Calibration and Validation of Lane Changing Following Gap Distance in VISSIM

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Abstract: Lane change (LC) is an essential feature of expressway driving behavior that affects traffic efficiency and safety. Thus, a wrongful execution of LC, could be due to the wrong choice of gap distance before the LC manoeuvre. This might lead to road crashes, mostly in form rear-end, sideswipe, or angled collision. This research evaluates the characteristics of drivers' Following Gap Distance (FGD) during LC using VISSIM traffic simulation program. Data were collected along a representative segment along with Kuala Lumpur – Seremban expressway for two days using an instrumented vehicle approach. A passenger car was instrumented with a Video Velocity Box (VBox), an on-board data acquisition system used for video recording of the road’s traffic event. A total of 75 and 20 following incidences of lane changing were observed in first and second day, respectively. Standstill Distance (CC0), Gap Time (CC1) and Following Distance Oscillation (CC2) were used as calibration parameters in VISSIM model. FGD was used as a measure of performance for the model. The data from second day was used for model validation. The findings indicate that the model was well calibrated and validated. Therefore, it can be used for modelling various scenarios involving LC on the expressway.

1.0 Introduction
Lane changing (LC) is referred to as the driving manoeuvre in which a vehicle moves from one lane to another, where both lanes have the same travel direction. An LC is one of the most sensible driving behavior characteristics, which has mostly influences traffic efficiency and safety[1]. Changing lanes happens for various reasons, such as entering the road, planning to leave the road, expecting other vehicles to merge on the highway, anticipating a slower leading vehicle, changing the number of lanes open, and so on.[2]. Wei [3] demonstrated that when a leading vehicle's speed in the current lane is lower than that of its follower, acceptable gaps are available in the target lane. The following driver tends to change lane.

The most common type of lane changing is a maneuver in which a driver changes lanes to pass a slower lead vehicle in order to continue with the current speed[2]. LC performance choice may be affected by some factors, including the emergence of the following vehicle, surrounding traffic impact, and driver's character[4]. A lane change's crash occurs when drivers attempt to change lanes and strikes or struck by other vehicles in the adjacent lane in most incidences. Following Gap Distance FGD is defined as a space interval that a subject vehicle requires to merge safely between two vehicles. On the other hand, FGD is the distance from front bumper of the following vehicle to the leading vehicle's rear bumper. Figure 1 depicts the following gap distance between the test car and the immediate following vehicle. However, an erroneous estimate (by the following driver) of FGD to the leading vehicle and unevaluated adequate time to pass safely are mostly the key reasons for LC crashes.
Following Vehicle

Following Gap distance

Test Vehicle

Figure 1. Following gap distance between vehicles

Microscopic traffic simulation has been the common approach used by transportation engineers to conduct traffic impact studies. In traffic simulation models, drivers of typical vehicles' stochastic behavior are delineated using chance distributions to obtain the parameter values [5]. A computer-based approach is used during a simulation phase to evaluate a model numerically, and data is generated to estimate the defined actual mode characteristics [6]. Researchers Srikanth [5], and Mehar [7] have recently shown an increased interest in traffic simulation programs and simulation of lane changing behavior with more emphasis and attention to safety gap distance. More recently, concerns have been raised by some relevant researchers [5], Farooq [8], who developed models via a traffic simulation approach for the determination of the safety of FGD while drivers change lanes.

To date, macroscopic-level lane-changing studies have been mostly centred on two aspects; (a) the relation between the number of lane changes and different traffic state variables, such as traffic flow, mean speed, density, and so forth, and (b) lateral and longitudinal distributions of lane changing. However, microscopic traffic models describe longitudinal car-following and lateral lane-changing behavior of individual vehicles [2].

It is most important to build individual driver behavior models based on the above arguments, which could simulate drivers' behavior, particularly for maneuvers that are susceptible to accidents. This work focussed on the calibration and validation of FGD via the application of VISSIM for motorway or expressway conditions. A behaviour simulation model would be developed that could simulate the findings following the objective somewhat similar to that was examined by Weber [9], and Xiaorui [10] established an LC scenario and derived a reasonable LC model, and subsequently affirmed the model's performance using VISSIM simulation. The results indicated that the FGD is appropriate for the safety LC manoeuvre, which may fit the perfect LC situation.

2.0 Literature Review

Based on homogeneous traffic conditions, various traffic simulation programs have been developed in different countries. VISSIM is one such microscopic traffic simulation model. This simulation software package by PTV Planung Transport Verkehr AG in Germany was based on Wiedemann's continuous work. VISSIM is a microscopic, time step and behaviour based simulation model developed to model freeways, urban traffic and public transit operations [7]. It performs trajectory-based analysis that utilizes psycho-physical driver behaviour developed by Wiedemann. VISSIM consists of some simulation parameters which have a direct influence on traffic flow, speed and capacity. VISSIM works based on the car-following driver behaviour model developed by Wiedemann. Some of the parameters have been found to be influential at capacity, while some of them affect the driver's behavior only under car-following situations [7]. The car-following behaviour contains ten different driver-related parameters ranging from CC0 to CC9 with their default values. In different scenarios, researchers examined these parameters' values and tested these parameters' sensitivity for simulated outcomes.

In VISSIM, LC behaviour has default values of specific parameters evaluated for the type of traffic prevailing in Europe and other developed countries [11]. Lane changing models are one in every one of
the essential elements of any microscopic traffic simulation. Therefore, developing an additional accurate LC model is a critical requirement for simulating drivers' behaviour. Lane changing manoeuvres was discovered to have a considerable influence on traffic flow characteristics due to the interfering impact they need on surrounding vehicles [12]. The Wiedemann VISSIM model's basic idea assumes that a driver can be in one of four driving modes; Free driving, Approaching, Following and Braking. The driver switches from one mode to another as soon as he/she reaches a certain threshold that can be expressed as a combination of speed difference and distance [13].

The VISSIM model classifies lane changes into two basic categories: free lane change and necessary lane change. In the case of a free lane change, the lane-changing model checks if the available lag time to a collision between the subject vehicle and the following vehicle in the target lane satisfies the "desired safety distance" and "minimum time headway". For a lane change in a queue, the model equally assesses the lead time to collision between the subject and the preceding vehicles in the target lane [14]. These parameters are deemed critical for model LC behavior through VISSIM.

Woody [13] conducted analysis centered on two elements relevant to the calibration and validation process; (a) calibration and validation methods for microsimulation traffic models and (b) adjustment of calibration parameters for freeway models. A sensitivity analysis was conducted on operational calibration parameters in VISSIM, including car following behavior, necessary lane-changing behaviour, and lane changing distances. Results from the sensitivity analysis showed that the headway (CC1), following variation (CC2), and oscillation acceleration (CC7) were the most influential Wiedemann 99 parameters for calibration of mainline freeway segments. In another study, Park [15] developed a procedure for simulation model calibration and validation and demonstrated the proposed method through a case study of coordinated actuated signal system using VISSIM. The study was performed based on a one day data and two measures of performance. After the data analysis, it was discovered that all the multiple runs were not statistically equal to the field distribution. In other words, the simulation output has passed the statistical test at different percentiles for each parameter set.

In a critical review of Liu [16] to determine the sensitive parameters associated with queue length and travel time, VISSIM was employed to examine the sensitive parameters at normal intersections and roundabout. The authors discovered that the average distance between parking, additional parts of the safety distance, multiple parts of the safety distance, the minimum headway are more sensitive parameters on the queue length or travel time at the intersection. Hence, it was suggested that these should be selected as the set of parameters to be corrected at first in the course of calibration. In another previous study, Lownes and Machemehl [17] examined the sensitivity analysis of VISSIM simulation capacity output under various values of driver behaviour parameters. The investigation was undertaken for a simulation developed for the interchange of US-75 and SH-190 north of Dallas, Texas, USA. For each driver behaviour parameter, including look-back distance, simulated capacity variations are noted as the specific parameter modified. Based on the finding, it was recommended that Look-back distance should be carefully calibrated for each particular situation so that the final simulation represents the real-world behaviour of traffic at best in both quantitative and qualitative perspectives.

Most recent, an application of microscopic traffic simulation flow using VISSIM for generating traffic flow data to obtain the essential parameters was reported by Srikanth [5]. The VISSIM model in the study was calibrated and validated based on the field data. Moreover, LC behaviour was analyzed with homogeneous vehicle type traffic on four-lane, six-lane, and eight-lane divided highways segments through VISSIM simulation model. The results revealed that addition of a lane offer more opportunity to the vehicles to change lanes but at the same times causes a reduction in traffic stream speed under non-lane discipline situation, which results in a reduction of per lane capacity [5].

Gomes [18] presented a technique for constructing and calibrating a detailed model of a freeway using VISSIM. The method was applied to a 15-mile stretch of I-210 West in Pasadena, California, USA. The model construction procedure comprised of (a) identification of critical geometric features,
collection and processing of traffic data, (c) analysis of the mainline data to identify recurring bottlenecks, (d) VISSIM coding, and (e) calibration based on observations from (c). A qualitative set of goals was established for the calibration process. These were met with relatively few modifications to VISSIM's driver behaviour parameters (CC-parameters).

An extensive review of the existing literature on LC execution, FGD and time headway that were simulated and calibrated in traffic simulation programs showed limited studies regarding drivers' behaviour during LC maneuver through VISSIM. Specifically, there are rare studies relating to Malaysian drivers' behaviour during LC, particularly using an instrumented vehicle, which allowed for the record of real-time relevant traffic events during the data sampling [12]. This paper investigates the FGD on a representative Malaysian expressway and calibrate the data using VISSIM traffic simulation program to explore the subject relating to Malaysian traffic condition. It is expected that this could provide information on Malaysian drivers' behaviour relating to FGD on multilane highways.

Generally, rare studies were conducted on FGD on multilane highways, concerning the estimation of the sensitive parameters using VISSIM simulation approaches as well as its modelling. Few among the related studies [5], [10], [12], [14], [15], [18], [20] worked on the estimation of the calibrating parameters in VISSIM, in which some of them focused on driver's behaviour parameters such as FGD and time headway. As stated earlier, lack of adequate information on FGD regarding Malaysian drivers, particularly relating to their behaviour, necessitated the current investigation.

Berkeley [21] presented a procedure for calibration of default parameters in VISSIM and discovered that driver's behaviour parameters, namely, CC0 (standstill distance) and CC1 (time headway) influences the capacity values. Further, for low-speed conditions, the impact of CC0 on capacity was significant, but as the speed increases, its effect diminishes while the impact of CC1 increases. In similar study, Park [22] described a technique for calibration of default parameters in VISSIM. They established that the safety distance reduction factor defined for the link indicates the aggressiveness of the driver. Sun [23] also performed a parameter calibration of VISSIM using an optimization algorithm approach. The authors developed a new methodology for evaluating the capacity by matching the speed-flow graphs from the field and simulation.

In microscopic traffic simulation, it is usually expected that all calibration parameters within the microscopic simulation model must are identified. Examples of the controllable calibration parameters include; lane change distance, desired speed, and minimum distance headways in the simulation model. Likewise, acceptable ranges for each of the calibration parameters should be well established [18].

Based on the preceding reviewed literature, it is evident that analysis and modelling of LC behavior using traffic simulation approach have been widely used for the past few decades. The application of simulation models is thus essential for solving the complexities associated with modelling macroscopic and microscopic traffic flow behaviours. In relation to traffic simulation application for calibration and validation of traffic parameters, key few researches are discussed as follows. Simulated effects are extremely sensitive to parameters; the literature indicates, namely, CC0 and CC1. As mentioned earlier, the term CC0 is the standstill distance in meters and CC1 is the time headway in seconds between two vehicles at any speed V (m/s). Other parameters CC2 to CC9 have different influence on driver behavior of simulated section[18]. The VISSIM user manual describes CC2 as the actual following distance oscillation process. The parameter CC2 controls the degree to which the driver's distance oscillation is gentle and gradual or sudden and violent. Obviously, parameter values represent a situation between these two extremes, and a small portion of drivers may be defined by these extremes[17]. VISSIM model calculates the safe distance between a following and leading vehicle using Equation 1.
Safe distance = CC0 + CC1 × √V + CC2

(1)

where, CC0, CC1 and CC2 are as defined earlier, V is speed of the leading vehicle (m/s)

Concerning the current study, it is worthy to mention that the investigation in this paper is founded based on the review by Woody [13]. The author focused on three parameters relating to drivers’ behaviour; referred to as CC-parameters. These parameters include; CC0 (Standstill Distance), CC1 (Gap Time) and CC2 (Following Distance Oscillation). Hence, the current study also focuses on these three parameters, which examine the Malaysian expressway’s condition.

3.0 Methodology

3.1 Field Data Collection

This study’s data were collected on a predefined representative segment along Kuala Lumpur – Seremban expressway, Malaysia with approximately 50.2 km length. The section utilized for the study was chosen because it is in good condition with a sizable volume of traffic. It is one of the major links of many parts of Malaysia to the capital city. Equally, the expressway's traffic volume comprises varying vehicles classes with considerable occurrences of lane changing manoeuvres due to the presence of many on- and off-ramps within the selected study section. This could allow for a reasonable sample of lane changing incidences observed on field. The expressway has three lanes in each direction of traffic with an approximate lane width of 3.70 m each with a paved shoulder of 1.50 m. The posted speed along the expressway is mostly 110 km/h. Data were collected during daylight period under varying traffic conditions. for a total of 3 hours on two days typical weekday, the first day data collection between 3:00 to 4:30 PM, the second day data collection duration between 3:30 to 4:30 PM. Data collection was performed in two direction of the chosen section. This study only considers LC incidences involving cars and heavy vehicles as they exhibit varying LC manoeuvres characteristics. Mainly, heavy vehicles are well known for being associated with low travel speed and usually used the outermost lane; hence, their LC behaviour is certainly different from those of cars. On the other hand, motorcycles’ LC manoeuvres were not considered in this study as different LC manoeuvre’s behaviour characterizes them.

The speed of the test and the following vehicles, FGD, traffic volume, and lane changing numbers using an instrument vehicle equipped with VBox. The VBox camera was calibrated for the estimation of the FGD. A regular saloon passenger car instrumented with a Video Velocity Box (VBox) was used for the data collection. A VBox is an on-board real-time data recording system used for observation of traffic events, speed of the instrumented vehicle, acceleration, and lap timing and so forth. It comprises a VBox video recorder, 10Hz GPS data logger, a video camera utilized to record traffic events recording, SD card, and a microphone. In this study, the VBox camera was fixed on the instrumented vehicle, facing backward for recording of LC incidences as the instrumented vehicle traverses the study segment. The VBox system has been established as promising for traffic studies through video recording technique as reported in an earlier study by Woody [13] that utilized it for measuring platooning on two-lane highways. Figure 2 shows a typical view of the segment’s part used for the study.
The data was then extracted manually from the video recording played back on the computer screen monitor [7]. The speed of the test vehicle was extracted when the following vehicle started changing the lane. At the same time, the speed of the following vehicle’s was measured. Table 1 shows descriptive statistics of the data collected on site.

|                         | First day (3:00-4:30 pm) | Second day (3:30-4:30 pm) |
|-------------------------|--------------------------|---------------------------|
|                         | Test Veh | Following Veh | Test Veh | Following Veh |
| Volume v/h              | --       | 1225          | --       | 1015          |
| LC Frequency            | 75       | 20            |
| Minimum speed m/s       | 17.39    | 18.75         | 23.96    | 25.00         |
| Maximum speed m/s       | 25.56    | 37.5          | 28.13    | 37.5          |
| Average speed m/s       | 22.41    | 27.1          | 26.00    | 30.3          |
| St.deviation            | 1.5924   | 4.3856        | 1.3625   | 3.1676        |

Table 2 illustrates the speed of following vehicle according to vehicle types on two days data collection.

|                         | Speed Parameters (km/h) |
|-------------------------|-------------------------|
|                         | Percentage (Numbers)    | Maximum | Minimum | Average | Std. Deviation |
| First day               |                         |         |         |         |               |
| Car                     | 89.33 (67)              | 135     | 67.5    | 97.24   | 15.782        |
| HV                      | 10.66 (8)               | 135     | 83.08   | 100.28  | 15.758        |
| Second day              |                         |         |         |         |               |
| Car                     | 90 (18)                 | 135     | 90      | 108.84  | 10.82         |
| HV                      | 10 (2)                  | 119.7   | 119.7   | 119.7   | 0             |
For the development of the VISSIM model, the first day data set (75 frequent lane changes) were used for calibration while those of the second day (20 regular lane changing) were utilized to validate FGD in VISSIM.

In the current study, the main variable, the following gap distance (FGD), was estimated as the longitudinal spacing between the rear bumper of the instrumented test vehicle and the front bumper of the immediate vehicle following the former. Table 3 presents the FGD data measured at the field on two days data collection. Figure 3 displays the methodology that followed in this paper.

| Sample size | Minimum FGD (m) | Maximum FGD (m) | Average FGD (m) | St. Deviation |
|-------------|----------------|-----------------|----------------|---------------|
| First day (3:00-4:30 pm) | 75 | 4.9 | 50.5 | 18.67 | 10.821 |
| Second day (3:30-4:30 pm) | 20 | 4.89 | 51.21 | 18.80 | 12.45 |

4.0 Calibration Procedures

In the calibration procedures, we first examined the default VISSIM values parameters standstill distances (CC0), minimum headway (CC1) and following distance oscillation (CC2). The selection of these three parameters (CC0, CC1 and CC2) for the homogenous traffic conditions, were conducted based on reviews. The FGD was estimated through VISSIM with default values of all parameters. Table 4 presents the FGD value obtained from the field and FGD value obtained from VISSIM using the default parameters values.

| FGD | N | Minimum | Maximum | Mean | Std. Deviation |
|-----|---|---------|---------|------|---------------|
| Field Data | 75 | 4.9 | 50.5 | 18.67 | 10.821 |
| VISSIM Default 10 (runs) | 75 | 8.72 | 9.02 | 8.837 | 0.06 |

The simulation was conducted for 10 runs and the simulated FGD was obtained. Figure 4 and Figure 5 show the FGD results for observed and simulated data.

As shown in Figure 4 and Figure 5 above, there are huge variations in the FGD for both observed and simulated data. Therefore, the default parameters of the VISSIM model are changed, for further calibration. Table 5 shows the proposed parameters values for each of the selected parameters (Case 1-Case 5).
Figure 3. Methodology chart

Figure 4. Results for FGD for both field and simulated data
The calibration process was ended when a good match between the FGD value obtained between the simulated model and field. In total, five different cases were examined, each case consist of different parameters values as shown in Table 5. Table 6 listed the obtained FGD values from the five cases and the field data. A comparison of the average value of FGD estimated on the field and average value of FGD estimated from each one of the five calibration cases were presented in Figure 6.

**Table 5. Candidate Parameter Sets[15]**

| Parameters                   | Default | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 |
|------------------------------|---------|--------|--------|--------|--------|--------|
| Standstill Distance CC0 (m)  | 1.5     | 1.55   | 1.60   | 1.65   | 1.7    | 2.50   |
| Minimum Headway CC1(sec)     | 0.9     | 0.9    | 0.9    | 0.9    | 0.9    | 0.9    |
| Following Distance Oscillation CC2(m) | 4.0 | 3.5    | 4.5    | 4.55   | 5.0    | 8.0    |

**Table 6. Descriptive statistics of FGD(m) of field data and the five cases**

| FGD  | N  | Minimum | Maximum | Mean    | Std. Deviation |
|------|----|---------|---------|---------|----------------|
| Field Data | 75 | 4.9     | 50.5    | 18.67   | 10.821         |
| Case1 | 75 | 13.1    | 20.24   | 15.197  | 1.228          |
| Case2 | 75 | 13.43   | 20.57   | 15.504  | 1.298          |
| Case3 | 75 | 13.53   | 20.71   | 15.614  | 1.34           |
| Case4 | 75 | 13.96   | 20.85   | 15.751  | 1.418          |
| Case5 | 75 | 13.23   | 24.11   | 17.31   | 2.28           |
4.1 Hypothesis Testing

In order to verify which one from the five cases represent the best calibration result hypothesis tests were conducted to determine if the average FGD obtained from the field is with good agreement with FGD estimated from the model. The test was conducted using 2-tailed t-test at a 5% level of significance ($\alpha = 0.05$) (H$_0$ null hypothesis: FGD (field data) = FGD (simulation). HA: FGD (field data) $\neq$ FGD (simulation) we reject H$_0$; null hypothesis if FGD of the simulated case is less than 0.05).

The purpose of the hypothesis testing for multiple scenarios was to determine if any significant difference exists between the means of two groups (a group of field data and cases data). The summary of the main conclusions of the T. test (p-value) process has been presented in Table 7.

![Figure 6. Comparison of FGD from the field and the five cases](image)

**Table 7. Significance of default VISSIM values and five cases of comparison with site data**

| Field data | VISSIM default | Case1 | Case2 | Case3 | Case4 | Case5 |
|------------|----------------|-------|-------|-------|-------|-------|
| p-value    | 0.0085         | 5.51E-08 | 0.0156 | 0.011 | 0.0072 | 0.078 |
| N          | 75             | 75    | 75    | 75    | 75    | 75    |

Based on the results listed in Table 7 there is significant difference between the FGD obtained from the field and the simulated FGD estimated from all the cases except case 5 as p-values are lesser than 0.05. Case 5 has p-value greater than 0.05 (0.078 > 0.05), indicating that there is no significant difference between the FGD obtained from field and simulated in case 5. Consequently, the values of CC0, CC1 and CC2 used in case 5 was adopted for this study.

5.0 Model Validation

Using new data set collected at the same segment at different day was used for model validation. Simulation parameters CC0, CC1 and CC2 for homogenous traffic stream were changed to 2.5 m, 0.90 s and 8.0 m, respectively for case 5 (better case) as indicated in Table 5. Table 8 presents the t-test result between the field and validation data. It is clear that from the t-test result that the model was successfully calibrated and validated.
**Table 8.** Significance of field data for 2nd day and case5 parameters

| Case5 | Field data(2nd day data) | T. test value | N |
|-------|--------------------------|----------------|---|
|       |                          | 0.198          | 20 |

**6.0 Conclusions**

This paper has outlined a methodology for the calibration and validation of simulation model for an expressway. The procedure included the generation and processing of field data from a representative segment on the expressway between Kuala Lumpur and Seremban, Malaysia. The study utilized a two-day data on following gap distance (FGD) as measure of performance. Model parameters such as Standstill Distance (CC0), Gap Time (CC1) and Following Distance Oscillation (CC2) were used as calibration parameters. As established earlier five different cases were examined each case consists of different values of CC0, CC1, and CC2. It is found that the combination of the parameter values in case 5 produced the closest FGD of the field. This result was verified by using other data set collected on a different day. This finding is well consistent with what was established in the existing literature as reported in [13]. Generally, findings deduced from this study could help to identify and quantify the influence of significant traffic parameters on lane changing for safety gap. Further, the research can be performed in VISSIM model to explore whether changing the significant traffic parameters with diverse distributions for a higher number of lanes has a significant positive effect on lane changing as equally suggested by [8]. This study showed that for such expressway that involves complex interactions between vehicles, the VISSIM simulation environment is reasonably suited. It is essential to state that this analysis's results were drawn based on a preliminary study, so it is recommended that more considerable sample data be collected over several days, particularly field data variability. It will also be useful to decide whether the methodology applies to an entire network or just a particular one.

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