DEVELOPMENT OF SIMULATION MODEL FOR ASSESSING THE PERFORMANCE OF WEAVING SECTIONS ON INTERCHANGES

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A thesis submitted in fulfillment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JANUARY 2016

Dedicated to my beloved family especially my wife, my children and my supportive supervisor –Associate Prof Dr Othman Bin Che Puan. Thank you very much for being supportive, helpful and understanding

ACKNOWLEDGEMENT

In the name of Allah the most beneficent the most merciful, first and foremost, I thank God for everything that has made this dissertation possible. This research project would not have been possible without the support of many people. I would like to express my deep gratefulness to my supervisor, Professor Dr. Othman Bin Che Puan who was abundantly helpful and offered invaluable assistance, support and guidance.

I would like to thank Mr Zainuddin Bin Abdullah, Mr Ahmad Sofi and Azdi Shafie for their help collecting data from Lembaga Lebuhraya Malaysia in Kuala Lumpur during the hot summer. They helped me to record camera for data collection at site 1, 3.

Also I would like to thank Mrs Nur Amani Binti Zakaria and Mrs Indawati Moho Aslar for their help collecting data from New Pantai Expressway in Kuala Lumpur. They helped me to record camera for data collection at site 2. My gratitude also goes to Dr Sayed Ehsan Alavi who assist me to edit and modification of the text.

And finally, my wife Leila, my daughter Melika and my son Mohammad Hossein provided me with love and understanding. Their constant encouragement and emotional support kept my vigor and life line alive in research. Finally, none of my studies would have been possible without the continuous support of my parents.

ABSTRACT

Weaving section is a common feature of an urban highway. A weaving area is characterized by frequent lane-changing maneuvers, which will reduce the capacity of a dual carriageway road. It is formed when a merge area is closely followed by diverge area, or when an on-ramp is closely followed by an off-ramp and the two are joined by an auxiliary lane. Current procedures and existing simulation models are inadequate for a detailed assessment and evaluation of traffic behaviour on the merging and diverging area. There is a need to develop an appropriate tool to assess the merging and diverging area accurately because such an assessment involves a large number of variables. This study aims at developing a simulation model of traffic operations at weaving sections in Malaysia based on some variables which affect weaving section performance. The microscopic time scanning simulation model developed is capable of representing and investigating traffic operations in merging areas. The model, which is written in the FORTRAN programming language, was validated and calibrated using data collected at three locations of weaving area in Kuala Lumpur. The lengths of the weaving areas considered were site1=450 m, site2=575 m and site3= 350 m, respectively. The simulation model was used to evaluate the capacity of Type A weave area with a range of traffic flow conditions. The regression model described in this thesis is based on the mainline volume, freeway to ramp volume and ramp to freeway volume. The comparison between on-ramp field data and relevant simulation results showed less than 8% disparity. The simulation results showed that for a weaving length less than 200 m the interactions between vehicles increase significantly and the capacity decrease considerably..

ABSTRAK

Bahagian jalinan ialah satu ciri biasa bagi kebanyakan lebuh raya bandar. Kawasan jalinan dicirikan dengan gerakan penukaran lorong yang kerap yang akan mengurangkan kapasiti jalan raya berkembar. Ia terbentuk apabila satu kawasan cantuman diikuti rapat dengan kawasan mencapah atau tanjakan masuk diikati dengan tanjakan yang disambung dengan lorong tambahan. Prosedur semasa dan model simulasi yang sedia ada tidak mencukupi untuk penilaian dan pentaksiran terperinci tingkah laku lalu lintas di kawasan percantuman dan mencapah. Oleh kerana terlalu banyak pembolehubah yang memberi kesan kepada pentaksiran kawasan-kawasan ini, adalah penting untuk membangunkan satu alat sesuai yang mampu mentaksirkan kawasan berkaitan dengan lebih tepat. Kajian ini bertujuan membangunkan satu model simulasi operasi lalu lintas di bahagian jalinan di Malaysia berdasarkan beberapa pembolehubah yang memberi kesan terhadap prestasi bahagian jalinan. Satu model simulasi imbasan masa mikroskopik telah dibangunkan bagi menyiasat operasi lalu lintas di kawasan percantuman. Model kajian ini yang mana ditulis dalam bahasa pengaturcaraan FORTRAN telah disahkan dan ditentukur menggunakan data yang dikumpulkan di tiga lokasi kawasan jalinan di Kuala Lampur. Panjang-panjang kawasan jalinan yang dipertimbangkan adalah tapak1 = 450, tapak2 = 575 dan tapak3 = 350 m. Model simulasi digunakan untuk menilai keupayaan kawasan lapangan jenis A dengan pelbagai keadaan aliran lalu lintas. Model regrasi dalam kajian ini adalah berdasarkan kepada isipadu lalu lintas laluan utama, isipadu lalu lintas laluan bebas ke tanjakan dan isipadu lalu lintas tanjakan ke laluan bebas. Perbandingan di antara data lapangan tanjakan dan keputusan relevan simulasi menunjukkan kurang 8% perbezaan. Hasil simulasi menunjukkan panjang bahagian jalinan yang kurang daripada 200 m meningkatkan interaksi antara kenderaan dan mengurangkan kapasiti dengan ketara.

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LIST OF ABBREVIATIONS

AADT	-	Annual Average Daily Traffic
AASHO	-	American Association of State Highway Officials
AASHTO	-	American Association of State Highway and Trans. Officials
AAWT	-	Annual Average Weekday Traffic
ATMS	-	Advanced Traffic Management Systems
FFS	-	Free Flow Speed
F-F	-	Freeway to Freeway
FHWA	-	Federal Highway Administration
F-R	-	Freeway to Ramp
HCM	-	Highway Capacity Manual
HGV	-	Heavy Goods Vehicles
HOV	-	High Occupancy Vehicle
INTRAS	-	INtegrated TRAnsportation Simulation
ITS	-	Intelligent Transportation System
Kph	-	Kilometre per hour
L	-	Length of the weaving section, meter
LC	-	Lane Change
LOS	-	Level Of Service
LOSNW	-	Level Of Service of non-weaving traffic
LOSW	-	Level Of Service of weaving traffic
ML	-	Mainline
NCHRP	-	National Cooperative Highway Research Program
NL	-	No. of lanes in WS multiplied by the length of WS
OD	-	Origin-Destination
OSCA	-	Overtaking on Single Carriageway Assessment
Pcph	-	Passenger Car Per Hour
Pcphpl	-	Passenger Cars per Hour per Lane

PHF	-	Peak Hour Factor
PREFO	-	Priority Entry at Freeway on-ramp
RE	-	Rear-end
R-F	-	Ramp to Freeway
R-R	-	Ramp to Ramp
SITS	-	Simulation of Intelligent Transportation System
SMOWS	-	Simulation Model Of Weaving Section
SNW	-	Average space mean speed of non-weaving traffic through WS L
STS	-	Simulation Time Step, seconds
SW	-	Average space mean speed of weaving traffic through WS L
TRB	-	Transportation Research Board
TSM	-	Transportation System Management
Vj	-	Space Mean Speed
Vpd	-	Vehicle per day
Vph	-	Vehicle per hour
ƲR	-	Volume Ratio, Ʋw/Ʋ
Ʋw	-	Weaving volume
WS	-	Weaving Section

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Traffic congestion is an important issue in urban areas especially in freeway or motorway system. It is very costly to build new freeways in order to reduce congestion due to the high capital and social cost. Thus, the effective management and operation of existing freeway facilities has become a preferred approach to reduce traffic congestion. For example it is utilized for vehicle’s entry and exit from merging and diverging areas. Therefore managing the turbulence in these areas is a considerable task.

Merging occurs when two separate traffic streams join to form a single stream. Merging can occur at an on-ramp to a freeway or multilane highway, or when two significant facilities join to form one. Merging vehicles often make lane changes to align themselves in lanes appropriate to their desired movement. Non-merging vehicles also make lane changes to avoid the turbulence caused by merging manoeuvres in the segment.

Diverging occurs when one traffic stream separates to form two separate traffic streams. This occurs at off-ramp from freeway and multilane highway, but can also occur when a major facility split to form two separate facilities. Again, diverging vehicles must properly align themselves in appropriate lanes, thus including lane-changing; non-diverging vehicles also make lane changes to avoid the turbulence created by diverge manoeuvres.

The traffic movement in a weaving section is different from separate merging or diverging movements. Weaving occurs when a merge is “closely followed” by diverge. The exact meaning of “closely followed” is not well defined. The HCM 2000 indicates that the maximum length over which weaving movement is 762 m (2500 ft). Thus, wherever merge and diverge points are separated by more than 762 m (2500 ft), they are treated as isolated merge and diverge movements. Even where the distance between a merge and diverge is less than 762 m (2500 ft), the classification of the movement depends upon the details of the configuration. For example, a one-lane, right-hand, on-ramp followed by a one-lane, right-hand, off-ramp is considered a weaving section only if the two are connected by a continuous auxiliary lane. If the on-ramp and off-ramp have separate, discontinuous acceleration and deceleration lanes. They are treated as isolated merge and diverge areas, respectively, independent of the distance between them (Roger et al, 2004).

Weaving areas, categorized by their lane configuration, consist of three kinds: Type A, Type B, and Type C. The HCM 2000 (TRB, 2000) defines a Type A weaving are by two conditions: non-weaving vehicles do not change lanes, and all weaving vehicles must make at least one lane change. Thus, there is a continuous lane line from the point of the merge gore to the point of the exit gore, across which only weaving vehicle must cross. There are two sub-categories of the Type A weaves: Type A Major and Type A Minor, shown in Figure 1.1. Type A Major weaves are used for freeway-to-freeway applications where there are two or more lanes on all entering and exiting roadways. On the other hand, Type A Minor weaves represent ramp weaves, where the entering and exiting roadways contain only single lane, as with a freeway entrance ramp and an exit ramp connected by an auxiliary lane. If there is no auxiliary lane, it is a ramp merge followed by a diverge and not a weaving area.

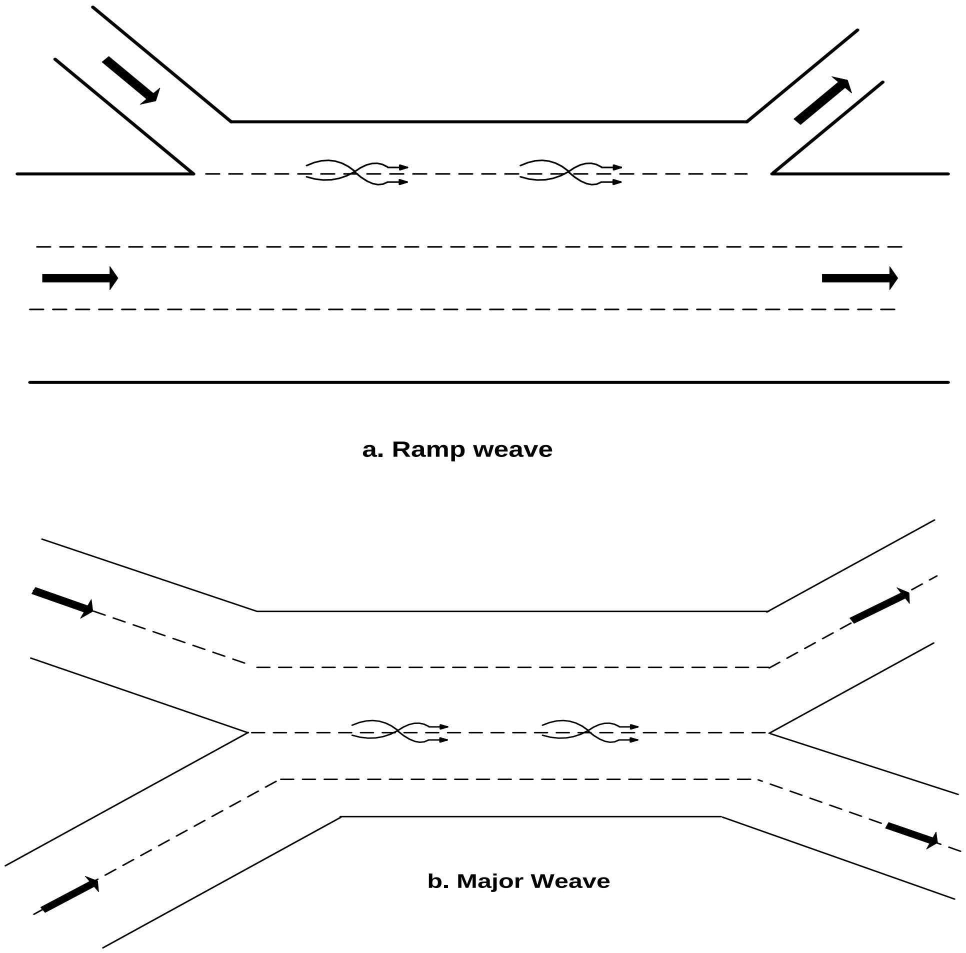


Figure 1.1 Type A Weaving Sections (HCM 2000)

Types B and C weaves are characterized by having one of the lanes entering from the right roadway leave to the left, or by having one of the lanes entering from the left roadway exit to the right. Thus, not all traffic that weaves must change lanes. Type B weaves include at least three entry and exit legs with multiple lanes, and their lane changing should satisfy two following conditions: One weaving movement can be made without making any lane changes and the other weaving movement requires at least one lane change. The larger weaving movement is assumed to be the one that does not change lanes. Three basic Type B weaves are shown in Figure 1.2. It should be noted that internal merges are shown in Figure 1.2 b and c. These are not considered good design but are included in the HCM to allow analysis of existing freeway geometries.

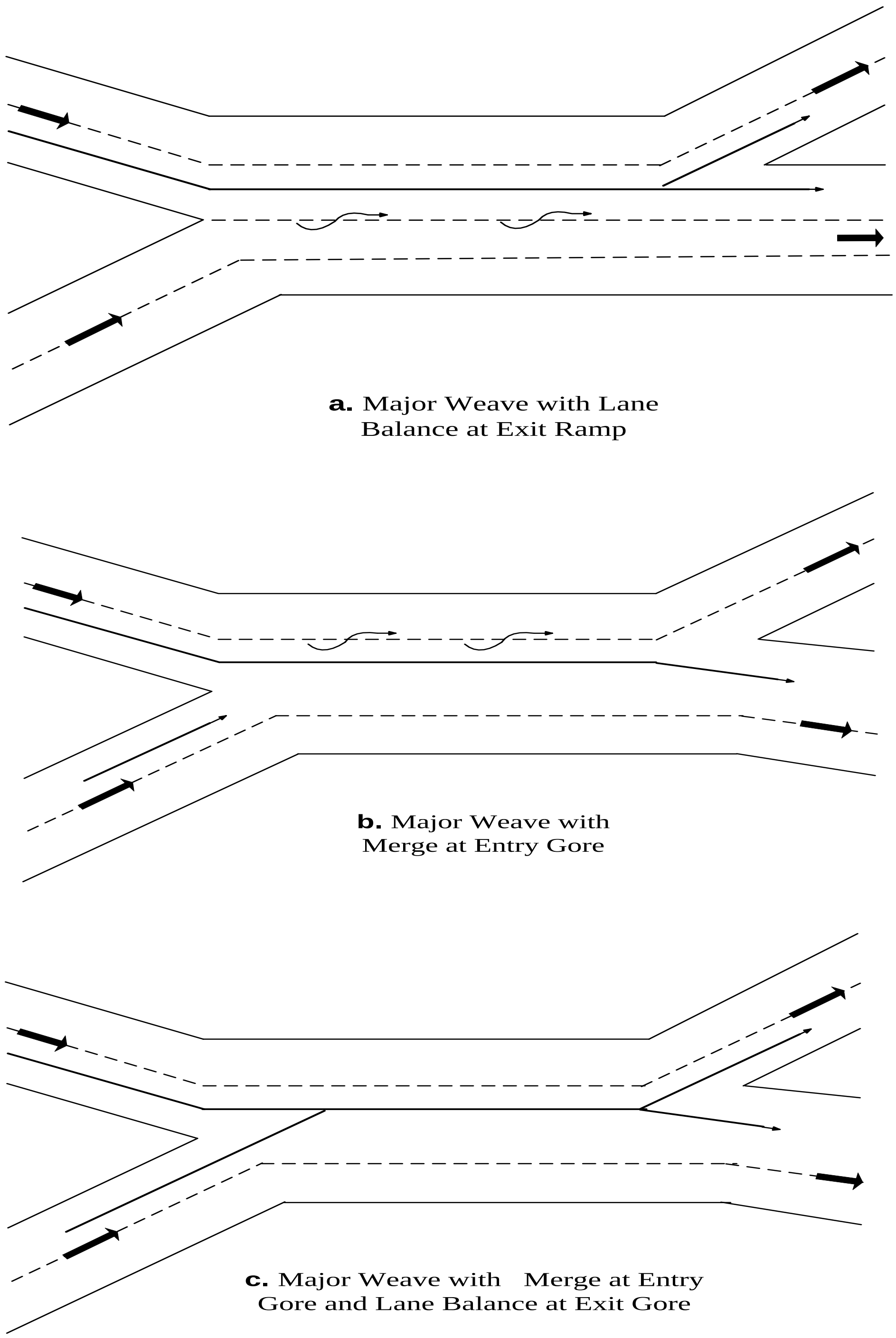


Figure 1.2 Type B Weaving Sections (HCM 2000)

In Type C weaves, the traffic weaving one way does not necessarily have to change lanes while the traffic weaving the other way has to change at least two lanes (see Figure 1.3a). A final special case of Type C weaves is the two-sided weave, formed when a right-hand on-ramp is followed by a left-hand off-ramp, or vice versa (see Figure 1.3b). Again, the larger weaving movement is assumed to be the one not changing lanes. In this case, the through freeway flow operates functionally as a weaving flow. Ramp-to-ramp vehicles must cross all freeway lanes to finish their desired manoeuvre.

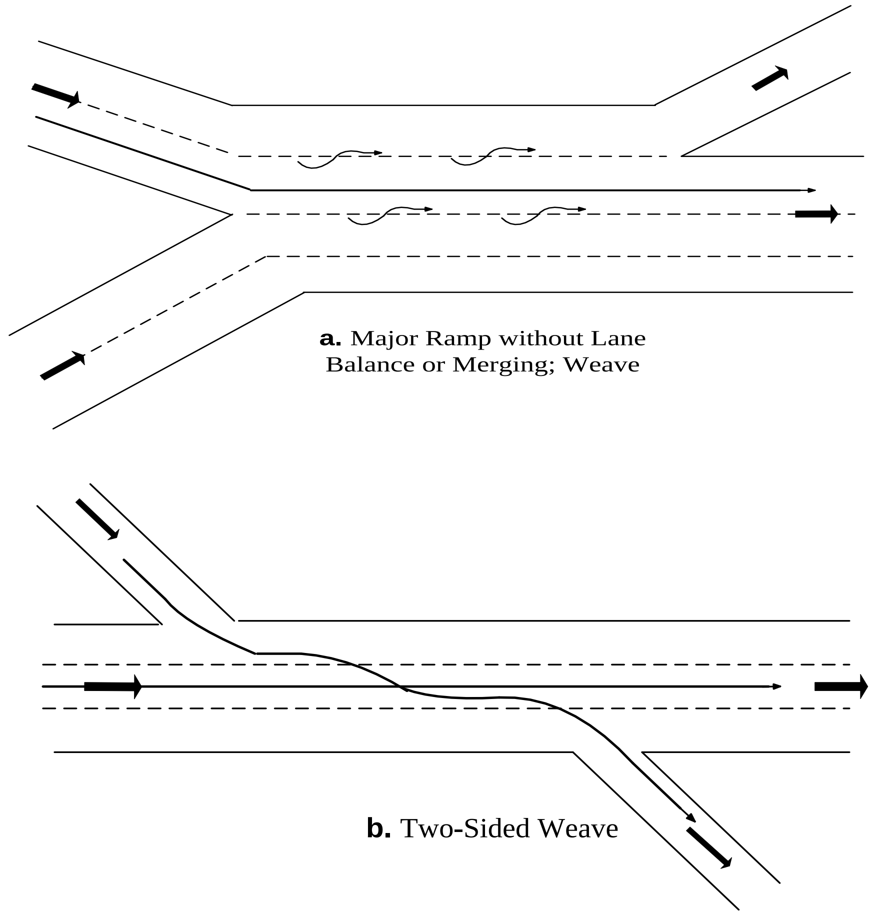
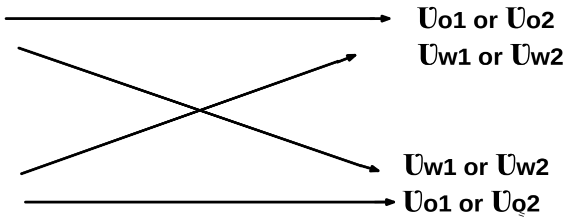


Figure 1.3 Type C Weaving Sections (HCM 2000)

Typically, a weaving section always has four flows: freeway to freeway (F-F), freeway to ramp (F-R), ramp to freeway (R-F), and ramp to ramp (R-R).

The HCM 2000 weaving methodology provides the classification type of weaving areas based on number of lane changes required by each weaving traffic stream as shown in Table 1.1.

Table 1.1: Configuration Type Based on the HCM 2000 Classification



Number of Lane-Changes Required by Movement Vw1	Number of Lane-Changes Required by Movement Vw2		
	0	1	>=2
0	Type B	Type B	Type C
1	Type B	Type A	N/A
>=2	Type C	N/A	N/A

Weaving area have long been studied by many researchers, however, only a few studies have directly addressed the estimation of weaving capacity. The procedures of the HCM (HCM 1950 and HCM 1965) for weaving area analysis were developed from data collected by a variety of agencies to estimate speeds at weaving areas. During the 1970s and 1980s, researchers developed models for weaving area analysis, which estimated speeds in the weaving section (HCM, 2000). These models provided Level Of Service (LOS) with speeds as the measure of effectiveness (MOE), but did not provide estimates for the capacity of weaving areas. In the 1985 edition of the HCM, improvements from the previous edition were in the estimation method for speeds of vehicles in the weaving areas and the classification of weaving area configurations. In the HCM 1985 edition, the methodology used to analyze the operational performance of weaving areas was still on the research conducted during the 1970s and 1980s. The only change from the previous edition was that the speeds of weaving and non-weaving vehicles were used to estimate density within the weaving area. The HCM 1985 still did not provide procedures for estimating the capacity of weaving segments. The most recent edition of the HCM (2000) for the first time provides capacity estimates for weaving areas. Capacity estimates are based on the assumption that the boundary between congested and uncongested regimes of traffic flow is 27 pc/km/ln for freeway and 25 pc/km/ln for multilane highways. There is no specific reason presented why these values are appropriate for capacity estimations. No research and data collection has been performed however to validate these capacity estimates. Speed estimation remains as the backbone of the HCM 2000 methodology to compute density and to identify capacity and LOS. As suggested by Cassidy et al (1991) and Wang et al (1993) speed appeared to be insensitive to the change of flow up to an average flow of 1600 passenger car per hour per lane (pcphpl), therefore it is difficult to establish Level Of Service (LOS) boundaries based on speed estimations.

The current procedures and existing simulation models are inadequate for a detailed assessment and evaluation of the capacity and effects of critical aspects of weaving section and traffic characteristics on traffic operations at weaving sections. There is a need to develop a comprehensive traffic simulation model to carry out this task.

1.2 Problem Formulation

Although the existing state-of-the-art analysis and design of weaving sections provide some basic information regarding the relation between geometric features of weaving and some traffic characteristics, some basic questions about the mechanism of weaving are yet to be explored.

For example, one might be interested in: the level of traffic at which weaving movement between lanes become hazardous, the effect of various lengths of weaving sections on traffic flow, or the impact of upstream condition on operational condition within weaving sections. Also today there are shortcoming in application of real analysis and evaluation of traffic problems. This problems address capacity in weaving section, high level of traffic turbulence in vicinity of ramps and in general reduction of weaving speed. Finally, there is limitation of design guidelines in weaving area.

1.3 Aim and Objectives of the Study

This study aims at developing a simulation model of traffic operations at weaving sections in Malaysia based on some variables which affect the assessment of weaving section performance. These variables include: length of weaving section, volume ratio, number of lanes, and weaving ratio. The model should be capable of representing and investigating traffic operations at merging area.

The following objectives are defined in order to achieve the aim of the study:

(i) To assess and evaluate the current practices of weaving section capacity assessment methods and their applications to the Malaysian interchange design and analysis standards.

(ii) To evaluate the effects of variables which are incorporated in weaving section performance

(iii) To develop an appropriate tool which is used to evaluate the performance and design of weaving section

(iv) To establish an equation in order to predict the capacity

1.4 Scope of Study

The research will first focus on development of a simulation program on microscopic vehicular traffic flow based on the analysis capacity of weaving section in urban area.

The FORTRAN compiler is used for coding purpose and Excel help to post process the output of the program. In the second step, collection of the field data performed in specific sites and finally a comparison will be made between field data and simulation program results for verification of the developed program.

1.5 Methodology

The simulation model developed in this study is based on the existing simulation model namely overtaking on single carriageway assessment (OSCA3) which was developed by Othman (1999) for British traffic conditions. OSCA3 is a microscopic stochastic simulation model which is capable of simulating traffic operation on the roadways and priority junctions. The specific features OSCA3 are discussed in Chapter 3.

OSCA3 is adopted in the development of the simulation model for this study because it considers almost all important aspects of road geometry configuration and drivers' behaviour that will influence the accuracy of the simulation results.

According to the geometrical variations and the movement of vehicles, in the logic of the program some modifications such as lane changing and car following are considered. Moreover, based on the similarities between the Great Britain's vehicles physical conditions with that of Malaysia, the same 7 vehicles types including 3 type car and 4 type truck (HGV) is used. This is explained in Chapter 3.

1.6 Thesis Layout

Chapter Two includes discussions on previous works related to weaving section performance, several existing simulation model for weaving section analysis and basic criteria's of simulation. The deliverable of this chapter provides a basis of the model to be developed in this study.

In **Chapter Three** the existing OSCA3 model is reviewed in detail to establish the extent of work that is required for the redevelopment of the new model.

Chapter Four describe the various aspects of road and traffic characteristics considered for the development of the enhanced simulation model and base on this aspects the new simulation model of weaving section (SMOWS) is developed and incorporated in the improved OSCA3 model to form an enhanced simulation model of traffic operations on dual carriageway roads in Malaysia. In this chapter also, the existing time scanning validated OSCA3 model is improved and re-programmed in the FORTRAN 95 programming language. The algorithms for simulating most aspects of traffic operations are explained in depth.

Via the data and information gathered which are presented in **Chapter Five** the development of the enhanced simulation model is feasible, in this regard data collection at three configuration type on freeway is described provides the details of the process for model development.

Chapter Six describes the procedure used for calibrating and validating the model developed in this study. The enhanced model is verified for traffic operations on weaving area. Vehicle trajectories, traffic delays and speed are assessed. The agreement between the enhanced model and the original OSCA3 model is established.

Chapter Seven describes the application of the developed enhanced simulation model to the speed/flow analysis and predictions of the capacity of dual carriageway roads. The results based on simulation, the standard HCM (TRB, 2000) method is compared. The potential effects of HGVs, speed of vehicles, on-ramp, acceleration, deceleration lane on capacity are assessed and evaluated.

Chapter Eight summarizes the thesis and the finding of the study. Several important areas of the research are recommended for future work.

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