



**The Effect of Tax-Related Emission Factors on
Vehicles Exhaust Emissions: Mediating Role of Driver
Motivations**

by

**YASSER AMMAR ABDULHAMEED AL-RAWI
(1442611383)**

A thesis submitted in fulfillment of the requirements for the degree of
Doctor of Philosophy

**School of Business Innovation and Technopreneurship
UNIVERSITI MALAYSIA PERLIS**

2019

ACKNOWLEDGMENT

First and foremost, Praise be to God and blessings and peace be upon his prophet, his Kinsfolk, and Companions, my thanks to Allah Almighty who helped me to finish this work.

Second, Special thanks to my mother, wife, and my daughter those who a source of encouragement and inspiration me throughout my life.

My special gratitude and appreciation go to my supervisor Dr. Mohammed Harith Imlus who actively supported my research study. I offer my gratitude and appreciation to my co-supervisor Prof. asst Dr. Yusri Yusup for the continuous support in my study. I would like to express my sincere gratitude also to my Co-Supervisor Prof. asst. Dr. Sofri Bin Yihya.

Last but not the least, I would like to thank my family, friends, or any person supported me to finish this work.

©This item is protected by original copyright

TABLE OF CONTENTS

	PAGE
DECLARATION OF THESIS	i
TABLE OF CONTENTS	iii
LIST OF TABLES	xii
LIST OF FIGURES	xiv
LIST OF ABBREVIATIONS	xvi
ABSTRAK	xvii
ABSTRACT	xix
CHAPTER 1 : INTRODUCTION	1
1.1 Background of the Study	1
1.2 Problem Statement	11
1.3 Research Questions	16
1.4 Research Objectives	16
1.5 Significance of the Study	17
1.5.1 Theoretical Contributions	18
1.5.2 Practical Contributions	20
1.6 Rationale of the Study	21
1.7 Scope of this Study	22
1.8 Definition of Key Terms	23
1.9 The Organization of This Study	26
1.10 Chapter Summary	27
CHAPTER 2 : LITERATURE REVIEW	28
2.1 Introduction	28
2.2 Environment in Malaysia	29

2.2.1	Geography of Malaysia	29
2.2.2	Urbanization in Malaysia	30
2.2.3	Air Pollution in Malaysia	32
2.2.4	Air Pollution Policies in Malaysia	35
2.3	Vehicle Air Pollution	40
2.3.1	Global Vehicle Pollutants	42
2.3.2	Local Vehicle Pollutants	42
2.3.3	Policies of Emission Reductions and Reforms	44
2.4	Vehicle Exhaust (Tailpipe) emissions (VEE)	50
2.4.1	Factors Affecting Vehicle Emissions	51
2.4.1.1	The Effect of Engine Size on Vehicle Exhaust Emissions	55
2.4.1.2	The Effect of Vehicle Age on Vehicle Exhaust Emissions	56
2.4.1.3	The Effect of Vehicle Kilometres Travelled on Vehicle Exhaust Emissions	59
2.5	Accounting for Emission Costs	62
2.6	Tax Progressivity	69
2.6.1	Progressive Tax in Malaysia	74
2.6.2	Progressive Exhaust Emission Tax (PEET)	75
2.6.3	Why Progressive Tax on Emission in Malaysia	81
2.6.4	Progressive Tax Policy Criteria	82
2.6.4.1	Progressive Tax Fairness	82
2.6.4.2	Progressive Tax Effectiveness	83
2.6.4.3	Progressive Tax Transparency	84
2.6.5	Progressive Tax Mechanism	85
2.6.6	Progressive Tax Design	86
2.6.6.1	The Intended Taxpayer	87

2.6.6.2	Assessment Base of the Tax	87
2.6.6.3	The Stage of the Tax Levied	88
2.6.6.4	Taxation Point	91
2.6.7	Progressive Tax Measurement	92
2.6.8	Progressive Vehicle Taxes (PVT)	95
2.6.8.1	Driving or Usage Taxes	97
2.6.8.2	Ownership Taxes	100
2.6.8.3	Purchase or Acquisition Taxes	102
2.6.9	The Optimal Progressive Tax Policy	106
2.6.10	Advantages and Difficulties of Vehicle Emission Taxes	109
2.7	Driver Motivations	113
2.7.1	The Importance of Tax Motivation Policy	116
2.7.2	The effect of High Tax Rate on Driver Motivations	120
2.8	Tax-Related Emission Factors(Progressive Engine Size Tax,Progressive Exhaust Emission Tax,Progressive Vehicle Age Tax,and Progressive Vehicle Kilometer Travelled Tax), Driver Motivation, and Vehicle Exhaust Emissions	122
2.9	Pigouvian Theory	125
2.10	Fairness Theory	130
2.11	Extrinsic Motivation Theory	134
2.12	Literature Gaps	135
2.12.1	Theoretical gaps	136
2.12.2	Practical gaps	138
2.13	Chapter Summary	139
 CHAPTER 3 : THEORETICAL FRAMEWORK AND RESEARCH		
METHODOLOGY		
3.1	Introduction	140
3.2	Theoretical Framework	141

3.3	Hypotheses Development	146
3.3.1	The Effect of Progressive Engine Size Tax on Vehicle Exhaust Emissions	146
3.3.2	The Effect of Progressive Vehicle Age Tax on Vehicle Exhaust Emissions	147
3.3.3	The Effect of Progressive Vehicle Kilometers Traveled Tax on Vehicle Exhaust Emissions	148
3.3.4	The Effect of Progressive Exhaust Emissions Tax on Vehicle Exhaust Emissions	149
3.3.5	The Effect of Progressive Engine Size Tax on Driver Motivations	150
3.3.6	The Effect of Progressive Vehicle Age Tax on Driver Motivations	152
3.3.7	The Effect of Progressive Vehicle Kilometers Traveled Tax on Driver Motivations	153
3.3.8	The Effect of Progressive Exhaust Emissions Tax on Driver Motivations	154
3.3.9	The Effect of Driver Motivations on Vehicle Exhaust Emissions	155
3.3.10	The Mediating Role of Driver Motivations in the Effect of Progressive Engine Size Tax on Vehicle Exhaust Emissions	156
3.3.11	The Mediating Role of Driver Motivations in the Effect of Progressive Vehicle Age Tax on Vehicle Exhaust Emissions	157
3.3.12	The Mediating Role of Driver Motivations in the Effect of Progressive Vehicle Kilometers Traveled Tax on Vehicle Exhaust Emissions	158
3.3.13	The Mediating Role of Driver Motivations in the Effect of Progressive Exhaust Emissions Tax on Vehicle Exhaust Emissions	159
3.4	Research Methodology	161
3.5	Population and Sampling Design	167

3.5.1	Sampling Frame	168
3.5.2	Sampling Size	169
3.5.3	Sampling Process	173
3.6	The Respondents of Mixed Method	175
3.7	Mixed Method Data Collection	176
3.7.1	Quantitative Data Collection	179
3.7.1.1	Questionnaire Design	179
3.7.2	Qualitative Data Collection	184
3.7.2.1	Semi-structured interview	185
3.7.2.2	Interview Design	187
3.8	Mixed Methods Data Analysis	188
3.8.1	Quantitative Data Analysis	190
3.8.1.1	Smart PLS Model Analysis	192
3.8.1.2	Measurement of Model Analysis	193
3.8.1.3	Structural Model Analysis	197
3.8.1.4	Bootstrapping Mediation Analysis	199
3.8.2	Qualitative Data Analysis	201
3.9	Variables Measurement	204
3.10	The proposed Tax System	206
3.10.1	Data Collection	206
3.10.2	Design Tax System	208
3.10.3	Progressive Emission Tax Model (PETM)	210
3.10.4	How does the System Work?	212
3.11	Chapter Summary	214
	CHAPTER 4: RESULTS AND DISCUSSION	215
4.1	Introduction	215

4.2	Quantitative Results	216
4.2.1	Respondent Demographics	216
4.2.2	Survey Response	217
4.2.3	PLS Model Assessment	220
4.2.3.1	Goodness of Fit (GOF)	221
4.2.3.2	Collinearity Assessment (VIF)	222
4.2.3.3	Assessment of Measurement Model	224
4.2.3.4	Assessment of Structural Model	229
4.2.3.5	Mediation Analysis	234
4.2.3.6	Summary of Hypotheses Analysis	236
4.3	Qualitative Results	237
4.3.1	Participants	239
4.3.2	Summary of Results	242
4.3.2.1	Vehicle Exhaust Emissions (VEE)	243
4.3.2.2	Tax Related Emission Factors (TREF)	244
4.3.2.3	The effect of Tax-Related Emission Factors (Progressive Exhaust Emission Tax, Progressive Vehicle Age Tax, Progressive Engine Size Tax. and Progressive Vehicle Kilometer Travelled Tax) on Vehicle Exhaust Emissions	245
4.3.2.4	Mediating Role of Driver Motivations for the Effect of TaxRelated Emission Factors (Progressive Exhaust Emission Tax, Progressive Vehicle Age Tax, Progressive Engine Size Tax. and Progressive Vehicle Kilometer Travelled Tax) on Vehicle Exhaust Emissions	246
4.4	Discussion of Results	248
4.4.1	The Level of Vehicle Exhaust Emissions	250

4.4.2	The Effect of Tax-Related Emission Factors (Progressive Engine Size Tax, Progressive Vehicle Age Tax, Progressive Vehicle Kilometer Travelled Tax and Progressive Exhaust Emission Tax) on Vehicle Exhaust Emissions	252
4.4.3	The Effect of Tax-Related Emission Factors (Progressive Engine Size Tax, Progressive Vehicle Age Tax, Progressive Vehicle Kilometer Travelled Tax and Progressive Exhaust Emission Tax) on Driver Motivations	258
4.4.4	The Effect of Driver Motivation on Vehicle Exhaust Emissions	259
4.4.5	The Mediating Role of Driver Motivation for the Effect of Tax-Related Emission Factors (Progressive Engine Size Tax, Progressive Vehicle Age Tax, Progressive Vehicle Kilometer Travelled Tax, and Progressive Exhaust Emission Tax) on Vehicle Exhaust Emissions	261
4.4.5.1	The Mediating Role of Driver Motivation for the Effect of Progressive Engine Size Tax on Vehicle Exhaust Emissions	262
4.4.5.2	The Mediating Role of Driver Motivation for the Effect of Progressive Vehicle Age Tax on Vehicle Exhaust Emissions	263
4.4.5.3	The Mediating Role of (Driver Motivation) for the Effect of (Progressive Vehicle Kilometer Travelled Tax) on (Vehicle Exhaust Emissions)	265
4.4.5.4	The Mediating Role of Driver Motivation for the Effect of Progressive Exhaust Emission Tax on Vehicle Exhaust Emissions	266
4.5	Design Tax System	269
4.5.1	Sample Profile	270
4.5.2	The Effect of Factors-Related Emissions on Vehicle Exhaust Emissions	270

4.5.2.1	The Effect of Engine Size on Vehicle Exhaust Emissions	274
4.5.2.2	The Effect of Vehicle Age on Vehicle Exhaust Emissions	275
4.5.2.3	The Effect of Vehicle Kilometer Ttravelled on Vehicle Exhaust Emissions	276
4.5.3	A Proposed Progressive Tax System	278
4.5.3.1	Progressive Engine Size Tax (PEST)	278
4.5.3.2	Progressive Vehicle Kilometer Travelled Tax (PVKTT)	279
4.5.3.3	Progressive Vehicle Age Tax (PVAT)	281
4.5.3.4	Progressive Emission Tax Model (PETM)	282
4.5.3.5	A Progressive Tax Calculation	286
4.6	Chapter Summary	294
	CHAPTER 5 : CONCLUSIONS AND RECOMMENDATION	295
5.1	Introduction	295
5.2	Contributions of the Study	295
5.2.1	Theoretical Contributions	296
5.2.2	Practical Contribution	297
5.3	Limitations of the Study	297
5.3.1	Theoretical Limitations	298
5.3.2	Practical Limitations	299
5.4	Recommendations of the Study	300
5.4.1	General Recommendations	300
5.4.2	Future Research Recommendations	300
5.5	Conclusions of the Study	301
5.5.1	Theoretical Conclusion	302
5.5.2	Practical Contributions	304
5.6	Chapter Summary	306

REFERENCES	307
APPENDIX A	360
APPENDIX B	369
APPENDIX C	379
APPENDIX D	381
APPENDIX E,F	377
APPENDIX G	401
APPENDIX H	410
APPENDIX I	412
APPENDIX J	414

©This item is protected by original copyright

LIST OF TABLES

		PAGE
Table 2.1	Emission standards for a petrol engine with total mass less than 2500 kg.	39
Table 2.2	Emission standard of pollutant for light duty motor vehicles (N1)	40
Table 2.3	Emission tax policies in some other countries	49
Table 2.4	Factors Influencing Motor Vehicle Emissions	52
Table 2.5	Motor Vehicle Cost Distribution	64
Table 2.6	Progressive tax brackets for CO ₂ emissions	80
Table 2.7	Progressive tax grade for NO _x emissions	80
Table 2.8	Definition of Different Types of Motivation	114
Table 3.1	Total Private Vehicle Registrations in Malaysia	169
Table 3.2	Similarities and differences of qualitative and quantitative data analysis	190
Table 3.3	Variables Measurement	204-205
Table 4.1	Profile of the respondents (n=308)	216-217
Table 4.2	Goodness of Fit (GOF)	222
Table 4.3	Outer VIF Values	223
Table 4.4	Loadings and Cross-Loadings (n=308)	225
Table 4.5	Measurement model of PLS (n=308)	227
Table 4.6	Discriminant validity of Fornell-Larcker Criterion (n=308)	228
Table 4.7	Significance of direct effects- Path coefficients (n=308)	230

Table 4.8	R-Square value and Q-Square value (n=308)	232
Table 4.9	<i>f-Square</i>	234
Table 4.10	Significance of indirect effects- Path coefficients (n=308)	235
Table 4.11	Summary of hypotheses analysis (n=308)	236
Table 4.12	Profile of participants (n=10)	240
Table 4.13	Profile of Sample (n=43)	270
Table 4.14	Vehicle Emissions Tests	272
Table 4.15	Progressive ES tax rules	279
Table 4.16	Progressive VKT tax rules	281
Table 4.17	Progressive VA tax rules	282
Table 4.18	Progressive CO emission tax rules	286
Table 4.19	Vehicles samples selected	287
Table 4.20	Total Taxes on Vehicle Emissions	293

LIST OF FIGURES

	PAGE
Figure 1.1 New passenger vehicles registered in Malaysia for the years from 1980 to 2017	2
Figure 1.2 VKT in Malaysia by states	3
Figure 1.3 Number of passenger vehicles registered in Malaysia according to the vehicles age.	4
Figure 1.4 Air pollution sources in Malaysia	5
Figure 2.1 West and east coast of Malaysia	30
Figure 2.2 Level of Urbanization state, Malaysia	32
Figure 2.3 Vehicle exhaust emissions	50
Figure 2.4 Pathway of transport emissions	53
Figure 2.5 Factors Affecting Emission Rates	53
Figure 2.6 Factors affecting vehicle emission	54
Figure 2.7 Factors-Related Emissions	55
Figure 2.8 Lorenz curve framework	94
Figure 2.9 Malaysian progressive tax curves	95
Figure 3.1 Mediating diagram	144
Figure 3.2 Schematic Diagram of Research Framework	145
Figure 3.3 Research Flow Diagram	163
Figure 3.4 Total sample size	171
Figure 3.5 Basic Triangulation Research Model	178

Figure 3.6	Mediation Analysis Using Bootstrapping Approach	201
Figure 3.7	The Instrument of KIGAZ 300	205
Figure 3.8	Interface of Microsoft Visual Studio C# 2010	209
Figure 3.9	Interface of a proposed progressive tax system	210
Figure 4.1	Conceptual Research framework	221
Figure 4.2	PLS-Path analysis of t-values (n=308)	231
Figure 4.3	PLS-Path analysis of R-square value (n=308)	232
Figure 4.4	Blindfolding (MVs) ($Q^2=0.189>0$); (DV) ($Q^2=0.206>0$)	233
Figure 4.5	Effects of ES on CO Emission	274
Figure 4.6	Effects of VA on CO Emission	276
Figure 4.7	Effects of VKT on CO Emission	277
Figure 4.8	PERDUA Axia 2016 Tax	288
Figure 4.9	PROTON Saga 2001 Tax	289
Figure 4.10	PERDUA Kancil 1999 Tax	290
Figure 4.11	PROTON Wira 2002 Tax	291
Figure 4.12	PROTON Wira 1993 Tax	292

LIST OF ABBREVIATIONS

ES	Engine Size
PEST	Progressive Engine Size Tax
VA	Vehicle Age
PVAT	Progressive Vehicle Age Tax
VKT	Vehicle Kilometers Travelled
VMT	Vehicle miles Travelled
PVKTT	Progressive Vehicle Kilometers Travelled Tax
VEE	Vehicle Exhaust Emissions
PEET	Progressive Exhaust Emissions Tax
TREF	Tax-Related Emission Factors
FRE	Factors-Related Emission
DM	Driver Motivations
MDOE	Malaysia's Department Of Environment
MAA	Malaysian Automotive Association
OECD	The Organisation for Economic Co-operation and Development
ppm	Parts Per Million
CO	Carbon Monoxide
NO _x	Nitrogen Oxides
CO ₂	Carbon Dioxide
HC	Hydrocarbons
PM	Particulate Matter
SO ₂	Sulphur Dioxide
SPM	Suspended Particulate Matter
VOC	Volatile Organic Compounds

Kesan Faktor Pelepasan Berkaitan Cukai ke atas Pelepasan Ekzos: Peranan Pengantara Motivasi Pemandu

ABSTRAK

Pemahaman yang menyeluruh oleh pihak pembuat keputusan mengenai kos yang bersangkutan dengan pelepasan ekzos dan impaknya dapat membantu mengurangkan kesan negatif yang berkaitan, yang merupakan salah satu keutamaan bagi pihak kerajaan di seluruh dunia. Pengetahuan ini membantu mewujudkan dasar yang membolehkan individu membuat keputusan yang selaras dengan kepentingan kerajaan dan masyarakat untuk memaksimumkan faedah keseluruhan dan mengurangkan kesan luaran akibat penggunaan kenderaan. Di seluruh dunia, terdapat satu matlamat pra-tetap berbanding dengan pelepasan purata maksimum. Walau bagaimanapun, matlamat ini hampir mustahil untuk dicapai tanpa campur tangan pasaran. Oleh itu, pihak kerajaan memperkenalkan cukai untuk membimbing individu di pasaran ke arah pengurangan pelepasan.

Tujuan kajian ini adalah untuk meneroka peranan pengantara motivasi pemandu yang mempengaruhi kesan faktor pelepasan berkaitan cukai (cukai saiz enjin progresif, cukai pelepasan progresif, cukai jangka hayat kenderaan progresif, dan cukai perjalanan perkilometer kenderaan progresif) ke atas pelepasan ekzos kenderaan. Kajian ini diterapkan berdasarkan pendekatan kaedah campuran untuk mengumpulkan data primer, yang bertumpu terutama pada soal selidik dan sebahagiannya pada temu bual. Analisis data kuantitatif kemudian dilakukan dengan menggunakan Smart PLS 3.2.7. Bagi peranan pengantara, kajian mendapati bahawa penerapan cukai progresif pada saiz enjin, jangka hayat kenderaan, dan pelepasan kenderaan, akan meningkatkan motivasi pemandu untuk membeli kenderaan yang mempunyai saiz enjin yang lebih kecil, menukar atau menyelenggarakan kenderaan lama yang mencemarkan atau mengatasi masalah pelepasan. Hasil yang diperoleh daripada temu bual mengesahkan hasil yang diperoleh daripada analisis kuantitatif.

Kajian ini menyumbang kepada kajian lepas dengan menyediakan satu rangka kerja sistematik yang menunjukkan asas teori motivasi Pigovian dan ekstrinsik. Rangka kerja ini juga mencapai matlamat teori dan praktikal dan menyampaikan mesej yang jelas kepada para pengamal dan mana-mana badan yang berkaitan di Malaysia bahawa cukai progresif dapat meningkatkan motivasi pemandu sebagai strategi untuk mengurangkan pelepasan ekzos kenderaan.

Cukai-cukai ini boleh dianggap sangat berkesan apabila ia dirancang dengan betul, ditetapkan pada kadar yang memadai dan adil, dan dikenakan sebaik mungkin ke atas bahan pencemar atau aktiviti yang merosakkan alam sekitar. Kajian ini merancang gabungan pelbagai cukai progresif yang menunjukkan teori keadilan (cukai saiz enjin, cukai jangka hayat kenderaan, cukai perjalanan perkilometer kenderaan dan cukai langsung ke atas pelepasan ekzos) dengan menggunakan bahasa visual studio 2010 (C#). Rancangan sistem cukai yang optimum memenuhi tujuan untuk mengubah motivasi ke arah pola yang kurang mencemarkan. Apabila pelepasan dikenakan bayaran, orang ramai akan sedaya upaya mengelakkan cukai dengan mengurangkan

pelepasan, seolah-olah kos yang ditanggung oleh orang lain akibat pelepasan itu ditanggung oleh para pemandu sendiri.

©This item is protected by original copyright

The Effect of Taxes-Related Emission Factors on Vehicles Exhaust Emissions: Mediating Role of Driver Motivations

ABSTRACT

The comprehensive understanding of the costs associated with emissions and understanding their impacts by decision-makers could help to reduce its negative effects, which is one of the main priorities for the governments in the worldwide. This knowledge would aid in establishing the policies that allow the individuals to make decisions consistent with the government and society interests in maximizing overall benefits and reducing externalities resulting from vehicle use. In the worldwide, there is pre-set goals vis-à-vis the maximum average emission. However, these goals are nearly impossible to realize without the intervention of the markets. Therefore many governments introduced the taxes to guide the personals towards reducing emissions.

The purpose of this study is to explore the mediating role of driver motivations in the effect of tax-related emission factors (progressive engine size tax, progressive emissions tax, progressive vehicle age tax, and progressive vehicle kilometres travelled tax) on vehicle exhaust emissions. The study was adopted on the mixed methods approach to collect primary data, where it was focused mainly on the questionnaire and partially on the interviews. An analysis of the quantitative data was then made using Smart PLS 3.2.7. For the mediating role, the study found that the progressive taxes on engine size, vehicle age, and vehicle emissions if imposed, it will increase driver motivations to buy smaller engine size vehicle, change or maintenance old polluting vehicle or fix emission problems. The results from the interviews confirmed the results obtained by the quantitative analysis.

This study contributes to the literature by presenting a systematic framework that demonstrates the underlying the Pigovian and extrinsic motivation theories. as well as achieves the theoretical and practical objectives by a clear message to practitioners and any related body of Malaysia that the progressive taxes can increase driver motivations as a strategy to reduce vehicle emissions.

The taxes may be considered as a very effective when they are designed properly, are set at an adequate and fairness rate, and are levied as close to the environmentally damaging pollutants or activity as possible. This study designed a combination of different progressive taxes that demonstrates the fairness theory (engine size tax, vehicle age tax, vehicle kilometre travelled tax and a direct tax on exhaust emissions) by using a language of visual studio 2010 (C#). The design of an optimal tax system may aim at changing motivations towards less polluting patterns. when emissions were priced, persons try to avoid taxes to the extent they can, by reducing emissions, as if the costs those emissions cause to others have become their own.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Malaysia is one of the most urbanized developing countries in the world (Duflot, 2012). It has a relatively well-developed economy within the ASEAN region (Kurabayashi et al., 2013). Malaysia's rapid urbanization rate surpasses China's urbanization rate. The annual rate of urbanization from 2010 to 2015 was estimated 2.4%, and if this trend continues, over 70% of the Malaysian population will be urban by 2020 (Duflot, 2012). As a result, vast population activities in urban areas exert an unprecedented impact on the environment. Such an impact results in higher demands for transport increased consumption patterns, and energy sources, as well as an increased number of vehicles on the country's cities' roads by 2050 (Okunola, 2012; Cassiani et al., 2013; Mathew, 2014). As analyzed by Kurabayashi et al. (2013), among (Thailand, Indonesia, Vietnam, Myanmar, and Malaysia), the percentage of households owning an "automobile" is the highest in Malaysia at 93.4 percent. This is mainly because private vehicles in Malaysia are more reliable and affordable than other ways of transport. Therefore, they have become one of the major modes of personal transport (Mohammed and Shakir, 2013; Borhan et al., 2014).

Shabadin et al. (2017) stated that the number of registered vehicles in Malaysia has increased by 100% in 2014. The data released by MAA shows that the total

number of Malaysian vehicles on roads standing at 28,181,203 units up to June 2017. That's mean 0.88 vehicles for every person in the country (<https://paultan.org>). Koonstra (1993) developed an exponential model to describe Malaysia's vehicle ownership in the year 2020. It was estimated that in 2000, a total of ~10 million vehicles were to be registered. This estimate is to some extent accurate because Malaysia has registered ~10.5 million vehicles in 2000. Koonstra (1993) pointed out that Malaysia will be saturated with vehicle ownership. It was found that there is one registered vehicle for every two persons in 2018 (cited in Rohayu et al., 2009). Owing two or three cars by individuals indirectly increases the kilometers traveled and substantially increases vehicle emissions (Keyvanfar et al., 2018). Figure 1.1 provides the statistics that are provided for the growth of passenger vehicles, which are registered in Malaysia until 2018.

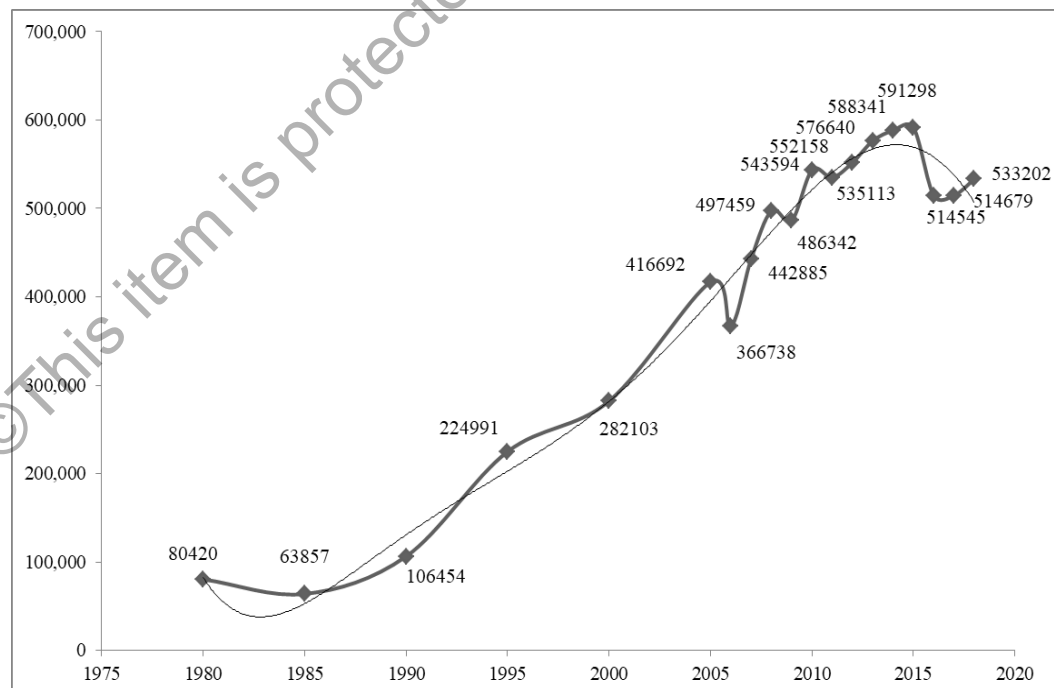


Figure 1.1 New passenger vehicles registered in Malaysia for the years from 1980 to 2018 (MAA, 2018)

The steadily increased number of vehicles is shown in Figure 1.0. This increased number of vehicles has led to an increase of the VKT, where the average annual kilometer vehicle traveled in 2013 has increased 4994 kilometers from those traveled in 2007 (Shabadin et al., 2017). Figure 1.2 shows the total kilometers traveled by Malaysian vehicles in 2013 according to Shabadin et al. (2017):

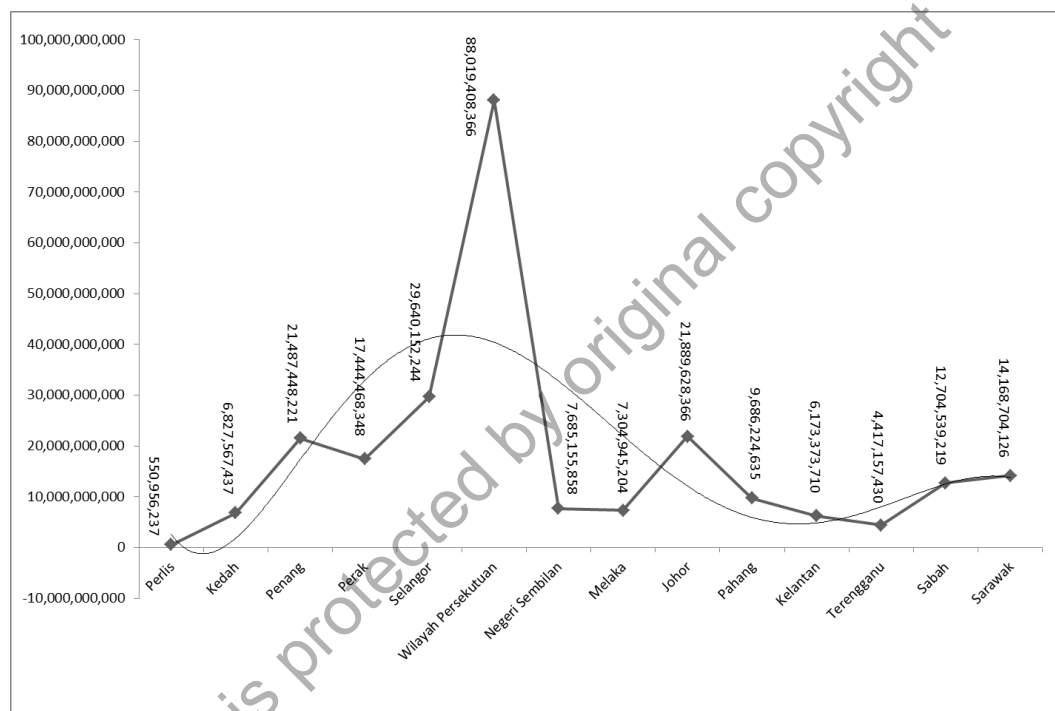


Figure 1.2 VKT in Malaysia by states (Shabadin, et al., 2017)

Figure 1.2 shows and confirms that Penang, Selangor, Wilayah Persekutuan, and Johor have the highest percentages of VKT in comparison with other states in Malaysia. The annually increased number of vehicles indicates that the number of old vehicles on the road is increasing. Old vehicles have obsolete engines with high levels of emissions (Ong et al., 2011). Studies showed that the average emissions are increased when vehicles are older, where CO emission is higher for vehicles that are older than 12 years. Also, HC emissions are higher in the case of vehicles that are older than 10 years (Filipczyk and

Kutrzyk-Nykiel, 2010). Borken-Kleefeld (2013) suggested that an emission is directly correlated to the vehicle's age, especially if it is over a decade. Figure 1.3 shows a comparison between the statistics of passenger vehicles that exceed 10 years with those that are less than 10 years in Malaysia until March 2019.

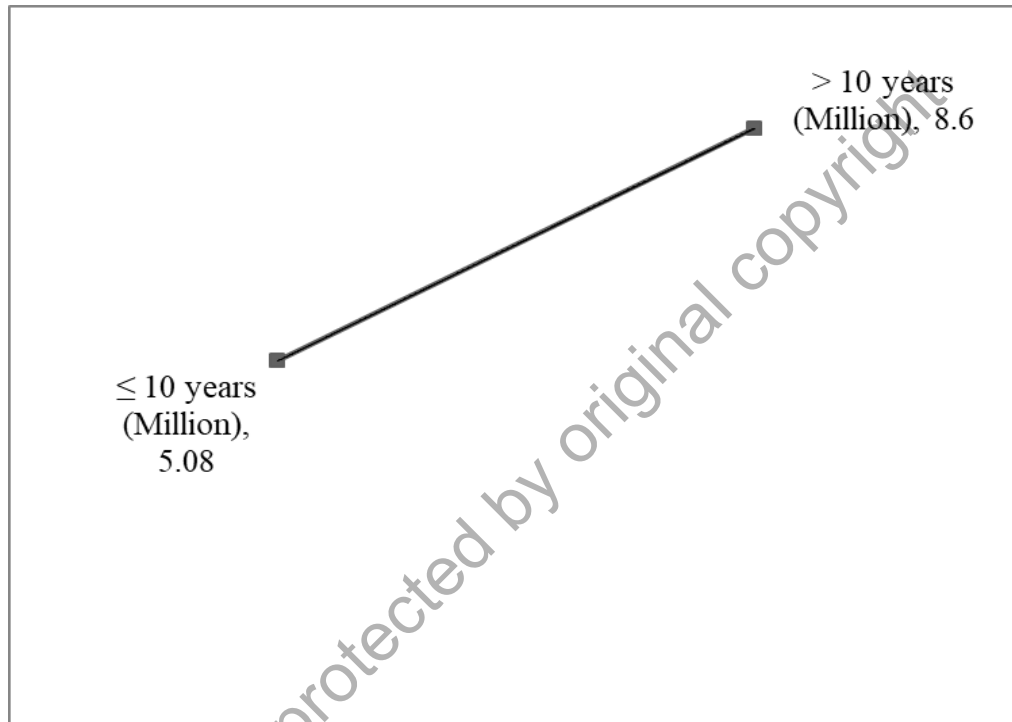


Figure 1.3 Number of passenger vehicles registered in Malaysia according to the vehicles age until March 2019 (<https://www.statista.com>; MAA, 2019)

Figure 1.3 shows that around 8.6 million old vehicles on roads are aged more than 10 years comparison with 5.08 million are less than 10 years; thus, the increasing number of old vehicles will lead to increased vehicle emissions as mentioned earlier.

Consequently, the emissions from motor vehicles represent the most significant sources of air pollution in many Malaysian urban areas. It has become a major environmental issue due to the increasing number of vehicles (mobile sources) (Teng and Tzeng, 1994; Innes, 1996; Shuhaili et al., 2013; Azid et al., 2015).

Therefore, the Malaysian Department of Environment (MDOE) stated, in its special report on air pollution, those industries, including power stations, motor vehicles, and open burning are the main contributors to the country's emissions, and emissions from mobile sources constitute a major source of air pollution (Innes, 1996; Mukhopadhyay and Thomassin, 2009; Salahudin et al., 2013; Mustafa and Rusli, 2016). For example, in 2015, motor vehicles were the main source of pollution, whereby the emissions from motor vehicles increased by 14.3 percent compared with those in 2010 (www.dosm.gov.my). Figure 1.4 provides the statistics of air pollution sources in Malaysia in 2016.

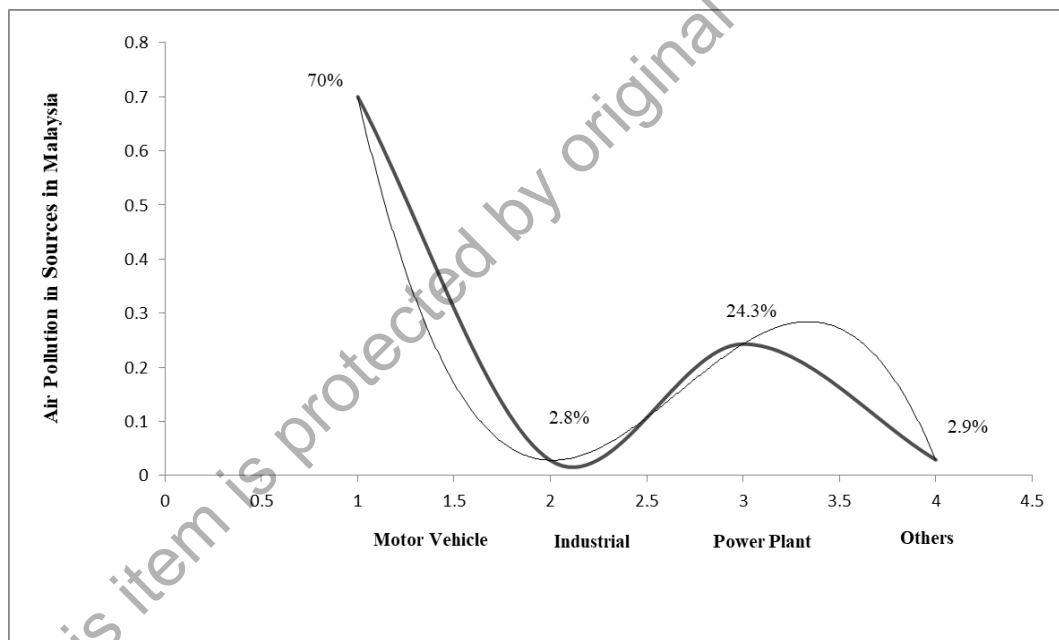


Figure 1.4 Air pollution sources in Malaysia (www.dosm.gov.my 2016)

Figure 1.4 shows that air pollution, which is caused by motor vehicles is high compared with other sectors. However, due to the social pressures to reduce environmental degradation, environmentalism has emerged in this country to a certain degree in the early 1970s, and more so in the 1990s (Hong, 2013). Moreover, the growth of urban population, numbers of vehicles, and distance traveled are some of the trends confirming that exposure to traffic-related air