# EMPIRICAL CALIBRATION INPUTS FOR MICRO-SIMULATION OF HETEROGENEOUS, NON-LANE-BASED TRAFFIC

H.G. Wijesekara[1*], H.R. Pasindu[1], V. Adikariwattage[1]
[1]*Department of Civil Engineering, University of Moratuwa, Moratuwa, Sri Lanka*

## ABSTRACT

Urban arterials in developing countries carry highly heterogeneous, non-lane-based traffic that fundamentally differs from the lane-disciplined streams for which conventional micro-simulation tools were designed. The calibration of lateral movement parameters in simulation platforms requires locally validated empirical data on where each vehicle class positions itself across the carriageway and what lateral clearances are accepted in practice. This study analyses trajectory data from a four-lane undivided urban arterial in Sri Lanka using a YOLOv11 and ByteTrack computer vision pipeline with homography-based spatial calibration, achieving positional accuracy below 0.15 m root mean square error. Two metrics are proposed: lateral position distributions (Metric A) across 11 vehicle classes and pairwise edge-to-edge lateral clearance distributions (Metric B) for major vehicle-class combinations. Results reveal pronounced area-based carriageway utilization with no effective lane discipline. Motorcycles and three-wheelers concentrate in kerb-adjacent zones, while motorcycles exhibit a median encroachment frequency of 17.67%. Motorcycle-involved vehicle pairs consistently record the smallest lateral clearances across all speed categories, with motorcycle–motorcycle and motorcycle–two-wheeler encounters averaging below 0.95 m. These findings provide a validated local parameter set for micro-simulation calibration and carry direct implications for lane-allocation policy and road safety interventions targeting two-wheeler interactions on heterogeneous traffic arterials.

**Keywords:** micro-simulation calibration, heterogeneous traffic, lateral clearance, non-lane-based traffic, two-wheeler safety

## 1. INTRODUCTION

Urban road networks in Sri Lanka and across much of South and South-East Asia accommodate a vehicle mix that spans motorcycles, three-wheelers, cars, buses, and light and heavy goods vehicles, all competing for carriageway space without adherence to lane boundaries. Under these conditions, drivers treat the full road width as a continuous two-dimensional manoeuvring surface, adjusting lateral position dynamically to exploit available gaps, filter through slower traffic, or execute overtaking manoeuvres. This behavior produces complex lateral dynamics that are fundamentally absent from the lane-based, car-following paradigms on which mainstream micro-simulation platforms such as VISSIM, SUMO, and PARAMICS were designed.

The calibration of lateral movement parameters in these platforms requires three categories of empirically derived local data: (i) lateral position distributions defining where each vehicle class habitually operates within the carriageway cross-section; (ii) minimum lateral clearance values at which gap-seeking and overtaking manoeuvres are initiated or aborted and (iii) vehicle-pair interaction parameters that reflect the asymmetric risk profiles arising from differences in vehicle size and manoeuvrability. Without locally validated inputs for these parameters, simulation studies of Sri Lankan arterials necessarily rely on overseas defaults or assumed lane-center positions, systematically misrepresenting actual operating conditions and undermining the reliability of infrastructure appraisal and safety audit outputs.

https://doi.org/10.31705/TRF.2026.7 

Sri Lanka's geometric design standards remain anchored to an outdated adaptation of the United States Highway Capacity Manual, which assumes lane-disciplined homogeneous traffic and makes no provision for lateral interaction behavior (Jayaratne et al., 2020). Despite recent advances in speed flow modelling and passenger car unit estimation for heterogeneous conditions, no prior study has simultaneously characterized lateral position distributions and pairwise clearance distributions across a full multi-class vehicle spectrum on a non-lane-based Sri Lankan arterial. This study addresses that calibration deficit directly.

## 2. LITERATURE REVIEW

Early empirical research established that lateral placement distributions in mixed traffic are not uniformly normal and can exhibit bimodal forms driven by interactions between slow and fast vehicle classes. Subsequent studies on undivided facilities confirmed that heterogeneous traffic parameters differ substantially from homogeneous models because of the two-dimensional nature of mass queue formations, with vehicles occupying lateral positions determined by speed differentials and the filtering behavior of smaller classes rather than by lane markings.

Research on quantifying lateral weaving in mixed traffic formalized the concept of Inconsistency in Lateral Placement, defined as the standard deviation of lateral positions within a fixed time frame, and demonstrated using artificial neural network-based classification that motorized motorcycles exhibit the highest inconsistency (mean 1.8 m) due to their superior manoeuvrability (Bhavna & Biswas, 2022).

## 3. METHOD

The study site is a 14.0 m wide, four-lane undivided mid-block arterial segment in Sri Lanka with four nominal 3.0 m lanes separated by a 2.0 m raised central median. A stationary overhead camera recorded traffic at 60 frames per second across a 35 m longitudinal observation window under daylight, free-flow conditions. Vehicle detection used a YOLOv11 model fine-tuned on a locally labelled dataset covering all 11 vehicle classes, with ByteTrack providing consistent multi-object tracking across frames. Validation results achieved a precision of 90.1%, recall of 88.0%, mAP@50 of 91.6%, and mAP@50–95 of 84.2%, indicating robust detection performance across vehicle categories.

Spatial calibration used 12 ground control points physically measured on the road surface. A projective homography matrix computed via OpenCV's findHomography with RANSAC mapped pixel coordinates to real-world metric coordinates, achieving a positional root mean square error below 0.15 m. Vehicle speed was estimated from the change in longitudinal world-coordinate over a 30-frame sliding window. The extracted dataset covers 5,246 unique vehicle tracks across both travel directions.

Two metrics were computed. Metric A characterizes lateral position distributions: for each vehicle class, a Kernel Density Estimate was fitted to all lateral reference-point observations using a Gaussian kernel with Silverman's bandwidth rule, which adapts to individual class spread and handles multimodal distributions. Metric B characterizes pairwise lateral clearance: for each frame, all vehicle pairs satisfying a longitudinal bounding-box overlap of at least 40% of the shorter vehicle's extent and a reference-point proximity of 2.5 m or less were evaluated, and the edge-to-edge lateral clearance was computed. Only the minimum observed clearance per unique pair was retained to avoid pseudo-replication from extended side-by-side travel. Encounters were classified as critical (clearance below 0.5 m), caution (0.5 to 1.5 m), or safe (1.5 m or more).

## 4. RESULTS AND DISCUSSION

Metric A results confirm pronounced area-based carriageway utilization with no effective lane discipline across any vehicle class. Motorcycles and three-wheelers exhibit the widest lateral spread, concentrating in kerb-adjacent zones. Motorcycles occupy Lane 4 (right kerb) in 40.46% of tracks and Lane 1 (left kerb) in 32.00%, while motorcycles show a corresponding 35.20% and 22.36% distribution. Cars distribute more symmetrically across Lanes two and three, at 29.94% and 31.27% respectively, consistent with center-seeking behavior associated with higher operating speeds. The most safety-critical finding is that 17.67% of motorcycle tracks traverse the central median zone (6.0 to 8.0 m), the highest median encroachment frequency among all classes. Table 1 summarizes lane occupancy for major vehicle groups.

**Table 1.** Lane Occupancy by Vehicle Group (%)

| Vehicle Group | N | Lane 1 (%) | Lane 2 (%) | CM (%) | Lane 3 (%) | Lane 4 (%) |
|---|---|---|---|---|---|---|
| Cars | 2,114 | 10.97 | 29.94 | 2.13 | 31.27 | 25.69 |
| Motorcycles | 1,409 | 22.36 | 11.28 | 17.67 | 13.48 | 35.20 |
| Motorcycles | 1,122 | 32.00 | 14.17 | 1.96 | 11.41 | 40.46 |
| Goods Vehicles | 601 | 17.83 | 22.17 | 1.83 | 22.00 | 36.17 |

*CM = Central Median zone (6.0–8.0 m). Note: Lanes 2 data omitted for brevity; columns do not sum to 100%.*

Metric B systematically identifies motorcycle-involved vehicle pairs as producing the most critical lateral interactions across all speed categories. At speeds below 30 km/h, Car–Motorcycle encounters average 1.01 m edge-to-edge clearance; Motorcycle–Motorcycle (MC–MC) and Motorcycle–Two-Wheeler (MC–TW) pairs fall to 0.93 and 0.95 m, respectively, approaching the 0.5 m critical threshold. At higher speeds, Car–Car mean clearance increases to 1.49 m, consistent with speed-adaptive gap-seeking, while MC-involved pairs remain below 1.10 m, indicating that motorcycles do not proportionately widen lateral margins as speed increases. Table 2 presents the full clearance results.

**Table 2.** Average Lateral Clearance (m) by Speed Category for Major Vehicle Pairs

| Vehicle Pair | N (<30) | Avg distance (m) | N (>30) | Avg distance (m) | Risk |
|---|---|---|---|---|---|
| Car–Car | 120 | 1.34 | 261 | 1.49 | Safe |
| Car–Three-Wheeler (TW) | 133 | 1.20 | 145 | 1.20 | Caution |
| Car–Motorcycle (MC) | 158 | 1.01 | 337 | 1.17 | Caution |
| Car–Goods Vehicle | 43 | 1.21 | 43 | 1.52 | Caution |
| MC–Motorcycle (MC) | 26 | 0.93 | 87 | 1.03 | Critical |
| MC–Three-Wheeler | 71 | 0.95 | 139 | 0.95 | Critical |
| MC–Goods Vehicle | 42 | 0.95 | 55 | 1.07 | Critical |
| TW–Three-Wheeler (TW) | 45 | 0.93 | 48 | 0.99 | Critical |

These clearance patterns align closely with Sri Lankan Road crash statistics, in which motorcycles account for approximately 40% of total road crashes and collisions involving lorries and buses carry fatality risk ratios of 7.31 and 7.08 respectively (Shajith et al., 2019). The sub-

https://doi.org/10.31705/TRF.2026.7 

1.0 m clearances recorded for MC-involved pairs at all speed ranges directly reflect the operational conditions that produce these crash outcomes and provide quantitative thresholds for both simulation conflict modelling and enforcement targeting.

From a simulation calibration perspective, the lateral position distributions (Metric A) provide empirically grounded desired-position distributions for each vehicle class, replacing the lane-center assumptions currently applied in heterogeneous traffic studies. The clearance distributions (Metric B) directly parameterize the minimum lateral gap acceptance logic, enabling differentiated interaction rules between vehicle classes rather than uniform defaults. Together, the two metrics constitute a locally validated parameter set for micro-simulation lateral model calibration on Sri Lankan undivided arterials.

## 5. CONCLUSION

This study presents an empirical characterization of lateral behavior in heterogeneous, non-lane-based traffic on a four-lane undivided urban arterial in Sri Lanka. Using high-resolution trajectory data extracted through a validated YOLOv11–ByteTrack framework, two complementary metrics were developed: lateral position distributions (Metric A) and pairwise lateral clearance distributions (Metric B).

The results reveal pronounced area-based carriageway utilization with limited adherence to nominal lane boundaries. Three-wheelers and motorcycles exhibited the widest lateral spread and predominantly occupied kerb-adjacent regions, while motorcycles recorded the highest proportion of observations within the central median zone. Pairwise clearance analysis showed that motorcycle-involved vehicle pairs consistently operated with smaller lateral clearances than most other vehicle combinations across both speed categories, highlighting their distinct interaction characteristics within heterogeneous traffic streams.

The present study focuses on the descriptive characterization of lateral positioning and vehicle interactions and does not directly evaluate traffic conflicts, crash occurrence, safety performance, or operational efficiency. Consequently, the findings should be interpreted as behavioral observations and calibration inputs rather than direct measures of safety risk or traffic performance. Future research should extend the analysis to multiple road environments, congested traffic conditions, and signalized facilities, while incorporating conflict- and safety-based measures to further examine the relationship between lateral interaction behavior and traffic operations.

## 6. REFERENCES

1. Bhavna, & Biswas, S. (2022). An ANN-based framework for estimating inconsistency in lateral placement of heterogeneous traffic. Physica A: Statistical Mechanics and its Applications, 592, 126847. https://doi.org/10.1016/j.physa.2021.126847
2. Charly, A., & Mathew, T. V. (2019). Estimation of traffic conflicts using precise lateral position and width of vehicles for safety assessment. Accident Analysis & Prevention, 132, 105264. https://doi.org/10.1016/j.aap.2019.105264
3. Dey, P. P., Chandra, S., & Gangopadhaya, S. (2006). Lateral distribution of mixed traffic on two-lane roads. Journal of Transportation Engineering, 132(7), 597–600. https://doi.org/10.1061/(ASCE)0733-947X(2006)132:7(597)
4. Jayaratne, D. N. D., Pasindu, H. R., & Rathnayaka, L. M. K. (2020). Development of capacity estimation models for multi-lane roads under heterogeneous traffic condition. Engineer: Journal of the Institution of Engineers, Sri Lanka, LIII(04), 73–84.