



2nd International Conference

on

Integrated Transport for Sustainable Mobility

(3-4 February 2023, Kathmandu, Nepal)

Modelling Delay due to Curb-Side Bus Stops at Signalized Intersection: A Case Study of New Baneshwor Intersection

Amul Shrestha^a, Rojee Pradhananga^{b*}

^aNepal Engineering College - Center for Postgraduate Studies (nec-CPS), Pokhara University, Lalitpur, Nepal

^bDepartment of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Kathmandu, Nepal

Abstract

This study analysed the patterns of vehicular delays at curb side lanes near intersection due to three bus stop parameters : distance between bus stop and intersection, length of bus loading area and maximum dwell time. The study was conducted at New Baneshwor, one of the busiest intersections in Kathmandu, Nepal. Traffic data were collected for three hours, of each five weekdays by videographic survey and field observations. VISSIM microsimulation model was calibrated to the local traffic conditions. Then, 192 combinations of scenarios were simulated for the variations in the three bus stop parameters and vehicular delays on the curb side lanes were evaluated. The simulation results showed that for higher values of maximum dwell times, downstream positions were found to have lesser vehicular delays than at upstream, while for lower values of maximum dwell times, the vehicular delays for upstream positions were found to be lesser than or near to that of downstream positions. Furthermore, the delay showed a decreasing trend when the distance of bus stop from intersection increased, while increase in the maximum dwell time showed significant increase in the delay. The vehicular delays for the optimum bus stop scenarios for minimum delays were found to reduce significantly by 82.83% and 75.66% from existing scenarios at the two curb side lanes of the study intersection, which shows that curb side bus stops were found to have significant impact on vehicular delays at the curb side lanes.

Keywords: Curb Side; Bus Stop; Vehicular Delay; VISSIM Simulation; Bus Loading Area; Maximum Dwell Time; Bus Blocking Effect

1. Introduction

The exponential increase in the number vehicles has been a major problem on Kathmandu's streets causing congestion and delays. As per 2019 statistics, vehicle registration in Kathmandu has an overall annual growth rate of 14% (DoTM, 2019).

In an urban context, curb side bus stops are usually present near intersections. When a bus arrives at a curb side bus stop, it creates a temporary bottleneck and obstructs the movement of vehicles in the curb lane, causing vehicular. Such delays can be reduced by proper configuration and service time regulation of curb side bus stops.

There have been several studies on where best to locate a bus stop relative to its nearby intersection (Wentao, Guomin, Dongfang, & Dian-hai, 2020; Liu & Jian, 2019; Chen, Xie, & Wang, 2019; Diab & El-Geneidy, 2015; Gu, Gayah, Cassidy, & Saade, 2014; Wong, Yang, Au yeung, & Cheuk, 1998; SanClemente & Furth, 2006). Some studies have found in favour of far-side stops, while others have reached the opposite conclusion. The matter has yet to be further established, because many studies have by necessity focused on relatively small numbers of select cases and traffic conditions. For example, Gu et al. (2014) used Markov chain model and discovered that the downstream bus stop was better when the intersection approaches saturation, or when the bus dwell time was too long. On the other hand, Liu & Jian (2019) used modified optimal velocity model and found that the upstream bus stop outperforms the downstream one, especially when the entering probability is larger and the distance between the bus stop and the intersection is in the range of 50 – 200 m. Only few literatures have examined the combined

* Corresponding author. Tel.: +977-9849835491

E-mail address: amuls0191203@nec.edu.np

effect of stopping configuration and dwell time of bus stops on vehicular delays. Furthermore, such studies are fewer in case of heterogenous traffic and non-lane behaviour conditions as generally prevalent in context of cities in developing countries of Asia. This shows an obvious gap in the literature and an opportunity to address them in this research.

So, this study aims to analyse the effects due to curb side bus stops near intersections on vehicular delays at the curb side lanes. As a study intersection, New Baneshwor has been taken, as it is one of the most congested intersections in Kathmandu (JICA, 2019). There are existing curb side stops at curb side lanes at East to West (Tinkune to Maitighar) and West to East (Maitighar to Tinkune) directions.

This study would help the traffic planning and management authorities to assess various scenarios for the proper placement of bus stops near the study intersection, which would help in minimizing the vehicular delays arising from the blocking effects of bus stop. It would also help understand the relation between vehicular delays at curb side lane due to variations in bus stop configuration and dwelling times. As the study is in context of heterogenous and non-lane behaviour traffic conditions relevant to developing countries like Nepal, the calibrated data of VISSIM driving behaviour parameters obtained would also help for traffic microsimulation studies in other cities with similar conditions.

2. Methodology

Videographic survey as well as field observations for maximum queue lengths, bus stop dwell times, speed and other traffic data was conducted at the study intersection from 8:30 am to 11:30 am in the morning for five weekdays within 6 to 13th June 2022. Based on this data, VISSIM model has been formed and scenario analysis have been carried out using the calibrated model.

2.1. Microsimulation Model and VISSIM

PTV VISSIM is one of the microscopic multi-modal traffic flow simulation software packages developed by PTV Planung Transport Verkehr AG in Karlsruhe, Germany (Wikipedia, 2022). In VISSIM microscopic simulation software, there are many parameters related to vehicle, driver behaviour, lane changing, trajectory, signal control and so on, which can be changed for modelling the driver behaviour patterns. The parameters have inbuilt default values, but can be adjusted during the calibration process to suit the local conditions (Suthanaya & Upadiana, 2019). The latest version of PTV Vissim 2022 (SP06) (Academic License) with unlimited network size and simulation time has been used.

2.1.1. Base Model Formation

The base model formation included the following steps:

- Geometry coding – The intersection road geometry was formed by the help of Google Earth Imagery. Links and link connectors were then formed over it.
- Vehicle inputs – Traffic demand data was input in the forms of entry volumes and turning movements at intersections at 15-minute interval as per vehicle types and composition to specific links within the VISSIM network. 3D models of each vehicle type prevalent at the study intersection along with their dimensions were input.
- Vehicle Routings: Routing decisions in the form of static vehicle routing decisions were coded on the corresponding links as the vehicle input.
- Speed – Maximum and minimum values of vehicle speed were entered as per the field data.
- Signal control –Phase sequence and Timings were input into the Signal Program and Signal Heads were added at the Stop line of each leg.
- Transit Stops: Transit Stops and their length were input. Similarly, field measured maximum dwell times were input to each stop based on different categories of public transit vehicles.
- Finally, Nodes, Data Collection points and Queue counters were placed to obtain output for calibration, validation and scenario analysis simulations.

Figure 1 shows the formation of links (blue lines) and connectors (pink lines) to depict the geometric configuration of New Baneshwor Intersection (left) and the setup of stops (right).

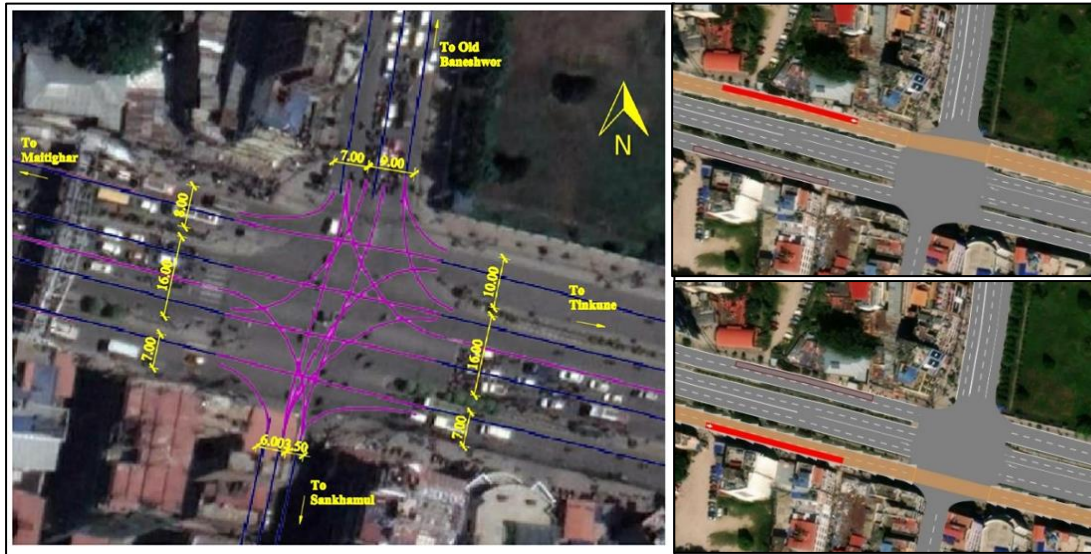


Figure 1. Setup of New Baneshwor Intersection (left) and transit stops (right) (Source: PTV VISSIM)

From review of literatures under heterogeneous and non-lane behaviour traffic conditions, the minimum lateral clearances for all categories of vehicles at stationary (0 km/h) and 50 km/h situations were adopted. The values of minimum lateral clearance for different categories of vehicles as per the corresponding literatures referred and that adopted in this study is shown in Table 1.

Table 1. Minimum Lateral Clearance of Vehicles adopted with reference from Literatures

Literatures referred	At Speed 0 km/h					At Speed 50 km/h				
	Two-wheeler	Three-Wheeler	Four-Wheeler	Bus	Truck	Two-wheeler	Three-Wheeler	Four-Wheeler	Bus	Truck
(Khan, et al., 2022)	0.25	0.25	0.3	0.4	0.4	0.3	0.3	0.5	0.5	0.7
(Maheshwary, et al., 2019)		0.4	0.6		0.8		0.4	0.6		0.8
(Mistrya, et al., 2022)	0.25	0.25	0.3	0.4	0.4	0.3	0.5	0.5	0.7	0.7
(Dey, et al., 2018)			0.6					0.8		
(Mondal & Gupta, 2021)	0.1	0.1	0.2	0.5	0.5	0.5	0.6	0.8	0.8	0.9
(Raju, et al., 2020)	0.25	0.25	0.3	0.4	0.4	0.3	0.3	0.5	0.7	0.7
(Jayasooriya & Bandara, 2018)			0.5					0.75		
Adopted for this study	0.25	0.25	0.3	0.4	0.4	0.3	0.5	0.5	0.75	0.75

2.1.2. Calibration

This study used the trial-and-error method by adjusting parameters iteratively to obtain the best match possible between the model outputs and field measurements. The calibration of model has been done using the three day's data. An effective calibration should include one system performance measure and localized performance measure (Karl Wunderlich; Meenakshy Vasudevan; and Peiwei Wang, 2019). For calibration, traffic volume has been selected as a key performance measure, while maximum queue length was selected as an additional calibration measure. The model calibration procedure used in this study is presented in Figure 2.

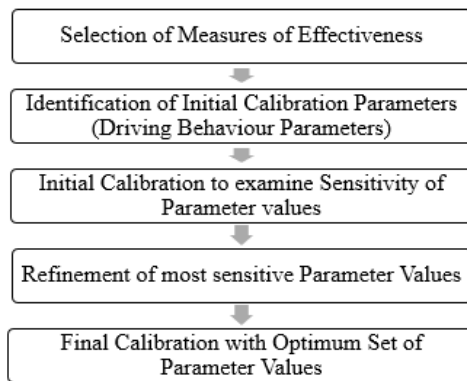


Figure 2: Steps in the Calibration Process

A comprehensive review of literatures related to VISSIM calibration under heterogenous and non-lane-based traffic was carried out. Based on the review, nine set of driving behaviour parameters were found to be suitable for calibration for these traffic condition. The range of these driving behaviour parameter values were adopted as per findings of the studies. Three values of each parameter within these ranges were taken, so that sensitivity of these parameters could be examined. The parameters taken for initial calibration have been presented in Table 2.

Table 2. Parameter value ranges taken for Initial Calibration with reference from Literatures

S.N.	Initial Parameters	VISSIM Default Values	Value Ranges with reference from Literatures	Values adopted for Initial Calibration		
Following						
1	Look ahead distance	Min (m)	0	10	20	30
2		Max (m)	250	100	120	140
3	Look back distance	Min (m)	0	6	12	18
4		Max (m)	150	80	100	120
Wiedemann 74						
5	Average standstill distance (m)	2	0.40 - 1.20	0.6	0.8	1.2
6	Additive part of safety distance	2	0.10 - 1.00	0.20	0.6	1
7	Multiplicative part of safety distance	3	0.60 - 1.20	0.6	0.8	1.2
Lane Change						
8	Min. clearance (front/rear) (m)	0.5	0.25 - 0.80	0.25	0.4	0.8
9	Safety distance reduction factor	0.6	0.20 - 0.60	0.25	0.4	0.6

Note:

Literatures Referred are (Khan, et al., 2022; Paul, et al., 2019; Bandi & George, 2021; Hussain, et al., 2017; R., et al., 2020; P.a, et al., 2019; Mistrya, et al., 2022; Dey, et al., 2018; Mondal & Gupta, 2021; Raju, et al., 2020; Acharya & Marsani, 2020; Sharma, 2016)

2.1.3. Statistical Methods used for Calibration and Validation

To check the accuracy of output, GEH (Geoffrey E. Havers) statistic will be used. Root Mean Squared Normalized Error (RMSNE) have been used, to measure the percentage deviation of the simulated data from field data. The equations for GEH and RMSNE are shown by equations (1) and (2) respectively.

$$GEH = \sqrt{\frac{2(M-C)^2}{(M+C)}} \dots\dots\dots (1)$$

Here, M = Modelled Value, C = Counted Value

$$RMSNE = \sqrt{\frac{1}{n} \sum_{i=1}^n \left(\frac{y_{i,sim} - y_{i,obs}}{y_{i,obs}} \right)^2} \dots\dots\dots (2)$$

Here, n= total number of traffic measurement observations, yi, sim and yi, obs = simulated and observed data

As per FDOT (2014), the acceptance threshold for GEH is less than 5%, for RMSNE is less than 0.15 and for % difference is less than 20%, for traffic volumes and queue lengths.

2.1.4. Scenario Analysis using Validated Model

There are various factors affecting vehicular travel time, delay and reliability. However, there are some basic factors that are widely agreed to have effects. Intersection control, traffic volumes, configuration of bus stops and bus passenger loadings are some of them which are mentioned in several literatures (Abdy, 2010; Alshnawa, 2017; B. Vinayaka, 2016; Buck, 2017; Chen, et al., 2019; Huo, et al., 2018; Dogan, et al., 2020; Wong, et al., 1998; Shidong, et al., 2016; Gu, et al., 2014). For this study, the scenario analysis was carried out by varying the following combination of bus stop parameters:

1. Distance between Bus Stop and Intersection Stop line
2. Length of Bus loading area (Bus Stop)
3. Maximum Dwell Time

Forty-eight combinations each due to variation of these bus stop parameter values were formed, for upstream and downstream positions at both the Maitighar-Tinkune and Tinkune-Maitighar directions. The distance between bus stop and intersection was varied from 40 m to 140 m at an interval of 20 m, 40 m and 60 m length of loading area were taken, while maximum dwell times were taken as 60 sec, 90 sec, 105 sec and 120 sec. A total of 192 scenarios were simulated including both the curb side bus stops as well as upstream and downstream positions.

To obtain the average vehicular delays for these scenarios, travel time for each simulation were collected with Travel Time Collection (TTC) segments. TTC segments were coded with a starting point and stopping point, at a distance 250 m upstream from the intersection and 250 m downstream from the intersection to allow for sufficient provision of distance for deceleration or acceleration distance on approaching and departing from the stop.

Prior to scenario analysis, the simulation was first run to get the average travel time of all vehicles was determined under no bus stop condition, so that it could be used as a basis to calculate delay due to the effect of bus stops only. Then the delay due to bus stops under several scenarios were calculated by subtracting it with the travel time under no bus stop condition.

3. Results & Discussion

The results from VISSIM calibration and the Scenario analysis from the validated model thereafter have been discussed in the subsequent subheadings.

3.1. Model Calibration

Model calibration was done in steps as described under previous heading and the results have been presented subsequently.

3.1.1. Initial Calibration

The initial calibration was carried out using the above values for the nine set of parameters. Each set contains three variations in values. During each run, only one parameter value was changes while keeping the other parameters unchanged from the VISSIM default values. Simulation output of Traffic volume showed very low percentage differences, from 0.86% to 21.76% in each of the intersection approaches, most of them bring close to 10%. The intersection approach wise percentage difference between field data and simulation output of maximum queue length has been presented in Table 3.

Table 3. Percentage Difference between Field Data and Simulation Output for Maximum Queue Length at each approach

Set	Parameter Values	Variation in Parameter Values	% Difference of Field Data and Simulation Output for Maximum Queue Length					Cumulative % Difference	
			MG SL	MG ML	TK SL	TK ML	OB		SM
1	Look ahead distance (Min)	10.00	94.32%	22.29%	5.04%	135.51%	3.61%	111.19%	371.95%
		20.00	73.95%	22.99%	21.23%	87.08%	9.68%	87.61%	302.54%
		30.00	77.13%	24.88%	17.09%	116.20%	6.44%	90.85%	332.60%

Set	Parameter Values	Variation in Parameter Values	% Difference of Field Data and Simulation Output for Maximum Queue Length						Cumulative % Difference
			MG SL	MG ML	TK SL	TK ML	OB	SM	
2	Look ahead distance (Max)	100.00	85.60%	23.57%	16.23%	67.09%	2.61%	95.67%	290.77%
		120.00	73.95%	22.99%	21.23%	87.08%	9.68%	87.61%	302.54%
		140.00	94.52%	29.28%	10.39%	129.51%	7.06%	90.06%	360.82%
3	Look back distance (Min)	6.00	68.91%	25.45%	7.06%	122.99%	6.84%	107.34%	338.58%
		12.00	73.95%	22.99%	21.23%	87.08%	9.68%	87.61%	302.54%
		18.00	75.51%	27.42%	11.39%	119.16%	3.84%	128.64%	365.96%
4	Look back distance (Max)	80.00	73.95%	24.25%	21.23%	87.08%	9.68%	87.61%	303.80%
		100.00	73.95%	22.99%	21.23%	87.08%	9.68%	87.61%	302.54%
		120.00	73.95%	24.25%	21.23%	87.08%	9.68%	87.61%	303.80%
5	Average standstill distance (m)	0.60	77.76%	10.72%	0.30%	59.71%	3.04%	70.23%	221.76%
		0.80	73.95%	22.99%	21.23%	87.08%	9.68%	87.61%	302.54%
		1.20	77.28%	41.06%	29.37%	158.34%	32.26%	155.22%	493.53%
6	Additive part of safety distance	0.20	87.06%	19.78%	0.12%	55.41%	0.21%	89.90%	252.48%
		0.60	73.95%	22.99%	21.23%	87.08%	9.68%	87.61%	302.54%
		1.00	65.67%	29.39%	25.60%	133.82%	7.85%	120.93%	383.25%
7	Multiplicative part of safety distance	0.60	81.98%	20.12%	9.98%	101.11%	7.20%	113.02%	333.41%
		0.80	73.95%	22.99%	21.23%	87.08%	9.68%	87.61%	302.54%
		1.20	49.83%	26.21%	10.59%	136.49%	9.21%	100.05%	332.38%
8	Minimum clearance (front/rear) (m)	0.25	92.69%	24.35%	5.38%	83.59%	5.60%	99.05%	310.66%
		0.40	73.95%	22.99%	21.23%	87.08%	9.68%	87.61%	302.54%
		0.80	58.99%	29.33%	21.84%	152.75%	4.47%	119.29%	386.67%
9	Safety distance reduction factor	0.25	75.12%	23.29%	36.46%	66.69%	8.76%	100.69%	311.01%
		0.40	73.95%	22.99%	21.23%	87.08%	9.68%	87.61%	302.54%
		0.60	78.31%	27.77%	8.93%	117.47%	6.17%	104.77%	343.42%

Note: MG – Maitighar, TK- Tinkune, OB – Old Baneshwor, SM – Sankhamul, ML – Main Lane, SL – Side Lane

The cumulative percentage difference gives a measure of sensitivity among the three parameter values to traffic volume and maximum queue length. The bold highlighted values showed, in general least percentage difference or better convergence from field maximum queue lengths, as compared to two other values of same parameter. From the simulation results, it is seen that simulation output of maximum queue length showed significant percentage difference from field values as high as 135.51%. Since, the percentage difference of the maximum queue length and traffic volumes have surpassed the acceptance threshold of 20%, it was felt necessary to further calibrate the parameter values for maximum queue length.

3.1.2. Refinement of Sensitive Parameters

On the basis of cumulative percentage differences, two parameters were then selected for further refinement as they showed significant sensitivity or variations in cumulative percentage differences for maximum queue length. The selected parameters are shown in Table 4, which were varied one at a time.

Table 4. Parameters selected for further refinement

Set	Parameter	Value taken for Final Calibration
Set 5	Average standstill distance (m)	0.40
Set 6	Additive part of safety distance	0.10

As before, simulated traffic volume showed better convergence to field values, with percentage difference for most of them less than or near to 10%. The simulation results for maximum queue length is shown in Table 5.

Table 5. Percentage differences of field data and simulation output for maximum queue length at each approach

Set	Parameter Values	Variations in Parameter Values	% Difference of Field Data and Simulation Output for Maximum Queue Length						Cumulative % Difference
			MG SL	MG ML	TK SL	TK ML	OB	SM	
5	Average standstill distance (m)	0.40	53.17%	3.49%	9.04%	28.27%	10.91%	4.48%	109.37%
		0.60	77.76%	10.72%	6.17%	59.71%	3.04%	44.65	202.05%
6	Additive part of safety distance	0.10	70.34%	11.68%	1.15%	31.45%	1.26%	37.99	153.85%
		0.20	87.06%	19.78%	6.35%	55.41%	0.21%	61.36	230.17%

Note: MG – Maitighar, TK- Tinkune, OB – Old Baneshwor, SM – Sankhamul, ML – Main Lane, SL – Side Lane

The percentage difference results obtained during refinement of both parameters indicates better convergence for both maximum queue lengths and traffic volumes. The bold highlighted values showed, in general less percentage difference or better convergence from field maximum queue lengths, as compared to the other value of same parameter. However, the percentage difference for maximum queue length at Maitighar Side Lane, Tinkune Main Lane and Sankhamul is still as high. This is because the simulation results are due to change in only one of the parameter values at a time, while keeping the values of another parameter constant. The combination of all optimum parameter values will be taken in the final calibration.

3.1.3. Final Calibration

The set of optimum parameter values obtained from the previous steps of calibration, was given as input in the final step of calibration. Ten simulation runs were done for peak hour duration for ensuring that different random seed values for these simulation runs showed consistent results. GEH and RMSNE values were calculated from the simulation results and field data. GEH and RMSNE results for Traffic Volume and Maximum Queue Length for all intersection approaches satisfied the threshold criteria with GEH less than 5 and RMSNE less than 0.15, as shown in Table 6 and 7 respectively.

Table 6. GEH and RMSNE values for Traffic Volume during Final Calibration at each approach

Time (AM)	Intersection Leg	Links	Traffic Volume (veh/hr)		GEH	RMSNE
			Field	Simulated		
10:30 - 11:30	Maitighar	MG SL	593	590	0.12	0.04
		MG ML	2,307	2,124	3.89	
	Tinkune	TK SL	1,513	1,524	0.28	
		TK ML	6,140	5,808	4.30	
	Old Baneshwor	OB	1,978	1,892	1.96	
		Sankhamul	SM	1,595	1,559	

Note: MG – Maitighar, TK- Tinkune, OB – Old Baneshwor, SM – Sankhamul, ML – Main Lane, SL – Side Lane

Table 7. GEH and RMSNE values for Maximum Queue Length during Final Calibration for each approach

Time (AM)	Intersection Leg	Links	Maximum Queue length (m)		GEH	RMSNE
			Field	Simulated		
10:30 - 11:30	Maitighar	MG SL	118.67	117.48	0.11	0.10
		MG ML	118.08	120.08	0.18	
	Tinkune	TK SL	96.42	82.87	1.43	
		TK ML	181.08	210.28	2.09	
	Old Baneshwor	OB	84.25	74.83	1.06	
		Sankhamul	SM	107.58	114.75	

Note: MG – Maitighar, TK- Tinkune, OB – Old Baneshwor, SM – Sankhamul, ML – Main Lane, SL – Side Lane

As the calibration threshold requirements have been satisfied, the final set of parameter values obtained have been summarized in Table 8.

Table 8. Final Calibrated Parameters Values

Parameters		Final Calibrated Values
Following		
Look ahead distance	Min (m)	20
	Max (m)	100
Look back distance	Min (m)	12
	Max (m)	100
Wiedemann 74		
Average standstill distance (m)		0.40
Additive part of safety distance		0.10
Multiplicative part of safety distance		0.80
Lane Change		
Min. clearance (front/rear) (m)		0.40
Safety distance reduction factor		0.40

The calibrated VISSIM model was also validated using the remaining two days data set, which is different than that used for calibration. Validation results for GEH and RMSNE were also found to be within threshold limits.

3.2. Scenario Analysis

The simulated travel time results for case without bus stops are shown in Table 9, while the average vehicular delay under existing bus stop condition is shown in Table 10.

Table 9. Average vehicular travel time without bus stops

Segments	Travel Time (sec)
Maitighar-Tinkune direction	127.06
Tinkune-Maitighar direction	96.12

Table 10. Average vehicular Delay under existing bus stop condition

Stop Position	Distance from Intersection (m)	Length of Bus Stop (m)	Maximum Dwell Time (sec)	Travel Time (sec)	Average Vehicular Delay (sec)
Maitighar-Tinkune direction	25	70	180	180.61	53.55
Tinkune-Maitighar direction	30	70	120	160.73	64.61

Table 11 shows the average vehicular delays due to bus stops, from simulation runs for all scenarios, with reference to the travel time obtained in Table 9.

Table 11. Average vehicular delays from Scenario analysis

Bus Stop Parameters			Average Delay due to Bus Stop (sec)			
Distance of Bus Stop from Intersection Stop line (m)	Length of Bus Loading Area (m)	Maximum Dwell Time (sec)	Maitighar- Tinkune Direction		Tinkune -Maitighar Direction	
			Upstream	Downstream	Upstream	Downstream
40	40	60	14.47	20.80	33.62	29.78
		90	21.93	29.38	62.72	54.04
		105	41.14	38.70	294.64	82.96
		120	52.23	42.63	441.12	93.60
		60	15.01	15.41	24.14	35.92
		90	21.68	21.26	49.00	55.18
	60	105	44.73	27.85	130.48	79.25
		120	46.48	30.43	280.70	90.05
		60	17.06	15.41	24.47	38.81
		90	20.63	21.26	59.72	56.71
		105	45.78	27.85	299.97	89.20
		120	58.90	30.43	406.13	107.49
60	40	60	17.06	13.98	19.76	28.33
		90	20.63	19.26	37.52	42.30
		105	39.39	24.81	92.35	59.88
		120	52.41	27.80	87.85	79.76
		60	15.39	13.98	21.23	28.72
		90	23.51	19.26	60.94	41.89
	80	105	38.73	24.81	105.88	66.71
		120	47.71	27.80	343.14	113.17
		60	15.39	17.33	22.15	29.37
		90	23.51	24.57	36.38	48.84
		105	40.20	33.51	73.93	77.93
		120	48.39	36.65	120.96	71.48
100	40	60	12.16	17.33	19.28	31.80
		90	16.21	24.57	75.99	52.00
		105	26.23	33.51	232.64	92.85
		120	38.18	36.65	273.72	100.42
		60	12.16	15.40	19.72	28.82
		90	16.21	21.50	36.01	45.91
	60	105	24.58	28.48	71.58	63.97
		120	41.97	31.29	73.01	88.58
		60	9.19	15.40	20.70	31.62
		90	22.39	21.50	46.34	51.89
		105	30.27	28.48	85.45	127.93
		120	36.14	31.29	241.34	113.25
120	40	60	9.20	14.74	19.71	29.69
		90	22.39	20.65	38.77	45.37
		105	29.27	26.39	54.17	74.56
		120	36.01	25.90	69.22	92.48
		60	12.08	14.74	15.72	33.12
		90	16.94	20.65	35.73	50.60
	60	105	33.16	26.39	182.57	87.11
		120	37.63	25.90	206.38	126.34
		60	12.08	13.23	16.19	29.06
		90	16.94	18.28	36.65	44.28
		105	32.87	24.23	72.81	58.14
		120	36.32	26.58	65.63	78.44

These results from Table 11 have been interpreted in the subsequent sub-headings.

3.2.1. Upstream Downstream Comparison

In the Maitighar-Tinkune direction, for lower values of maximum dwell time (60 sec and 90 sec), the delays at upstream positions are less by few seconds or very near to that of downstream positions. However, for higher values of maximum dwell time (105 sec and 120 sec), the delays at downstream positions are significantly less than at the upstream positions, particularly when the distance of bus stop from intersections are 80 m or less. These patterns are the same whether the bus loading area lengths are 40 m or 60 m.

On the other hand, in the Tinkune-Maitighar direction, for lower values of maximum dwell time (60 sec and 90 sec), the delays at upstream positions differ less to downstream positions. However, for higher values of maximum

dwelling time (105 sec and 120 sec), the delays at upstream positions are significantly higher than at the upstream positions, particularly when the distance of bus stop from intersections are 80 m or less. The extremely high delays for bus stops located closer to the intersections (less than 80 m) at the upstream positions are because of longer queues being generated due to high traffic volume in the Tinkune-Maitighar direction. The delays reduced when the distance of bus stop from the intersection increased, due to decreasing interaction between bus stop dwelling and queue at the back of intersection. Within the Tinkune-Maitighar direction, the delays were lower for 60 m loading area length than for 40 m.

3.2.2. Variation in bus stop parameters

Distance between start of bus stop and intersection stop line

At both the upstream and downstream positions of both Maitighar-Tinkune and Tinkune- Maitighar directions, when the distance between start of bus stop and intersection stop line is increased, the delay decreases provided the length of bus loading area and maximum dwell time remained constant. This can be interpreted as, the farther the bus stop loading areas are placed from the intersection, the dwelling public transport vehicles (bus, micro and tempo) interfere less with the queues formed at the intersection and arriving vehicles don't have to stop beneath. So, the blocking effects caused due to the dwelling vehicles are reduced.

Length of bus loading area

The delays for either 40 m or the 60 m values in the upstream and downstream positions of Maitighar-Tinkune directions are almost the same. However, for upstream position of Tinkune- Maitighar direction, there are significant reductions in delay when the loading area is increased from 40 m to 60 m. Similarly, in downstream position of Tinkune-Maitighar direction, the delays have slightly decreased for increase in loading area length. Greater loading area length occupies more public transport vehicles causing less queues to form behind bus stops.

Maximum dwell time

At the upstream and downstream positions in both the Maitighar-Tinkune and Tinkune- Maitighar directions, when the maximum dwell time is increased from the range of 60 sec to 120 sec, the delay increased significantly. This is obvious, as the more vehicles dwell at the stops near intersection, the more their own delay increases. Furthermore, the increasing vehicles dwelling time also block other approaching vehicles behind them for longer durations, thus increasing the delay of other vehicles too.

4. Conclusion

In this study, calibration and validation of a micro-simulation model to replicate the traffic conditions at the New Baneshwor intersection was done using VISSIM. Then, the effects on vehicular delays due to three bus stop parameters at upstream and downstream positions of curb side bus stops were analysed. Finally, the scenario for minimum vehicular delays was also obtained. For most of the simulation results, the downstream positions were found to have lesser vehicular delays than the upstream ones for higher values of maximum dwell times (105 sec and 120 sec). On the other hand, for lower values of maximum dwell times (60 sec and 90 sec), the vehicular delays for upstream positions were found to be lesser than or near to that of downstream positions. With respect to the bus stop parameters, the delay showed a decreasing trend when the distance between bus stop and intersection was increased from 40 m to 140 m. The bus loading area length didn't show any significant effect on delays. Increase in the maximum dwell time from 60 sec to 120 sec showed a significant increase in the delays. The results showing the scenarios for minimum delay have been summarized in Table 12.

Table 12. Scenarios with Optimum Bus Stop parameters for Minimum Delay

Direction	Position	Distance of Bus Stop from Intersection Stop line (m)	Length of Bus Loading Area (m)	Maximum Dwell Time (sec)	Average Travel Time (sec)	Average Delay due to Bus Stop (sec)	% Reduction in Delay from Existing Condition
Maitighar – Tinkune direction	Upstream	120	40	60	136.25	9.19	82.84 %
Tinkune-Maitighar direction	Upstream	140	40	60	111.84	15.72	75.67 %

When the vehicular delays in these optimum bus stop configurations and maximum dwell times were compared to that of existing conditions, the delays were found to reduce significantly by 82.84% for the Maitighar-Tinkune direction and by 75.66% for the Tinkune-Maitighar direction. This shows that curb side bus stops have significant impact on vehicular delays on their respective curb side lanes.

There are some limitations in this study, which should be analysed for better verification of the results. The effect of green time ratio of the intersection traffic signal and variation in saturation flow rate shall also be examined in addition to the bus stop parameters. The study could cover only morning time data. Analysis of day and evening periods shall also be carried out.

Acknowledgement

This research is a part of research grants provided by the Society of Transport Engineers Nepal (SOTEN), which is a professional organization for engineers working in transport sector of Nepal. The authors would like to thank the executive and staff members of SOTEN for their valuable support.

References

- Acharya, A., & Marsani, A. (2020). Prediction of Traffic Conflicts at Signalized Intersection : A Case Study of New Baneshwor Intersection. Kathmandu: IOE Graduate Conference.
- Bandi, M. M., & George, V. (2021). Calibration of Vehicle and Driver Characteristics in VISSIM and ANN-based Sensitivity Analysis. *International Journal of Microsimulation*, 13(2), 79-101.
- Chen, H., Xie, Q., & Wang, R. (2019). Research on Bus Station Setting of Adjacent Signalized Intersection Based on Vissim. *IOP Conference Series: Materials Science and Engineering*(688).
- Dey, A. C., Roy, S., & Uddin, M. (2018). Calibration and validation of VISSIM model of an Intersection with modified driving behaviour parameters. *International Journal of Advanced Research*, 6(12), 107-112.
- Diab, E. I., & El-Geneidy, A. (2015). The far side story: Measuring the benefits of bus stop location on transit performance. *Transportation Research Record*(2538), 1-10.
- Dogan, E., Korkmaz, E., & Akgüngör, A. (2020). The effect of lane blockage on signalised intersection performance -analysing and modelling. *Journal of the South African Institution of Civil Engineering*, 62(3), 53-60.
- DoTM. (2019). Vehicle Registration statistic . Department of Transport Management, Government of Nepal.
- FDOT. (2014). Traffic Analysis Handbook a reference for planning and operations. System Planning Office: Florida Department of Transportation.
- FHWA. (2014). Guidance on the Level of Effort Required to Conduct Traffic Analysis Using Microsimulation. U.S. Department of Transportation. Washington: Federal Highway Administration.
- Gu, W., Gayah, V. V., Cassidy, M. J., & Saade, N. (2014). On the impacts of bus stops near signalized intersections: Models of car and bus delays. *Transportation Research, Part B*, 123-140.
- Huo, Y., Li, W., Zhao, J., & Zhu, S. (2018). Modelling Bus Delay At Bus Stop. *Transport*, 33(1), 12-21.
- Hussain, E., Nawaz, M. B., & Ali, D. M. (2017). Calibration and Validation of microsimulation software for intersection of Karachi. Karachi, Pakistan: 9 th International International Civil Engineering Congress (ICEC).
- Jayasooriya, N., & Bandara, S. (2018). Calibrating and Validating VISSIM Microscopic Simulation Software for the Context of Sri Lanka. University of Moratuwa: Moratuwa Engineering Research Conference.
- JICA. (2017). The Project on Urban Transport Improvement for Kathmandu Valley in Federal Democratic Republic of Nepal Final Report . Japan International Cooperation Agency.
- JICA. (2019). Data collection survey on urban transport in Kathmandu valley. Kathmandu: Japan International Cooperation Agency.
- Khan, A., Dhamaniya, A., & Arkatkar, S. (2022). Modification In HCM Delay Model for Roundabout For Mixed Traffic Conditions - A Pilot Study. *Civil Engineering in Transport*, 24.
- Liu, Z., & Jian, M. (2019). Traffic impacts analysis of bus stops near signalized intersections based on an optimal velocity model. *Advances in Mechanical Engineering*, 11(5), 1-11.
- Maheshwary, P., Bhattacharyya, K., Maitra, B., & Boltze, M. (2019). A methodology for calibration of traffic micro-simulator for urban heterogeneous traffic operations. *Journal of Traffic and Transportation Engineering (English Edition)*.
- Mistrya, J., Chaudharib, P., Arkatkar, S., & Antoniou, C. (2022). Examining Traffic Operations at Multi-Legged Intersection Operating under Heterogeneous Traffic: A Case Study in India. *Transportation Research Procedia* , 62 , 83–90.

- Mondal, S., & Gupta, A. (2021). Microsimulation based framework to analyse urban signalized intersection under mixed traffic environment. *Proceedings of the Institution of Civil Engineers - Transport*, 1-13.
- P.a, C. B., G.J.a, J., & Purnimab, P. (2019). Car following model for urban signalised intersection to estimate speed based vehicle exhaust emissions. *Urban Climate*, 29.
- Paul, M., Verma, R., & Ghosh, I. (2019). An Efficient Calibration Methodology of Microsimulation Model for Signalized Intersections Under Heterogeneous and Indiscipline Traffic Environment. Washington D.C., USA: 98th Annual Meeting of Transportation Research Board (TRB).
- PTV Group. (2022). *PTV VISSIM 10 USER MANUAL* (10 ed.). Karlsruhe, Germany.
- R., G. R., S., S., M., V., & L, D. P. (2020). Development Of Micro Simulated Vissim Model for Signalized Intersection. *-manager's Journal on Civil Engineering*, 10(1).
- Raju, N., Arkatkar, S., & Joshi, G. (2020). Modeling following behavior of vehicles using trajectory data under mixed traffic conditions: an Indian viewpoint. *Transportation Letters : The International Journal of Transportation Research*.
- SanClemente, J. L., & Furth, P. (2006). Near side, far side, uphill, downhill: impact of bus stop location on bus delay. *Transportation Research Record*, 1(1971), 66–73.
- Shi-dong, L., Shu-zhi, Z., Ming-hui, M., Hua-sheng, L., & Chun-xiu, L. (2016). *Impacts of linear Bus Stop on Car Delays*. Changchun, China: College of Transportation, Jilin University.
- TRB. (2013). *Transit Capacity and Quality of Service Manual* (Third ed.). Washington DC: Transportation Research Board.
- Wentao, Z., Guomin, Q., Dongfang, M., & Dian-hai, W. (2020). A bus delay model considering the influence of the upstream stop at the intersection. *Journal of Zhejiang University (Engineering Edition)*, 54(4), 796-803.
- Wikipedia. (2022). *PTV VISSIM*. Retrieved 05 21, 2022, from https://en.wikipedia.org/w/index.php?title=PTV_VISSIM&oldid=1084422149
- Wong, S. C., Yang, H., Au yeung, W., & Cheuk, S. (1998). Delay At Signal-Controlled Intersection With Bus Stop Upstream. *American Society of Civil Engineers, Journal of Transportation Engineering*, 124(3), 229.