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Assessing the Impacts of Queue Jump Lanes at a Signalized Intersection: A Case Study of Narayan Gopal Intersection

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Abstract

One of the main causes of congestion in Nepal's urban areas is the preference for private transportation over public transportation. In other contexts, research on bus priority measures has demonstrated their potential to reduce transit delays, enhance bus reliability in mixed-traffic conditions, and optimize travel times. This study aims to assess the effectiveness of introducing queue jump lanes in an isolated signalized intersection of Kathmandu Valley, applying these concepts to Nepal's heterogeneous traffic conditions. VISSIM microsimulation software was used to model the existing scenario and four different QJL configurations at the Maharajgunj intersection to assess the impacts on travel time and delay. Results reveal that adding a left-turn-only lane adjacent to a QJL with pre-signal can significantly save travel time and reduce delay at the Maharajgunj intersection.

Keywords: queue jump lane, pre-signal, traffic microsimulation, public transportation

1. Introduction

1.1 Background

Nepal has experienced significant urbanization as a result of economic and population growth. According to the preliminary census report 2021, the urban population reached 66.8%, which is an increase from what was reported in the 2011 report, where the urban population was at 63.2%. This population growth has led to the emergence of multiple urban centers with ever-expanding road networks. In metropolitan cities, roads are built to accommodate high volumes of traffic between important traffic generators and attractors. However, the quality and standards of transportation on these roads are still lacking. A key reason behind this is that Nepal has a massive traffic congestion problem. This problem is a side effect of unplanned rapid urbanization, higher internal migration rates, weak traffic regulations, high yearly growth rates of private vehicles, inadequate road infrastructure, poor vehicle quality and standards, and unfavorable population densities in metropolitan areas (CEN, 2020). Researchers in Nepal have attempted to tackle this predicament by suggesting the implementation of infrastructures such as Bus Rapid Transit (BRT) and metrorails, while also utilizing technologies like Geographic Information System (GIS) in conjunction with Global Positioning System (GPS) (UNESCAP, 2022; Marsani & Rajbamshi, 2004). However, there is a notable gap in the literature regarding the implementation of measures that would assist in a modal shift from private to Public Transportation (PT). This gap is significant given the rapid growth in the number of vehicles on the road which is currently growing at a rate of above 14% every year. Currently, motorcycles alone make up a substantial 78% of registered vehicles, the low-density vehicles (LDV) such as cars/jeeps/vans account for 6%, tractors and trucks comprise 4%, pickups 3% and buses represent the lowest share with just 2% (CEN, 2020). This trend is further underscored by the fact that two-wheeler ownership has been growing at the rate of 17% each year from 1990-2018 and the overall PT share in the overall fleet of the country decreased from 11% in 2011 to 5% in 2018, which indicates unattractive PT system in the country (DoTM, 2019). Given this

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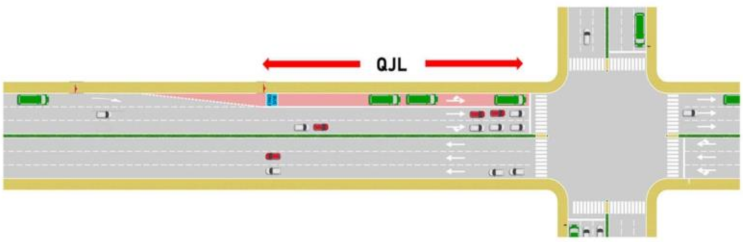
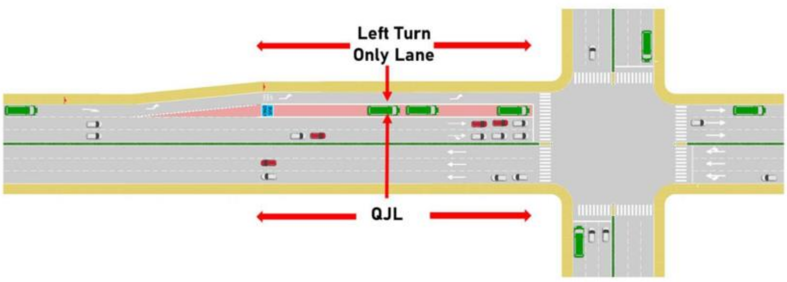
context, developing public transport infrastructure becomes essential, as increased PT usage can lead to fewer people relying on single-occupant vehicles (SOVs). Bus priority treatments could be instrumental in improving bus travel time, thereby enhancing the perceived advantage of buses by reducing average person delays as well as congestion (Lehtonen & Kulmala, 2002). Currently, there is limited incentive for people to prefer buses over their private vehicles. Buses, the only means of public transportation in Kathmandu, have to sit in a long queue with other small vehicles and do not exercise any right of way (ROW) priority on any road stretch of the valley which inevitably causes reduced stream speed and increased delay for the passengers. The lack of bus priority measures at this intersection exacerbates these issues and hinders the effectiveness of public transportation in the area. Special privileges should be provided to the public buses in Kathmandu to mitigate this issue and could hopefully cause a modal shift from private vehicles to PT. Queue jump lanes (QJL), bus-only lanes, and transit signal priority (TSP) are examples of public transit priorities (PTP) that have the potential to decrease transit wait times, increase dependability in mixed-traffic environments, optimize travel time, and reduce fleet size (TCRP, 2010; Altun, 2009). Due to limited road space in Kathmandu and the requirement for significant enforcement by police personnel, exclusive bus lanes (XBL) are not very efficient as urban conditions necessitate the use of critical resources like police personnel for other purposes (Danaher, 2010). As a result, nonpriority traffic often violates parking and lane-restriction rules, making bus lanes less effective, as noted by Atkins (2004). In this aspect, an alternative is to provide Queue Jump Lane as a short bus lane upstream of a traffic signal that enables buses to travel through congested areas with reduced delay by avoiding long queues of vehicles at signalized intersections (TRB, 2013). An implementation-based case study by Bhattacharyya et al. (2019) found that QJL operates as a feasible alternative under conditions of urban heterogeneous traffic. A curbside queue jump lane is a brief bus lane at intersections that enables buses to enter and then proceed from a left-turning lane, avoiding traffic jams in neighboring lanes (NACTO, 2012). A typical curbside QJL is shown in Figure 1 (a). Curbside QJLs are made up of brief, separated transit facilities that either have an active signal priority system or a leading bus interval that allows buses to enter traffic flow in a priority position. Sometimes, a left turn-only lane is added adjacent to the QJL. Unlike mixed left turn/curbside queue lanes, in this configuration, transit vehicles enter the approach lane without switching lanes. Figure 1 (b) shows a typical example of this configuration.



(a)



(b)

Figure 1. QJL configurations; Curbside QJL (a) and Left turn lane with QJL (b)

1.2. Objectives

The main objective of this research is to assess the effectiveness of QJL at the major approaches of the signalized Maharajgunj intersection. The specific objectives of this research are:

1. To identify the current status of delay and travel time.
2. To determine changes in delay and travel time with bus priority.

2. Literature Review

Delicately configured queue j can reduce delays considerably, resulting in travel time savings and increased reliability (Farid, et al., 2015). Bhattacharyya, et al. (2019) performed an implementation-based evaluation of QJL with or without pre-signal at two isolated urban intersections with heterogenous traffic conditions and evaluated a 10%–15% reduction in bus travel time during the peak hours. In continuation, Bhattacharyya, et al. (2020) provided an eight-step procedure for field implementation of QJL considering heterogeneous traffic conditions. Gan (2009) sought to present a signal control design for a QJL utilizing various simulation scenarios produced in VISSIM and assess the performance of the suggested method using data from a general actuated mixed-lane TSP (Gan, 2009). In comparison to a far-side stop with TSP but no queue jump, simulation model results demonstrated a 3–17% reduction in time when combining a queue jump lane and a near-side stop with an active TSP. A micro-simulation research with VISSIM revealed a potential cumulative effect from combining TSP and QJLs (Zlatkovic, et al., 2013). Except for one intersection, which was a free-running intersection, the QJL-TSP approach was situated at thirteen locations with actuated-coordinated signalized intersections. As a result, the case study area saw a reduction in travel times of 13 to 22 percent and an increase in bus speed of 22 percent. Maitra, et al. (2015) evaluated the impact of providing QJL as a bus priority strategy for three representative four-arm isolated signalized intersections in Kolkata, India. The study showed that QJL is expected to be beneficial even in a heterogeneous traffic environment that is prevalent in the Indian scenario and found that QJL was instrumental in reducing person delay. Bugg, et al. (2016) used VISSIM to understand the effect of selected transit preferential treatments on transit and non-transit vehicle travel time and found that TSP in one direction tends to provide less negative effects to side-street traffic than if TSP is provided in both directions and queue jump lanes provide negligible benefits if the volume-to-capacity ratio of an approach is 0.8 or less. Syed et.al. (2016) found that a 150m transit approach lane provided good results at high traffic volume, not only in terms of the reduction in delay of the buses but also in reduction of delay for the cars. Another priority measure, exclusive bus lane, was also implemented that resulted in reduction of the road width for other traffic. For lower volumes, the delay for cars was much higher. But as the volume increased the delay for both cars and buses was lower than the intersection without any priority. Due to the reservation of lanes, the queue length in all approaches was also considerably reduced. Farid, et al. (2015) used analytical and simulation models to evaluate various space TPTs with person-based measures such as person delay and person discharge flow. Results indicated that implementation of space TPTs decreases bus person delay by up to 55%. When QJL and Double Bus Lane are added, auto person delay is reduced by 18% because of the reduction in lane blocking by the stopped buses. Vedagiri & Jain (2012) analyzed various Bus Priority Measures in terms of change in delay with respect to normal intersection for the buses and also for whole traffic flow with the help of VISSIM simulation software for various volumes of traffic flow. It was concluded that all of the tested priority methods were efficient for reducing the delay not only for buses but also for whole traffic flow, especially for the cases of higher heterogeneous traffic flow. Tianzi et al. (2013) compared the accuracy of VISSIM and other microsimulation software SIDRA on signalized intersections. Results show that SIDRA's operation is easier while VISSIM's output is more accurate. Delay (Ma et al., 2013; Maitra et al.,2015; Farid et al., 2015; Zhou & Gan, 2005; Zlatkovic et al., 2013; Vedagiri & Jain, 2012) and Travel time (Currie et al., 2007, Lahon, 2011) have been used to evaluate the effectiveness of bus priority techniques. Similarly, VISSIM is the most popular choice for microsimulation (Ma et al., 2013; Maitra et al., 2015; Farid et al., 2015; Zhou & Gan, 2005; Zlatkovic et al., 2013; Lahon, 2011; Vedagiri & Jain, 2012).

3. Methodology

3.1. Study Area

A case study was conducted in the Maharjgunj (Narayan – Gopal) intersection, Kathmandu Metropolitan City. This is the intersection where the Kathmandu Ring Road (NH39) meets Bansbari Sadak and Maharajgunj Sadak. Figure 2 gives a general visual overview of the study area. This stretch of NH39 falls under the second phase of Ring Road expansion program providing more space for future development and making it an ideal location for implementing queue jump lanes. Congestion is highly prominent at the intersection where a long queue of vehicles can be observed during the peak hours. During peak hours, the buses are driven slowly and bus riders endure lengthy hours of travel in cramped, small buses. In addition, if a person owns a motorcycle or an automobile, they are more likely to use them for short journeys as opposed to cycling and walking (JICA, 2017).

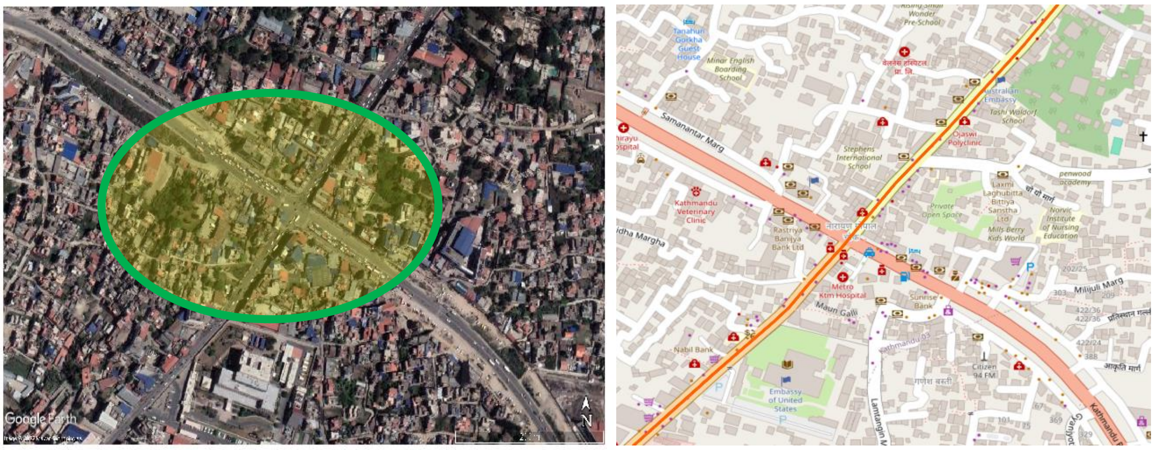


Figure 2. Study site (Screenshots from Google Earth and OpenStreetMap respectively)

3.2. Data Collection

The parameters related to road geometry required for the creation of the VISSIM simulation model were measured in the study area with the help of a measuring tape. Videographic recordings were then used to capture the entire traffic flow of the study area during peak periods during working days to obtain the necessary traffic data. A four-hour traffic survey was conducted from date 2022-09-13 to date 2022-09-15. The data from date 2022-09-13 and date 2022-09-15 were used in model calibration while the data obtained from date 2022-09-14 were used in model validation. Speed study was conducted in a section of the major road (Dhumbarahi section – 48.9m) and a section of the minor road (Bansbari section – 54.83m). Speed was determined by marking two points on the road – the first point representing the start of the section and the second point representing the end of the section. Speeds of each vehicle class were calculated for both sections as; the length of the section divided by the time taken by the vehicles to cross that section. The speed distributions of each of the five vehicle types on both major and minor roads were determined. Calculated average speed distributions were provided as a calibration input in VISSIM in the form of a cumulative frequency percentage diagram. Queue lengths on both the major road and the minor road of the intersection were collected on the field during the study hours. As queue length was a performance measure used to validate the simulation model, 10 observations were taken on both major and minor roads to compare the field observations with the simulation results.

3.3. Model Calibration

Calibration was done for lane change behaviour parameters, lateral behaviour, volume and speed distribution. Area-specific model calibration such as lane change distance, and lateral distance between vehicles was done by visual check and by adjusting the parameter value that yielded similar results to that of field observations. Speed distribution for each vehicle type was created by plotting a graph with speed on the X-axis and percentage cumulative frequency distribution on the Y-axis and was provided as an input to VISSIM. Traffic Volume was calibrated using Geoffrey E. Havers (GEH) statistic. There are some parameters that cannot be measured directly on the field. These include several driver behavior parameters that affect the output significantly in case of heterogeneous traffic and hence need to be calibrated so that the on-field conditions can be replicated. In a study done by Maheshwary, et al. (2020), several critical parameters were identified and a heuristic-based optimization using genetic algorithm was carried out to obtain a set of optimized parameter values for each mode. Eight car-following parameters from the Wiedemann 99 model were found to be the most sensitive parameters for the optimization of the VISSIM model for heterogeneous traffic. Furthermore ANOVA analysis was conducted by Maheshwary, et al. (2020) on these eight parameters and the three most optimal parameters were identified. These included standstill distance (CC0), headway time (CC1), and threshold for entering following (CC3).

3.4. Model Validation

To perform validation of the microscopic simulation model, a new set of field data for different hours of the day was collected and tested against the calibrated model. It was also important to check the visual proximity of the simulation to the traffic flow observed in the field thus ensuring the plausibility of the calibrated parameter set. The model was validated for Traffic Volume, Average Speed, and Maximum Queue Length. Traffic Volume was validated using the GEH statistic. Speed and maximum queue length were validated by calculating the Mean Absolute Percentage error (MAPE) between the observed and simulated values.

3.5. Design of Queue Jump Lanes

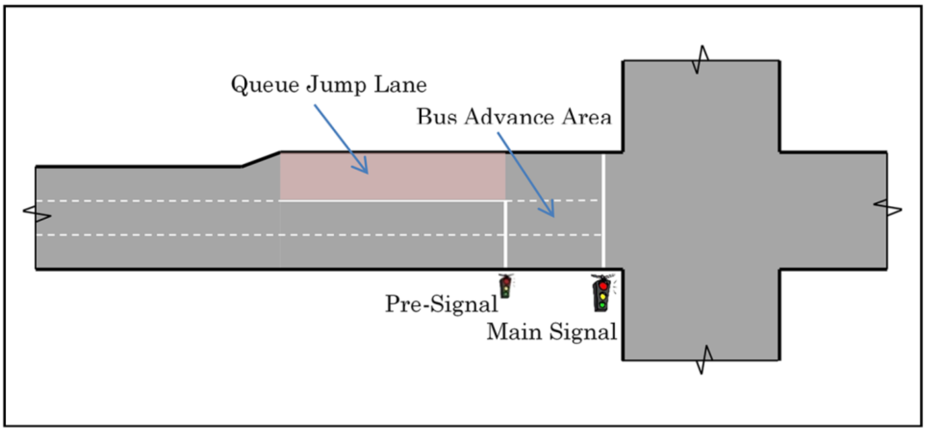


Figure 3. QJL Components *(Bhattacharyya, et al., 2019)*

A typical design of a QJL and its components is shown in Figure 3. The width of a QJL depends upon the type of vehicle allowed in the exclusive lane. Depending upon the share of transit vehicles, QJL can be designed as Bus Only Lane, Bus and Left Turn Lane or Bus and Bicycle Lane. Considering the standard width of vehicle is 2.m for Nepal according to the Nepal Road Standard 2070, the minimum width of QJL should be 3-3.5m. QJL may be accompanied by a bus advance area (BAA) which helps to minimize the conflict between buses and other traffic near the intersection, and it also acts as a sorting area that helps in increasing the vehicle throughput at the intersection. Wu & Hounsell (1998) provided an equation to calculate the length of the bus advance area. It is calcluated as,

$$L_{BAA} = \frac{v_d + v_{db}}{N_m} \times r_m H \qquad \text{(Eq. 3.1)}$$

where LBAA is the length of the bus advance area and H is the average vehicle queued headway from the approach. Nm, vd, vdB, and rm are the number of traffic lanes in the bus advance area, rate of traffic demand in veh/sec, rate of bus flow in buses/sec, and effective red time at the main signal respectively. Based on the regression analysis, Bhattacharyya, et al. (2020) developed models that suggest the maximum queue length under different scenarios, which shall act as a basis to design the length of the QJL under a particular condition. In the models, QL_{max} is the maximum queue length in meters in the nonpriority traffic lane. The length of the QJL should be greater than or equal to the maximum queue length in order to ensure smooth movement at the upstream end and allow unhindered access of buses to the QJL. The queue length prediction models are summarized in Table 1. QJLs can be combined with a pre-signal which is a traffic signal that is implemented in advance of the main signal at signalized intersections and provides priority for buses in choosing their approach to the main intersection by giving the red signal to other non-priority vehicles. Generally, green time initiated at the pre-signal is a few seconds before the initiation of green time at the main signal to ensure the smooth progression of traffic (Wu & Hounsell, 1998).

Table 1. QJL length Prediction Model (Bhattacharyya, et al., 2020)

Priority	**Length of BAA (m)**	**Function**
PS1	25	$QL_{max} = 199 \text{ x } TF + 21 \text{ x } BUS_{TM} + 14 \text{ x } CAR_{TM} – 27 \text{ x } CAR_{Share} – 23 \text{ x } BUS_{freq} – 4 \text{ x } M3W_{freq}$
	50	$QL_{max} = 176 \text{ x } TF + 21 \text{ x } BUS_{TM} + 14 \text{ x } CAR_{TM} – 23 \text{ x } CAR_{Share} – 15 \text{ x } BUS_{freq} – 6 \text{ x } M3W_{freq}$
PS2	25	$QL_{max} = 214 \text{ x } TF + 10 \text{ x } BUS_{TM} + 6 \text{ x } CAR_{TM} – 16 \text{ x } CAR_{Share} – 30 \text{ x } BUS_{freq} – 6 \text{ x } M3W_{freq}$
	50	$QL_{max} = 197 \text{ x } TF + 9 \text{ x } BUS_{TM} + 6 \text{ x } CAR_{TM} – 15 \text{ x } CAR_{Share} – 28 \text{ x } BUS_{freq} – 6 \text{ x } M3W_{freq}$

Here,

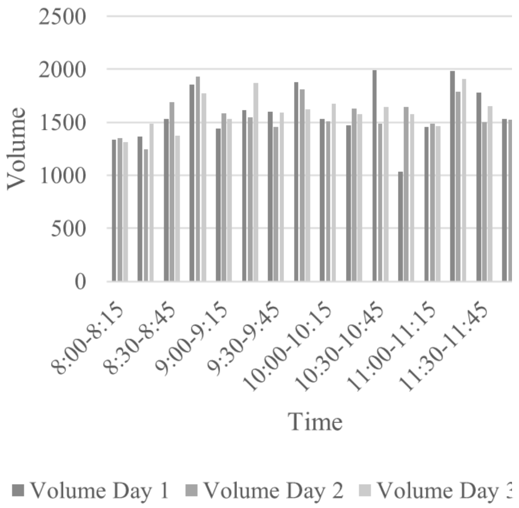
PS1 = Priority strategy without pre-signal
PS2 = Priority strategy with pre-signal
QL_{max} = Maximum Queue Length
TF = Traffic Flow Parameter which is the Degree of Saturation

CAR_{Share} is the share of cars in nonpriority traffic; CAR_{TM} is 1 if a substantial left turn exists among nonpriority traffic, and 0 otherwise; BUS_{freq} and $M3W_{freq}$ are the bus and M3W frequencies, respectively, in 100 vehicles per hour; and BUS_{TM} is 1 if substantial right-turning bus exists, and 0 otherwise.

4. Results and Discussions

4.1. Traffic Data

The 15-minute traffic volume count is shown in the figure below. As seen in Figure 4, there is not a particular peak hour traffic flow. Thus, the entire period of 8:00 AM to 12:00 AM was taken as the input for vehicle flow in VISSIM. This period is referred to as the AM peak period throughout this paper. The vehicles were sorted into five different categories: Motorcycles (M2W), Cars (small cars, large cars, jeeps, vans), Bus, Microbuses and Heavy Vehicles (trucks, tippers, dump trucks, construction vehicles, and other large utility vehicles). Motorcycles were found to be the most dominant mode of transportation; averaging at around 72% of the total share throughout the intersection. Similarly, cars shared 22%, bus and microbus shared 4% and 1% respectively, and heavy vehicles only shared 1% of the total traffic volume at the intersection. The reasoning behind creating a separate class for microbuses and not incorporating it with buses is that bus priority was not given to microbuses in this study. Speed distribution is used as an input for VISSIM. For this, the speed distribution curve of all of the vehicle classes was created by plotting the average speed in the X-axis and cumulative frequency % in the Y-axis. The frequency distribution graph is provided in Figure 5. On average, a total cycle length of 6 minutes (360 seconds with 3 seconds amber time in each phase) was adopted at the intersection. The signal operation occurs in 4 phases with the left turns left uncontrolled in each leg. Traffic is mostly controlled by traffic signals during the AM peak period.



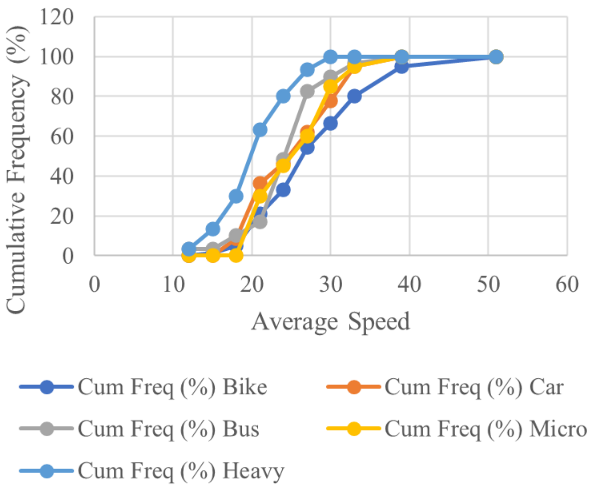


Figure 4. 15-min traffic flow

Figure 5. Speed Frequency Distribution

4.2. Model Calibration

Once the model was set up with the help of links and connectors in VISSIM, it was run with default values in order to check if there was a need for calibration. The simulated results of traffic volume in each direction were compared with the actual field value and it was found that there was a need for calibration as eleven out of twelve links were out of the acceptable GEH statistic range. The speed distributions of all 5 modes obtained from the field observations were used as an input. The lane changing and lateral behaviour were adjusted according to the field conditions. This included allowing free lane selection, optimizing the distance from which a road user decides to change the lane and the lateral distance while moving and at a standstill, especially for motorcycles. The CC0 and CC1 values of each vehicle class were optimized to best represent the field conditions. The optimized values for the area-specific model adjustments and the driving behaviour parameters are provided in Table 4.1.

Table 2. Parameters Calibration

Parameter	Default Value	Range Tested	Optimized Value
Lane Change Behaviour	Slow Lane Rule	--	Free Lane Selection
Lane Change Distance	200m	150m-400m	300m
Lateral Distance at 50 kmph			
Motorcycle	1	0.5-1.5	0.3
Car	1	0.5-2	0.4
Bus	1	0.5-2	0.5
Microbus	1	0.5-2	0.4
Heavy Vehicles	1	0.5-2	0.5
Car following parameters			
Motorcycle			
CC0	1.5	0.2-2	0.35
CC1	0.9	0.5-2.5	0.9

Table 2. Parameters Calibration

Parameter	Default Value	Range Tested	Optimized Value
Car			
CC0	1.5	0.2-2	0.8
CC1	0.9	0.5-2.5	2
Bus			
CC0	1.5	0.2-2	1
CC1	0.9	0.5-2.5	2.45
Microbus			
CC0	1.5	0.2-2	1
CC1	0.9	0.5-2.5	2.5
Heavy Vehicles			
CC0	1.5	0.2-2	1.09
CC1	0.9	0.5-2.5	2.85

4.3. Model validation

The model was validated using volume, speed, and queue length. GEH statistic was used to compare the traffic volume from field observations and from simulation results. 91.6% (>85%) of the links were found to have GEH < 5.0. The average speed of vehicles obtained from field observations and from simulation results were compared. The mean absolute percentage error (MAPE) for the stream was found to be 6.5%. A study has shown that even the best models can have errors of up to errors of 20% (Brockfeld, et al., 2004). The maximum queue length per hour obtained from ten field observations and from ten simulation results were compared. The mean absolute errors were 3.96% for the major leg and 1.82% for the minor leg.

4.4. Design of Queue Jump Lane

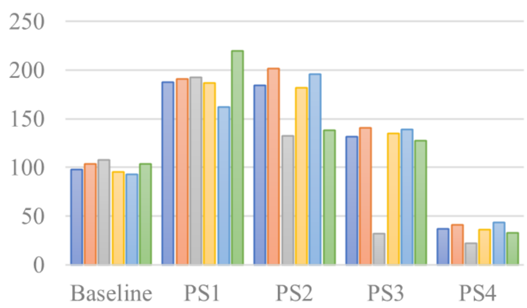
A queue jump lane was provided on both legs of the Ring Road. The width of QJL was set to be 3.5m. The bus advance area was calculated as 50m using Eq. 3.3 given by Wu & Hounsell (1998). The length of QJL was obtained from Table 3.1. The predicted maximum queue length for bus advance area of 50m was calculated using the prediction model provided by Bhattacharyya, et al. (2020). The predicted lengths were obtained as 92.7m and 96.6m for the Basundhara and Dhumbarahi legs respectively. Thus, a 100m QJL was provided in both legs.

4.5. Scenario Analysis

Five different scenarios were modeled in VISSIM with the help of links and connectors. All the priority scenarios were provided with a 100m queue jump lane with a 50m bus advance area. The Scenarios were: baseline scenario (BS), curbside QJL (PS1), curbside QJL with pre-signal (PS2), left turn-only lane alongside QJL (PS3), and left turn-only lane alongside QJL with pre-signal (PS4).

Figure 6. Business as usual scenario (BS) modeled in VISSIM

Figure 6 shows the baseline scenario designed in VISSIM. The baseline scenario plays a critical role in establishing the context and reference point for evaluating the performance of the intersection under different bus priority scenarios. Its use provides a foundation for comparison and validation of the simulation results and enables meaningful analysis and interpretation of the findings. Ten simulation runs, with a warmup time of 900 seconds, were taken to evaluate each scenario to simulate travel time performances and delays. Currently, the average travel time for all vehicles operating in ring road over a stretch of 150 meters is 106 seconds with buses having an average travel time of 110 seconds. Similarly, over the same stretch, there is an average vehicle delay of 65 seconds with buses having a delay of 67 seconds. Most of the reasons causing an increase in travel time and delay are attributed to the bottleneck that occurs 120 meters and 130 meters upstream of the stop line in the Basundhara leg and the Dhumbarahi leg respectively. This bottleneck occurs due to 2-lane roads diverging into 4-lane roads. As a result of this, the leftmost lane which is, technically, reserved for left turns only gets unoccupied once the queue reaches the bottleneck as the left-turning vehicles cannot maneuver into the left turn lanes since they are stuck in the queue. The results of average travel time and delay for different BP measures is provided in Figure 7 and Figure 8 respectively. The percentage changes in travel time and percentage reduction in delay for the five created scenarios are expressed with respect to the baseline scenario (BS) as shown in Table 3. The most positive impacts for each case are marked in bold. The evaluation was carried out by comparing the percentage travel time savings of motorcycles, buses, cars, microbuses, heavy vehicles, and passengers individually for each scenario design with the baseline scenario.



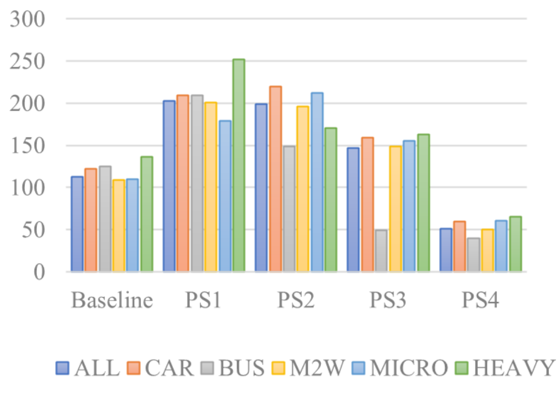


Figure 7. Average Travel Time for different scenarios

Figure 8. Average Vehicle Delay for different scenarios

Table 3. Average % Travel Time Saving and Vehicle Delay Reduction for different scenarios

	Average % Travel Time Saving		**Average % Vehicle Delay Reduction**	
Scenario	**Bus**	**Non-Bus**	**Bus**	**Non-Bus**
PS1	-68.24	-81.20	-79.19	-93.49
PS2	-19.18	-79.83	-22.83	-91.94
PS3	**60.60**	-35.32	**70.14**	-40.60
PS4	**68.33**	**53.46**	**79.15**	**61.58**

Table 4. Average % Reduction in Person Delay

	Average % Reduction in Person Delay					
	ALL	**CAR**	**BUS**	**M2W**	**MICRO**	**HEAVY**
PS1	-82.13	-86.00	-77.70	-97.55	-73.65	-113.73
PS2	-51.93	-98.35	-20.34	-91.75	-109.76	-27.00
PS3	**25.67**	-37.11	**69.79**	-43.14	-50.47	-26.44
PS4	**71.72**	59.71	**79.16**	61.98	53.52	68.12

There was a negative effect in using the curbside lane as the QJL while also allowing the lane to operate as a left-turn lane. This caused a 68.24% increase in travel time for priority traffic and an 81.20% increase for non-priority vehicles. There is a similar negative effect on Vehicle Delay and Person Delay as seen in Table 3 and Table 4 respectively. The reasoning behind this is that the left turns are not controlled by the traffic signals but the through/right turning traffic is. Because of this, the through/right turning priority vehicles (Bus) queue up in the bus advance area, and when there isn't sufficient space to switch lanes, they occupy the left turning lanes. This causes the left-turning vehicles to queue up when under base scenarios, they would have been freely allowed to turn left. Adding pre-signal in this scenario caused a -19.18% of travel time saving for priority vehicles and -79.83% for non-priority vehicles which is a bit better but still, cannot be considered as an effective priority strategy at the intersection. Adding a left turn-only lane alongside the QJL has proved to be the most effective BP technique for reducing bus travel time and delay at the Maharajgunj Intersection. This is essentially due to the fact that this priority technique eliminates the issue that caused the left-turning vehicles to queue up at the intersection. Without pre-signal, this combination caused a 60.60% average travel time saving, 70.14% average vehicle delay reduction, and 25.67% average person delay reduction for priority vehicles. However, this still has a negative effect on non-priority vehicles. This is due to the development of longer queues at the intersection as one of the lanes is effectively reserved for buses only. And once the queue reaches the bottleneck where the two-lane road meets the four-lane road, a traffic jam occurs. Introducing pre-signal into the mix, however, resolves this. The addition of pre-signal means the bus advance area is almost always allocated to buses and as the composition of buses is considerably low, there is less chance for the queue to reach the bottleneck. This shows in the results as there are positive impacts on travel time, vehicle delay and person delay for both priority and non-priority vehicles.

5. Conclusions

This research showed a significant potential for improving traffic efficiency at the Maharajgunj intersection through the implementation of queue jump lanes. The findings indicate that by integrating a left-turn-only lane adjacent to a queue jump lane in conjunction to a pre-signal for the non-priority vehicles, travel time and delay can be discernibly reduced. These results further underscore how specific infrastructure modifications might be crucial in raising general operational performance at the intersection for the greater good of public transport efficiency and congestion reduction.

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