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

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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


# TABLE OF CONTENT

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td></td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td></td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>v</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td></td>
<td>vi</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>xviii</td>
</tr>
<tr>
<td>LIST OF ABREVIATIONS</td>
<td></td>
<td>xxi</td>
</tr>
<tr>
<td>LIST OF SYMBOLS</td>
<td></td>
<td>xxii</td>
</tr>
<tr>
<td>1</td>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1</td>
<td>Overview</td>
<td>1</td>
</tr>
<tr>
<td>1.2</td>
<td>Background to the Research Problem</td>
<td>2</td>
</tr>
<tr>
<td>1.3</td>
<td>Research Objectives</td>
<td>3</td>
</tr>
<tr>
<td>1.4</td>
<td>Method of the Study</td>
<td>4</td>
</tr>
<tr>
<td>1.5</td>
<td>Research Scope and Limitations</td>
<td>4</td>
</tr>
<tr>
<td>1.6</td>
<td>Significance of the Study</td>
<td>5</td>
</tr>
<tr>
<td>1.7</td>
<td>Organisation of Thesis</td>
<td>6</td>
</tr>
</tbody>
</table>
2 THEORETICAL BACKGROUND

2.1 Overview

2.2 Midblock U-turning Facilities

2.2.1 Previous Studies of Traffic at Midblock U-turn Facilities

2.3 Maximum Traffic Flowrate Concepts

2.3.1 Speed v Density

2.3.2 Flow v Density

2.3.3 Speed v Flow

2.3.4 Traffic Volume and Flow

2.4 Capacity Estimation Methods

2.4.1 Estimation with Headways

2.4.2 Estimation with Traffic Flows

2.4.2.1 Bimodal Distribution Method

2.4.2.2 Selected Maximal Method

2.4.2.3 Expected Extreme Value Methods

2.4.2.4 Asymptotic Method

2.4.3 Estimation with Traffic Speed/Flow

2.4.3.1 Product Limit Method

2.4.4 Estimation with Flow, Speed and Density

2.4.4.1 Fundamental Approach Using the Quadratic Function

2.4.4.2 Malaysia Highway Capacity Manual 2011 (MHCM2011) Approach

2.5 Impact of Midblock U-turn Facilities on Passenger Car Equivalency (PCE)

2.6 Hypothetical Midblock Zone and Traffic Stream Relationships

2.7 Traffic Kinematic Wave Propagations from Midblock Facilities
3 RESEARCH METHODOLOGY

3.1 Overview

3.2 Research Methodology

3.3 Criteria of Site Selection

3.4 Exploration of Selected Sites

3.4.1 Site 1: Senai Johor Bahru Highway FT001, Johor

3.4.2 Site 2: Skudai Johor Bahru Highway FT005, Johor

3.4.3 Site 3: Kota Tinggi Johor Bahru Highway FT001, Johor

3.4.4 Site 4: Pasir Gudang Johor Bahru Highway FT019, Johor

3.5 Survey Methods Used in the Study

3.5.1 Sample Survey

3.5.2 Survey Site Coding

3.5.3 Survey Team and Equipment

3.5.3.1 Survey Team Member

3.5.3.2 Installation of the Tube

3.5.3.3 Status of the Automatic Traffic Counter

3.5.3.4 Automatic Traffic Counter Set Up

3.5.3.5 Downloading Data from the Detector

3.5.3.6 Problem Encountered in Setup and Data Collections

3.5.4 Setting up Impact Site Studies

3.5.5 Traffic Volume Surveys

3.5.6 Vehicles Speeds Survey

3.5.7 Headway and Vehicle gap Surveys
3.6 Appraisal of Sample Data and Analytical Methods
   3.6.1 Reliability of Analytical Methods
   3.6.2 Appraisal of Sample Data
   3.6.3 Reliability of Maximum Flowrate Estimation Method
3.7 Summary

4  EMPIRICAL RESULTS OF SAMPLES SURVEYS
   4.1 Overview
   4.2 Empirical Results from Surveyed Sites
      4.2.1 Site 1D-Senai Johor Bahru Highway FT001, Johor
      4.2.2 Site 1M-Senai Johor Bahru Highway FT001, Johor
      4.2.3 Site 2D-Skudai Johor Bahru Highway FT005, Johor
      4.2.4 Site 2M-Skudai Johor Bahru Highway FT005, Johor
      4.2.5 Site 3D-Kota Tinggi Johor Bahru Highway FT001, Johor
      4.2.6 Site 3M-Kota Tinggi Johor Bahru Highway FT001, Johor
      4.2.7 Site 4D-Pasir Gudang Johor Bahru Highway FT005, Johor
      4.2.8 Site 4M-Pasir Gudang Johor Bahru Highway FT005, Johor
   4.3 Summary

5  TRAFFIC FLOWRATE ANALYSIS USING MHCM2011 PCE VALUES
   5.1 Overview
   5.2 Establishing the Maximum Flowrate Contraction using MHCM2011 PCE Values
5.2.1 Site 1D: Diverging Section of Midblock Facilities

5.3 Site 2D: Diverging Section of Midblock Facilities

5.4 Site 3D: Diverging Section of Midblock Facilities

5.5 Site 4D: Diverging Section of Midblock Facilities

5.6 Model Coefficients for Diverging Section of Midblock Facilities

5.7 Site 1M: Merging Section of Midblock Facilities

5.8 Site 2M: Merging Section of Midblock Facilities

5.9 Site 3M: Merging Section of Midblock Facilities

5.10 Site 4M: Merging Section of Midblock Facilities

5.11 Model Coefficients for Merging Section of Midblock Facilities

5.12 Summary of Traffic Flow Contraction

5.13 Summary

6 Estimation of Modified PCE Values

6.1 Overview

6.2 Assessment of PCE Values for Midblock and Free-Flow Zones

6.3 Statistical Test of PCE Values

6.4 Summary

7 Traffic Flow Analysis Using Modified PCE Values

7.1 Overview

7.2 Traffic Flowrate Estimation for Diverging Section Using Modified PCEs’

7.2.1 Traffic Flow Estimation for Site 1D

7.2.2 Site 2D: Diverging Section

7.2.3 Site 3D: Diverging Section

7.2.4 Site 4D: Diverging Section

134

146

147

151

155

159

163

164

167

169

170

178

180

182

183

188

191

194
7.2.5 Summary of Model Coefficients for Diverging Section 197
7.3 Traffic Flow Estimation for Merging Section 198
  7.3.1 Site 1M: Merging Section 198
  7.3.2 Site 2M: Merging Section 201
  7.3.3 Site 3M: Merging Section 204
  7.3.4 Site 4M: Merging Section 207
  7.3.5 Summary of Model Coefficients for Diverging Section 210
7.4 Traffic Flow Contraction using Modified and MHCM PCEs’ Compared 211
7.5 Impact of Midblock on Traffic Kinematic Wave Propagation 212
  7.5.1 Traffic Kinematic Wave for Diverging Section 213
  7.5.2 Traffic Kinematic Wave for Merging Section 218
7.6 Summary and Recommendations Based on Findings 223

8 CONCLUSIONS 225
8.0 General 225
8.1 Summary of Traffic Flow Reduction Analyses Major Findings 227
8.2 Summary of Traffic Flowrate Contraction Analyses Major Findings 228
8.3 Synthesis of Evidences Obtained From PCEs Modifications 228
8.4 Synthesis of Evidences from Traffic Kinematic Wave Propagations 229
8.5 Conclusions 230
8.6 The Way Forward 231

REFERENCES 233
## LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Overview of Capacity-Estimation Methods</td>
<td>22</td>
</tr>
<tr>
<td>2.2</td>
<td>Classification of Roadway Capacity-Estimation Methods</td>
<td>23</td>
</tr>
<tr>
<td>2.3</td>
<td>Product Limit Method Calculation</td>
<td>33</td>
</tr>
<tr>
<td>2.4</td>
<td>Recommended Peak Hour Factor Based on Flowrate for Multilane Highways</td>
<td>39</td>
</tr>
<tr>
<td>2.5</td>
<td>Passenger Car Equivalents for Multilane Highways</td>
<td>40</td>
</tr>
<tr>
<td>3.1</td>
<td>Summary of Feature for Survey Site</td>
<td>61</td>
</tr>
<tr>
<td>3.2</td>
<td>Survey Summary Sheets for All Sites</td>
<td>62</td>
</tr>
<tr>
<td>3.3</td>
<td>Example of Typical Survey Summary Sheets</td>
<td>68</td>
</tr>
<tr>
<td>3.4</td>
<td>Survey Site Coding Summary Sheets</td>
<td>70</td>
</tr>
<tr>
<td>3.5</td>
<td>Vehicle Logging Information</td>
<td>75</td>
</tr>
<tr>
<td>3.6</td>
<td>Sample of Individual Vehicles for Site 5D</td>
<td>88</td>
</tr>
<tr>
<td>3.7</td>
<td>Traffic Count During Peak Hour</td>
<td>89</td>
</tr>
<tr>
<td>3.8</td>
<td>Traffic Stream Data for Pilot Test Site 5D</td>
<td>88</td>
</tr>
<tr>
<td>3.9</td>
<td>Flow, Speed and Density Data During Peak Hour</td>
<td>95</td>
</tr>
<tr>
<td>3.10</td>
<td>Summary of Critical Density and Maximum Flowrate</td>
<td>96</td>
</tr>
<tr>
<td>4.1</td>
<td>Data Collection Schedule for Diverging Movement Sites</td>
<td>99</td>
</tr>
<tr>
<td>4.2</td>
<td>Data Collection Schedule for Merging Movement Sites</td>
<td>100</td>
</tr>
<tr>
<td>4.3</td>
<td>Site 1D Volume and Speed Data during Off-Peak</td>
<td>102</td>
</tr>
<tr>
<td>4.4</td>
<td>Traffic Composition at Study Site 1D</td>
<td>103</td>
</tr>
<tr>
<td>4.5</td>
<td>Site 1M Volume and Speed Data during Off-Peak</td>
<td>105</td>
</tr>
<tr>
<td>4.6</td>
<td>Traffic Composition at Study Site 1M</td>
<td>106</td>
</tr>
</tbody>
</table>
4.7 Site 2D Volume and Speed Data during Off-Peak 108
4.8 Traffic Composition at Study Site 2D 108
4.9 Site 2M Volume and Speed Data during Off-Peak 111
4.10 Traffic Composition at Study Site 2M 111
4.11 Site 3D Volume and Speed Data during Off-Peak 114
4.12 Traffic Composition at Study Site 3D 114
4.13 Site 3M Volume and Speed Data during Off-Peak 117
4.14 Traffic Composition at Study Site 3M 117
4.15 Site 4D Volume and Speed Data during Off-Peak 120
4.16 Traffic Composition at Study Site 4D 120
4.17 Site 4M Volume and Speed Data during Off-Peak 123
4.18 Traffic Composition at Study Site 4M 123
5.1a Computed Flows and Densities (Off Peak FZ) for Site 1D 129
5.1b Computed Flows and Densities (Off Peak MZ) for Site 1D 130
5.2 Site 1D Summary of Observed and Predicted Traffic Parameter 134
5.3a Computed Flows and Densities (Off Peak FZ) for Site 2D 135
5.3b Computed Flows and Densities (Off Peak MZ) for Site 2D 136
5.4 Site 2D Summary of Observed and Predicted Traffic Parameter 137
5.5a Computed Flows and Densities (Off Peak FZ) for Site 3D 139
5.5b Computed Flows and Densities (Off Peak MZ) for Site 3D 140
5.6 Site 3D Summary of Observed and Predicted Traffic Parameter 141
5.7a Computed Flows and Densities (Off Peak FZ) for Site 4D 143
5.7b Computed Flows and Densities (Off Peak MZ) for Site 4D 144
5.8 Site 4D Summary of Observed and Predicted Traffic Parameter 145
5.9 Summary of Model Coefficients for Off-Peak Traffic 146
5.10a Computed Flows and Densities (Off Peak FZ) for Site 1M 148
5.10b Computed Flows and Densities (Off Peak MZ) for Site 1M 149
5.11 Site 1M Summary of Observed and Predicted Traffic Parameter

5.12a Computed Flows and Densities (Off Peak FZ) for Site 2M

5.12b Computed Flows and Densities (Off Peak MZ) for Site 2M

5.13 Site 2M Summary of Observed and Predicted Traffic Parameter

5.14a Computed Flows and Densities (Off Peak FZ) for Site 3M

5.14b Computed Flows and Densities (Off Peak MZ) for Site 3M

5.15 Site 3M Summary of Observed and Predicted Traffic Parameter

5.16a Computed Flows and Densities (Off Peak FZ) for Site 4M

5.16b Computed Flows and Densities (Off Peak MZ) for Site 4M

5.17 Site 4M Summary of Observed and Predicted Traffic Parameter

5.18 Summary of Model Coefficients for Off-Peak Traffic

5.19 Off-Peak Results Summary for all Sites at Diverging Road Section

5.20 Off-Peak Results Summary for all Sites at Merging Road Section

6.1 Summary of Modified PCE Values

6.2 Computed PCEs for FZ at Diverging Section

6.3 Computed PCEs for MZ at Merging Section

6.4 Computed PCEs for FZ at Diverging Section

6.5 Computed PCEs for MZ at Merging Section

6.6 PCE Values for Study and MHCM2011

6.7 Chi-Square Test MHCM and Modified PCE Values

7.1a Computed Flows and Densities (Off-Peak FZ) for Site 1D

7.1b Computed Flows and Densities (Off-Peak MZ) for Site 1D

7.1c Site 1D Summary of Flow, Speed and Density

7.2a Site 2D Summary of Traffic Parameters

7.2b Computed Flows and Densities (Off-Peak FZ) for Site 2D

7.2c Computed Flows and Densities (Off-Peak MZ) for Site 2D

7.3a Site 3D Summary of Traffic Parameters
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.19</td>
<td>Summary of Model Coefficients for Merging Flowrate at MZ</td>
<td>218</td>
</tr>
<tr>
<td>7.20</td>
<td>Flowrate and Density for Merging Road Segment</td>
<td>219</td>
</tr>
<tr>
<td>7.21</td>
<td>Comparative Flow/Density at Merging Sections</td>
<td>219</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Typical Direct Midblock U-turn Facility in Malaysia</td>
<td>3</td>
</tr>
<tr>
<td>2.1</td>
<td>Example of a Divided Multilane Highway in Malaysia</td>
<td>9</td>
</tr>
<tr>
<td>2.2</td>
<td>Direct U-turn in Malaysia</td>
<td>11</td>
</tr>
<tr>
<td>2.3</td>
<td>Indirect U-turn in Malaysia</td>
<td>11</td>
</tr>
<tr>
<td>2.4</td>
<td>Maximum Traffic Flowrate Continuity</td>
<td>14</td>
</tr>
<tr>
<td>2.5</td>
<td>Speed v Density</td>
<td>16</td>
</tr>
<tr>
<td>2.6</td>
<td>Flow v Density</td>
<td>17</td>
</tr>
<tr>
<td>2.7</td>
<td>Speed v Flow</td>
<td>18</td>
</tr>
<tr>
<td>2.8</td>
<td>Flow / Density Relationship</td>
<td>36</td>
</tr>
<tr>
<td>2.9</td>
<td>Typical Layout of Midblock Opening</td>
<td>45</td>
</tr>
<tr>
<td>2.10</td>
<td>Hypothetical Traffic Flow Rate Contraction at Midblock Zone</td>
<td>46</td>
</tr>
<tr>
<td>2.11</td>
<td>Flow-Density Curve With kinematic Wave ABC</td>
<td>50</td>
</tr>
<tr>
<td>3.1</td>
<td>Flow Chart Logic of the Analytical Procedure</td>
<td>57</td>
</tr>
<tr>
<td>3.2</td>
<td>Selected Federal Route FT001, FT003, FT005 and FT017</td>
<td>59</td>
</tr>
<tr>
<td>3.2</td>
<td>Location of Sites</td>
<td>60</td>
</tr>
<tr>
<td>3.3</td>
<td>Schematic Diagram Site 1</td>
<td>63</td>
</tr>
<tr>
<td>3.4</td>
<td>Schematic Diagram Site 2</td>
<td>64</td>
</tr>
<tr>
<td>3.5</td>
<td>Schematic Diagram Site 3</td>
<td>65</td>
</tr>
<tr>
<td>3.6</td>
<td>Schematic Diagram Site 4</td>
<td>66</td>
</tr>
<tr>
<td>3.8</td>
<td>Installation Process</td>
<td>72</td>
</tr>
<tr>
<td>3.9</td>
<td>Portable Automatic Traffic Counter Place on Site</td>
<td>72</td>
</tr>
<tr>
<td>3.10</td>
<td>Portable Automatic Traffic Counter</td>
<td>73</td>
</tr>
</tbody>
</table>
3.11  Downloading Process  76
3.12  Downloading Profiles  77
3.13  Flat Engine Belt  78
3.14  Drilling Holes Process  78
3.15  Screw installation  79
3.16  Layout of Typical Survey Site  80
3.17  Speed Survey Using Automatic Traffic Counter  82
3.18  Headway and Vehicle Gap  83
3.19a  Sample Worksheet for Data Processing in the Excel Platform  85
3.19b  Sample Worksheet for Data Processing in the Excel Platform  86
3.20  Flow-Density Relationship with Constant During Peak Hour  92
3.21  Free Flow Zone Flow/Density Model for Test Site 5  94
3.22  Midblock Zone Flow/Density Model for Test Site 5  94
3.23  Site 5 Flow-Density Model Plot for FZ and MZ  96
4.1  Site 1D Traffic Flow Profile  101
4.2  Site 1D Volume-Density Plot  101
4.3  Site 1M Traffic Flow Profile  104
4.4  Site 1M Volume-Density Plot  104
4.5  Site 2D Traffic Flow Profile  106
4.6  Site 2D Volume-Density Plot  107
4.7  Site 2M Traffic Flow Profile  109
4.8  Site 2M Volume-Density Plot  109
4.9  Site 3D Traffic Flow Profile  112
4.10  Site 3D Volume-Density Plot  112
4.11  Site 3M Traffic Flow Profile  115
4.12  Site 3M Volume-Density Plot  115
4.13  Site 4D Traffic Flow Profile  118
4.14  Site 4D Volume-Density Plot  118
4.15  Site 4M Traffic Flow Profile  121
4.16 Site 4M Volume-Density Plot 121
5.1 Schematic Evaluation Procedure 127
5.2 Flow/Density Curves for Site 1D 132
5.3 Flow/Density Curves for Site 2D 137
5.4 Flow/Density Curves for Site 3D 141
5.5 Flow/Density Curves for Site 4D 145
5.6 Flow/Density Curves for Site 1M 150
5.7 Flow/Density Curves for Site 2M 154
5.8 Flow/Density Curves for Site 3M 158
5.9 Flow/Density Curves for Site 4M 162
7.1 Diverging Movement Kinematic Waves Graphical Illustrations for Site 1D 216
7.2 Diverging Movement Kinematic Waves Graphical Illustrations for Site 2D 216
7.3 Diverging Movement Kinematic Waves Graphical Illustrations for Site 3D 217
7.4 Diverging Movement Kinematic Waves Graphical Illustrations for Site 4D 217
7.5 Merging Movement Kinematic Waves Graphical Illustrations for Site 1M 221
7.6 Merging Movement Kinematic Waves Graphical Illustrations for Site 2M 221
7.7 Merging Movement Kinematic Waves Graphical Illustrations for Site 3M 222
7.8 Merging Movement Kinematic Waves Graphical Illustrations for Site 4M 222
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADT</td>
<td>Annual Daily Traffic</td>
</tr>
<tr>
<td>ATC</td>
<td>Automatic traffic count</td>
</tr>
<tr>
<td>FD</td>
<td>Fundamental Diagram</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>GQM</td>
<td>Generalised queuing model</td>
</tr>
<tr>
<td>HCM</td>
<td>Highway capacity manual</td>
</tr>
<tr>
<td>JKR</td>
<td>Jabatan Kerja Raya</td>
</tr>
<tr>
<td>LOS</td>
<td>Level of service</td>
</tr>
<tr>
<td>MHA</td>
<td>Malaysian Highway Authority</td>
</tr>
<tr>
<td>MHCM</td>
<td>Malaysian Highway Capacity Manual</td>
</tr>
<tr>
<td>PCE</td>
<td>Passenger car equivalency values</td>
</tr>
<tr>
<td>PSD</td>
<td>Passing sight distance</td>
</tr>
<tr>
<td>PWD</td>
<td>Public Work Department</td>
</tr>
<tr>
<td>SPM</td>
<td>Semi-poisson model</td>
</tr>
<tr>
<td>SSD</td>
<td>Stopping sight distance</td>
</tr>
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<td>TRB</td>
<td>Transportation Research Board</td>
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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
\( Q, q_e \)  - 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 329,847m² 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.

![Diagram of a typical direct midblock U-turn facility in Malaysia with labels for free-flow zone (FZ), transition zone (TZ), and midblock zone (MZ).]

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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