



MODELLING AND CONTROL OF THROTTLE AND BRAKE CONTROL SYSTEM USING PID CONTROLLER



**BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY
(AUTOMOTIVE TECHNOLOGY) WITH HONOURS**

2022



**Faculty of Mechanical and Manufacturing Engineering
Technology**



**MODELLING AND CONTROL OF THROTTLE AND BRAKE
CONTROL SYSTEM USING PID CONTROLLER**

Abdul Hayee Bin Ab Malik

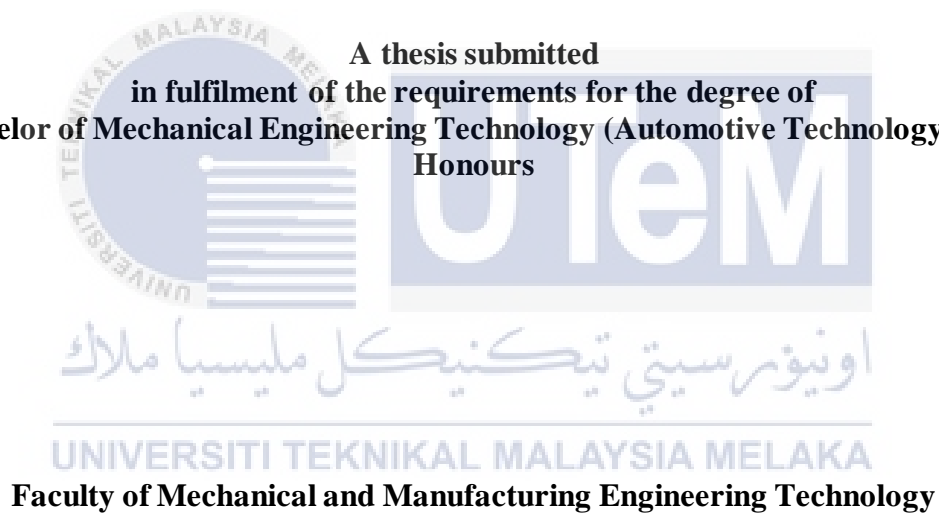
**Bachelor of Mechanical Engineering Technology (Automotive Technology) with
Honours**

2022

**MODELLING AND CONTROL OF THROTTLE AND BRAKE CONTROL
SYSTEM USING PID CONTROLLER**

ABDUL HAYEE BIN AB MALIK

**A thesis submitted
in fulfilment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Automotive Technology) with
Honours**



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this project entitled “**Modelling and Control Of Throttle And Brake Control System Using PID Controller**” is the result of my research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature

:



Name

:

Abdul Hayee Bin Ab Malik

Date

:


28 January 2022

اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

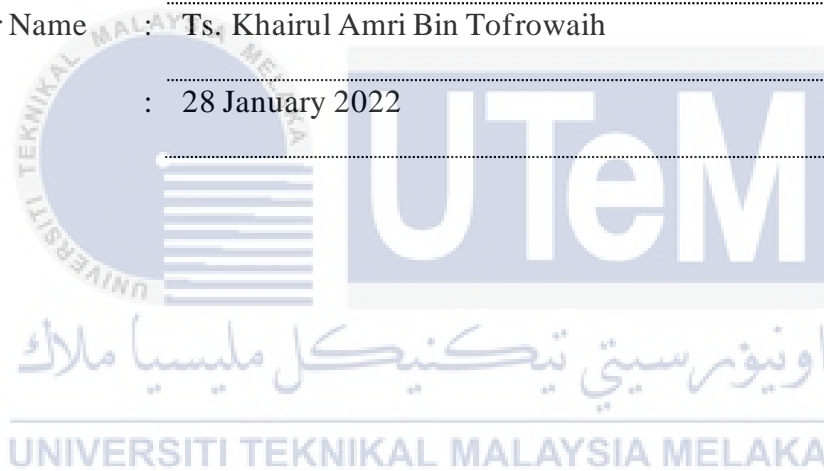
APPROVAL

I hereby declare that I have checked this thesis, and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature : 

Supervisor Name : Ts. Khairul Amri Bin Tofrowaih

Date : 28 January 2022



DEDICATION

At the first dedicating this work to Almighty ALLAH, without His mercy and sympathy, I was not able to accomplish this work. I am also dedicated to my supervisor, Ts. Khairul Amri Bin Tofrowaih because giving me this opportunity, experience and knowledge in my life to complete this meaningful research. My special dedication to my beloved late brother Muhammad Shukri Bin Ab Malik that have become as my inspiration, my obligations and my strength to further studies in the automotive field and to complete this project. My sincere appreciation also to my family members and colleagues for all the encouragement, spirituals and moral support that had been given to me all the time.

اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRACT

Various control intervention thresholds have been introduced to the automotive industries as it can reduce the possibility of road crash occurrences. This project's aims are to derive transfer function of acceleration and braking of vehicle MATLAB model using system identification method and compare the rise time, settling time, and overshoot of original input source with tuned signal by varying responses time and transient behaviour in PID controller tuner. Road slope is one of the factors that influence road crash occurrences, and it is essential to have good configuration of throttle and brake system. A system identification method used to obtain transfer function from default model where a PID controller can be tuned from the transfer function then applied in the full model. Various input and output variable used to train a transfer function and validate in the system identification toolbox in MATLAB to get the best-fit transfer function according to the default responses. The response of tuned controller model will be analysed and compared towards the default controller model. The model of the tuned PID controller for step input managed to satisfy the desired response compared with the drive cycle source, it does not manage to satisfy the desired response.



ABSTRAK

Pelbagai ambang intervensi kawalan telah diperkenalkan kepada industri automotif kerana ia dapat mengurangkan kemungkinan kejadian kemalangan jalan raya. Matlamat projek ini adalah untuk mendapatkan fungsi pemindahan pecutan dan brek model MATLAB kenderaan menggunakan kaedah pengenalan sistem dan membandingkan masa kenaikan, masa penyelesaian, dan overshoot sumber input asal dengan isyarat ditala oleh masa tindak balas yang berbeza-beza dan tingkah laku sementara dalam penala pengawal PID. Cerun jalan raya adalah salah satu faktor yang mempengaruhi kejadian kemalangan jalan raya, dan penting untuk mempunyai konfigurasi pendikit dan sistem brek yang baik. Kaedah pengenalan sistem yang digunakan untuk mendapatkan fungsi pemindahan dari model lalai di mana pengawal PID boleh ditala dari fungsi pemindahan kemudian digunakan dalam model penuh. Pelbagai pemboleh ubah input dan output yang digunakan untuk melatih fungsi pemindahan dan mengesahkan dalam kotak alat pengenalan sistem dalam MATLAB untuk mendapatkan fungsi pemindahan yang paling sesuai mengikut respons lalai. Tindak balas model pengawal yang ditala akan dianalisis dan dibandingkan dengan model pengawal lalai. Model pengawal PID yang ditala untuk input langkah berjaya memenuhi tindak balas yang dikehendaki berbanding dengan sumber kitaran pemacu, ia tidak berjaya memenuhi tindak balas yang dikehendaki.



ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

Predominantly, I would like to express gratitude and praise Allah the Almighty, my Creator, my Sustainer, for everything I obtained since the beginning of my life. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

I would like to convey my earnest gratitude to my advisor, Ts. Khairul Amri Bin Tofrowaih for his motivation, patience and immense knowledge. His supervision helped me throughout the research, project management, and writing of this research. My thanks and appreciations also go to my colleagues for their kindness and cooperation to help each other. Last but not least, I would like to thank my family for supporting me spiritually throughout writing this research. Without their precious support, it would not be possible to conduct this research.



TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	ii
ABSTRAK	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF ABBREVIATIONS	xi
LIST OF APPENDICES	xii
CHAPTER 1 INTRODUCTION	13
1.1 Background Study	13
1.2 Problem Statement	16
1.3 Research Aims	20
1.4 Scope of Study	20
CHAPTER 2 LITERATURE REVIEW	21
2.1 Overview	21
2.2 Relationship Of Road Characteristics and Road Traffic Accidents	21
2.3 Factors Influencing Crash Occurrence	24
2.3.1 Road Geometry	24
2.3.2 Sight Distance	30
2.3.3 Cross Section	32
2.4 Autonomous System	34
2.4.1 Introduction To Autonomous System	34
2.4.2 Autonomous Assisting Driving	34
2.5 Automated Vehicle Dynamic Control System	36
2.5.1 PID Controller Algorithm	39
2.6 Validation Model	40
2.6.1 2D Framework Model	40
2.7 Longitudinal Model	42
2.7.1 Accelerator And Brake Model	42
2.7.2 Road Slope Model	43

CHAPTER 3	METHODOLOGY	45
3.1	Overview	45
3.2	Methodology Process	45
	3.2.1 Project Flowchart	46
	3.2.2 Gantt Chart	48
3.3	Plant Representation	50
3.4	System Identification Toolbox	57
3.5	Training Data Process	58
3.6	Validation Data Process	63
3.7	Transfer Function Process	67
3.8	Tune PID Controller Process	69
3.9	Different Parameter of Input Sources	73
3.10	Modelling System Specification	74
	3.10.1 Modelling Software	74
	3.10.2 Laptop Computer Specification	75
	3.10.3 MATLAB And Simulink Requirements (Windows)	76
CHAPTER 4	RESULTS AND DISCUSSION	77
4.1	Overview	77
4.2	Open-loop response for the plant	78
4.3	System identification	82
	4.3.1 Parameter 1	82
	4.3.2 Parameter 2	83
	4.3.3 Parameter 3	84
	4.3.4 Drive Cycle Source	87
4.4	PID Controller Tuning	89
	4.4.1 Parameter 1	89
	4.4.2 Parameter 2	91
	4.4.3 Parameter 3	94
	4.4.4 Drive Cycle Source	96
4.5	Performance analysis	100
	4.5.1 Parameter 1	101
	4.5.2 Parameter 2	104
	4.5.3 Parameter 3	107
	4.5.4 Drive Cycle Source	111
CHAPTER 5	CONCLUSION AND RECOMMENDATIONS	114
5.1	Introduction	114
5.2	Achievements and Limitation on Research Aims	114
5.3	Recommendation	116
REFERENCES		117
APPENDICES		125

LIST OF TABLES

TABLE	TITLE	PAGE
Table 1.1	Total fatalities cases to state roads by the state year 2013-2017	19
Table 3.1	Process of Obtaining Training Data	58
Table 3.2	Process of Obtaining Validation Data	63
Table 3.3	Process of Obtaining Transfer Function	67
Table 3.4	Process of Tuning PID Controller	69
Table 3.5	Process of Changing Input Source	73
Table 3.6	Laptop Computer Specification	75
Table 3.7	MATLAB and Simulink Requirements	76
Table 4.1	Value of Time Domain Responses Comparison	102
Table 4.2	Value of Time Domain Responses Comparison	105
Table 4.3	Value of Time Domain Responses Comparison	108
Table 4.4	Value of Time Domain Responses Comparison	112

LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 1.1	Malaysia Road Accident 2010 - 2019	17
Figure 1.2	Malaysia Road Fatalities 2010 - 2019	18
Figure 2.1	Driving Level Automation	35
Figure 2.2	PID speed control system structure (Pan et al., 2016)	40
Figure 2.3	Vehicle with external forces (Sebsadji et al., 2008)	41
Figure 2.4	Vehicle with external forces in slope view (Sebsadji et al., 2008)	42
Figure 3.1	Simplified Project Flowchart	46
Figure 3.2	Full Project Flowchart	47
Figure 3.3	Timeline of The Project for PSM 1	48
Figure 3.4	Timeline of The Project for PSM 2	49
Figure 3.5	Simplified Concept of The Model	50
Figure 3.6	Full Block Diagram of The Model	51
Figure 3.7	Driver Block Diagram	51
Figure 3.8	Engine Block Diagram	52
Figure 3.9	Engine Torque Limiter Block Diagram	53
Figure 3.10	Engine Power Block Diagram	53
Figure 3.11	Calculate Efficiency Block Diagram	54
Figure 3.12	Driveline Block Diagram	55
Figure 3.13	Find Gear Block Diagram	55
Figure 3.14	Driveline Torque Losses Block Diagram	56
Figure 3.15	Glider Block Diagram	56

Figure 3.16 System Identification Toolbox	57
Figure 4.1 Step Input Profile	79
Figure 4.2 Response of Step Input Profile	79
Figure 4.3 New European Driving Cycle Source Profile	80
Figure 4.4 Response of New European Driving Cycle Source Profile	80
Figure 4.5: Simulated Model Output for Parameter 1	82
Figure 4.6: Simulated Model Output for The Best Fit Transfer Function for Parameter 1	83
Figure 4.7: Simulated Model Output for Parameter 2	83
Figure 4.8: Simulated Model Output for The Best Fit Transfer Function for Parameter 2	84
Figure 4.9: Simulated Model Output for Parameter 3	85
Figure 4.10: Simulated Model Output for The Best Fit Transfer Function for Parameter 3	85
Figure 4.11: Simulated Model Output for New European Driving Cycle Source	87
Figure 4.12: Simulated Model Output for The Best Fit Transfer Function for New European Driving Cycle Source	88
Figure 4.13: Closed Loop Control System for PID Tuning	89
Figure 4.14: Parameters of Tuned PID Controller	90
Figure 4.15: Graph of Tuning PID Controller	90
Figure 4.16: Graph of Tuned PID Controller	91
Figure 4.17: Closed Loop Control System for PID Tuning	92
Figure 4.18: Parameters of Tuned PID Controller	92
Figure 4.19: Graph of Tuning PID Controller	93

Figure 4.20: Graph of Tuned PID Controller	93
Figure 4.21: Closed Loop Control System for PID Tuning	94
Figure 4.22: Parameters of Tuned PID Controller	95
Figure 4.23: Graph of Tuning PID Controller	95
Figure 4.24: Graph of Tuned PID Controller	96
Figure 4.25: Closed Loop Control System for PID Tuning	97
Figure 4.26: Parameters of Tuned PID Controller	98
Figure 4.27: Graph of Tuning PID Controller	98
Figure 4.28: Graph of Tuned PID Controller	99
Figure 4.29: Full Vehicle Model for Step Input	100
Figure 4.30: Full Vehicle Model for Drive Cycle Source Input	100
Figure 4.31: Graph of Actual Output for Full Model for Parameter 1	101
Figure 4.32: Graph of Actual Output for Full Model for Parameter 2	104
Figure 4.33: Graph of Actual Output for Full Model for Parameter 3	107
Figure 4.34: Graph of Actual Output for Full Model for Drive Cycle Source	111

LIST OF ABBREVIATIONS

ADAS	-	Advance Driver-Assistance System
ARIMA	-	Autoregressive Integrated Moving Average
DSD	-	Decision Sight Distance
ESC	-	Electronic Stability Control
ESC	-	Electronic Stability Control
GIS	-	Geographical Information System
GPS	-	Global Positioning System
ISD	-	Intersection Sight Distance
JKR	-	Road Safety Department of Malaysia
LOS	-	Level of Service
MIROS	-	Malaysia Institute of Road Safety
MOT	-	Ministry of Transport Malaysia
MPC	-	Model Predictive Controller
MP-DTC	-	Model Predictive Direct Torque Controller
NCAP	-	New Car Assessment Programme
NEDC	-	New European Driving Cycle
PHEV	-	Plug-In Hybrid Electric Vehicle
PID	-	Proportional, Integral, Derivative
PSD	-	Passing Sight Distance
RMP	-	Royal Malaysian Police
SSD	-	Stopping Sight Distance
TCS	-	Traction Control System
TCS	-	Traction Control System
UTeM	-	Universiti Teknikal Malaysia Melaka
WHO	-	World Health Organization
WHO	-	World Health Organization
2DOF	-	Two Degree of Freedom

LIST OF APPENDICES

APPENDIX PAGE	TITLE	
APPENDIX A	Borang Pengesahan Status Laporan Projek Sarjana	125
APPENDIX B	Turnitin Originality Report	126



CHAPTER 1

INTRODUCTION

1.1 Background Study

The road network is an essential aspect for a developing country because every country tends to pursue their development and modernisation in every inch of its region. To ensure they can achieve their mission and vision, connecting rural areas with cities is crucial to makeover since development primarily connects to every city and rural area. It requires roadway development across a wide range of mountainous topography areas. A suitable road network is vital to make sure it is safe to be used.

Malaysia has two main road networks: federal roads and state roads that link up the entire country. Federal roads link up state capitals and those that lead to entry points and exit from the country. It is classified as highways, main highways, regional road structure, and minor roads that give access to government buildings. State roads are also another type of road network. It consists of main roads, secondary roads, minor roads, residential roads, and local streets. These types of the network are then classified into three topography groups, where the topography refers to road geometry elements such as arrangements, slopes, eyesight distance, and cross-section. These three groups of topography are flat, rolling, and mountainous. Firstly, flat ground means that sight distances are identifiable, and average pass inclinations of the earth often below 3% on flat terrain. Geological grades continuously climb over or drop underneath the road grade. In a rolling ground, the cross slopes on the ground range from 3 to 25%. Finally, mountainous ground refers to a topographical state in which longitudinal and transverse variations throughout the height of the earth adjacent to a

route as well as highway were abrupt and unexpected, and in which benching and sidehill extraction is commonly used to achieve appropriate horizontal and vertical alignment. In steep hills, ground surface cross-slopes are frequently more than 25% (JKR, 2000).

Road slope or road grade is the ratio which the roadway goes up and down concerning the horizontal across its course referred to the gradients of the roadway, another phrase, the longitudinal slope delivered to the trail's formation-level across its path (Sautya, 2017). The slopes are the mountain's grade or slant. A sloped driveway denotes a significant inclination, while a moderate slope denotes a minor incline (DeYoung, 2018). The roadway's slope is described as the roadway's elevation as it ascends and descends along its course. Road slope always referred to the hilly area or mountainous area since these types of terrain mostly have the highest road grade level and become the steepest road. Mountainous areas have always been a dangerous area to drive since it has a higher road slope or road grade than other types of terrain. According to (L. Li et al., 2013), mountain roads are high-risk sites for car crashes due to their complicated geographical circumstances and road geometry. Additionally, a study claimed that bad curve layout, the presence of guide rails, limited margin drop-offs, limited visibility at bend or valley crossings, and improper lighting placement are the primary factors impacting crashes in a hilly environment (Fatma et al., 2020).

According to the New Car Assessment Programme (NCAP), to ensure more comfortable and safe travel, particularly on challenging terrain, every car must include an adequate vehicle safety system. To guarantee the ride quality in a dangerous state while reducing crash risk during routine driving, control intervention thresholds must be deliberately constructed using travelling data and ambient factors (Lutz et al., 2017). The best approximation is yet another level of car electronic stability control (ESC). The

automobile traction control system (TCS) has been an active vehicle security system that integrates a tire slip ratio program to enhance traction performance and steering wheel ride quality, particularly on slippery roads. An active control system is required that assists the operator in maintaining control of their vehicle during a tricky scenario. Numerous control methods can be applied to TCS, including the threshold control, proportional-integral-derivative (PID) control, sliding-mode control, and fuzzy control (Austin & Morrey, 2000),(Koker et al., 2006). Although the threshold control process is simple, it takes multiple dynamic analysis to obtain fair values for various road conditions (Wang et al., 2010). The fuzzy control method proposed by some researcher has been proved to meet the requirements of vehicle safety and comfort, and it has been proposed that the fuzzy PID control algorithm is applied to the vehicle speed control system (Preindl & Bolognani, 2013), (Choi et al., 2013). The fuzzy control scheme has also been used to manage the moving wheel's slip ratio, but it requires numerous assessments to determine the precise controls (M. Bauer & Tomizuka, n.d.). The benefit of PID controllers above other systems is that they do not require a specific computational formula. Nonetheless, obtaining the process variables necessary to get a satisfying result is not straightforward. Considerable changes in the friction between the tire and the roadway may lead to substantial control faults in the PID controllers (Ameddah & Benmokrane, 2010)

PID controller is one kind of device with a feedback control loop to regulate all the process variables where it controls different process variables like pressure, flow, temperature, and speed in industrial application. The PID controller is one of the foremost common sorts of controllers. The PID controller has gotten wide application in various objective and design systems of programmed control of the working parameters of tools, making it easy to provide signal generation (Ajwad et al., 2015). Approximately 90–95 per

cent of controllers in use today employ the PID algorithm. This extremely popular is the comprehension of construction and manufacturing processes, the ease of operation, the appropriateness for tackling the majority of actual problems, and the economics (Doroshenko, 2017). However, some difficulties arise because of the complexity of the operation, such as in numerous PID controllers. The differential element is disabled only because it is difficult to set up perfectly.

1.2 Problem Statement

Road accidents rapidly increase over the years due to the massive amounts of vehicles on the road because of the great competition among the automotive industry worldwide. The World Health Organization (WHO) predicts that road traffic injuries will climb from ninth place in 2004 to fifth place in 2030 as one of the leading causes of death worldwide (WHO, 2009). Human mistake, activity, vehicle and street conditions, and the nearby environment have been decided as a critical point that affects driving habits, which can, in turn, contribute to a car accident. In Malaysia, the authorised by the Royal Malaysian Police (RMP) research-based by the Malaysian Institute of Road Safety Research (MIROS) conduct and evaluate the accidents statistic every year. MIROS was set up to control and improve road security in Malaysia. It acts as the most coordinator in creating youthful minds and teaching individuals almost road safety.

The severity of crashes in hilly areas or mountainous areas is higher than in flat areas or level areas due to the topological condition that requires high concentration and perfect vehicle's condition. Mountainous road engineering work requires considerable technological capacities and resources to build safer roads; however, these are not always available, making it challenging to maintain desirable roadway geometric features that ensure the safety of the road users (Yun et al., 2013). Violent driving, speed up and braking, will wastes

energy considerably (Kamal et al., 2011). Moreover, topographical features and road environments are closely linked with driving performance, as driving along high and steep mountain grades is often challenging. Continuous braking along downgrades may make brake pads hot, cause them to lose their grip, and eventually lead to brake function loss (Rusli, 2017). Once again, it was demonstrated that diverse road features, such as middle fences, margins and lane widths, level and perpendicular turns, the frequency of entry points, and pedestrian conditions, all play an important role in the frequency and intensity of road traffic accidents (Musa et al., 2020).

According to the Ministry of Transportation Malaysia, accidents tend to increase gradually, according to Figure 1. The number of road accidents in Malaysia for the last ten years shown in Figure 1, where 414,421 cases in 2010 kept increasing to 489,606 cases in 2015 and peaked at 567,516 cases in 2019. In the meantime, the death toll has decreased steadily ever since it crested at 7,152 during 2016 then reached a ten-year low of 6,167 in 2019. (Figure 2).

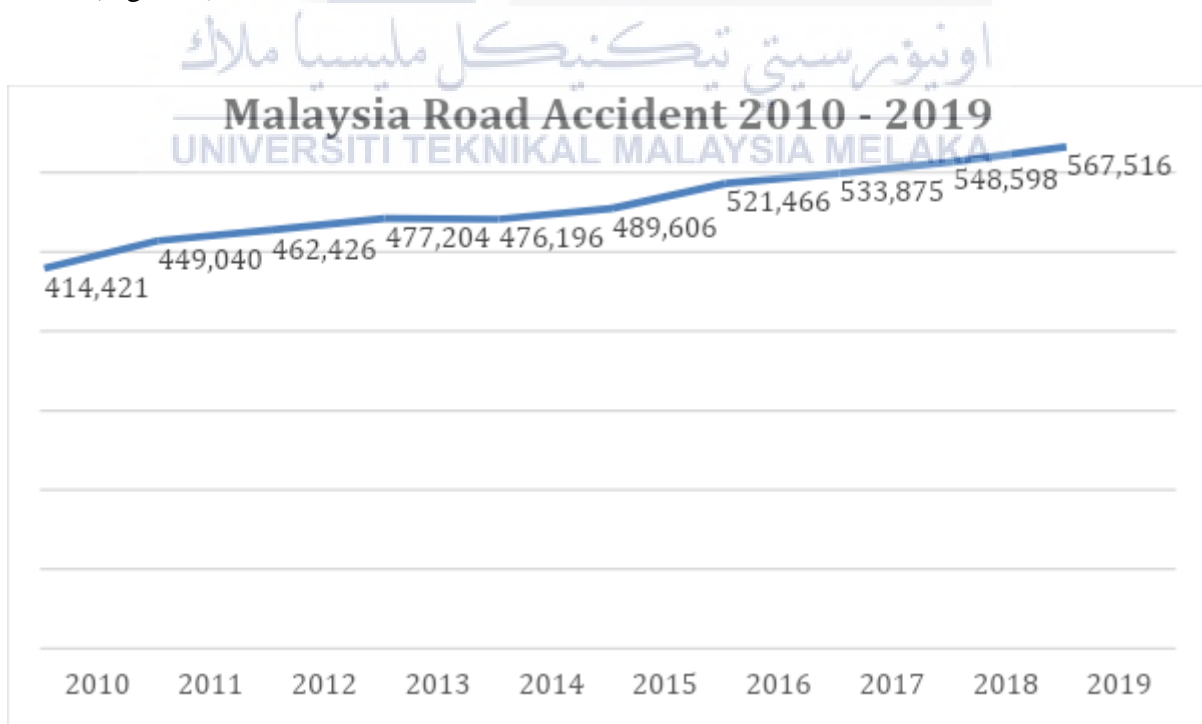


Figure 1.1 Malaysia Road Accident 2010 - 2019



Figure 1.2 – Malaysia Road Fatalities 2010 - 2019



Table 1.1 Total fatalities cases to state roads by the state year 2013-2017

State/ Year	2013	2014	2015	2016	2017	Total
Perlis	72	61	65	67	37	302
Kedah	517	525	530	572	327	2,471
Pulau Pinang	381	378	360	411	240	2,773
Perak	770	750	726	789	429	3,464
Selangor	1,019	1,068	1,028	1,140	627	4,882
Wilayah Persekutuan	243	238	256	232	132	1,101
Negeri Sembilan	396	379	355	414	214	1,758
Melaka	258	236	256	247	120	1,117
Johor	1,128	1,018	1,040	1,135	596	4,917
Pahang	592	539	532	539	293	2,495
Kelantan	378	354	426	453	260	1,871
Terengganu	320	276	307	342	191	1,436
Sabah	420	420	392	379	211	1,822
Sarawak	421	432	433	432	236	1,954
Total	6,915	6,674	6,706	7,152	3,913	31,360

Based on the death data from road accidents provided by the Road Safety Department of Malaysia (JKR), Ministry of Transport Malaysia. The data taken are obtained from the Road Accident Statistics Book. The fatalities cases on the state road for five years from 2013 to 2017 was stated in Table 1.1. The highest number of fatal cases recorded in Johor were 4,917 cases recorded in the five years the followed by Selangor, 4,882 cases recorded. The lowest cases recorded was in Perlis were 302 cases during the five years compared to Johor and Selangor. It was a massive difference for these three states. Johor recorded the highest