INFLUENCE OF MIDBLOCK U-TURN FACILITY ON TRAFFIC FLOW REDUCTION AND ITS EFFECT ON KINEMATIC WAVE PROPAGATION

RAHA BINTI ABD RAHMAN

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Universiti Teknologi Malaysia

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This thesis is especially dedicated to the followings who are very much appreciated for their patience, steadfast and sympathy.

My parents
HJ ABD RAHMAN BIN ABDULLAH

HJH HAMIDAH BINTI ABDULLAH

My loving husband
MOHD FARID BIN HASSAN

My children
UMAR ABDUL AZIZ BIN MOHD FARID
UMAR LUQMAN AL HAQIM BIN MOHD FARID

May ALLAH swt. increase our faith and good deeds and save us from any calamities and
disasters in the Day of Judgment and put us into His Heaven, Amin.

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ABSTRACT

Midblock median opening facilities are constructed on multilane highways in Malaysia solely for the purpose of facilitating U-turn movements along federal road segments. In Malaysia, a persistence problem of traffic conflicts and congestion at multi-lane highway intersections forced the federal authorities to invest in midblock median opening facilities as traffic conflict reduction mechanism. Although the authorities have succeeded in reducing traffic conflicts at intersections, the realisation of maximum traffic flow at the midblock zone is in doubt. The aim of the study is to determine influence of midblock U-turn facility on traffic flow reduction and its effect on kinematic wave propagation. The objectives are to determine traffic volume, speeds as well as vehicle types at the midblock and free-flow zones for both directional flows. As well as examine the effect of traffic flow reduction on kinematic wave propagation. It was assumed that traffic density was a resultant of speed and traffic flow hence not directly affected by midblock zone. It implies that traffic flow reduction was fully the result of speed changes. Where traffic flow reduction has occurred, the ensuing kinematic wave propagation would be investigated in order to determine whether it is a rarefaction wave or traffic shockwave. Vehicle types, traffic volumes and vehicles speeds were collected using automatic traffic counters at each directional flow of the four surveyed sites for six months. The survey data were collated and analysed. Passenger car equivalent values were modified and used to convert traffic volume to flow. Results show that midblock facility would cause about 4 per cent reduction in traffic flow at the diverging section and 10 per cent reduction in traffic at the merging section. The findings give traffic capacity values under different scenarios and can be incorporated into a wider strategy for dynamic traffic management. Findings from kinematic wave propagations confirm that midblock facility would cause traffic shock wave at the merging not the diverging section. Estimated traffic flow reduction from the study can be used as evidence to highlight the need to redesign midblock facility in Malaysia. One possible solution among others is to incorporate appropriate acceleration lane at the merging section thereby minimising the potential for vehicle collision. The study concluded that midblock facility will cause traffic significant flow reduction.

ABSTRAK

Pembukaan kemudahan pembahagi jalan yang dibina pada jalan dua lorong dua hala di Malaysia bertujuan memberi kemudahan kepada kenderaan membuat pusingan 'U' di sepanjang jalan Persekutuan. Di Malaysia, keadaan di mana masalah dan konflik yang berlaku di jalan dua hala dua lorong telah mendorong Pihak Berkuasa untuk memperkenalkan penggunaan pembukaan pembahagi jalan sebagai salah satu mekanisma untuk mengurangkan konflik tersebut. Walaupun Pihak Berkuasa telah berjaya mengurangkan konflik trafik di persimpangan jalan tetapi realitinya maksimum aliran trafik di zon pembahagi jalan adalah diragui. Tujuan kajian ini dilakukan adalah untuk menentukan pengaruh daripada kemudahan pusingan 'U' terhadap pengurangan aliran trafik dan kesannya terhadap gelombang kinematik trafik. Objektif bagi kajian ini adalah untuk menentukan jumlah isipadu lalulintas, kelajuan dan jenis kenderaan yang melalui zon aliran bebas dan zon kemudahan pusingan 'U' bagi kedua-dua arah dan seterusnya mencari kesan pengurangan aliran trafik terhadap gelombang kinematik trafik. Dianggap bahawa ketumpatan trafik adalah terhasil daripada kelajuan dan aliran trafik dan bukan daripada kesan zon kemudahan pusingan 'U'. Telah didapati bahawa pengurangan aliran trafik adalah berpunca daripada perubahan kelajuan kenderaan. Sekiranya terdapat pengurangan aliran trafik, kajian terhadap gelombang kinematik trafik akan dijalankan untuk menentukan samada ia adalah 'rarefaction' atau kejutan gelombang trafik. Data jenis kenderaan, jumlah lalulintas dan kelajuan kenderaan telah didapati menggunakan alat 'automatic traffic counters' di setiap arah trafik di empat lokasi selama enam bulan. Data kaji ini kemudian dikumpulkan, disusun dan dianalisis. Nilai bagi Setaraan Kenderaan Penumpang diubahsuai dan digunakan untuk menukar isipadu trafik kepada aliran trafik. Daripada keputusan yang diperoleh, didapati bahawa kemudahan pembahagi jalan pusingan 'U' ini boleh menyebabkan terjadinya pengurangan aliran trafik sebanyak 4% di bahagian pencambahan trafik manakala 10% pengurangan trafik di bahagian cantuman trafik. Penemuan ini memberi kapisiti lalulintas kepada beberapa scenario berlainan dan ia membuka ruang dengan luasnya kepada kajian terhadap pengurusan dinamik trafik. Penemuan daripada gelombang kinematik trafik mengesahkan bahawa kemudahan pusingan 'U' ini menjadi punca kepada gelombang kejutan trafik di bahagian cantuman trafik dan bukan di bahagian pencambahan trafik. Pengiraan dalam pengurangan aliran trafik hasil daripada kajian ini boleh digunakan untuk mengkaji keperluan merekabentuk semula kemudahan pusing 'U' di Malaysia. Salah satu jalan penyelesaian yang boleh digunapakai untuk mengurangkan risiko kemalangan adalah menyediakan panjang yang mencukupi di laluan/jalan susurmasuk pada bahagian cantuman trafik. Kesimpulannya melalui kajian ini mendapati bahawa kemudahan pusingan 'U' boleh mengakibatkan pengurangan aliran trafik .

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LIST OF ABBREVIATIONS

ADT	-	Annual Daily Traffic
ATC	-	Automatic traffic count
FD	-	Fundamental Diagram
FHWA	-	Federal Highway Administration
GQM	-	Generalised queuing model
HCM	-	Highway capacity manual
JKR	-	Jabatan Kerja Raya
LOS	-	Level of service
MHA	-	Malaysian Highway Authority
MHCM	-	Malaysian Highway Capacity Manual
PCE	-	Passenger car equivalency values
PSD	-	Passing sight distance
PWD	-	Public Work Department
SPM	-	Semi-poisson model
SSD	-	Stopping sight distance
TRB	-	Transportation Research Board

LIST OF SYMBOLS

a	-	acceleration
D	-	sight distance
D_b	-	braking distance
D_p	-	passing sight distance
D_r	-	reaction distance
D_s	-	stopping sight distance
g	-	gap
h	-	headway
h_m	-	mean time headway
h_{ij}	-	Headway of vehicles class i under condition j
h_p	-	time of headway vehicle p to preceding vehicle
k	-	density
k_c	-	critical density
k_j	-	jam density
L		average length of vehicles in the traffic stream
q	-	flow
Q,q_c	-	capacity
q_m	-	maximum traffic flowrate
s	-	distance
S_w	-	Shockwave
t	-	time
t_f	-	travel time at free-flow speed
u	-	speed
u, v	-	initial velocity and final velocity, respectively
u_f	-	free-flow speed
u_o	-	optimum speed
u_o-v	-	Mean speed

CHAPTER 1

INTRODUCTION

1.1 Overview

Flow, speed and density are known three parameters that govern traffic stream operations. For the purpose of quantifying traffic flow, often flow/density relationship is used where flow is the dependent variable and density the independent. Traffic flow contracts when capacity is oversubscribed. Direct midblock opening on multi-lane highways is one of the factors that may trigger traffic flow contraction and kinematic waves to an extent that has yet to be quantified.

In Malaysia, peak hour traffic conflicts and congestions that at daily occurrences at the highway intersections have continue to worsen. One commendable attempt by authorities to solve the problems of intersection conflicts and congestion is the installation of direct midblock facilities that will allow motorists to make U-turning movements before reaching the intersection.

This thesis presents studies that investigated the influence of direct midblock U-turn facilities at multilane highway on traffic flow reduction and their kinematic wave implication. Relying on the flow, density and speed fundamental relationships, traffic flow scenarios with and without midblock U-turn facilities under daylight and dry weather conditions were modeled and compared. Where there are evidences to show that traffic flow contraction has occurred, associated kinematic waves propagations were investigated.

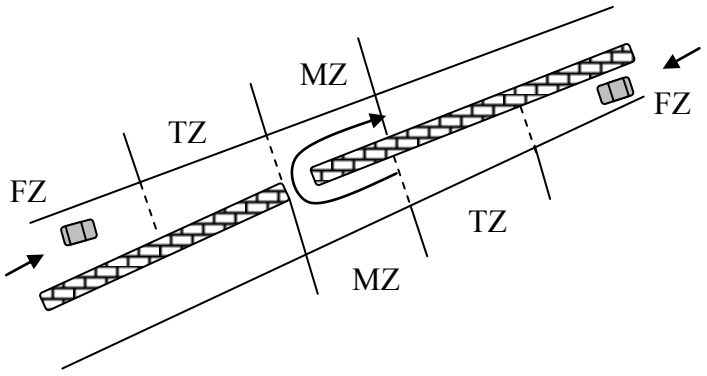
This chapter has been divided into six sections; in the immediate Section 1.2, background to the research problem is presented. It will be followed by the research objectives in Section 1.3. The method of study is discussed in Section 1.4. The scope and limitations of the study are described in Section 1.5. The significance and contributions of the study presented in Section 1.6. Organization of the thesis is presented in Section 1.7.

1.2 Background to the research problem

Roads have a major impact on our daily lives. Roads serve as the primary mean of access to employment, services and social activities. Moreover, by linking people and other modes of transport, roadways are a tremendous asset for achieving greater travel passage within and beyond Malaysia. Generally roads are built to provide better accessibility and enhance mobility in Malaysia. Malaysia consists of thirteen states and three federal territories and has a total landmass of 329,847m^2 separated by the South China Sea into two similarly sized regions, Peninsular Malaysia and Malaysian Borneo. The capital city is Kuala Lumpur. In 2010, the population exceeded 27.5 million, with over 20 million living on the Peninsular. Malaysia has a good road network. Roads are paved or unpaved, private or public. Public roads are often referred to as highways and a road network is an amalgamation of highways. A highway irrespective of functional classification is made up of segments and intersections/interchanges.

Midblock facilities are median openings on multi-lane highways as illustrated in Figure 1.1. They are built as u-turning facilities aimed at easing traffic conflicts and pressures at highway intersections. While some are built as complimentary facilities to existing road geometric designs, others are built as a complete replacement to existing facilities on the premises that they will reduce conflicts and ease traffic congestions at adjoining intersections. In Malaysia, where the left hand driving rule is in place, drivers decelerate when diverging; accelerate when converging at the midblock facilities. These dangerous manoeuvres beg the questions; ‘What are the traffic flow consequences when the lead vehicle decelerates or accelerates abruptly? It can be argued that when the lead vehicle decelerates abruptly in a traffic stream, kinematic waves can be triggered. Therefore, it is not

surprising that the issue of midblock u-turning facilities has provoked fierce national debates. Proponents of midblock facilities argue that their installation has brought succour to motorists plagued with conflicts and congestions at adjoining intersections. Whereas, opponents argued that the road safety problems associated with midblock facilities far outweigh the benefits of direct midblock facilities. However, both contending camps failed to support their arguments with empirical evidences.



Note: FZ denotes free-flow zone; TZ denotes transition zone and MZ denotes midblock zone

Figure 1.1: Typical Direct Midblock U-turn Facility in Malaysia

1.3 Research Objectives

The objectives of the study are to investigate the followings:

i. Traffic flow reduction at midblock and free-flow sections under dry weather and daylight conditions
ii. The effects of midblock facility on speed, flow and density relationships
iii. The kind of relationship that exists between midblock facility and traffic flow reduction; and
iv. The extent and type of traffic kinematic wave propagations resulting from midblock facility

1.4 Method of the study

The method of study is both empirical and analytical. It is empirical because sample surveys were taken at selected sites and analytical because flow, density and speed relationships were used to develop models. Models were developed for two scenarios (midblock facility and free-flow zones) under daylight and dry weather conditions. Empirical data collected at selected sites reflected the study objectives as stated in Section 1.3. Multi-lane highway with direct midblock facilities was divided into three sections to reflect free-flow, transition and midblock restrained. Automatic traffic counters were installed at the sections in order to collect traffic volume, speed, headway, vehicle type continuously per time period. Collected data were collated and fed into the developed models for evaluation of relevant traffic parameters. Once the traffic contraction objective was achieved, associated kinematic wave propagations as well as the acceptability of Malaysian Highway Capacity Manual (MHCM 2011) passenger car equivalent values were investigated. Passenger car equivalent values were adjusted where necessary and reapplied into the models.

1.5 Research Scope and limitations

The scope of this research is restricted to multi-lane highways because midblock facilities with direct U-turning movements can only be found on such roads. Multi-lane highways are classified as federal routes in Malaysia. There carriageways are physically separated by central medians. All traffic volume and speed survey data were collected with automatic traffic counters continuously for eight weeks, only dry weather and daylight data were used for analysis. This is needed in order to minimise multiple traffic flow contraction constraints aside from midblock facilities. All selected sites have the same geometric design, good road surface and layout so as to minimise errors associated with traffic volume and speed data collection. Each directional flow is treated exclusively. Different empirical road capacity estimation methods were considered and tested for suitability before using the fundamental diagrams. Malaysian Highway Capacity Manual passenger car equivalent values were modified and used to convert traffic volume to flow. With regard to the research limitations; monsoon periods being November-January and

April to June were avoided in order to minimise the effect of wet and rainy conditions on survey data. Only motorised vehicles were considered. The total number of survey sites was constrained by fund, equipment and manpower; nonetheless, eight sites were surveyed. Automatic traffic counters were often chained to the nearest pole to minimise theft and vandalism. Survey sites were visited daily during data collection period partly to check the state of the equipment and also to download captured data from the equipment to a laptop.

1.6 Significance of the study

The influence of midblock facilities on traffic flow reduction and its effect on kinematic wave propagation, have neither been fully explored, nor well understood. Often passenger car equivalent values were broadly applied to all conditions and kinematic wave treated as shockwave propagation in previous studies. In this study, dynamic passenger car equivalent values were used and traffic shockwave taken as function of traffic congestion. Modified passenger car equivalent values can point to overestimation or underestimation of capacity values on specific sites and under prevailing conditions. Traffic shockwave irrespective of what triggered it, is a safety indicator on the roadway. The study would throw more light on the issues of traffic shockwave at midblock facilities and by extension assist policy and decision making process in Malaysia. The flow-speed relationships available in Malaysia Highway Capacity Manual have serious limitations. This is so because speed is not a function of flow. In particular they cannot be used to predict future traffic states. Whereas the fundamental diagram approach used in the study gives a robust predictive tool for computing traffic variables at the capacity state. The results of the capacity predictions are consistent with attainable values on roadway sections and in line with standard specifications. The findings in this thesis give highway capacity values under different scenarios and can be incorporated into a wider strategy for dynamic traffic management. Predicted capacity states can also be used for traffic management scenario building.

1.7 Organisation of Thesis

The thesis is made up of eight chapters. This section provides brief information about each chapter. Chapter 2 presents a theoretical background on traffic flow contraction and disturbances. It provides the theoretic arguments on which the research hinges. Empirical road capacity definitions, estimation methods, generalised and specific capacity disturbances and their relationships with capacity, passenger car equivalent values are discussed. Traffic kinematic, rarefaction and shockwaves are all covered in this chapter.

Chapter 3 presents literature two-lane perdirection highways and midblock facilities in Malaysia.

Chapter 4 is on midblock facilities impact study setup and data collection. It gives the criteria for site selection, assessment of the selected sites, the survey method employed, analytical framework, data, hypothesis and equipment testing.

Chapter 5 presents the empirical results from surveyed sites that include traffic volume and speed profiles, graph dispersion plots, empirical evidence of flow contraction, and macroscopic data and site summary.

Chapter 6 is on the main traffic flow contraction analysis using standard Malaysia Highway Capacity Manual passenger car equivalent values.

Chapter 7 is based on traffic flow contraction using modified passenger car equivalent values. The implications of traffic flow contraction on kinematic wave propagations are also discussed.

Chapter 8 is the concluding chapter and it gives some research directions for the future works.

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