AGGREGATE LEVEL CALIBRATION OF SUMO FOR HETEROGENEOUS TRAFFIC CONDITIONS AT SRI LANKAN SIGNALISED INTERSECTIONS

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ABSTRACT

SUMO (Simulation of Urban MObility) provides considerable capability for traffic studies in developing countries. However, by default it is calibrated for lane-disciplined, homogeneous traffic of Europe. This study developed an aggregate level calibration strategy to make SUMO suitable for heterogeneous traffic in signalized intersections. In this regard, two traffic signalized intersections in Sri Lanka, namely Piliyandala (four-legged) and Katubedda (three-legged), were studied through detailed geometric and signal timing information. Traffic data collected through videos on site comprised vehicular classification, discharge rates, and queue lengths in each approach for each signal cycle, which were then aggregated at 15-minute intervals. Nine vehicle types corresponding to local traffic mixture were introduced, along with iterative calibration of behavioral parameters to match observed traffic operation. Model validity in Piliyandala was evaluated using the mean absolute percentage error (MAPE) and Geoffrey E. Havers (GEH) statistic, with results indicating satisfactory agreement for classified traffic discharge counts and queue lengths, as reflected by MAPE values below 15% and GEH values below 5, with minor exceptions in complex shared-lane queues. Once satisfied, the same SUMO parameter set was used in Katubedda to forecast the flow and the queue length. Results show that in Katubedda, statistical tests satisfy the accepted thresholds without further calibration. This establishes the model transferability of SUMO in various intersections in areas with similar traffic patterns without resource intensive individual calibration.

Keywords: SUMO, calibration, heterogeneous traffic, microscopic simulation, intersections

1. INTRODUCTION

The use of microscopic traffic simulation has emerged as a crucial instrument for analyzing many aspects related to traffic engineering, including the examination of intersection operations, the development of effective traffic signal management systems, and the assessment of policy changes and measures. One of the notable traffic simulation tools that have been receiving growing recognition in recent years is the Simulation of Urban MObility (SUMO) due to its open-source architecture, transparency, and high degree of extensibility.

Traffic environments in nations like Sri Lanka are fundamentally different from the homogeneous and lane-following flows commonly seen in Europe and North America. Urban signalized intersections are defined by their extremely heterogeneous fleets of motorcycles, three-wheelers, cars, buses, and freight vehicles operating in lanes with weak lane-following behavior, strong gap acceptance capabilities, and high starting tendencies. These features generate complicated interaction scenarios that are vastly different from the basic assumptions made in traditional traffic engineering models like the Highway Capacity Manual (HCM), ARR 123, and ORN13.

The purpose of this research is to design and test a methodology to structurally calibrate the SUMO model with respect to heterogeneous traffic behavior at signalized intersections, based on two intersections, namely four legged Piliyandala and three legged Katubedda, in Sri Lanka, using 15-minute aggregate traffic data.

2. LITERATURE REVIEW

The use of SUMO, in particular, stands out as especially promising because of its open-source nature, clarity, and flexibility. The ability of SUMO to implement user-defined control algorithms, custom calibration routines, and detailed data extraction through *TraCI* functionality and *Python* scripting capabilities makes it uniquely useful for academic purposes and in resource-constrained conditions (Krajzewicz et al., 2012).

SUMO's default parameters for vehicles have been configured based on the traffic situation in Europe, where it is expected that traffic streams will be relatively homogeneous and lanes will strictly be followed. In the case of South Asia, however, traffic conditions are defined by heterogeneous and less-lane-bound traffic streams where there are high variations in terms of types of vehicles and their behavior (Sai Kiran & Verma, 2016; Papathanasopoulou & Antoniou, 2018). In cases where there are large numbers of motorized two-wheelers, drivers take advantage of gaps, move laterally, and demonstrate poor lane discipline. These contribute to complex interaction patterns that are not well captured by conventional lane-based models.

Although there have been efforts to extend the applicability of SUMO to heterogeneous traffic conditions, there is an observation that much work done in calibration efforts in a developing country setting tends to concentrate mainly on parameters related to driving behavior or speed. Only a limited number of papers address model validation through aggregated intersection variables like 15-minute turning counts and queue lengths. (Chowdhury & Chakraborty, 2024). This study essentially addresses that gap by designing experiments to SUMO model validation through aggregated traffic counts and queue lengths, and establishing transferability in areas with similar traffic patterns.

3. METHOD

3.1 Data Collection and Aggregation

Traffic data were collected at two signalized intersections during peak hours using fixed camera systems covering all approaches, vehicle movements, and queues. Vehicles were classified into nine categories: motorcycles, three wheelers, cars, vans, minibuses, buses, light goods vehicles, medium goods vehicles, and heavy goods vehicles. Observations were aggregated at 15-minute intervals for classified discharge counts and queue lengths, with queues measured to the nearest five meters.

3.2 SUMO Network and Signal Replication

The intersections were created with the aid of *OpenStreetMaps Web Wizard* and enhanced through high resolution images and observations from Google Maps. The traffic light operation logic was established according to the phase diagrams provided by the Road Development Authority (RDA). Information related to cycle time, green split, yellow phase and all-red phase was precisely defined in SUMO. *Entry Exit detectors* were placed at each entrance to observe the flow of traffic and to calculate queue length at each junction.

3.3 Vehicle Parameter Calibration

The initialization of the simulation was carried out using SUMO default values for all the vehicle parameters, and then the parameters were refined through iterations. Some of the main refinements carried out include accelerations/deceleration, vehicle lengths, minimum gap acceptance, maximum speed, speed variation, and parameters governing lane changes (*lcStrategic* and *lcCooperative*). A lateral resolution of 0.1 m was applied to enable fine-grained lateral positioning, replicating weak lane discipline and motorcycle filtering behavior observed in the field. Krauss car following model was used. Table 1 shows the calibrated vehicle parameters reflecting observed Sri Lankan traffic behavior.

Table 1. Calibrated vehicle parameters reflecting observed Sri Lankan traffic behavior

Vehicle Type	Accel. (m/s^2)	Decel. (m/s^2)	Length (m)	Min. Gap (m)	Max Speed (km/h)
Motorcycle	6.0	4.5	2.0	0.1	60
Three-wheeler	4.0	4.5	2.6	0.8	45
Car	3.2	4.0	4.2	1.5	55
Van	2.2	3.0	5.0	1.8	35
Mini bus	2.0	3.0	8.0	2.0	35
Large bus	1.8	2.8	11.0	2.5	30
Light goods vehicle	2.0	3.0	5.5	2.0	35
Medium goods vehicle	1.8	3.0	7.5	2.5	30
Heavy goods vehicle	1.5	2.5	10.5	3.0	25

3.4 Calibration Acceptance Criteria

The model's effectiveness was analyzed using two different metrics, mean absolute percentage error (MAPE) and Geoffrey E. Havers (GEH) statistic. The calibration was deemed successful when the MAPE results were lower than 15%, and the GEH statistics were less than 5.0 for major vehicle classes. The iterative process continued until these criteria were satisfied across all major vehicle categories, movements, and intersection approaches.

3.5 Model Transferability

Once the calibrated model satisfied Piliyandala intersection with minor exceptions in complex shared-lane queues, the same parameter set was applied to Katubedda intersection without doing any changes. Then the MAPE and GEH values were checked.

4 RESULTS AND DISCUSSION

4.1 Piliyandala Intersection

Calibration results of the SUMO model at the four-legged Piliyandala intersection indicated a good correlation between the simulated and measured traffic data. For all types of vehicles, the GEH values remained lower than the acceptability limit of 5.0. For queue length estimation, GEH values generally remained below 5.0. However, a maximum GEH value of 7.8 was observed in one 15-minute aggregation interval for the Horana and Katubedda approaches, likely due to the complexity of shared-lane queue behavior under heterogeneous traffic conditions. The flow accuracy statistics further supported this result, as the MAPE of through and turning flows was generally under 15% and showed that dedicated lanes had lower errors compared to combined lanes (left-through or through-right). Generally, the results indicate that with proper calibration, SUMO can adequately replicate heterogeneous traffic and, to a lesser degree, queuing behavior at four-leg intersections.

4.2 Katubedda Intersection

The same calibrated parameters used for the Piliyandala junction were then used unmodified at the three-legged Katubedda junction, providing an independent assessment of the calibrating approach's transferability. With the same set of parameters, the simulated flows of discharge in SUMO closely agreed with actual flows, with only minor discrepancies in one or two movements making MAPE<15% in all approaches, all movements. The results of queue GEH analysis for the three approaches considered were promising, with a GEH value of between 0 and 3.6, which is less than the acceptable level of 5.0. Essentially, Katubedda produced outstanding performance under similar heterogeneous traffic flow conditions, proving that the calibration procedure was not site-specific and can be transferred among intersections under similar conditions.

5 CONCLUSION

This study provides a well-calibrated and validated SUMO simulation for heterogeneous traffic flows based on a comprehensive traffic data collection at two distinct signalised intersections with different geometries in Sri Lanka. The values of calibrated parameters showed good correspondence with the real traffic flow rates, turn counts, and queue lengths at all approaches, proving that SUMO is capable of modelling mixed traffic streams with poor lane discipline. The validation process using two different layouts of the junctions demonstrates that the developed calibration procedure is not site-dependent but can be extrapolated to other urban junctions with similar traffic characteristics. This technique provides a feasible and replicable methodology for the modelling of non-lane-based traffic flow for researchers and practitioners who wish to work on similar projects with fewer data resources availability. The findings of this study support applications in traffic performance evaluation, signal optimisation, and policy analysis in South Asian developing-country contexts. However, the limitations include that only two intersections were tested and some approaches occasionally exceeded the queue GEH marginally above the accepted threshold. Future work should include more junctions in the same geographical area for validation.

6 REFERENCES

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