

Performance Evaluation of Exclusive Bus Lane System using Simulation-based Analysis - A Case Study of a Section in Kathmandu-Bhaktapur Route during Morning Peak Hour

Samrat Acharya¹, Anil Marsani²

¹Department of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal, 079mstre019.samrat@pcampus.edu.np

²Department of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal, anil.marsani@pcampus.edu.np

Abstract

In developing cities with heterogeneous vehicle composition and limited road space, such as Kathmandu, urban roads are becoming highly congested, especially the major corridors like the Kathmandu-Bhaktapur Road. This study aims to examine whether exclusive bus lanes and signal priority system can be effectively implemented in such an environment. A microsimulation model was developed using PTV VISSIM replicating existing traffic conditions on which various scenarios involving exclusive bus lanes and signal priority were simulated for morning peak hour where performance indicators like queue length and travel time were analyzed. Introduction of exclusive bus lanes prioritizes public transport by providing separate lane, but it heavily penalizes general traffic by amplifying the queue in the normal lanes. Signal priority when used with EBLs eliminates queues in bus lanes to minimal level while also softening the negative impact on normal lanes. Similarly, the travel time of public transport reduces by 7-13% after the introduction of exclusive bus lanes, but delivers the biggest improvement in both directions when used in conjunction with signal priority, resulting the reduction of 20-23%. In contrast, EBL implementation increased travel time for vehicles in normal lanes; however, the increase was substantially reduced when combined with signal priority, dropping from +21% to -13% in the Tinkune-Lokanthali approach and from +98% to +67% in the Lokanthali-Tinkune approach. Hence, highlighting the effectiveness of exclusive bus lane system with signal priority for the Kathmandu-Bhaktapur Route.

Keywords: Exclusive Bus Lane, Signal Priority, Simulation, VISSIM

1. Introduction

The rapid growth of urban populations worldwide has led to a surge in private vehicle ownership, presenting significant challenges for cities trying to maintain efficient and sustainable transportation systems. This increasing reliance on private vehicles stresses existing road infrastructure, creating chronic traffic congestion, especially at peak hours. This congestion results in longer commute times, reduced productivity, and increased delay and queue length in intersection, and higher fuel consumption, negatively impacting both the economy and the environment.

Public transport plays a crucial role in addressing urban mobility challenges, such as traffic congestion. They can transport a large number of passengers efficiently, reducing the overall number of vehicles on the roads and the associated environmental and economic costs. The road traffic in Kathmandu Valley has increased at a very steep rate in the recent past, from 1.4 million vehicles plying on the roads of valley to 1.75 million in just a span of year, according to Kathmandu valley Traffic Police Office (Kandel et al., 2023). As a result, urban transportation systems in Kathmandu face significant challenges in providing efficient and reliable public transportation services.

Under heterogeneous traffic conditions, the larger size of buses makes it difficult for them to navigate through mixed traffic efficiently. Continuous acceleration and deceleration lower operating speeds and reduce passenger comfort, resulting in higher delays and longer travel times, which negatively affect the attractiveness of public transport (Arasan & Vedagiri, 2009). Similar challenges are also observed in Kathmandu, where traffic conditions are predominantly heterogeneous.

By focusing on infrastructure upgrades like introduction of Mass Rapid Transit (MRT), Bus Rapid Transit (BRT), integration of multimodal transportation system, intelligent transportation system, the policy makers can create a

more efficient, reliable, and sustainable public transport system. Nevertheless, these enhancements are expensive, and there is a need for finding alternative solutions to the problem. One way to improve the efficiency of existing road infrastructure is by prioritizing the movement of people rather than vehicles. This can be accomplished through the provision of exclusive bus lanes, which enhance bus operations and mobility (Arasan & Vedagiri, 2009). Consequently, a greater number of passengers can be transported with fewer vehicles, thereby reducing traffic congestion.

The main objective of the study is to evaluate the performance of an exclusive bus lane with bus signal priority during morning peak hour using simulation-based analysis. Specifically, this study aims to:

1. Develop a simulation model that accurately represents the characteristics of the study area, including the lane configuration, signal control, and mixed traffic conditions.
2. Assess the impacts of the exclusive bus lane and signal priority on bus travel time, and queue length during morning peak hour.

The findings of this study would contribute to the understanding of the potential benefits of implementing exclusive bus lanes, particularly in the context of Kathmandu-Bhaktapur route. The results can inform policymakers and urban planners, providing evidence-based recommendations in developing effective public transport strategies that prioritize bus operations while minimizing the impact on general traffic.

2. Literature Review

This review will focus on studies that examined the influence of EBLs and BSP systems on bus travel times, general traffic flow and the balance between bus and general traffic performance. The simulation-based analyses play an important role due to the complex interactions between buses and general traffic in various situations.

2.1 Exclusive Bus Lane (EBL) and its Significance

Exclusive bus lanes (EBLs), also known as dedicated bus lanes or bus-only lanes, are sections of roadways reserved solely for the use of buses and, sometimes, other high-occupancy vehicles (HOVs) like taxis or carpools. The core concept is to provide buses with a dedicated right-of-way, separating them from general traffic improving the efficiency and reliability of the public bus service by minimizing delays caused by mixed traffic. By reducing delays and improving efficiency, EBLs aim to make bus travel more attractive to commuters, potentially leading to a modal shift from private vehicles to public transport.

There are several types of exclusive bus lanes, primarily differentiated by their location within the roadway.

- Curb-side bus lanes
- Median bus lanes
- Contra-flow bus lane
- Dynamically activated exclusive bus lanes

While EBLs offer significant benefits for bus transit and potentially overall traffic efficiency, the effectiveness of EBLs is highly context-dependent and requires tailored solutions for specific urban environments. Jha (2023) argues that implementing a BRT system, which includes EBLs, can significantly alleviate traffic congestion in Kathmandu valley. The study emphasizes that BRT can serve city to establish rapid, safe, comfortable, equitable, efficient, sustainable, economical, and efficient modern mass transit system that can ensure carry of a high number of passengers. Similarly, the implementation of EBLs has been recognized as a practical strategy to improve bus operations, particularly in urban areas with high congestion levels.

2.2 Bus Signal Priority and its Strategy

Bus Signal Priority (BSP), also known as Transit Signal Priority (TSP), is a traffic management strategy aimed at reducing bus delays at signalized intersections. The core concept is to adjust the normal traffic signal timing to give buses preferential treatment, allowing them to proceed through intersections more quickly than other vehicles, thereby reducing delays and improving service reliability. BSP is particularly relevant in heterogeneous traffic conditions, where buses often experience significant delays due to interactions with slower-moving vehicles.

The choice of BSP strategy depends on various factors, including traffic volume, bus frequency, intersection geometry, and the desired balance between bus priority and general traffic flow. This preferential treatment can involve various techniques such as:

- Green Extension (GE)
- Red Truncation (RT)
- Phase Insertion
- Conditional Priority
- Unconditional Priority

2.3 Exclusive Bus Lane system with Bus signal Priority

There have been various studies suggesting that the bus signal priority when used in combination with EBLs, can be effective measures in enhancing the operational performance of public transportation. For instance, study by Rahmat et al. (2013) demonstrated that the introduction of bus signal priority (BSP) in conjunction with EBLs led to a reduction in bus travel time by approximately 19% and average delays by 38% at signalized intersections. This aligns with findings from Khakimov & Tanaka (2024), who noted that exclusive bus lanes combined with signal priority could lead to a modal shift, encouraging more commuters to use public transport. Similarly, Baalaganapathy et al. (2023) evaluated the effectiveness of bus signal priority (BSP) and dedicated bus lanes (DBL) in Chennai, India, using VISSIM simulation. Their study found that the combination of BSP and DBL resulted in a significant reduction in bus travel time and delays at signalized intersections, whereas the use of DBL only resulted in reduction of travel time of buses in expense of increment in travel time of other modes.

While there is a growing body of literature on EBLs and bus priority systems globally, research specific to Kathmandu valley remains limited.

3. Methodology

3.1 Study Area Selection

For this study, about 1.75km stretch of Kathmandu-Bhaktapur route between Tinkune and Lokanthali is considered because this section consists of two major congested intersection where vehicle conflicts and intersection delays are most significant. Also, these intersections have existing signalized control system with the potential for signal priority. The selected road section consists of 6 lanes, each with a lane width of 3.5m, split into a combination of at least 3 and 3 lanes separated by a median. Figure 1 below shows the general overview of the study area.



Figure 1: Study Area Location

3.2 Data Collection

The following data were collected during the study for the comprehensive development of simulation model.

3.2.1 Road Network Data

The detailed road geometry data of the selected section was collected. This includes road configuration, no. of lanes, lane width, intersection layout, bus stop location and layout. These data are required setting up the model in simulation software. This road section consists of two major signalized intersection i.e. Koteshwor intersection

and Jadibuti intersection as well as one minor unsignalized intersection i.e. Manoharafat intersection. The general layout of the study area is shown in the Figure 2 below:

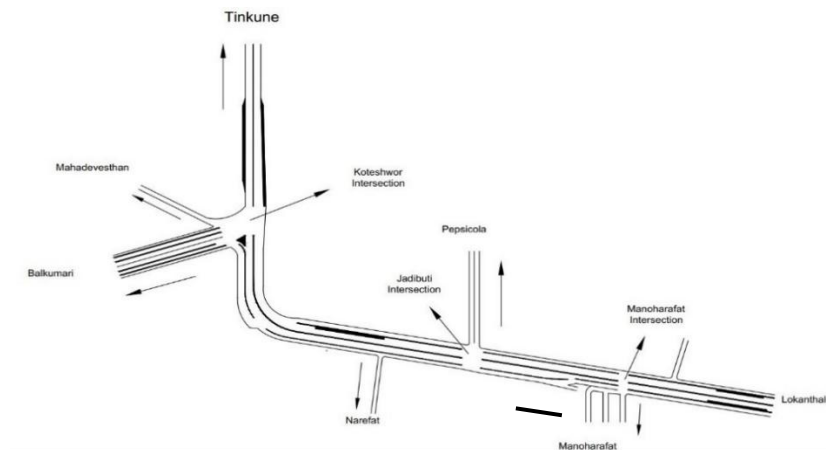


Figure 2: Study Area Road Network Layout

3.2.2 Traffic Volume Data

The traffic flow data for three consecutive week-days from 26th January 2025 to 28th January 2025 were obtained through the recordings of 11 CCTV cameras installed at various locations along the study area. The access to the video recordings was provided at Kathmandu Valley Police Office, Ranipokhari. Appropriate CCTV Camera location capturing the required traffic flow and directional movement at intersection was selected based on location, camera angle and the clarity of the video. From the recordings, classified volume count was conducted manually at 15-minute interval during morning period (9:00am to 12:00pm) which were converted into equivalent passenger car using equivalency factors from Kathmandu Sustainable Urban Transport Project (2010) as shown in Table 1, except motorcycle for which a lower equivalency factor of **0.35** (JICA, 2012) was used for effective calibration.

Table 1: Equivalency Factor as per KSUTP (2010)

S.N	Vehicle Type	Equivalency Factor	S.N	Vehicle Type	Equivalency Factor
1	Motorcycles	0.25	5	Heavy Truck	3
2	Tempo	1	6	Micro Bus	1.5
3	Cars/Taxi/Utility Vehicles	1	7	Mini Bus	2.5
4	Light Truck	1.5	8	Large Bus	3

(Source: KSUTP, 2010)

At two major intersections, the total PCU's that entered the intersection from all approaches during each 15-minute interval in the morning period were determined. By summing the successive four 15-minute period counts in PCU, hourly volumes in PCU entering the intersection from all the approaches were determined for the morning period. Thus, peak hour in the morning was observed to be at **9:30am to 10:30am**. The three-days average peak hourly traffic volume and PCU's at both of the major intersections is shown in the Table 2 below.

Table 2: Peak hourly PCU and Volume at Koteshwor and Jadibuti Intersection

Intersection	Morning (9:30-10:30am)	
	Peak hour PCU	Peak hour Volume
Koteshwor Intersection	10203	17755
Jadibuti Intersection	7988	14246

The vehicles were sorted to 10 different categories and the three-days average percentage composition was identified. Large bus, micro, minibus and tempo being the public transportation were kept under one category and

constituted 3.36% of total vehicles. The most dominant vehicle type was motorcycle with 78% share followed by car/jeep/van with 14.48% share. The summary of average vehicle composition is shown in the Table 3 below:

Table 3: Average Vehicle composition in study area

S.N	Vehicle Type	Percentage Composition	S.N	Vehicle Type	Percentage Composition
1	Motorcycle	78.09%	6	Light Truck	0.65%
2	Car/Jeep/Van	14.48%	7	Heavy Truck	0.15%
3	Utility Pickup	1.85%	8	Emergency	0.07%
4	Public Transportation	3.36%	9	Cycle	0.94%
5	Private Bus/Micro	0.41%	10	Tractor	0.01%

3.2.3 Signal Timing Data

The current signal phasing and timing plans of the two selected intersection was recorded from the CCTV footage which includes cycle length and green phase for each phase. The cycle time of 442s and 480s were observed at Koteshwor and Jadibuti intersection respectively. These existing signal timing data were vital for scenario analysis. The phasing diagram for the Koteshwor intersection is shown in the Figure 3.

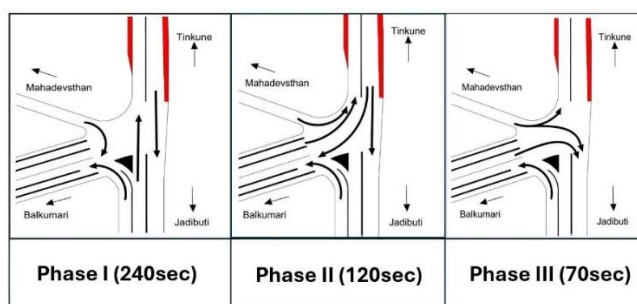


Figure 3: Phasing diagram and green time at Koteshwor intersection

Similarly, the phasing diagram at Jadibuti intersection is shown in the Figure 4.

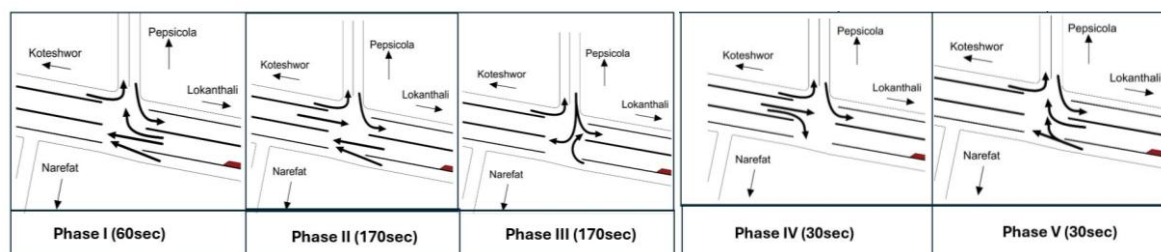


Figure 4: Phasing Diagram and green time at Jadibuti Intersection

3.2.4 Public Transportation Operational Data

The public transportation that operates on the selected route consists of large bus, minibus and micro. The operational data like travel time, dwell time at the stops, delay at intersection for all public transportation were collected using onboard survey during morning peak hour. Both the approaches Tinkune-Lokanthali and Lokanthali-Tinkune were considered for onboard survey.

4 Analysis and Results

4.1 Directional Movement

The directional volume and the directional split were calculated for two major signalized intersections (i.e Koteshwor and Jadibuti) and one minor intersection (i.e Manoharafat intersection) during morning peak hour. This directional split was used while calculating the total volume in the defined routes in VISSIM modeling. The directional split for each intersection is shown in schematic diagram in Figure 5, Figure 6 and Figure 7 below:

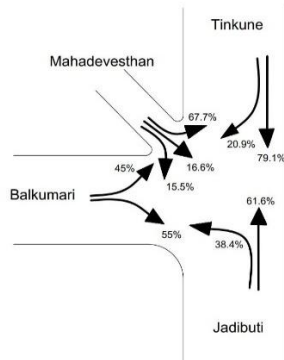


Figure 5: Directional split at Intersection

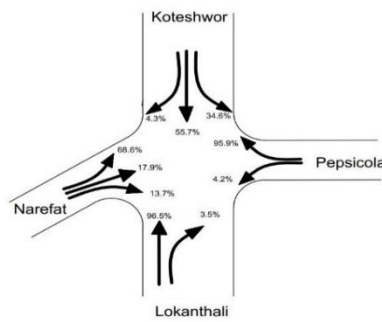


Figure 6: Directional split at Jadibuti intersection

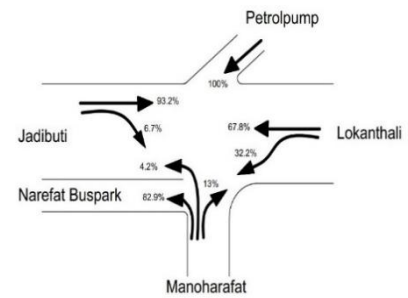


Figure 7: Directional split at Koteshwor Manoharafat intersection

4.2 Analysis of Public Transport Operational Data

The public transportation that operates on the selected route consists of large bus, minibus and micro. The number of samples required for each category of public transportation (Bus, minibus, micro) was determined according to their proportions and onboard survey was performed. The operational data like travel time, dwell time during boarding and alighting at the stops, no. of stops on this section, delay in intersection for the sample size was determined. The summary of those data is shown in the Table 4 for Koteshwor-Lokanthali approach and Lokanthali-Koteshwor approach:

Table 4: Average travel time and delay from onboard survey

Time	Public Transport	Average Travel time (s)	Average Delay at Stop (s)	Average Delay at intersection (s)	Average Total Delay (s)
Tinkune-Lokanthali Approach	Bus	666	236	210	446
	Minibus	711	250	227	476
	Micro	506	149	155	304
	Average (s)	628	211	197	408
	(in Minutes)	10min 28sec	3min 31sec	3min 17 sec	6min 48sec
Lokanthali-Tinkune Approach	Bus	682	229	223	452
	Minibus	666	239	206	444
	Micro	511	142	177	319
	Average (s)	620	203	202	405
	(in Minutes)	10min 20sec	3min 23 sec	3min 22 sec	6min 45sec

4.3 Simulation Analysis

Once the model was setup with links and connectors in VISSIM, it was simulated with the default value to check if there is a need for calibration. The total volume of vehicle with their composition during morning peak hour were entered in VISSIM and routes were assigned. Similarly, the signal heads with recorded signal timings were added in model at both the signalized intersection.

4.3.1 Calibration of the Model

Once the model was setup with links and connectors in VISSIM, it was simulated with the default value to check if there is a need for calibration. A comprehensive review of literatures related to VISSIM calibration under heterogenous and non-lane-based traffic was carried out. Wiedemann 74 and Lane change parameters with the recommended range from different literatures were adjusted by iteration process till the simulated output was within acceptable range. The values as shown in the Table 5 were then adopted for further study. Some snapshot of the simulation runs at three intersections are shown in the Figure 8 below:

Table 5: Average travel time and delay from onboard survey

S.N.	Parameters		VISSIM	Range tested with	Values adopted for Calibration	
			Default Values	reference from literature		
1	Following	Look ahead	Min (m)	0	10-30	10
2		distance	Max (m)	250	100-140	100
3		Look back	Min (m)	0	5-24	5
4		distance	Max (m)	150	80-150	100
5	Wiedemann 74	Average standstill distance (m)		2	0.2-1.5	0.2
6		Additive part of safety distance		2	0.1-1.5	0.2
7		Multiplicative part of safety distance		3	0-1	0.25
8	Lane Change	Min. clearance (front/rear) (m)		0.5	0.11-0.8	0.2
9		Safety distance reduction factor		0.6	0.2-0.6	0.2

Literature referred: (Manandhar, 2023); (Shrestha & Pradhananga, 2023); (Siddharth & Ramadurai, 2013); (Kunwar et al., 2025); (Chhetri, 2023); (Dutta & Ahmed, 2019); (Mathew & Radhakrishnan, 2010); (Jayasooriya & Bandara, 2018); (Acharya & Marsani, 2020); (Khan et al., 2022); (Paul et al., 2019); (Hussain et al., 2017); (Mondal & Gupta, 2020); (Mistry et al., 2022); (Raju et al., 2021).

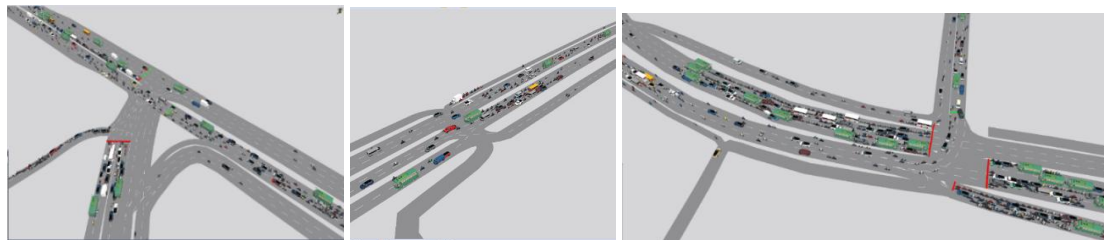


Figure 8: Simulation in VISSIM

4.3.1.1 Calibration of Model for Traffic Volume

The average field data from Day 1 and Day 2 were entered into VISSIM with the adjusted parameters and the simulation was run. For calibration of developed model, GEH (Geoffrey E. Havers) statistics was used. The GEH formula (Oregon, D. O. T, 2011) for hourly flows is shown in Equation 1.

$$GEH = \sqrt{\frac{2(m-c)^2}{(m+c)}} \dots\dots\dots(\text{Equation 1})$$

where,

m = output traffic volume from the simulation model (vehicle per hour)

c = input traffic volume (vehicle per hour)

The simulated volume was then compared to the observed average volume. More than 85% GEH results for traffic volume of the major selected route satisfied the threshold criteria with GEH less than 5. Hence, the model was calibrated successfully for traffic volume.

4.3.1.2 Calibration of Model for Maximum Queue Length

The maximum queue length for each given approach for three days was measured from the video footage. This average of two-days observed maximum queue length was then compared with the maximum queue length generated by the VISSIM simulation. For calibrating of queue length, Root Mean Squared Normalized Error (RMSNE) as shown in Equation 2 was used, which measures the percentage deviation of the simulated data from field observed data.

$$RMSNE = \sqrt{\frac{1}{N} \sum \left(\frac{y_{i,sim} - y_{i,obs}}{y_{i,obs}} \right)^2} \dots\dots\dots(\text{Equation 2})$$

where,

N = total number of traffic measurement observations

$y_{i,sim}$ = simulated data

$y_{i,obs}$ = observed data

The RMSNE value was calculated to be 7.92% which is less than 15% hence, considered acceptable for traffic model calibration (FDOT, 2014).

4.3.2 Validation of the Model

The validation is meant to determine whether the calibrated simulation model can reproduce accurately the real-world traffic conditions beyond the calibration data. Different sets of data than the ones used in calibration of the model i.e. field data from Day 3 were used for validation of the model. Similar to calibration, more than 85% GEH results for traffic volume of the major selected route satisfied the threshold criteria with GEH less than 5 and RMSNE value was calculated to be 9.36% which is less than 15%. Hence, the model was validated successfully.

4.4 Scenario Analysis

Various scenarios involving exclusive bus lanes and signal priority were created as described below:

4.4.1 Scenario S1: Base-case Scenario

The base-case scenario model was established in the VISSIM from the previously validated model. The three-days average field data were used as input for the simulation keeping other all parameters same as in calibrated and validated model. The simulation was run and the results were obtained.

4.4.2 Scenario S2: Exclusive Bus Lane with Existing Signal

In this scenario, the curb side exclusive bus lane was introduced in the base-case model keeping all other parameters constant. The bus lanes were introduced similar to the express bus service layout carried out by Department of Roads in September 21, 2023 A.D. The layout showing the exclusive bus lanes is shown in Figure 9. The simulation was run, and the results were compared with base-case scenario.



Figure 9: Layout showing the exclusive bus lanes in scenario 2

4.4.3 Scenario S3: Exclusive Bus Lane (Modified) with Existing Signal

In this scenario, minor modifications were made to the alignment of the exclusive bus lane while maintaining all other conditions consistent with scenario S2. The bus lane was rerouted between the Manoharafat and Jadibuti intersections to create additional continuous space for mixed traffic. Similarly, near the Koteswor intersection, the bus lane was extended directly through the intersection, and the upstream bus stop was relocated downstream to reduce traffic interruptions and improve lane availability for other vehicles. The modifications are further clarified through Figure 10 below:

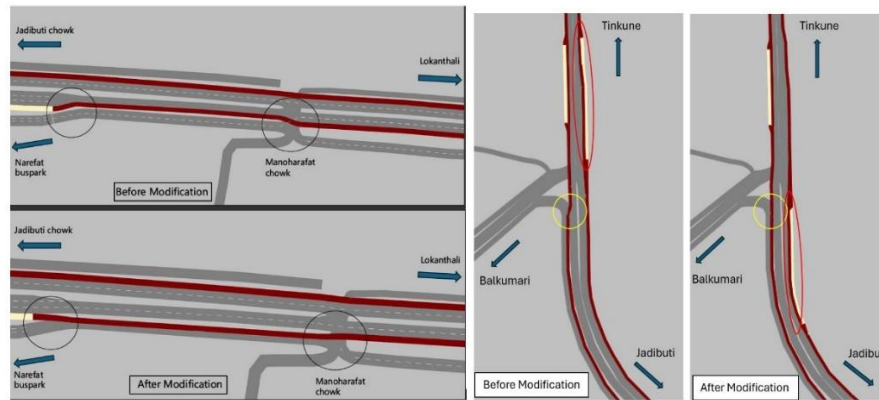


Figure 10: Modification near Jadibuti bridge and Koteswor intersection respectively

4.4.4 Scenario S4: Exclusive Bus Lane (Modified) with Through Priority

In this scenario, the bus lane alignment remained the same as in scenario S3, while priority measures for public transport were introduced at both intersections. Public transportation was allowed uninterrupted movement through conflict-free lanes of Tinkune-Jadibuti approach at the Koteswor intersection. Similarly, public transportations from Lokanthali were given full priority for uninterrupted flow through Jadibuti intersection against vehicle flowing from Narefat buspark approach and the resulting operational performance was evaluated through simulation.

4.4.5 Scenario S5: Exclusive Bus Lane with Signal Priority (Phase Insertion)

In this scenario, along with the priority provided to public transportation as in Scenario S4, an additional level of signal priority was introduced on the other approaches. The phase insertion technique, one of the simplest forms of signal priority, was adopted in this study. It operates by introducing an additional phase dedicated to bus movement after each existing signal phase. This can be implemented through minimal modifications to existing signal timing, making it a cost-effective and practically deployable near-term solution.

To apply this, the original phase that served buses in the exclusive bus lane was divided into smaller segments and inserted between each phase at both intersections. Cycle length and the timing of all other phases were kept unchanged. The new signal time after phase insertion is shown in Figure 11 below. The simulation was run with these changes and the results were compared with other two scenarios.

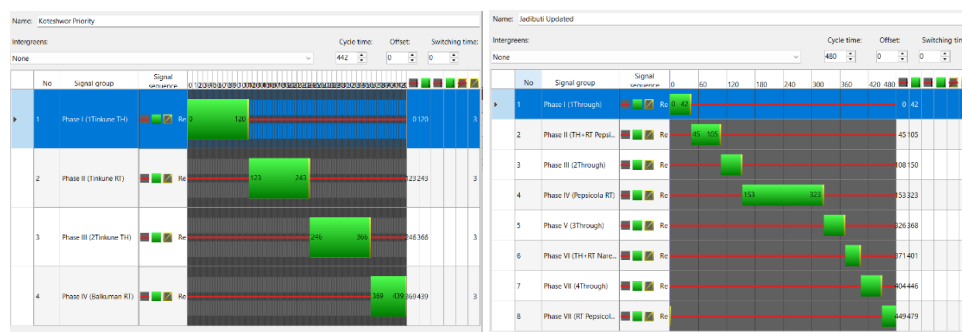


Figure 11: Updated Signal timing for signal priority (Phase insertion) at Koteswor and Jadibuti intersection

4.4.6 Scenario Analysis Result

The results obtained after simulating all the above-mentioned scenarios in VISSIM, focusing on maximum queue length and travel time are analyzed along with their impacts on overall traffic conditions.

4.4.6.1 Maximum Queue Length Analysis

The maximum queue lengths reflecting the worst-case congestion recorded across all twelve sections for each of the five simulated scenarios during the morning peak hour, as obtained from VISSIM microsimulation is presented

in Table 6. The percentage change is calculated with respect to base-case scenario where negative sign indicates reduction of queue length from the base-case scenario.

Table 6: Maximum Queue Length Results across all Scenarios

		Maximum queue length (m) & percentage change w.r.t base-case scenario								
Section No. & Name	S1	S2	%	S3 EBL	%	S4 BSP	%	S5 BSP	%	
	Base Case	EBL	Change	Modified	Change	Through	Change	Phase Insertion	Change	
Normal Lanes	1: From Manoharafat chowk towards Lokanthali	158	961	508%	689	336%	675	327%	426	170%
	2: From Jadibuti chowk towards Lokanthali	252	458	82%	425	69%	433	72%	408	62%
	3: From Jadibuti chowk towards Pepsicola	1137	1405	24%	1402	23%	1405	24%	1405	23%
	4: From Jadibuti chowk towards Koteshwor	162	212	31%	162	0%	164	1%	145	-10%
	5: From Koteshwor chowk towards Jadibuti	330	609	84%	593	80%	605	83%	565	71%
	6: From Koteshwor chowk towards Balkumari	192	192	0%	192	0%	194	1%	191	-1%
	7: From Koteshwor chowk towards Tinkune	296	522	76%	300	1%	316	7%	215	-27%
Exclusive Bus Lane	8: EBL from Manoharafat chowk towards Lokanthali	158	25	-84%	26	-84%	25	-84%	21	-87%
	9: EBL from Jadibuti chowk towards Lokanthali	252	114	-55%	114	-55%	0	-100%	0	-100%
	10: EBL from Jadibuti chowk towards Koteshwor	162	141	-13%	157	-3%	156	-4%	116	-28%
	11: EBL from Koteshwor chowk towards Jadibuti	268	158	-41%	101	-62%	105	-61%	77	-71%
	12: EBL from Koteshwor chowk towards Tinkune	296	35	-88%	31	-89%	0	-100%	0	-100%

Scenario S2 shows that introducing EBL significantly worsens queue lengths on normal traffic lanes due to reduced road space, with Section 1 showing the highest increase (from 158 m to 961 m, +508%), while while section 5 increases by 84% (from 330 m to 609 m) and Section 7 by 76% (from 296 m to 522 m). In contrast, bus lanes in S2 benefit greatly, with sections 8 and 12 dropping by 84% and 88% respectively, confirming that the physical separation of bus traffic substantially improves bus flow.

Scenario S3 offers slight improvements over S2, with marginal reductions in queues on some sections, while maintaining similar or slightly better bus lane performance. Scenario S4 shows similar results on normal lanes but improves bus operations further, achieving zero queues in key bus lane sections due to uninterrupted flow.

Scenario S5 emerges as the most effective scenario. On the normal traffic lanes, section 1 sees its maximum queue fall to 426 m from 961 m in S2, an increase of 170% over base case compared to 508% in S2. More significantly, several sections show queue lengths below base case under S5: section 4 drops to 145 m (-10%), Section 6 to 191 m (-1%), and Section 7 to 215 m (-27%), indicating genuine capacity relief rather than mere redistribution. On the exclusive bus lanes, S5 consistently achieves the highest reductions, with section 8 falling 87%, section 11 by 71%, and sections 9 and 12 recording zero queues.

4.4.6.2 Travel Time Analysis

Similarly, the travel time for the different vehicle class travelling from Tinkune to Lokanthali and vice-versa along with the percentage changes with respect to the base case are presented in Table 7 which was obtained after the simulation of all five scenarios in VISSIM. The negative sign indicates reduction of travel time from the base-case scenario.

Table 7: Travel time Results across all Scenarios

Approach	Vehicle Class	Travel Time (in seconds) and % change w.r.t base-case scenario								
		S1 Base Case	S2 EBL	% Change	S3 EBL Modified	% Change	S4 BSP Through	% Change	S5 BSP Phase Insertion	% Change
Tinkune-Lokanthali	Large Bus	666	558	-16%	531	-20%	523	-21%	514	-23%
	Mini Bus	711	585	-18%	572	-20%	555	-22%	529	-26%
	Micro	506	484	-4%	474	-6%	450	-11%	450	-11%
	Average of PT	628	545	-13%	531	-16%	517	-18%	505	-20%
	All Vehicle except PT	331	400	21%	340	3%	334	1%	288	-13%
	Private Vehicles	330	399	21%	340	3%	334	1%	287	-13%
	Lokanthali-Tinkune	Large Bus	682	588	-14%	580	-15%	539	-21%	489
Mini Bus		666	629	-6%	625	-6%	562	-16%	514	-23%
Micro		511	507	-1%	505	-1%	426	-17%	424	-17%
Average of PT		620	579	-7%	570	-8%	509	-18%	476	-23%
All Vehicle except PT		438	869	98%	855	95%	853	95%	731	67%
Private Vehicles		437	870	99%	855	96%	855	95%	732	67%

The introduction of EBL in scenario S2 provides significant travel time savings for public transport, particularly in the Tinkune-Lokanthali approach, where average PT travel time decreases by 13%, while the Lokanthali-Tinkune approach records a 7% reduction. These improvements result from segregated bus lanes that reduce conflicts with mixed traffic. Scenarios S3 and S4 further enhance public transport performance, while Scenario S5 achieves the greatest improvements in both directions, reducing average PT travel time by 20% and 23% in the Tinkune-Lokanthali and Lokanthali-Tinkune approaches respectively.

However, the reduced lane availability in Scenario S2 substantially increases travel time for other vehicles, particularly in the Lokanthali-Tinkune direction, where travel time nearly doubles (+98%). Scenario S3 provides slight relief for mixed traffic, while scenario S5 achieves the best balance between public transport priority and general traffic performance. In the Tinkune-Lokanthali approach, travel time for other vehicles drops by 13%

below the base case, whereas in the Lokanthali-Tinkune approach, although travel time remains 67% higher than the base case, it is still significantly improved compared to earlier scenarios. Overall, scenario S5 emerges as the

most effective option, delivering the highest benefits for public transport while minimizing adverse impacts on general traffic.

5. Conclusion

This study aimed to evaluate the potential effectiveness of exclusive bus lanes with signal priority in heterogeneous traffic conditions, using the Kathmandu-Bhaktapur Road as a case study. The traffic data were processed to reflect actual conditions, and an appropriate simulation model was developed using those data for local traffic characteristics. The model was then calibrated and validated for traffic volume and maximum queue length and then the base model was formed. Scenarios involving exclusive bus lanes and signal priority were created and simulated using VISSIM and their performance were analyzed using queue length and travel time as performance indicator.

Looking across all scenarios, introduction of exclusive bus lanes prioritizes public transport by providing separate lane, but it heavily penalizes general traffic by amplifying the queue in the normal lanes (up to 508%). Similarly, the travel time for public transport reduces by 7-13% whereas the travel time for other vehicles in normal lanes increases by 21-99%, with greater increase in Lokanthali-Tinkune approach.

Signal priority when used with exclusive bus lanes delivers the most consistent results across every approach. It preserves the major improvements for public transportation by eliminating queues to minimal level while also softening the negative impact on normal lanes. The queues in exclusive bus lanes gets reduced by 18-100%. In normal lanes, queues previously worsen by 508% drops to 170%. Although the queue is still above base case but it still represents a notable mitigation of adverse impacts. The travel time results also show the similar pattern. Public transport gets faster after the bus lane is introduced, but signal priority when used with exclusive bus lanes delivers the biggest gains in both directions. The travel time for public transport reduces by 20-23% in both approaches, whereas the travel time for other vehicles in normal lanes drops by 13% in Tinkune-Lokanthali approach and increases by 67% in Lokanthali-Tinkune approach.

This concludes that signal priority used in conjunction with exclusive bus lanes is the most effective option among the five scenarios studied. It gives public transport the largest travel-time savings on both approaches, but it doesn't punish the other vehicles on normal lanes as severely as other scenarios.

Limitations and Future Works

- Only 1.75km section of Kathmandu-Bhaktapur Road is considered. Future works should extend the model to broader network to get more clearer picture of how bus lane and signal priority behaves.
- The model excludes pedestrian movements, crossings and pedestrian-vehicle interactions. Future works should incorporate these pedestrian flow data and crossing behaviors.
- Simple signal priority technique, in the form of phase insertion is used in the study. Future works may explore the performance evaluation using advance signal priority strategies.
- This study is limited to curb-side exclusive bus lanes only. So, further studies may perform the comparative evaluation of median-side bus lanes.

Acknowledgement

The authors would like to acknowledge Safe and Sustainable Travel Nepal - SSTN for providing the valuable research grant which greatly helped to enhance the quality of the research. Similarly, we would also like to extend our appreciation to CCTV Department of Kathmandu Valley Police Office, Ranipokhari for granting us the permission to use the CCTV footage of the study area

References

- Acharya, A., & Marsani, A. (2020). Prediction of Traffic Conflicts at Signalized Intersection: A Case Study of New Baneshwor Intersection. *Kathmandu: IOE Graduate Conference*.
- ADB, & MPPW Nepal. (2010). *Kathmandu Sustainable Urban Transport Project*.
- Arasan, V. T., & Vedagiri, P. (2009). Simulating Heterogeneous Traffic Flow on Roads with and without Bus Lanes. *Journal of Infrastructure Systems*, 15(4), 305–312. [https://doi.org/10.1061/\(ASCE\)1076-0342\(2009\)15:4\(305\)](https://doi.org/10.1061/(ASCE)1076-0342(2009)15:4(305))

- Baalaganapathy, V. L., Girijan, A., Vanajakshi, L. D., & Chilukuri, B. R. (2023a). Evaluation of Bus Signal Priority and Dedicated Bus Lane for Efficiency Improvement. In L. Devi, A. Das, P. K. Sahu, & D. Basu (Eds.), *Proceedings of the Sixth International Conference of Transportation Research Group of India* (Vol. 271, pp. 293–309). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-3505-3_20
- Chen, X. M., Yu, L., Yu, L., & Guo, S. X. (2007). Impacts of Exclusive Lanes and Signal Priority on Bus Rapid Transit Effectiveness. *International Conference on Transportation Engineering 2007*, 364–369. [https://doi.org/10.1061/40932\(246\)60](https://doi.org/10.1061/40932(246)60)
- Chhetri, A. (2023). *Calibration of Car Following Parameters in VISSIM for Traffic in Kathmandu* [MSc Thesis]. Department of Civil Engineering, IOE Pulchowk Campus, Tribhuvan University.
- Dumbliauskas, V., Grigonis, V., & Vitkienė, J. (2017). Estimating the Effects of Public Transport Priority Measures at Signal Controlled Intersections. *The Baltic Journal of Road and Bridge Engineering*, 12(3), 187–192. <https://doi.org/10.3846/bjrbe.2017.23>
- Dutta, M., & Ahmed, M. (2019). Calibration of VISSIM models at three-legged unsignalized intersections under mixed traffic conditions. *Advances in Transportation Studies*, 48.
- Florida, D. (2014). *Traffic analysis handbook*. Florida Department of Transportation.
- Hussain, E., Nawaz, M. B., & Ali, D. (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. *2018 Moratuwa Engineering Research Conference (MERCon)*, 494–499.
- Jha, M. K. (2023). *Bus Rapid Transit System For Kathmandu Valley*.
- JICA. (2012). *Data Collection Survey on Traffic Improvement in Kathmandu Valley*. Japan International Cooperation Agency (JICA).
- Kandel, S., Khadka, S., Giri, S., & Thapa, S. (2023). Public Transportation Assessment Along Kathmandu Bhaktapur Route. *Journal of Interior Designing and Regional Planning*, 8(2), 22–30. <https://doi.org/10.46610/JoIDRP.2023.v08i02.003>
- Khakimov, B., & Tanaka, S. (2024). Evaluation of the impact of exclusive bus lanes on traffic in Tashkent. *Asian Transport Studies*, 10, 100151. <https://doi.org/10.1016/j.eastsj.2024.100151>
- Kunwar, D. B., Pradhananga, R., Parajuli, S., & Shrestha, S. (2025). Enhancing Traffic Operations and Safety Performance at Roundabout Intersections: A Simulation-Based Case Study of Dhalkebar Roundabout on the East-West Highway. *Journal of Transportation System and Engineering*, 1(1), 103–116.
- Lin, Y., Yang, X., Zou, N., & Franz, M. (2015). Transit signal priority control at signalized intersections: A comprehensive review. *Transportation Letters*, 7(3), 168–180. <https://doi.org/10.1179/1942787514Y.0000000044>
- Maheshwary, P., Bhattacharyya, K., Maitra, B., & Boltze, M. (2020). A methodology for calibration of traffic micro-simulator for urban heterogeneous traffic operations. *Journal of Traffic and Transportation Engineering (English Edition)*, 7(4), 507–519. <https://doi.org/10.1016/j.jtte.2018.06.007>
- Manandhar, A. (2023). *Calibration of VISSIM Parameters for Modeling Heterogeneous Traffic Conditions in Kathmandu using Genetic Algorithm: Case Studies of Singhadurbar, Padmodaya, and Putalisadak Intersections* [MSc Thesis]. Department of Civil Engineering, IOE Pulchowk Campus, Tribhuvan University.
- Mondal, S., & Gupta, A. (2020). Microsimulation-based framework to analyse urban signalised intersection in mixed traffic. *Proceedings of the Institution of Civil Engineers-Transport*, 176(4), 237–249.
- Shrestha, A., & Pradhananga, R. (2023). Modelling delay due to curb-side bus stops at signalized intersection: A case study of new baneshwor intersection. *Available at SSRN 4940013*.

Siddharth, S. M. P., & Ramadurai, G. (2013). Calibration of VISSIM for Indian Heterogeneous Traffic Conditions. *Procedia - Social and Behavioral Sciences, 2nd Conference of Transportation Research Group of India (2nd CTRG), 104*, 380–389. <https://doi.org/10.1016/j.sbspro.2013.11.131>

Zhang, W., Huang, Y., & Hu, G. (2003). Study on design standard for urban bus-lane. *Communications Standardization, 7*, 3

Zhu, L., Yu, L., Chen, X.-M., & Guo, J.-F. (2012). Simulated Analysis of Exclusive Bus Lanes on Expressways: Case Study in Beijing, China. *Journal of Public Transportation, 15*(4), 111–128. <https://doi.org/10.5038/2375-0901.15.4.6>