Effect of the Traffic Flow with Change in Time on Driver Behavior Parameter Values in Micro-Simulation

Dinakara GUNARATHNE[a], Niranga AMARASINGHA[b] and Vasantha WICRAMASIGHE[c],

[a,b,c] *Faculty of Engineering, Sri Lanka Institute of Information Technology, Malabe, Sri Lanka*
[a] *Email: dinakara.g@sliit.lk*
[b] *Email: niranga.a@sliit.lk*
[c] *Email: vasantha.w@sliit.lk*

Abstract: Most of the factors related to traffic such as the traffic flow, traffic congestion, driver behavior, accident rate, etc. have a possibility to vary with time. The main objective of this study is to determine the effect on the traffic flow with change in time on driver behavior parameter values in micro-simulation. VISSIM is used as the microscopic traffic simulation software for the study. Average queue length was used as the performance indicator. Comparison of driver behavior before and after the first wave of COVID-19 situation for the same intersection showed that there is a reduction in traffic flow and driver behavior parameter values could be changed with time. Average standstill distance, multiplicative part of safety distance, look ahead distance and the distance driving has been increased by 7.603%, 34.972%, 100% and 8.019% respectively. Additive part of safety distance and distance standing has been decreased by 0.162% and 135.075% respectively.

Keywords: Junction, Unsignalized, Micro Simulation, Driver Behavior, Traffic Flow

1. INTRODUCTION

To improve the liveability, workability, and a sustainability of a city, a proper traffic management system is required, and it is a current need for Sri Lanka. With the proper traffic management system, the delays can be reduced which will allow the people to get more rest time to spend the leisure with family and make use of time efficiently. The social and economic benefit would go for all people. The few of the main factors that cause the traffic congestion in general are the roadway design, improper signal timings, signal light malfunction, and the driver behaviour which includes reckless and irresponsible driving without adhering to the road rules and regulations, illegal parking, illegal stopping, etc. (Ratyela, 2017). In most situations it is not possible to do geometric changes to reduce the traffic congestions due to the scarcity of land. Therefore, to minimize the traffic congestions it is required to driver behaviour improvements or use traffic control strategies which will adapt to the current traffic conditions (Wang *et al.*, 2019). It is essential for the researchers in traffic engineering and the traffic engineers to gather the traffic data and analyse them thoroughly for providing traffic management methods to prevent the traffic congestions.

Traffic Management refers to as the method to be undertaken to manage the traffic across a road network. Traffic management ensures that the roads are used efficiently such that the traffic congestion is minimized. In the world the number of pedestrians and vehicles increases daily but the roads which are designed has a low probability to be reconstructed such that there is a possibility for the traffic congestion to rise with the increase in the private vehicle usage.

Several software have been developed to model the real-world traffic scenarios such as VISSIM, PARAMICS and AIMSUN (Hidas, 2005). This micro-simulation software is widely used for transportation operations and management analysis as it is economical and time saving to conduct simulations for traffic operations and management before implementing directly in the real-world. The micro-simulation software has the required tools to model the real-world traffic and roadway characteristics and many more which also include evaluations to make improvements and alternatives for the existing conditions.

For this study, the VISSIM software is used, which is a multimodal traffic simulator. It has the capability to change the driver behaviour, vehicle behaviour, etc from the origin to destination. VISSIM is applicable for multiple of scenarios and through comparison with the other simulation software. VISSIM is efficient in modelling interactions. Many research has been conducted for calibration and validation of microsimulation software for local conditions but there is a possibility for the driver behaviour parameter values and the traffic flow to change with time which may cause errors in the model simulations in case the driver behaviour parameter values which were identified a year before are used after a year later.

The objective of the study is to determine how the traffic volume and the driver behaviour parameter values were changed from year 2019 to year 2020. As a result of the COVID-19 situation there is a possibility for the driver behaviour parameters values to vary due to the variation in the traffic flow. Due to the only availability of the driver behaviour parameter values and the traffic volume data gathered at the earlier part of this research, only the effect of traffic volume and driver behaviour parameter values with time were considered. A comparison between the driver behaviour parameter values obtained in 2019, which was done through the VISSIM software, with the driver behaviour parameter values obtained in 2020 for the same intersection is done to determine the change in the driver behaviour parameter values within the time gap.

2. LITERATURE REVIEW

In the past years, many research have been done to determine the most suitable traffic management methods for intersections through microsimulation. Cunto and Saccomanno (2008) suggested a systematic procedure to specify model inputs based on safety performance measures for rear-end crashes at signalized intersections and to determine whether the model inputs are transferable for modeling different traffic conditions. VISSIM was used as the microsimulation software by using vehicle tracking data extracted through FHWA/NGSIM software. The calibration was conducted in four steps; the initial model inputs were obtained by heuristic selection, Placket - Burman Design had been used for the statistical screening, safety performance inputs using fractional factorial analysis and a genetic algorithm to obtain the optimum input parameter values. Crash Potential Index (CPI), total conflict duration per vehicle and number of vehicles involved in the conflict were considered as the three safety performance measures. The simulated and observed safety parameters were compared to determine the consistency of the model through a separate validation sample. The research was conducted for signalized intersections due to the higher probability of rear-end crashes. To estimate the safety performance for individual vehicles over the time, simulation profiles of speed and spacing in VISSIM were used with an assumption of that the fundamental indication for crash risk is provided by the individual vehicle's safety performance. Vehicle data were obtained from five cameras for a 9-hour period and the collected video data were transcribed for each 1/10s and the first 15 min sample was used for the calibration of the software and the second 15 mins for validation. Safety performance measures considered were time to collision (TTC), deceleration of avoid crash (DRAC), post encroachment time (PET). DRAC was considered as the safety performance measure. The braking capability, CPI, and Maximum

Available Deceleration Rate which are unique for each vehicle and depends on the pavement condition; however, these were not considered as the factors for DRAC. The selection of the initial model input parameters was determined by a sound engineering judgment and 13 parameters were selected. The Plackett–Burman with fold over fractional design provides a resolution IV procedure for treating factor interactions. Resolution IV is a four-factor design of the Plackett-Burnam design. The ANOVA was used to determine the significance of the parameters. The relationship between the safety performance and input parameters were determined. Through the fractional factorial design, the input parameters were minimized to 3 parameters. The most optimum parameters values were found by running a genetic algorithm. Through validation process, it was confirmed that the proposed procedure was effective to determine the optimum parameters based on the matching safety performance measures obtained from the validation model.

Paul *et al*. (2017) investigated on the calibration methodology of microsimulation model for unsignalized intersection under heterogenous traffic conditions. The purpose of the study was to propose a calibration methodology of the PTV VISSIM simulation model for unsignalized heterogenous traffic conditions. The performance measure in the calibration was the 85th percentile gap time. The Wiedemann 74 Car Following model was used as the selected location was a semi-urban unsignalized intersection. The gap acceptance was smaller due to the driver behavior as the vehicles from the minor roads tries to cross the main road as the drivers lose their patience waiting to cross the road. The vehicle counts were obtained using video recordings at off-peak hours under good visibility. Gap values were calculated by the time difference between the exit vehicle at the major road and the next arrival of the major road vehicles. The Morris sensitivity analysis was used to determine the most sensitive parameters and the optimum values of these sensitive parameters were obtained using Genetic Algorithm (GA). Through the simulation they found that the VISSIM provides reasonable gap time for unsignalized intersections and hence it could be concluded that the proposed methodology is accurate and performs well.

Pratico *et al*. (2012) studied on the performance at roundabouts that can affect urban transport systems in terms of environmental and operational impacts, safety, and efficiency by developing road traffic microsimulation models where the individual vehicles travelling around the network are determined by car following models, lane changing, and gap acceptance. The calibration of the model was carried out by analysis of the variance of kinematic parameters of an n-tuple of roundabout scenarios. Through the calibration, the most significant input parameters were found which affect the output results of the model under each simulation scenarios. The geometric data, and vehicular flow data were collected and input to the simulation software and simulated under different scenarios. The time of service was collected per minute interval for each entry vehicle to the roundabout which showed an exponential relationship. The Wiedemann 74 car following model was used for calibrating the VISSIM software. The most significant parameters were carefully chosen to be used to set up 216 scenarios. The scenarios were run for many times and the average was considered to provide a 95% confidence. Through the analysis, it was found that reduced speed zones did not perform a satisfactory simulation of observations. The best position of the desired exiting speed section was the one immediately after the exit from the circular road. The optimal critical gap ranged from 3.5 s to 4.0 s, while the optimal length of the reduced speed zone for each entry was at least 6-8 m, in order to obtain an accurate speed profile for the through movement...

Osei *et al*. (2019) studied improvement of the capacity and reduction of delays at roundabouts by signalization and geometrical improvements through microsimulation models. A four-leg roundabout was considered for the study. The field data were collected on a weekday and a weekend day and used for calibration of the microsimulation model. The geometric data were collected through Google Earth and validated through field measurements. The traffic flow was recorded using videotapes. The travel time was determined using the floating car method using a test vehicle. The app used for determining the travel time also provided the speed and time stamp and the distance data which were used to determine the queue length. The objective was to improve the functional benefits and the safety at the roundabouts and improve the capacity and reduce the delay. The improvement used for this study is to implement an unconventional signalized roundabout with increase in the number of circulating traffic lanes which will prevent rollover accidents in single lane and prevent side swipe. The model was calibrated for field travel time, maximum queue length, and volume data. The simulated and observed data were compared using analysis of variance and the model was calibrated in terms of volume by the Geoffrey E. Harvers Test (GEH) which showed that the observed and simulated data were almost similar. The error margin was considered as 10% for the queue length. Through the proposed improvements, the operational performance of the roundabout was increased, and the maximum queue length was reduced drastically. The proposed improvements of signalization and increasing the circular traffic lanes would reduce the traffic congestion, delays, and queue length.

Bhattacharyya *et al.* (2020) studied on the gap acceptance behavior of right-turning vehicles as maneuvering vehicles interacting with opposing through vehicles in the major traffic streams at urban signalized intersections with permitted right-turn and heterogeneous, non-lane-based traffic operations. The vehicle class is a key factor influencing the gap acceptance behavior. A methodology was proposed for calibrating traffic microsimulation models with a primary focus on realistic representation of vehicular interaction at conflict zones in signalized urban intersections. The study was conducted in a central business district in India which consisted of mixed traffic operations and an absence of lane discipline. Four intersections with similar traffic, signals, and geometric characteristics were selected. The maneuvering vehicle class, through moving vehicle class, accepted gap time, rejected gap time, and clearing time for the maneuvering vehicle data were collected after conducting videotape recordings at the intersection. And the intersection geometry, vehicle composition, flow rate, routing decisions, and speed profiles were collected for the intersection. A variation in critical gap at the aggregate level across intersections compared to the disaggregate level was found. The results also showed that the gap time and class of through moving vehicle influences the acceptance or rejection of gaps for maneuvering vehicles in mixed traffic streams. For the analytical model development, a binary logit model was considered as the decision involves only two alternatives. The analytical model showed the gap size has relatively more influence on the probability of gap acceptance for both cars and two wheeled motor vehicles. The VISSIM microsimulation software was used for traffic microsimulation model development. The clearing time which is the time difference between the maneuvering vehicle accessing and leaving the conflict area was considered as the measure of effectiveness. For VISSIM software calibration, Linear regression models were developed to identify the sensitive parameters and the clearance time. An exhaustive search technique was used to obtain the optimal parameter estimates for different vehicle classes. It was concluded that the methodology was successful in calibrating a traffic microsimulation software by identifying and modifying two sensitive parameters and modeling realistic conflicting movement of vehicles for a complex traffic scenario.

Mathew and Radhakrishnan (2010) proposed a methodology for representing non-lane-based driving behavior and calibration of microsimulation model on highly heterogenous traffic conditions at signalized intersections. Sensitivity analysis was done to determine the calibration parameters. The GA was used to determine the optimum parameter values through sensitivity analysis. Diverse traffic conditions and geometric characteristics of signalized intersections of two cities were considered. The stopped time delay was taken as the measure of effectiveness for calibration and validation. The highway capacity manual (HCM) was used to determine the technique to collect field delay. The validation was done for different traffic and geometric conditions and the error was determined to ensure it was within the satisfying limits. The proposed methodology is useful in adapting simulation tools even though there are some issues that hinder the model such as stacking of vehicles at intersections.

The above studies which have been conducted for calibration and validation of microsimulation software for local conditions and proposing various traffic management measures but as they are conducted at a specific time there are no studies found on explaining the effect on the driver behaviour parameter values and the traffic flow with time. There is a possibility for the driver behaviour parameter values and the traffic flow to change with time which may cause errors in the model simulations in case the driver behaviour parameter values which was identified a year before are used after a year later which will be found out through this study. In this study a selected intersection was modelled, and driver behaviour parameter values obtained in in 2019 and the driver behaviour parameter values obtained in 2020 were tested on the model developed in 2020 to see the effect on the driver behaviour parameter values and the traffic flow with time.

3. METHODOLOGY

3.1. Study Area

The Weliwita intersection which is situated in western province of Sri Lanka as shown in Figure 1 is an unsignalized "T" intersection which is located right in front of the SLIIT Campus, Malabe, Sri Lanka. The intersection consists of 3 legs and it has a heavy traffic volume. The traffic volume in each leg were considered for the study and all the legs consist of single lanes on each direction as shown in Figure 2.

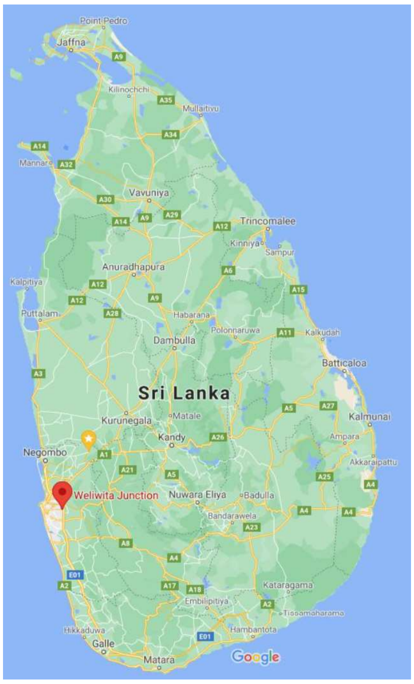

Figure 1: Weliwita Intersection (Google Maps, 2021)

Figure 2: Study Area Close View (Weliwita Intersection)

3.2. Data Collection and Analysis

Traffic, transportation and highway engineers widely use collect the traffic data and analysis them to manage and control the traffic. The data collection in 2019 was done during the peak hour of 4:30 pm to 5:30 pm in the Weliwita intersection on 6th August 2019 and the data collection was done during 10:00 am and 11:00 am in the Weliwita intersection on 17th September 2020. This can be considered can an off-peak time because there were no difference in the traffic flow during the daytime due to the COVID-19 situation. The studies on the geometry of the road network, vehicle volume counts and queue lengths on each leg of the intersection were done. To obtain the queue length with a 5m accuracy for the three legs of the intersection, masking tapes were pasted on the road at 5m intervals from the vehicle stopping lines in the three legs. The queue length was recorded at the intersection at the same time of the recording of the traffic volume. The traffic volume was recorded by using a drone and a videorecorder. The collected vehicle volume counts data, as shown in Figure 3; vehicle compositions data, as shown in Figure 4; and queue lengths in each direction were sorted. These data were used as input data for the VISSIM microsimulation software.

3.3. Model Development and Calibration

With the collected and analyzed data, the intersection was modelled in the VISSIM microsimulation software. Figure 5 shows a screenshot of the geometric model developed for the Weliwita intersection. The average queue length was considered as the measure of effectiveness. The developed model was then simulated and the difference between the observed and the simulated average queue length were calculated to obtain the percentage error using equation 1 (Stephanie, 2016).

$$\%\ Error = \frac{Observed\ Average\ Queue\ Length - Simulated\ Average\ Queue\ Length}{Observed\ Average\ Queue\ Length} \quad (1)$$

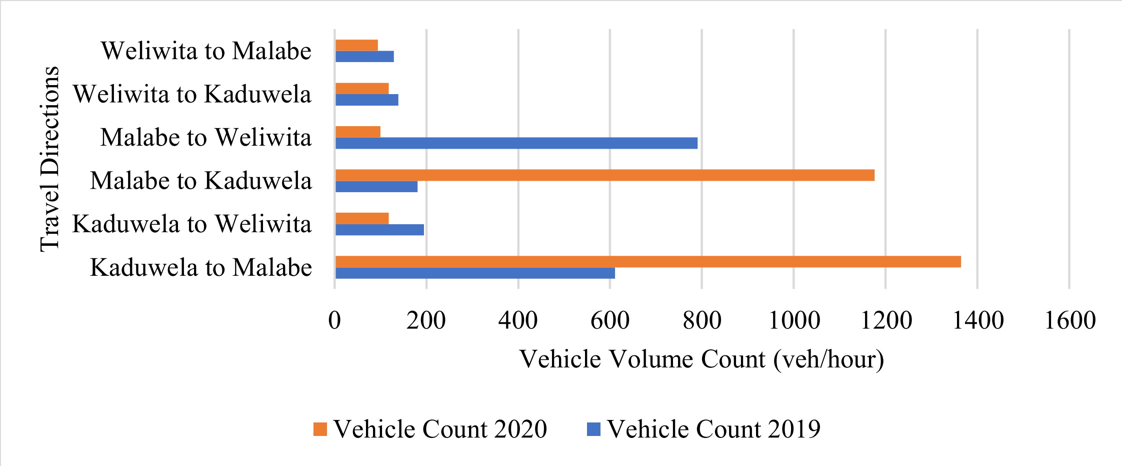

Figure 3: Vehicle Volume Counts of 2019 and 2020 at Weliwita 3-legged Intersection

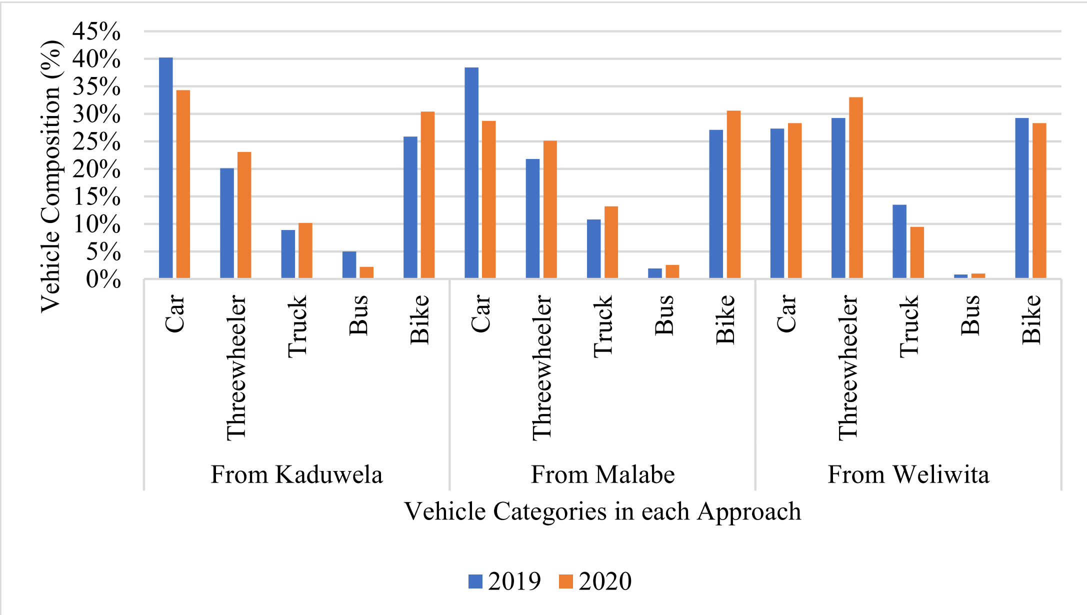

Figure 4: Vehicle Composition of 2019 and 2020 at Weliwita Intersection

Figure 5: Screenshot of the Geometric Model of the Weliwita Intersection

Then the Mean Absolute Percentage Error (MAPE) was calculated using equation 2 (Stephanie, 2021).

$$MAPE = \frac{Sum\ of\ all\ the\ \%\ Errors\ at\ each\ leg\ of\ the\ intersection}{Number\ of\ legs\ at\ the\ intersection} \quad (2)$$

Based on the previous literature, a 15% - 22 % error or lesser error was considered acceptable to confirm that the model was calibrated (Brockfled *et al*., 2004 and Raju *et al*. 2020) For this study, the acceptable range of the MAPE was considered as 15%. In case if the MAPE was greater than 15% the driver behavior parameter values were optimized. For optimization, GA optimization was done using the GA Toolbox in the MATLAB software (Gunarathne *et al*., 2020). The optimization was done for the fitness function developed based on the percentage error and the changes done to the driver behavior parameter values to obtain that percentage error. The obtained parameter values were then tested on the VISSIM model to check whether the percentage error was within the acceptable range. Therefore, the most suitable parameter values were found. After obtaining the most suitable parameter values, those parameter values were compared with the parameter values obtained for the same intersection before the COVID–19 situations to identify the variation of the driver behavior parameter values before and after the first wave of the COVID-19 situation.

4. RESULTS AND DISCUSSION

After modelling Weliwita intersection in VISSIM with default driver parameter values, the model was simulated. The average queue length observed was compared with the average simulated queue length and % Error and MAPE were found. The simulation results as shown in Table 1 gave the MAPE was greater than 15%.

Table 1: Simulation Results with Default Driver Behavior Parameter Values at Weliwita Intersection

Direction	Queue Length		% Error	MAPE
	Observed	Simulated		
From Kaduwela	20.41	31.46	-54.14%	
From Malabe	15.38	14.53	5.53%	26.33%
From Weliwita	7.04	5.68	19.32%	

To minimize the MAPE, a fitness function was developed by varying the values of the critical driver behavior parameters. The developed fitness function was optimized in the GA Toolbox in MATLAB which provided with a set of optimized driver behavior parameter values which reduced the MAPE within the acceptable range as shown in Table 2.

Table 2: Simulation Results with Optimized Driver Behavior Parameter Values at Weliwita Intersection

Direction	Queue Length		% Error	MAPE
	Observed	Simulated		
From Kaduwela	20.41	23.26	-13.96%	
From Malabe	15.38	15.57	-1.24%	10.09%
From Weliwita	7.04	5.98	15.06%	

The obtained optimized driver behavior parameter values were compared with the driver behavior parameter values obtained in 2019 for the Weliwita Intersection as shown in Table 3.

Table 3: MAPE Comparison with Driver Behavior Parameter Values from 2019 and 2020

Parameter	**Default Values**	**17th September 2020**	**8th August 2019**	**% Variation from 2019 to 2020**
Average Standstill Distance	2.000	2.078 m	1.920 m	+ 7.603 %
Additive Part of Safety Distance	2.000	1.238 m	1.240 m	- 0.162 %
Multiplicative Part of Safety Distance	3.000	3.783 m	2.460 m	+ 34.972 %
Look Ahead Distance (min)	0.000	29.620 m	0.00 m	+100.000 %
Distance Standing (0 km/h)	0.200	0.268 m	0.63 m	- 135.075 %
Distance Driving (50 km/h)	1.000	0.848 m	0.78 m	+ 8.019 %
MAPE	**26.33 %**	**10.09 %**	**48.48 %**	

The comparison showed that with the time there has been variations in the driver behavior parameter values. It was found that the driver behavior parameter values of average standstill distance, multiplicative part of safety distance, look ahead distance and the distance driving haves been increased by 7.603%, 34.972%, 100% and 8.019% respectively during the time duration of before the COVID-19 situation and after the first wave of the COVID-19 situation. The main reason for the variation of these driver behavior parameter values as shown in Table 3 within the years 2019 and 2020 was due to the variation of the traffic flow. And the driver behavior parameter values of additive part of safety distance and distance standing have been decreased by 0.162 % and 135.075 % during the time duration of before the COVID-19 situation and after the first wave of the COVID-19 situation. From 2019 to 2020 there was an average 37.649 % increment in few driver behavior parameters and an average 67.619 % decrement in the rest of the driver behavior parameter values. As the parameter values used for the comparison was which obtained in 2019 and 2020, it is clearly visible that within one year the driver behavior parameter values were either increased or decreased due to the variation of the traffic flow. It was also observed that by using the driver behavior parameter values obtained in 2019, the model developed for 2020 gave a percentage error of 48.48% which is not within the acceptable error range. Through this finding, it could be concluded that the calibration of the software is essential before utilizing the model for further requirements such as proposing traffic management measures, etc. A statistical t-test was conducted with a significance level of 0.05 to determine whether the variation of the driver behavior parameter values with time are significant. The results from the t- test are shown in in Table 4.

Table 4: The t-test Results for Comparing the Driver Behavior Parameter Values in 2019 and 2020

Statistics	**8th August 2019**	**17th September 2020**
Mean	1.1717	6.3058
Variance	0.8088	131.9432
Hypothesized Mean Difference	5.1342	
df	5	
t Stat	-2.0944	
P(T<=t) one-tail	0.0452	
t Critical one-tail	2.0150	

Through the t-test result, it showed that the probability (0.045) is lesser than the significance level of 0.05 which rejected the null hypothesis that there is no significance in the effect of the driver behavior parameter values with time. Therefore, the alternative hypothesis was accepted which was concluded that there is a significance in the effect of the driver behavior parameter values with time.

Through the changes in the driver behavior parameter values within the time duration from 2019 to 2020, it was possible to conclude that there was a reduction in the traffic flow approaching from the Weliwita direction and an increment in the traffic flow approaching from Malabe and Kaduwela direction at this intersection with comparison to the traffic flow which was visible before the COVID-19 situation and that there was a possibility for the driver behavior parameter values to increase or decrease with time due to the variation of the traffic flow.

5. CONCLUSION AND RECOMMENDATIONS

In this study, comparison between the driver behavior parameter values in two consecutive years were conducted. The study was done to the Weliwita unsignalized three-legged intersection. Through the study it was found that the driver behavior parameters values were completely changed within the two consecutive years. From the year 2019 to 2020 there was an average 37.649 % increment in few driver behavior parameters and an average 67.619 % decrement in the rest driver behavior parameter values. This shows that several driver behavior parameter values; average standstill distance, multiplicative part of safety distance, look ahead distance and the distance driving have been increasing with the time and the rest driver behavior parameter values such as additive part of safety distance and distance standing have been decreasing with time. The main reason for the variation of these driver behavior parameter values within the years 2019 and 2020 may be due to the variation of the traffic flow. Through the t-test conducted, it showed that there is a significant effect in the driver behavior parameter values with the time. Therefore, it could be concluded that the time influences the driver behavior parameter values and the traffic flows as they have the possibility to vary with the time and calibration of the software is essential before utilizing the model for further studies as the driver behavior parameter values vary with time.

As the driver behavior parameter values and the traffic flows have the possibility to vary with the time it is recommended to calibrate more often when doing the microsimulation modelling as it was observed in this study that the driver behavior parameter values obtained in 2019 were not suitable to be used in 2020.

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