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A MICROSCOPIC TRAFFIC SIMULATION FRAMEWORK TO EVALUATE THE PERFORMANCE OF BUS PRIORITY LANES

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ABSTRACT

Bus priority measures are widely considered effective at reducing traffic congestion and bus travel times. Traditionally, the performance of a bus priority measure is evaluated using traffic survey-based methods. However, traffic simulations can also be used as a decision support tool for transport planners to test different bus priority measures in a simulation environment and evaluate the measure's performance before physical implementation. This research presents the development of a microscopic traffic simulation framework to simulate traffic flows when a bus priority lane (BPL) is in operation and compares its performance against the case where no BPL is in operation. A test-bed along the Galle Road corridor (in Colombo, Sri Lanka) from Cross Junction to Ratmalana was chosen to test the developed simulation framework. The performance of the BPL was evaluated by considering the changes in the vehicle speeds before and after implementing the BPL. Different demand configurations were simulated by varying the general traffic flow and bus flow to understand the BPL's feasible demand configuration(s). The simulation results showed that the BPL was feasible with a relatively high bus flow (240 buses per hour) and a relatively moderate general traffic flow (2,000 / 2,500 vehicles per hour).

Keywords: *Bus Priority Measures, Bus Priority Lane, Microscopic Traffic Simulations, Heterogeneous Traffic, SUMO, Traffic Simulations*

1. INTRODUCTION

The rapid increase in motorisation in emerging countries has led to various negative externalities. These include traffic jams and excessive and unreliable travel times in urban areas. Prioritising high-occupancy vehicles, such as buses, effectively reduces the adverse effects of motorisation [1][2]. Segregation of bus lanes and implementing a fully-fledged Bus Rapid Transit (BRT) system are higher-end solutions to prioritise buses. However, not all cities have the required road space: as cities become denser, acquiring land for road widening is expensive. The use of bus priority lanes (BPL) is a more flexible and practical solution applicable in a broader range of contexts, including urban areas with limited space [3]. A BPL-based solution should serve the needs of private vehicle users and public transportation users [4]. It is challenging to identify in which situations (e.g., location/corridor identification, demand conditions to be satisfied) a BPL could be feasible.

Traffic Models and Traffic Simulation Models help address such kinds of problems. Hoogendoorn describes the difference between a Traffic Model and a Traffic Simulation Model: ' A model is a mathematical representation of traffic; a simulation model is a numerical process, generally based on a mathematical model, used to simulate traffic flow on a digital computer.' [5, p. 217]. Traffic simulation models are applicable when the system components' interactions are complex and cannot be adequately described using a Traffic Model [6]. Therefore, a Traffic Simulation Model based approach is suitable to identify whether a BPL is feasible.

In the Sri Lankan context, BPLs were in operation, and their performance was evaluated using traffic measurements collected from surveys conducted before and after implementation. However, based on the literature and to the best of the authors' knowledge, a traffic simulation framework has yet to be used to evaluate the performance of BPLs in Sri Lanka.

This paper presents the development of a microscopic traffic simulation-based framework to simulate BPL operations. The automated modelling framework allows users to change input parameters (e.g., bus flow, general traffic flow) and rapidly generate and evaluate different scenarios. Thus, it can work as a decision support tool for transport planners to identify the performance of a BPL under different demand configurations. The development of the simulation framework is described in detail in Section 3. Section 4 describes the application of the developed simulation framework for an existing network and the results obtained for simulating different demand configurations. Section 5 discusses the limitations of the research and future research areas.

2. LITERATURE REVIEW

The performance of a bus priority measure (BPM) can be evaluated using two different approaches. The conventional approach is to test empirically by conducting traffic surveys before and after implementing the BPM. Such surveys help researchers to understand ground realities, but surveys tend to be expensive and time-consuming [7]. Therefore, the data is generally collected briefly and must be recollected if a reassessment is required.

A more recent approach uses Traffic Simulation Models to evaluate BPMs ([4], [9]-[11]). Simulation models help understand different BPMs' effects on the traffic flow by providing different simulation outputs. This provides a solid basis for excellent and cost-effective decision-making. One of the additional advantages is that since the simulations are run in a controlled environment, the disturbance of external factors (e.g., roadside incidents) can be omitted [8]. Therefore, the simulation outputs generated are responsive only to the changes made to the input parameters. However, one of the disadvantages of traffic simulations is that the model is a simplified representation of reality. Therefore, simulation models can not cover all real-world aspects [8].

2.1. Simulation-based Methods to Evaluate Bus Priority Measures

Table 1 summarises some previous research work that used traffic simulation tools to evaluate different spatial and temporal bus priority measures.

2.2. Bus Priority Measure-Based Studies Conducted in Sri Lanka

The bus services in Sri Lanka started in 1907 with no regulatory interventions. Since then, the bus operator has undergone a series of regulatory interventions [12]. Currently, the passenger bus services are operated by a state-owned large, formal bus operating company and many private bus operators who are ‘single-bus’ owners and work independently. Any interventions to the bus operations like BPLs can become challenging due to the above nature of the ownership and operational practices.

In Sri Lanka, the BPL is the primary BPM tested and evaluated for performance using field-observed data. Kumarage and De Silva conducted a study at a section in Galle Road Corridor from Moratuwa Cross Junction to Ratmalana Junction to assess the performance of the BPL during the morning peak time by implementing a curbside BPL [13]. Travel time observations were taken using a registration number plate survey for all the buses and a sample of other vehicles to calculate the general traffic speeds. The speeds were calculated for a scenario where no BPL was in operation (base case), and the BPL was in operation. The result showed that the travel speeds of general traffic and buses decreased with implementing the BPL.

Table 1: Use of traffic simulations to evaluate bus priority measures

Study	Bus Priority Measure	Findings
Papageorgiou et al., [4]	Dedicated Bus Lane (DBL) and DBL + Bus Advance (B.A.) signal priority methods were tested using PTV (Planung Transport Verkehr) Vissim Simulator for a test simulation area in Nicosia, Cyprus.	DBL + B.A. scenario reduced the total travel time for buses by 27%, increased average speed by 45%, delay time decreased by 28% and a speed drop for private vehicles by 2%.
Al-Deek et al., [9]	Simulated multiple Bus Rapid Transit (BRT) and Transit Signal Priority (TSP) combination scenarios using a PTV Vissim simulator using a test simulation area in Orlando, Florida (USA).	BRT with conditional TSP 3 minutes behind significantly improved travel times (17% - 26%), average speed (30% - 39%), and average total delay per vehicle (11% - 32%) for the main through movements compared to the base scenario (No BRT, No TSP).
Huan et al., [10]	Evaluate Bus Signal Priority's adaptability to find an optimum balance between the efficiency of bus flow and environmental costs (emissions). It was tested using PTV Vissim for an intersection in the Haidian district of Beijing, China.	When the traffic volume is relatively small (2000 - 3000 PCU/h), bus signal priority significantly improves the efficiency of the intersection. However, when the traffic volume is rather large (4000 - 5000 PCU/h), the decrease in time cost resulting from bus signal priority cannot offset the increase in the environmental cost. (PCU = Passenger Car Unit)
Ma and Xu, [11]	Conducted experiments on intermittent bus lane (IBL), IBL and multiphase bus priority control (IBL + MBPC), and IBL and green wave coordination control (IBL + GWCC).	It was found that IBL + GWCC strategy works best, and the process reduced the delay for BRT vehicles by 15.74%. Delay of trunk vehicles and the length of queues were also reduced, with a slight increase in average queue lengths.

Traffic cones were used to restrict the BPL and car lane. This use of traffic cones was identified as one of the reasons for the speed reduction of cars, as it creates side friction for the vehicles. Furthermore, multiple reasons were identified for the decrease in the speed of buses in the BPL. They are 1) bicycle movement on the bus lane, 2) pedestrian movement on the bus lane due to obstructions in the sidewalks, 3) insufficient length of the bus bays, 4) buses not stopping closer to the kerb at bus bays, 5) gullies and accumulation of sand on bus lanes, and 6) parking of vehicles on the bus lane.

Fernando et al. conducted a study evaluating the performance of BPLs at two sections (Section 1 – Cross Junction to Ratmalana Junction, Section 2 – Wellawatta Savoy Junction to Kollupitiya Junction) of the Galle Road corridor that had BPLs demarcated with paint on the road [14]. The demarcation using painted markings helped to remove one of the barriers identified in [13]. The data was collected from a number plate survey at different locations that were later used to calculate the speeds of the buses. The results show a significant increase in bus speeds in both sections when the BPL is in operation. The mean velocity of section 1 was increased from 18kmph to 23kmph, whereas the speeds in section 2 were increased from 14kmph to 18kmph. The study mentioned that once BPL was in operation, the speeds of the fast-moving buses could be affected by slow-moving buses travelling ahead of them. Here, slow-moving buses belong to short-distance bus routes with more significant stopping duration (dwell time) at bus stops than fast-moving buses. Fast-moving buses are generally long-distance buses which travel faster with fewer stops and dwell times.

2.3. Research Gaps

The previous research conducted in Sri Lanka was based on sample data of actual traffic flows. The comparison was made based on the data collected when the BPL was in operation and when it was not. Also, a few qualitative reasons were identified for speed reduction in BPLs. However, this method only helps to understand the performance of the BPL in a particular window of time when survey data was collected. Further, this approach fails to evaluate the suitability of a bus priority lane under different demand conditions (e.g., frequency of buses, general traffic flow, vehicle mix)

To the authors' knowledge, no previous attempts were made to evaluate a BPL’s performance using traffic simulation tools in Sri Lanka. Using a microscopic traffic simulation-based approach helps to simulate different demand configurations and find favourable demand configurations for BPLs. One of the additional advantages of the simulation-based system is that a controlled experiment can be conducted without disturbance of other qualitative barriers, as identified in [13]. Therefore, the simulation results will help transport planners better evaluate BPL’s performance.

3. METHODOLOGY

Most traffic simulators have reached a mature state of development. Therefore, the simulation software was chosen based on the modelling capabilities and availability. All the established microscopic simulation software (e.g., PTV Vissim, AIMSUN, PARAMICS, SUMO) can simulate bus priority lanes. Open-source software was given a higher priority than commercial products, not only for its cost but also for its ability to customise. In this study, SUMO (Simulation of Urban Mobility) microscopic traffic simulation software was used as the simulation software. SUMO is a free, open-source, portable, microscopic, and continuous multi-modal traffic simulation package that handles large networks [15]. Figure 1 below illustrates the schematic overview of the simulation framework development process. The simulation framework development process was automated using the existing Python scripts available with SUMO and custom Python scripts to generate general traffic flows (Figure 2), and bus flows (Figure 3) so that different demand configurations can be generated quickly.

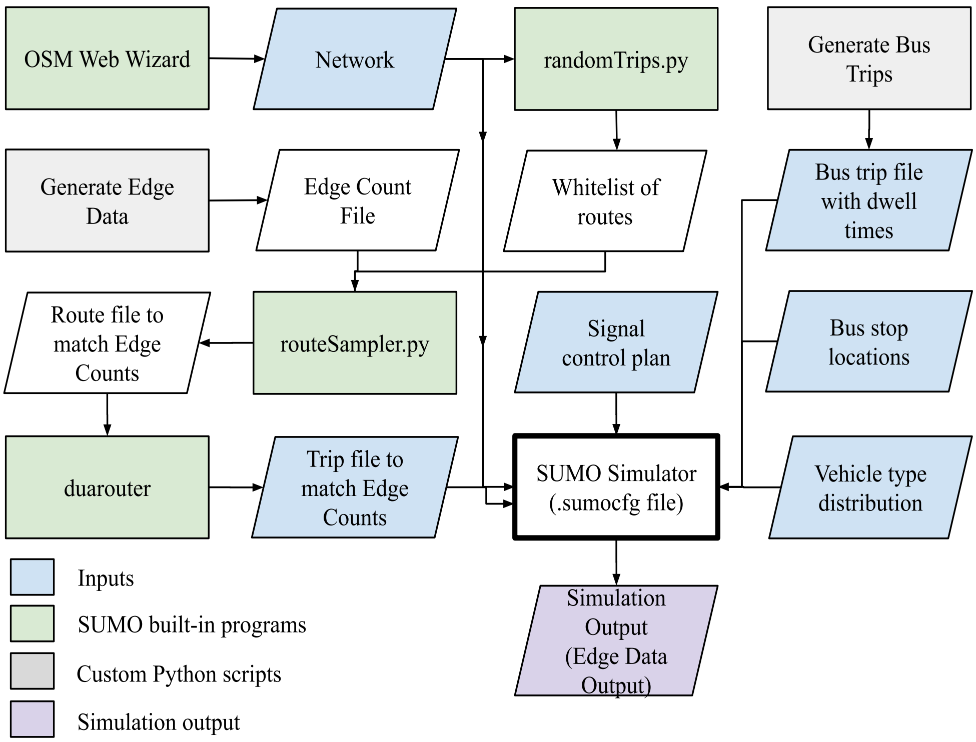

Figure 1: Simulation framework development workflow with SUMO

```
Algorithm: Generate Edge Count File as input for routeSampler.py
Inputs:
                MajorEdgeList: EdgeID list of the significant road segment
                MinorEdgeList: EdgeID list of the minor roads
                MajorFlow: Vehicles per hour in the major flow
                Minor%: Minor Road vehicle flow as a % of major flow
                IntervalBegin: Time stamps list for interval begin times.
                IntervalEnd: Time stamps list for interval end times
Open XML
For start, end in zip(IntervalBegin, IntervalEnd)
                For MajorEdge in MajorEdgeList:
                      WriteXML (MajorEdge, MajorFlow)
                For MinorEdge in MinorEdgeList:
                      WriteXML (MinorEdge, MajorFlow × Minor%:)
Close XML
Output: SUMO Edge Data File
```

Figure 2: Pseudocode for generating an edge data file

```
Algorithm: Generate Bus Trips as an Input for SUMO Simulator
Inputs:
                BusFlow: Buses per hour to be simulated
                BusType:  Whether the bus is a short-distance or long-distance bus
                LongDistance%: Percentage of long-distance buses
                StartEdges: EdgeIDs in the network in which the routes start
                EndEdges: EdgeIDs in the network in which the routes end
                BusStops: Bus stop sequence for long-distance / short-distance
                buses
                ActDwellTimes: Actual dwell times of buses (based on a survey)
BusTrips =      CreateBusTripDataFrame(BusFlow, BusType, LongDistance%,
                DepartTimes, StarEdges, EndEdges, BusStops)
Open XML
For Trip in BusTrips:
                WriteXML (TripID, BusType, DepartTime, StartEdge, EndEdge)

                For BusStop in BusStops:
                      DwellTime = GenerateDwellTimes (ActDwellTimes)
                      WriteXML (BusStop, DwellTime)
Close XML
Output: SUMO Additional File contains Bus Trips with dwell times
```

Figure 3: Pseudocode for generating bus trips

3.1. Generation of General Traffic Flows

A custom Python script generated different demand scenarios for general traffic. The pseudocode for general traffic flow generation is given in Figure 2. When generating traffic flows, it is crucial to consider the vehicle flows from the minor roads. This study calculated vehicle flow on the minor roads as a percentage (Minor%) of the general vehicle flow on the major road.

The difference between bus trips and the general traffic flow is that buses make stops at selected bus stops for a specific duration. The stop duration (dwell time) can be modelled with values drawn from a particular distribution to make the simulation closer to reality. It is possible to provide the best guess for the parameters of the selected distribution or find the most suitable distribution for the observed dwell times gathered from a survey and generate dwell times from that fitted distribution. In this study, the latter was implemented using the 'distfit' Python package, used for probability density fitting of univariate distributions for random variables [16].

3.2. Generate Traffic Scenarios

Once the base scenario was developed, the vehicle flow was simulated for a scenario where BPL is in operation, and its performance was evaluated against the base scenario. When implementing the BPL scenario, the changes to the simulation must be done in a real-time fashion. These changes can be done by TraCI (Traffic Control Interface), which provides access to a running SUMO simulation, retrieve values of simulated objects, and manipulate their behaviour online. This study uses TraCI to activate and deactivate BPL, as shown in Figure 4. In this implementation, the leftmost lane is converted to a BPL only when the bus priority lane operates (BPL time was set from 1800 to 5400 simulation seconds).

3.3. Generation of Bus Trips

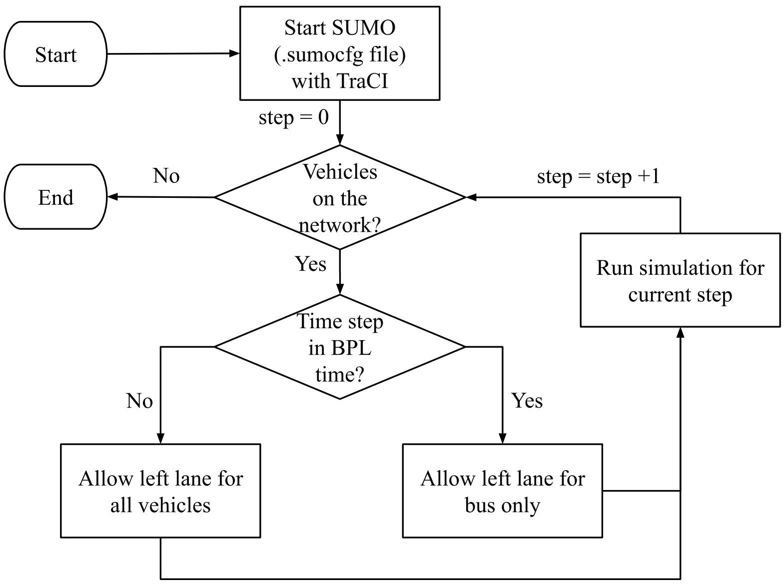

Figure 4: SUMO TraCI implementation for bus lane

3.4. Simulation Outputs

Out of the many different simulation outputs available with the SUMO simulator, the edge-based traffic measure was used as the simulation output for this study as it has vehicle speeds as one of the outputs. An aggregated speed was calculated for each five-minute interval for general vehicles and buses. The simulation outputs were taken for both the base case and the BPL scenario so that the results could be compared using appropriate statistical tests and evaluate the suitability of the BPL for a given demand scenario.

3.5. Statistical Tests

A schematic overview of the statistical tests is given in Figure 5. Standard simulation outputs in SUMO are in .xml format. The outputs related to the base case and BPL scenario were converted to .csv format and combined for analysis. The idea behind statistical analysis was to find whether there is a significant difference between the base scenario and BPL scenario for a given demand configuration concerning the speeds of the vehicle types (general vehicles and buses).

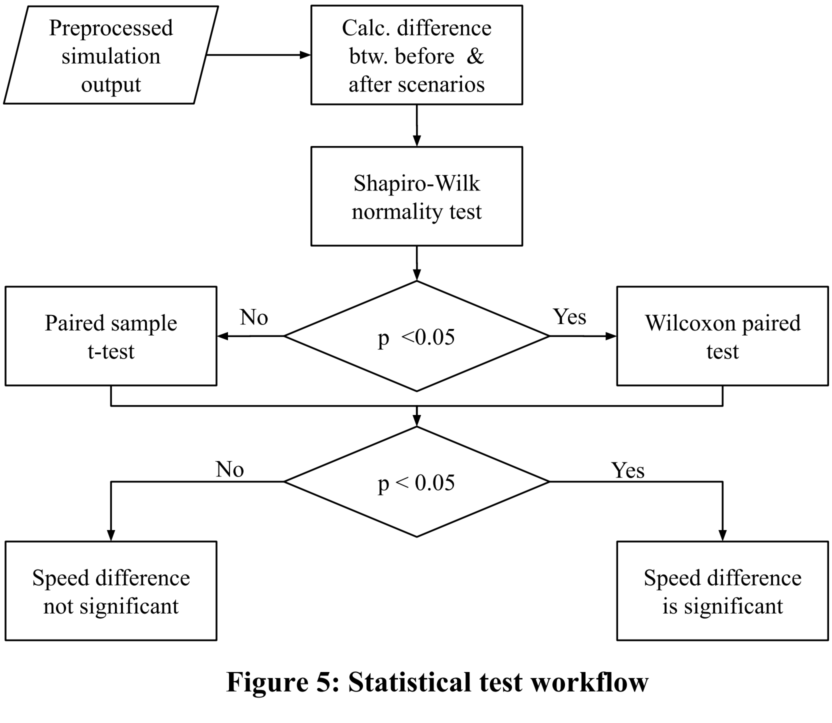

Figure 5: Statistical test workflow

Therefore, the differences in speed (hereafter referred to as 'speed differences') were calculated for a given vehicle type. Then Shapiro-Wilk test was conducted to check whether these speed differences are normally distributed. A p-value less than 0.05 of the Shapiro-Wilk test suggests that the speed differences are not normally distributed.

In such cases, the Wilcoxon paired test was conducted to check whether the speed differences significantly differed from zero. If the speed differences were normally distributed (p-value is greater than 0.05 from Shapiro-Wilk normality test), paired sample t-test was conducted to check whether the speed differences were significantly different from zero. If the speed differences were significantly different from zero, it can be concluded that there would be a significant difference in vehicle speeds between the base and BPL scenarios. Based on the results, the suitability of the BPL for a given demand condition was determined.

4. APPLICATION OF SIMULATION FRAMEWORK

The methodology explained in the previous section is applied to a road network in Sri Lanka. The implementation details and the results obtained are provided in the following subsections.

4.1. Introduction to the Network

The 4.2km road segment between Cross Junction Moratuwa and Ratmalana was selected as the study network, as shown in Figure 6.c. The road includes three lanes in each direction. It consists of 14 bus stops and many minor roads where vehicles can enter the arterial road. The base scenario (no BPL) is shown in Figure 6.a (simulation) and Figure 7.a (real world). The BPL was planned on the leftmost lane. The implementation of BPL is shown in Figure 6.b (simulation) and Figure 7.b (real world)

General traffic flows were generated using custom Python scripts, as mentioned in Figure 2. Vehicle types used to represent the general traffic were cars (34.2%), motorcycles (20.9%), vans (19.9%), three-wheelers (19.8%), goods vehicles (4.9%), multi-axle (0.2%) vehicles (values were calculated using data extracted from [17]). The bus flows were generated separately, as mentioned in Figure 3. To factor in drivers' poor lane discipline, the SUMO sub-lane-model was activated to drive in parallel on a single lane (e.g., a car and a motorcycle drive parallel in a given lane).

The default car-following model in SUMO is called the 'Krauss' model. This study used one of the 'Krauss' model's parameters called 'sigma' (which governs the driver imperfection) as a calibrated model parameter. The calibration was done in a previous study [18]. After further calibration, a calibrated value for 'sigma' equal to 0.2342 was used in this study to pre-calibrate the simulation platform for the selected network.

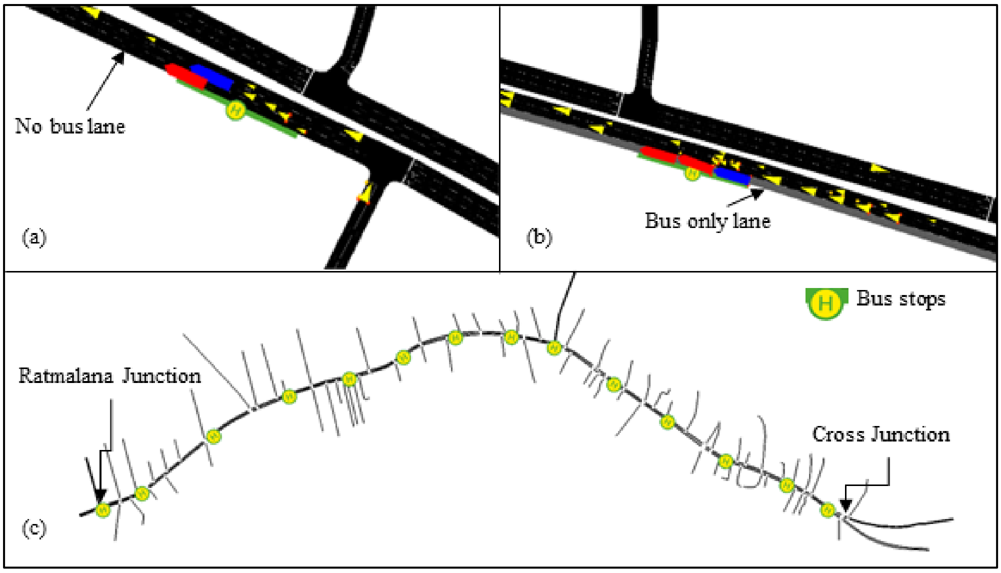

Figure 6: Network a) Base case b) Bus Lane in operation c) Overview

Figure 7: a) BPL is not in operation

Figure 7: b) BPL in operation

Source: [19]

4.2. Scenario Development

Altogether 16 different demand configurations were created to test the suitability of a bus priority lane by changing two parameters. The first parameter was the general traffic flow on the major road (2000, 2500, 3000, and 3500 vehicles per hour). The second parameter was the bus flow (60, 120, 180, and 240 buses per hour). When defining bus flows, the ratio of long-distance buses to short-distance buses was set to 1:3. The vehicle flow from minor roads was set at two per cent of the general traffic flow.

A survey conducted to capture the dwell times of buses on the same corridor was used to generate dwell times. These were used to define the stopping times of the buses (refer to Figure 3). The 'distfit' Python package [16] was used to identify the most suitable distribution for the dwell time. As shown in Figure 8, the best-fit distribution determined for the observed dwell times was the 'generalised extreme value distribution'. The identified parameters (shape = -0.496113, location = 6.48832, scale = 7.04518) generated dwell times. A capping method was used to avoid generating extreme values far from the actual dwell times. Based on the observed data, the maximum dwell time is ~175 seconds. Therefore, any value drawn from the fitted distribution greater than 175 seconds was ignored and instead used 175 seconds as the dwell time.

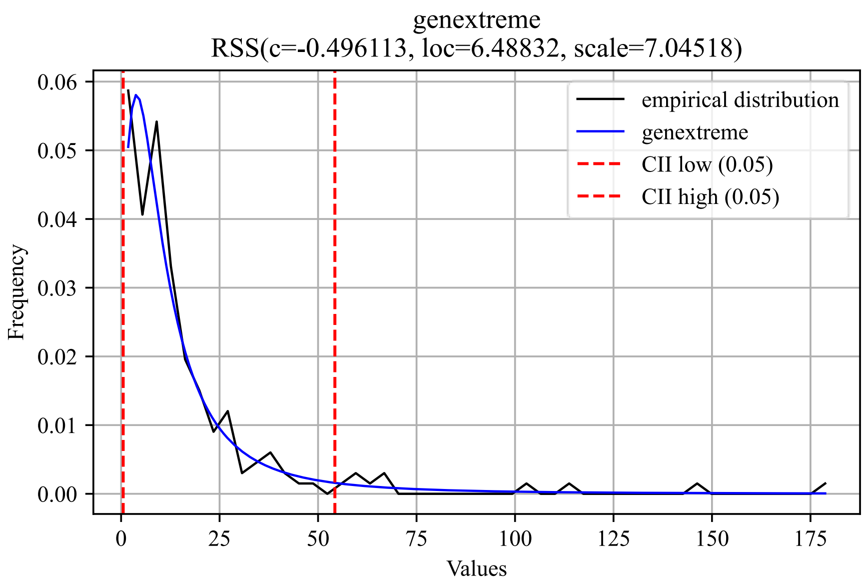

Figure 8: Distribution of dwell times

4.3. Results

As described in subsection 4.2, sixteen different demand configurations were simulated for the base case and when the BPL is in operation. Speed outputs were extracted from the simulation, and statistical tests were conducted to check whether the speed gains (or losses) differed significantly from the base scenario as described in subsection 3.5.

In this study, the suitability of a bus priority lane was decided only by considering the speeds of the vehicles obtained from the simulation. For a given demand condition, a BPL was considered suitable only when there was a significant speed increase in buses, and the speeds in the general vehicles were either 1) increased or 2) the speed dropped insignificantly compared to the base case scenario. The details of the statistical tests are given in Table 2. The speed variation in each demand configuration for buses and general vehicles is shown in Figure 9. Considering the speed changes of the general vehicles, the general vehicle speeds reduce as the flow increases. In addition, it can also be seen that the variation of the speeds of the general vehicles is higher when the BPL is in operation in almost all cases. This could be because of 1) higher interactions among the general vehicles as they now travel in two lanes (earlier three), and 2) the higher waiting time for general vehicles entering from the minor roads as they cannot enter the leftmost lane when BPL is in operation.

The speeds of the buses drop when there are more buses in the network. This could be mainly because the buses must stop at the bus halts, and buses can only enter the bus stop once the buses ahead of them leave. It is observed that bus speeds are higher when BPL is in operation compared to a no-bus lane scenario, and in some cases, the speed variation has also fallen. This indicates that BPL helps to regulate the speeds of the buses.

Table 2: Scenario Evaluation

General Flow (veh/hr)	Bus Flow (veh/hr)	General Vehicle Speeds B: Before, A: After, p-val.: p-value[1]	Bus Speeds B: Before, A: After, p-val.: p-value	Suitability of a BPL
2000	60	B: 43.45 (1.45) A: 42.41 (1.45) p-val.: 0.001 P	B: 27.99 (1.69) A: 28.99 (2.01) p-val.: 0.001 P	Not suitable
2000	120	B: 42.57 (1.67) A: 41.97 (1.95) p-val.: 0.019 P	B: 27.64 (1.59) A: 27.39 (2.66) p-val.: 0.85 W	Not suitable
2000	180	B: 41.37 (1.87) A: 41.57 (1.98) p-val.: 0.627 P	B: 23.58 (3.83) A: 24.57 (3.73) p-val.: 0.211 P	Not suitable
2000	240	B: 37.78 (3.29) A: 40.19 (2.39) p-val.: 0.004 P	B: 12.74 (5.27) A: 14.27 (6.27) p-val.: 0.003 P	--Suitable--
2500	60	B: 40.52 (2.71) A: 39.19 (3.48) p-val.: 0.015 P	B: 24.47 (1.41) A: 26.44 (2.58) p-val.: 0.025 P	Not suitable
2500	120	B: 39.79 (2.80) A: 36.85 (4.83) p-val.: 0.003 P	B: 24.46 (2.01) A: 24.79 (2.49) p-val.: 0.549 P	Not suitable
2500	180	B: 36.32 (4.46) A: 34.20 (7.51) p-val.: 0.176 W	B: 16.26 (5.43) A: 16.29 (5.78) p-val.: 0.964 P	Not suitable
2500	240	B: 37.16 (3.79) A: 34.23 (7.88) p-val.: 0.063 P	B: 18.91 (5.42) A: 21.43 (6.52) p-val.: 0.000 P	--Suitable--
3000	60	B: 38.74 (2.90) A: 31.68 (6.70) p-val.: 0.000 P	B: 27.56 (2.45) A: 30.09 (1.33) p-val.: 0.000 W	Not suitable
3000	120	B: 35.92 (3.44) A: 31.68 (6.88) p-val.: 0.005 P	B: 24.79 (2.09) A: 26.96 (3.02) p-val.: 0.011 P	Not suitable

[1] Superscripts on p-values 1) P: Paired sample t-test, 2) W: Wilcoxon signed-rank test

General Flow (veh/hr)	Bus Flow (veh/hr)	General Vehicle Speeds B: Before, A: After, p-val.: p-value	Bus Speeds B: Before, A: After, p-val.: p-value	Suitability of a BPL
3000	180	B: 34.12 (3.90) A: 28.69 (8.33) p-val.: 0.003 P	B: 17.81 (4.75) A: 18.86 (4.64) p-val.: 0.013 P	Not suitable
3000	240	B: 34.61 (3.25) A: 27.47 (8.79) p-val.: 0.001 P	B: 17.52 (3.83) A: 19.85 (3.70) p-val.: 0.000 P	Not suitable
3500	60	B: 31.89 (4.92) A: 26.35 (7.47) p-val.: 0.000 P	B: 25.37 (1.80) A: 27.88 (2.03) p-val.: 0.004 P	Not suitable
3500	120	B: 29.72 (5.57) A: 26.35 (7.47) p-val.: 0.000 P	B: 22.52 (3.21) A: 27.88 (2.03) p-val.: 0.003 P	Not suitable
3500	180	B: 28.33 (6.07) A: 24.63 (9.19) p-val.: 0.006 P	B: 19.47 (3.73) A: 22.76 (3.87) p-val.: 0.001 P	Not Suitable
3500	240	B: 25.64 (6.88) A: 22.64 (8.71) p-val.: 0.002 P	B: 13.25 (4.90) A: 16.32 (5.46) p-val.: 0.000 P	Not suitable

According to the evaluation criteria described above, a bus priority lane is feasible for the selected network when the general traffic flow is 2000 or 2500 vehicles per hour and the bus flow is 240 buses per hour. Further comparison to actual scenarios could have been made if all the required actual data for a given hour (i.e., actual vehicle flow, actual bus demand, actual long-distance to short-distance bus ratio, percentage of vehicles arriving from minor roads) is available, and the additional scenario mentioned above is calibrated and validated.

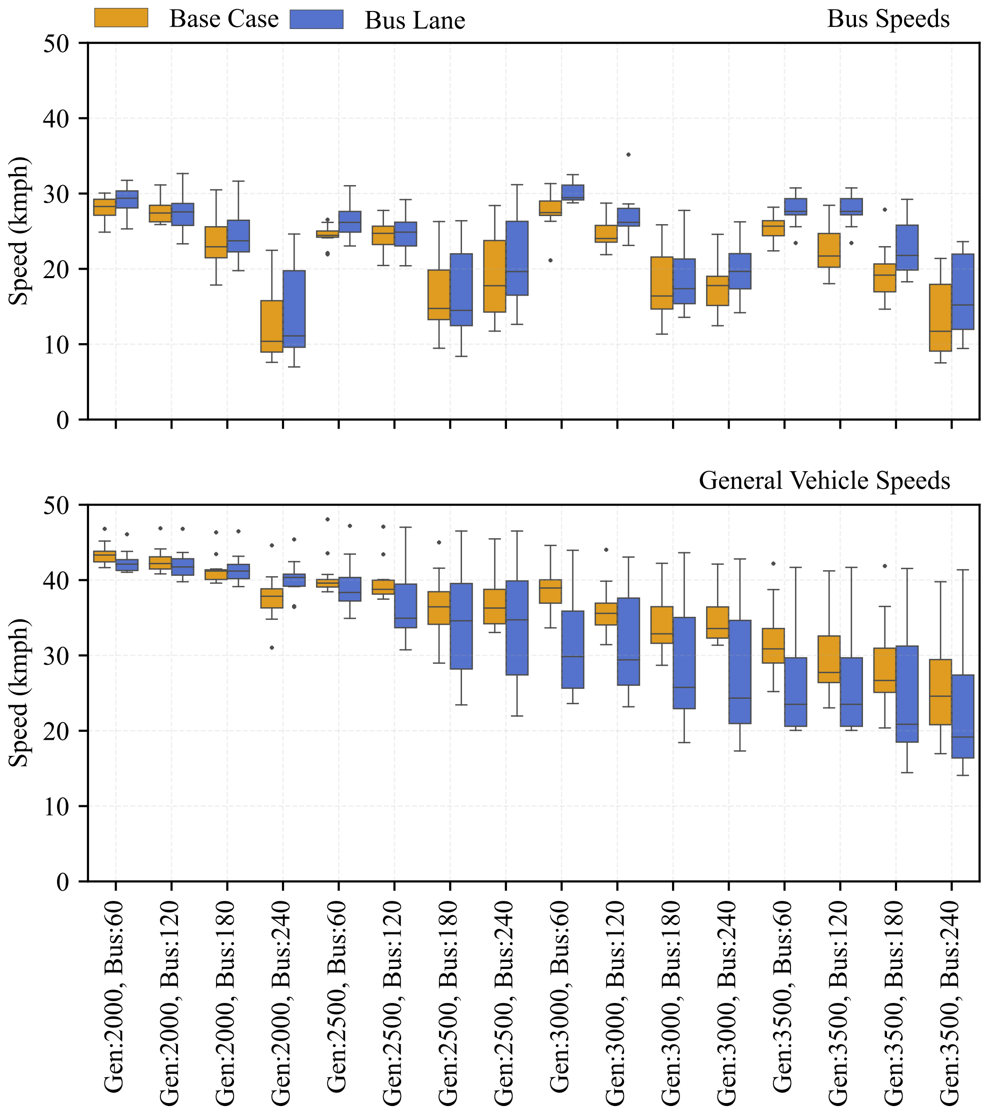

Figure 9: Comparison of speeds under different demand conditions

5. CONCLUSION AND FUTURE RESEARCH

This paper presents a microscopic traffic simulation framework to evaluate the performance of a bus priority lane (BPL). The method developed was applied to an urban corridor along Galle Road in Colombo, Sri Lanka, to evaluate the performance of the BPL under different demand conditions. The simulation platform provided results for a given demand configuration. The statistical tests indicated whether implementing a BPL is suitable for the selected demand configuration by considering the vehicle speeds before and after the implementation of the BPL. The demand configurations considered in this study were synthetic and covered 16 different demand configurations. Based on the evaluation criteria defined in this research, simulation results show that a bus priority lane for the selected corridor was feasible when the demand for buses is 240 buses per hour, and the demand for general vehicles is either 2000 or 2500 vehicles per hour. Transport planners can use this simulation platform as a decision support tool to run simulations based on actual traffic counts and check whether opening a BPL is feasible given the existing demand conditions.

This simulation platform is intended to be further developed to evaluate the performance of different spatial and temporal bus priority measures. Also, different simulation output types, such as emissions, energy consumption, and travel time savings, can be generated from the simulation to evaluate the suitability of the selected bus priority measure. In addition, impacts on other roadside activities to bus lanes (e.g., on-street parking, pedestrian movements, and parking violations [20]) can be tested by improving the base scenario by adding on-street parking slots and pedestrian crossings. These additions will help generate more realistic simulations.

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REFERENCES

[1] G. Beirão and J. A. Sarsfield Cabral, “Understanding attitudes towards public transport and private car: A qualitative study,” Transp. Policy, vol. 14, no. 6, pp. 478–489, Nov. 2007, doi: 10.1016/j.tranpol.2007.04.009.

[2] J. Wu and N. Hounsell, “Bus Priority Using pre-signals,” Transp. Res. Part Policy Pract., vol. 32, no. 8, pp. 563–583, Nov. 1998, doi: 10.1016/S0965-8564(98)00008-1.

[3] A. Agrawal, T. Goldman, and N. Hannaford, “Shared-Use Bus Priority Lanes on City Streets: Approaches to Access and Enforcement,” J. Public Transp., vol. 16, no. 4, pp. 25–41, Dec. 2013, doi: 10.5038/2375-0901.16.4.2.

[4] G. Papageorgiou, P. Ioannou, A. Pitsillides, T. Aphamis, A. Maimaris, “Development and Evaluation of Bus Priority Scenarios via Microscopic Simulation Models,” presented at the Control in Transportation Systems, Sep. 2009, pp. 434–441. doi: 10.3182/20090902-3-US-2007.00065.

[5] S. Hoogendoorn, “Traffic Flow Theory and Simulation,” Transportation and Traffic Engineering Section. Faculty of Civil Engineering and Geosciences, Delft University of Technology. [Online]. Available: https://ocw.tudelft.nl/wp-content/uploads/Reader_ct4821.pdf

[6] E. Lieberman and A.K. Rathi, “Traffic Simulation,” U.S. Department of Transportation, Federal Highway Administration. Jan. 2017, [Online]. Available: https://www.fhwa.dot.gov/publications/research/operations/tft/chap10.pdf

[7] A. Al-Mudhaffar, “Impacts of Traffic Signal Control Strategies,” Doctoral Thesis, Division of Transport and Logistics, Royal Institute of Technology, Stockholm, Sweden, 2006.

[8] J. Wahlstedt, “Evaluation of bus priority strategies in coordinated traffic signal systems,” Licentiate Thesis, Division of Transport and Logistics, Royal Institute of Technology, Stockholm, Sweden, 2014.

[9] H. Al-Deek, A. Sandt, A. Alomari, and O. Hussain, “A technical note on evaluating the effectiveness of bus rapid transit with transit signal priority,” J. Intell. Transp. Syst., vol. 21, no. 3, pp. 227–238, May 2017, doi: 10.1080/15472450.2017.1286987.

[10] N. Huan, E. Yao, Y. Fan, and Z. Wang, “Evaluating the Environmental Impact of Bus Signal Priority at Intersections under Hybrid Energy Consumption Conditions,” *Energies*, vol. 12, no. 23, p. 4555, Nov. 2019, doi: 10.3390/en12234555.

[11] C. Ma and X. “Daniel” Xu, “Providing Spatial-Temporal Priority Control Strategy for BRT Lanes: A Simulation Approach,” *J. Transp. Eng. Part Syst.*, vol. 146, no. 7, p. 04020060, Jul. 2020, doi: 10.1061/JTEPBS.0000385.

[12] A. S. Kumarage and M. D. R. P. Jayaratne, “Lessons in ownership, regulation and management from 100 years of bus transport in Sri Lanka,” Res. Transp. Econ., vol. 22, no. 1, pp. 109–117, Jan. 2008, doi: 10.1016/j.retrec.2008.05.025.

[13] A. Kumarage and D. De Silva, "Feasibility of A Bus Priority Lane for Galle Road," presented at the Institution of Engineers Sri Lanka Annual Sessions, Colombo, Oct. 2003.

[14] W. W. P. M. Fernando, J. A. Munasinghe, D. D. Dhananjaya, A. S. Kumarage, and T. Sivakumar, "Assessing the Performance of Bus Priority Lane on Galle Road, Sri Lanka," in *Proceedings of the Eastern Asia Society for Transportation Studies,* 2021, vol. 13.

[15] P. A. Lopez *et al.*, "Microscopic Traffic Simulation using SUMO," in *The 21st IEEE International Conference on Intelligent Transportation Systems*, Nov. 2018, pp. 2575–2582. [Online]. Available: https://elib.dlr.de/127994/

[16] E. Taskesen, "distfit - Probability density fitting." Jan. 2020. [Online]. Available: https://erdogant.github.io/distfit

[17] Department of Transport & Logistics Management, "Appendix-C to the Final Report (Turning Movement Counts/Trip Generation & Attraction Analysis," University of Moratuwa, Sri Lanka, Mar. 2013.

[18] T. Jayasinghe, T. Sivakumar, A. Kumarage, "Development of a Microscopic Traffic Simulation Model For Galle Road, Colombo," presented at the Research for Transport and Logistics Industry Proceedings of the 7th International Conference, Colombo, 2022. [Online]. Available: https://slstl.lk/wp-content/uploads/2022/10/R4TLI-2022-Proceedings.pdf

[19] M. Borham, "Priority bus lane improves road discipline," Sunday Observer. Accessed: Mar. 09, 2023. [Online]. Available: https://www.sundayobserver.lk/2017/08/27/features/priority-bus-lane-improves-road-discipline

[20] G. S. Samarakoon and T. Sivakumar, "Microscopic Simulation of Parking Violations in Curbside With-Flow Bus Priority Lanes Using Sumo Traffic Control Interface (TraCI)," presented at the Research for Transport and Logistics Industry Proceedings of the 7th International Conference, Colombo, 2022. [Online]. Available: https://slstl.lk/wp-content/uploads/2022/10/R4TLI-2022-Proceedings.pdf