A MICROSIMULATION APPROACH TO EVALUATE OPERATION OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Amr K. Soliman* and Mostafa A. Abo-Hashema**

*Graduate student at the Department of Civil Engineering, Faculty of Engineering, Fayoum University. Email: Amr.soliman@gmail.com
**Professor of Highway Engineering, Department of Civil Engineering, Faculty of Engineering, Fayoum University. Email: maa03@fayoum.edu.eg

ABSTRACT

Unconventional median U-turn intersections have been extensively implemented along major corridors in Cairo, Egypt. These intersections do not involve signalization at any point; they utilize a non-traversable median with a U-turn crossover at the downstream to merge movements, thus movements and thus, creating a two-sided weaving between the minor approach and the U-turn crossover between the minor approach at turn slot on both sides of the median. In this paper, VISSIM was used to simulate these weaving sections through an experimental analysis which included major demand, minor demand, weaving length and length minor through traffic split (% Mi THR). The experimental design resulted in scenarios which were simulated using through an Visual Basic program developed specifically for this study. Various programs were developed for the simulation output extraction and manipulation. The first stage...
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

An analysis was dedicated to estimate the capacities of weaving sections, and the minor entrance which were found to have a negatively correlated correlation. Increasing the major demand decrease in the minor entrance capacity and an increase in the capacities of weaving sections. It was also found that increasing capacities increase with the increase in weaving length. However, increasing the length beyond 200 meters was not beneficial. Increasing the minor through split caused an increase in volume ratio and a decrease in capacities. Furthermore, regression analysis was used to develop simulation based capacity prediction models that resulted in a relatively high R² value. The second stage of the analysis covered was dedicated to the extent the application approach of the HCM 2010 weaving methodology when applied to the urban weaving sections. Predicted capacities, lane change rates, and speeds were computed, lane change and non-weaving speeds for each weaving section. Comparisons between the predicted and the simulated estimates with the simulation models showed that the HCM 2010 methodology underpredicted extremely high capacity prediction algorithms up to 1.6 times the capacity estimates almost double the simulated capacity. The HCM 2010 also provided lower capacities for higher weaving lengths, which increased sensitivity to the increase in volume ratio and a lower sensitivity to the increase in weaving length. On the other hand, the developed regression models on the other hand, yielded more accurate estimations that were more consistent with capacities of similar weaving configurations. Further comparisons using tests and parity plots between the simulated and the predicted estimates showed that the HCM 2010 methodology also underpredicted the lane change rates in the weaving sections. The methodology producing higher predicted speeds was more suited to the increase in simulated speeds estimated at each weaving section. Finally, an effort undertaken to calibrate and modify the speed prediction algorithms of the 2010 speed prediction algorithms using the simulation data points, however, did not produce any significant results.

Keywords: VISSIM, Microscopic traffic simulation, Urban weaving, Urban sections, HCM 2010, Capacity analysis, Unconventional intersection treatments

INTRODUCTION

Most of the weaving related research is focused on freeway weaving section due to the complexity of analyzing operations with interruptions to the flow. In urban, environment disturbances to the traffic flow could be causes by various elements, such as cross streets, driveways, traffic signals, yield control, stop signs, pedestrians, on-street parking, and access." In urban environments, there has not been a recognized procedure for the analysis of urban weaving, however, simulation seems to be a reliable and sophisticated analysis approach extending used nowadays to address limitation of available methodologies and complex traffic phenomenon. VISSIM traffic simulator is a very sophisticated microscopic time-based simulation model developed to model urban traffic, and public transportation to pedestrian’s flows. VISSIM offers flexibility in several respects. The concept of links provides a concept of links. It offers a concept of links in the concept of links. It provided a concept of links in the concept of links. It provided a concept of links in the concept of links. It provided a concept of links in the concept of links.
A MICRO SIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO


As consequence of implementing this unconventional intersection treatment, direct left turning (DLT) vehicles of minor street are forced to make a right turn followed by a right turn (RTUT). On the other hand, minor through traffic (Mi THR) are forced to make a RTUT and then a right turn (RT) into the minor approach at the downstream. Left turning traffic of the main street must also utilize the median side lanes to make a U-turn followed by a right turn (UTRT) into the minor approach at the downstream.

The RTUT movement requires a series of lane changes to reach the innermost lane towards the U-turn crossover, thus creating a weaving segment that causes excessive turbulence to the main traffic stream. Similarly, UTRT movement must change lanes to reach the outer lane toward the minor approach creating weaving related turbulence to the main stream flow, as well.

Figure 2: Typical Intersection Treatment in Cairo

Figure 1: Typical un conventional intersection design at an urban corridor in Cairo

The HCM 2010 [1] defines weaving as the crossing of two or more traffic streams without the aid of traffic control devices along a significant length of highway. Traffic passing the weaving section experience turbulence in excess of the normally present on roadway. This additional turbulence causes a reduction in capacity and performance.

In Cairo, many urban intersections have been treated with U-turns as shown in figure the full median opening is substituted with a crossover, downstream of the intersection handle all crossing movements. This treatment does not involve any signals control point. Conflicts between traffic streams are managed through yield signs, therefore, vehicles are forced to yield to the mainstream traffic at all times.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

As a consequence of implementing this type of design, direct left turning vehicle minor street are forced to make a right turn followed by a U-turn (RTUT). On the other hand, minor through traffic (% Mt THR) are forced to make a RTUT and then a right turn (RTUT) on the minor street, downstream of the U-turn crossover. Left turning traffic of the main street must also utilize the median side lanes to make a U-turn followed by a right turn (UT) the minor approach. The RTUT movement requires a series of lane changes to reach main lane towards the U-turn crossover; similarly, UTRT movement must change reach the outer lane toward the downstream minor approach.

Figure 2 shows a close up of the analysed intersection, and illustrates the formation of weaving sections resulting from the local intersection treatment. Ramp to ran and ramp to arterial (R-A) flow components are also shown in the figure.

Figure 22: Formation of weaving sections at intersection (i) and flow components.

Most of the weaving related research focused on freeway weaving sections due to the complexity analyzing operations with interruptions to the traffic flow. In urban, environments, disturbance traffic flow could be caused by various elements, such as cross street access, driveways, traffic yield control, stop signs, pedestrians, on street parking, etc. Despite, being the latest transportation document, the highway capacity manual (HCM 2010) [1], also stops addressing weaving in urban areas and provides a methodology limited to freeway conditions. Practitioners use the HCM 2010 methodology to design and analyze alternative weaving sections. However, using it to address urban sections is controversial.

To date, there has not been a recognized procedure for the analysis of urban weaving However, simulation seems to be a reliable and sophisticated analysis approach that is extensively used nowadays to address limitation of available methodologies and evaluate complex phenomenon. Hence, a simulation approach using VISSIM microscopic simulator was adopted to research address urban weaving sections.

VISSIM is a sophisticated time step and behavioral based simulation model developed to model traffic, public transit and pedestrian flow. VISSIM offers flexibility in several respects. The programmability overcomes the limitation of the graphical interface. In addition, the concept and connectors allows users to model geometries with any level of complexity.

The objective of this paper is to evaluate the capacity of Urban weaving sections using simulation models and test the appropriateness of using the HCM methodology to preoperational measures namely; capacity, lane change rates, speed. The paper also presents and develop several capacity predictions models and calibrate the Speed prediction algorithms 2010 using the simulation data.
Figure 2: Flow components and the formation of weaving sections

6. In this study, a network similar to Figure 1 is coded in VISSIM and used as an experimental setup to analyse weaving sections. The interactions between the four weaving sections are studied. Figure 2 shows a close-up of the analysed intersection and the formation of the section.

8. At weaving section (A), the minor entrance represents the on-ramp and the U-turns the off-ramp. At weaving section (B), the U-turns become the on-ramp and the minor entrance the off-ramp. Weaving length is measured as shown in Figure 2 for both sections.

From the HCM 2010 perspective, these local weaving sections are similar to the two-sided weaving sections. The HCM 2010 methodology states that two-sided weaving sections are similar to the two-sided weaving sections.

BACKGROUND

Freeway weaving has been a subject of extensive research that aimed at improving the HCM analysis methodology. Efforts to design and analyze weaving sections trace back to the fifties, with the first edition of the highway capacity manual HCM 1950. It contained the first weaving analysis methodology. Later in 1965, the manual was updated, and the concept of weaving sections was enhanced by Jack Leisch, introducing the concept of weaving sections.

Over the period from 1965 to 1985, new methodologies and approaches emerged as new concepts such as the proportional use of lanes by weaving and non-weaving vehicles, and the introduction of geometric configurations. The 1985 HCM incorporated new concepts and defined three types of geometric configurations: Type A, Type B, and Type C. Further updates were carried out in 1994 and 1997 where coefficients of the speed estimation equations were revised, and the LOS was altered to be dependent on density rather than six levels.

In 2006, the NCHRP sponsored project 3-75, which led to the development of a new analysis methodology that was later incorporated in the HCM 2010. The study utilized modern data using aerial photography and divided weaving sections into one-sided and two-sided weaving sections. The new approach relied on the lane changing activity within the weaving sections, reflecting the impact of configuration and type of operation on the performance of the sections, which was later merged into levels of service.

Although Section.

Although various methodologies have been established to analyze weaving sections, they are common design elements in the urban roadway system. The previous methodologies have...
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONV. INTERSECTIONS IN CAIRO


This paper presents a microsimulation approach to evaluate operations of weaving sections where vehicles operate under uninterrupted flow conditions and access to ramp locations only. Interrupted flow conditions on the other hand are more complex to manage. For example, traffic simulation is widely used as an alternative analysis tool to efficiently model complex traffic operations of real world physical systems using a computer program. Microsimulation modeling has proven to be a reliable alternative analysis tool that allows researchers to explore traffic phenomenon and conduct experimental analysis with real life or synthetic data computer program.

WEAVISIM is a microscopic freeway simulation program designed specifically for weaving sections. WEAVISIM was used to investigate the effect of different arrival speed on overall speed and delay of ramp weaving sections and develop a regression model to predict measures of performance using a total of 243243 experimental simulation runs [8].

INTRAS is a stochastic vehicle specific time stepping simulation model developed by Wicks and Lieberman [9]. Skabardonis, et al. (1989) utilized INTRAS to simulate weaving freeway weaving sections in California with various types of geometric configurations. Researchers were able to predict weaving and non-weaving speeds that closely matched field observations. Fazio et al. (1990) also used INTRAS to simulate weaving sections and proposed the use of conflict points as a measure of effectiveness for weaving sections modelling instead of speed [11].

FRESIM is a simulation model enhanced and reprogrammed from its predecessor, NETSIM was designed to be more compatible with the characteristics of urban frontage roads. He used data from multiple simulations to develop a density prediction model that managed to set recommendations on the minimum and desired weaving length [14].

INTERSEGMENTATION is a microscopic model developed by Michael Van Aerde [15], Stev H. (1996) estimated Capacities of the weaving sections using INTERSEGMENTATION and stated that length affects capacity only for shorter weaving sections, while the number of lanes is the most critical factor affecting capacity [16]. Zhang & Rakha (2010) Used INTERSEGMENTATION to perform an analysis of three weaving sections in Toronto, Canada and managed to obtain simulated estimates that closely matched field capacities. The study also found that weaving rates influenced the capacity even though it was not accounted for in the HCNG2000 model [17].

VISSIM is a microscopic step by step and behavioral based simulation model developed to urban traffic and public transport operations [18]. The model developed at the University of Karlsruhe in Germany based on the work of R. Wiedemann [1].

A study by Fitzpatrick (2011) utilized VISSIM to investigate relationships between length, speed, and overall vehicle operations for successive ramps on Texas freeways [21]. VISSIM model was calibrated and used as an experimental test bed for a total of 360 scenarios. Factors that were used to design the experiment were traffic volume, weaving length, post-length, and proportion of volumes. Evaluation of the simulation data revealed that weaving length is significant in predicting speed when included as a continuous variable that assumes relationship between speed and weaving length. The study provided guidance on recognizing distances between ramps and used simulation and field data to develop a speed prediction equation function of geometry and traffic.

Liu et al. (2012) used VISSIM to model the impact of cross weave maneuvers on the capacity of freeways with managed lanes [22]. The cross weave weaving maneuver is not considered in the study.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hasha, M.A. Soliman, A.K. and Abo-Hasha, M.A.

the two-sided weaving maneuver described in the HCM 2010. A test bed VISSIM model was carry out multiple runs with different levels of mainstream demand, cross-weave demand, number of lanes, and minimum lane changing distance (LCW-min). Speed-flow curves were derived using Van Aerde’s Curve-curve fitting and capacities were estimated for each scenario. The researchers also developed a simulation based regression model to predict the reducti weaving section capacity as a function of cross weave flow rate, number of mainstream lanes, weaving length with $R^2$ of 0.9837 indicating a perfect fit.

It was concluded that the simulation approach is very reliable and allows researchers to explore the effects of weaving length, minor demand, major demand and various traffic phenomenon and conduct experimental analysis with real life or synthetic data. Based on the comparisons and finding of previous researches, VISSIM traffic simulator fi appeared to be the most suitable software for this research due to its modeling flexi capabilities in conducting weaving related studies of freeway and urban sections.

15. METHODOLOGY

The methodology adopted herein, is an experimental analysis with synthetic demands using microscopic simulation models to simulate urban weaving sections, resulting from intersection design under various combinations of weaving lengths and volume demand. The simulations were conducted using the default parameters of the urban driver behavior in VISSIM.

Experimental analysis often involves the investigation of numerous scenarios. However, there is no scenario manager where one could predefine all the scenarios and all combinations caused the weaving sections to reach capacity which was predicted using the HCM methodology. It was concluded that the simulation approach is very reliable and allows researchers to explore the effects of weaving length, minor demand, major demand and various traffic phenomenon and conduct experimental analysis with real life or synthetic data. Based on the comparisons and finding of previous researches, VISSIM traffic simulator appeared to be the most suitable software for this research due to its modeling flexi capabilities in conducting weaving related studies of freeway and urban sections.

The experimental designs allowed the simulation of the weaving sections at different weaving and non-weaving sections, and under various levels of demand inputs and volume ratios. Some of these demands combinations caused the weaving sections to reach capacity which was predicted using the HCM methodology. After capacities were derived using the simulation, SPSS statistical package was used to develop simulation based capacity prediction models for the urban weaving sections.

Finally, to test the reliability of the HCM 2010 weaving operation methodology, a scenario was applied to the each weaving section to test the methodology’s reliability in representing urban weaving operations, the methodology was applied to the local weaving sections key. Key weaving operational measures were predicted using the HCM methodology, namely, lane change rates, weaving and non-weaving speeds. These predicted measures were compared to those of the simulation models using statistical and graphical methods. Finally, was undertaken to calibrate and modify the investigate the HCM 2010 speed models in representing urban weaving operations when calibrated using non-linear regression using the simulation data points to reflect urban conditions.

3.1 Simulated network

In this study, a network similar to Figure 1 was coded in VISSIM to serve as an experiment to explore the effects of weaving length, minor demand, major demand and the percentage through split on the operations of weaving section (A) and (B) as shown in Figure 2.

The simulated network is similar to the network illustrated in Figure 1. It consists of two at grade intersections, 1 km apart. The simulated network depicts a typical intersection desi...
A microsimulation approach to evaluate operations of weaving sections at urban unconventional intersections in Cairo


1.

is widely adopted at major intersections corridors in the city of Cairo. There is no traffic control
the conflict points; however, yield control is applied at the U-turns and at the major int
through a combination of conflict areas and priority rules features provided by VISSIM.

The main stream has 3 lanes each lane is 3.65 meter wide, while the minor approaches have
3.65 m each also 3.65 meter wide. U-turn slot is a single lane without any acceleration or deceleration
bays, at any point. The posted speed limit is 60 km/hr and a turning speed of 2C assumed for all vehicles. This study focuses on the analysis of the two sections that are formed at one of the intersections only. The study also assumed simila conditions at both intersections. The simulations were conducted using the default parameters urban driver behavior in VISSIM.

15.2 Experimental design

A general factorial design was adopted. The influential factors chosen for the experiment
weaving length (WL), the minor approach demand, the major approach demand, and the proportion
of minor through split (% Mi THR).

Weaving length (WL) was measured as shown in Figure 2 with four levels starting from 100 meters with a 100-meter increment.

The next consecutive set of weaving sections are similar to weaving section (A) and (B) in and volume conditions; therefore, these sections are excluded from the research analysis.

Hypothetical traffic volumes were used in this current study. Minor approach demand ranged from 100 vph to 2000 vph, with a 100 vph increment up to a level of 1000 then the increment is increased to 200 vph (i.e., 15 volume levels). Major approach demand ranged from 1000 vph to 2400 vph, with a 200 vph increment (i.e., 8 volume levels were chosen based on the observed animations of a few trial simulations with low volume conditions to guarantee that these volumes covered a wide range of levels.

All minor approach volume scenarios were modeled with 20% left turn volumes. The major
was modeled with a 10% major LT and 20% major RT. The major approach right turns were divided into two 10% right turns for each intersection.

Minor approach through split (% Mi THR) was defined as 25% of the minor approach for the first through minor split-level (Mi THR) and then increased to 50% minor demand for the second level of (% Mi THR), i.e., minor traffic splits = 25% LT, 55% RT, and then changed to 50% of the minor demand for the second level i.e., (Mi split = 50% THR, 20% LT, 30% RT).

Changing the minor through split was intended to increase the weaving traffic. Increasing the minor through from 25% to 50% increases the percentage of ramp-to-ramp vehicles from 45% to 70% of the minor demand approach.

In total, 960 combination runs were generated using a general factorial design provided by a statistical package. Each weaving length had 120 combination runs for each level of the split (% Mi THR = 25% & Mi THR = 50%).

Weaving section of different length and traffic splits required different configurations; therefore, two test beds corresponding to two levels of Mi THR split for each weaving section were coded. In total, 8 VISSIM models were prepared to run 120 combinations of minor and major volume levels.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

15.3 Automation program development

All 960 scenarios generated by the factorial design were simulated using PTV VISSIM, a traffic simulator through an external program developed in visual basic script. Each needed to be run 3 times with different random number seeds, which makes it 2880 runs. This would have been very time consuming, therefore efficiency required automation of the process using computer programming.

A computer program called AUTOMATE was developed using Excel Visual Basic to automate the scenario runs generated by the factorial design. The program simply changes the major and minor demand volume for each iteration (scenario) automatically using a visual basic next loop. Once iterations are completed, the program moves to another network and the code is repeated again until all networks have been processed. Figure 3 depicts a flow chart that the logic of the developed program where each iteration (scenario) has a unique run order.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONV INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

WEAVING SECTION MODELLING

The VISSIM network is modeled using a system of links and connectors. Conflict; priority rules were used to accurately depict the interaction between crossing streams. Vehicles (vph) were loaded and changed automatically by the developed VBA program. The program immediately loads the predefined network and then the vehicle input (VBA) program is accessed through COM interface to assign vehicle inputs at the proper chosen links. The assigned vehicle input value corresponds to a specific run (scenario) according to the run matrix generated by factorial design and embedded within the program. Static routing was used to route vehicles from a start point (red) to any of the defined destinations (green) using a static percentage for each destination. Routing decisions are similar for each VISSIM network, and Table 1 summarizes the traffic split for each route.

Fig. 3: Routing decisions as modeled in VISSIM

Figure 3: Logic of the AUTOMATE program for automation of simulation runs
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONV


16. WEAVING SECTION MODELLING

The VISSIM network is modeled using a system of links and connectors. Conflict areas and priority rules were used to accurately depict the interaction between crossing vehicle inputs in (vph) were loaded and changed automatically by the develop program AUTOMATE.

The VBA program immediately loads the predefined network and then and access vehicle input object in VISSIM is accessed through COM interface to assign vehicle the proper proper chosen links. The assigned vehicle input value corresponds to a specific run (scenario) according the run matrix generated by factorial design and embedded within the program.

Static routing was used to route vehicles from a start point (red) to any of the defined destinations (green) using a static percentage for each destination. Routing decisions are similar for both intersections and for each VISSIM network. Figure 4 shows all routing decisions as specified in VISSIM and Table 1 summarizes the percentage of traffic split for each route.

Figure 4: Routing decisions as modeled in VISSIM

<table>
<thead>
<tr>
<th>Intersection (i) or (ii)</th>
<th>25 % minor Through</th>
<th>50 % minor Through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Through</td>
<td>70%</td>
<td>70%</td>
</tr>
<tr>
<td>Major Left Turn</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Major Right turn (1)</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Major Right Turn (2)</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Minor (4) Left turn</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Minor (4) Right turn</td>
<td>55%</td>
<td>30%</td>
</tr>
<tr>
<td>Minor (1) Through</td>
<td>25%</td>
<td>50%</td>
</tr>
<tr>
<td>Minor (3) or (2)</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 1: Traffic splits
The percentage of heavy vehicles were assumed 2% for all cases; therefore, all compositions are 98% passenger cars and 2% heavy vehicles. Each vehicle type had a stochastic distribution of desired speed and for this research the speed distribution for cars was 60 km/hr (58 km/hr) while for the heavy vehicles (HGV) the desired speed distribution was selected at 48 km/hr - 58 km/hr.

VISSIM provides a wide range of evaluations that must be defined and configured in order desired model output from the simulation run. The common form of these outputs, are offline text files containing the results delimited by a semicolon. The period of the each run is set to 4500 seconds; however, the first 900 seconds were considered warm up and outputs were collected for last 3600 seconds of simulation. The following evaluations were activated and configured in VISSIM:

- **Link evaluation**: The link evaluation feature allows the user to gather simulation results based on the area of the weaving for the last 3600 sec of the simulation as (density, Throughput, average speed).
- **Lane change rates**: Allows the collection of the total lane change rates executed within each weaving section for the last 3600 sec of the simulation.
- **Data collection Points**: Collects vehicle counts and spot speeds at the major entrance upstream of weaving section (A).
- **Travel time sections**: Allows the collection of travel times and vehicle counts or user defined travel time section. Travel times sections are set up to capture weaving volumes, flow rates and speeds as shown in figure 5.
A microsimulation approach to evaluate operations of weaving sections at urban unconventional intersections in Cairo

Soliman, A.K. and Abo-Hashema, M.A.

Figure 4: Travel time sections as defined in VISSIM

From the HCM 2010 perspective, these local weaving sections are similar in their characteristics to the two-sided weaving sections. The HCM 2010 methodology states that in case of two sided sections the ramp-to-ramp movement is the only weaving movement, while all other movements are considered non-weaving. To maintain consistency with HCM, this research paper adopts definitions to differentiate between weaving and non-weaving flows. Therefore, travel times were set accordingly based on the HCM 2010 definitions of weaving and non-weaving movements shown in Figure 5, where the dashed line represents the weaving flow and the solid lines represent non-weaving flows.

At weaving section (A), the minor entrance represents the on ramp and the U-turns represent the off ramp, while at weaving section (B), the U-turns represent the on-ramp and the minor approach downstream is the off ramp.

Travel time sections produce the average travel time of a number of vehicles passing a use travel time section with a known distance during a specific time interval. By dividing the travel time by the length of the travel time section, the space mean speed of each movement can be calculated.

Analysis of Simulation Results

After 960 simulation runs with 3 different random number seeds were conducted, a total evaluation output files were generated for each individual evaluation type previously configured.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

A.K. Soliman and Abo-Hashema, M.A. Soliman, A.K. and Abo-Hashema, M.A.

to extract the simulation outputs from each file, 4 Visual Basic programs were developed to facilitate the extraction and manipulation of the output data.

4 programs were developed using the same data extraction logic, however, the difference is how the data was organized for each evaluation type.

When executing the program, it automatically prompts the user for the output folder directory. After selecting the directory, the program loops through all the output files importing each file into Microsoft Excel. The program then extracts the evaluation data. The program also calculates the average of all the results for each repeated simulation run with different number seeds and preforms any necessary calculations such as converting the travel times to speeds when extracting the travel time data.

5.1 Capacity estimation using simulation

VISSIM or any other simulation tool does not produce capacity estimates directly. The easiest way to estimate Capacity is to observe the link (Study segment), throughput against an increasing input. The throughput represents the actual vehicles processed by VISSIM, while the input represents the vehicle inputs that are assigned to the simulated network.

At first, the throughput equals the input demand up to a certain point, indicating that the system is not able to accommodate any more vehicles and is operating at its capacity. The throughput represents the actual processed vehicles while the demand represents the inputs that are assigned to the simulated network.

It was also expected to observe that the throughput of weaving section (A) is almost equal to the throughput of section (B). Theoretically, the throughput of weaving section (A), should be equal to the throughput of weaving section (B) assuming similar volume inputs and routing at the next consecutive intersection of the network, in addition to similar number of seeds (i.e., number of seeds, number of runs and seeds for each run).

Figures 6 and 7 show the relationship between the total demand and throughput of weaving sections, and the relationship between maximum demand and throughput respectively. From the surface plot, Figure 6, it is noticeable that the throughput increases with the increase in total demand (Major + Minor) until reaching a certain threshold where it becomes nearly constant and unresponsive to further increases in demand. This point of maximum constant throughput represents the capacity of the weaving section. The graph also shows that the capacity of the weaving section is directly proportional to the major demand level and to the weaving length.

From the same figure, it is also noticed that the throughput decreases with an increase in minor through traffic split. This is attributed to the fact that increasing the percentage of minor vehicles through increased the flow from 45% of the minor demand to 70% leading to a higher minor volume ratio (VR), which causes higher lane changing related turbulence and turbulence, and lower capacities.

Figure 7 shows the simulated capacities of all weaving lengths at each major demand level. The capacities increased with major demand up to a point and then started to level off when major demand exceeded 2000 and 1600 vph respectively for both weaving sections.

---

**Note:** The formatting and layout of the text in the image have been preserved as closely as possible to maintain the readability and coherence of the document content.
It was found that increasing the weaving length beyond 200 meters did not increase the capacity of the sections, on the contrary, capacity was less than the values associated with the shorter length (200 meters) for major demand levels greater than 2000 and 1600 VPH for at 50% Mi THR respectively for both sections.

Capacity difference between sections (A) and (B) for all cases of Mi THR (25% and 50%) was neglected, as the maximum difference did not exceed 2.5%. The slight variation in throughputs between weaving section (A) and (B) is only attributed to the stochastic behavior of the simulation model.
A microsimulation approach to evaluate operations of weaving sections at urban unconventional intersections in Cairo


a. Simulated throughput of weaving section (A) at WL=100m

b. Simulated throughput of weaving section (A) at WL=200m
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

Figure 5: Relationship between total demand and throughput of weaving section (A) at different weaving lengths.

![Graph showing relationship between total demand and throughput of weaving section (A) at different weaving lengths.]

Figure 6: Relationship between weaving section (A) demand and throughput at different weaving lengths.

![Graph showing relationship between weaving section (A) demand and throughput at different weaving lengths.]

25% MI THR
- 500
- 1000
- 1500
- 2000

50% MI THR
- 500
- 1000
- 1500
- 2000

a. Simulated throughput of weaving section (A) at WL = 100m

b. Simulated throughput of weaving section (A) at WL = 200m
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO.

A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO.

Soliman, A.K. and Abo-Hashema, M.A.

Figure 667: Simulated capacities at different weaving lengths.
The impact of volume ratio on capacity is summarized in figure 8 and 9. The points on each graph represent the capacity at a certain major demand level. In figure 8, the relationship between capacity and volume ratio for a weaving length of 100 meters is shown. Figure 9 shows the capacity versus volume ratio for WL = 100.

The reduction in capacity for each pair of capacity estimates at different % Mi THR is represented by a ΔCap on the graph. Although capacities of section (A) and (B) are equal at capacity of weaving section (B) is noticeably lower than its corresponding value of section (A). This explains why sections (B) at some points will operate at a relatively higher LOS than section (A) which is why it should be treated as a separate configuration.

When the weaving length was increased beyond 200 meters as shown in figure 9, capacity increase after major demand exceeded 2000 (vph) and 1600 (vph) for 25% and 50% respectively even though volume ratio seems to be decreasing. From figure 9 it is also noticed that % Mi THR s 25% to 50% is sustained for major demand levels ≤ 1400 (vph).

It is worth mentioning that when length was increased to 200 meters the simulated volume ratio increased. However, the estimated capacities were higher than the shorter weaving sections as the extra length compensates for the capacity losses due to the increase in volume ratio. The volume ratio increases with length due to an increase in the minor entrance throughput of weaving section (A).

When investigating the relationship between the throughput of the minor entrance and the demand, it was noticed that capacities of the minor entrance have a negative correlation with the minor through split. This is why it should be treated as a separate configuration.

The impact of volume ratio on capacity is summarized in figure 8 and 9. The points on each graph represent the capacity at a certain major demand level. In figure 8, the relationship between capacity and volume ratio for a weaving length of 100 meters is shown. Figure 9 shows the capacity versus volume ratio for WL = 100.

The reduction in capacity for each pair of capacity estimates at different % Mi THR is represented by a ΔCap on the graph. Although capacities of section (A) and (B) are equal at capacity of weaving section (B) is noticeably lower than its corresponding value of section (A). This explains why sections (B) at some points will operate at a relatively higher LOS than section (A) which is why it should be treated as a separate configuration.

When the weaving length was increased beyond 200 meters as shown in figure 9, capacity increase after major demand exceeded 2000 (vph) and 1600 (vph) for 25% and 50% respectively even though volume ratio seems to be decreasing. From figure 9 it is also noticed that % Mi THR s 25% to 50% is sustained for major demand levels ≤ 1400 (vph).

It is worth mentioning that when length was increased to 200 meters the simulated volume ratio increased. However, the estimated capacities were higher than the shorter weaving sections as the extra length compensates for the capacity losses due to the increase in volume ratio. The volume ratio increases with length due to an increase in the minor entrance throughput of weaving section (A).

When investigating the relationship between the throughput of the minor entrance and the demand, it was noticed that capacities of the minor entrance have a negative correlation with the minor through split. This is why it should be treated as a separate configuration.
Capacity of the weaving sections increases with the decrease in volume ratio for both cases, through split. The reduction in capacity for each pair of capacity estimates at different % Mi is represented by a ∆Cap on the graph. Although capacities of section (A) and (B) are equal, volume ratio at capacity of weaving section (B) is noticeably lower than its corresponding value of section (A) for both levels of minor through traffic. This explains why sections (B) at some points will operate at a relatively higher LOS than section (A).

When the weaving length was increased beyond 200 m, capacities did not increase after major demand exceeded 2000 (VPH) and 1600 (VPH) for 25% and 50% Mi THR respectively even though volume ratio seems to be decreasing as shown in figure 9.

![Figure 8: Capacity versus volume ratio for WL= 300](image)

Form the same figure it is also noticeable that ∆Cap is associated with a major demand (VPH) for weaving sections (A) and (B) respectively is minimum. Which indicates that the turbulence resulting from increasing the Mi THR split from 25% to 50% is sustained for major demand 1400 VPH. After major demand exceeds these values a decrease in capacities is noticed however this decrease is not more than 8% for both weaving sections.

It is worth mentioning that when length was increased to 200 m the simulated volume ratios however, the estimated capacities were higher than the shorter weaving section (100 m) as the length compensates for capacity losses due to the increase in weaving intensity as volume increases.

The volume ratio increases with length as a consequence of an increase in minor throughput of weaving section (A). When investigating the relationship between the throughput of the entrance and minor demand it was noticed that capacities of the minor entrance have a relatively lower LOS than section (A).
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

The capacities of the weaving sections are inversely proportional to the major demand and directly proportional to the weaving length up to 200 meters. Increasing the length beyond 200 meters does not increase the capacity of the minor approach as shown in the Figure 10.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

Figure 9: Minor entrance capacities at all levels of major demand and at different weaving lengths.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO
Soliman, A.K. and Abo-Hashema, M.A.

5.2 Simulation based capacity prediction models
Simulation based Capacity prediction models were developed to predict the capacity of section (A) and (B) for a specific length. These models, however, are limited to a weaving length and the range of data used to develop the models. In addition, the models constrained to the assumptions made for the study network. Increasing the weaving length beyond 200 meters was not beneficial as illustrated and therefore no models were developed for these lengths.

Linear and non-linear regression procedures provided by the Statistical analysis software SPSS were utilized to develop two capacity prediction models as illustrated below shown below.

For WL of 100 m the following models were developed:

**Model 1111: Logarithmic Capacity Prediction Model**

For section (A):

$\text{CAP} = 875.184172 \times \ln(\text{MD}) - 1.287523 \times \text{VR} \times \text{MD} - 3433.603297$

For Section (B):

$\text{CAP} = 1053.65 \times \ln(\text{MD}) - 1.065 \times \text{VR} \times \text{MD} - 4016.67$

**Model 2222: Linear Capacity Prediction Model**

- For section (A):
  
  $\text{CAP} = 2510.466 + 0.33 \times \text{MD} - 0.865 \times V_{W}$

- Where,
  
  - $\text{CAP}$: Weaving section Capacity capacity in VPH-vph
  - $\text{MD}$: Major Approach approach Demand demand in VPH
  - $\text{VR}$: Volume Ratio ratio at weaving section (A) or (B)
  - $V_{W}$: Weaving flow in VPH (i.e. the ramp to ramp-to-ramp vehicles).

The $R^2$ values...
A MICRO SIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

logarithmic models are relatively high (0.992) which indicates a perfect fit. The negative coefficient of volume ratio is also logical which means that when volume ratio is increased, capacity decreases. The R² value of the linear models are also high, (0.975) are respectively, and all coefficient signs are also relevant indicating logical correlation between dependent variable and the predictors.

For WL of 200 m the following models were developed:

- Model 3333: Logarithmic Capacity Prediction Model
  
  For section (A):  
  \[ \text{CAP} = 866.1925.075 \times \ln(\text{MD}) - 0.298 - 0.312 \times \text{VR} \times \text{MD} - 3538.473956.661 \]
  
  For section (B):  
  \[ \text{CAP} = 949.27 \times \ln(\text{MD}) - 0.42 \times \text{VR} \times \text{MD} - 4111.98 \]
  
  \[ \text{CAP} = 925.075 \times \ln(\text{MD}) - 0.312 \times \text{VR} \times \text{MD} - 3956.661 \]

- Model 4444: Linear capacity prediction model
  
  For section (A):  
  \[ \text{CAP} = 1977.41 + 0.495 \times \text{MD} - 0.1 \times \text{VW} \times \text{CAP} = 1912.324 + 0.556 \times \text{MD} - 0.129 \times \text{VW} \]
  
  For section (B):  
  \[ \text{CAP} = 1968.56 + 0.52 \times \text{MD} - 0.16 \times \text{VW} \times \text{CAP} = 1912.324 + 0.556 \times \text{MD} - 0.129 \times \text{VW} \]

The R² values for of the logarithmic models is equal (0.983961) and (0.968), which is high while the linear model has a R² respectively, which is relatively high, while the linear model have an R² values of (0.96929) and (0.932), respectively. All models coefficient signs are also high. All models have relevant signs indicating logical correlation between the dependent variable and the predictors.

5.3.1 Applicability

To facilitate the application of HCM, an excel based calculation sheet was developed to the operational measures of weaving section (A) and (B) using the simulated weaving volumes obtained from 960 simulation runs. All the algorithms embedded in the calculation sheet is explained in the HCM 2010 chapter 12[1].

- The HCM 2010 presents a straightforward equation to estimate the lane capacity of weaving sections, which in this case will be a two-sided weaving section, make comparisons possible some adjustments were made to the capacity values derived in HCM 2010 to be more compatible with the capacities estimated using VISSIM. These adjustments as following:
  
  - Simulated capacities are provided for the entire section therefore, HCM capacities are multiplied by the number of lanes N=3.
  - Simulated capacities are were given obtained in [X] and therefore, HCM capacities should be adjusted to [X] using the weaving vehicle factor FHV.
  - Weaving Length should be in units of feet.

The following equation is used to estimate the capacity of the weaving section in HCM 2010:
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

\[ C_{WLT} = C_{FPL} - [438.2(1 + VR)^{1.6}] + [0.0765L_{S}] + [119.8N_{WL}] \]

capacity of the weaving segment under equivalent ideal conditions, per lane (pc/h/ln)

\[ F_{W} = \frac{V_{R}}{L_{S}} \]

length of the weaving segment (ft), number of lanes from which a weaving maneuver may be made with one or no lane changes for two-sided weaving section \( N_{WL} = 0 \)

The comparison is established for the urban weaving sections studied in this research, i.e., number of lanes is 3 lanes - configuration is a two-sided weaving section, number of weaving lanes \( N_{WL} = 0 \), and FFS = 60 km/h (37.5 mph). No base capacity was established for speeds less than 55 mi/h in HCM 2010 therefore, base capacity per lane was assumed 1800 vph. Factor of heavy vehicles calculated using the methodology provided in chapter 11 of the HCM 2010 [1]. It is evident that the HCM model overpredicts capacities and should not be used for similar urban configurations. Capacities predicted by HCM are at some points more than double the simulated C/IWL capacity of the weaving segment under equivalent ideal conditions, per lane (pc/h/ln). Capacities predicted by HCM are at some points more than double the simulated per lane (pc/h/ln) capacity of a basic freeway segment with the same FFS as the weaving segment under equivalent ideal conditions, per lane (pc/h/ln).

The following Figure 11 shows a comparison of the relationship between the simulated capacities predicted using the developed models and the HCM 2010 model capacity for weaving section (A).
Attempts to calibrate the HCM model structure to fit the simulated capacities using non regression yielded very low $R^2$ values indicating that the model structure itself is not suit this type of urban weaving section and the develop model structure clearly is better and suitable for this type of weaving section.

### 5.3.2 Lane change rates

The speed prediction models of the HCM 2010 mainly depends on the rate of lane changes $v$ weaving section of study. The total lane-changing rate of all vehicles in the weaving s computed by combining weaving lane change rates and non-weaving lane change.

#### The model for predicting weaving lane changing rate in HCM 2010 is as following:

$$\text{LC}_{\text{MIN}} = \text{LC}_{R} \times \text{V}_{W}$$

Where,

- $\text{LC}_{MIN}$ Minimum equivalent hourly rate weaving vehicles must make to successfully complete all weaving maneuvers
- $\text{LC}_{R}$ Minimum number of lane changes that must be made by one ramp to ramp vehicle to execute the desired maneuver successfully
- $\text{V}_{W}$ Weaving volume in pc/h
- $\text{LC}_{W}$ Equivalent hourly rate at which weaving vehicles make lane changes within the weaving section (Le/h);
- $L_{S}$ Length of the weaving section (ft);
- $N$ Number of lanes within the weaving section;
- ID Interchange density.

For the urban two-sided weaving sections studied in this research $\text{LC}_{R}=2$, and ID is 0.67.

#### The model for predicting non-weaving lane changing rate in HCM 2010 is as following:

- First, a non-weaving vehicle index, $\text{I}_{NW}$, needs to be calculated and then depending on the non-weaving lane changing rates are calculated using one of the three non-weaving change rate equations below.
In VISSIM, lane change evaluations were set to calculate the total number of lane changes per hour that occurs at each weaving section. Paired t-tests were executed using SPSS statistical package to test the null hypothesis, which states that there is no significant difference between the simulated and the predicted lane changes at section (A) and (B) for each weaving length.

Parity plots of the simulated versus predicted estimates were also generated, which gives description of the relationship between the observed simulated and the predicted values. If the points of the plots to the 45° Line, the more accurate the predicted speeds. If points are on t the 45° Line, predicted lane changes are generally larger while predicted lane changes are lower for the points are to the right of the line.

Parity plots are shown in figure 12 for weaving length of 100 and 200 meters as an example. By examining the plots, it is evident that there is a moderate to high magnitude of fit and positive correlation between the predicted and the simulated values. Clearly most of the plot of points to the 45° Line, the more accurate the description of the relationship between the simulated and the predicted lane changes at section (A) and (B) for each weaving length.

The following table shows the result of paired t-test with a significance value < 0.05 indicates a statistically significant difference between the simulated and the predicted values; the predicted values, and thereby rejecting the null hypothesis.
From the previous section, it was concluded that the lane change prediction models by HCM 2010 clearly under-predicts the rate of lane changes for this type of urban weaving sections. Consequently, the predicted speeds are likely to be higher than the actual speeds.

<table>
<thead>
<tr>
<th>Pair</th>
<th>Simulated LC – HCM LC</th>
<th>Paired Samples Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 6</td>
<td>646.39</td>
<td>391.31</td>
</tr>
<tr>
<td>Pair 7</td>
<td>352.22</td>
<td>411.38</td>
</tr>
<tr>
<td>Pair 8</td>
<td>524.27</td>
<td>430.23</td>
</tr>
</tbody>
</table>

**Table 22:** Lane change rates Paired Samples Test.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

Figure Fig. 11: Parity plots for the simulated versus predicted lane change rate for WL=100 and 200 meters.

a. HCM 2010 Predicted total lane change rates versus Simulated total lane change rates for WL=100 m

b. HCM 2010 Predicted total lane change rates versus Simulated total lane change rates for WL=200 m

Simulated Lane change rates (L.C/h)

Simulated total Lane change rates (L.C/h)

Regression

Regression

Regression

Regression
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

5.3.3 weaving and non-weaving speed ($s_w, s_{nw}$)

The HCM 2010 presented two models for the prediction of weaving and non-weaving speed models and dependant on the rate of lane changes where speeds would decrease with increasing lane changing activity – a real measure of weaving intensity. It is worth mentioning that the predication of non-weaving vehicle speed is the weakest part of the HCM 2010 methodology [6].

\[ S_w = 15 + \frac{FFS - 15}{1 + W} \]

\[ W = 0.226 \cdot \left( \frac{LC_{ALL}}{LC_{MIN}} \right)^{0.789} \]

(Weaving speed prediction)

\[ S_{NW} = FFS - (0.0072 \cdot LC_{MIN}) \left( \frac{0.0048 \cdot \sqrt{V}}{N} \right) \]

(Non-weaving speed prediction)

Where,

- $S_w$: Average speed of weaving vehicles in (mi/h);
- $s_{nw}$: Average speed of non-weaving vehicles in (mi/h);
- $LC_{MIN}$: Minimum lane change rate depending on geometry;
- $LC_{ALL}$: Total rate of lane changes;
- $N$: Number of lanes in the weaving section;
- $FFS$: Free flow speed;
- $V$: Total flow rate in pcu;
- $W$: Weaving intensity factor;
- $V$: Total flow rate in pcu;
- $LS$: Weaving length in ft.

In VISSIM, travel time sections were utilized to capture the weaving and non-weaving speeds of both weaving section (A) and (B) and the travel time sections were set based on the definitions of weaving and non-weaving movements to maintain consistency when comparing simulated and predicted samples.

All HCM predicted weaving and non-weaving speeds that were estimated using HCM 2010 were previously-converted into Km/h for consistency as well in the HCM 2010 calculation sheet previously developed for this study.

A Paired sample t-test was carried out to compare the simulated and predicted weaving speeds and parity plots were also developed generated for each weaving length. Figure 14-13 shows parity plots for weaving length of 100 and 400 meters example.

As expected the HCM models over predicted the speeds of all movements as shown in the plots. The Goodness of fit ($R^2$) was very small and all the plotted points were on the left side of the 45° line, which means that the predicted speeds are higher.

It is also noticeable that the simulated speeds were more spread compared to that of the predicted speeds; however, there is a significant degree of linearity and a positive correlation. The weaving and non- weaving speeds failed the T-test with significance value $< 0.05$ and concluded that the speeds were significantly different as shown in Table 3.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

Table 3333: Weaving and non-weaving speeds Paired Samples Test

<table>
<thead>
<tr>
<th>Daily WL Sections</th>
<th>Paired Differences Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 WL=100 A</td>
<td>Simulated Sw – HCM Sw</td>
<td>-25.43</td>
<td>4.43</td>
<td>.29</td>
<td>-25.99</td>
<td>-24.87</td>
<td>-89.01</td>
</tr>
<tr>
<td>Pair 2</td>
<td>Simulated_Snw – HCM Snw</td>
<td>-13.84</td>
<td>8.72</td>
<td>.56</td>
<td>-14.95</td>
<td>-12.73</td>
<td>-24.58</td>
</tr>
<tr>
<td>Pair 3 B</td>
<td>Simulated Sw – HCM Sw</td>
<td>-21.41</td>
<td>1.48</td>
<td>.10</td>
<td>-21.60</td>
<td>-21.22</td>
<td>-223.38</td>
</tr>
<tr>
<td>Pair 4 B</td>
<td>Simulated_Snw – HCM Snw</td>
<td>-14.68</td>
<td>4.54</td>
<td>.29</td>
<td>-15.26</td>
<td>-14.11</td>
<td>-50.13</td>
</tr>
<tr>
<td>Pair 5 WL=200 A</td>
<td>Simulated Sw – HCM Sw</td>
<td>-17.80</td>
<td>6.41</td>
<td>.41</td>
<td>-18.62</td>
<td>-16.99</td>
<td>-43.02</td>
</tr>
<tr>
<td>Pair 6 B</td>
<td>Simulated_Snw – HCM Snw</td>
<td>-5.77</td>
<td>7.52</td>
<td>.49</td>
<td>-6.72</td>
<td>-4.81</td>
<td>-11.88</td>
</tr>
<tr>
<td>Pair 7 B</td>
<td>Simulated Sw – HCM Sw</td>
<td>-17.38</td>
<td>3.73</td>
<td>.24</td>
<td>-17.86</td>
<td>-16.91</td>
<td>-72.11</td>
</tr>
<tr>
<td>Pair 8</td>
<td>Simulated_Snw – HCM Snw</td>
<td>-15.97</td>
<td>8.92</td>
<td>.58</td>
<td>-17.10</td>
<td>-14.84</td>
<td>-27.72</td>
</tr>
<tr>
<td>Pair 9 WL=300 A</td>
<td>Simulated Sw – HCM Sw</td>
<td>-14.03</td>
<td>10.74</td>
<td>.69</td>
<td>-15.39</td>
<td>-12.66</td>
<td>-20.24</td>
</tr>
<tr>
<td>Pair 10</td>
<td>Simulated_Snw – HCM Snw</td>
<td>-6.53</td>
<td>12.84</td>
<td>.83</td>
<td>-8.16</td>
<td>-4.90</td>
<td>-7.88</td>
</tr>
</tbody>
</table>
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

<table>
<thead>
<tr>
<th>Pair</th>
<th>VL=400</th>
<th>B</th>
<th>Simulated Sw – HCM Sw</th>
<th>-27.11</th>
<th>3.75</th>
<th>.24</th>
<th>-27.59</th>
<th>-26.63</th>
<th>-112.00</th>
<th>239.00</th>
<th>.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 12</td>
<td></td>
<td>B</td>
<td>Simulated_Snw – HCM Snw</td>
<td>-14.80</td>
<td>11.58</td>
<td>.75</td>
<td>-16.28</td>
<td>-13.33</td>
<td>-19.80</td>
<td>239.00</td>
<td>.00</td>
</tr>
<tr>
<td>Pair 13</td>
<td></td>
<td>A</td>
<td>Simulated Sw – HCM Sw</td>
<td>-11.48</td>
<td>11.17</td>
<td>.72</td>
<td>-12.90</td>
<td>-10.06</td>
<td>-15.91</td>
<td>239.00</td>
<td>.00</td>
</tr>
<tr>
<td>Pair 14</td>
<td></td>
<td>B</td>
<td>Simulated_Snw – HCM Snw</td>
<td>-4.47</td>
<td>13.04</td>
<td>.84</td>
<td>-6.12</td>
<td>-2.81</td>
<td>-5.31</td>
<td>239.00</td>
<td>.00</td>
</tr>
<tr>
<td>Pair 15</td>
<td></td>
<td>B</td>
<td>Simulated Sw – HCM Sw</td>
<td>-12.79</td>
<td>7.24</td>
<td>.47</td>
<td>-13.71</td>
<td>-11.87</td>
<td>-27.37</td>
<td>239.00</td>
<td>.00</td>
</tr>
<tr>
<td>Pair 16</td>
<td></td>
<td>B</td>
<td>Simulated_Snw – HCM Snw</td>
<td>-13.07</td>
<td>11.93</td>
<td>.77</td>
<td>-14.59</td>
<td>-11.56</td>
<td>-16.97</td>
<td>239.00</td>
<td>.00</td>
</tr>
</tbody>
</table>
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

1
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONV. INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

Figure 12: Parity plots of simulated versus the predicted weaving and non-weaving speeds

Figure 14: Parity plots of HCM 2010 predicted speeds versus VISSIM simulated speeds for WL = 100 m

Figure 15: Parity plots of HCM 2010 predicted speeds versus VISSIM simulated speeds for WL = 400 m
8.4 Calibrating the HCM speed prediction models

Using the non-linear regression procedure in SPSS, an effort was undertaken to calibrate the HCM speed prediction algorithms with using the simulation data points to represent more accurately the hope of representing better urban conditions. The model original forms use a minimum speed of upper and lower 15 mph and a maximum speed equal to the free flow speed FFS(FSS).

The minimum value observed from simulated simulation models speeds for the urban sections were lower than 15 mi/h, therefore the original models were modified by using the actual observed minimum speed of 6 mi/h. Also all lengths were used in units.

Each weaving section was considered as a separate configuration. Free flow speed (FFS) value of 37.5 mi/h (60 km/h) was used for substituting the FFS in SPSS; therefore, the model format was used as following:

\[ S_W = 6 + \frac{FFS - 6}{1 + W} \]

where \( W_{wW} = 0.322437 \times \left( \frac{L_{CAM}}{L_S} \right)^{1.385716} \)

The calibrated model resulted in \( R^2 \) of 0.54 which is not bad when compared to a 0.614 obtained by freeway based data [6].

Calibrated Weaving speed prediction model for Section (B):

\[ S_W = 6 + \frac{FFS - 6}{1 + W} \]

where \( W_{wW} = 0.557494 \times \left( \frac{L_{CAM}}{L_S} \right)^{0.787467} \)

The calibrated model resulted in an \( R^2 \) of 0.343 compared to the previous calibrated model.

Attempts to calibrate the non-weaving speed prediction model failed to produce any significant results, which was quite expected given that, the non-weaving speed prediction model was a weak part of the HCM 2010 weaving analysis methodology [6].

In view of the above, it is evident that the structure of the model gives a very low \( R^2 \) even for section (A). On the other hand, efforts to calibrate the non-weaving speed prediction model provided 2010 failed completely Therefore, it is not recommended for any future attempts.

In view of the above, it is evident that speed prediction is extremely difficult and rarely results in statistically acceptable models.

\[ S_W = 6 + \frac{FFS - 6}{1 + W} \]
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

CONCLUSION

This paper presented an effort to model and simulate urban weaving sections resulting from an unconventional intersection design adopted widely in Cairo, Egypt. Due to this design type, and the lack of traffic control, merging of minor traffic into the mainstream and its ability to cross-weave is greatly affected by major approach demand. Higher major approach volumes produces lesser minor merging traffic, therefore lesser minor approach throughput and capacity. Each major demand was associated with a maximum throughput that can propagate through the entrance ramp i.e. capacity of the entrance ramp.

It was found that at some point, continuous increase in weaving length does not necessarily improve traffic operations and could reduce the capacity and LOS. It was also concluded that 200 meters is the optimum length for maximum capacity and throughput of the weaving sections and the minor entrance. However, it is recommended to try to experiment lengths between 200 and 300 m for future work. It is worth mentioning that Michigan department of transportation (MDOT) recommends a weaving length of 200 ± 30 m as the optimum weaving length for efficient operations which agrees with the findings of this research.

From the comparative analysis with HCM 2010 methodology, it was concluded that, methodology for these types of urban weaving configurations will produce unreliable HCM 2010 models are more likely to predict lower lane changing rates, overestimated capacities and higher speeds. This is probably attributed to the fact that the prediction models of the HCM 2010 were designed for freeway conditions which involves lower rates of lane changes, higher speeds and higher capacities compared to urban conditions. It was also concluded that the HCM capacity model structure fails to compensate the capacity losses due to the increase in weaving ratio when length increases.

Efforts to calibrate the speed prediction algorithms revealed that the original structure of the models is not suited to represent weaving operation even when fitted and calibrated with the simulation data points. It was also concluded that speed prediction of weaving operations is extremely difficult, and rarely produces “statistically acceptable” results.

Utilizing this intersection design at areas with high crossing demand volumes are likely to cause spills back into the minor approach and enhances the chances of forming a bottleneck at the conflict point between the arterial and the crossing.

At high crossing demands, mainstream vehicles penetrates through the section with very low speeds and could be forced to queue with the U-turning vehicles until sufficient gap arises. Therefore, efficient weaving operations the design should be implemented at areas with low crossing conditions and cannot be used at major intersections.

This study assumed similar volume condition at both intersection of the simulated network. Intersection with different volume conditions will result in a more complex weaving operation with 4 weaving section interacting with each other. This can be for future work.
A MICROSIMULATION APPROACH TO EVALUATE OPERATIONS OF WEAVING SECTIONS AT URBAN UNCONVENTIONAL INTERSECTIONS IN CAIRO

Soliman, A.K. and Abo-Hashema, M.A.

REFERENCES