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STUDYING THE LEVEL OF SERVICE OF TWO SIDED WEAVING SECTION ON URBAN ROADS

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Abstract : The stream of traffic movement within the weaving section doesn't only have an effect on freeways but additionally affects urban roads. The important aim of this paper is to check the two-sided weaving section on urban roads because the previous model by HCM (Highway Capacity Manual) sixth Edition 2016 was targeted only at studying the weaving section on highways. Three selected two-sided weaving section sites were chosen to capture different traffic conditions and are utilized in a simulation model by the Vissim software system to calculate the level of service (LOS). After that, the obtained results from the calibrated and validated models of every site would be compared to the LOS generated by the HCM equation for a similar. This paper shows that HCM provides a similar LOS and nearly a similar density compared thereto obtained through simulation at the values V/C (Volume per capacity) equals 0.44. For the weaving section with V/C values of 0.63 & 0.93, there was a major distinction between the LOS and density results obtained from the simulation model rather than HCM manual methodology.

KEYWORDS: HCM, Weaving Section, VISSIM, Calibration, Validation, LOS.

Introduction

The crossing of two or more traveling traffic streams within the same direction on a specific length of the road without the help of traffic control devices is considered the definition of a weaving section. The weaving sections are often in any class of roads such as freeways, highways, arterial, collector, and local roads.

HCM 2016 shows a detailed methodology of freeway weaving sections analysis/design, a lot of the previous studies focused on the freeway weaving section where many models were established to assess the data of the freeway weaving section but offer no guidance to assess the arterial or collector roads (Urban streets), which are much more complicated. It mentions that this methodology can be used in practice to design alternative weaving sections located on urban roadways (arterials and collectors). The appropriateness of using this approximation is, however, questionable.

Based on the above, the main aim of this paper is to use the VISSIM simulation model, which is the most commonly used simulation program for calibration and validation to make a simulation model for two-sided weaving sections in urban roads according to HCM 2016 or type C as per Highway capacity manual 2000. The developed models were calibrated and validated by using collected site data. The calibrated/validated model was used as a test-bed to assess weaving sections in urban roads and compare the LOS results obtained by the simulation models with the Level of service calculated by the HCM 2016 equation for the same. To be able to clarify the discrepancies with the obtained results.

2. BACKGROUND

Studying the weaving section started half a century ago. While several studies were discussing this subject, HCM, in 1940, started one of the first methods for assessing the weaving section. Then, this method was updated overtime to capture a correct representation of the weaving area.

HCM 1950 developed the primary methodology to be used in calculating, designing, and assessing the weaving section [1]. In 1981, PINY (Polytechnic institute of New York) updated and simplified a method to calculate the weaving and non-weaving speed in the weaving area. In the 1985 HCM edition, a complete definition for types A, B, and C were displayed in terms of the successful number of lane changes in each weaving maneuver, and the way to differentiate between the constrained and unconstrained operations developed as well [2].

Four scientists (Wang, Cassidy, Chan, May), in 1993, developed a method to analyze the capacity of highway weaving sections. The function value of capacity is defined by 5900 pcu/hr for the critical region [3]. Further improvement has been applied in HCM 2000 edition, utilizing the harmonic mean of weaving and non-weaving vehicles used to calculate weaving areas' speed and traffic flow. The level of service (LOS) was estimated by weighted average density for all vehicles within weaving sections or separate vehicles. [4].

There was a new method for weaving segment analysis done in NCHRP project 3-75, which was published in HCM 6TH Edition 2016. There are two main differences between the HCM 2000 and 2016 in the weaving analysis methodology. the maximum length of weaving area in HCM 2000 was 2500 ft (762m), a constant number. On the other hand, the maximum length of weaving area in the HCM 2016 depends on the volume and the configuration, and it is not becoming a constant value anymore. The second difference is the weaving classification. HCM 2000 weaving segments were classified into Type A, Type B, and Type C; whereas, in HCM 2016, there is no such classification. All weaving segments are analyzed in the same way depending on the input parameters and configuration [5].

In 2020, Ali Kashani developed a model to study the Maximum Weaving Length Based on HCM 2016. In this study, four traffic parameters and two geometric parameters (Nwl and Lwmax) were considered variables. It was noted for Nwl = 2 the accepted regression model containing three new variables has an R2 value equal to 0.95, and for Nwl = 3 two of the three variables were used for the model produced with an R2 value equal to 0.7 [6].

A lot of the studies were developed for highway weaving areas, but a significantly fewer number of researches were developed to study the weaving areas on urban roads. In 2004, M. Park and Y. zhang had a study on the effect of weaving section maneuvering on the operation of the free right turn lane on the ramp. In this study, a Linear regression model was established based on the results obtained from CORISM (traffic simulation model) to calculate the delay that occurs in the free right turn lane that is a result of the stopping or slowing of cars that need to create a weaving movement on the arterial road [7].

R. galiza and J. regidor 2009, assessed the speed of weaving section U-turn spots in metro manila, in this paper two models were conducted for two sites with similar geometric characteristics to calculate weaving and non-weaving speeds within the weaving area. Both models predict weaving and non-weaving speeds that show strong connections with the measured speeds. Also, the results of the calibration models show that weaving and non-weaving speeds can be accurately calculated by using the models that have been created [8].In 2015, a model for calculating road capacity at weaving sections on the urban road has been developed by Mahmoud Sarhan. The results from this research show that HCM can reasonably be used to get the traffic speed and density for uncongested situations, where the volume to capacity (V/C) ratio is below 0.70 - 0.85, but the difference becomes significant when the V/C ratio exceeds this limit. [9].

A computer simulation is a supportive tool for traffic operational analysis. However, there were only a few studies found that directly discussed the analysis of weaving areas by using simulation. INTEGRATION is a microscopic traffic simulation model and Zhang and Rakha (2005) used the INTEGRATION simulation model to estimate the capacity of weaving sections and study the weaving length impact [10].

INTRAS is a microscopic, stochastic, simulation model used to assess the weaving section on the freeway [11]. In INTRAS, Wicks has used the software for studying freeway incident detection and control strategies. In the field, when the total weaving flow rate increases, vehicles traveling from the freeway to the ramp required lane changes over shorter traveled distances. However, INTRAS was unable to duplicate these delicate motorists' responses to varying flow conditions. In 2020, George Taylor, Developed Microsimulation Model by FWASIM for Freeway Weaving Areas. In this study, it was found that the extracted data by FWASIM software was almost similar to that obtained by VISSIM software. Also, FWASIM software could be used to analyze the design of highway sections under different local traffic conditions with a range of geometric configurations [12].

VISSIM is considered as a traffic microscopic, stochastic, time step simulation model, including the lane changing logic and car following. The capacity estimation model for the weaving area and the calibration processes are linked with the evaluation and data collection because the results can be used for both simulation and calibration. The VISSIM model shows the capability of using a useful and effective tool for the analysis of weaving sections on urban arterials [13].

Many studies have been developed on highway weaving areas and only a few were developed to assess the weaving section on urban roads. Based on that, there was no standard methodology for assessing the weaving section on urban roads. So, assessing and studying the LOS of weaving sections on urban roads is still needed.

3. PROBLEM DEFINITION & OBJECTIVES OF THE RESEARCH

The weaving section has specific needs for traffic operation that need special considerations in the design. Studying the weaving section in urban roads is more difficult because of the interruptions that happen to the operational traffic flow ensuing from the traffic signals, pedestrian crossings, street parking, and vehicles incoming from side streets. Also, highways have a typical configuration and constant variables affect the weaving section. On the contrary, the urban roads have many variables as the configuration keeps changing from one section to another. This paper aims to introduce an appropriate model to study the weaving section in urban roads as most of the studies concerted on the weave along the highway. As a result, the available models to assess the weaving sections are applicable for the freeway scenario however don't apply to the weaving section in urban roads, thence there's no way to assess the weaving section in urban roads.

Accordingly, the objective of this paper is to concentrate on the weaving section in urban roads. Three different sites were chosen with a two-sided weaving section configuration (i.e., entering from one side, crossing the main road, and emerging from the other side). The general contents of this paper are described as follows:

- Developing Calibration and validation of a traffic simulation model for the weaving sections in urban roads by using VISSIM and COM interface tools.
- Defining the most effective parameters for the two-sided weaving section under operating conditions and its effect on the road's LOS using the validated model.
- Checking the results with HCM parameters.
- Creating a set of recommendations and conclusions.

The outcome of the paper can provide guidelines for researchers to assess weaving sections in urban roads and compare the LOS results with HCM. Additionally, VISSIM software, which is the most commonly used simulation program for calibration and validation, will help to assess and test weaving sections on urban roads under different operating conditions.

4. RESEARCH METHODOLOGY

The main objective of this study is to develop a traffic simulation model to assess the two-sided weaving section in urban roads. The proposed methodology is arranged to achieve the aim of the thesis, which consists of four stages as shown in Fig. 1:

- **First stage:** this stage includes reviewing the older versions of the HCM, as well as the published papers done on the weaving section for the highway along with the studies completed earlier on the weaving sections of urban roads. Since this paper is going to use a traffic simulation model, earlier studies that use a traffic simulation model of the weaving section will be checked. One of the main aims of this stage is to define the weaving section configuration and appropriate simulation tool to achieve the purpose of this paper.
- **Second stage**: Three different sites for a two-sided weaving section have been elected to achieve the required data. The collected site data includes two features traffic data and field data. All site data is collected and arranged to be used in the next stage.
- **Third stage:** The VISSIM model for every location that has been selected needs validation and calibration for the collected site data. At first, validation and calibration use the default VISSIM parameters, after that selecting the parameter for calibrating and running numerous runs to test the changing parameters finally validating the model against the actual site results. To extract the

results for multiple runs, we use VBA / Python with VISSIM to facilitate this process.

- **Fourth stage:** this stage aims to build a combined model of the three models created prior in order to obtain parameters applicable generally for the two-sided weaving section of urban roads. Then, using the traffic model to test the level of service and check it against the level of service obtained from the HCM.

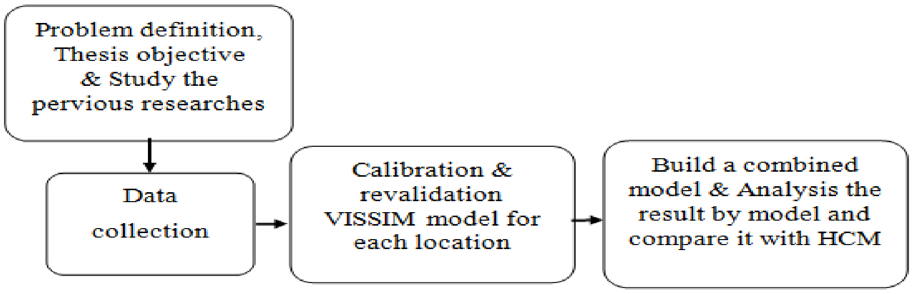

Fig 1. Research Methodology Steps

5. DATA COLLECTION

The study sites were selected to fulfill the aim of this thesis in line with predetermined criteria. The three selected sites had different configurations such as (Number of lane changes, Volume, Speed, number of lanes for entry/exit ramps,…etc.), three selected locations are described below:

- **Site_01:** The weaving section on the main road with a classification of collector road with a speed limit of 60 kph. Fig. 2., shows a sketch of the weaving section area.
- **Site_02:** The weaving section on the main road with a speed limit of 80 kph and a one-lane exit ramp. Fig. 3., shows a sketch of the weaving section area
- **Site_03:** The weaving section on the main road with a classification of collector road and three lanes on the main road. Fig. 4., shows a sketch of the weaving section area.

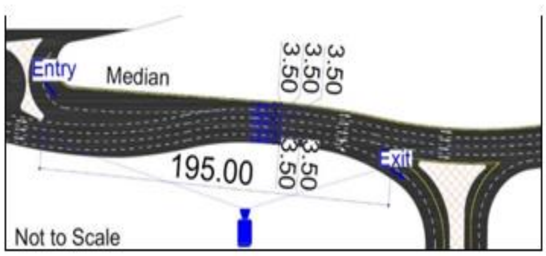

Fig. 2. Site_01 Configuration and Data Collection Setup

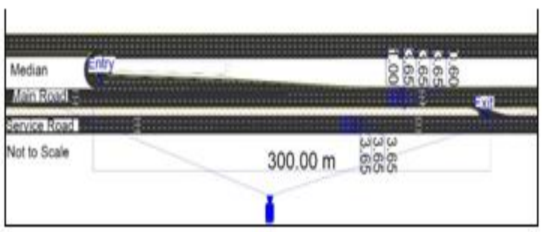

Fig. 3. Site_02 Configuration and Data Collection Setup

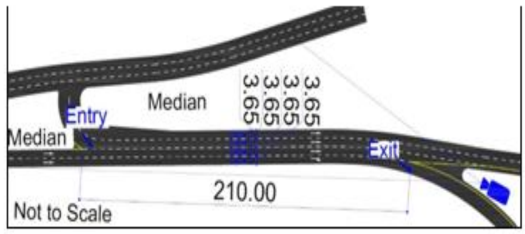

Fig. 4. Site _03 Configuration and Data Collection Setup

5.1 Site data Collection

Two kinds of data were required for this paper: "fundamental data" and "calibration data", and these data are needed for the simulation model of each site:

- First, fundamental data are mentioned below:
  - Geometry data (number of lanes, lane width, section length)
  - Traffic data (volumes in mainline, entrance, exit ramps, % of heavy vehicles)
- Second, calibration data are the speed, volume, and lane change which were used as the operational measures data for the calibration and validation purposes.

In order to collect the site data, each selected site has been visited by the team twice before data collection to find the proper locations for data collection equipment. This includes selecting a suitable and safe location for the camera and setting the camera view angle. In addition, the study team would get the geometric data for each site during the arranged site visits.

The traffic data collection included three types of surveys that were accomplished simultaneously. These surveys were:

- Video Monitoring for the two-sided weaving section;
- Speed per lane using GPS;

- Speed for the whole weaving section using Video.

5.2 Videotaping Site Data

Various data were extracted using videotapes, such as different traffic volumes, heavy vehicle percentage, number of lane changes, and speed. The videotapes of each site were played many times and data were extracted after every 5-minute interval. Then, these data were aggregated in 15-minute intervals in such a way that 4 records were obtained for each survey period of each site. It was possible to trace vehicular movements within the weaving area and identify the number of lane changes achieved by various movements using the video camera.

6. Results

In this paper, VISSIM software [14] has been used to build a traffic simulation model for the three selected two-sided weaving sections.

A rigorous trial-and-error methodology with multiple runs has been applied for the calibration/validation process, as shown in Fig. 5. According to earlier studies[15, 16, 17], the average speed and the number of lane change maneuvers of weaving section two parameters have been considered as MOF (Measures of Effectiveness) parameters to assess the appropriateness of selected parameter values and used in the calibration/validation process.

The key and non-key parameters and their range to be considered in the calibration / Validation process are summarized in table 1.

Table 1: Calibration Parameters with selected values

No	Type	Parameter	Unit	Default Value	Significance	Selected Values	
						Min	Max
1	General	Simulation resoultion	Time Step/sim.sec	5	Non Sig.	5	
2	Car Following	Average standstill distance	m	2	Sig.	1	3
3		Additive part od desired safety distance	-	2	Sig.	1	3
4		Multiole part of desired safety distance	-	3	Sig.	1	3
5		Number of preceding vehicles	Veh	4	Non Sig.	4	
6		Maximum look ahead distance	m	200	Non Sig.	200	
7	Lane Change	Lance Change Distance for downstream connectors	m	200	Non Sig.	200	
8		Min headway	m	0.5	Non Sig.	0.5	
9		Maximum deceleration - For own - For trailing	m/s2	-4 -3	Sig.	-5	-3
10		Reduction rate (For own and trailing)	m	100	Non Sig.	100	
		Accepted deceleration (for own and trailing)	m/s2	-1	Non Sig.	-1	
11		Waiting time before diffusion	S	60	Non Sig.	60	
12	Desired Speed	Desired speed distribution	kph	-	Sig.	**Desied Speed for arterial** (82kph-98kph) **Existing Arterial Speed** (70kph-90kph) **Existing Flow Speed** (50 kph-70kph)	

Data were separated into two parts; the first hour and the following half an hour for each location. The First hour's data were used in the calibration process, while the next half-hour data were used for validation purposes. Considering the first 5 warm-up minutes were dropped from the evaluation.

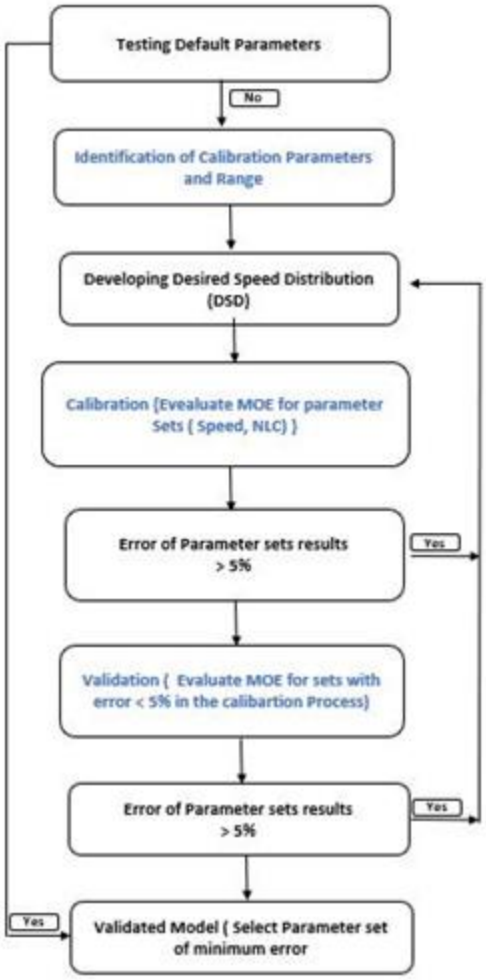

Fig. 5. Flow Chart for calibration and validation process of each model

The calibration and validation process requires testing a lot of scenarios with multiple runs (models with specific parameter sets). VISSIM simulation model can be run from other applications as an Add-in for transportation planning algorithms. Access to model data and simulations parameter can be achieved through a COM interface, which allows VISSIM to work as automation software and extract the required data as well. The VISSIM COM interface supports scripting languages like Python Script. In this paper, numerous macros were developed using Python and Visual Basics for Application (VBA) to automate the process and facilitate extracting the results for different scenarios. VISSIM software has many calibration/validation parameters that can be changed and these parameters are divided based on their characteristics. The calibration & validation parameters that will be considered in this paper are as mentioned below:

1. Basic calibration parameters: the simulation resolution will be considered only
2. Lane Change parameters
3. Car Following parameters: the Wiedemann 74 model is appropriate for an urban network based on the VISSIM user manual. Therefore, all three parameters in the Wiedemann 74 model have been considered.
4. Desired speed distributions (DSD): Four-speed distributions are considered (70, 80, 90, 100), where the speed profile is linearly distributed for the average speed ± 10 kph.

In the calibration process, affected key model parameters were adjusted to match the model output with the field data. The objective of the calibration process was to find the best parameter combination (p 1, p 2, …, p n) that minimizes the sum of differences between modeled and observed data (average speed, number of lane changes) according to Eq. (1).

$$Min\left\{\sum\left[x_i^{Sim}\left(p_{1,}p_{2,}p_{3,}p_{4,}\dots p_n\right)-x_i^{obs}\right]^2\right\} \tag{1}$$

where:

x_i^{Sim} = simulation results from VISSIM (average speed and number of lane changes)

x_i^{obs} = field data (average speed and the number of lane changes).

The term xiSim (p1…, pn) in the objective function in Eq.(1)., is non-linear and depends on the number of parameters. Finding the best parameter combination may be difficult to solve as an optimization problem. Instead, the model calibration problem was formulated to find a parameter combination (p1, p2, …, pn) that satisfies the following conditions as shown in Eq.(2):

$$\frac{\left|x_i^{Sim}(p_1,p_2,p_3,p_4,\dots p_n)-x_i^{obs}\right|}{x_i^{obs}} \leq \varepsilon \quad \forall j \qquad (2)$$

$$p_j^{Min} < p_j < p_j^{Max} \quad \forall j$$

where:

ε (%) = permitted error set to 5 percent in this study, and

p_j^{Min}, p_j^{Max} = the minimum and maximum value pairs that define feasible intervals where close to optimum values of each model parameter pj may be searched.

The number of simulation runs of the combination parameters is about 81. For every combination, five multiple runs shall be conducted. Thus, 405 runs are completed for every DSD. In order to accomplish the evaluation criteria, one or more parameter sets error range must be less than 5%. That means the calibration criteria are achieved by using this group of parameter sets. Then, this group of parameter sets should be checked against another site's data for revalidation purposes. If the simulation model results fall below the allowed error range of 5%, this model is considered a validated model. On the opposite, if the values of the parameters do not below the permitted error range of 5% with specific desired speed distribution (DSD), a new trial must be conducted by using another DSD. After that, calibration/validation processes for each site shall be conducted, then a one-set parameter was used to verify the permitted error for all three selected two-sided weaving sections. Based on that, the parameter values that give a minimal error for all models were considered. The total number of runs have been conducted in this paper around 3645 runs to achieve the combined calibrated & validated model.

For all models the best-set values of parameters are as follows:

- Maximum Deceleration (Own & Trailing): - 4 m
- Accepted Deceleration (Own & Trailing): 1.5 m
- Car Following Parameters
  - ➢ Average standstill distance: 3
  - ➢ Additive part of desired safety distance: 2
  - ➢ Multiple parts of desired safety distance: 2
- Desired Speed Distribution (DSD): It has a significant effect on the speed and number of lane changes for each site and it is considered a major factor, accordingly the DSD should be the Free Flow Speed.

6.1 Assessing the Calibrated & Validated Model

As clarified prior, HCM created a method to assess the weaving section in highways, hence the HCM procedure for highways is used for assessing the weaving sections on urban roads. A traffic simulation run will be conducted for each calibrated & validated site in order to obtain the density of the two-sided weaving section for each site, based on that the LOS from the model will be calculated. Then, the LOS of each site will be calculated according to High-capacity manual method (HCM) and (Highway Capacity Software) HCS software for confirmation purpose. Then, a comparison will be conducted between the LOS obtained from HCM & HCS and simulation model for checking purpose.

6.2 Estimate LOS Based on Highway Capacity Manual

To calculate the Density and the level of service for all selected weaving sections a spreadsheet was developed to obtain these data. Fig. 6 shows a snapshot for the created sheet. For confirmation purpose, the software HCS7 (version 7.3) has been used to calculate the level of service (LOS) and Density for all selected weaving sections and the software give almost the same results extracted from spread sheet.

No	Length		VFF		VRR		VRF		VFR		Vw		Vnw		Vtotal		VR
	Meter	Feet	vph	pc/hr	vph	pc/hr	vph	pc/hr	vph	pc/hr	vph	pc/hr	vph	pc/hr	vph	pc/hr	
Site_01	195	640	3167	3715	1028	1206	160	188	248	291	1028	1206	3575	4194	4603	5400	0.223
Site_02	300	984	4519	4906	311	338	1526	1657	55	60	311	338	6100	6623	6411	6961	0.049
Site_03	210	689	957	1105	836	965	538	621	209	241	836	965	1704	1967	2540	2932	0.329

No	Ciwl	Cw1	Cw2 (NWL=0)	Cw	V/C	LC min	LC w	LCnw					LC all	W	Speed			Density	LOS
	pc/hr/ln	vph	vph	vph				Inw	LCnw1	LCnw2	LCnw3	LCnw			Sw	Snw	S	pc/mi/ln	
Site_01	1827	9045	0	8406	0.64	4824	5027	46	440	0	0	440	5276	1.194	39.3	28.4	30.3	35.6	D
Site_02	2002	7929	0	7369	0.94	1217	1443	326	1127	0	0	1127	2367	0.452	58.2	62.0	61.8	28.2	C
Site_03	1762	6876	0	6710	0.43	2634	2774	23	8	0	0	8	3043	0.730	53.0	56.4	55.2	13.3	B

Fig. 6. Calculation of LOS from HCM for All Locations

6.3 Estimate LOS Based on VISSIM Simulation Model

In order to calcu late the level of service (LOS) for all selected two-sided weaving sections from the traffic simulation model, an excel sheet was developed. One simulation for the calibrated & validated model of every location has been run in order to obtain the density and speed for each lane at the weaving section by using link evaluation tools in the VISSIM model. The summary of VISSIM simulation model results for each location is shown in table 2. The density from the simulation model was Veh/km/ln and it has been converted to Pcu/mil/ln in order to be able to use the HCM table for the level of service criteria of weaving sections.

Table 2. Summary Table of VISSIM Simulation Model Results

Summary Table of VISSIM Simulation Results			
Locations	Site 01	Site 02	Site 03
V/C	0.63	0.93	0.44
Density (Pcu/mi/ln)	111.8	76.8	13.7
LOS	F	F	B

A comparison table is created between the simulation model results and HCM for the operational level of service (LOS) and density of the selected two-sided weaving section. The comparison table is shown below in table 3.

Table 3. Comparison between LOS Results from Simulation and HCM

Comparison Table				
Locations		Site 01	Site 02	Site 03
V/C		0.63	0.93	0.44
Sim (VISSIM Model)	Density (Pcu/mi/ln)	111.8	76.8	13.7
	SIM	F	F	B
HCM Methodology Results	Density (Pcu/mi/ln)	32.6	28.2	13.4
	SIM	D	C	B

In general, the data in Table 3 shows that the LOS and density of HCM are almost the same compared to that obtained through traffic simulation models at the third location (Site 03) only. For the weaving section of Site 01 & Site 02, the results in the table indicate that there are significant differences between the level of service for HCM and the simulation model and differences in the density values as well. Generally, the simulation model for the two-sided weaving section gives LOS similar to HCM at the value V/C equal to 0.44. However, with the high volume and V/C of more than 0.63, there is a significant difference between the LOS of the simulation model and the HCM method.

It has been noticed that in high traffic volume with higher V/C values the driving behavior factor including (Car following parameter, maximum declaration of the own vehicle and trailing vehicle) along with the weaving section average speed has a big effect on increasing the average density of weaving sections which makes a significant difference between the simulation model and HCM as shown. Accordingly, more researches with different V/C values of the weaving section should be conducted in the future to confirm these data and to cover more V/C values.

6.5 Conclusions

This paper focused on the two-sided weaving section configuration where the entry ramp is from one side while the exit ramp is on the opposite side of the road. To complete this study, three weaving sites were chosen with different traffic criteria (Number of lane changes, Volume, Speed, number of lanes for entry/exit ramps, etc.)in order to cover different weaving section criteria. VISSIM (Microscopic simulation model), considered as the most widely used simulation program for calibration and validation, will help to assess and test weaving sections on urban roads under different operating conditions. The main findings of this paper can be summarized as follows:

1. Three locations of weaving sections on urban roads with different characteristics have been chosen to cover more criteria and increase the quality of results
2. To make sure that the developed simulation model reflects the real behavior of traffic movements at weaving areas, calibrated and validated processes have been conducted against field data for each site.
3. In this paper we figure out that the LOS & Density of HCM method gives almost the same results compared to that obtained through the simulation model at the values V/C equal to 0.44. For the weaving section with V/C values of 0.63 and 0.93, there is a significant difference between the LOS and density obtained from the simulation model rather than the HCM method.

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