Journal of Al Azhar University Engineering Sector
Vol. 11, No. 40, July, 2016, 1015-1037

JAUES

A MICROSIMULATION APPROACH TO EVALUATE OPERAT OF WEAVING SECTIONS AT URBAN UNCONVENTIONAI INTERSECTIONS IN CAIRO

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الآونة الأخيرة ظهور طرق غير تقليدية لمعالجة بعض التقاطعات رباعية الارجل بمدينة القاهرة. ~~طرق~~ هذه
طرق ~~هذه~~ لا تتضمن ~~أي~~ استخدام إشارات مرورية للتحكم في التقاطع ولكنها تتضمن اغلاق الجزيرة الوسطي
نع المرور المباشر من خلالها والاعتماد الكلي على فتحات الدوران الي الخلف وبالتالي تتقاطع مسارات
انوي مع مسارات الطريق الرئيسي وتتكون قطاعات تقاطع المسارات على جانبي الجزيرة الوسطي. هذه
ول النمذجة والمحاكاة المرورية لقطاعات تقاطع المسارات الناتجة عن هذا النوع من التقاطعات الرباعية وذلك
نامج ~~فيزيم~~ (VISSIM) للمحاكاة المرورية~~.~~ التي اتاحت ~~المحاكاة المرورية~~ اختبار القطاعات تحت تأثير احجام
تلفة واطوال قطاعات مختلفة كما اتاحت أيضا حساب ~~السعات~~ السعة المرورية للقطاعات المختلفة ~~للقطاعات~~
ض المعادلات للتنبؤ بالسعة المتوقعة بطريقة تحليل الانحدار. ~~بعد حساب سعات القطاعات تمت~~تتضمن الدراسة
ب سرعات المسارات المختلفة بكل قطاع بالإضافة الي ~~العدد~~ معدل الكلي لتغير الحارة المرورية ~~تغيرات~~
لي ~~و~~ذلك لمقارنتها بالقيم المحسوبة باستخدام المعادلات ~~الموضوعة~~ الموجودة بدليل سعة الطريق (HCM 2010)
بتصميم و تحليل قطاعات تقاطع المسارات~~من قبل مجلس بحوث النقل والأكاديمية الوطنية للعلوم في الولايات~~
~~مقارنة~~ المقارنة ~~القيم المحسوبة بالمحاكاة~~ وجد ان المعادلات دليل سعة الطريق (HCM 2010) ~~الموضوعة~~ لا
هذا النوع من القطاعات ~~و~~ذلك لأن المعادلات الموضوعة تعطي قيم~~م~~ سعات مرورية ~~غير منطقية~~أكبر
سارات اعلي من المتوقع بالإضافة الي ~~اعداد~~ معدل اقل لتغير ~~التغير~~حارة المرورية~~ات اقل~~. لذلك توصي
م استخدام المعادلات الخاصة بدليل سعة الطريق (HCM 2010) لتصميم او تقييم اداء قطاعات تقاطع المسارات
ع في المناطق الحضرية ويفضل استخدام النماذج المذكورة في هذا البحث بعد اجراء المعايرة المطلوبة.

ABSTRACT~~:~~

Unconventional median U-turn intersections ~~intersection treatments~~ have been ex implemented along major corridors in Cairo, ~~,~~ Egypt. These unconventional ~~tr~~ intersections do not involve signalization ~~ve any signal control~~ at any ~~point, they~~poi utilize –a non-traversable median with a U-turn crossover at the downstream to ma crossing ~~movements, thus~~ movements and thus, creating ~~a~~ two-sided weaving between the minor approach and the U-turn -crossover~~between the minor approach ar turn slot on both sides of the median. In~~. In this paper, VISSIM ~~is~~ was used to m simulate these weaving sections through~~out~~ an experimental analysis ~~with~~ with influential factors namely;~~;~~ major demand, minor demand, weaving ~~length and~~length minor through traffic ~~split~~split (% Mi THR). The experimental design resulted ~~scenarios which~~scenario runs, which were ~~simulated~~ automated ~~using~~ through an Visual Basic program developed specifically for this stud~~y. Various programs w developed for the simulation output extraction and manipulation~~. The first stag

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

~~Soliman, A.K. and Abo-Hashema, M.A.Soliman, A.K. and Abo-Hashema, M.A.~~
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analysis ~~was dedicated~~was dedicated to estimate the capacities of ~~to estimate the cap~~
the weaving sections and the minor ~~entrance which~~entrance, which were found ~~t~~
negatively ~~correlation~~ correlated. ~~with each other.~~Increasing the major demand
decrease in the minor entrance capacity and an increase in the capacities of the
~~It~~sections. It –was also found that ~~increasing~~ capacities increase with the increa
weaving length–; however, increasing the length beyond 200 meters was not b
Increasing the minor through split caused an increase in volume ratio and a de
capacities~~ Furthermore~~. Furthermore, regression analysis was used to develop~~,~~
simulation based capacity prediction models that resulted in a relatively high R^2 val
second stage of the analysis ~~covered~~ was dedicated to ~~the~~test the ~~application~~ approp
of the HCM 2010 weaving methodology ~~to~~ when applied to the urban weaving se
predict capacities, lane change rates, and speeds~~compute capacities, lane chan~~
~~weaving and non-weaving speeds for each weaving section~~. Comparisons betw
predicted and the simulated estimates ~~with the simulation models s~~showed that
HCM 2010 ~~2010~~ methodology ~~provides~~ provided higher ~~extremely high~~capacity pr
up to 1.6 times the ~~capacity estimates almost double the~~ simulated ~~capacities~~capaciti
~~HCM 2010 also provided lower capacities for higher weaving lengths, which inc~~
~~higher sensitivity to the increase in volume ratio and a lower sensitivity to the in~~
~~weaving length .~~On the other hand, ~~The~~the developed regression models ~~on the ot~~
~~provided~~ produced capacity ~~more accurate estimations~~estimations that were more
This provided evidence that the structure of the developed models ~~were~~ is more s
represent capacities of similar weaving configurations. Further comparisons using
tests and parity plots ~~between the simulated and the predicted estimates~~ showed tha
~~2010~~the HCM 2010 methodology also underpredicted ~~the~~ lane change ~~rates in the~~
~~section~~rates; ~~s and thereby~~ therefore, ~~producing higher~~ speed predictions were higher
simulated speeds ~~estimates~~at each weaving section. ~~. Finally~~Finally, an effort
~~undertaken~~ carried out to calibrate and modify the speed prediction algorithms of t
~~2010~~ 2010~~speed prediction algorithms using the simulation data points,~~; however, t
did not ~~produce~~ yield any significant results.

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

INTRODUCTION

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~~Most of the weaving related research is focused on freeway weaving section du~~
~~complexity of analyzing operations with interruptions to the flow. In urban, envir~~
~~disturbances to the traffic flow could be causes by various elements such as cr~~
~~access, driveways, traffic signals, yield control, stop signs, pedestrians, on street park~~

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~~Despite, being the state of the art transportation document, the HCM 2010 also stops~~
~~addressing weaving in urban areas with interrupted flow conditions .It pr~~
~~methodology limited to freeway conditions. Practitioners use the HCM 2010 metho~~
~~design and analyze alternative weaving sections. However, using it to address urban~~
~~is controversial.~~

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~~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 approac~~
~~extensively used nowadays to address limitation of available methodologies and~~
~~complex traffic phenomenon. VISSIM traffic simulator is a very sophisticated time~~
~~behavioral based simulation model developed to model urban traffic, and public tra~~
~~addition to pedestrian's flows. VISSIM offers flexibility in several respects. The s~~
~~programmability overcomes the limitation of the graphical interface. Also the concep~~

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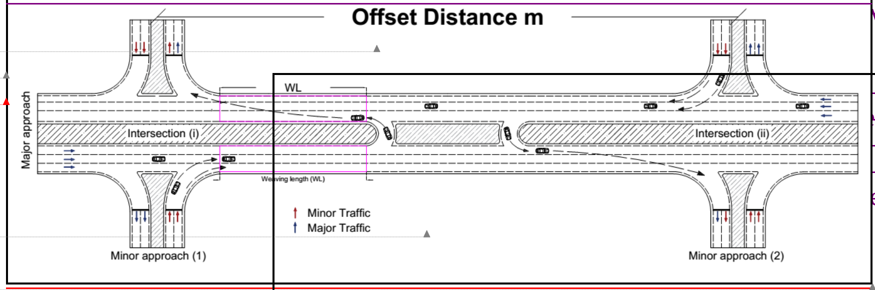

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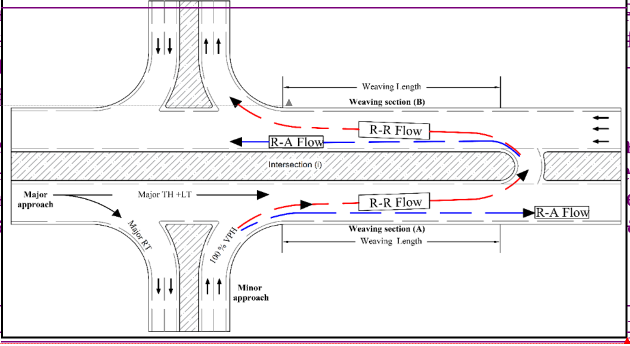
~~**Figure 1: Typical Intersection Treatment in Cairo**~~

~~As consequence of implementing this unconventional intersection treatment, di turning (DLT) vehicles of minor street are forced to make a right turn followed by a (RTUT). On the other ha RT then a right turn (RT) int f street must also utilize t r (UTRT) into the minor ap~~



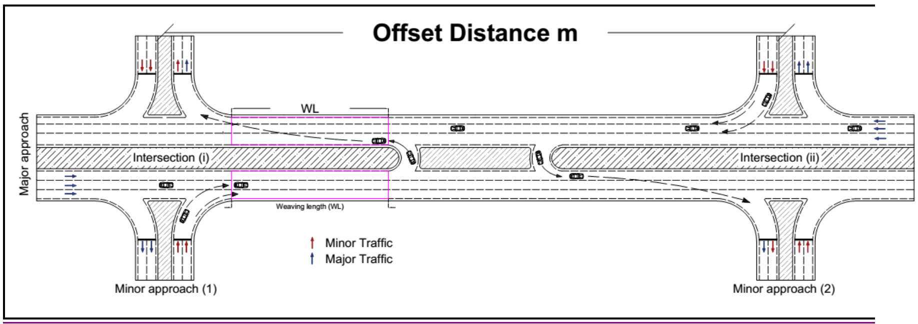
~~The RTUT movement re he the U-turn crossover, thu en main traffic stream. Sim o toward the minor appro a flow, as well.~~

~~Figure 2 illustrates the t intersection treatment. F~~

~~Flow components and the formation of weaving sections~~

The HCM 2010 **[1]** defines weaving as the crossing of two or more traffic streams wi 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 interse handle all crossing movements. This treatment does not involve any signals contro point. Conflicts between traffic streams are managed through yield signs, therefore, vehicles are forced to yield to the mainstream traffic at all times.



Fig~~ure~~. 1~~11~~~~:~~. Typical unconventional intersection design at an urban corridor in Cairo

~~1~~

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 otl minor through traffic (% Mi THR) are forced to make a RTUT and then a right turn (the minor street, downstream of the U-turn crossover. Left turning traffic of the ma 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 most 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 formatic urban 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.

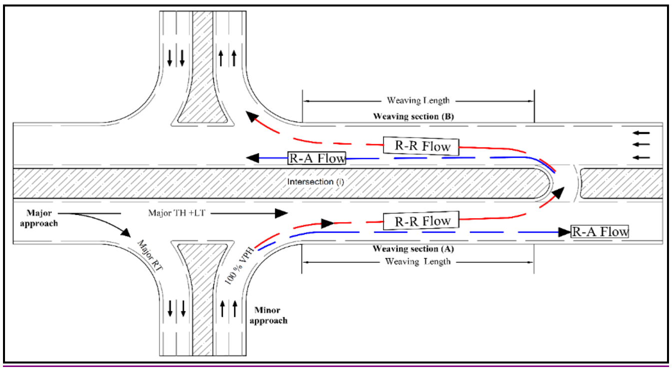


Figure 2~~22~~: Formation of weaving sections at intersection (i) and flow components.

Most of the weaving related research focused on freeway weaving sections due to the com analyzing operations with interruptions to the traffic flow. In urban, environments, disturban traffic flow could be caused by various elements, such as cross street access, driveways, traffi yield control, stop signs, pedestrians, on street parking, etc. Despite, being the latest state transportation document, the highway capacity manual (HCM 2010) **[1]**, also stops addressing weaving in urban areas and provides a methodology limited to freeway c Practitioners use the HCM 2010 methodology to design and analyze alternative weaving 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 ex used nowadays to address limitation of available methodologies and evaluate comple phenomenon. Hence, a simulation approach using VISSIM microscopic simulator was adopt research to address urban weaving sections.

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

~~1.~~ The objective of this paper is to evaluate the capacity of Urban weaving sectio simulation models and test the appropriateness of using the HCM methodology to pr operational measures namely; capacity, lane change rates ,speed. The paper also presents ar develop several capacity predictions models and calibrate the Speed prediction algorithms 2010 using the simulation data.

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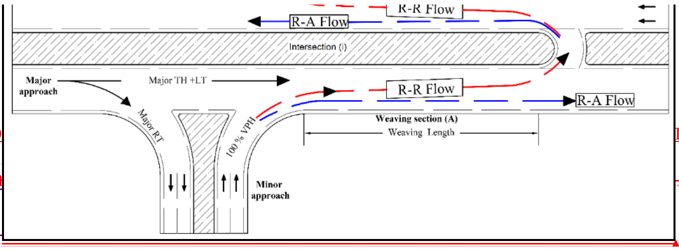

~~5. Figure 2: Flow components and the formation of weaving sections~~

~~6. In this study, a network similar to Figure 1 is coded in VISSIM and used as an exp~~
~~test bed to explore the effects of weaving length, minor demand, major demand and the pro~~
~~minor through on the operations of weaving section formed at intersection (i) shown in Figu~~
~~analyse of both intersections and the interactions between all four weaving sections are left~~
~~study. Figure 2 shows a close up of the analysed intersection and the formation of the~~
~~sections.~~

~~7.~~

~~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 becomes the on-Ramp and the minor~~
~~downstream is the off ramp. Weaving length is measures as shown in figure 2 for both sectio~~

~~9.~~

~~From the HCM 2010 perspective, these local weaving sections are similar~~
~~characteristics to the two-sided weaving sections. The HCM 2010 methodology states that i~~
~~two-sided weaving sections ramp to ramp movement is the only weaving movement while~~
~~movements are considered to be non-weaving. To maintain consistency with HCM, this resea~~
~~adopts the same definitions of weaving and non-weaving flows~~

~~10. for both of the analysed weaving sections.~~

~~11.~~

~~12.~~ BACKGROUND

Freeway weaving has been a subject of extensive research that -aimed at improving the HCM
analysis methodology. Efforts to design and ~~analysis~~ analyze weaving sections trace back to t
fifties with the first edition of the highway capacity manual ~~HCM 1950~~ HCM 1950, ~~th~~
contained the first weaving analysis methodology [**2**]. Later in 1965, the manual was update
methodology was enhanced by Jack Leisch [**3**], ~~introducing~~ who introduced the concept of
realm of weaving and quality of flow~~, which was later mapped into levels of services.~~, which
mapped into levels of service.

Over the period from 1965 to 1985, new methodologies and approaches emerged as re
adopted concepts such as, the proportional use of lanes by weaving and non-weaving
~~and~~vehicles, and the introduction of geometric configurations. The1985 HCM [**4**] incorpora
new concepts and defined three types of geometric ~~configurations~~configurations; type A, ty
Type C. Further updates were carried out in 1994 and 1997 where coefficients of the speed
equations were revised, and the LOS was altered to be dependent on density rather than sp
HCM 2000 ~~edition~~ [**5**] contained further improvements and introduced a multi-page tabl
~~estimating the~~ capacity estimation of weaving sections, which was a major improv
methodology.

In 2006, the NCHRP sponsored project 3-75, which lead to the development of a new
analysis methodology **[6]** that was later incorporated in the HCM 2010 **[1]**. The study util
modern data using aerial photography and divided weaving sections into one-sided and
weaving sections. The new approach relied on the lane changing activity within the weaving
reflect the impact of configuration and type of operation on the performance of the section,
originally presented by Fazio in 1986 **[7].** The methodology also provided a
~~forward~~straightforward ~~equation for~~equation to ~~the~~ predict, the capacity ~~prediction~~ of the
~~section capacity.~~

~~Although~~Section.

Although, various methodologies have been established to analyze weaving sections, ~~weav~~
~~are common design elements in the urban roadway system, all previous methodologies hav~~

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~~on freeway 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~~
~~However, traffic simulation is widely used as an alternative analysis tool to efficiently~~
~~complex traffic operations of real world physical systems using a computer program.~~s
modeling has proven to be a reliable alternative analysis tool that allows researchers to explo
traffic phenomenon and conduct experimental analysis with real life or synthetic data
computer program.

WEAVSIM is a microscopic freeway simulation program designed specifically for s
weaving sections ~~[8]~~. WEAVSIM was used to investigate the effect of different arrival spee
overall speed and delay of ramp weaving sections and develop a regression model to predict
measures of performance using ~~a total of 243~~243 experimental simulation runs**[8]**.

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

FRESIM is a simulation model enhanced and reprogrammed from its predecessor, INT
includes enhancements to it's geometric and operational capabilities **[12]**. For urban ~~a~~
another simulator called NETSIM was design to be more compatible with the characteristics
areas [**13**]. Nowlin (1998) used NETSIM to analyze urban two-sided weaving sections on
frontage roads. He used data from multiple simulations to develop a density prediction m
managed to set recommendations on the minimum and desired weaving length **[14]**.

INTEGERATION is a microscopic model developed by Michael Van Aerade [**15**]. Stev
(1996) estimated Capacities of the weaving sections using INTEGERATION and stated that
length affects capacity only for shorter weaving sections, while the number of lanes is the mo
factor affecting capacity [**16**]. Zhang & Rakha (2010) Used INTEGERATION to perform a
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 rat
influenced the capacity even though it ~~is not accounted for~~neglected in the HCM2000 model |

VISSIM is a microscopic time step and behavioral based simulation model developed to
urban ~~traffic and~~traffic, ~~-~~public transport operations, and flows of pedestrians **[18]**. The m
developed at the University of Karlsruhe in Germany based on the work of R. Wiedemann **[1**
al (2007) used VISSIM to simulate a type B, six lane weaving section in Emeryville, Califor
extremely detailed data provided by the next generation simulation team (NGSIM). The re
also ~~and used~~ output data to generate speed-flow relationships and estimate capacities acc
The study further investigated speed-flow relationships at different volume ratios and fo
capacities decrease noticeably with the increase in volume ratio **[20]**.

Another 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** s
Factors that were used to design the experiment were traffic volume, weaving length, post
and proportion of volumes. Evaluation of the simulation data revealed that weaving length ~~is~~
significant variable in predicting speed when included as a continuous variable that assume
relationship between speed and weaving length. The study provided guidance on recon
distances between ramps and used simulation and field data to develop a speed prediction ec
function of geometry and traffic.

Liu et al (2012) used VISSIM to model the impact of cross weave maneuvers on the s
capacity of freeways with managed Lanes [**22**]. The cross weave ~~weaving~~ maneuver is ~~is~~

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the two-~~-~~sided weaving maneuver described in the HCM 2010. A test bed VISSIM model wa
carry out multiple runs with different levels of mainstream demand, cross-weave demand, m
number of lanes, and minimum lane changing distance (LCW-min). Speed-flow curves were
using Van Aerde's ~~Curve~~ curve fitting and capacities were estimated ~~for each scenario~~acc
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 l
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 t~~
~~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 f
appeared to be the most suitable software for this research due to its modeling flexil
capabilities in conducting weaving related studies of freeway and urban sections.

~~13.~~ .
~~14.~~

~~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~~ demande
~~The simulations were conducted using the default parameters of the urban driver behavior in~~

Experimental analysis often involves the investigation of numerous scenarios. However,
doesn't provide a scenario manager where one could predefine all the scenarios ~~and~~ allo
~~model~~ program to run them in sequence; therefore, an external programme called **AUTO**
was developed in ~~visual~~ Visual ~~basic~~ Basic programming language to automate the simula
through the COM interface feature provided by VISSIM.

The experimental design~~s~~ allowed the simulation of the weaving sections at different weavin
and ~~under~~ various levels of demand inputs ~~input and volume ratios~~. Some of these dema
combinations caused the weaving sections to reach ~~capacity which~~capacity, which was pc
~~out~~. After capacities were derived, using the simulation, ~~-~~SPSS statistical package ~~was~~ is u
~~derive~~ develop s~~S~~imulation based logarithmic and linear capacity prediction models for the
urban weaving sections.

Finally, t~~To test the reliability of t~~he HCM 2010 weaving analysis methodology was
~~methodology~~ applied to the each weaving section to test the methodology's reliability in rep
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 ~~were~~
to those of the ~~Simulation~~ simulation models using statistical and graphical methods. Finally,
~~was undertaken~~was made to calibrate and modify the ~~investigate the~~ HCM 2010 speed p
models ~~in representing urban weaving operations when calibrated using non-linear regression~~
using the simulation data points to reflect urban conditions.

~~3.1 s~~Simulated network

In this study, a network similar to Figure 1 was coded in VISSIM to serve as an experimenta
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 co~~
~~at grade intersections, 1 km apart.~~ The simulated network depicts a typical intersection desi

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

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

~~1~~

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

The main stream has 3 lanes each lane is 3.65 meter wide, while the minor approaches hav
~~3.65 m each~~ also 3.65 meter wide. U-turn slot is a single lane without any acceleration or de
bays at any point. The posted speed limit is 60 km/hr and a turning speed of 20
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 paramet
urban driver behavior in VISSIM.

~~15.2~~ ~~experimental~~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 p
percentage of minor through split (% Mi THR).

Weaving length (WL~~),~~) ~~is~~ was measured as shown in Figure 2 with four levels starting
meters to 400 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 ~~e current~~ study. Minor approach
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
ranged from 1000 vph to 2400 vph, with a 200 vph increment (i.e. 8 volume levels
ranges 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 s
levels.

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

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

~~Changing~~Increasing the minor through ~~was~~split was intended to increase th~~e~~ int
weaving ~~traffic.~~. Increasing the minor through from 25% to 50% increases the perce
~~ramp to ramp~~ramp-to-ramp vehicles from 45% to 70% of the minor demand ~~-~~ approac

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

Weaving section of different length and traffic splits required different
~~configurations,~~configurations; therefor, two test beds corresponding to ~~two~~ both lev
Mi THR split for each weaving section length ~~was~~ were coded. In total, 8 ~~VISSIM~~
models were prepared to run 120 combinations of minor and major volume levels.

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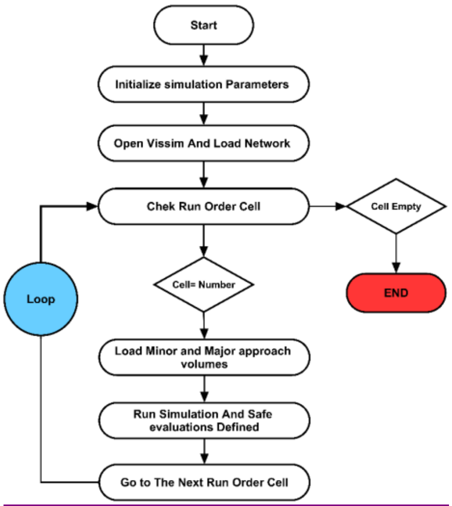
~~15.3~~ Automation ~~automation~~ program development

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

A computer program called **AUTOMATE** was developed using Excel Visual Basic automate the scenario runs generated by the factorial design. The program simply changes and minor demand volume for each ~~iteration~~iteration (scenario) automatically using a visual next loop. Once iterations are completed, the program moves to another network and th repeated again until all networks are ~~have been~~ processed. Figure 3 depicts ~~a flow chart tha~~ the logic of the developed program where each iteration (scenario) has a unique run order.



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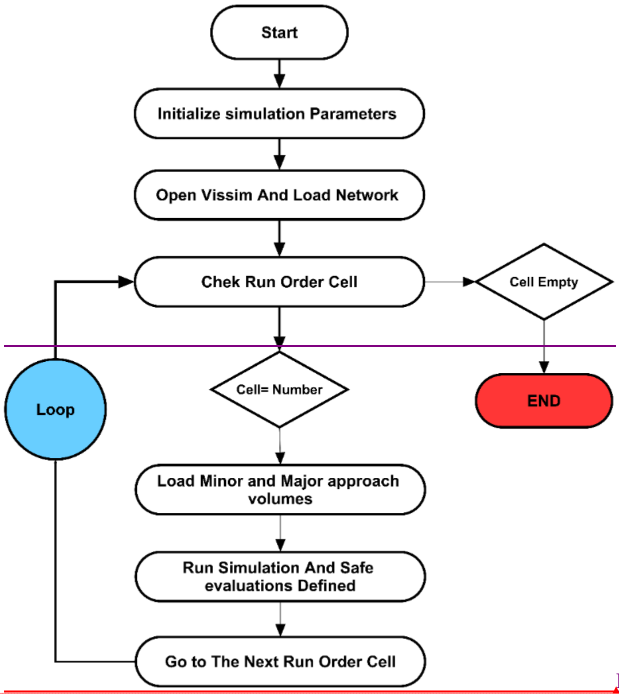
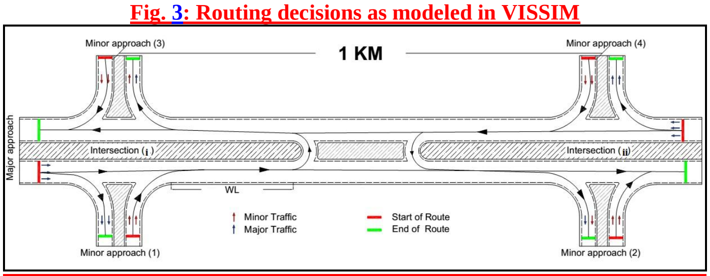


Fig~~ure~~. ~~3~~: Logic of the VBA
AUTOMATE

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. Vehi
in (vph) were loaded and changed automatically by the developed VBA program. T
program immediately loads the predefined network and then the vehicle input
VISSIM is accessed through COM interface to assign vehicle inputs at the proper chos
The assigned vehicle input value corresponds to a specific run (scenario) accordin
matrix generated by factorial design and embedded within the program. Static routing
to route vehicles from a start point (red) to any of the defined destinations (green) usin
percentage for each destination. Routing decisions are similar for each VISSIM network.
shows all routing decisions as specified in VISSIM and Table 1 summarizes the traffic spli
route.

Fig. 3: Routing decisions as modeled in VISSIM



~~Figure 3: Logic of the AUTOMATE program for automation of simulation runs~~

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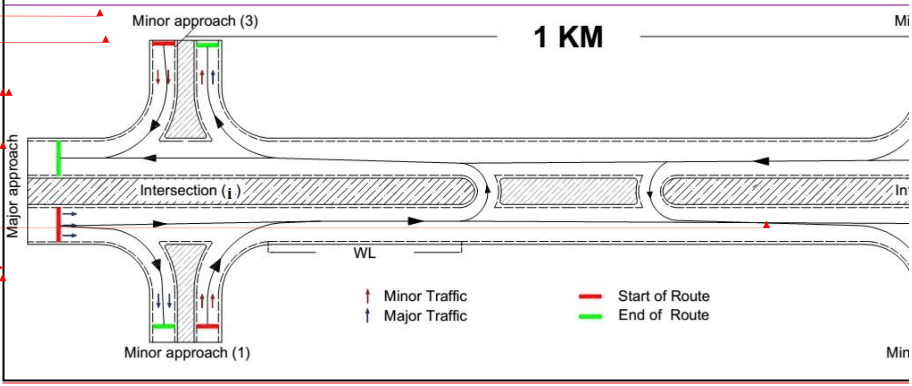
~~16. WEAVING SECTION MODELLING~~

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

~~The.~~

~~The VBA program immediately loads the predefined network~~ and then ~~and acce~~ ~~vVehicle 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 spe~~



~~**Figure 44: Routing decisions as modeled in VISSIM**~~

Table 1~~11~~:Traffic splits

Intersection (i) or (ii)	**25 % minor Through**	**50 % minor Through**
	Percentage	
Major Through	70%	70%
Major Left Turn	10%	10%
Major Right turn (1)	10%	10%
Major Right Turn (2)	10%	10%
Minor~~(1)~~ Left turn	20%	20%
Minor ~~(1)~~ Right turn	55%	30%
Minor ~~(1)~~ Through	25%	50%
~~**Minor (3) or (2)**~~	~~100%~~	~~100%~~

The percentage of heavy vehicles were assumed 2% for all cases; therefore, all compositions ~~are~~ were 98% passenger cars and 2% heavy vehicles. Each vehicle type had a stochastic distr desired speed and for this research the speed distribution for cars ~~will~~ was ~~be~~ 60 km/hr (58 k km/hr) while for the heavy vehicles (HGV) the desired speed distribution ~~will be~~was selec km /hr (48km/hr:58 km/hr).

VISSIM provides a wide range of evaluations that must be defined and configured in order desired model output from ~~the~~ a simulation run. The common form of these outputs, are of files containing the results and delimited by a semicolon. The period of the each run is se seconds; however, the first 900 seconds were considered warm up and outputs were collect last 3600 seconds of simulation ~~The~~.

For this research, ~~common form of these outputs, are offline text files containing the results by a semicolon. T~~the following evaluations were activated and configured in VISSIM:

- **Link evaluation**: The link evaluation feature ~~allows~~ allows the ~~user to gather~~coll simulation results based on the area of ~~the~~ weaving ~~for the last 3600 sec of the simula~~ as (density, Throughput, average speed).
- **Lane change rates**: Allows the collection of the total lane change rates ~~s~~ executed w weaving section ~~for the last 3600 sec of the simulation~~.
- **Data collection Points**: Collects vehicle counts and spot speeds at the major a entrance upstream of weaving section (A).
- **Travel time sections**: Allows the collection of travel times and vehicle ~~counts~~ cc ~~user defined travel time section~~. Travel times sections are set up to capture weaving weaving ~~volumes~~ flow rates and ~~speeds~~ speeds as shown in figure 5~~as Figure~~ .

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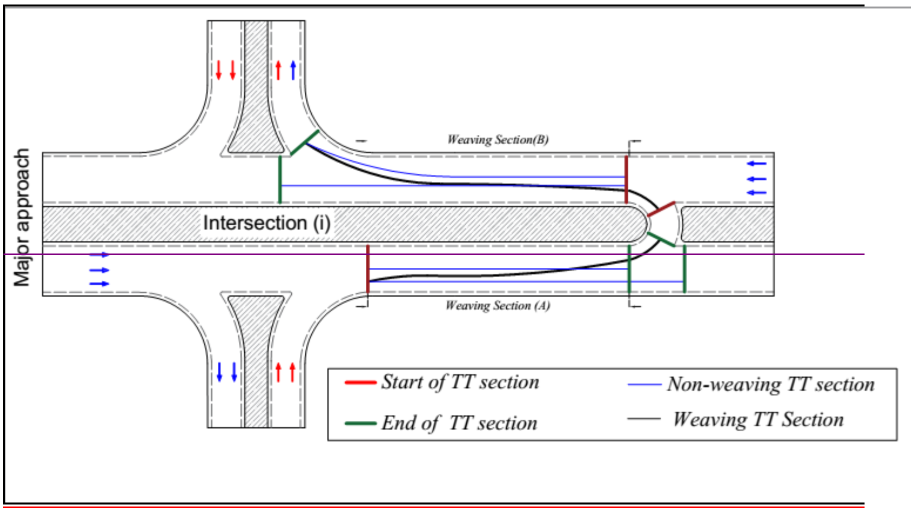

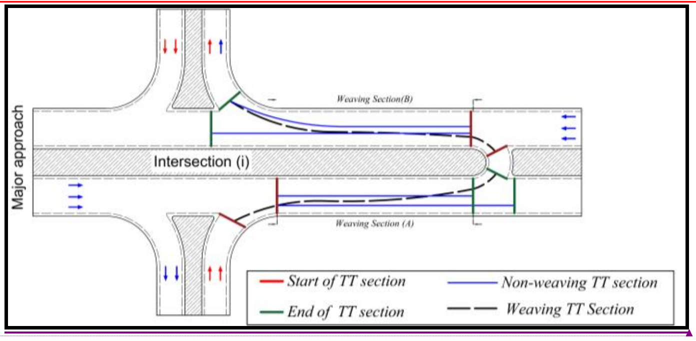

~~Figure~~ Fig. 445~~5~~: Travel time sections as defined in VISSIM

From the HCM 2010 [1] perspective, these local weaving sections are similar in their charact 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 move considered non-weaving. To maintain consistency with HCM, this research paper adopts definitions to differentiate between weaving and non-weaving flows. Therefore, travel time were set accordingly ~~based on the HCM 2010 definitions of weaving and non-weaving mov~~ shown in figure 5, where the dashed line represents the weaving flow and the solid lines repr non-weaving flows.

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

Travel time sections produces 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 th travel time by the length of the travel time section, the space mean speed of each movemen calculated.

~~17.~~ 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 conf

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VISSIM (link evaluation, lane change rates , travel times, and data collection points). To t extract the simulation outputs from each file, 4 ~~visual~~ Visual ~~basic~~ Basic programs were deve the extraction and manipulation of the output data.

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

When executing the program, it automatically prompts the user for the output folder directo choosing the ~~directory~~directory, the program loops through all the output files importing eac Microsoft excel and ~~extracts~~ extracting the evaluation data. The program also calculates the a each repeated simulation run with different number seeds and preforms any necessary ca such as converting ~~the~~ travel times ~~to~~ into ~~speeds~~speeds ~~when extracting the travel time~~ converting vehicles into Passenger car equivalents.

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~~5.1 capacity~~Capacity estimation using simulation

VISSIM or any other simulation tool does not produce capacity estimates directly. The easie 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 represents the vehicle inputs that are assigned to the simulated network.

~~The~~ At first, the throughput equals the input demand up to a certain point, and then l indicating that the system is not able to accommodate any more vehicles and is operating at ~~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 equ throughput of section (**B**). Theoretically, the throughput of weaving section (**A**), should b 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. simulated vehicular arrival times).~~.

Figures 6 shows the relationship between the total demand and throughput of weaving sectio a ~~100~~100 meters ~~and~~ and ~~200 m~~200 meters weaving lengths as an example. From ~~the surfac~~ Figure 6, it is noticeable that the throughput increases with the increase in total demand ~~major~~Major) until reaching a certain threshold where it becomes nearly constant and unresp further increase in ~~the continuous d~~demand ~~increase~~. The point of maximum constant th represents the capacity of the weaving section. The figure also shows that the capacity of the directly proportional to the major demand level and to the weaving length.

From the same ~~figure~~figure, it is also noticed that the ~~Throughput~~ throughput decreases ~~with increase in~~ minor through traffic split increased from 25% to 50%. The decrease in capa 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 ~~VR~~volume ratio (VR), which causes higher lane changing related ~~turbulence and~~turbulence, and lower capacit~~y~~ies.

Figure 7 shows the simulated capacities of all weaving lengths at each major demand lev length was increased beyond 200 meters, the capacities increased with major demand up to point and then started to level after major demand exceeded 2000 and 1600 ~~VPH~~ vph for . 50% Mi THR split, respectively for both weaving sections.

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It was found that increasing the weaving length beyond 200 meters did not increase the ca the sections , on the contrary capacities~~y~~ was less than the values associated with the shorter length (200 meter~~-~~) for major demand levels greater than 2000 and 1600 ~~VPH~~ vph ~~for~~ at 50% Mi THR respectively~~ for both sections~~.

Capacity difference between sections (**A**) and (**B**) ~~for~~ at both ~~cases~~ levels of % Mi ~~THR~~THR 50%) was ~~neglected~~neglected, as the maximum difference ~~was~~ did not exceed 2.5 %~~ maxi~~ slight variation in throughputs between Weaving section (**A**) and (**B**) is only attribute stochastic behaviour of the simulation model.

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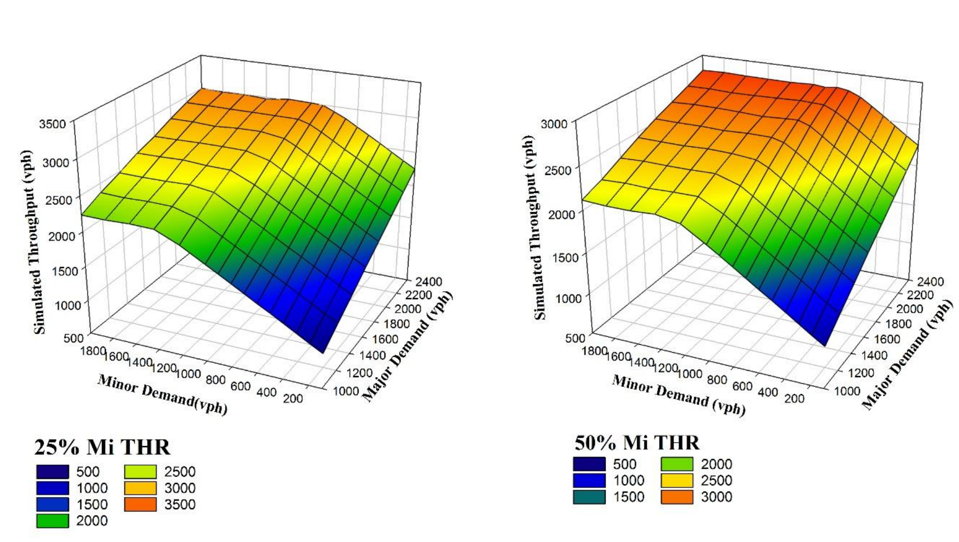
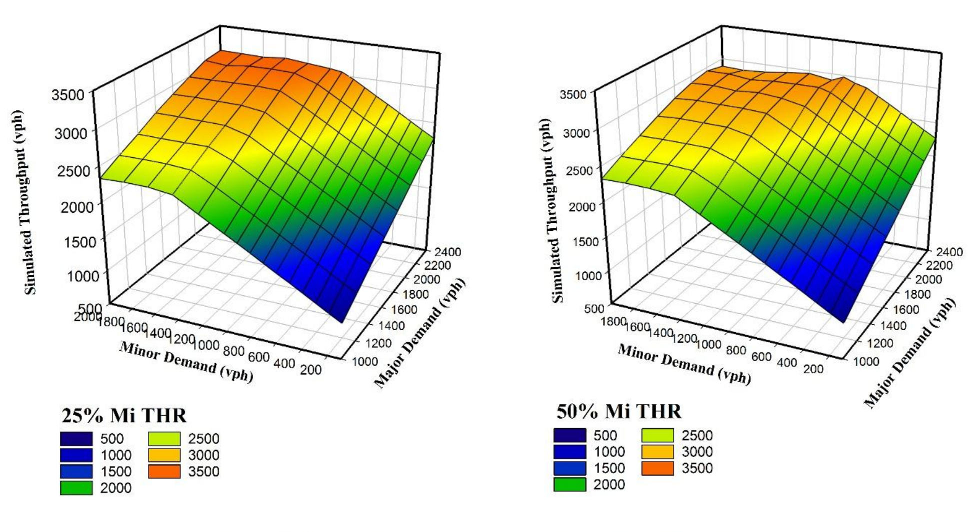


a. Simulated throughput of weaving section (A) at WL= 100m



b. Simulated throughput of weaving section (A) at WL= 200m

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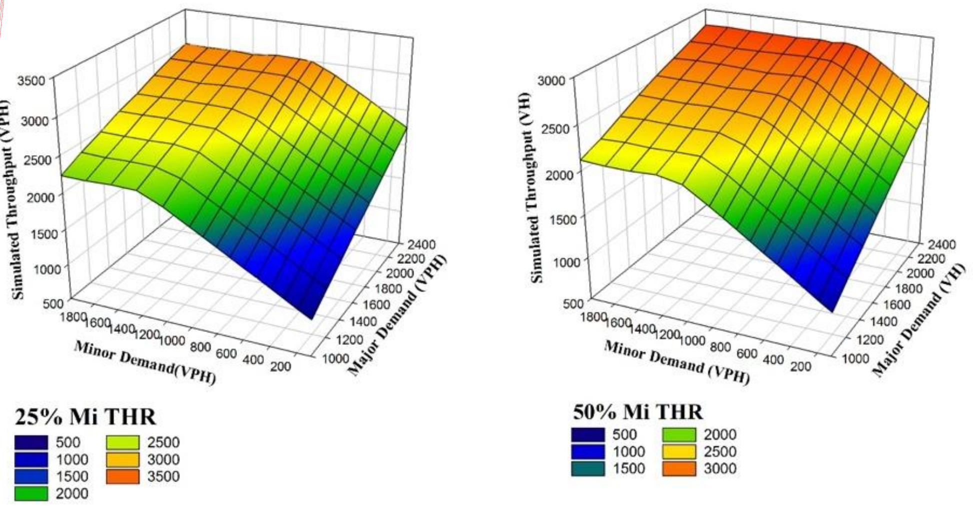
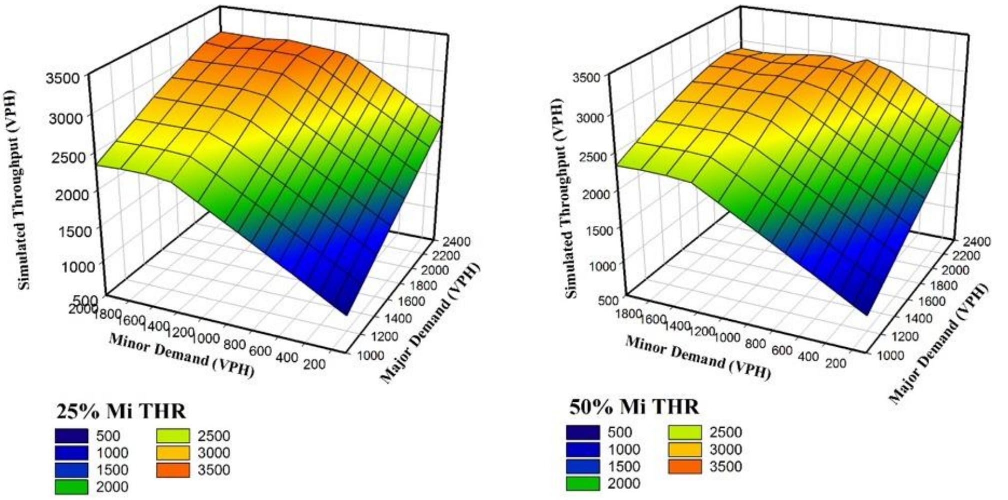
Figure ~~55~~6: Relationship between total demand and throughput of weaving section (A) at different weaving lengths



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



b. Simulated throughput of weaving section (A) at WL= 200m

~~**Figure 6: Relationship between weaving section (A) demand and Throughput at different weaving lengths**~~

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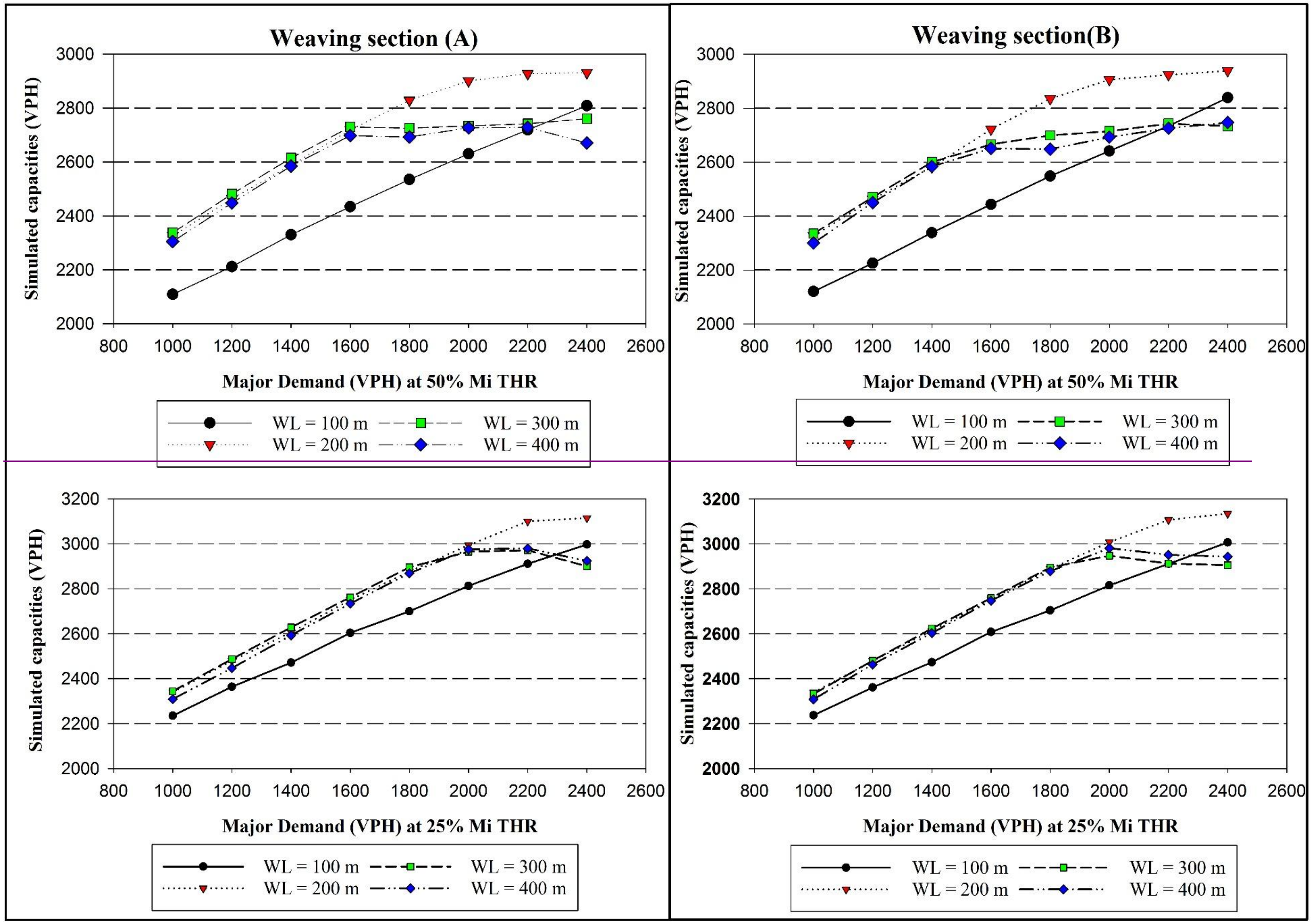

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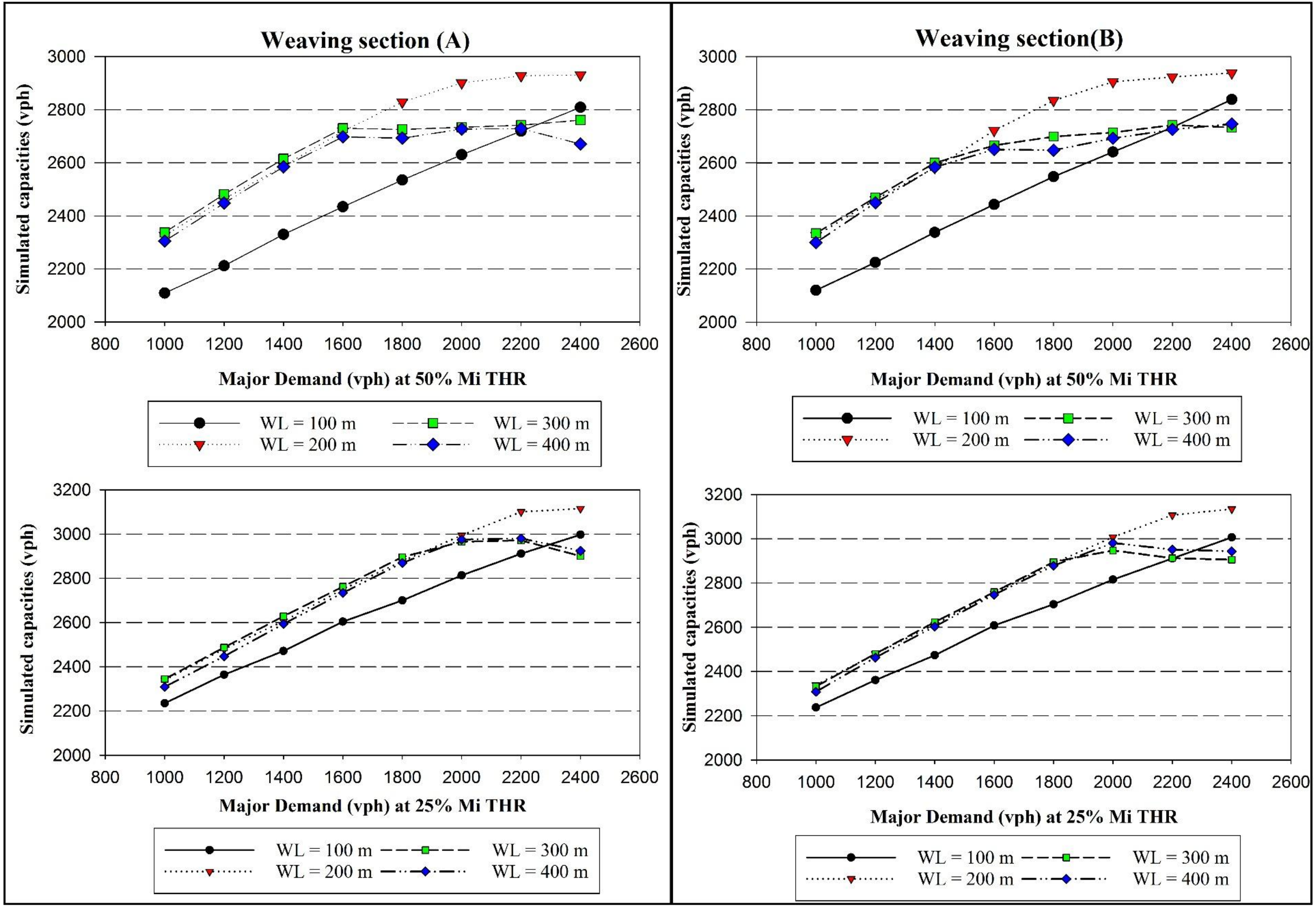

Figure 6~~67~~: Simulated capacities at different weaving lengths

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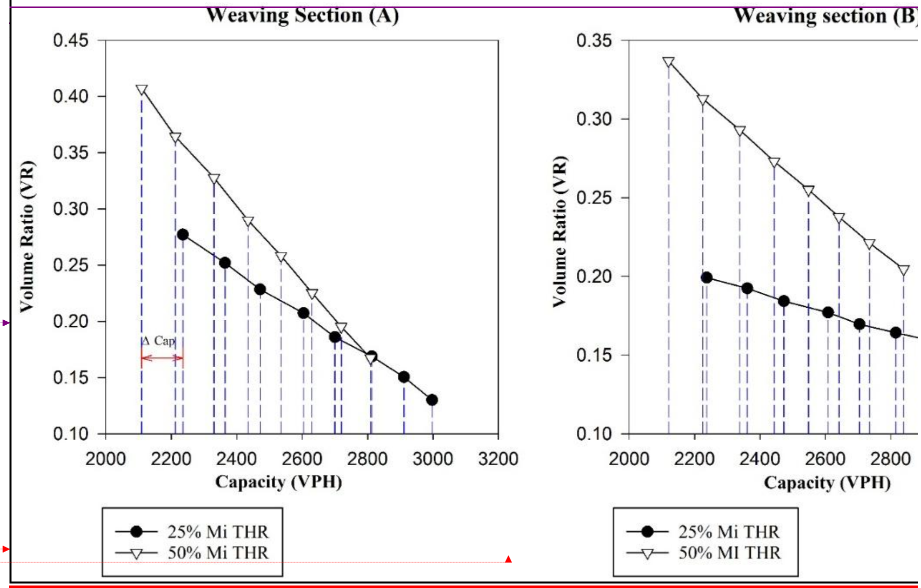
The impact of volume ratio on capacity is summarized in figure 8 and 9. The points on ea represent the capacity at a certain major demand level.~~d in Figure 8.~~ ~~The f~~Figure 8 sl relationship between capacity and volume ratio for a weaving length of 100 meters as an



Fig~~ure.~~ 8~~8~~: ~~capacity~~ Capacity versus volume ratio for WL= 100

The reduction in capacity for each pair of capacity estimates at different % Mi THR represented by a ΔCap on the graph. Although capacities of section (**A**) and (**B**) are equal ratio at capacity of weaving section (**B**) is noticeably lower than its corresponding value of se for both levels of minor through traffic. This explains why sections (**B**) at some points will c 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, capacitie increase after major demand exceeded 2000 (vph) and 1600 (vph) for 25% and 50% respectively even though volume ratio seems to be decreasing. Form figure 9 it is also notice Δ Cap associated with a major demand < 1400 (vph) for weaving sections (**A**) and (**B**) respe minimum. Which indicates that the turbulence resulting from increasing the % 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 volu increased. However, the estimated capacities were higher than the shorter weaving sect meters) as the extra length compensates for the capacity losses due to the increase in as volu 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 t demand, it was noticed that capacities of the minor entrance have a negative correlation capacities of the weaving sections. The Capacities of the Minor entrance is inversely propo the major demand and directly proportional to the weaving length up to 200 meters. Incre length beyond 200 meters does not increase the capacity of the minor approach a in the Figure 10.

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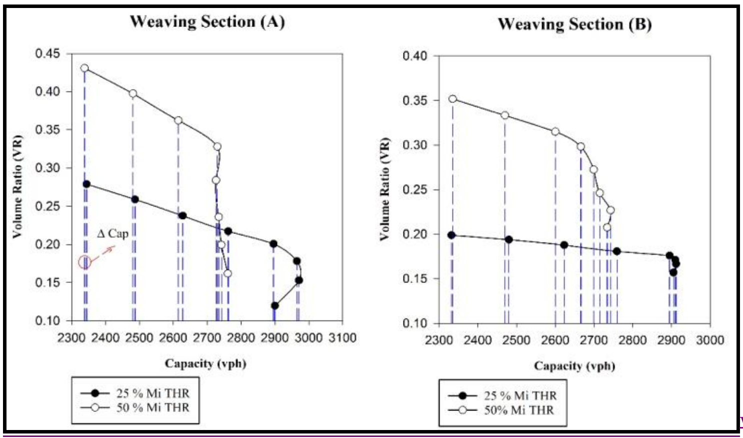
~~Capacity of the weaving sections increases with the decrease in volume ratio for both cases through split. The reduction in capacity for each pair of capacity estimates at different % Mi is represented by a ΔCap on the graph. Although capacities of section (A) and (B) are equal, ratio at capacity of weaving section (B) is noticeably lower than its corresponding value of se for both levels of minor through traffic. This explains why sections (B) at some points will op a relatively higher LOS than section (A).~~



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

Figure 88~~9~~: ~~c~~Capacity versus volume ratio for WL= 300

~~Form the same figure it is also noticeable that Δ Cap is associated with a major demand (VPH) for weaving sections (A) and (B) respectively is minimum. Which indicates that the tu 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 how 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 i however, the estimated capacities were higher than the shorter weaving section (100 m) as tl 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 neg~~

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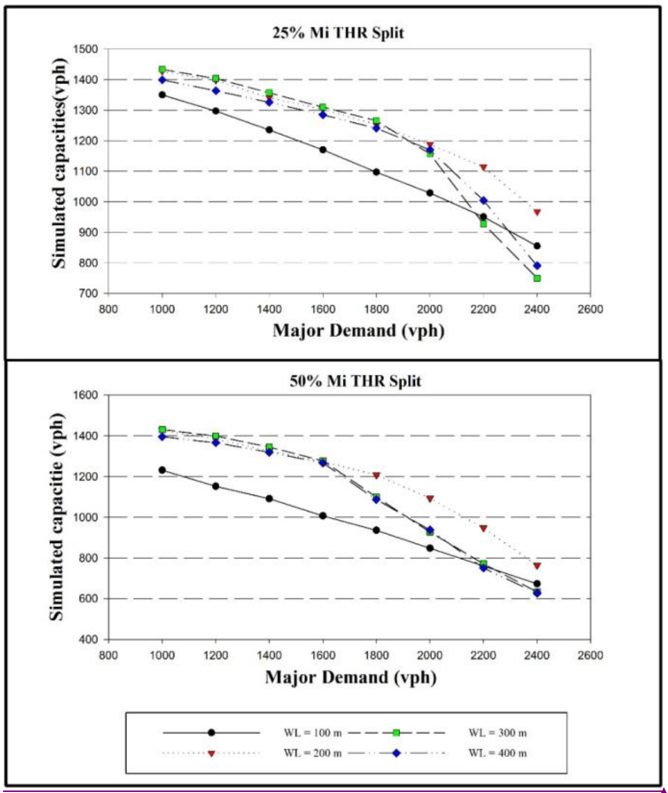
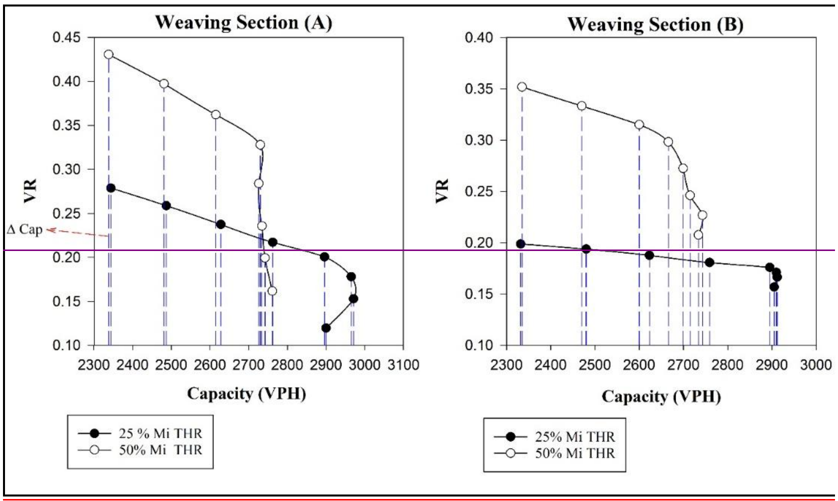
~~correlation with the capacities of the weaving sections. The Capacities of the Minor entra inversely proportional to the major demand and directly proportional to the weaving length u meters. Increasing the length beyond 200 meters does not increase the capacity of the minor a as shown in the Figure 10.~~





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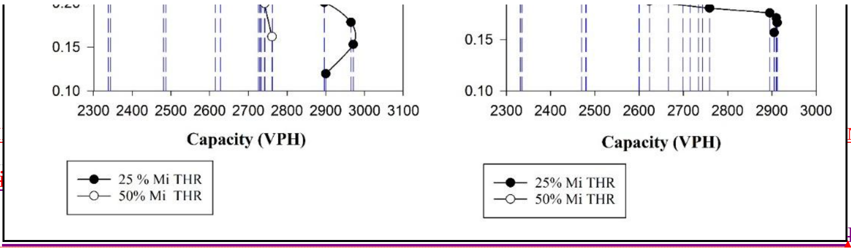

~~Fig~~

~~capacity versus volume ratio for WL= 300~~

Figure 99~~1010~~: Minor entrance capacities at all levels of major demand and at different weaving lengths

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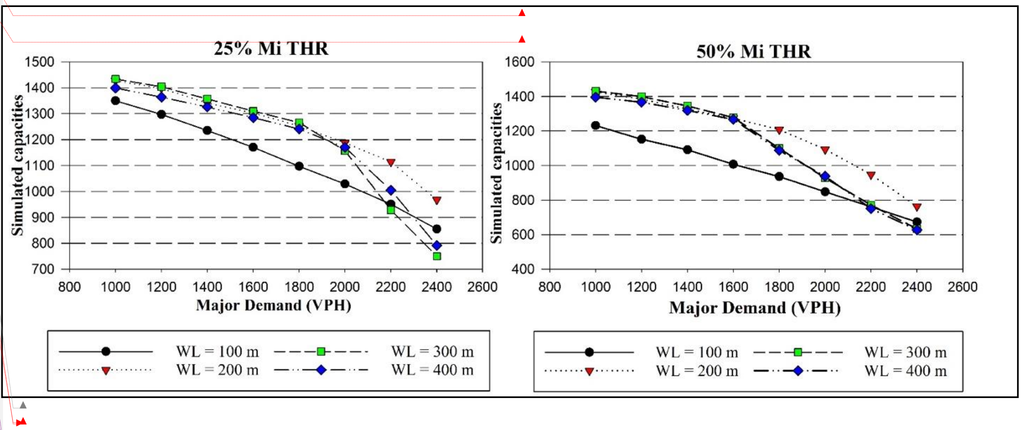

~~5.2 simulation~~Simulation based capacity prediction models

Simulation based Capacity prediction models were developed to predict the capacity of section (A) ~~and~~ 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~~models. In addition, the m constrained to the assumptions made for the study network~~.~~. ~~Increasing~~Increasing the weavi beyond 200 meters was not beneficial as illustrated ~~and~~before, and ~~they are not recomme field implementation~~ therefore no models were developed for these lengths.

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

For WL of 100 m the following models were developed:

Model 1~~11~~1: ~~logarithmic~~ Logarithmic Capacity Prediction Model

For section (A):

$$CAP = 875.184172 * \ln(MD) - 1.287523 * VR * MD - 3433.603297$$

For Section (B): $CAP = 1053.65 * \ln(MD) - 1.06\square * VR * MD - 4846.67$

Model 2~~22~~2: Linear Capacity Prediction Model

For section (A):

For Section (B):

$$CAP = 2510.466 + 0.33 * MD - 0.865\ V_W$$

Where,

CAP	Weaving section ~~Capacity~~ capacity in ~~VPH~~ vph ,
MD	Major ~~Approach~~ approach ~~Demand~~ demand ~~In~~ in ~~VPH~~vph,
VR	Volume ~~Ratio~~ratio at weaving section (A) or (B) ,
V_W	Weaving flow in ~~VPH~~ vph (i.e. the ~~ramp to ramp~~ramp-to-ramp vehicles).

The R^2 values ~~for~~

logarithmic models ~~is~~ are relatively high (0.992) which indicates a perfect fit. The negative the coefficient of volume ratio is also logical which means that when volume ratio is incr capacity decreases. The R^2 value of the linear models are ~~2 is~~ also high, (0.975) anc respectively. ~~and a~~All coefficient signs are also relevant indicating logical correlation bet dependant variable and the predictors.

For WL of 200 m the following models were developed:

Model 3~~33~~3: ~~logarithmic~~ Logarithmic Capacity Prediction Model

For section (A):

$$\mathrm{CAP} = 866.13925.075 * \ln(\mathrm{MD}) - 0.298 - 0.312 * \mathrm{VR} * \mathrm{MD} - 3538.473956.661$$

For section (B): $\mathrm{CAP} = 949.27 * \ln(\mathrm{MD}) - 0.42 * \mathrm{VR} * \mathrm{MD} - 4111.98$

$$\mathrm{CAP} = 925.075 * \ln(\mathrm{MD}) - 0.312 * \mathrm{VR} * \mathrm{MD} - 3956.661$$

Model 4444: Linear capacity prediction model

For section (A):

$$\mathrm{CAP} = 1977.41 + 0.495 * \mathrm{MD} - 0.1V_W \mathrm{CAP} = 1912.324 + 0.556 * \mathrm{MD} - 0.129\ V_W$$

For section (B):

$$\mathrm{CAP} = 1968.56 + 0.52 * \mathrm{MD} - 0.16\ V_W \mathrm{CAP} = 1912.324 + 0.556 * \mathrm{MD} - 0.129\ V_W$$

The R^2 values ~~for~~ of the logarithmic models ~~is~~ equal (~~=~~ 0.~~983~~961) and (0.968) ~~which is high while the linear model has a R^2~~respectively, which is relatively high, while the linea have an R^2, values ~~of~~ of (0.~~969~~929) and (0.932) ~~which~~respectively. All models coefficien relevant signs.

~~is also high. All models have relevant signs indicating logical correlation between the depen variable and the predictors.~~

~~5.3 applicability~~APPLICABILITY OF ~~hcm~~ HCM 2010 WEAVING ANALYSIS METHODOLOGY

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

~~5.3.1 capacity~~Capacity

The HCM 2010 presents a ~~straight forward~~straightforward equation to estimate the lane ca the weaving ~~section which~~section, which in this case will be a two-~~-~~sided weaving sectio make comparisons possible some adjustments were made to the capacity values derived u HCM 2010 to be more compatible with the capacities estimated using VISSIM. These adjust as following:

- Simulated capacities are provided for the entire section therefore, HCM capac multiplied by the number of lanes N= 3.
- Simulated capacities ~~are~~ were ~~given~~ obtained in ~~VPH~~ vph ~~therefor,~~therefor; HCM c should be adjusted to ~~VPH~~ vph using the heaving vehicle factor FHV.
- Weaving Length should be in units of feat.

The following equation is used to estimate the capacity of the weaving section in HCM 2010:

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

~~Soliman, A.K. and Abo-Hashema, M.A.~~~~Soliman, A.K. and Abo-Hashema, M.A.~~
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$$C_{IWL} = C_{IFL} - [438.2(1 + VR)^{1.6}] + [0.0765 L_S] + [119.8 N_{WL}]$$

Where,

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

C_{IFL} capacity of a basic freeway segment with the same FFS as the weaving segment under equivalent ideal conditions, per lane (pc/h/ln)

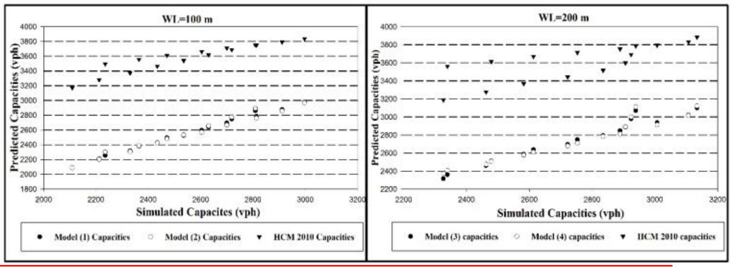
VR volume ratio, v_W/v,

L_S length of the weaving segment (ft),

N_{WL} 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.,~~i.e. of lanes is 3 lanes ~~-~~,configuration is a two-sided weaving section, ~~number of weaving lanes~~ ~~2~~0,and FFS = 60 km/h (37.5 mph). No base capacity was established for speeds less than 55 HCM 2010 therefore, base capacity per lane was assumed 1800 vph. ~~.~~Factor of heavy vehicl calculated using the ~~mythology~~ methodology provided in chapter 11 of the~~-~~ HCM 2010 [1]. I heavy vehicle factor could be ignored, as 2% heavy vehicles is ~~an~~ insignificant. ~~valu~~

~~The following f~~Figure 11 shows ~~a comparison~~the relationship between the simulated capaci the capacities predicted using the developed models and the HCM 2010 model ~~capacity me~~ weaving section (A).



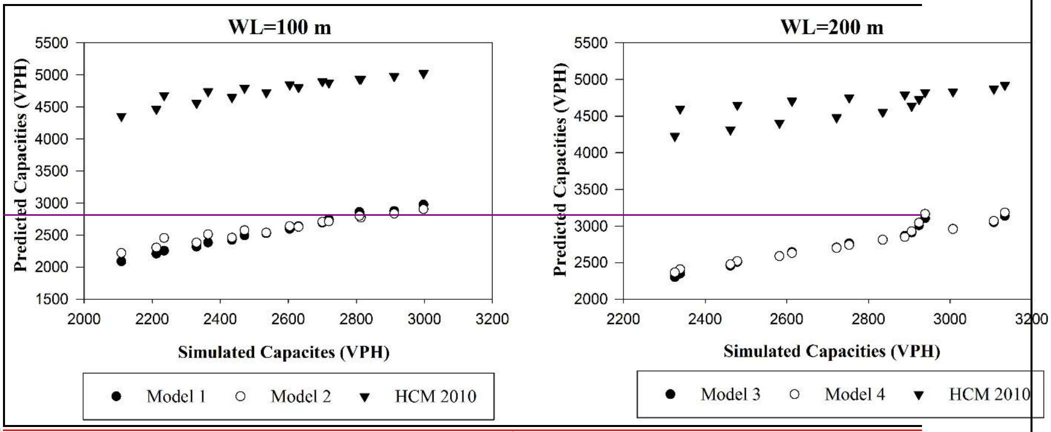


Figure 10~~10~~11~~11~~: Predicted ~~versus simulated~~ capacities using HCM2010 and the develope models for weaving section (A)

~~It is evident that the HCM model over predicts capacities and should not be used for simi configurations. Capacities predicted by HCM are at some points more than double the s~~

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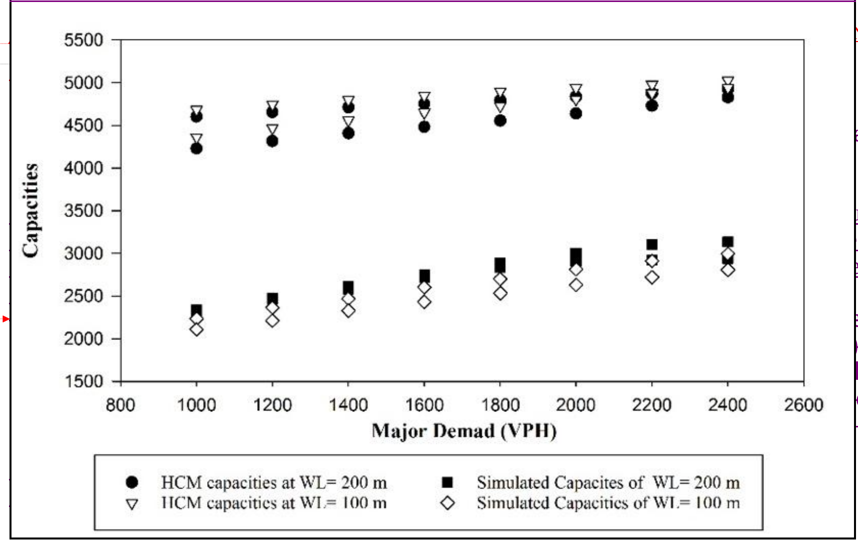

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~~Figure 12: predicted and simulated capacities for WL=100 and 200 m~~

~~**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 sui 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~~Lane change rates

The speed prediction models of the HCM 2010 mainly depend~~s~~ 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:

$$LC_{MIN} = LC_{RR} \times V_w$$

$$LC_W = LC_{MIN} + 0.39 [(L_S-300)^{0.5} N^2 (1+ ID)^{0.8}]$$

Where,

LC_{MIN}	Minimum equivalent hourly rate weaving vehicles must make to successfully complete all weaving maneuvers
LC_{RR}	Minimum number of lane changes that must be made by one ramp to ramp vehicle to execute the desired maneuver successfully
V_W	Weaving volume in pc/h
LC_W	Equivalent hourly rate at which weaving vehicles make lane changes within the weaving section (Lc/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 LC_{RR} = 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, "I_{NW}, needs to be calculated and then depending of t the non-weaving lane changing rates are calculated using one of the three non-weav change rate equations below.

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$$I_{NW} = \frac{L_S * ID * V_{NW}}{10000}$$

If $I_{NW} \leq 1300$ then $LC_{NW} = LC_{NW1}$

If $I_{NW} \geq 1950$ then $LC_{NW} = LC_{NW2}$

If $1300 < I_{NW} < 1950$ then $LC_{NW} = LC_{NW3}$

$$LC_{NW1} = (0.206*V_{NW}) + (0.542*L_S)-(192.6*N)$$

$$LC_{NW2}=2,135 +0.223(V_{NW}-2,000)$$

$$LC_{NW3} =LC_{NW1}+ (LC_{NW2} -LC_{NW1})*((1/650) (I_{NW}-1300))$$

The total lane-changing rate of all vehicles in the weaving section is then computed by c LC_W and LC_{NW}.

$$LC_{ALL}=LC_W+LC_{NW}$$

In VISSIM, lane change evaluations were set to calculate the total number of lane changes that occurs at each weaving section. Paired t-tests were executed using SPSS statistical packa the null ~~hypothesis which~~hypothesis, which states that there is no significant difference bet 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. T the plot of points to the 45º Line, the more accurate the predicted speeds. If points are on t the 45º Line, predicted lane changes are generally larger while predicted lane changes are values on the right of the line.

Parity plots are shown in figure 12 for weaving length of 100 and 200 ~~as~~meters as an ex ~~Figure 13~~. By examining the plots, it is evident that there is a moderate to high magnitude ~~degree of~~a high positive correlation between the predicted and the simulated values. Clearly the points are to the right of the 45º ~~degree line which~~line, which indicates that the simul change rate is higher than the predicted. The same analogy can be applied on the rest of the lengths in this study.

The following table shows the result of paired t-test with a significance value < 0.05 indica there is a statistically significant difference between the ~~simulated and the predicted valuess~~ the predicted values, and thereby rejecting the null hypothesis.

				Paired Differences					**t**	**df**	
Samples	**WL**	**Section**	**Lane change rates**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				**Sig. (2-tailed)**
							Lower	**Upper**			
Pair 1	100	A	Simulated_ LC – HCM _LC	63.64	257.64	16.63	30.87	96.40	3.83	239.00	.00
Pair 2		B	Simulated_ LC – HCM _LC	130.71	137.49	8.87	113.22	148.19	14.73	239.00	.00
Pair 3	200	A	Simulated_ LC – HCM _LC	396.49	317.66	20.50	356.09	436.88	19.34	239.00	.00
Pair 4		B	Simulated_ LC – HCM _LC	821.62	326.68	21.09	780.08	863.16	38.96	239.00	.00
Pair 5	300	A	Simulated_ LC – HCM _LC	490.53	389.40	25.14	441.01	540.04	19.51	239.00	.00

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Pair 6		B	Simulated_ LC – HCM _LC	646.39	391.31	25.26	596.63	696.15	25.59	239.00	.00
Pair 7	400	A	Simulated_ LC – HCM _LC	352.22	411.38	26.55	299.91	404.53	13.26	239.00	.00
Pair 8		B	Simulated_ LC – HCM _LC	524.27	430.23	27.77	469.57	578.98	18.88	239.00	.00

Table 2~~22~~: Lane change rates Paired Samples Test

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From the previous ~~section~~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 Consequently, the predicted speeds are likely to be higher than the actual speeds.

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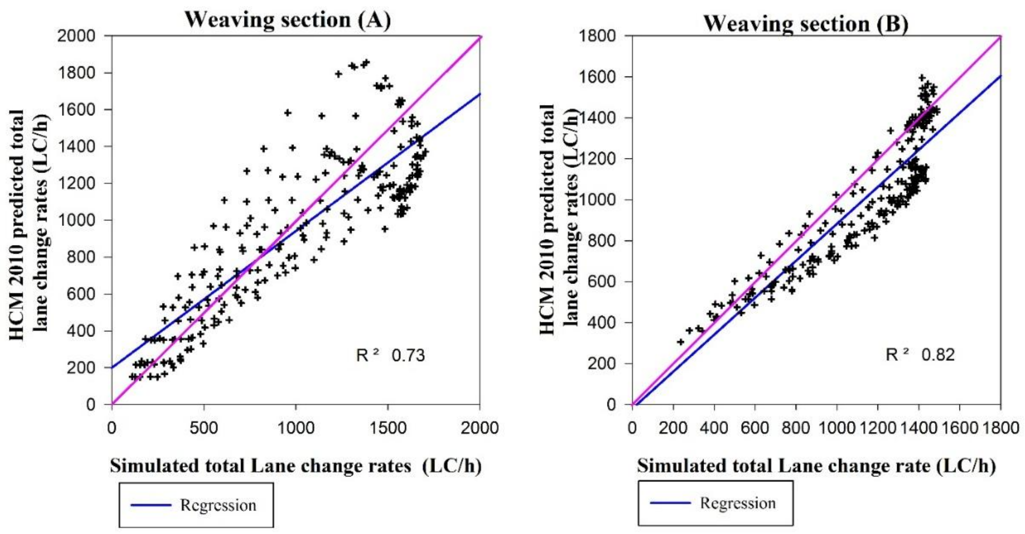
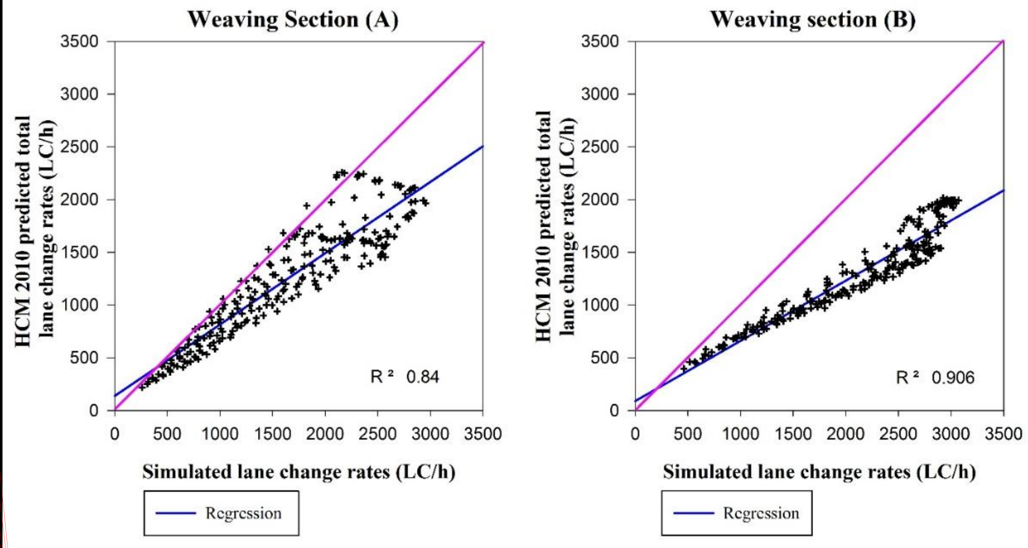


a. HCM 2010 Predicted total lane change rates versus Simulated total lane change rates for WL=100 m



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

~~Figure~~ Fig. 11~~11~~12~~13~~: Parity plots ~~for~~ of the simulated verses predicted lane change rate for WL=100 and 200 meters

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

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

$$S_W = 15 + \frac{FFS - 15}{1 + W} \quad , \quad W = 0.226 * \left(\frac{LC_{ALL}}{L_S}\right)^{0.789}$$ **(Weaving speed prediction**

$$S_{NW} = FFS - (0.0072 * LC_{MIN}) - \left(0.0048 * \frac{V}{N}\right)$$ **(Non-weaving speed prediction ı**

Where,

S_W	Average speed of weaving vehicles in (mi/h);
Snw	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 sı
both weaving section (**A**) and (**B**) ~~and~~ .The travel time ~~were~~sections were set based on t
definitions of weaving and non-weaving movements to maintain consistency when є
comparing simulated and predicted samples.

~~All HCM predicted weaving and non-weaving s~~Speeds that were estimated using HC
~~previously~~ converted into Km/h for consistency aswell. ~~in the HCM 2010 calculation sheet p~~
~~developed for this study.~~

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

As expected the HCM models over predicted the speeds of all movements as shown in the p
Goodness of fit (R^2) was very small and all the plotted points were on the left side of the 45
~~line~~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
~~speeds,~~speeds; however, there is a significant degree of linearity and a positive correlat
weaving and non- weaving speeds failed the T-test with significance value <~~>~~ 0.05 an
concluded that the ~~results~~ speeds were significantly different as shown in Table 3.

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Table 3~~333~~: Weaving and non-weaving speeds Paired Samples Test

			Weaving and non-weaving speeds	Paired Differences					t		
Pairs	WL	Sections		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			df	Sig (2-tailed)
							Lower	Upper			
Pair 1	WL=100	A	Simulated Sw –HCM Sw	-25.43	4.43	.29	-25.99	-24.87	-89.01	239.00	.00
Pair 2			Simulated_Snw –HCM Snw	-13.84	8.72	.56	-14.95	-12.73	-24.58	239.00	.00
Pair 3		B	Simulated Sw –HCM Sw	-21.41	1.48	.10	-21.60	-21.22	-223.38	239.00	.00
Pair 4			Simulated_Snw –HCM Snw	-14.68	4.54	.29	-15.26	-14.11	-50.13	239.00	.00
Pair 5	WL=200	A	Simulated Sw –HCM Sw	-17.80	6.41	.41	-18.62	-16.99	-43.02	239.00	.00
Pair 6			Simulated_Snw –HCM Snw	-5.77	7.52	.49	-6.72	-4.81	-11.88	239.00	.00
Pair 7		B	Simulated Sw –HCM Sw	-17.38	3.73	.24	-17.86	-16.91	-72.11	239.00	.00
Pair 8			Simulated_Snw –HCM Snw	-15.97	8.92	.58	-17.10	-14.84	-27.72	239.00	.00
Pair 9	WL=300	A	Simulated Sw –HCM Sw	-14.03	10.74	.69	-15.39	-12.66	-20.24	239.00	.00
Pair 10			Simulated_Snw –HCM Snw	-6.53	12.84	.83	-8.16	-4.90	-7.88	239.00	.00

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Pair 11		B	Simulated Sw –HCM Sw	-27.11	3.75	.24	-27.59	-26.63	-112.00	239.00	.00
Pair 12			Simulated_Snw –HCM Snw	-14.80	11.58	.75	-16.28	-13.33	-19.80	239.00	.00
Pair 13	**WL=400**	A	Simulated Sw –HCM Sw	-11.48	11.17	.72	-12.90	-10.06	-15.91	239.00	.00
Pair 14			Simulated_Snw –HCM Snw	-4.47	13.04	.84	-6.12	-2.81	-5.31	239.00	.00
Pair 15		B	Simulated Sw –HCM Sw	-12.79	7.24	.47	-13.71	-11.87	-27.37	239.00	.00
Pair 16			Simulated_Snw –HCM Snw	-13.07	11.93	.77	-14.59	-11.56	-16.97	239.00	.00

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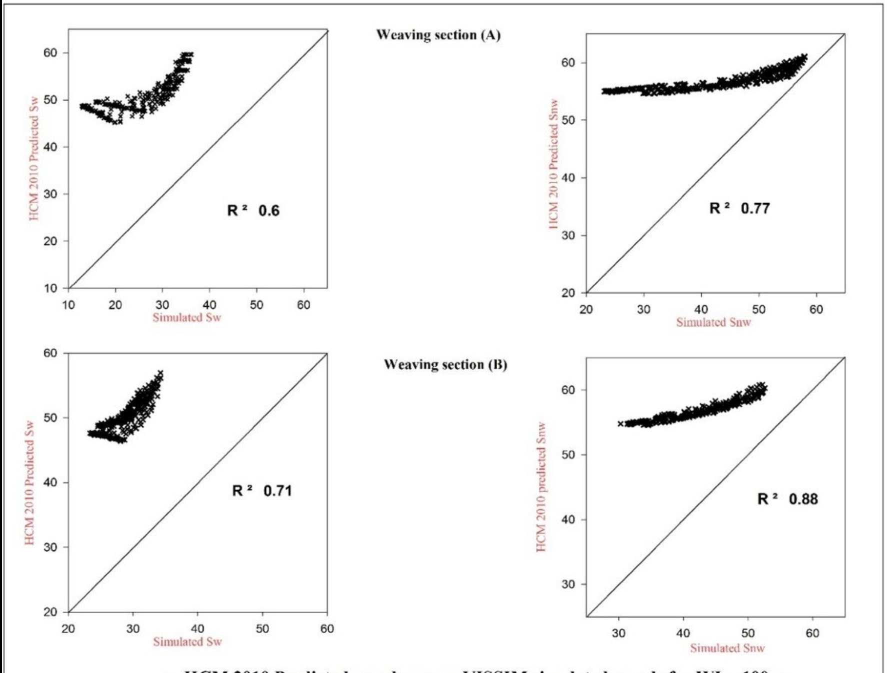
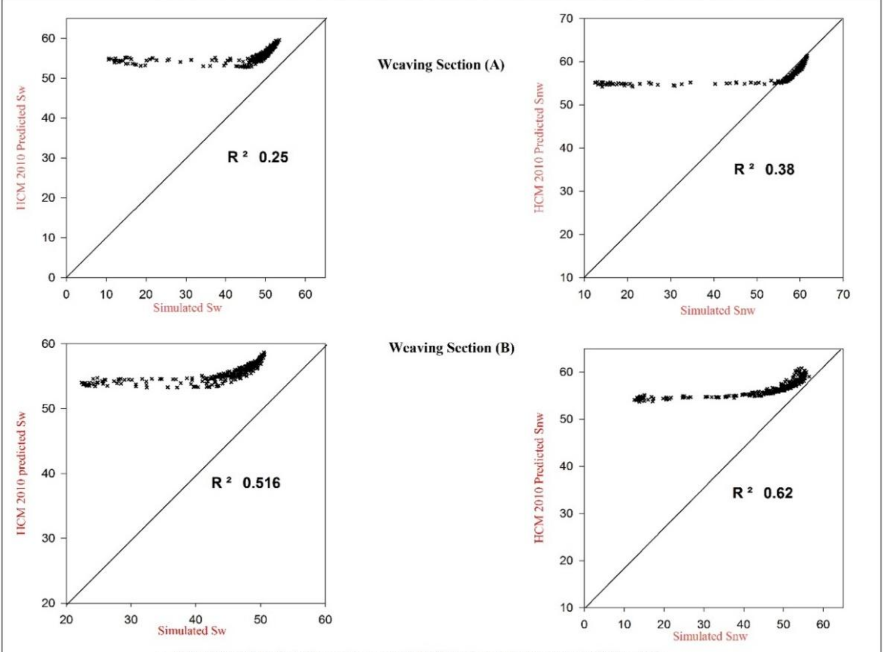


a. HCM 2010 Predicted speeds versus VISSIM simulated speeds for WL= 100 m



a. HCM 2010 Predicted speeds versus VISSIM simulated speeds for WL =400

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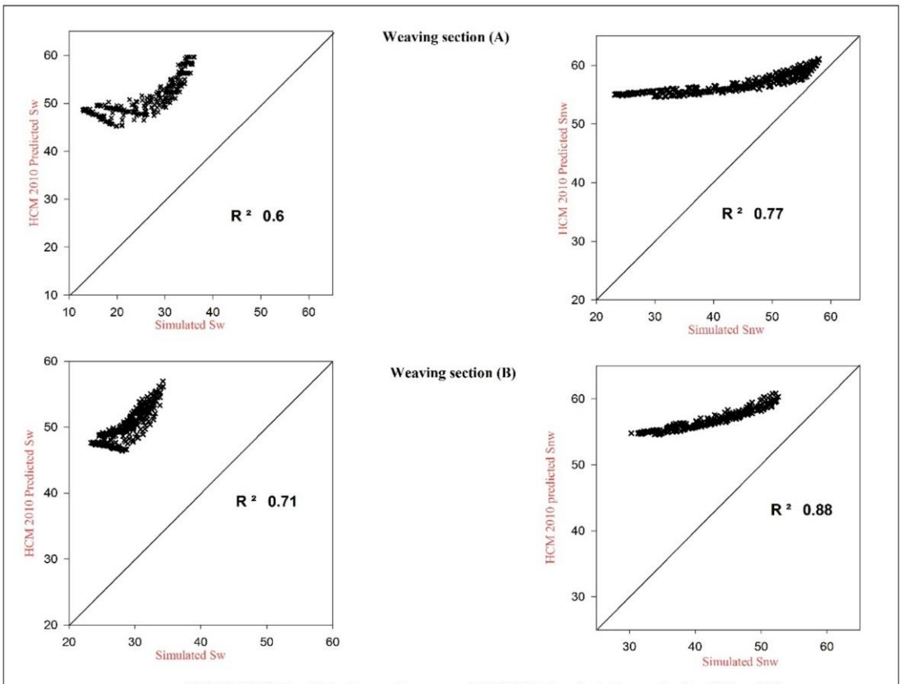
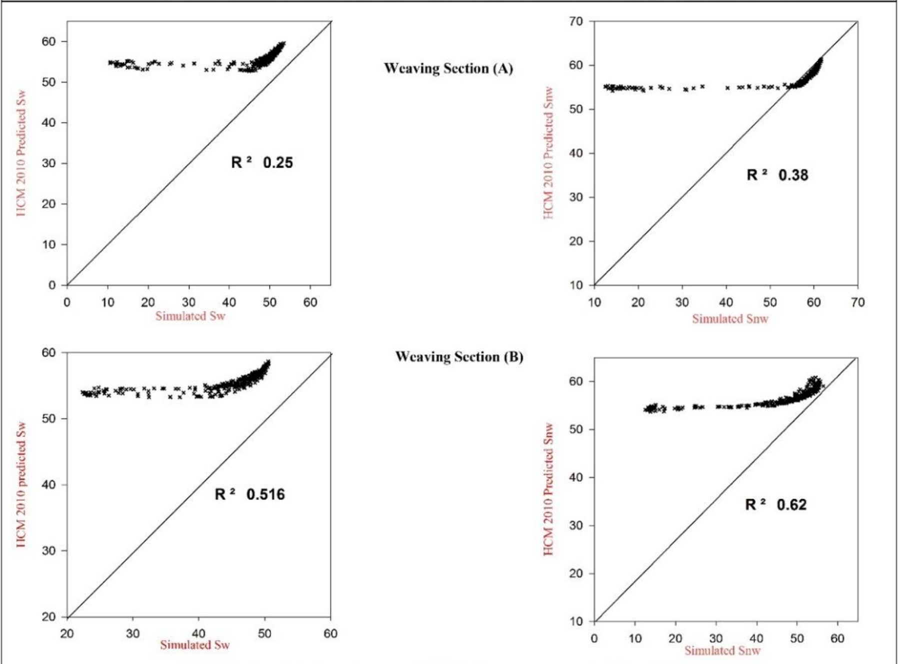


a. HCM 2010 Predicted speeds versus VISSIM simulated speeds for WL= 100 m



a. HCM 2010 Predicted speeds versus VISSIM simulated speeds for WL =400

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Figure 12~~12~~13~~14~~: Parity plots ~~for~~of ~~simulated~~the simulated verses the predicted weaving anc weaving Speeds

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~~5.4~~ Calibrating the HCM speed prediction ~~model~~modelss

Using the non-linear regression procedure in SPSS, an effort was undertaken to calibrate an the HCM speed prediction algorithms ~~with~~ using the simulation data points to represe conditions more accurately~~with 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~~ spee to ~~to~~ the free flow speed ~~FFS~~(FFS).

-The minimum value observed ~~of~~ from ~~simulated~~ the simulation models~~speeds for the urban sections was~~ were lower than 15 ~~mi~~ mph/~~hr,~~; ~~therefore~~therefore, the original models were mo using the actual observed minimum speed of 6 mph ~~mi/h~~. Also all lengths were used in units

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

$$S_W = 6 + (FFS\cancel{+}-\cancel{a}6) / (1 + (b*(L_{CALL}/L_S)^{C})$$

Calibrated Weaving speed prediction model for Section (A)

$$S_W = 6 + \frac{FFS - 6}{1 + W} \qquad where \qquad WwW = 0.322437 * \left(\frac{LC_{ALL}}{L_S}\right)^{1.386716}$$

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

-Calibrated Weaving speed prediction model for Section (B)

$$S_W = 6 + \frac{FFS - 6}{1 + W} \qquad where \qquad WwW = 0.557494 * \left(\frac{LC_{ALL}}{L_S}\right)^{0.787467}$$

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 si results, which was quite expected given that, the non-weaving speed prediction model was ϵ a weak part of the___ HCM 2010 weaving analysis ~~methodology~~ methodology.~~[6].~~

~~In view of the above, it is evident that the structure of the model gives a very low R² even fo (A). On the other hand, efforts to calibrate the non-weaving speed prediction model provided 2010 failed completely t~~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 i statistically acceptable models.

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~~28.~~ CONCLUSION

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

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

Form the comparative analysis with HCM 2010 methodology, it was concluded that,
methodology for these types of urban weaving configurations ~~will~~would produce unreliabl
HCM 2010 models are more likely to predict lower lane changing rates, overestimated capa
higher speeds. This is probably attributed to the fact that the prediction models of the HCM 2
designed for freeway ~~conditions which~~conditions, which naturally involves lower rates of
lower 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 capac~~
~~due to the increase in weaving ratio when length increases.~~

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

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

-At high crossing demands, mainstream vehicles penetrates through the section with very lo
and could be forced to queue with the U-turning vehicles until sufficient gap arises. There
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
Intersection with different volume conditions will result~~s~~ ~~in a more complex weaving opera~~
more complex weaving operation with 4 weaving section interacting with each other. This c
for future work.

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~~7.~~ REFERENCES

1. Manual, H. C. (2010). Transportation Research Board of the National Academies, 2010.
2. Manual, H. C. (1950). Practical Applications of Research. Bureau of Public Ro Department of Commerce, Washington DC.
3. Normann, O. K. (1957). Operation of Weaving Areas. Highway Research Board Bulletin
4. Manual, H. C. (1985). Special report 209. Transportation Research Board, Washington 985
5. Manual, H. C. (2000). HCM 2000. Washington, DC: Transportation Research Board.
6. Roess, R., and J. Uliero. "Analysis of Freeway Weaving Sections." *Final Report, NCHR* (2008): 3-75.
7. Fazio, J. (1985). Development and Testing of a Weaving Operational Design and Procedure. Master's thesis, University of Illinois at Chicago, Chicago IL.
8. Zarean, M., & Nemeth, Z. A. (1988). WEAVSIM: A microscopic simulation model of weaving sections (No. 1194).
9. Wicks, D. A., & Lieberman, E. B. (1976). Development and testing of INTRAS, a mi freeway simulation model. Volume I. Program design and parameter calibration (No. FH 76-75 Final Rpt.).
10. Skabardonis, A., Cassidy, M., May, A. D., & Cohen, S. (1989). Application of simu evaluate the operation of major freeway weaving sections (No. 1225).
11. Fazio, J., & Rouphail, N. M. (1990). Conflict simulation in INTRAS: Application to wea capacity analysis. Transportation Research Record, (1287).
12. Halati, A., Torres, J., & Mikhalkin, B. (1990). Freeway simulation model enhance integration—FRESIM technical report. Federal Highway Administration, Report No. I 85-C-00094.
13. Rathi, A. K., & Santiago, A. J. (1990). Urban Network Traffic Simulations: TRAF- Program. Journal of transportation engineering, 116(6), 734-743.
14. Nowlin, R. L., & Fitzpatrick, K. (1998). ANALYSIS OF TWO-SIDED W OPERATIONS. In 68th Annual Meeting of the Institute of Transportation Engineers.
15. Van Aerde, M. (1992). INTEGRATION, a Model for Simulating Integrated Traffic N User's Guide for Model Version 1.4 D.
16. Stewart, J., Baker, M., & Van Aerde, M. (1996). Evaluating weaving section desig INTEGRATION. Transportation research record: Journal of the transportation researc (1555), 33-41.
17. Zhang, Y., & Rakha, H. (2010). Systematic analysis of capacity of weaving sections. Sayed, Alnuaimi & Masad (eds.), Efficient Transportation and Pavement Systems, 151-1
18. PTV, A. (2011). VISSIM 5.40 User Manual. Karlsruhe, Germany.
19. Wiedemann, R. (1974). SIMULATION DES STRASSENVERKEHRSFLUSSES
20. Vu, T. T., Roess, R. P., Ulerio, J. M., & Prassas, E. S. (2007). Simulation of a weaving s Transportation Research Board 86th Annual Meeting (No. 07-0111).
21. Pesti, G., Chu, C. L., Fitzpatrick, K., Porter, R. J., & Le, T. Q. (2011). Simulation of Traffic Between Freeway Ramps. In Transportation Research Board 90th Annual Mee 11-3084).

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22. Liu, X., Wang, Y., Schroeder, B., & Rouphail, N. (2012). Quantifying Cross-Weave I Capacity Reduction for Freeway Facilities with Managed Lanes. Transportation Researc Journal of the Transportation Research Board, (2278), 171-179.