicle transactions. The model is developed separately for different types of vehicles. They are as follows:

Bus

$$T_{PD} = 0.145 + 2.80B_P + 2.03A_P + 4.22N_T$$

$R^2 = 0.696$

$T_{SD} = 8.148 + 14.34\, B_S$

$R^2 = 0.513$

Jumbo Micro

$$T_{PD} = 1.192 + 2.50B_P + 2.32A_P + 2.96N_T$$

$R^2 = 0.602$

Micro

$$T_{PD} = -0.228 + 4.30B_P + 2.03A_P$$

$R^2 = 0.67$

Tempo (3-wheeler)

$$T_{PD} = 1.075 + 3.38B_P + 3.47A_P + 6.02N_T$$

$R^2 = 0.496$

Van

$$T_{PD} = 5.68 + 1.21A_P + 4.43N_T$$

$R^2 = 0.701$

Here,

B_P = Number of primary boarding

A_P = Number of primary alighting

B_S = Number of secondary boarding

N_T = Number of off-vehicle transactions

The modeling of secondary dwell was not possible for jumbo micro, micro, tempo and van because very few vehicles had secondary boarding. So, the secondary dwell time is more related to drivers' willingness to wait for more passengers, than the actual passenger movement at that time. For the same reason, a reasonably significant relation between primary dwell and number of off-vehicle transaction could not be established for micro buses.

4. Conclusion and Recommendation

The above developed models show strong correlation of the dwell time with the number of boarding and alighting passengers, and number of off-vehicle transactions. Collection of fare before alighting can reduce the dwell time. Off-vehicle transaction in case of 3-wheelers has maximum coefficient of 6.02, which suggests that a large portion of dwell time is contributed to off-vehicle transaction. But because no helper is employed, off-vehicle collection of fare is the only safe option.

The value of R^2 varies from 0.5 to 0.7. This means there are additional factors contributing to the dwell times. Crowding of the vehicle is one of them. It contributes to additional delay in boarding and alighting of passengers which ultimately increases the dwell time. Intervention to reduce the crowding of vehicles can help reduce the dwell time. Variation in boarding and alighting rate can also be seen for different bus route operators.

Higher boarding and lighting rate for tempo and van suggests the necessity of bigger public vehicles. Inverse relation of rate of boarding and alighting with respect to the vehicle height/ internal clearance height is also seen, but a more comprehensive study should be done to quantify the extent of its effect.

A very large proportion of vehicle stopped at the first half of the stop, which results in under-utilization of the other half. This is undesirable also because 8.49% (which is nearly 14% of the vehicles that stopped) of the vehicles were parked on the curb lane in front of entry of bus bay while, latter half was still empty. The reason for this is gathering of most of the passengers in the first half. Also, only 14.32% of vehicles stopped close to the curb stone, which means, passengers have to walk further from the waiting area to board the vehicles. It can be unsafe, if the rate of arrival of the vehicles is high especially if the passengers have to walk to the edge of the curb lane to board the vehicle. Proper opening and closing of the vehicles while in motion is not followed. This further makes the bus stop operations unsafe.

There are many factors, as discussed above, which contribute to inefficiency and unsafe conditions of public vehicle operations at bus bay bus stops of Kathmandu. So, it is pertinent to conduct a comprehensive study of the bus stops in Kathmandu and formulate a bus stop regulation dictating limiting criterion for vehicle operations to ensure reduction of unnecessary delay and enhanced safety.

Introduction of new technologies to track the boarding, alighting and dwell of vehicles with proper recording system can help to provide data for proper further analysis and quantifying effects of other factors as well.

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