DEVELOPMENT OF VEHICLE LANE CHANGING MODEL 
WITHIN U-TURN FACILITIES

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A thesis submitted in
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U-turning movements at roadway segments are channelized and aided with splitting islands in the middle so that drivers can be on their desired trajectories and the road segment are often accompanied with weaving, merging and diverging movement. The objectives are to determine the speed differences \((V_d)\), reaction time \((RT)\) and safe distance where from those parameters and their relationships, the statistical model was developed and used in estimating the safe distances to execute the lane changing within the U-turn facilities. The data were taken from the field which is video recording, picture and geometric design and was used to simulate the driving simulator like an actual environment while the driving simulator come out with the speed differences, reaction time and distance as a raw data. Result show that the mean value of reaction time \((RT)\) of the driver in making the lane changing at the U-turn area is 2.5s where the distance to execute the lane changing is 16.467m from the merging vehicle. Through the relationship between the RT, \(V_d\) and distance of the subject vehicle within U-turn facilities, the findings from the statistical model has been developed with the equation \([\text{Safe distance} = (13.448 + 1.410 \ RT - 0.075 \ V_d)]\). The model was used to estimate the safe distance which is 15.00m within U-turn facilities. The result shown that the safe distance will increase when the driver slowing down their speed and increasing the reaction time. The research concluded that the speed difference and reaction time have a significant relationship in estimating the safe distance in executing the lane changing within U-turn facilities.
ABSTRAK

Pergerakan pusingan U pada segmen jalan biasanya dibantu oleh pemisah pada bahagian tengah jalan yang membolehkan pemandu berada pada kawasan yang betul dan kebiasaanya disertai oleh pergerakan seperti weaving, merging dan diverging. Objektif kajian ini adalah untuk mendapatkan perbezaan halaju, masa tindak balas dan jarak selamat dalam melakukan pertukaran lorong dimana melalui parameter-parameter tersebut dan hubungkait, model pertukaran lorong dibangunkan dan digunakan untuk membuat anggaran jarak selamat untuk melakukan pertukaran lorong dalam kawasan pusingan U. Data diambil pada kawasan kajian seperti rakaman video, gambar dan rekabentuk jalan dimana ianya digunakan untuk mensimulasikan driving simulator menyamai persekitaran jalan sebenar dan driving simulator akan mengeluarkan data-data yang diperlukan seperti halaju, masa tindakbalas dan jarak melakukan pertukaran lorong. Hasil kajian ini menunjukkan purata bacaan untuk masa tindakbalas pemandu dalam melakukan pertukaran lorong iaitu 2.5s dimana jarak daripada merging vehicle ialah 16.467m. Melalui hubungkait diantara masa tindakbalas (RT), perbezaan halaju (Vd) dan jarak kenderaan subjek kepada merging vehicle, model statistik telah dibina iaitu [Jarak selamat = (13.448 + 1.410 RT – 0.075 Vd)]. Model tersebut telah menganggarkan jarak selamat untuk melakukan pertukaran lorong iaitu 15.00m daripada merging vehicle. Kajian ini juga menunjukkan jarak selamat akan meningkat apabila pemandu menurunkan halaju dan meningkatkan masa tindakbalas mereka. Kajian ini membuat kesimpulan bahawa perbezaan halaju, masa tindakbalas mempunyai hubungkait yang ketara dan penting dalam membuat anggaran jarak selamat untuk melakukan pertukaran lorong dalam kawasan pusingan U.
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE</td>
<td>i</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>iii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>vi</td>
</tr>
<tr>
<td>CONTENTS</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF SYMBOLS AND ABBREVIATIONS</td>
<td>xv</td>
</tr>
<tr>
<td>LIST OF PUBLICATIONS</td>
<td>xvii</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xviii</td>
</tr>
</tbody>
</table>

## CHAPTER 1  INTRODUCTION  1

1.1 Overview  1
1.2 Problem statement  2
1.3 Research Objectives  5
1.4 Research scope and limitations  5
1.5 Significance of research  6
1.6 Thesis layout  6

## CHAPTER 2  LITERATURE REVIEW  8

2.1 Introduction  8
2.2 U-turn road segment
2.3 Midblock U-turning facilities
2.4 Types of vehicle U-turn in Malaysia
   2.4.1 Light vehicle U-turn
   2.4.2 U-turn for all vehicles
2.5 Types of lane changing in traffic movement
   2.5.1 Understanding of weaving process in traffic movement
   2.5.2 Understanding of merging process in traffic movement
   2.5.3 Understanding of diverging process in traffic movement
2.6 Previous method in gathering the data
   2.6.1 Studies using the video recording
   2.6.2 Studies using driving simulation
2.7 Drivers lane selection and lane changing behaviour
   2.7.1 Previous study of lane changing
   2.7.2 Decision making to execute lane changing
2.8 Space mean speed and speed differences
   2.8.1 Previous studies for speed
   2.8.2 Effects of speeding over speed limit
2.9 Previous studies for driver reaction
2.10 Factors affecting driver reactions
   2.10.1 Human factors
   2.10.2 Environment factors
   2.10.3 Mechanical factors
   2.10.4 Road layout and design factors
2.11 Safe distance in execute the lane changing
2.12 Chapter summary
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Introduction</td>
<td>39</td>
</tr>
<tr>
<td>3.2</td>
<td>Research methodology framework</td>
<td>39</td>
</tr>
<tr>
<td>3.3</td>
<td>Research data collection</td>
<td>41</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Video recording and picture capture</td>
<td>41</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Site road measurement</td>
<td>42</td>
</tr>
<tr>
<td>3.4</td>
<td>Research location and criteria of site selection</td>
<td>42</td>
</tr>
<tr>
<td>3.5</td>
<td>Screen development for driving simulator</td>
<td>44</td>
</tr>
<tr>
<td>3.6</td>
<td>Number of sample and driver criteria</td>
<td>46</td>
</tr>
<tr>
<td>3.7</td>
<td>Driving simulation procedure for data collection</td>
<td>48</td>
</tr>
<tr>
<td>3.8</td>
<td>Procedure in analyze the driver speed</td>
<td>49</td>
</tr>
<tr>
<td>3.9</td>
<td>Statistical analysis for driver speed</td>
<td>50</td>
</tr>
<tr>
<td>3.10</td>
<td>Procedure in analyze driver reaction time</td>
<td>51</td>
</tr>
<tr>
<td>3.11</td>
<td>Procedure in determine driver speed differences in making lane changing</td>
<td>52</td>
</tr>
<tr>
<td>3.12</td>
<td>Procedure in determine driver distance in making lane changing</td>
<td>53</td>
</tr>
<tr>
<td>3.13</td>
<td>Procedure in develop the statistical model for lane changing</td>
<td>54</td>
</tr>
<tr>
<td>3.13.1</td>
<td>Determine the Data Outliers</td>
<td>55</td>
</tr>
<tr>
<td>3.13.2</td>
<td>Descriptive Statistic</td>
<td>57</td>
</tr>
<tr>
<td>3.13.3</td>
<td>Determine the dependent and independent variable</td>
<td>57</td>
</tr>
<tr>
<td>3.13.4</td>
<td>Multicollinearity test for the variables</td>
<td>57</td>
</tr>
<tr>
<td>3.13.5</td>
<td>Multiple regression of the data</td>
<td>58</td>
</tr>
<tr>
<td>3.13.6</td>
<td>Validity check of the result</td>
<td>58</td>
</tr>
<tr>
<td>3.13.7</td>
<td>Model validation</td>
<td>59</td>
</tr>
<tr>
<td>3.14</td>
<td>Predicted safe distance by using the model</td>
<td>59</td>
</tr>
<tr>
<td>3.15</td>
<td>Chapter summary</td>
<td>60</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>4.1</td>
<td>Introduction</td>
<td>61</td>
</tr>
<tr>
<td>4.2</td>
<td>Road profile in determining the driver speed</td>
<td>62</td>
</tr>
<tr>
<td>4.3</td>
<td>Driver speed</td>
<td>64</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Significance test of driver speed</td>
<td>65</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Driver speeding discussion</td>
<td>66</td>
</tr>
<tr>
<td>4.4</td>
<td>Reaction time of driver</td>
<td>67</td>
</tr>
<tr>
<td>4.5</td>
<td>Relationship between speed with reaction time of driver</td>
<td>69</td>
</tr>
<tr>
<td>4.6</td>
<td>Distances of the driver in execute the lane changing</td>
<td>70</td>
</tr>
<tr>
<td>4.7</td>
<td>Determining driver speed differences</td>
<td>71</td>
</tr>
<tr>
<td>4.8</td>
<td>Determining the driver distances with merging vehicle at U-turn area</td>
<td>72</td>
</tr>
<tr>
<td>4.9</td>
<td>Data boxplot and outliers</td>
<td>72</td>
</tr>
<tr>
<td>4.9.1</td>
<td>Boxplot of distance data</td>
<td>72</td>
</tr>
<tr>
<td>4.9.2</td>
<td>Boxplot of speed data</td>
<td>73</td>
</tr>
<tr>
<td>4.9.3</td>
<td>Boxplot of reaction time data</td>
<td>74</td>
</tr>
<tr>
<td>4.10</td>
<td>Descriptive analysis of speed, reaction time and distance</td>
<td>75</td>
</tr>
<tr>
<td>4.10.1</td>
<td>Descriptive and frequencies analysis for distances data</td>
<td>75</td>
</tr>
<tr>
<td>4.10.2</td>
<td>Descriptive and frequencies analysis for speed data</td>
<td>76</td>
</tr>
<tr>
<td>4.10.3</td>
<td>Descriptive and frequencies analysis for reaction time data</td>
<td>77</td>
</tr>
<tr>
<td>4.10.4</td>
<td>Multicollinearity result for the variables</td>
<td>78</td>
</tr>
<tr>
<td>4.10.5</td>
<td>Developing the lane changing model</td>
<td>78</td>
</tr>
<tr>
<td>4.10.6</td>
<td>Regression analysis for final model in estimating safe distance</td>
<td>80</td>
</tr>
<tr>
<td>4.10.7</td>
<td>Model validation</td>
<td>84</td>
</tr>
<tr>
<td>4.11</td>
<td>Estimation of safe distance</td>
<td>86</td>
</tr>
</tbody>
</table>
4.12 Chapter summary 88

CHAPTER 5  CONCLUSION 90
5.1 General 90
5.2 Conclusion 90
5.3 Knowledge contribution 92
5.4 Suggestions to solve the U-turn affair 92
5.5 Recommendations for future research 93

REFERENCES 94

APPENDIX 105
# LIST OF TABLES

1.1 Summary of U-turn from KM1 to KM21 FT050 Batu Pahat - Kluang 4

2.1 Type of vehicles definition 13

3.1 Drivers’ characteristics 47

4.1 Descriptive statistic for speed during U-turn area and speed before approaching U-turn area 66

4.2 T-test result for speed during and speed before approaching midblock U-turn area 66

4.3 T-test result for speed during U-turn area and speed limit approaching U-turn area 66

4.4 Descriptive statistic for relationship between speed during U-turn area and reaction time of the driver 69

4.5 Pearson correlation result for relationship between speed during U-turn area and reaction time 69

4.6 Descriptive statistic of the distances data 75

4.7 Descriptive statistic of the speed data 76

4.8 Descriptive statistic of the reaction time data 77

4.9 Multicollinearity test of the variables 78

4.10 Safe distance model development coefficients 78

4.11 Analysis of variance (ANOVA) for final model safe distance 81

4.12 Regression analysis for final model for estimating safe distance 82

4.13 Distance comparison for model and validation 85

4.14 Speed comparison for model and validation 85
LIST OF FIGURES

1.1 Malaysia Accident Data (Royal Malaysia Police, 2014) 3
1.2 Johor Accident Data (Royal Malaysia Police, 2014) 4
2.1 Example of U-turn Road Segment 10
2.2 Example of Median U-turn (Rahman and Ben-edigbe, 2015) 12
2.3 Signboard of U-turn for Light Vehicle Only 14
2.4 Signboard of U-turn for All Vehicles 15
2.5 Example of Changing Lane Process (Ben-Edige et al., 2013) 16
2.6 Weaving Process in Road Segment 17
2.7 Merging Process in U-turning Facilities Road Segment 18
2.8 Diverging Process in U-turning Facilities Road Segment 19
2.9 Example of Driving Simulator 22
2.10 The driver’s Action When Facing with Various Queue Lengths Approaching the U-turn Segment 23
2.11 Flowchart for Decision Making in Approaching U-turn Facilities (Meng & Weng, 2012) 26
2.12 Safe Distance Visualization for the Driver 37
3.1 Research Methodology Framework 40
3.2 Flowchart of the Driving Simulator Processes Involved 41
3.3 Geometric Layout for U-turn facilities at KM15 road FT050 Batu Pahat - Jalan Kluang 42
3.4 Site Location 1- KM15 Jalan Kluang 44
3.5 Process in Developing the Midblock U-turn in for Screen View in Driving Simulator 45
# LIST OF SYMBOLS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FT</td>
<td>Federal Route</td>
<td></td>
</tr>
<tr>
<td>KM</td>
<td>Kilometer</td>
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<tr>
<td>m</td>
<td>Meter</td>
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<tr>
<td>m²</td>
<td>Meter square</td>
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<tr>
<td>RMP</td>
<td>Royal Malaysia Police</td>
<td></td>
</tr>
<tr>
<td>JKR</td>
<td>Malaysia Public Work Department</td>
<td></td>
</tr>
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<td>V</td>
<td>Speed</td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>Reaction Time</td>
<td></td>
</tr>
<tr>
<td>SSD</td>
<td>Stopping sight distance</td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>Safe distance</td>
<td>Distance in approaching the U-turn</td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>MLC</td>
<td>Mandatory lane changing</td>
<td></td>
</tr>
<tr>
<td>s</td>
<td>Second</td>
<td></td>
</tr>
<tr>
<td>β</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>Percent</td>
<td></td>
</tr>
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<td>Critical gap</td>
<td></td>
</tr>
<tr>
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<td>Annual daily traffic</td>
<td></td>
</tr>
<tr>
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<td>Road standard 5</td>
<td></td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Term</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>Gravity</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
<td></td>
</tr>
<tr>
<td>LAA</td>
<td>Lane assignment approach</td>
<td></td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
<td></td>
</tr>
<tr>
<td>km/h</td>
<td>Kilometer per hour</td>
<td></td>
</tr>
<tr>
<td>ASIS</td>
<td>Automotive simulator for driving behaviour and competency evaluation</td>
<td></td>
</tr>
<tr>
<td>VIF</td>
<td>Variance inflation factor</td>
<td></td>
</tr>
<tr>
<td>UTHM</td>
<td>Universiti Tun Hussein Onn Malaysia</td>
<td></td>
</tr>
<tr>
<td>UiTM</td>
<td>Universiti Teknologi Mara</td>
<td></td>
</tr>
</tbody>
</table>
LIST OF PUBLICATIONS

Published


Accepted


In review

# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Example of data output from driving simulation</td>
<td>106</td>
</tr>
<tr>
<td>B</td>
<td>Example of data analysis in SPSS</td>
<td>111</td>
</tr>
<tr>
<td>C</td>
<td>List of publication</td>
<td>113</td>
</tr>
<tr>
<td>D</td>
<td>Driving simulator promotion</td>
<td>116</td>
</tr>
<tr>
<td>E</td>
<td>Simulator driving form</td>
<td>117</td>
</tr>
<tr>
<td>F</td>
<td>Driving simulator screen development</td>
<td>118</td>
</tr>
<tr>
<td>G</td>
<td>Data tables</td>
<td>120</td>
</tr>
<tr>
<td>H</td>
<td>Calculations</td>
<td>124</td>
</tr>
<tr>
<td>I</td>
<td>Procedure for the driver and driving simulator technician</td>
<td>125</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Overview

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. The capital city is Kuala Lumpur. Statistic department (2010) described that Malaysia consists of thirteen states and three federal territories and has a total landmass of 329,847 m² separated by the South China Sea into two similarly sized regions, Peninsular Malaysia and Malaysian Borneo. The researcher also stated that in year 2010, the population was exceeded from 27.5 million and now in 2015 it has grown into 30 million, with over 20 million living on the peninsular. Malaysia has a good road network which are paved or unpaved, private or public. Public roads are often referred to as highways and a road network is a combination of highways. A highway irrespective of functional classification is made up of segments and intersections/interchanges.

In Malaysia, peak hour traffic conflicts and congestions have continued to worsen at the highway intersections. One commendable attempt by authorities to solve the problems of intersection conflicts and congestions problems is through the installation of direct midblock facilities that will allow motorists to make U-turning movements before reaching the intersection (Ben-Edigbe et al., 2013). U-turning movements involve the diverging, weaving and merging movement for the vehicle to
enter the preferred lane. Therefore, the scenario will produce a lot of movement for the road that may lead to traffic accident and fatal.

A lot of studies have been done about the lane changing behaviour whether for roundabout, traffic light, junction and road curve/ design for heavy and light vehicle. The latest research done by Sharma et al. (2017) studied the critical gap for the merging vehicle to enter the freeways for U-turning operation for median opening and the studies was focuses on the U-turn without the midblock facility for the vehicle to accelerate to merge into the freeways. Other than that, Mohanty et al. (2017) studied the effect the movement of approaching vehicles at the freeways leading them to either slow down or change their lanes just to avoid the conflict with U-turn and the present study applies Markov’s process to estimate lane changing patterns of approaching through vehicles due to the presence of U-turns. However, in this research focusing on lane changing model. This research was developed a vehicle lane changing model within U-turn facility road segment. It requires the performance of vehicle movement by considering the parameters which related to Malaysian driver’s reaction such as reaction time, speed and distance in executing the lane changing. The establishment of suitable U-turn and appropriate condition is needed in order to achieve the entire objectives. The reasonable method to perform the data is by using driving simulator where this technique can allow data collection to be reliable and well-organized. Leitão et al. (1999) stated that driving simulator can give a real scenario for the driver that can make the model valid to use. In addition, this research concerns on the U-turn road segment situation due to the study implementation. Therefore, this research provided knowledge, understandings and new findings in the field of traffic engineering.

1.2 Problem statement

Abdul Manan and Várhelyi (2012) stated that roads accident has caused a major problem in all over the world especially in Malaysia. Some accidents occurred because of the aggressiveness and inappropriate driving behaviours of driver. (Abdul Manan and Várhelyi, 2012; Abdul Manan, 2015a) shows that in Malaysia, there are 56,513 people killed, 234,959 people were slightly injured and 55,295 people were seriously injured on the road crashes that recorded from year 2000 to 2009.
Referring to Figure 1.1, Royal Malaysia Police, RMP (2014) shows that Johor was the second highest for the accident statistic with 64,473 accident cases which is 73,336 number of accident differences behind Selangor with 137,809 cases. Comparing the number of fatal for that single year, Johor was also the second highest for the number of fatal with 1,018 with only 50 number of fatal differences compared to Selangor with 1,068. It shows that Johor has a highest percent of fatal by comparing the number of accident and the number of fatal statistics.

![Malaysia Accident Data](image)

**Figure 1.1: Malaysia Accident Data (Royal Malaysia Police, 2014)**

Figure 1.2 shows the accident data for Johor district in year 2014. The figure shows that Batu Pahat was the second highest in number of accident occurred with 7,445 cases behind the combination of Johor Bahru Utara and Johor Bahru Selatan area with 22,563 cases. However, for the number of fatal cases, Batu Pahat district was the highest with 165 cases. RMP (2014) showed the number of accident in U-turning facilities segment in 2014 the number of accident in the U-turn road segment is 469 accident cases with 104 fatal. This cases shows high number of accident occurred in U-turn that need to re-visualize and rearrange to give a better focus in this types of facilities. In single year of 2014 that recorded by Batu Pahat police station have stated 1286 accident cases in this FT050 road which is the site location. Table 1.1 shows the number of U-turn for all types of U-turn where there are 6 midblock U-turn from 8 U-turn facilities along the KM0 to KM21. Therefore, there are highest possibilities for the number of accident to keep increasing every year if the area is not treated properly.
The Star newspaper reported on 4 May 2009 that Jalan Batu Pahat – Kluang (FT050) has been identified as the “deadliest stretch of road” in Malaysia, as announced by the Works Ministry of Malaysia (KKR). That is proved the dangerousness of this road that can cause a lot of fatal.

![Johor Accident Data](image)

**Figure 1.2: Johor Accident Data (Royal Malaysia Police, 2014)**

<table>
<thead>
<tr>
<th>Segment</th>
<th>Intersection (km)</th>
<th>U-Turn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>All Vehicle</td>
</tr>
<tr>
<td>1</td>
<td>1 – 5</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>5 – 10</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>10 – 15</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>15 – 18</td>
<td></td>
</tr>
</tbody>
</table>

Table 1.1: Summary of U-turn from KM1 to KM21 FT050 Batu Pahat - Kluang

Attitude of the drivers such as anger, selfish and so on contribute to an accident. For certain drivers, rude manners were the driver attitude that have some difficulties to change. When the drivers want to change their lane, make a U-turn, at the traffic light, and enter the roundabout, drivers always consisting impatient, compete and always in hurry (Md Diah et al., 2008). They would in highly of speed and the
possibility for an accident to occur with the surrounding vehicles also high when the drivers are covered by this emotions and manner. Furthermore, (Crundall et al., 2008; Darren et al., 2009) stated that driver’s reaction can be influenced indirectly in making all appropriate visual checks and their reactions can be influenced by environment, mechanical or design of the road. Besides that, Yeoh et al. (2011) stated that attitude changes is believed to increase the driving reaction to achieve the traffic safety. Through this research, the model has been developed based on the safe distance, speed and reaction time using the simulator and the model predicted the safe distance for lane changing within the U-turn facilities.

1.3 Research Objectives

The objectives of the research are:

i. to determine driver’s speed, reaction time and distance in approaching U-turn facilities;

ii. to developed the vehicle lane changing model within U-turn facilities; and

iii. to predict the safe distance by using the vehicle lane changing model within the midblock U-turn facilities.

1.4 Research scope and limitations

This research was conducted using driving simulation and visualized based on the environment of the research area. This research has been done only at multi-lane dual carriage highways because of direct U-turning movements with the midblock can be found only at this types of road. Central medians are the medium to separate the carriageways where it can be found at the federal routes. Other than that, this research was carried out in a dry condition and daytime to make sure the data taken is valid without any disruption for vehicle to slow down at the site area. Therefore, the data taken is corresponding to the driver reaction when passing through the site area. Driving simulator are used to simulate the condition and environment of the road where driving simulator is fully used in this research in providing the data needed. This research focus on determining the speed, reaction time and distance from subject vehicle to the merging vehicle due to changing lane at U-turn facility road segment
and reaction of the driver when passing through the midblock U-turn facilities at CH000 – CH021 of FT050 Jalan Batu Pahat – Kluang.

1.5 **Significance of research**

This research finds out the speed of the driver inside the freeways of the U-turn area which are comparing with the speed limit at 60km/h. At the freeways, the speed limit is 90km/h while at the U-turn area is 60km/h. Therefore, along the FT050 Jalan Batu Pahat – Kluang has a lot of speed limit changing for the driver to adapt. Therefore, this research finds out that driver tend to speeding based on their normal speed which is about 90km/h based on the usual speed limit. The lane changing model predicted the safe distance within U-turn facilities. Other than that, this research also developed a model within the U-turn facilities that can be used for driver to implement in real scenario. Therefore, this research will provide the understanding and guide for the driver in order to reduce the number of accident especially in U-turn facility road segment. This research also directly knows the reaction of drivers whether they have a precaution on a safety issue with slowing down the speed or given a chance for merging vehicle at the U-turn road segment to enter the main road of the highways.

1.6 **Thesis layout**

This section provides brief information about each chapter and there are six chapter in total for this thesis. Chapter one elaborated the introduction and explanation to the problem, aims, and contribution of the research. It is giving general explanation and introduction on the research and the scope of work. Other than that, Chapter two takes a literature review or theoretical review which take a closer look at the U-turn, driver reactions and the driving simulator. Additionally, literatures on multilane highways and midblock facilities are also presented to give an understanding about the work involved in this research.

Chapter three explained the research methodology on midblock U-turn facilities data collection. It gives the criteria for site selection, the survey method and the driving simulator used to carried out all the test and analysis. Chapter four Since this research investigate the effects of midblock facilities road segment into the driver reactions on speed, reaction time, and distance to execute the lane changing, this
Chapter explained the results of that parameters especially in approaching a U-turn facility road segment. Other than that, Chapter four also explained about the process and analysis involved in developing the statistical model. The model using three parameters which are, distance, speed differences and the reaction time of the driver. All the data has been screened and follow all the process involved in developing the statistical model using SPSS. Other than that, this chapter involved the regression analysis of the model and the model validation in order to ensure the model developed are relevant and valid to be used. Chapter five shows the summary and conclusion in achieving the aim of the research. The research aim has been achieved by completing the three objectives that has been concluded in this chapter.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The change from one lane to next adjacent lane of a vehicle is defined as a lane change. It is involving the decision making such as in a midblock facilities road segment that always been done for any driver whether they are notice it or not. This is because, driver's will experience different type of situation in approaching any midblock U-turn facilities because of the different desire and target of driver’s that contribute to various type of movement such as merging, diverging and weaving. Correspondingly, Rahman and Hassan (2014) asserted that a U-turn refers to vehicles performing a 180° rotation to reverse the direction of travel. Often U-turning movements at roadway segments are channelized and aided with splitting islands in the middle so that drivers can be on their desired trajectories. Therefore, this chapter discusses and explained various facts and previous studies with references to the topic and objectives of the research which is the development of vehicle lane changing model within U-turn facilities which means to find out the speed, reaction time and distances that can guide the driver’s when approaching the U-turn facilities road segment by develop the model. This chapter given a better understanding about the types and condition of highways in Malaysia especially in U-turn and also the guidelines from the previous study to complete the test involved. Other than that, driver speeds, reaction time are discussed since this research involves the speed and reaction time in collecting the data and also developing the model.

In addition, which speed drivers choose to drive in various road and traffic conditions is an important characteristic towards their reaction. The most influential in
determining driver’s choice of speed is the characteristics of drivers. Taylor (2011) stated that characteristics of the road they were driving was strongly contributing to the driver speed. Furthermore, Summala (2000) mentioned that to allow an assessment to be made of whether driver response times depend on vehicle speed which is in accident litigation, the legal process often tends to determine whether the participant driver reacted to the impending collision within “acceptable” time, vehicle speed was observed for some circumstances. Correspondingly to Benedetto et al. (2011), to avoid the collision the drivers have to react to the sudden braking of the lead vehicle. While Rahman and Ben-edigbe (2015) showed that travel speed at free-flow section decreased significantly at the median opening zone at all sites. Speed reductions are greater at the diverging sections than the merging sections. At the merging section vehicles exiting from the U-turn facilities must give a way to all approaching vehicle, hence the slight drop of driver speed is about 5 percent at the merging sections. Nonetheless the assertion that median openings would cause travel speed reduction remain valid. Therefore, the reaction of driver’s in approaching the midblock U-turn facilities need to be study properly.

2.2 U-turn road segment

Often U-turn traffic movements at roadway segments are channelized and aided with splitting island so that the drivers can be on their desired trajectories. Figure 2.1 show the example of U-turn that had been used nowadays in many countries. Midblock U-turn facilities are often constructed as a cost effective way of alleviating congestion and road safety problems. Some highway midblock U-turn facilities are built to complement existing road geometric design; others are built as a complete replacement to existing facilities on the premises that they will reduce conflicts and ease congestion at adjoining intersections. That may be so, but there are road safety consequences that are often ignored. It is inherent because of driver’s desire to position their vehicle along the appropriate carriageway lane. Misjudgment of ensuing gaps is not an option. When exiting the facility, driver may reject gap on the major road and wait for a subsequent gap. Poor gap acceptance decisions have severe consequences. They may cause traffic shockwave and lead to accidents. In any case, the existence of traffic shockwave at the weaving area of midblock u-turning facilities is a clear indication of inherent road safety risk.
Ben-Edigbe et al. (2013) studies about the effect of U-turning manoeuvres at midblock facilities on traffic kinematic waves aimed to determine the U-turning manoeuvres at roadway midblock facilities inducing the extent of traffic kinematic waves, they have surveyed 150,000 vehicles where the data supplemented with information culled from the Malaysian Public Work Departments highway design manual and find out that midblock facilities can be called to account for severe kinematic waves on approached to the entry lane is has no evidence to suggested. When merging, significant kinematic waves of about 21 km/h occurred. The research concludes in the results showed acceleration and merging from exit lane to major carriageway caused more kinematic waves rather than deceleration and diverging to entry lane. Therefore, this research was given a very good contribution to help in reducing the number of accidents and give a good come out in order to make a better condition in U-turn facilities.

2.3 Midblock U-turning facilities

Midblock facilities in Malaysia are built as complimentary facilities to existing infrastructure design, others are built as a complete replacement to existing facilities on the premises that they will reduce conflicts and ease congestion at adjoining intersections. 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 right hand driving rule is in place, drivers decelerate when diverging, accelerate when converging at the midblock facilities. Therefore, it is not surprising that the issue of midblock U-turning facilities has provoked fierce national debates. Proponents of midblock facilities argued that their installation has brought some help to motorists plagued with conflicts and congestions at adjoining intersections. Median U-turn exist at the multilane highways which has two lanes in each directions and separated by median in the middle of the highways. Midblock facilities are installed to facilitate vehicle U-turning movement. Divided highways are separated with rigid barrier or flexible barrier such as landscape with maximum speed limit of 90 km/h. These multilane highways have many signalized or non-signalized intersections that the fact is when more intersections in the highways exist, the more conflict occur. Prasetijo et al. (2014) stated that traffic conflicts are created when two or more vehicular movements on the roads cross each other and that conflicts may cause traffic congestion and delay with the possibility of road accidents.

Traffic movement is interrupted by these midblock U-turn junctions. The U-turn vehicles will be waiting for the large enough gap and make U-turn movement after arriving in the midblock median opening. Therefore, requirement needed for a satisfactory design of a U-turn such as width of a highway and median size that must be sufficient to permit the vehicle to turn without any unconvincing. It must allow the vehicle moving smoothly to enter the U-turn lane, make a U-turn and merge into the flow or preferred lane of the road. Figure 2.2 show the example of median U-turn. Driver can choose any lane whether to choose fast lane or the slow lane before the U-turn signboard. Whenever any merging vehicle in front enter the fast lane, the driver on the freeways have to react.
Figure 2.2: Example of Median U-turn (Rahman and Ben-edigbe, 2015)

The geometric design of a median U-turn (MUT) intersection introduces some unique design elements not typically present at a conventional intersection. These elements include:

i. To facilitate the movements of median U-turn, wide median is often needed. Typically, the intersection and main crossing street is uniform, but to reducing the length of the wide median or locate the median on the minor street needed some variations in the design.

ii. Large enough vehicle path at the U-turn crossover needed to accommodate trucks and allow for efficient movements through the U-turn by passenger vehicles.

iii. Design element that providing positive guidance using design elements and signage needed to reduce chances of driver error and discourage prohibited turns.

iv. For the U-turn movements that would otherwise be unexpected or not familiar to driver or motorists needed a signing, marking, and geometric design in order to promoting safe and efficient movements.

v. In order to promote safe and efficient access to these properties needed a corridor-wide access strategies and management considerations to properties along the median street.

The purpose of using midblock facilities is to assist and guide the driver with right turning movements on multilane highways. Iskandar Regional Development
(2011) suggested that one potential treatment to combat congestions and safety problems at intersections was by the installation of non-traversable medians and directional median opening. While (Ben-Edigbe et al., 2013; Ben-Edige et al., 2013) showed that travel speed at free-flow section decreased significantly at the median opening zone at all sites and there is correlation between traffic safety and midblock U-turning facilities. Speed reductions are greater at the diverging sections than the merging sections. At the merging section vehicles exiting from the U-turn facilities must give way to all approaching vehicle, hence the slight drop of about 5 percent at the merging sections. Nonetheless the assertion that median openings would cause travel speed reduction remain valid.

2.4 Types of vehicle U-turn in Malaysia

U-turn in Malaysia can be categorized into two types of vehicle which is for light vehicle and for all types of vehicle. Abdelwahab and Abdel-Aty (2004) categorized vehicles into two which are large and small vehicles where the large vehicles typically are heavy while small ones are light. Light vehicle can be divided into two which is passenger cars and light commercial vehicles. Heavy vehicle also can be divided into two which is heavy trucks and buses or coaches. The vehicle type and definitions is explained in Table 2.1

<table>
<thead>
<tr>
<th>Type of vehicle</th>
<th>Vehicle</th>
<th>Definitions</th>
</tr>
</thead>
</table>
| Light vehicles  | Passenger cars | - Motor vehicles with at least four wheels.  
- Used for the transport of passengers.  
- Comprising no more than eight seats in addition to the driver’s seat. |
| Light commercial vehicles | | - Motor vehicles with at least four wheels.  
- Used for the carriage of goods.  
- Weight are between 3.5 to 7 tonnes. |
Table 2.1: Type of vehicles definition (continued)

<table>
<thead>
<tr>
<th>Type of vehicle</th>
<th>Vehicle</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy vehicles</td>
<td>Heavy trucks</td>
<td>- Vehicles intended for the carriage of goods</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Weight are over seven tonnes.</td>
</tr>
<tr>
<td>Buses and coaches</td>
<td></td>
<td>- Used for the transport of passengers.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Comprising more than eight seats in addition to the driver’s seat.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Weight over 7 tonnes.</td>
</tr>
</tbody>
</table>

2.4.1 Light vehicle U-turn

U-turn for light vehicle only means that only light vehicle can make a U-turning movement and prohibited for heavy vehicles. This type of U-turn exists caused by a small U-turn facility that make the heavy vehicle difficult to accelerate. Other than that, this type of U-turn also exists in a signalized junction. However, the function of U-turn is still the same. The signboard of U-turn for light vehicle are shown in Figure 2.3.

![Figure 2.3: Signboard of U-turn for Light Vehicle Only](image_url)

2.4.2 U-turn for all vehicles

This type of U-turn is available for all types of vehicle in order to reverse the direction of travel. Signboard of U-turn for all type of vehicles are shown in Figure 2.4. This type of U-turn need a big area and U-turn facility that allow the vehicle to accelerate to enter the fast lane. This signboard can be seen in display about 150m to 200m of SSD. Therefore, this research was conducted in this type of U-turn because of the
availability of diverge and merge vehicle. This signboard was visualized inside the
driving simulation with the same standard as provided by JKR.

Figure 2.4: Signboard of U-turn for All Vehicles

2.5 Types of lane changing in traffic movement

Lane changing is a process of determining the best lane to drive without any
interruption on the road. Lane changing also occurred when a driver wants to enter the
preferred lane of destination. Figure 2.5 shows the example of changing lane process
that usually occurred due to driver lane desire. The process of changing lane will have
caused a weaving, merging and diverging process that will vary the road environment.
Weaving, merging and diverging are traffic stream deft manoeuvre that are often laden
with profound risk of accident occurring. According to Xiaorui and Hongxu (2013),
drivers misjudgment or driving skills of different levels during the lane changing is
likely to cause traffic accidents, and accidents caused by lane changing accounting for
6 percent of the total traffic accidents and causing in delay time in traffic more than 10
percent of total delay time by traffic accidents.
2.5.1 Understanding of weaving process in traffic movement

Road movement always involving many types of behaviour that make the road had a various types of uncertainty. One of the movement is weaving. (Ben-Edige et al., 2013; Kusuma et al., 2014; Rahman and Hassan, 2014) defined weaving occurs when vehicles crisscross the carriageway lanes often with a view to repositioning for traffic stream advantage which are crossing two or more traffic stream travelling in the same direction along a significant length of the roadway without traffic control device. It is inherent because of driver’s desire to position their vehicle along the appropriate carriageway lane. When exiting the facility, driver may reject gap on the major road and wait for a subsequent gap. Poor gap acceptance decisions have severe consequences. It can cause traffic shockwave and lead to accidents. Weaving is often triggered on approach to highway ramps, intersections as well as midblock facilities among others.

Hwang and Park (2005) defined the weaving movement as a situation where there are two or more traffic streams crossing each other without any aid of traffic control devices in order to adjust their lane position due to their destination lane or to seek a chance to pass a vehicle in front of them, each driver therefore seeks the gap event both in their current lane and target lane. High number of weaving movements and an aggressive driving movement can create traffic instability and shockwave effects. In terms of road safety issues, the movement contributes to a high accident risk considering that the traffic has to share the space at the same time without any assistance of traffic control. Kusuma et al. (2014) found that in the first 50m to 100m from the merge point, 25.25 percent of the weaving movements took place and one
lane changing movement from 30 percent of the total traffic involved. Figure 2.6 show the weaving process in road segment. These dangerous manoeuvres beg the question; 'what are the driver behaviour when approaching the U-turning facilities? What are the speed of the vehicle whether accelerate or decelerate when see any car want to merge into the main lane? Wei and Wanjing (2013) showed the weaving section capacity as the total number of vehicles passing through the section and crossing among the traffic along the weaving section length. They stated the maximum flow for through traffic is 2200 PCU/hr/ln and for cross traffic is between 1100 and 1200 per hour per 76 m of weaving section.

![Figure 2.6: Weaving Process in Road Segment](image)

**2.5.2 Understanding of merging process in traffic movement**

Acceleration and merging is a deft manoeuvre because through traffic flows have priority in the conflict sections, and vehicle attempting to enter the main lane after making a U-turn can only do so during larger gaps of successive vehicles in the fast lane. Major source of conflicts and congestion on motorways were when motorway merging. Wang (2006) stated that traditional studies of merging behaviour are based on gap acceptance models developed mainly for urban intersections, which tend to oversimplify the very complex dynamic interactive merging behaviour.

Merging is more difficult than diverging because through traffic flows are traversing along the faster lane. It is a very dangerous manoeuvre that can trigger road accident. This is because drivers along the main lane or fast lane are forced to either abandon the overtaking move in order to avoid collision. Ben-Edige et al. (2013) concluded that there is correlation between traffic safety and midblock U-turning facilities and got the estimated delay of about 8.55s per vehicle at the exit lane of U-turn. However, it can be easy when driver have cooperation and tolerance during
driving in this area as stated by (Wang et al., 2005). They are study sensitivity analysis of the model suggests that cooperative lane-changing and yielding have a significant effect on the proportion of merges that are made easily. Similarly, the higher the proportion that successfully merge into their first choice of gaps when more alert the drivers.

Figure 2.7 shows the example of merging process in U-turning facilities road segment. In order to avoid collision, the vehicle in the main lane need to be careful with the merging vehicle because the merging vehicle need to find the safe gap acceptance to enter the main lane. Wang (2006) investigated the driving behaviour in the merging motorway section using both the traffic surveillance and MIDAS data and the video observation showed that most of the lane-changing occurs at the first available gap. In the other words, the main traffic and entry-slip road traffic meet at the end of the taper marking leads to the lane changing occurrence. The length of the auxiliary lanes in merging area length affects the merging behaviour. In fact, in order to seek for larger gap rather than accept the first gap, lane change drivers become conservative along auxiliary lane. The average speed between the lanes is relatively similar, where most of the lane changing occurs.

![Merging Process in U-turning Facilities Road Segment](image.png)

**Figure 2.7: Merging Process in U-turning Facilities Road Segment**

### 2.5.3 Understanding of diverging process in traffic movement

Diverging in this case means from the main lane the drivers enter the U-turn due to their preferred destinations. In Malaysia where the right hand driving used, the driver’s that trying to enter the midblock U-turn facility need to enter the fast lane in order to enter the U-turn facilities road segment. Figure 2.8 show the example of diverging
process in U-turn. The vehicles need to slow down the acceleration in order to enter the U-turn lane which is vice-versa with the merging process where the vehicles need to accelerate.

![Figure 2.8: Diverging Process in U-turning Facilities Road Segment](image)

2.6 Previous method in gathering the data

Data collection is to answer relevant questions and evaluate outcomes by the process of gathering and measuring information on targeted variables in an established systematic fashion. To capture quality evidence that then translates to allows the building of a convincing and credible answer to questions that have been posed is the main goal for all data collection. Data collection is the process to run the test in order to gained information and data from the site. Therefore, in this research was used several test to collect data which is video recording and driving simulator.

2.6.1 Studies using the video recording

Abdullah et al. (2014) explained that traffic monitoring is a challenging task on crowded roads. Traditional traffic monitoring procedures are manual, time consuming, expensive and involve human efforts. Because of the involvement of human effort and sometimes provide inaccurate monitoring results make it subjective matter. Due to limited availability of storage and compute resources in the past, large scale storage and analysis of video streams were not possible. Recent advances in processing, data storage and communications have made it possible to store and process huge volumes
of video data and develop applications that are neither subjective nor limited in feature sets. Now, it is possible to implement object detection and tracking, behaviour analysis of traffic patterns, number plate recognition and automate security and surveillance on video streams produced by traffic monitoring and surveillance cameras.

The importance of video recording is already explained that it is very familiar nowadays especially in traffic monitoring because of the helpful work that can store the video and can reduce the human effort. Several new technologies for video display devices have since been invented like Semi-Automatic Video Analysis (SAVA) that widely used in United Kingdom (UK). Kusuma et al. (2014) mentioned that in order to capture the traffic characteristic and driving behaviour on a specific motorway network, SAVA data has been used in a wide range. (Benedetto et al., 2011; Jooho et al., 2006; Kusuma et al., 2014; Liu. R and Wang, 2007) used video recording in developing model and analysis of driving behaviour and validation of car following model which are can extract the movement characteristic of each vehicle and the vehicle trajectory. Corresponding to Itoh et al. (2007), they extracted behaviour of other vehicles on the passing lane by analyzed the video image stored by the driving recorder and by observing the video image. Kassner and Vollrath (2006) used the CAN-bus provide information about velocity, braking, accelerating and the steering wheel angle during the merging process and CAN-bus equipment can be used to observed the head of the driver and the surroundings in front and the behind the car. Wu et al. (2014) also used CAN-bus in studies about the driving behaviour to identify relevant features extracted from a frontal video camera. Other than that, the cameras system makes the possible to localize exactly the point driver changing lane where it can help in setting up the simulation and scenario for driving simulator.

2.6.2 Studies using driving simulation

Experts conducting analysis and reconstruction of traffic accidents now have at their disposal advanced computerized systems of collision and traffic simulation. Most of them can create a computer animation of a reconstructed complex crash situation, so it could be able to present a virtual simulation of an accident. The result of the reconstruction is thus presented not as complex calculations that has been used, but in the form of an animated film, in which the background can be a real environment scene of an accident that actually occurred. This animation is very suggestive for a
participant, so it should be performed with the very best and sense of responsibility. The credibility of the reconstruction carried out by an expert depends on many factors where one of the most important is the selection of the input parameters for the calculation. For instance, this applies to the adhesion coefficient, coefficient of restitution, reaction time as stated by Jurecki and Stańczyk (2014). Driving simulators are used for entertainment as well as in training of driver's education courses taught in educational institutions and private businesses and are also used for research purposes in the area of human factors and medical research, to monitor performance, driver behaviour, and attention. In the car industry, it is used to design and evaluate new vehicles or new advanced driver assistance systems.

Hwang and Park (2005) stated that modeling lane changing behaviour is complex because it considers three elements which is the possibility of changing lanes, the need to change lanes and the trajectory for changing lanes. It also must be considered not only the vehicle in the front, but also the vehicle nearby. Many studies have been done by using driving simulator in order to find the behaviour of the driver’s Islam and Hadhrami (2012) proposed a mandatory lane changing model and extended the work by developing a new model for heavily congested traffic flow by using the driving simulator and find out that there are very little gaps of acceptable lengths in heavy congestions. Hence, by forcing the lag vehicle to slow down, a forced merging model is proposed which can capture instances of merging through the creation of gap. Md Diah, J. et al. (2012) used driving simulator in determining the lane changing behaviour in approaching the heavy vehicles at signalized junctions where the research find out that 15.4 percent reaction time and speed contributing to the safe changing lane distance at the signalized junction. (Ben-Edigbe et al., 2013; Rahman and Hassan, 2014) used the same layout of survey site to study the midblock U-turning impact where the fast lane is influenced by diverging vehicle that want to enter the U-turn lane while in the slow lane are influenced by merging vehicle. It shows this layout can collect the data for speed that can contribute in achieving the objective. Figure 2.9 show the example of driving simulator that is very common used nowadays and it show like driving in real situation.
2.7 Drivers lane selection and lane changing behaviour

When the drivers are not satisfied with the driving condition in the current lane and wish to gain a speed advantages, discretionary lane changing (DLC) manœuvres are executed. That means the drivers want to maintain or increase the speed because of the disruption from any vehicle such as diverge car in U-turn facility. When the driving conditions are not satisfactory, automatically the drivers will compare the driving conditions to the other lane. Important factors affecting the decision include the difference between the density of traffic, the presence of heavy vehicle in the target lane, speed of traffic, merge and diverge vehicle. Lane changing process is One of the Malaysian driving behaviour. Because of intolerant driving while selecting and making lane changing, it creates problems such as delays and accidents. Figure 2.10 illustrated the real scenario of the driver’s action whether to choose lane one, two or three for the driver from eastbound on lane two and driver’s action whether to choose lane five or six when the driver drives on lane five from westbound and facing on various kind of diverging and merging movement at the U-turn road segment. The drivers will try to make a lane changing when facing this type of situation. Zhao et al. (2014) found that 640 mandatory lane changing (MLC) occurred from a naturalistic driving database. The result show that MLC are approximately 4.5 times to have a critical gap to occur.

Therefore, this research focused on providing a new model of lane changing in approaching merging vehicle at the U-turn facility road segment that can assist driver
to facing various possibilities in U-turn facility especially in making the lane changing from the merging vehicle.

![Diagram of U-turn road segment](image)

Figure 2.10: The driver’s Action When Facing with Various Queue Lengths Approaching the U-turn Segment

### 2.7.1 Previous study of lane changing

(Md Diah, J. *et al*., 2010; Md Diah, J. *et al*., 2011) claimed that there is a “lack of knowledge” of corresponding methods for the traffic performance at the intersection and of Malaysian driver behaviour. Many researcher have defined the lane changing such Zhao *et al*. (2014) defined lane change as a driving manoeuvre that moves a vehicle from one lane to another lane where both lanes have the same direction of travel. Moridpour *et al*. (2010) asserted that lane changing models need the accuracy of essential components of microscopic traffic simulation in develop lane changing model. It is assumed that a driver makes consideration between expected own advantage and the disadvantages when a lane change is considered. Kesting *et al*. (2007) divided the lane changing model into multistep process which is on a strategic level, the drivers know the route and a network that can influence the lane choice. In the tactical stage, the intended lane change is prepared and initiated by advance acceleration. Finally, in operational stage, immediate lane change is both safe and desirable. Their research in develop car-following model use a concept to simulate two lane freeway traffic with an on-ramp as merging zone.
Other than that, in car following lane changing model in freeways also have been studied. Xiao'ru and Hongxu (2013) studies the car following behaviour using the model that developed by MATLAB simulation. While, Al-Kaisy and Karjala (2010) studied the car following interaction in two lane rural highways that is studies about time headways and speed choice in executed the lane changing. Guo et al. (2013) studied about lane change using driving simulation on multilane freeway. The research finds out the characteristics such as speed, acceleration rate, and glancing of drivers where the speed of the driver in executed the lane changing depends on the length and space available with the front vehicle. The behaviours of lane changing also have been studied. Lane changing behaviours has a direct influence on traffic safety. Tian (2011) claimed that in lane changing process, the different types of drivers have a different manner and in different environment will show different behaviour. While Aghabayk (2012) claimed that different longitudinal driving manner to a large extent determines the distributions of speeds and densities throughout the lanes can lead to lane changing. With the traffic scale growing, lane changing has become driving routine that driver facing.

Deeper understanding of long term driving assistance is required to provide drivers with versatile and various advanced assistant services especially in midblock U-turn facilities road segment. Some studies on lane changing behaviour have been done such as by Wei and Wanjing (2013) that studies simulation based study on a lane assignment approach for freeway weaving section. Their study on freeway simulator with real world weaving data with new concept which is lane assignment approach (LAA) to reduce the disruption between the cars of different destinations and prevent unsafe weaving manoeuvres. Moreover, Keyvan-Ekbatani et al. (2015) categorize the lane change decision process on freeways using microscopic traffic simulation. They asked driver to drive on a freeway with a camera equipped vehicle and asked the driver to comment on lane and speed preferred. Zheng et al. (2013) studies the effects of lane changing on the immediate follower by measuring the induced transient behaviour and the change of driver behaviour because of immediate follower. Lv et al. (2011) studied lane changing behaviour on three lane highways using simulation. The optimal velocity model obtained continuous position and velocity in space and time. However, in this study, it focused on the lane changing in approaching the U-turn facility road segment because of the diverge vehicle. Previous study about the DLC’s carried out by Zhao et al. (2014) found that 2035 numbers of DLC’s occur and find out over 10
REFERENCES


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