Determinants of Car and Motorcycle Ownership and Use in Sarawak

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The candidate confirms that the work submitted is her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others. Chapters 4 and 5 are partly produced from the following conference paper.

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Abstract

This thesis investigates the determinants of car and motorcycle ownership and use in a city-region which has the dual characteristics of being situated in a developing economy but also having very high car and motorcycle dependence. The rise of car and motorcycle ownership in Sarawak, a state in Malaysia, has caused severe congestion as well as environmental and accessibility issues, particularly in urban areas. Inadequate access to public transport plays an important role in this high dependency. This case study investigates some of the important gaps in the literature relating to car and motorcycle ownership. Firstly, it is commonly assumed that those with lower income tend to purchase motorcycles, while those with higher income tend to own cars. Hence, both types of vehicle are usually considered as substitutes for each other. In the case of Sarawak, however, the simultaneous rise of car and motorcycle ownership challenges this perspective on the interdependency. Secondly, the demand for private vehicle ownership and use is typically investigated using socio-economic and built-environment factors. There are limited studies on the role of human psychological factors towards private vehicle ownership and use, especially with respect to motorcycles. Moreover, most studies have been conducted in the context of the developed world. Understanding the interrelationships between the variables is of significant importance to policymakers to effectively strategize their key initiatives as well as to ensure that the policies are suitable with respect to the context and nature of the population of interest.

A two-part approach incorporating aggregate and disaggregate data analysis is used. First, an aggregate approach using a vector error correction model (VECM) is applied to investigate the determinants of car and motorcycle ownership using time series data at the state level. Second, a disaggregated model is developed by applying partial least squares-structural equation modelling (PLS-SEM) using cross-sectional urban household data. For this purpose, a travel behaviour survey is conducted on a sample of 688 urban households in Sarawak, allowing not only socio-economic and built-environment factors to be obtained, but also a large number of psychological determinants to be gathered. The latter were based on the theory of planned behaviour (TPB) and the norm activation model (NAM), based on which social norms, perceived behavioural control, attitudes and pro-environmental motives were measured. Aside from these factors, the study also explored the

interdependency between car and motorcycle ownership as well as the relationships between ownership and use between these two modes.

Based on the aggregate modelling, the VECM analysis showed that gross domestic product (GDP), fuel price and level of employment are significant determinants of car and motorcycle ownership. The findings revealed that as the standard of living rises, both car and motorcycle demand increases. At the state aggregate level, it is found that there is a substitution relationship between both modes. This indicates that, people are highly likely to shift from motorcycle ownership to car ownership in the long-run. For the disaggregate modelling, the PLS-SEM analysis outcomes are separated into four main sub-models, which are (1) the car ownership sub-model, indicating that the socio-economic, pro-environment and social norms factors are significant determining factors, (2) the motorcycle ownership sub-model, indicating that the socio-economic, built-environment, attitude towards transport policy and pro-environment factors are significant determining factors, (3) the car use sub-model, indicating the car ownership, socio-economic and attitude towards transport policy factors are significant determining factors, and (4) the motorcycle use sub-model, indicating the motorcycle ownership, distance to city centre and attitude towards transport policy factors are significant determining factors. The findings highlight the importance of psychological factors as the determinants of ownership and use alongside socio-economic and built-environment factors, although the most important attitudinal factors are attitudes towards transport policy and, in opposition, environmental motives and social norms. In contrary with the state aggregate model, the disaggregate model found a complementary relationship between car and motorcycle ownership, which shows that both demands grow together rather than being alternatives to each other. This may be due to the important functionalities of both cars and motorcycles in the households, which serve other purposes than commuting. Based on the findings, the policy implications in the study include encouraging shifts to other modes of transport through public transport reforms (e.g. buses) in urban Sarawak as well as providing incentives for more environmentally friendly vehicle usage (such as electric cars and motorcycles) through taxes and toll charge exemptions, considering the high level of car dependency.

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Chapter 1

Introduction

1.1 Introduction

Since the invention of the automobile in the 19th century, the role of cars has become significantly important throughout the world. Initially, the imperatives of owning cars were mainly built upon economic development, which later led to changes in trends in employment, social settings and infrastructure development. Furthermore, the ability to access rural counterparts and the convenience gained through mobility enabled individuals to engage in economic activities. The need to travel in the era of the industrial revolution essentially led to the expansion of the car manufacturing industry, creating jobs and also government revenue through taxation. Globally, there was a substantial rise in the number of registered cars, increasing by 45 per cent between 2005 and 2015 (OICA, 2018).

However, over the past few decades, the growth in population, urbanisation and the economy has changed the travel patterns in numerous regions of the world, which brings our attention to Asian developing countries. This is particularly important as the Asian region is projected to have 60 per cent of the world's population by 2050. Given the population impetus, there is a high likelihood that there will be significant growth in motorisation in this region. Indeed, Asian developing countries have experienced rapid growth in motorisation. Between 1999 and 2016, the number of vehicles per 1000 population for Far East Asian countries rose substantially, by 170 per cent (105.6 vehicles per 1000 population in 2016), compared to the 5 per cent (606 vehicles per 1000 population in 2016) and 14 per cent (831.9 vehicles per 1000 population in 2016) increases in Western European countries and the USA, respectively, during the same time period (Davis and Boundy, 2019).

While cars are generally considered as the primary measure for motorisation, it proves to be otherwise for Asian developing countries. This is because the Asian region has a high level of motorcycle ownership compared to the rest

of the world (Senbil et al., 2007). The growth of motorcycle ownership and use is at a very high level, particularly in low- and medium-income countries. Barter (1999) introduced the term *motorcycle cities* to describe cities which are motorcycle-oriented, such as Ho Chi Minh (Vietnam), Phnom Penh (Cambodia) and Vientiane (Laos). The main reason for such high motorcycle ownership and use in Asian developing countries is due to the affordability of motorcycles and inadequate access to public transport.

In Asian developing countries, there is a very different spectrum in terms of motorisation compared to developed countries. Some Asian developing countries tend to have very high car ownership and low motorcycle ownership, and vice versa. Meanwhile, other Asian developing countries demonstrate a high level of motorisation in terms of both car and motorcycle ownership. According to Senbil et al. (2007), there are 65.9 motorcycles per 1000 population in affluent Asian cities and a staggering 117.21 motorcycles per 1000 population in other Asian cities. Both regions of Asian cities record the highest level of motorcycle ownership compared to other regions in the world. It appears that some other cities in Asia are following similar high motorcycle ownership patterns, such as Malaysia (Kuala Lumpur), Indonesia (Jakarta), Thailand (Bangkok) and Vietnam (Hanoi) with levels of motorcycle ownership greater than 100 motorcycles per 1000 inhabitant (Hsu et al., 2003; Sanko et al., 2014). Hence, it is important to study the determinants of car and motorcycle ownership and use in a city or state of a country with the same trajectory.

1.2 Motivation of The Study

Cars and motorcycles are important private modes of transport in Malaysia. Malaysia is an Asian developing country and, with over 439 vehicles per 1000 inhabitants in 2015, it has one of the highest levels of vehicle ownership in the region (OICA, 2018). It is also noted that all the states in Malaysia demonstrate a high level of vehicle ownership. Sarawak, a state in Malaysia, had a significant increase in car ownership, from 53,484 in 1980 to 754,778 in 2015 (DOSM, 2019). Similar patterns emerged for motorcycle ownership within the same period of time. Apart from cars, motorcycles are a key mode of transport in many Asian developing cities, and they provide low-cost and flexible transport, especially for low- to middle- income earners (Inaba and Kato,

2017). The steady increase in private vehicle ownership in Asian developing cities, specifically Sarawak, has resulted in transport-related issues, such as traffic congestion, road accidents, fossil fuel consumption and anthropogenic pollution. According to IEA (2013), energy consumption in developing countries is projected to account for approximately two-thirds of worldwide energy consumption by 2040, surpassing the consumption of developed countries. It is worth noting that the long-term usage of privately vehicles may lead to car and motorcycle dependence. This may cause a hindrance in shifting road users to more sustainable modes of transport, such as public transportation. This poses a significant challenge towards achieving sustainable transport systems. To tackle the above-mentioned issues, several transport-related policies have been proposed. These include the Malaysian National Transport Policy 2019-2030, which outlines initiatives such as developing a sustainable transport sector by increasing the modal share of public transport (MOT, 2018). One point to note is that there are still no clear policies to counter the continuous vehicular growth at the state level. Hence, to design effective policy instruments, there is a serious need to study car and motorcycle ownership.

A plethora of studies have been conducted to investigate vehicle ownership and use. The investigation of factors influencing car ownership and use is an imperative process, particularly for governments as an efficient transport policy relies on the understanding of the characteristics and behaviour of the end-users. Studies on car ownership and use have been done at both the aggregate and disaggregate levels. Past studies have shown that socio-economic and built-environment factors are significant determinants for car ownership and use (de Jong et al., 2004; Van Acker and Witlox, 2010; Anowar et al., 2014). However, previous studies have also reported that socio-economic and built-environment factors are less able to explain the development in vehicle ownership and use over time (Maltha et al., 2017). It has been suggested that psychological factors may help to explain the relationship (Choo and Mokhtarian, 2004). Most of the studies involving psychological factors have, however, been conducted on car ownership and use in developed countries, and very few have been undertaken in developing countries (Setiawan et al., 2015; Wu et al., 1999a; Weinberger and Goetzke, 2010; Belgiawan et al., 2016). Despite an abundance of studies on car ownership and use, the literature on motorcycle ownership and use is very limited. Most studies were conducted in Asian developing countries (Leong

and Mohd. Sadullah, 2007; Srinivasan et al., 2007), and these studies investigated the impact of socio-economic and built-environment characteristics on motorcycle ownership. Also in this context, the impact of psychological factors on motorcycle ownership and use is likely to be relevant, yet it has received little attention. For example, it can be expected that those who are pro-environment may be less likely to own a car than a motorcycle as cars contribute to higher emissions compared to motorcycles. On top of that, people may also opt for motorcycles because of their socio-economic conditions as they can be obtained at a lower price compared to cars. For that reason, psychological factors (e.g. attitudes) could be imperative, and their effect should be further examined alongside socio-economic and built-environment characteristics.

The simultaneous increase of both car and motorcycle ownership in Sarawak triggers the need to study the interdependency between these private modes of transport. One of the main reasons for high car and motorcycle dependency is the insufficient public transport infrastructure and services in many of these countries (Herwangi, 2018). Most studies on the interdependency of car and motorcycle ownership were concentrated in Asian developing countries as these countries demonstrate a high level of both modes compared to the developed countries (Yamamoto, 2009; Sanko et al., 2014). In a previous study by Tuan (2011), it was found that there is a long-run substitution relationship between car and motorcycle ownership at the aggregate level in Malaysia. A similar relationship was found by Yamamoto (2009) in a study conducted in Kuala Lumpur at the disaggregate level. In addition, Sanko et al. (2014) found that there are substitution relationships between car and motorcycle ownership in Bangkok, Thailand, and Kuala Lumpur, Malaysia, apart from a complementary relationship in Nagoya, Japan. Aside from the socio-economic and built-environment attributes, other factors, such as psychological factors, may contribute to a high level of car and motorcycle ownership. For this reason, it is important to compare the relationship at the aggregate and disaggregate levels in the case of Sarawak. Considering the high reliance on car and motorcycle use in Sarawak, it is interesting to understand factors that influence the ownership and use of both modes in a joint model.

Understanding the interrelationships between modes of transport and the underlying driving factors is of significant importance to policymakers to

effectively design their key initiatives as well as to ensure that the policies are suitable concerning the context and nature of the population of interest. By investigating the determinants of car and motorcycle ownership and use, the critical areas to eliminate the barriers to reducing vehicle ownership and use can be further identified. Moreover, the psychological aspects provide a wide number of approaches that can be utilised by policymakers to encourage environmental knowledge and awareness in terms of how the negative externalities issues can be tackled.

The above problem statement can be summarised through four research questions that will be central to this thesis:

1. What are the factors that determine car and motorcycle ownership at the aggregate level in the case study area?

2. What is the influence of socio-economic, built-environment and psychological factors on car and motorcycle ownership and use at the disaggregate level in the case study area? This specifically integrates the role of psychological factors in the case study area in a developing country.

3. What is the relationship between car ownership and motorcycle ownership at the aggregate and disaggregate levels in the case study area? This in particular highlights the interdependency of both modes at different levels of aggregation.

4. What are the potential sustainable transport policies that can be proposed for the case study area and similar developing countries?

1.3 Research Aims and Objectives

The thesis aims to provide a better understanding regarding the role of socio-economic, built-environment and psychological factors in influencing car and motorcycle ownership and use in a state in an Asian developing country that has a high dependency on car and motorcycle ownership. This is important as policymakers or local authorities will be able to identify the areas of concern and potential influence which can be used in regulating road traffic and its

negative consequences for the environment and society. In particular, the analyses in this thesis are conducted to achieve the following objectives:

1. To investigate factors that determine car and motorcycle ownership at the aggregate level in the selected case study area. This is achieved by estimating a time series aggregate model for car and motorcycle ownership.

2. To investigate the relative impacts of socio-economic, built-environment and psychological factors on car and motorcycle ownership and use at the disaggregate level in the case study area.

3. To examine the interdependence between car and motorcycle ownership at the aggregate and disaggregate levels in the case study area.

4. To use the results to propose recommendations on appropriate sustainable transport policies that might be formulated in the case study area and comparable developing countries.

1.4 Study Approach and Contribution

Globally, there has been a high dependency on private-based transport, particularly car ownership, over the past few decades. In developing countries, despite lower levels of income, there is also a high dependency on private modes of transport, specifically motorcycle ownership. Sarawak in Malaysia is only one of a few developing cities in the world that has a high level of car and motorcycle ownership. To understand its reliance on private modes of transport, this region has been selected as the case study area. This study focuses on the role of end-users because investigating car or motorcycle users plays an important role in understanding their psychological factors (aside from the socio-economic and built-environment attributes), which can be utilized by local government for policy intervention. Hence, this study specifically focuses on the interdependency between car and motorcycle ownership and use.

In summary, the contributions of this thesis focus on the three main gaps in the research. Firstly, the thesis incorporates the psychological factors as the determinants of motorcycle ownership and use. There are insufficient studies that include the psychological factors in determining motorcycle ownership and use (Marquet and Miralles-guasch, 2016), and most studies that do incorporate the psychological factors were conducted on car ownership and car use models. Hence, this gap will be covered by the second research question and objective of the thesis, which recognises the interdependencies between car ownership and motorcycles at the aggregate and disaggregate levels. Meanwhile, there are very few studies investigating the interdependency between car and motorcycle ownership. Most studies were conducted at the disaggregate level, concentrating on Asian developing countries (Hsu et al., 2007; Yamamoto, 2009; Sanko et al., 2014). Furthermore, these studies only focused on a particular level of data aggregation (for instance, only disaggregate data), without providing a comparison to explore the interdependency at the aggregate and disaggregate levels. This gap will be addressed by the third research question and objective. Finally, the thesis investigates an integrated model of car and motorcycle ownership and use. To date, there is no model investigating both modes while integrating psychological factors as part of the explanatory variables. The thesis addresses the gap through the second and third research questions and objectives. Hence, the thesis attempts to fill a gap in the literature by answering the above-mentioned research questions and objectives. This is imperative as the outcome from the analysis can provide guidelines for transport policymakers, specifically in the case of developing countries with high levels of car and motorcycle ownership.

1.5 Thesis structure

Chapter Two provides a literature review on private vehicle ownership and use modelling. First, the review summarises the relevant modelling approaches related to the topic of research. Following this, the review provides the theoretical background of the thesis from both the economic and psychological perspectives. Next is the review on the determinants of car and motorcycle ownership and use. In particular, previous studies on the interdependency between car and motorcycle ownership are also reviewed.

Chapter Three identifies the case study area, Sarawak, which represents a state in an Asian developing country with both high car and motorcycle dependency. This includes the justification for selecting this area for the aggregate and disaggregate modelling and provides some background information on its socio-economic characteristics and levels of motorisation. The latter includes information about the transport system, mode share, total registered vehicles and car ownership in the rural and urban contexts of the state of Sarawak.

Chapter Four presents the flow of the thesis, the aggregate data modelling, the disaggregate data modelling, the conceptual framework and the survey design. The modelling of the aggregate data entails the justification for and methodology of using the vector error correction model (VECM) in the study. Next, the structure of the conceptual framework is presented for the disaggregate model, which integrates a joint model consisting of the socio-economic, built-environment and psychological determinants of car and motorcycle ownership and use. Following that, this chapter also presents a data analysis method, namely the partial least squares-structural equation model (PLS-SEM), as well as the justification for its usage and its components for the disaggregate model.

Chapter Five presents the aggregate car and motorcycle ownership model. The modelling applies a vector error correction model (VECM) using Sarawak annual time series data from 1980 to 2018. This chapter also includes the model specification and the VECM methodology and justifications. Later in this chapter, the results and discussions of the output are presented.

Chapter Six presents the survey design, data collection and descriptive statistics of the disaggregate data model. First, the sampling method is presented, including the sample selection process and the calculation of the sampling. Details on the survey pre-pilot and pilot tests are also discussed in this chapter. Later, the survey sample characteristics are described and compared with the national statistics. This chapter includes the discussion of the survey response, the socio-economic and travel behaviour characteristics, and the psychological factors.

Chapter Seven presents the analysis and results of the disaggregate model based on the PLS-SEM model. This chapter analyses the outcomes of the analysis and compares the outputs with the wider literature.

Lastly, Chapter Eight concludes the thesis by revisiting the research objectives, clarifying how and whether the research outcomes have been achieved. The originality and significance of the thesis are highlighted, and the policy recommendations are also presented. Finally, the limitations of the research are discussed, and additional appropriate work is suggested.

Chapter 2

Literature Review on Vehicle Ownership and Use Modelling

2.1 Introduction

The previous chapter introduced the aims and objectives of the thesis. This chapter focuses on the literature review on private vehicle ownership and use. There is a large body of literature on vehicle ownership and use which is basically derived from the microeconomic theory of consumer behaviour. However, the studies undertaken over the past two decades have mainly shown the importance of including the role of psychological factors to complement the more widely used determinants, such as socio-economic and built-environment factors. Furthermore, this chapter also discusses motorcycle ownership and use, which has received very little attention in the literature but serves a very important purpose as a main mode of transport, particularly in Asian developing countries. In light of this, there is a need to study both modes of private transport simultaneously and understand the nature of their relationship (e.g. interdependencies).

The structure of the chapter is as follows. The previous literature on understanding and modelling vehicle ownership and use, in general, is introduced in Section 2.2. Section 2.3 provides the theoretical background of this thesis. Section 2.4 explains the dependent variables and determinants of private vehicle ownership and use to be taken forward in this study, namely the three main factors of socio-economic, built-environment and psychological factors. The interdependency between car and motorcycle ownership is also discussed in this section, as is the utilisation of joint models of ownership and use. Finally, Section 2.5 highlights the key points of this chapter to be carried forward in the research.

2.2 Modelling Approaches

2.2.1 Vehicle Ownership Models

Based on previous studies, there are several modelling approaches to investigate the relationship between car and motorcycle ownership. As a result, a lot of methodologies are taken into consideration. This section summarises the relevant modelling approaches to examine the relationship (refer to Table 2.1).

Table 2. 1 Summary of Vehicle Ownership Models.

	Models/Method	**Sources**
Aggregate Model	• Cohort Models • Car Market Models • Time Series Models (Weighted Least Squares, Two-Stage Least Squares)	• Stock and Watson (2007), De Jong et al. (2004), Mogridge (1967); Reza and Spiro (1979); Witt and Johnson (1986); Romilly et al. (1998); Dargay and Gately (1999); Fouquet (2012)
Disaggregate Model	• Discrete Choice Model ○ Multinomial Logit Model and Probit Model ○ Ordered Response Logit or Ordered Response Probit Model • Car Type Choice Model • Structural Equation Model (Covariance-Based Structural Equation Model, Partial Least Squares-Structural Equation Model)	• Bhat and Pulugurta (1998), Nolan (2010); Kumar and Krishna Rao (2006), Chu (2002); Potoglou and Kanaroglou (2008) • Hensher and Mannering (1994); de Jong et al. (2004); de Jong and Kitamura (2009) • Fujii and Gärling (2003); Wu et al. (1999); Weinberger and Goetzke (2010); Belgiawan et al. (2016)

Two main forms of vehicle ownership models have been developed, that is, aggregate and disaggregate models. Aggregate models comprise three main types of models: (i) cohort models, (ii) car market models, and (iii) time series models. Aggregate cohort models involve the segregation of the car fleet into diverse groups by the year of production and cohorts of people, later changing the cohorts in terms of the future, explaining how, as the cohort becomes older, it acquires, keeps, and/or loses cars. The aggregate car market model predicts the size and composition of vehicle stock that changes over time. While the model can be utilized to forecast the effect of government policy (for instance, taxation on the stock of cars, the model does not forecast car ownership at the individual household level (de Jong et al., 2004).

Time-series aggregate modelling is vital as it allows for the analysis of vehicle ownership in response to changes in socio-economic factors, for instance, gross domestic product or the price of fuel over time. According to Tsay (2000, p. 638), time-series purposes in economics are conducted “(i) to study the dynamic structure of a process, (ii) to investigate the dynamic relationship between variables, (iii) to perform seasonal adjustment of economic data such as the gross domestic product and unemployment rate, (iv) to improve regression analysis when the errors are serially correlated and (v) to produce point and interval forecast for both level and volatility series”.

Based on these assumptions, aggregate modelling is appropriate for forecasting in the long run. The disadvantage of aggregate models, based on de Jong et al. (2004), is the inability to incorporate vehicle types and policy variables, which causes the model to be restricted to an inadequate number of variables. Nevertheless, in developing countries where more disaggregate data are found to be hard to obtain, aggregate data modelling is frequently being considered as the most suitable method.

The aggregate model’s inability to identify the factors or attributes of individuals influencing vehicle ownership has led to disaggregate data being used in transport modelling. In recent years, studies of vehicle ownership have tended to be centred around using disaggregate models, whereby individual or household inclination to own vehicles is related to socio-economic and built-environment attributes, the cost of owning vehicles, and the availability of other travel modes. In the beginning, studies showed that data for disaggregate models tend to be cross-sectional (Burns et al., 1975; Train, 1980), while in recent decades, the data used have included pooled time-series cross-sectional data or panel data (Hanly and Dargay, 2000; Cornut, 2016; and Yang et al., 2017).

Among the most prominent disaggregate models of vehicle ownership is the discrete choice model (DCM), which deals with households’ car ownership. According to Bhat and Pulugurta (1998), there are two classes of disaggregate choice models: the ordered response (e.g. the ordered response logit or ordered response probit model) and unordered response mechanisms (e.g. multinomial logit model and probit model). Ordered response models use a discrete, ordinal variable that is mutually exclusive as the dependent variable.

The general assumption for ordered response models is that the estimation is assumed to have parallel slopes, that is, the coefficient for the independent variables that influence the probability of the dependent variable would be the same for all outputs. In the case where this assumption is not valid and there are different coefficients across different levels of the dependent variable, ordered response models are no longer suitable, which leads to the utilisation of unordered response models.

Multinomial logit models (MNLs) are the most widely used unordered discrete choice models as they are known to have computational simplicity and do not pose any restraint on the impact of household attributes across car ownership levels. However, MNLs are susceptible to a violation of the independence of irrelevant alternatives (IIA), which leads to the nested logit model. A nested logit model estimates car ownership levels or types of travel mode that are assumed to be similar to one another and grouped into nests. The requirement of the nested logit model includes the need to assign alternatives in the structure in the nests and also the number of nesting levels. In addition, there is a rising demand to study the impact of unobserved latent or psychological factors, which was previously less integrated into the transport choice models. The sophistication of this model is demonstrated in the integrated choice and latent variable (ICLV) models in studies by Vredin Johansson et al. (2006), Theis (2011), and Johansen (2013). Challenges with ICLV include model specification and estimation, for example, the control of unobserved heterogeneity (attitude, preference), whereby the interpretation of the results could be biased.

On the other hand, there are studies of car type choice for households given car ownership models. Both include either static or pseudo-dynamic vehicle type choice models (Hensher and Mannering, 1994; de Jong et al., 2004; de Jong and Kitamura, 2009). Disaggregate car type choice is used to forecast the size and composition of the car fleet, which includes car use and emissions, while the disaggregate household car ownership model is developed, among other things, to obtain inputs for the multimodal transport system. Based on this explanation, it is noted that model selection differs according to the level of aggregation and data types required in respective studies. Aside from this, understanding the theoretical background is also necessary to understand the utilisation of a particular model in the analysis.

In the past decades, studies involving the structural equation model (SEM) have emerged in transport studies due to its ability to test theories or the extension of a theory by including a number of latent variables in the model. Furthermore, the usage of SEM as a model enables the testing of a number of dependent variables and independent variables in a complex model. Several studies have been conducted to test the influence of psychological factors on car ownership (e.g., Fujii and Gärling, 2003; Wu et al., 1999; Weinberger and Goetzke, 2010; Belgiawan et al., 2016). Further explanation on SEM is given in Section 4.5.

In summary, the models explaining vehicle ownership are outlined in this section by classifying them based on aggregate and disaggregate modelling. The selection of models is based on the availability of the data and the purpose of the model. In the condition of data scarcity, which is usually the case in developing countries, aggregate time series may be suitable as the most promising model to study vehicle ownership demand. In the case where the aim of the model is to investigate the individual-specific factors driving car ownership, including attitudes, it is plausible to consider latent variables in the disaggregate models. The following sections explain the review of vehicle use models.

2.2.2 Vehicle Use Models

Following the reviews on vehicle ownership modelling, there are concerns about how many private vehicles are being used. The measure for the amount of use is usually in the form of the number of trips or the vehicle miles/kilometres travelled (VMT/VKT) on such trips. There are some similarities in terms of the level of data aggregations and the econometric approach used in both determining vehicle ownership and determining vehicle use. Some models use data which capture the temporal change in VKT from year to year, while others utilise a single year sampling from a vast cross-sectional household dataset. The advantage of applying time series data is that it can be used to monitor how VKT is affected by allowing changes in monetary factors, for example over time. On the other hand, cross-sectional VKT usually consists of national surveys which are conducted on an individual or household basis. This section summarises the relevant modelling approaches to examine the relationship (refer to Table 2.2).

Table 2. 2 Summary of Vehicle Use Models.

	Models/Method	Sources
Aggregate Model	• Ordinary Least Squares Model, Three Stage Least Squares (3SLS)	• Button et al. (1993), Small and Dender (2007), Hymel et al. (2010),
Disaggregate Model	• Regression Model, Seemingly Unrelated Regression Model • Discrete Choice model; Logit Model • Structural Equation Model (Covariance-Based Structural Equation Model	• Emrath and Liu (2008), Akar and Guldmann (2012), Woldeamanuel and Kent (2014), McCahill and Spahr (2013), Ke and McMullen (2017), Boarnet (2004), Zegras (2007), Liu et al. (2007), Van Acker and Witlox (2010),

Higher private vehicle ownership, particularly of cars, presumably leads to higher VKT. Contemporary progress has concerned the public regarding the extent to which people drive their cars. In essence, the method used to assess the determinants of vehicle use consists of aggregate and disaggregate data. According to Dong et al. (2012), one of the most successful models is the corporate average fuel economy (CAFÉ), which was introduced in the 1980s. CAFÉ involves aggregate, state-level and long time series data which reports the VMT, price of fuel and use of fuel. The advantage of including time series data is the ability to include lagged effects or the effect of time on VMT. Among the studies involved are Small and Dender (2007), Barla et al. (2009), and Hymel et al. (2010). The time-series approach also allows for the identification of whether there is a stationary or non-stationary relationship between the variables and it produces short-run elasticity using error correction models and long-run elasticity based on a cointegration regression.

In addition to the time series data, there are also studies that involve pooled time-series or disaggregate cross-sectional data using the items or variables of the cross-sectional surveys. This includes studies by Feng et al. (2005), Dargay et al. (2007), and Gillingham (2010). In these cases, they applied governmental sources to investigate the VMT trends on a nationwide scale. There is a vast literature on mileage-based fees in the U.S. as for the road user, per mile charges are considered as an option to tax fuel to improve and upgrade the road infrastructure. This includes mileage-based user fees (Baker et al., 2008; Zupan et al., 2012), road user charges (Ke and McMullen, 2017), vehicle miles travelled (VMT) taxes (McMullen et al., 2010), and VMT fees

(Zhang et al., 2009). Previous models that have frequently been applied using disaggregate data include the regression model, such as Akar and Guldmann (2012), Woldeamanuel and Kent (2014), and Ke and McMullen (2017), and the multinomial logit model (Zegras, 2007). In more complex settings involving a larger number of independent variables, which may include latent variables, SEM has been applied. This includes studies by Bagley and Mokhtarian (2002), Van Acker and Witlox (2010), and Banerjee and Hine (2016).

In summary, models explaining vehicle use are listed in this section and are classified based on being aggregate or disaggregate in nature. Similarly, the selection of a model is primarily based on the availability of the data and the objective of the study. While sections 2.2.1 and 2.2.2 elucidated the individual models utilized in explaining vehicle ownership and use, the following section provides a review of the literature on vehicle ownership and use utilizing joint models.

2.2.3 Vehicle Ownership and Use Joint Modelling

While Sections 2.2.1 and 2.2.2 explained the modelling approaches for vehicle ownership and use in isolation, this section discusses joint models of private vehicle ownership and use. By estimating a joint model, it is possible to better understand the relationships involved (i.e. the interdependency between the ownership of the two modes and their respective use). Very few studies were found to have jointly examined the relationship between the ownership and usage of two modes of transport, in this case, car and motorcycle, considering the importance of analysing this multi-complex relationship. Therefore, in this sub-section, we point out an array of literature which explains different types of joint modelling (refer to Table 2.3).

Table 2. 3 Summary of Joint Models.

	Models/Methods	**Sources**
Aggregate		
	Seemingly Unrelated Regression Model	Jou and Chen (2014)
Disaggregate		
	Nested Logit Model	Dissanayake and Morikawa (2010)
	Bivariate Ordered Probit (BOP)	Sanko et al. (2014)
	Multiple Discrete-Continuous Extreme Values (MDCEV)	Bhat (2005); Bhat (2008)
	Copula-Based Model	Spissu et al. (2009), Bhat and Eluru (2009)
	Simultaneous Equation System	Schimek (1996), Bhat and Koppelman (1993), Chen et al. (2008)
	Covariance Based-Structural Equation Model (CB-SEM)	Bagley and Mokhtarian (2002); Choocharukul et al. (2008)
	Partial Least Squares-Structural Equation Model (PLS-SEM)	Sompie (2014); Scott et al. (2016); Liu et al. (2017).

In a study by Jou and Chen (2014), the authors applied a seemingly unrelated regression equation (SURE) model to examine the connection between public transportation, car and motorcycle use in 336 Taiwanese townships using annual cross-sectional data for 2010. The model configures the substitution relationships between the three modes based on pairwise covariance analysis for any two of the three modes. Very few aggregate studies were found to analyse vehicle ownership and use in an aggregate setting. However, an array of studies were conducted using various disaggregate models.

According to Anowar et al. (2014), there are two main types of joint models. The first type uses a standard discrete choice model to examine joint choice by describing the alternatives of choices as a mixture of various choices. The second type of joint model is where unobserved correlations or dependencies are included across the choice methods. These two types comprise a wide range of models, including the discrete choice model, mixed multidimensional choice model, discrete-continuous model, copula-based model, Bayesian

model, simultaneous equation model and structural equation model (SEM). In a standard discrete choice model, choices are considered as the endogenous part and are modelled as a single joint choice.

Dissanayake and Morikawa (2010) produced a nested logit model to examine vehicle ownership, trip chain behaviour and mode choice of households in Bangkok, Thailand. However, the model cannot be utilised in the case of continuous characteristics of travel, such as VKT. Another approach is the mixed multidimensional choice model, whereby many decision procedures, including continuous, count, ordinal and multinomial, are jointly modelled through the formulation of a series of sub-models for different choice dimensions. Unlike the standard discrete choice model, this method can include the mass relationship among the dimensions of choices, for example self-selection, correlation and relationship between the observed and unobserved variables. Bhat and Guo (2007) used a multinomial logit model for residential location and ordered logit model of vehicle ownership, taking into consideration the effect of self-selection for residential areas.

Sanko et al. (2014) used bivariate ordered probit (BOP) to analyse the relationship between car and motorcycle according to two aspects, which are interaction and correlation, or substitution. The correlation of error terms of the propensity to own cars or motorcycles leads to unobserved factors, which may affect the relationship in a similar or reverse direction. Gómez-Gélvez and Obando (2014) applied ordered response probit (ORP) to study car and motorcycle ownership interdependency by including the number of cars and the number of motorcycles as explanatory variables of each other’s function of propensity.

In the discrete-continuous model, the decision of vehicle ownership is simultaneously related to the choice of various alternatives (number of cars owned) and the continuous variable (VKT). This is represented by multiple discrete-continuous extreme values (MDCEV) (Bhat, 2005; Bhat, 2008), which can cater for unobserved heteroscedasticity and correlations of error for the utility functions for vehicle types. The drawback of the model is, depending on the specification of utility function, total vehicle utilizations (which takes into account non-motorized transport modes) with regard to miles travelled are fixed per household (Fang, 2008). Meanwhile, the copula-based model is a

joint distribution model for vehicle ownership/type and use. Spissu et al. (2009) used the method to jointly analyse the type choice and utilisation of the purchased vehicle. In the model, the copulas are used to define the error terms of joint distributions. In the study by Bhat and Eluru (2009), they used the copula method on 3,696 households based on 2000 San Francisco Bay Area Household Travel Survey (BATS) data to model residential neighbourhood choice and daily household VMT. Based on the independent-independent copula and Frank-Frank copula models, the results of the study indicate that all variables are significant in explaining households' VMT. This includes households' vehicle ownership, employment, full-time students, the density of bicycle lanes and accessibility to shopping.

Other approaches include a simultaneous equation system, whereby the model consists of mutually dependent discrete choice models. Chen et al. (2008) conducted a study with datasets from the New York Metropolitan Region using a simultaneous equation system. The model includes two mutually interacting endogenous variables, which are car ownership and the propensity to use automobiles. The model can capture the effects of unobserved traits or attitudinal variables. This is supported by Schimek (1996) and Bhat and Koppelman (1993).

Finally, there is the structural equation model (SEM), which has been the most widely used joint model in the recent decade. SEM generally consists of two elements, which are the measurement model and the structural model. The measurement model is applied to identify which latent indicators belong to which latent factors/variables, while the structural model defines the relationship between the latent factors/ variables. There are two types of SEM, which are the covariance-based SEM (CB-SEM) and the partial least squares-structural equation model (PLS-SEM). CB-SEM is basically parameter-oriented SEM, which requires normally distributed (parametric) data and has a large data requirement (further explanation to distinguish these two SEM models is presented in Section 4.5).

Meanwhile, PLS-SEM is a prediction-oriented SEM which is non-parametric and can use a smaller data sample. CB-SEM is more predominant compared to PLS-SEM, which has been developed in recent years in the field of transport studies. Demand for PLS-SEM in transport studies has risen due to its flexible

nature in terms of data requirements, size and its ability to cater for complex models (with a large number of indicators). Many studies have utilised CB-SEM, such as Bagley and Mokhtarian (2002) and Choocharukul et al. (2008), and PLS-SEM, such as Sompie (2014), Scott et al. (2016) and Liu et al. (2017).

Sompie (2014) investigated the relationship between socio-demographic, attitude and mode choice behaviour in Indonesia by utilising the partial least squares-structural equation model (PLS-SEM). By using a sample of 209 respondents, the outcome of this study found that socio-economic factors, such as age and car ownership, have a positive and significant relationship towards attitude, while family size has an adverse effect. The research also showed that attitude relating to cost, accessibility, safety and comfort in public transport is a major concern in reducing private cars. Interestingly, the study used an approach in which the attitude is based on certain types of vehicles rather than looking at a different spectrum of psychological variables.

Liu et al. (2017) conducted a study on an integrated model based on the norm activation model and theory of planned behaviour using PLS-SEM to investigate the factors that influence an individual's intention to reduce car use. Using a survey of 600 car drivers in China metropolitan area, their study found that perceived behaviour control, attitude and norm influence the intention to reduce car transport.

Scott et al. (2016) applied PLS-SEM to investigate decision-making related to public transportation acceptance and the utilisation of mass transit using 463 respondents in the metropolitan south-west of the United States. The results of the analysis showed that price, knowledge about public transportation, and public transportation security have significant effects on a positive attitude toward public transportation, while convenience has a significant impact on a negative attitude toward public transportation. While the study provided new insights on decision-making factors for public transit commuters, the number of factors being used in the model was restricted to provide an anchored model based on the theories being used, namely the theory of reasoned action and the theory of planned behaviour.

In summary, most of the studies have investigated vehicle ownership and usage in isolation rather than jointly. These studies did not integrate car and motorcycle ownership and use in a joint model, with the exception of the study by Jou and Chen (2014) and Sanko et al. (2014), which only studied either usage or ownership. This is due to the inadequate data availability on motorcycle ownership and use, which hindered the joint model of both modes from being conducted. Considering this, the thesis aims to investigate the determinants of car and motorcycle ownership and use in a joint model. To further understand the factors that contribute to a joint model, the following section presents the literature review for the determinants of car and motorcycle ownership.

2.3 Determinants of Car and Motorcycle Ownership and Use

2.3.1 The Dependent Variables

2.3.1.1 Vehicle Ownership and Use as a Dependent Variable

In this section, the studies with vehicle ownership and use for both cars and motorcycles as the dependent variable at the aggregate and disaggregate levels are presented. The summary of vehicle ownership and use as the dependent variable is shown in Table 2.4. Different vehicle ownership and use models require a variety of variables depending on the data availabilities, level of data aggregations and purposes. Car ownership data at the aggregate level generally involve time-series based modelling, which includes variables such as per capita car ownership (Romilly et al., 1998), new car registration per capita (Reza and Spiro, 1979), and passengers cars per 1000 population (Senbil et al., 2007). At the disaggregate level, data that represent car ownership include the availability of owning a car or not (Nolan, 2010) and the number of cars owned (0,1, 2, ≥ 3) (Potoglou and Kanaroglou, 2008).

Table 2. 4 Summary of Vehicle Ownership and Use as the Dependent Variable.

	Aggregate/ Disaggregate	**Dependent Variables Used**	**Sources**
Car Ownership	*Aggregate*	Per capita car ownership, new car registration per capita, passenger cars per 1000 population	Romilly et al. (1998), Reza and Spiro (1979), Senbil et al. (2007)
	Disaggregate	Availability of cars (0,1), number of cars owned (0,1,2, ≥3)	Nolan (2010), Potoglou and Kanaroglou (2008)
Motorcycle Ownership	*Aggregate*	Gross sales of motorcycles, Stock of motorcycles per capita aged 15–60, number of motorcycle and mopeds	Duffy and Robinson (2004), Law et al. (2015)
	Disaggregate	Individuals owning zero, one, or two-plus motorcycles, motorcycle owned by a household, the number of motorcycles owned by the household, number of two-wheelers owned	Burge et al. (2007), Wedagama (2009), Hsu and Lin (2007), Gopisetty and Srinivasan (2013)
Car Use	*Aggregate*	Kilometres per vehicle, vehicle miles traveled (VMT) divided by adult population	Button, Ngoe and Hine (1993), Small and Dender (2007)

	Disaggregate	Annual average per capita VMT per sampled individuals, household annual miles driven	Woldeamanuel and Kent (2014), Zhang et al. (2009),
Motorcycle use	*Disaggregate*	Vehicles kilometres travelled by household	Shirgaokar (2016)

Meanwhile, the dependent variables which represent motorcycle ownership at the aggregate level include stock of motorcycles per capita (Duffy and Robinson, 2004) and the number of motorcycle and mopeds (Law et al., 2015). At the disaggregate level, the dependent variables include individuals who own zero, one, or two-plus motorcycles (Burge et al., 2007), motorcycles owned by a household (Wedagama, 2009), the number of motorcycles owned by the household (Hsu and Lin, 2007) and the number of two-wheelers owned (Gopisetty and Srinivasan, 2013).

The variables that represent car use at the aggregate level include kilometres per vehicle (Button, Ngoe and Hine, 1993) and vehicle miles travelled (VMT) divided by the adult population (Small and Dender, 2007). Meanwhile, a study by Shirgaokar (2016) applied vehicle kilometres travelled by the household as the dependent variable for motorcycle use. It appears that there are very few studies on motorcycle use as a dependent variable at the aggregate and disaggregate levels for both developed and developing countries.

In summary, it is pointed out that most studies have concentrated on car ownership, car use and motorcycle ownership as the dependent variable while very few were found on motorcycle use. This is due to the limited data availability worldwide on motorcycle use. In addition, the motorcycle is not the main mode of transport in most developed countries, which have better transport options, such as trains and public buses. The review has indicated that there is a critical need to investigate motorcycle use, particularly in the context of developing countries, which have very high motorcycle ownership. The next section explains the factors influencing car ownership and use.

2.3.2 Factors Influencing Car Ownership and Use

In this section, studies which have investigated the determinants of car ownership and use will be reviewed, using either aggregated or disaggregated approaches. First, ownership studies are summarised, followed by usage and, in each case, the determinants are grouped into socio-economic, built environment and psychological characteristics (refer to Table 2.5).

Table 2. 5 Factors Influencing Car Ownership and Use.

Independent Variables	**Variables Description**	**Sources**
Car Ownership		
Aggregate		
Socio-economic	• Gross domestic product (GDP), Gross national product (GNP), minimum wage, national average wage, • Fuel price • Level of employment	• Mogridge (1967), Reza and Spiro (1979), Witt and Johnson (1986), Romilly et al. (1998), Dargay and Gately (1999), Fouquet (2012), Senbil et al. (2007), Law et al. (2015), Button et al. (1993), Alpizar and Carlsson (2003), and Zegras and Hannan (2012). • Witt and Johnson (1986), Ingram and Liu (1999), Bradburn and Hyman (2002), Clark (2007), and Fouquet (2012) • Hanly and Dargay (2000), Matas and Raymond (2008), Clark (2009) Ritter and Vance (2013), and Van-Dender and Clever (2013)
Built-environment	• Roadway mileage, population density	• Sillaparchan (2007), Prevedouros and An (1998),
Disaggregate		
Socio-economic	• Household income, household structure, motoring costs and licence holding • Number of licensed drivers, household size, number of children, number of workers and occupation	• Nolan (2010), Kumar and Krishna Rao (2006), and Chamon et al. (2009) • Chu (2002), Potoglou and Kanaroglou (2008)
Built-environment	• Dwelling unit density, diversity, design, destination	• Potoglou and Kanaroglou (2008), van Acker et al.

	accessibility (distance to central business district [CBD], job accessibility), distance to transit	(2010), Zegras, 2010), Cervero et al. (2009), Zegras (2010), Guerra (2014)
Car Use		
Aggregate		
Socio-economic	• Income per capita and household median income and fuel price (gasoline price), unemployment rate	• Pongthanaisawan and Sorapipatana (2010), Pindyck (1979), Wheaton (1982), Hensher et al. (1990), Johansson and Schipper (1997), Button et al. (1993)
Built-environment	• Road network	• Button et al. (1993)
Disaggregate		
Socio-economic	• Household income, age, education, ethnicity • Vehicle ownership, hybrid car ownership, number of vehicles	• Emrath and Liu (2008), • Akar and Guldmann (2012), McCahill and Spahr (2013)
Built-environment	• Distance to work, population density, accessibility, mixed-use development, walkability, better access to transit, residential density	• Woldeamanuel and Kent (2014), Boarnet (2004), Handy et al. (2005), Liu, (2007), Ewing and Cervero (2007), Akar and Guldmann (2012), Van Acker and Witlox (2010)

2.3.2.1.1 Socio-Economic Determinants of Car Ownership

Many studies reveal vehicle ownership as relating to the wealth and social status of particular individuals or households. Income is thus far known to be the most crucial factor in explaining vehicle ownership and use in both aggregate and disaggregate studies. A number of aggregate data studies have incorporated income as a determinant of vehicle ownership (Mogridge, 1967; Reza and Spiro, 1979; Witt and Johnson, 1986; Romilly et al., 1998; Dargay and Gately, 1999; Fouquet, 2012). In many aggregate studies where the aggregation of income is high, the national data for income as a determinant of vehicle ownership is usually obtained in the form of a country's gross domestic product (GDP), gross national product (GNP) and real personal disposable income deflated by mid-year total population estimates. This includes studies from developing countries, such as Prevedouros and An (1998), Senbil et al. (2007) and Law et al. (2015). Studies in other developing regions, such as Latin America, used minimum wage or the national average wage to represent income, such as Button et al. (1993), Alpizar and Carlsson (2003), and Zegras and Hannan (2012).

Other explanatory variables that have proven to be essential determinants of vehicle ownership are fuel price, population, and motoring cost (purchase cost and running cost) for aggregate models. Fuel price, unlike total motoring cost, is more readily available and was thus used in many studies, including those by Witt and Johnson (1986), Ingram and Liu (1999), Bradburn and Hyman (2002), Sillaparchan (2007), Clark (2007), and Fouquet (2012). Level of employment is also considered as one of the critical determinants for vehicle ownership, as found in studies by Hanly and Dargay (2000), Matas and Raymond (2008), Clark (2009) Ritter and Vance (2013), and Van-Dender and Clever (2013). Van-Dender and Clever (2013) highlighted that the role of employment is crucial as working involves commuting and frequent car use. An advantage of aggregate models is that the methodology does not necessitate broad survey-based data and the ability to include time effects to influence vehicle ownership (e.g. macroeconomic shocks and cyclical effects in a country).

The drawbacks of using aggregate modelling include missing user-specific preferences, which can only be obtained from cross-sectional or longitudinal survey data. Thus, studies on the socio-economic determinants of vehicle ownership are also often examined at the disaggregate levels. An array of studies has been identified to explore the role of socio-economic factors towards car ownership in developed countries. This includes studies by Whelan (2007), Nolan (2010), and Ritter and Vance (2013). Whelan (2007) concentrated on the role of demographic factors in developing a car ownership model in Great Britain, including household income, household structure, motoring costs and licence holding. Nolan (2010) studied household car ownership in Ireland and found that income and previous car ownership to be the most significant determinants. Nolan further added household composition and lifestyle effects as other important factors to consider. Other socio-economic factors include the number of licensed drivers, household size, number of children, number of workers and occupation (Chu, 2002; Potoglou and Kanaroglou, 2008). The role of socio-economic determinants at the disaggregate level is also crucial in determining vehicle ownership in developing countries. This was demonstrated in studies by Kumar and Krishna Rao (2006) and Chamon et al. (2009) in determining car ownership in different states in India.

2.3.2.1.2 Socio-Economic Determinants of Car Use

Similar to the car ownership model (Section 2.3.2.1.1), economic progress plays an important role in the growth of vehicle use (Pongthanaisawan and Sorapipatana, 2010). The inclusion of income and fuel price, specifically the gasoline price, has been applied in some studies (Pindyck, 1979; Wheaton, 1982; Hensher et al., 1990; Johansson and Schipper, 1997). It is known that fuel price increments may reduce vehicle ownership, as Johansson and Schipper (1997) indicated that fuel price increments cause vehicle use to decline and the average fuel efficiency of the vehicle stock to increase due to the purchase of vehicles with fuel efficiency.

The types and sources of data available to identify the determinants of VKT may involve aggregate based modelling using country-based data from year to year or a single period sample which consists of a cross-sectional household survey. The determinants of VKT can be traced back to the work of Button et al. (1993), which included factors such as income, fuel price, level of urbanisation and also road network using aggregate modelling.

Equation 2.1 shows the modelling framework which was adapted from Tanner (1983).

$$\ln\left(\frac{Km}{V}\right) = K + aT + bT^2 + \sum \delta_k c_k + clnGDP + \sum d_j lnFL_j$$

Equation 2.1

Where Km/V denotes kilometres per vehicle, T denotes a time trend, GDP denotes gross domestic product per capita, and FL indicates the price of fuel type j (per 100 litres). The outcome of the study is an inevitable rapid rise in car ownership and use as the country develops.

A key aspect of utilising time series data is the capability to capture the impact of fuel price increments on VKT during a specified period (e.g. a fuel price hike or drop). Another advantage includes the ability to examine the effect of time changes in influencing VKT. The sophistication of time-series econometric approaches has advanced through time in the analysis of VKT. That includes the derivation of long-run elasticities using cointegration regression and error correction models to identify short-run elasticities over longer time trends. One of the prominent studies is by Small and Dender (2007), who utilized state-

level aggregate data, based on which they used the three stage least squares (3SLS) and ordinary least squares (OLS) methods from 1966 to 1971 to estimate short-run and long-run income elasticity for travel in the U.S. They found a positive relationship for both periods, which indicates that VMT increases as income increases.

In addition, Hymel et al. (2010) extended the data to 2010 and showed that VMT decreases as there is an increase in congestion. The critical findings in the study identified that the cost per mile and fuel price effect on driving is lower over time along with greater income and higher congestion. McMullen and Eckstein (2012) elaborated that in the condition where VKT is considered as a normal good, a causal relationship is perceived from income towards VKT using the data from 1982 to 2007 in the U.S. According to Hymel (2014), the three critical economic factors that influence aggregate VMT in California, USA, are the unemployment rate, income per capita and household median income. First of all, unemployment tends to largely reduce VMT as those who are unemployed often stop making trips. Second, the decline in income per capita and household median income lead to fewer optional vehicle trips, which reduces driving.

However, as data limitations in terms of the consistency and reliability of the database have become a major issue, especially in the developing world, this thesis only studies the car usage model using primary data with the main focus on the psychological variables as the determining factors instead of using aggregate secondary data. Furthermore, Button et al. (1993) explained that the deficiency in the extent and quality of the data employed particularly for low-income countries leads to the usage of aggregate based data.

Following those limitations, many studies have tended to use disaggregate based data. Emrath and Liu (2008) explain that households with a larger size, lower education level, younger age, and higher income and are white or Hispanic are significant in explaining VMT. Akar and Guldmann (2012) stated that household income level, hybrid car ownership and vehicle ownership increase the VMT per capita. Woldeamanuel and Kent (2014) conducted a regression analysis using National Household Travel Survey (NHTS) data in 2001 and 2009 to identify the determinants of per capita VMT in California, US. They found that there is a shift towards a more different group of

determinants that influence VMT. Variables that significantly affect VMT are the distance to work, population density, travel day trips, public transport trips, and the number of vehicles in the households. They suggest that VMT can be reduced in the long run through incentives and by encouraging non-motorized mode of transport.

Their view is similar to McCahill and Spahr (2013), whereby they stated that income, automobile ownership and licensing rates are less likely to contribute significantly towards the increase in VMT. Changes that occur in the determinants of VMT are no longer predominantly influenced by these factors due to lifestyle changes, specifically the cultural shifts of the younger generations and the development pattern. By applying the Oregon Household Activities Survey (OHAS), Ke and McMullen (2017) used ordinary least squares to study the effect of socio-economic and built-environment factors on VMT in Oregon, U.S. They found that income positively and significantly affects VMT.

2.3.2.1.3 Built-Environment Determinants of Car Ownership

Mobility demand is not merely attributed to socio-economic factors, as previously discussed in Section 2.3.2.1.1 and Section 2.3.2.1.2. Transport demand studies reveal built-environment elements, including density, infrastructure provision and travel distances, to have a substantial effect on mobility as they define the existing travel alternatives. For instance, considering the absence of nearby public transit, road users have to opt for private cars or motorcycles despite their high enthusiasm for travelling by public buses.

A plethora of studies have shown that built-environment factors are essential to travel decision-making (Boarnet and Sarmiento, 1998; Boarnet, 2004; Handy et al., 2005; Cao et al., 2009). A synthesis was made by Ewing and Cervero (2001) followed by a meta-analysis study conducted by Ewing and Cervero (2010) on the relationship between travel and the built environment. Based on Cervero and Kockelman (1997), travel demand is known to be heavily influenced by the built environment, represented by the "three Ds", which are density, diversity and design, followed by destination accessibility and distance to transit (Ewing and Cervero, 2001; Ewing and Cervero, 2010).

Studies have shown that car ownership generally declines as built-environment density increases (Potoglou and Kanaroglou, 2008; van Acker et al., 2010; Zegras, 2010). Wang et al. (2018) showed that those living in a lower density residential area in Changchun, China, tend to experience dense land use and a transit-oriented city, in which people live in areas near the CBD and have good accessibility, hence causing them to have a lower dependency on motorised travel. Diversity is also generally found to have a negative relationship with car ownership (Cervero and Kockelman, 1997; Zegras, 2010; Chatman, 2013). Zegras (2010) showed that density (dwelling unit density) and diversity together have a significant negative effect on vehicle ownership. This study also highlights that the income factor has a greater role compared to the built environment in vehicle ownership decision-making.

The connection within the city infers that commuting time and convenience, which includes aspects such as the quantity and quality of cities, can affect travel behaviour. This includes attributes such as bicycle infrastructure and street designs (Cervero et al., 2009; Zegras, 2010; Guerra, 2014). Some studies incorporated the availability of parking spaces, which creates a preference for private vehicle ownership (Alpizar and Carlsson, 2003; Medina, 2012). In addition, Krizek (2003) indicated that destination accessibility consists of distance to the CBC and job accessibility. According to Miller and Ibrahim (1998), vehicle ownership declines with increasing distance to the CBD in Toronto, Canada. On the contrary, studies by Arrington and Cervero (2008) found that as the distance to CBD increases, so does the vehicle ownership. These contradictory results suggest that the negative relationship may be attributed to the use of other modes of transport, such as buses and trains, for longer travel. Distance to transit may also influence car ownership. For instance, Li and Zhao (2017) identified that greater land-use mix and accessibility from home could lessen car ownership for those who reside close to Beijing metro stations.

In a recent study by Ao et al. (2018), they conducted a survey of 374 rural households in Sichuan China using the multinomial logit model (MNL) to explore the connection between household structure and built-environment characteristics and vehicle ownership. The outcome suggested that household structure has the strongest link with vehicle ownership, followed by built-environment factors. Furthermore, it showed that greater road density, building density and destination accessibility led to high-carbon vehicle

ownership. The study was conducted in rural settings, whereby the results differ to those studies conducted in urban counterparts (urban Chinese cities), which indicates a negative relationship. This may occur due to the considerable gap in the built-environment indicators between rural and urban cities in China.

2.3.2.1.4 Built-Environment Determinants of Car Use

Aside from the socio-economic factors, numerous studies have revealed that the built environment, notably built structures and land use, is a primary contributing factor to vehicle use. Several attempts to investigate vehicle use have been carried out using meta-analyses (Leck, 2006; Ewing and Cervero, 2010). Leck (2006) conducted a meta-analysis which identified 40 published literature pertaining to the built environment and travel and 17 which met the minimum statistical and methodological criteria. The meta-analysis estimated the average effect sizes and found that residential density, employment density and land-use mix (i.e., a measure of the composition of residential buildings, hotels, restaurants, supermarkets, parks, squares, malls, schools, hospitals, banks, and government departments (Wang et al., 2018)) to significant and negatively affect VMT. In a meta-analysis study conducted by Ewing and Cervero (2010), they found that destination accessibility is most strongly associated with VMT while job accessibility by car has a negative relationship with VMT, which is similar to their previous findings (Ewing and Cervero, 2001). They also found that distance to downtown has a negative effect on VMT, which shows that living in cities indicates good regional accessibility. The findings highlighted the role of attitudes as a controlling factor in determining travel, and this was discussed in studies by Kitamura et al. (1997) and Ewing and Cervero (2007).

Boarnet (2004) applied the ordinary least squares model of sociodemographic, land-use, and housing attributes towards total nonwork vehicle travel distance using the 1994 Portland Travel Diaries. The results indicate that distance to the CBD is significant in explaining the nonwork vehicle miles travelled (VMT) per person. By drawing such an outcome, the results indicate that income is still the most significant determinant of VMT and that the effect of land use is at par with other socio-demographic variables when income is excluded. Similarly, the study was supported by Zegras (2007), who examined the role of the built environment in influencing

household car use in Santiago de Chile. Using ordinary least squares (OLS) to estimate household total car use, the outcome of the study found that distance to the CBD is significant in explaining the daily automobile use per household. Income and number of vehicles were also shown to be significant determinants of vehicle use.

Handy et al. (2005) studied the effect of land-use on vehicle miles travelled (VMT) in eight neighbourhoods in North California. Based on the results, it was proven that different analyses lead to a different outcomes linked to the causal relationship between the built environment and travel behaviour. The results highlighted that the built environment and changes in driving are associated with the presence of attitude. A multivariate analysis using cross-sectional data showed that the hypothesis of the built environment in influencing travel behaviour is not supported and suggested that self-selection plays a crucial role in determining the correlation between travel behaviour and the built environment. According to the ordered probit model analysis, an increase in the accessibility factor and the safety factor is associated with greater propensity to drive less.

A number of studies have found that subdivision compactness and dwelling unit density have negative effects on per capita VMT (Liu, 2007; Ewing and Cervero, 2007; Akar and Guldmann, 2012). The results from these studies led to a promising long-term policy that prompted transit-oriented development (TOD) and smart growth involving elements such as mixed-use development, walkability, better access to transit, and a high residential density, which all have an inverse relationship with per capita VMT. Van Acker and Witlox (2010) analysed the dual role of car ownership by assuming that car ownership mediates the relationship between the built environment and car use using a structural equation model. It is evident that the built-up index and land-use diversity have a negative effect on car use. Meanwhile, distance to the railway station, distance to CBD and accessibility by car have a positive effect on car use. The outcome of the study confirmed that car ownership mediates the relationship between the built environment and car use and it is indicated that car use is indirectly affected by income through car ownership.

This study also suggests some other socio-psychological traits based on previous studies (for example Bagley and Mokhtarian, 2002) which may add

explanatory power, such as lifestyle, perceptions, attitudes and preferences. Further explanation in terms of the previous literature on the psychological determinants of car ownership and use is presented in Section 2.4.

2.3.3 Factors Influencing Motorcycle Ownership and Use

In this section, the studies which have investigated the determinants of motorcycle ownership and use using either aggregated or disaggregated approaches will be reviewed. First, the ownership studies are summarised, followed by usage and, in each case, the determinants are grouped into socio-economic, built-environment and psychological characteristics (refer to Table 2.6).

Table 2. 6 Factors Influencing Motorcycle Ownership and Use.

Independent Variables	**Variables Description**	**Sources**
Motorcycle Ownership		
Aggregate		
Socio-economic	• Real household disposable income deflated by mid-year total population estimates, gross domestic product per capita (GDP), Motoring cost index of an aggregate index for the purchase and running costs of private motor vehicles, interest rate, consumer price index (2005 = 100), urban population, population	• Duffy and Robinson (2004), Law et al. (2015)
Built-environment	• Road density (km per 1000 population)	• Law et al. (2015)
Disaggregate		
Socio-economic	• Household income, size of motorcycle engines, mean purchase cost, household size, car price, home ownership, education level	• Burge et al. (2007), Wedagama (2009), Hsu and Lin, (2007), Leong and Mohd. Sadullah (2007), Srinivasan et al. (2007), Hsu et al. (2007), Senbil et al. (2007), Yamamoto (2009), Chiou et al. (2009), Gopisetty and Srinivasan

		(2013), and Dash et al. (2014)
Built-environment	• Distance to transit, neighbourhood road length,	• Herwangi (2018), Sanko et al. (2014), Senbil et al. (2007)
Motorcycle Use		
Aggregate		
Socio-economic	N/A	N/A
Built-environment	N/A	N/A
Disaggregate		
Socio-economic	• Household income, age, fuel cost, age of motorcycle, fuel price, maintenance cost, parking cost	• Chiou et al. (2009), Wen et al. (2012)
Buitl-environment	• Distance to transit, accessibility to work and distance to transit	• Senbil et al. (2006), Shirgaokar (2016)

2.3.3.1 Socio-Economic Determinants of Motorcycle Ownership and Use

Numerous studies have reported the association between economic growth and motorcycle ownership (Prabnasak and Taylor, 2008; Pongthanaisawan and Sorapipatana, 2010). It is found that there is higher motorcycle ownership in developing countries compared to the developed countries. The motorcycle ownership per 1000 inhabitants for Australia was 35 in 2017, compared to Malaysia, where it is 416 for the motorcycle ownership per 1000 inhabitants. Socio-economic factors, including low-cost to purchase and low maintenance costs, generally mean that motorcycles are the main mode of transport for low income or Asian developing countries. Motorcycle ownership is very high in Asian developing countries compared to African and South American countries due to the other countries' reliance on other modes of transport, primarily informal transport. This informal transport is also referred to as privately developed paratransit, which profits from non-existing regulatory frameworks (Heinrichs et al., 2017). Examples of informal transport in South American countries include bicycle rickshaws in Bogota, Columbia, and minibus taxi industries in African countries.

Against this backdrop, it is interesting to explore how socio-economic factors (for example, fuel price) influence motorcycle ownership. Consistent with car

ownership, previous findings have identified socio-economic factors as the determinants of motorcycle ownership. Since there is a higher dependence on motorcycle ownership in Asian developing countries, studies on motorcycle ownership have been mainly undertaken in developing countries compared to developed countries. There are very few studies applying aggregate modelling to motorcycle ownership compared to the disaggregated models. In an aggregate econometric study by Duffy and Robinson (2004), they suggest that there is a promising growth prospect for motorcycle ownership in the UK. Using a stock adjustment model, they found a long-run income elasticity of demand for motorcycles in combination with a high cross-elasticity of a substitution effect pertaining to motoring cost. A cross-country analysis was conducted by Law et al. (2015) using aggregated modelling, in which they found an inverted U-shaped relationship between the MPC (motorcycle per car) ownership ratio and the gross domestic product per capita using a sample of 80 countries from 1963 to 2010. The study concluded that motorcycle growth happens in less advanced countries as a result of greater income and urbanization. It has been suggested that the opposite outcome happens for advanced economic countries, whereby motorcycles are replaced by cars as income rises.

While very few motorcycle ownership studies use aggregate modelling, a growing number of studies used disaggregate modelling, primarily in the context of Asian developing countries, such as the case study area. With respect to the disaggregated approach in the case of a developed country, Burge et al. (2007) conducted a study on motorcycle ownership decision-making in the UK, which consisted of the number of motorcycles owned by a household and the size of engines using a nested logit model. The study found that decision-making depends on the attributes of the individual and the mean purchase cost. Wedagama (2009) investigated the factors affecting motorcycle ownership in Denpasar, Bali, using a multinomial logit model. Based on the study, an increase in the number of family members most likely leads to higher motorcycle ownership, which is in contrast to the results by Hsu and Lin (2007). Meanwhile, the study suggested that lower-income households tend to have either one or two motorcycles, which aligns with the study by Leong and Mohd. Sadullah (2007). In addition to these, studies by Srinivasan et al. (2007), Gopisetty and Srinivasan (2013), and Dash et al. (2014) stated that the socio-economic determinants of car ownership also affect two-wheeler ownership. The research was conducted in India, which is

the fourth-ranked country in terms of petroleum consumption and has seen a significant increase in private vehicle ownership over the past few years. All of these studies applied discrete choice modelling with the exception of Gopisetty and Srinivasan (2013), which applied the three-stage least squares (3SLS) model. The outcome of these studies indicates the significance of socio-economic factors, such as car prices, household sizes, home ownership and education level.

In comparison with cars, motorcycles are more frequently used as they can easily manoeuvre on roads to overcome congestion issues, particularly in the CBD of most Asian developing countries (Leong and Mohd. Sadullah, 2007). By accessing alternative roads, motorcyclists are able to avoid congestion, and thus achieve a faster travel time. Furthermore, in some parts of developing countries, the road infrastructure is not fully developed or is too narrow to allow access for cars and buses. They are also small bridges which can only be accessed by foot, cycle and motorcycle. Although there are some emerging studies on motorcycle ownership, the past literature has shown that motorcycle use has not been extensively discussed. This is critical considering the importance of motorcycle use, particularly for developing countries which face severe road transport issues, such as traffic congestion. Some authors (Duffy and Robinson, 2004; Kopp, 2011) have mentioned that traffic congestion is one of the reasons that contribute to motorcycle use as it can save travel time.

Few studies have thus far identified the role of socio-economic factors in motorcycle use. Chiou et al. (2009) found that income, age and fuel cost have a negative impact on motorcycle usage in Taiwan, using a stepwise regression of annual miles travelled on the explanatory factors. Using a different methodology, Wen et al. (2012) developed motorcycle ownership and usage models using a large-scale panel survey in Taiwan cities with three types of panel data regression models, including ordinary, fixed and random effects. Similar results were obtained, whereby income, the age of the motorcycle, gas price, maintenance cost and parking cost were shown to have negative effects on annual kilometres travelled.

2.3.3.2 Built-Environment Determinants of Motorcycle Ownership and Use

As noted before, most studies on the built-environmental effects mainly focus on cars rather than motorcycles. Exceptions include Lin and Yang (2009) and Herwangi (2018). Lin and Yang (2009) studied the relationship between urban form and travel demand at the aggregate level by utilising traffic analysis zone (TAZ) data in Taipei, Taiwan, using structural equation modelling. In this study, the private mode split consists of the percentage of car use and motorcycle use in a traffic analysis zone. The study found that the design (road density and grid network) has a direct negative effect on car and motorcycle use. A similar negative but indirect effect was also seen from density on the car and motorcycle mode split based on diversity and trip generation. Herwangi (2018) studied the impact of spatial and socio-economic factors on motorcycle dependency in relation to low-income inhabitants in urbanised Jogjakarta. They found that poor transport infrastructure has led to low-income countries relying on motorcycle ownership. The study indicates that low-income people who live in a transport disadvantaged area (TDA) became captive motorcycle users as they have no option to select alternative housing locations due to financial constraints. Furthermore, a TDA has no public facilities and is not crossed by public transport routes, leading inhabitants to opt for the motorcycle. For low-income people living in non-transport disadvantaged areas (NTDA), motorcycle ownership is associated with occupations such as peddlers and security workers as well as flexible labour and irregular working hours which do not match with public transport services. This suggests that spatial variables which link with the settlements, public transport infrastructure, services, cost and operating time for low-income people should be included in transportation planning.

While socio-economic and built-environment are proven to contribute towards vehicle ownership, attempts to further understand travellers' decision-making can be made more effective by addressing their behavioural antecedents, that is, by integrating relevant psychological factors as determinants. The following sub-section discusses the role of psychological factors as determinants of vehicle ownership, which are driven from two main theories, as summarised in 2.3, which are the theory of planned behaviour (TPB) and the norm activation model (NAM).

Few studies have been found on the effect of the built environment on motorcycle use, either in developed or developing countries. The built environment and road transport infrastructure are assumed to have a significant impact on motorcycle use. This is because, in some cities in Asian developing countries, some streets are narrow and high in density, which imposes constraints on cars (Senbil et al., 2007). This is further supported by Tuan (2015), who sees commuting using motorcycles as undemanding as it is easy to acquire parking spaces, which are much smaller space compared to those for cars.

Senbil et al. (2006) use a Poisson regression and bivariate binary probit model to explain the effect of the number of home-based trip chains with private car and motorcycle based on a 2003 survey of household trips in Jabatobek, Indonesia. Based on the results, they found that neighbourhood road length increases car and motorcycle ownership. In addition, average land-use diversity was found to reduce motorcycle use while increasing car use. Shirgaokar (2016) investigated the impact of the built environment on two-wheeler use in Mumbai, India, using Tobit and censored quartile models. The study found that accessibility to work and distance to transit have a positive impact on two-wheeler (TW) VKT. On the other hand, land-use diversity, population density, employment density and street density have a negative effect on two-wheeler VKT. It is worth noting that only a few studies have explored the relationship between built-environment factors and motorcycle use.

2.3.3.3 Car and Motorcycle Ownership Interdependency

This section describes the interdependency between private vehicles, namely cars and motorcycles. Economic progress has accelerated the level of motorisation in developing countries. However, unlike their developed counterparts, the rise in motorisation, particularly in Asian developing countries, is not only dominated by cars but also by motorcycle ownership. In general, motorcycle ownership is considered as an inferior mode of transport in developing countries as it cannot provide the comfort and independence of cars. Nonetheless, such an opinion may different for each country. Problems such as severe congestion and very poor public transport may also contribute to high motorcycle ownership. Hence, it is important to note the

interdependency between car and motorcycle ownership, the study of which can be conducted using various methods/models (refer to Table 2.7)..

Table 2. 7 Studies on the Interdependency between Car and Motorcycle Ownership**.**

		Model/Methodology	**Interdependency**
Aggregate	**Country/ Case study**		
Pongthanaisawan and Sorapipatana (2010)	Thailand	Logistic function	Substitution
Tuan (2011)	Japan, South Korea, Taiwan, Malaysia, Indonesia	Quadratic log-linear models, logistic model	Japan: Substitution South Korea: Substitution Taiwan: Substitution Malaysia: Substitution Indonesia: Substitution
Disaggregate			
Yamamoto (2009)	Osaka, Japan and Kuala Lumpur, Malaysia	Trivariate binary probit model	Osaka: Bicycle as substitute for car Kuala Lumpur: Motorcycle as substitute for car
Sanko et al. (2014)	Nagoya, Japan, Kuala Lumpur, Malaysia, and Bangkok, Thailand	Bivariate ordered probit model	Nagoya: Complementary Kuala Lumpur: Substitution Bangkok: Substitution
Hsu et al. (2007)	Taiwan	Poisson model	Substitution

Chiou et al. (2009)	Taiwan	Multinomial logit model, nested logit model	Substitution
Senbil et al. (2007)	Jabotabek, Indonesia, Manila, Philippines, and Kuala Lumpur	Bivariate ordered probit model	Jabotabek: N/A Manila: N/A Kuala Lumpur: Substitution

Pongthanaisawan and Sorapipatana (2010) investigated the relationship between motorcycles per 1000 people (MAO) with passenger cars per 1000 people (CAO) in Thailand using aggregate data from 1991 to 2007. They found that as income increases, there is a shift to CAO for reasons such as prestige, convenience and safety. In another aggregate based study by Tuan (2011) on the dynamic interaction between motorcycle and car ownership in Asia, it was found that households in developing countries opt for multiple motorcycles per household at low income and later opt for their first cars. However, current motorcycle ownership may hamper the purchase of more cars.

A further understanding of the interdependency between these private-based vehicles can be seen in studies using disaggregated data. Yamamoto (2009) examined the interdependency among different types of vehicle ownership, namely car, motorcycle and bicycle, in Osaka, Japan, and Kuala Lumpur, Malaysia, using simultaneous vehicle ownership models. The results suggest that motorcycles are considered as substitutes for cars in Kuala Lumpur while bicycles are considered as substitutes for cars in Osaka. The high population in Osaka leads to bicycles as substitutes for cars, while the high car travel times lead to motorcycles as substitutes for cars in Kuala Lumpur.

Similar results supporting the substitution relationship between cars and motorcycle in Kuala Lumpur, Malaysia, and Bangkok, Thailand, but a complementary relationship in Nagoya, Japan, were reported by Sanko et al. (2014), who investigated car and motorcycle ownership using a bivariate ordered probit model in these three locations. Interestingly, while the income variable was not included in the model, other socio-demographic variables,

such as household size, gender and age, were shown to have a positive and significant relationship with motorcycle ownership.

In the case of Taiwanese cities, Hsu et al. (2007) and Chiou et al. (2009) found a substitution effect between cars and motorcycle. Hsu et al. (2007) further identified that the provision of public transportation dampens motorcycle ownership in cities with a better public transportation system. On the other hand, Senbil et al. (2007) studied the interdependent relationship between car and motorcycle ownership in Jabotabek, Indonesia, Manila, Philippines, and Kuala Lumpur, Malaysia. The output of the studies, which used a bivariate ordered probit model, indicated that there is no relationship between the former and the latter, except for a substitute relationship for Kuala Lumpur. They further elucidate that income has a greater impact on car ownership than it does on motorcycle ownership. In a different geographical region, Anastasopoulos et al. (2012) and Gómez-Gélvez and Obando (2014) found a negative association between car and motorcycle ownership in Athens, Greece, and Bogota, Colombia, respectively.

Only a few studies are found in the context of the developed world. Most studies on the interdependency between car and motorcycle ownership primarily originate from the developing world, particularly in the South Asian and Southeast Asian regions, with attention focused on disaggregate based modelling. This is because motorcycle ownership is considered to be one of the main modes of transport in the region, and there is low motorcycle ownership in developed countries compared to developing countries. This is because public transport is considered as the substitute for cars in developed countries due to better public transport infrastructure. Hence, very few evidence is found in the literature discussing this subject matter. Interestingly, limited studies have been made on the aggregate level in comparison with the disaggregate level. Given this situation, there is a need to further understand the interdependency between these two modes to investigate the relationship based on the intertemporal and the cross-sectional aspects. While section 2.3.3 and 2.3.4 presented the socio-economic and built environment determinant of ownership and use (including car ownership as the determinant of motorcycle ownership, vice versa), the following section provides the review of psychological determinants of car and motorcycle ownership and use. Prior to reviewing the psychological determinants of car and motorcycle ownership and use, the next section explains the underpinning theory of travel behaviour,

which later informs the psychological factors in Section 2.4.3 and Section 2.4.4.

2.4 Theoretical Framework of Travel Behaviour

Following the review on modelling approaches for vehicle ownership and use as well as the determinants of car and motorcycle ownership and use, it is noted that there are gaps in terms of the integration of psychological factors as the determining factors. Prior to the discussion of the psychological determinants of vehicle ownership and use, this section provides a brief overview of relevant psychology-based theories that were used in the past literature on travel behaviour. According to Burns et al. (1975), the decision-making behaviour of households is posited to be a consequence of individuals' cost and benefit trade-offs in terms of transport-related choices. This notion relates to the utility function developed in economic theory. A household's total utility is described as being dependent on the consumption of all goods, the availability of leisure time, and travel to destinations in a particular period. The household increases its mobility along with vehicle purchase, but thereby sacrifices other types of consumption. That is the purchase decision-making that occurs in the case where the utility of rising mobility surpasses the loss of utility when consuming other goods, for example, considering a car as a homogenous good at a fixed price. The extent to which the alternative of having a car satisfies the household's need to travel is represented by the set of destination accessibility using the alternative travel mode and the travel time. Considering that the best alternative to the car is the public bus in a developing country (e.g. Malaysia), the utility of not owning a car is a function of income, non-travel time and trips to predetermined destinations using the alternative mode.

The household then needs to reassess the utility maximisation derived by making the best out of travelling by car or by public bus. The theory provides an explicit proposed association between car ownership and transport system attributes. Specifics on the functional form of the utilities are a precursor to the theory implementation. The property of consumer sovereignty is a critical consequence, whereby consumers' preferences are predetermined and do not rely on the availability of alternative choices (McFadden, 2001). In this sense, the implementation of economic theory tends to neglect the reliance

on perception without invoking experience or the state of emotion. Considering the limitations, a number of studies have suggested including socio-psychological attributes, for example, attitude and perception, which may add explanatory power to understanding the decision-making process of households regarding their travel behaviour.

Following that, some studies have identified the importance of including psychology-based individual attributes in shaping how people travel (Kitamura et al., 1997; Bagley and Mokhtarian, 2002). Among the prominent theories that integrate the psychological framework is the theory of planned behaviour (TPB) (Gardner and Abraham, 2008) (see Figure 2.1) and the norm activation model (NAM).

2.4.1 Theory of Planned Behaviour

The theory of planned behaviour (TPB) was put forward by Ajzen (1991) as an extension of Fishbein's (1967) theory of reasoned action. According to TPB, behaviour is influenced via intention by attitudes, social norms and perceived behavioural control (PBC) (Figure 2.1). Attitude is described as an overall evaluation by a person towards specific objects or behaviours. Attitudes are themselves founded on the behavioural beliefs of the consequences of an action and the judgement regarding a specific behaviour. Subjective norms or social norms are a person’s estimation of social pressure to perform a specific type of behaviour. This includes influence from society, peers and institutions. PBC is characterised by the extent to which a person believes they can enact a specific behaviour. It has two components, which are the perceived control of the specific behaviour and the confidence to perform that particular action. As TPB involves the reaction of an individual towards a specific action, the attitudes and perceived control of an individual are determined by how well-informed and knowledgeable they are regarding it (Ajzen, 1991).

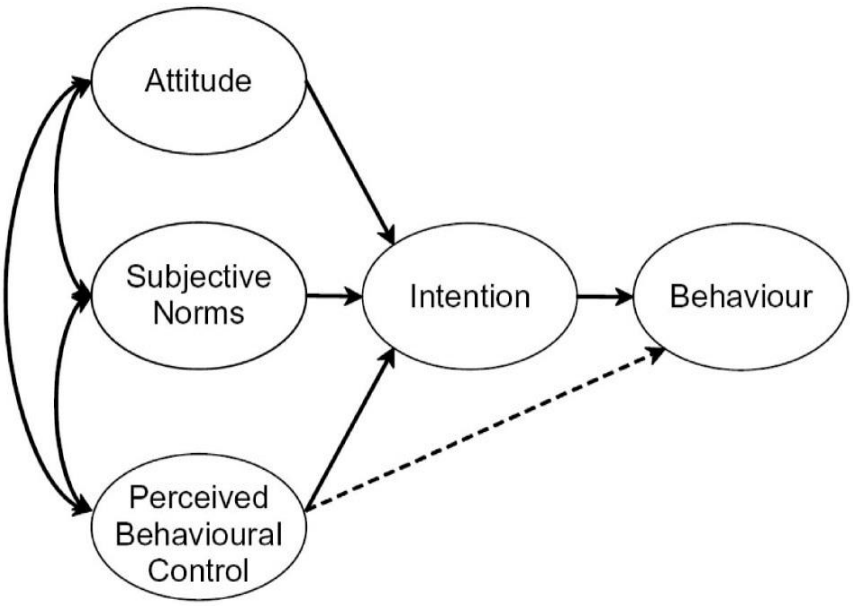


Figure 2. 1 Theory of Planned Behaviour (Ajzen, 1991).

TPB has been used in numerous fields of transport behavioural studies, including in the work by Heath and Gifford (2002), Bamberg and Schmidt (2003) Gardner and Abraham (2008). Gardner and Abraham (2008) conducted a meta-analysis using 23 units of unique study datasets, supporting the predictive utility of variables derived from TPB towards car use, although support for pro-environment cognition towards driving was found to be weak.

The widespread use of TPB in the literature and its empirical validation by numerous studies related to travel behaviour deems it essential as the foundation for incorporating psychological factors as predictors of private vehicle ownership and use in this thesis. The theory's success stems from its capacity to consciously evaluate the advantages and disadvantages of making specific decisions, subject to given social and perceived situational limitations. Nevertheless, TPB is not without its limitations, which have also been widely documented in the literature (Parker et al., 1995; Conner and Armitage, 1998; Liu et al., 2017). In particular, TPB is criticised for having an understanding of a person's behaviour that is inclined towards self-interest. Consequently, this theory is often integrated with another dominant theory, namely the norm activation model (NAM), which incorporates an understanding of the effect of morality on car ownership and use. The integration of both theories is necessary considering that the reduction of car travel is a function of a combination of pro-social concern and self-interest (Liu et al., 2017).

2.4.2 Norm Activation Model

Like the random utility maximization, the TPB underlines the individual as an actor that maximises utility (Bamberg and Schmidt, 2003). However, other theories, particularly that of the norm activation model (NAM) (Schwartz, 1977), emphasise the altruistic and environmentally friendly behaviour of an individual. Based on Schwartz (1977), some behaviour is beneficial to others as a result of internal values expression, regardless of the underpinning social and material networks. In this scenario, a person decides to perform an action as a result of their moral obligation concerning the decision-making. As an example, personal norm internalisation is activated when a person identifies a person in need and perceives adverse outcomes if no action is taken. The general postulation of NAM is that personal norms are a direct and unmediated determinant of pro-social behaviour (Bamberg et al., 2007). Personal norms were clearly distinguished from social norms in TPB by Schwartz (1977), whereby a social norm is considered a fear of social rejection while a personal norm is based on a person's conviction of what is right or wrong. TPB and NAM are two distinctive theories that are widely used to explain travel behaviour. In this sense, it is imperative to consider reducing car transport (to reduce negative environmental externalities) as being instigated by either self-interest or pro-social motives.

There are some cases that integrate both theories as they can be used to validate these two conditions. Hence, for the thesis, the integration of TPB and NAM provides a balancing insight between the two perspectives of norms, specifically social norms (from TPB) and personal norms (from NAM). Many studies have integrated TPB and NAM to understand travel decision-making, including studies by Harland et al. (1999), Abrahamse et al. (2009) and Liu et al. (2017).

2.4.3 Psychological Determinants of Car Ownership and Use

Asian developing countries have experienced an increasing trend of car dependency over the past few decades. Despite the negative externalities caused by the rapid growth in car ownership, such as traffic congestion and air pollution, car ownership continues to appeal to the general public. Given the aforementioned issues, it is thus necessary to investigate plausible measures that could regulate the demand for car use. As mentioned by Maltha et al. (2017), the influence of traditional factors (e.g. socio-economic) has

lessened over the years; this may be attributed to the role of psychological factors, which are often excluded in many studies. Choocharukul and Fujii (2007) suggest a psychological method to regulate demand for transport by the modification of psychological factors, including attitude and norms. For that purpose, this study examines the determinants of vehicle ownership and use by including the role of psychological factors by integrating two of the prominent psychology-based theories, namely the theory of planned behaviour (TPB) and the norm activation model (NAM). The following sub-sections will discuss the literature pertaining to TPB and NAM as the determinants of car and motorcycle ownership (refer to Table 2.8).

Table 2. 8 Psychological Factors Influencing Vehicle Ownership and Use.

Independent Variables	**Variables Description**	**Sources**
Car Ownership and Use		
Psychological Factors	• Attitude	• Fujii and Gärling (2003), Wu et al. (1999), Belgiawan et al. (2016), Bagley and Mokhtarian (2002), Choo and Mokhtarian (2004) • Handy et al. (2005), Banerjee and Hine (2016), Flamm (2009)
	• Social norms	• Nishihara et al. (2017), Belgians, Moons and de Pelsmacker (2012), Belgiawan et al. (2014), Belgiawan et al. (2017), Dharmowijoyo et al. (2015) • Choocharukul and Fujii (2007), Choocharukul et al. (2008), Setiawan et al. (2015)
	• Perceived behavioural control	• Liu et al. (2017), Setiawan et al. (2015)
	• Personal norms	• Bamberg et al. (2007), Klöckner and Blöbaum (2010), Olsson et al. (2018), Bamberg and Schmidt (2003), Steg and Vlek (2009)
Motorcycle Ownership and Use		
Psychological Factors	• Perceived freedom and ideology	• Marquet and Miralles-guasch (2016)

2.4.3.1 Attitude as a Determinant of Car Ownership and Use

To the best of the author's knowledge, attitude, a component of TPB, is the most widely used factor in many of the psychology-based studies on vehicle ownership (Fujii and Gärling, 2003). Attitude based on TPB relates to instrumental, symbolic and affective, or social orderliness. According to Dittmar (1992), instrumental motives refer to the functional attributes whereas affective motives are related to a deeper emotional feeling. Symbolic and affective motives are then grouped as the attributes perceived to be almost similar. The attitudinal component of TPB alone is extensively used in travel-based studies and is known to be an imperative determinant of car ownership (Wu et al., 1999; Belgiawan et al., 2016). Other applications of attitudinal factors have been used against vehicle mode choices in studies by Kitamura et al. (1997), Choo and Mokhtarian (2004), Parkany et al. (2004), Thogersen and Olander (2006), and Johansson et al. (2006). Johansson et al. (2006) stated that attitude and personality add more powerful mode choice models in addition to socio-economic variables.

The previous literature on attitudinal factors was dominated by studies undertaken in developed contexts. Kitamura et al. (1997) investigated the travel behaviour determinants in the San Francisco Bay Area by including the land-use and attitudinal variables effects. The multivariate regression analysis indicated that socio-economic and neighbourhood characteristics are associated with travel amount and mode split. Nonetheless, it is also highlighted that attitudinal factor groups (such as pro-environment, pro-transit, automotive mobility and time-pressure) are found to have significant explanatory power towards travel. Kitamura et al. further argue that the association between land-use and travel mainly exists due to the correlation between land-use and attitudinal factors. The regression of socio-economic and neighbourhood characteristics against the number and proportion of trips by various modes suggests that the best model is achieved when neighbourhood characteristics add significant explanatory power by controlling for the socio-economic difference. Second, by adding the attitudinal variables in the model, it is noted that when compared to land-use variables, these attitudinal variables have stronger associations with travel.

Bagley and Mokhtarian (2002) examined factors influencing 515 households in the San Francisco Bay Area in terms of travel behaviour using a structural equation model (SEM), including ten groups of attitudinal factors (e.g. pro-environment, pro-growth, pro-transit and pro-driving) and eleven groups of lifestyle factors (e.g. hobbyists, nest-builder, and athletic). Interestingly, the study reported that neighbourhood has little impact on travel behaviour in the presence of attitudinal, lifestyle and socio-demographic variables, as previously suggested by Kitamura et al. (1997). When compared with other explanatory variables, attitudinal and lifestyle variables are found to have the most significant influence on travel demand in terms of both direct and total effects. In summary, when socio-economic, attitude and lifestyle factors are gathered, only a small effect of land-use variables on travel behaviour is identified.

Choo and Mokhtarian (2004) identified the incorporation of travel attitudes, lifestyle, personality, and mobility factors as being substantively powerful in future vehicle type choice models using a survey of 1904 residents in the San Francisco Bay Area, USA. Similarly, using 1,803 Dutch respondents, Steg (2003) investigated their motivation to acquire a driving license and found that people are favourable towards cars compared to public transport due to instrumental functions and symbolic factors. Steg (2005) later performed a continuation of this study and found that people love driving, not only because driving is instrumental but due to its symbolic and affective motives.

Anable and Gatersleben (2005) examined the instrumental and affective factors in the work and leisure journeys of 235 staff and students in the University of Surrey via various travel models. They found that convenience is more important than affective factors for work journeys, while for leisure, there is almost equal importance to both aspects. In addition, car users regard salient attributes (convenience and flexibility) as inferior in alternative modes of transport.

Lois and Lopez-Saez (2009) applied a structural equation model (SEM) in Spain to identify the role of affective motives as a mediator for instrumental and social orderliness towards car use, which confirms the theory proposed by Steg and Tertoolen (1999). They confirmed that instrumental motives, including aspects of cars such as speed and convenience, can increase the

likelihood of car use only if an aspect of affective motives is present. Symbolic motives represent how individuals or groups of people who identify themselves by their cars could affect the affective motives as a result of the car providing a more enhanced fine-tuning between the real self and the ideal self.

In a non-western/developed context, a multinomial logit model was applied by Van and Fujii (2011) to investigate the effect of psychological variables in explaining transportation mode choice (namely car, public transport or other modes) using 1118 respondents from six Asian countries, including Japan, Thailand, China, Vietnam, Indonesia, and the Philippines. The study included symbolic affective, instrumental and social orderliness using principal component analysis of the car and public transport in these countries. Using the intention to use one of three modes for work travel after obtaining a job as the dependent variable, the independent variables consist of three attitudinal variables. Confirming the importance of attitude in explaining behavioural intention, as mentioned in TPB, the results found attitude variables to be a significant determinant for all the country samples, while social orderliness has shared importance for Asian developing countries. The results also found that attitude is less significant for countries where car use is high while significant for countries with low car use. Based on this study, the effect of altruism and environmental friendliness was mentioned as part of social orderliness, but this did not include other types of psychological factors from TPB, such as social norms and perceived behavioural control. The findings on the importance of the symbolic affective and instrumental influence on cars are consistent with the studies conducted by Steg (2005) and Gatersleben et al. (2002) in European countries. Van et al. (2014) further extended the study of Van and Fujii (2011) by studying the intention to use one of either car, public transit or other modes by applying multinomial logit models using similar datasets. The study found all the attitudinal factors to be significant for cars for the entire Asian sample.

2.4.3.2 Social Norms as a Determinant of Car Ownership and Use

Social norms in the context of this thesis relates to the "rules and standards that are understood by members of a group, and that guide and/or constraint social behaviour without the force of law" (Cialdini and Frost, 2008, p. 152). Injunctive norms, also known as subjective norms or social norms, motivate

behaviour via the expectations of society regarding what is acceptable or unacceptable. An individual who fears being sanctioned by society (social exclusion) may choose to abide by the social norms. The expectation for the hypothesis is based on the motivation to comply, that is, the societal expectations are salient only if the particular group of individuals is considered pivotal in the person's life.

As a sub-group of a society, the nature of a family has a very strong impact on the demand for goods. For instance, if a family member has a positive expectation for a certain individual to own a car, the relationship may be an imperative factor due to the overall significance of that particular member for that individual. In other words, a particular traditional interest may have developed in the family, in this case, owning and using cars, which may persist until the next generations. This is because individuals rely on several predefined roles (for example, the head of a family), including the degree of visibility as well as the necessity, involvement and relevance within the society regarding the demand for cars and motorcycles. Previous studies have stated that decision-making in mode choice is better explained by including not only individual travel patterns but also the tours and activities made by other members of the household (Ronald et al., 2011; Pinjari and Bhat, 2011).

Individuals usually conform to the behaviour of others for a reason. Paez and Scott (2007) highlighted that individuals depend on their observations regarding their behaviour, especially in new or urgent circumstances in which details from other sources are expensive or challenging to obtain. As discussed by Kelman (1958), there are three processes of conformity, which are compliance, identification and internalisation. Compliance involves altering behaviour publicly to receive a favourable reaction or to escape punishment or discontentment from others. Meanwhile, identification is the process in which an individual adopts and believes in the attitude of others with the purpose of establishing, self-defining or maintaining a relationship with other parties. Finally, internalisation is the process in which a person adopts others' attitudes in private as they are aligned with the person's value system.

An individual is most likely to own a car or motorcycle based on a consideration of the visibilities and necessity of car or motorcycle usage by

their peers within the society. Similarly, a degree of involvement applies in which the society may own cars due to a dependency within the society, which means that the individual will have to conform to their rules and expectations. Bandura (1986) elucidates that individuals tend to develop certain behaviours by modelling the behaviours of other people. This suggests that the ownership and use of cars and motorcycles relate to the consumption characteristics which are determined by the connection to a particular group of society, which causes them to be ascribed the term of a consumption sub-culture. According to Solomon (1992), cars have developed into the most important entity in popular culture. This includes the connection to expressions of cultural values, for example, individualism, power, freedom and materialism. This means that, via art, literature, popular music and brand advertising, the car is linked with a specific type of identity while society is built upon a car-owning culture and driving is considered as a modern form of self-expression.

A number of studies have integrated the role of social norms specifically in the context of developed countries. Individual travel decision-making is better explained by the activities of other people rather than of the individual. In the long run, in travel decision-making (vehicle ownership, mode choice), the role of other people in the household is even more necessary. Other than household members, close friends and colleagues, the role of a group of people in geographically more extensive social networks is considered crucial. A study was conducted by Nishihara et al. (2017) to explore how their significant others affect students' decisions to purchase a car or not using data of 300 respondents in a Japanese university. The study found that significant others (parents') attitudes and the students' respect towards their parents significantly affect car ownership decision-making, which explains the profound role of social norms. Using a sample of 1202 respondents, Belgians, Moons and de Pelsmacker (2012) examined TPB in terms of the usage intention of electric cars with the addition of emotion as part of the determining factor. They indicated that attitude, emotions, social norms and perceived behavioural control were significant factors.

Previous studies on the role of social norms were also conducted using data sets from both developed and developing countries. Belgiawan et al. (2014) conducted a study involving younger people and their car purchasing behaviour after graduation in seven countries, namely China, Indonesia, Japan, Lebanon, Netherlands, Taiwan and the USA. The results showed that

the expectation of others is an imperative determinant of purchase intentions, whereby the symbolic affective meaning of car and income are less correlated with intention to purchase. In their study, Belgiawan et al. (2017) investigated the role of social norms by applying ordered hybrid choice models in exploring car purchasing behaviour based on 1229 university students from three developed and four developing countries. The study indicated that social norms strongly correlate with the intention to purchase cars, in particular highlighting that group-specific influence may differ significantly and that university peers strongly affect the car ownership motivations. In the case of a developing country, Dharmowijoyo et al. (2015) discovered that there is a significant effect of social norms on the intention to use a motorized vehicle for out-of-home based activities for 584 respondents in the Bandung Metropolitan Area (BMA), Indonesia.

A study by Choocharukul and Fujii (2007) extended TPB to examine the role of psychological factors as a predictor for private cars, using predictors for future work trips. The study used Thailand as a case study, based on a sample of 156 faculty of engineering undergraduate students who were expected to graduate in the next few months. Using SEM, the results found that 74 per cent of the variance in the intention of driving to work after graduation was influenced by the psychological variables, whereby the standardised direct effects on car use were attitude, social norms, perceived behavioural control, and moral obligation. Social norms was measured based on the influence from an individual's friends and family in terms of driving; attitude was measured by the individual's preference to drive after graduation; and perceived behavioural control was measured based on the ease or difficulties in driving after graduation. They found that social norms, attitude and moral obligation are a significant predictor for behavioural intention while, in contrast to TPB, perceived behavioural control was not found to be significant. The study also focused only on the psychological variables as the predictors of private car use. The study specifically mentioned TPB with the inclusion of moral obligations but did not clarify moral obligation driven by NAM, although evidently, the indicators in terms of moral obligation were identified as being pro-social.

2.4.3.3 Perceived Behavioural Control as a Determinant of Car Ownership and Use

Another component of TPB is perceived behavioural control (PBC) in addition to attitude and social norms. Abrahamse et al. (2009) defined PBC as the perceived ease or difficulty of engaging in a behaviour, for instance, driving a car to work or using other modes of transport. Hunecke et al. (2007) defined PBC as an individual's perception regarding their capability to use a particular mode of transport, which is attributed to traffic infrastructure and personal living conditions.

According to Sheeran et al. (2003), PBC relates to how an individual perceives the extent of their action to be within their control and this is generally measured by the evaluation of the ease against the difficulties experienced while performing such behaviour. Also, PBC could relate to intention as an individual is not likely to perform a behaviour that is beyond their control. The individual is more likely to perform a behaviour if they believe that it is within their capability and means to accomplish their action.

PBC is assumed to have a direct effect on both intention and behaviour (Ajzen, 1991). Actual behavioural control denotes the obtainability of options and means, including income, time and the participation of other individuals, and has direct effects on behaviour. However, due to the difficulty in measuring this factor, PBC is utilised as a proxy for actual behavioural control (Dijst et al., 2008). In a meta-analytic review by Armitage and Conner (2001), the inclusion of PBC was essential as it enabled the prediction of certain behaviours that are not under complete volitional control. Armitage and Conner added that PBC reveals some details on the possible limitations as perceived by the individual and it is used to clarify why intentions do not predict behaviour all the time.

In the previous literature, the component of PBC was widely integrated using developed country case studies. In the context of Belgium, Moons and de Pelsmacker (2012) implied that those who are in an environmentally friendly group are more likely to take the behavioural control aspect into consideration compared to those who are reluctant to use an electric car. Eriksson and Forward (2011) identified that PBC, along with other components of TPB, is

significant in determining the intention to use a car based on studies in the central part of Sweden.

According to Liu et al. (2017), PBC explains an individual's perception regarding the effectiveness and difficulty of reducing car-transport in China. Stark et al. (2018) stated that the stronger the attitude, social norms and PBC, the higher an individual’s intention to perform such a behaviour, which leads to a high likelihood to perform the actual behaviour. Stark et al. (2018) further elucidated that PBC can contribute directly to behaviour prediction and that greater PBC is related to better intention-behaviour consistency. An important aspect of PBC is as a regulating factor in the decision-making process. An example of a study in the context of a developing country can be explained by Setiawan et al. (2015) in Surabaya, Indonesia. They found that an increase in PBC increases students' behavioural intention (BI) to use a car to travel to campus, which then increases the actual behaviour.

One of the contexts describing the ease of accessing a particular mode of transport (e.g. car) can be observed by the difficulties in accessing another mode of transport (e.g. public bus). Limited access to public transport is associated with higher car ownership (Kamba et al., 2007; Mulalic et al., 2015), and vice versa. This is because more enhanced public transport may ease many transport-related issues (e.g. congestion and parking), which is linked with private car usage in the first place. The previous study conducted by Button et al. (1980) also suggested that households with greater public transport accessibility to work are more likely to have lesser car ownership and are also more reluctant to own cars. This view is supported by Badland et al. (2010), who pointed out that individuals who had an objectively measured public transport or greater accessibility to public transport had a higher likelihood to use public transport to go to work. Such issues, including convenience and accessibility in terms of work-related travel behaviour, which also encompass the comfort and quality of services, determine the number of passengers on public transport. In addition, Kamba et al. (2007) suggested that improved public transport services for passengers, including improving reliability and route accessibility, may lower car use.

2.4.3.4 Personal Norms as a Determinant of Car Ownership and Use

Ajzen (1991, p. 189) stated that “the personal considerations tended to overshadow the influence of perceived social pressure”. Nonetheless, the role of personal norms was previously exempted from the study by Ajzen and Fishbein (1969) as it was seen unnecessary because it has no link with individual behavioural intentions. This leads to social norms being the only normative component of TPB.

Fang et al. (2017) categorised social norms as externalised norms, specifically injunctive norms (display behaviours to receive approval from others in which compliance is encouraged while violations may lead to punishments); social norms (behaviour is expected by surrounding individuals or support systems, such as family members, friends and colleagues); descriptive norms (informational social influence in which practices to which individuals adhere whenever they encounter unfamiliar circumstances or notions). They differentiated personal norms as being derived from NAM as internalised norms, described as the self-expectation and obligation to perform what is perceived as morally right.

A study by Harland et al. (1999) shows that the inclusion of personal norms, driven by NAM, increases the predictive power of TPB. The elements of personal norms used in this study include moral norms, reflecting internalised moral rules and anticipated regret (to reflect expected feelings when rules are broken). Their study was conducted using a sample of 305 Dutch citizens in a behavioural change intervention program on environmentally relevant behaviour. The study found that PBC and attitude significantly influence car use and intention to use a car, while the social norms explained these to a lesser extent. Hence, some studies have supported the integration of both TPB and NAM, including Bamberg et al. (2007) and Klöckner and Blöbaum (2010).

Subsequently, the application in the literature of NAM to conceptualise the car-commuting reducing behaviour is derived by from a pro-social behavioural incentive. This condition is reflected by the postulation that normative self-expectations or personal norms are the most significant factor determining mode choice. As described by Schwartz and Howards (1984, p. 245), personal norms are distinguished from social norms as the following:

“whereas other attitudinal concepts refer to evaluations based on material, social, and/or psychological payoffs, personal norms focus exclusively on the evaluation of acts in terms of their moral worth to the self”. This aspect of NAM also associates with the awareness of adverse impacts related to a specific behaviour. Those who are aware of the adverse impacts of using a car are found to have significant intention to lessen the action (Olsson et al., 2018). Many studies have demonstrated a significant effect of the pro-environment factor in their models (Bamberg and Schmidt, 2003; Steg and Vlek, 2009).

In a meta-analysis study by Lanzini and Khan (2017), they found that TPB and environmental concerns were associated with the intention to opt for a green mode of transport. Another study by Peters et al. (2011) integrated both TPB and NAM in their research on 302 Swiss respondents regarding fuel-efficient cars using SEM. Their study found that valence of less power and small size, as well as PBC, are significant determinants for fuel-efficient cars while personal norms, on the other hand, are not significant. In contrast, Liu et al. (2017) conducted a study on car-transport reduction in China using a survey of 600 car drivers, integrating both TPB and NAM. The results suggest that personal norms mediate social norms and the intention to reduce car transport. Abrahamse et al. (2009) identified that car-commuting is mainly determined by factors that associate with PBC and attitude, while the intention to use is mainly determined by factors related to morality, specifically personal norms. They also add that greater personal norms only relate to intention when PBC is low.

Flamm (2009) used a sequence of multiple regressions to study the impacts of environmental knowledge and attitudes on vehicle ownership and use on 1436 respondents of Sacramento in the USA. The outcome of the study suggested that households own more vehicles with increasing knowledge of the environment, while it is not associated with vehicle use. Both environmental knowledge and attitude are significantly and negatively related to annual miles driven and annual fuel consumption. Some households' cars also have a significant and positive effect towards annual miles driven and annual fuel consumption and have the largest effect on the former and the latter compared to the other variables, including the household income. Flamm pointed out that the association between environmental impact and behaviour enables vehicle ownership and usage to be reduced, provided that there are high-quality alternatives. The study also suggested that it is easier

for owners of vehicles to alter the vehicle types that they use than it is to change their actual travel behaviour, and that includes their trip frequency and miles driven.

Steg and Sievers (2000) examined the association among myths of nature, perceived and evaluation of environmental risks, strategies in managing, and risk-taking behaviour, and car use. The study was conducted on 413 Dutch respondents in September 1996 using an analysis of variance (ANOVA) test and Pearson's product-moment correlation. Based on the results, it was shown that there was a higher awareness of environmental problems, the need to travel fewer kilometres, and the need to shift to another mode of transport. It was noted that a sense of responsibility in terms of environmental belief is not significant but is rather geared towards policy-making in regulating the issues of concern. This study showed that individuals have different views on how they handle the problems of car use and stress and that the appropriate policies may only be effective when the beliefs and perceptions of the target group are taken into consideration.

Only a few studies have incorporated the use of TPB and/or NAM in determining travel behaviour in developing countries. Setiawan et al. (2014) studied car travelling behaviour on campus by integrating TPB and NAM in Surabaya, Indonesia. Khoo and Ong (2015) assessed the public acceptance of a sustainable transport system in the Klang Valley, Malaysia, using TPB. In the same year, Afroz et al. (2015) used TPB to study the purchase intention towards environmentally friendly vehicles in Kuala Lumpur, Malaysia. Some studies have utilised TPB to examine the behavioural intention to use public transport in different states in Malaysia (Ambak et al., 2016; Madha et al., 2016; Zailani et al., 2016). However, none of these studies have investigated the role of TPB and/or NAM in determining car ownership or car purchase intention in Malaysia. In addition, very limited studies have been done on TPB and/or NAM in terms of motorcycle ownership/motorcycle purchase intention in either developed or developing countries. This is rather surprising, considering the importance of motorcycles as the main mode of transport, particularly in developing countries.

Consequently, few studies have incorporated the psychological determinants of vehicle use based on TPB and/or NAM specifically in developing countries. That includes studies by Choocharukul and Fujii (2007), Choocharukul et al. (2008), and Setiawan et al. (2015).

Choocharukul et al. (2008) examined the psychological effects of travel behaviour on residential location choice by commuters based on 176 samples from two cities in Thailand, namely Bangkok and Ubon Ratchathani, by applying SEM. The results indicated that moral obligation, gender and the instrumental attitudinal aspect of a car influence the intention for a future life with frequent car use. Moral obligations for car reduction negatively influence the intention for future car use, while instrumental attitude (the pleasant, useful, attractive, friendly, convenient, and esteem components of a car) positively affects car use. The study also pointed out that those who prefer to engage in frequent car use in the future are less likely to stay in an environment with convenient public transport. The study incorporated only a few elements of TPB, such as attitude and intention towards car use, while not including social norms and perceived behavioural control.

Another study in an Asian developing country was conducted by Setiawan et al. (2015), who incorporated TPB and NAM to discover the effect of habit and car access on student behaviour in using cars to commute to campus. They included the altruism behaviour from NAM to complement for non-altruism from TPB as the former is known as being the primary driver in reducing car usage. The study examined 312 students from three university campuses in Surabaya, Indonesia, using a structural equation model (SEM). The study found that attitude, social norms, perceived behavioural control and personal norms explained 50 per cent of the behavioural intention. Meanwhile, behavioural intention, habit and car access explained 55 per cent of the variance of the actual car use. Personal norms was represented by reducing car use, moral obligations, and higher tax for car users. Attitude was represented by favouring driving cars, while social norms was represented by the influence of family, friends and peers as deciding factors for car use. The study, however, did not include socio-demographic and built-environment factors in explaining the characteristics of the students in the model, instead merely focusing on the psychological variables.

Based on the findings, it is evident that most of the psychology-based studies related to vehicle ownership and use took place in the context of developed countries rather than developing countries. Furthermore, there is scarce information on how psychological factors influence motorcycle ownership and use. As there could be a different psychological perspective for people in developing countries, as they have different socio-economic and cultural backgrounds as well as different transport services availabilities, it is imperative to conduct a study which incorporates the role of psychological factors.

2.4.4 Psychological Determinants of Motorcycle Ownership and Use

Following the reviews of psychological determinants of car ownership and use, this section presents the psychological factors affecting motorcycle ownership and use. Prabnasak and Taylor (2008) agreed with some studies that among the socio-economic variables, income plays the most critical role in shaping motorcycle ownership (refer to Section 2.3.3). In relation to this, there has been a changing pattern in the motorcycle literature, whereby in recent years the influence of psychological variables have slowly emerged as one of the key elements of motorcycle behaviour (Özkan et al., 2012; Huth et al., 2014; Marquet and Miralles-Guasch, 2016).

Marquet and Miralles-Guasch (2016) applied logistic and multinomial regression models to examine the predictors for motorcycle ownership and modal choice in Barcelona, Spain. The study identified that other than the objective factors, which include price, speed and the availability of parking, subjective factors, such as perceived freedom and ideology, are crucial in determining motorcycle use. Another study conducted by Huth et al. (2014) used focus group discussions with 42 participants to acquire insights on the nature of motorcycle riding in Austria. The key concerns that emerged the findings included riders' behaviour, the interaction between riders, environmental hazards and safety concerns. Huth et al. (2014) pointed out that social norms are the most powerful predictor for riders, behavioural intention in terms of speeding, and the usage of assistance systems. However, the findings on behaviour have been identified as a result of small-scale surveys, and they may differ in the case of a larger sample, thus resulting in a gap in the literature that needs to be addressed.

This reveals the literature gap, particularly in the context of developing countries. Not much evidence can be found to explain the relationship based on psychological factors towards motorcycle ownership in particular. Thus, studies for both car and motorcycle in the context of developing countries need to be addressed under consideration of their socio-economic gap with developed countries as it suggests that they may experience a different effect in terms of the psychological perspectives towards travel behaviour decision-making. The inclusion of TPB and NAM serves to better understand the role of psychological factors in the thesis in addition to the role of socio-economic and psychological factors. For instance, if there is a significant relationship with social norms, policies which relate to the component should be revised in such a way as to influence vehicle ownership.

In summary, there is a growing body of literature on the determinants of motorcycle ownership. Interestingly, there are more disaggregate based studies in comparison with aggregate based studies. The aggregate studies were conducted mainly in Southeast Asian developing countries, particularly in Taiwan, Indonesia, Vietnam and Malaysia, which have a high level of motorcycle ownership. Despite this, there are very few studies on motorcycle use. The review also pointed out that there are very limited studies on the psychological determinants of both motorcycle ownership and use, which highlights the need to understand the human aspect of motorcycle ownership and use in these regions. Apart from having socio-economic, built-environment and psychological factors as the determinants, car ownership may also be the determinant of motorcycle ownership, and vice versa.

2.5 Chapter Conclusion

This chapter has summarised the modelling approaches, the theoretical backgrounds and the determinants of private vehicle ownership and use, specifically the socio-economic, built-environment and psychological factors. In summary, the literature has recognized three main gaps addressed by the study:

- First, there are limited number of studies on the role of psychological factors in determining motorcycle ownership and use. Previous studies mainly focused on car ownership and use, particularly in developed countries.

- Second, there are few studies on the interdependency between car and motorcycle ownership. To date, studies were conducted only in some cities in Asian developing countries.

- Third, a gap in the literature has been identified in that there are very few studies using joint modelling which features both car and motorcycle ownership and use in a single integrated framework. Thus, joint models integrating car and motorcycle ownership and use are very few for both developed and developing countries.

According to the literature, socio-economic factors serve as a universal determinant for vehicle ownership and use for both developed and developing countries, whether using aggregate or disaggregate based modelling. Most of the studies indicated significance by including socio-economic factors, particularly income, in determining vehicle ownership. It is noted that socio-economic (income, fuel price etc.) and built-environment factors (accessibility, distance, road network etc.) are the precursors to determining private vehicle ownership and use. However, the problems of data availabilities and quality in developing countries have always been one of the main hurdles in developing a model. The inadequate amount of public data available for these countries causes a limited number of variables to be included in the models.

The previous results also suggest that those with a higher income tend to have high car ownership, while there is a negative association between income with motorcycle ownership. The role of the interdependency between car and motorcycle ownership has been discussed, and the need for private vehicle ownership and use modelling has been highlighted. However, very few studies have discussed motorcycle ownership, particularly in developed countries, although motorcycles are considered as a substitute to cars in the developing world. This is because the public transport in many developing countries is not sufficient or reliable enough to cater to the demand for transport. In addition, motorcycles are also considered a less expensive private vehicle option and are less prone to traffic congestion.

Considering the above interdependency is crucial to configure the link between these two private modes of transport. Studies in recent decades have

identified that most of the car-motorcycle ownership interdependency in developing countries has been found using disaggregate modelling, with a substitution relationship shown between both. Hence, it is essential to explain these two variables in the modelling, especially when the motorcycle is considered as an essential mode of transport in developing countries. Therefore, the role of joint modelling, as discussed previously, could bridge the gap in the studies. Therefore, given the issues with data constraints and the limited number of relevant studies, a time-series model is conducted to provide insight into current private vehicle ownership at the aggregate level (without aggregate vehicle use), while cross-sectional vehicle ownership and use modelling is performed using primary data obtained through the researcher's survey at the disaggregated level for the thesis.

Apart from the above-mentioned explanatory variables, the psychological factors have also been highly considered by some of the previous studies in vehicle ownership and use models, considering the importance of human psychological values in travel decision-making. Based on the meta-analysis by Armitage and Conner (2001), social norms are found to have a weaker correlation with intention compared to other factors in TPB. This is supported by van den Putte (1991), leading to the exclusion of social norms in some studies applying TPB in their frameworks. However, these studies often only included a single item/indicator to represent social norms, which may not adequately measure them. Other crucial results from Armitage and Conner (2001) also indicate that PBC has the strongest association with the intention, which shows that the greater PBC, the greater the intention to perform the action. Perceived behavioural control is seen as a factor that has greater direct and indirect impacts on car ownership due to its ability to control a person’s actions.

Although the use of psychological variables provides an advantage, such as better explanatory power in the modelling, their inclusion is not without concern. Studies which examined the role of psychological factors mostly used disaggregate models rather than aggregate models. This is because of the difficulties of incorporating the psychological model in aggregate models as the nature of the data itself represents an individual level rather than the national level. The inability of many developing countries to provide sufficient data, particularly disaggregate data, adds to the lack of studies incorporating psychological variables.

Chapter 3

Case Study Approach

3.1 Introduction

While the previous chapter presented the literature review on vehicle ownership and use modelling, the purpose of this chapter is to introduce the case study used to test the hypotheses in this study. The chapter defines the scope and limitation of the case study and discusses the background of the case study area for the thesis, which is Sarawak, Malaysia. This chapter is divided into four sub-sections. The first sub-section elaborates on the socio-economic characteristics of the case study area. The second sub-section describes the level of motorisation in Malaysia (and the Asian developing region), which includes the proportion of passengers by transport type in Malaysia, modal split by country, mode share by public-private transport as well as vehicle ownership and traffic fatalities in Malaysia. The third and fourth sub-section discusses car ownership in Malaysian urban and rural areas as well as vehicle usage. The final section summarises the overall outline of the study approach and the expectations of the adopted research strategy.

3.2 Case Study Site: Sarawak, Malaysia

To further understand the demand for car and motorcycle ownership and use, Sarawak, a state in a developing country, is selected as the case study site. The case study site selection is characterized by several features in this thesis, namely (i) the socio-economic characteristics, (ii) the level of motorisation, (iii) car ownership in Malaysian urban and rural areas, and (iv) vehicle usage, which will be elucidated in the next sub-section.

3.2.1 Socio-Economic Characteristics

The state of Sarawak is situated on the island of Borneo in the eastern part of Malaysia and is geographically the largest state in the country. Sarawak's land area is approximately 124,449.5 km^2 and the state is positioned north of the equator, between latitudes 0^o 50' and 5'N and longitudes 109^o 36' and 115^o

40' (refer to Figure 3.1). Sarawak borders Brunei Darussalam to the north and its border to West Kalimantan is characterised by high peaks and highlands; Sabah, another Bornean state of Malaysia, is to the northeast. Sarawak, along with Sabah, is separated from Peninsular Malaysia by the South China Sea (SPU, 2013). Sarawak has a population of 2.71 million residents and encompasses 11 main divisions and 31 districts. The divisions consist of Kuching, Samarahan, Sri Aman, Betong, Sarikei, Sibu, Mukah, Bintulu, Kapit, Miri and Limbang. The capital of Sarawak is known as the Kuching division.

Source: Google, (2019).

Figure 3. 1 Map of Sarawak.

The present economic situation in Malaysia and Sarawak is shown in Table 3.1 and Figure 3.2. The population density in Sarawak is 21.78 per km^2, while the total number of households is 540,999. The low population density of Sarawak is due to Sarawak's vast area, comprising more than one-third of the entire area of Malaysia. According to Table 3.1, the labour force in Sarawak is 1.3 million, while the unemployment rate is 3.5 per cent, which is higher than the total Malaysian rate of unemployment of 3.1 per cent. The per capita income for Sarawak is USD 8,458 per annum, lower than the Malaysian annual per capita income of USD 10,588.30. The key economic activity of Sarawak consists of industry based on petrochemical energy, hydropower, tourism and agriculture (SPU, 2011). This is consequential due to its influence on the Malaysian economy by providing supplies of energy to both the domestic market and the global market (exports), which represent an important component in the country's trade balance (OBG, 2015).

In 2017, the Department of Statistics, Malaysia, recorded Sarawak as having the fourth-highest GDP per capita in the country (USD 12,403), behind Kuala Lumpur, Labuan and Penang. However, in terms of the overall GDP, Sarawak is the third highest after Selangor and Kuala Lumpur. The economic significance of Sarawak in Malaysia shows that there is high economic activity and hence, a sizeable demand for travel needs and mobility.

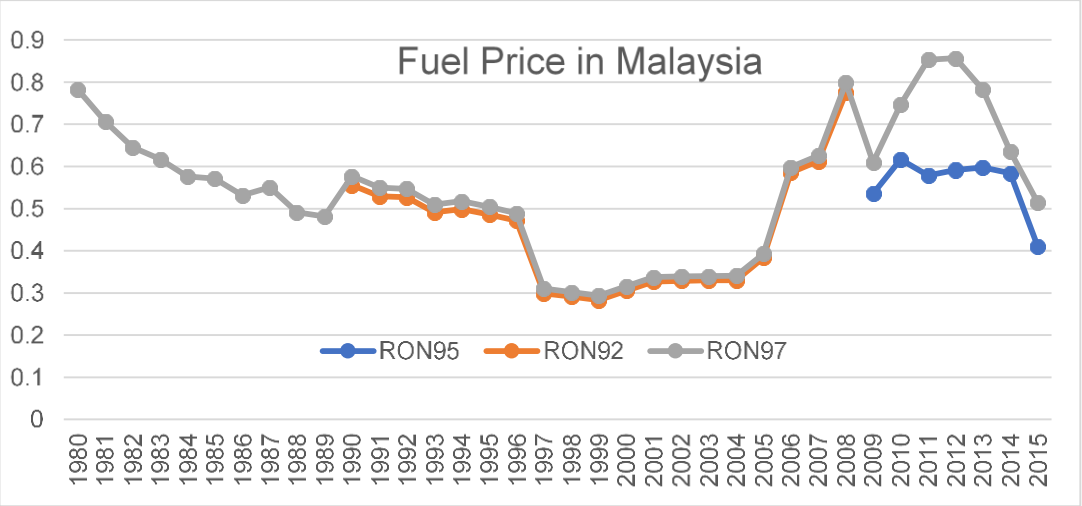
Table 3. 1 Summary of Indices in Sarawak.

	Sarawak	Malaysia
Population (million)	2.71	31.0
Population density (per km^2)	21.78	93.71
Area (km^2)	124,449.5	330,803
Number of Households	540, 990	6, 341, 273
Labor Force (million)	1.3	14.5
Employment (million)	1.1	12.2
Unemployment Rate (%)	3.5	3.1
Per capita Income (USD)	10,588.3	8,458.0
Exports (USD billion)	20.9	181.8
Imports (USD billion)	8.3	159.8

Source: Sarawak State Planning Unit (2015). All figures are from 2015 except for several household data which is based on the 2010 census.

The increasing trend in motorisation is further enhanced by the ability of the citizens to buy fuel at affordable prices due to petrol subsidisation in these past few decades (Begum et al., 2015). Figure 3.2 indicates the trends for the three fuel categories, which are RON97, RON95 and RON92 in Malaysia (MTCC, 2016; MTCC, 2019). The fuel price data pre-1980 is not presented due to data inaccessibility. Malaysian fuel prices have been considerably subsidised since 1983 (International Institute for Sustainable Development, 2013), and it is estimated that USD4.45 billion, (2.45% of GDP), was spent on fossil fuel subsidies by Malaysia in 2009. Petrol, diesel and liquefied petroleum gas (LPG) prices have been set by the Automatic Pricing Mechanism (APM) since 1983. RON92 was discontinued to pave the way for RON95, with a higher and better quality research octane number (the higher the octane number the more compression the fuel can withstand before detonating). According to Figure 3.2, one of the predominant declines in fuel price occurred throughout the Asian Financial crisis, whereby the price of RON97 and

RON92 dropped by 37 per cent and 36 per cent from 1996 to 1997, respectively.



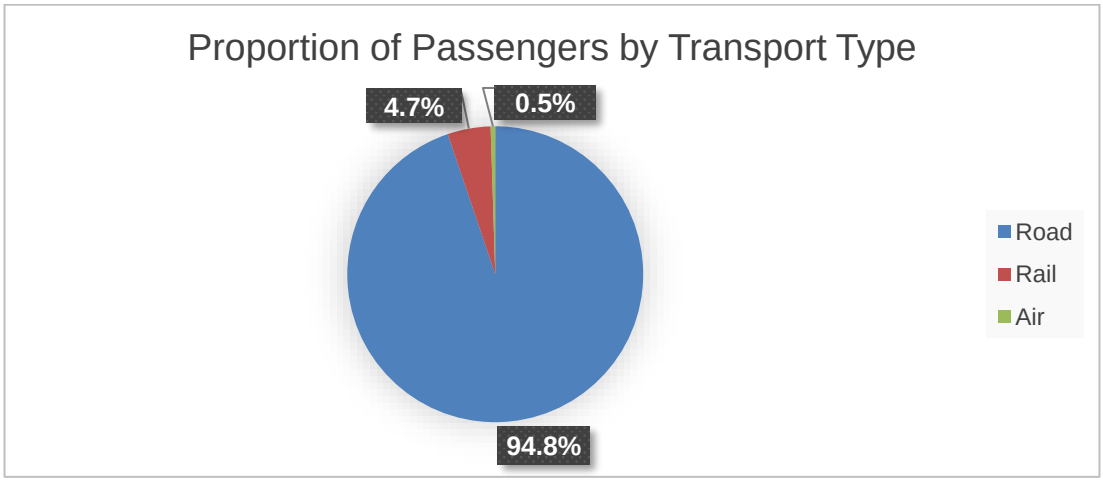
Source: Ministry of Trade, Cooperatives & Consumerism (MTCC, 2016). [a]RON: Research Octane Number. RON 97, RON 95, and RON92 are the types of fuel based on the types of octane rating measurement. RON 97 is considered the premium fuel with higher octane while RON 95 and RON92 is regarded as the regular unleaded lower octane fuel. The fuel price data are adjusted to CPI (base year = 2010) and in USD per litre.

Figure 3. 2 Fuel Price in Malaysia by Fuel Type (1980-2015).

Another substantial drop of 24 per cent can be found from 2008 to 2009, mainly due to the Global Financial crisis. The price then increased to a peak in 2012 for RON97 (USD 0.6 per litre) and 2013 for RON95 (USD 0.86 per litre). The substantial drop in fuel price post-2013 is generally due to the supply glut driven by US shale oil production and the post-sanctions emergence of Iranian oil production. The subsidisation for RON97 lasted until September 2009, since which the fuel price has been floated according to the international market price. There were further reductions in the fuel subsidies for RON95 and diesel in 2014 via the managed floating system in order to adjust the current account deficit, leading to a USD3.4 billion in savings for the government. Notwithstanding the fuel price fluctuations and the incessant upsurge in Sarawak's GDP over the past four decades, the number of cars and motorcycles is found to be continuously increasing. Henceforward, the next section presents the characteristics of the case study site selected for the thesis.

3.2.2 Level of Motorisation

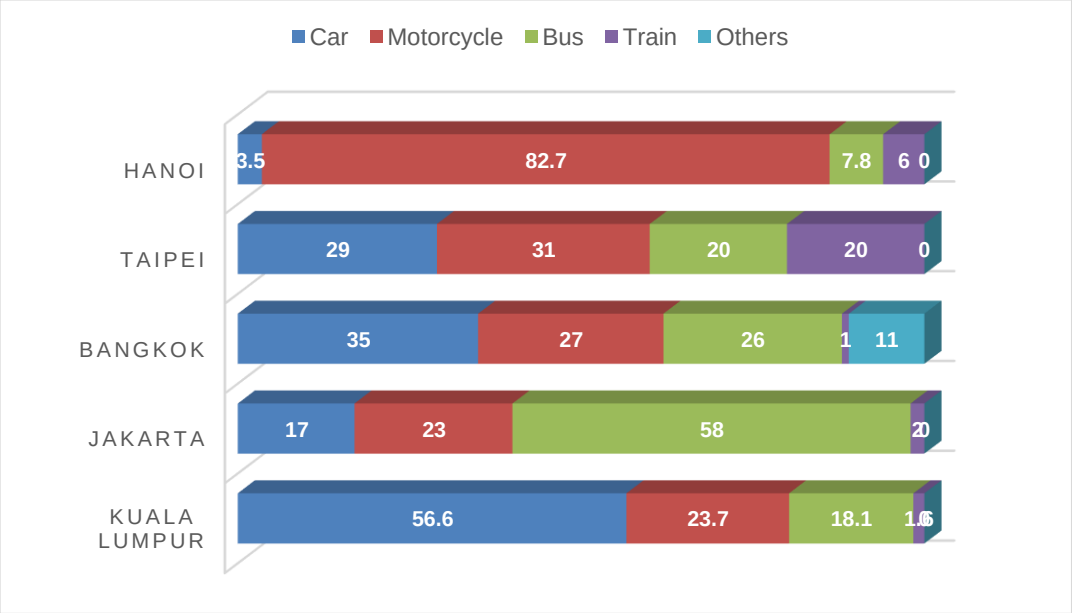
The substantial growth in motorisation is arguably an essential factor determining mobility and accessibility in developing countries. In addition, several studies have indicated a positive association, whereby economic development leads to higher demand for motorisation (Hensher et al., 1990; Button et al., 1993; Chin and Smith, 1997). Ingram and Liu (1999) stated that there is a significant relationship between income and the level of motorisation. To understand this pattern, we begin with the identification of the most observed transport type. This is depicted in Figure 3.3, which presents the proportion of passengers by transport type. Road-based transport (including cars, motorcycle and buses) is found to have the highest number of passengers as it is the most viable type of transportation in Malaysia. The figure shows that road-based transport accounted for 94.8 per cent of all passengers in 2006, followed by rail with 4.7 per cent and air transport with 0.5 per cent. The rail transport infrastructure is not fully developed in all states in Malaysia and is mostly developed in Kuala Lumpur, the Malaysian capital, it which explains why road-based transport is the primary type of transport in other states. In brief, there is a high percentage of road-based transport compared to other transport types, as seen in Figure 3.3.



Source: Public Works Department (KKR, 2006).

Figure 3. 3 Proportion of Passengers by Transport Type in Malaysia.

Following that, Figure 3.4 presents the mode split between private and public transport vehicles for road transport in 2007. Since the data for modal shares are not available for the whole of Malaysia, and Sarawak in particular, the mode share statistics are only shown for Kuala Lumpur. In Kuala Lumpur, car share has remained the highest at 56.6 per cent of total motorized trips despite being the state with the best public transport infrastructure, including improved LRT lines as well as a dense bus network. In contrast, Jakarta has the highest mode share by bus, with 58 per cent of total motorized trips. Meanwhile, Hanoi recorded the highest percentage for motorcycle share, accounting for 82.7 per cent of total motorized trips as a result of poor public transport infrastructure. Sizeable percentages of motorcycle trips were found in Taipei (31 per cent), Bangkok (27 per cent), Jakarta (23 per cent) and Kuala Lumpur (23.7 per cent), which indicates that the motorcycle remains the important mode in the region.

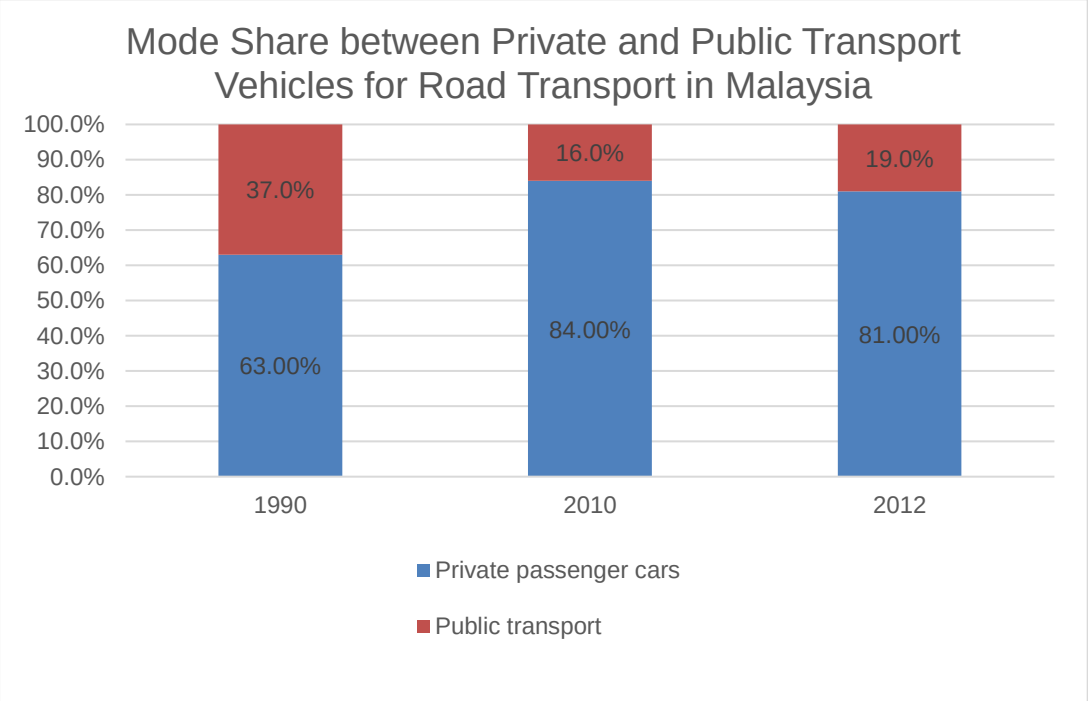


Source: Tuan (2015).

Figure 3. 4 Modal Split in Developing Asian Countries.

Based on Figure 3.5, in the capital Kuala Lumpur, the share of private vehicles is found to be higher than that of public, and the percentage increased from 1990 to 2012. The share for public transport vehicle decreases from 37.0 per cent in 1990 to 19.0 per cent in 2012. The share for public transport declined as a result of a deficiency in bus services as well as greater personal wealth, which led to an increase in car ownership (DBKL, 2002). This shows that the

demand for private-based transport has substantially risen over the past few decades. Furthermore, as presented in Figure 3.4, there is a high car and motorcycle share among the modes of transport. Subsequently, lowering the negative externalities (e.g. traffic accidents) is a common social challenge for these countries. For this purpose, a case study using Sarawak, a state in Malaysia, is used to further explore the issue. Based on Table 3.2, it is indicated that Sarawak possesses almost similar characteristics with the abovementioned cities in terms of the income, car and motorcycle ownership, and motorcycle fatalities.



Source: Land Public Transport Commission (SPAD, 2013). Mode share = percentage of journeys made by land-based public transport (including bus and rail) in Kuala Lumpur (the Malaysian capital).

Figure 3. 5 Mode Share between Private and Public Transport Vehicles for Road Transport in Malaysia.

Table 3. 2 Vehicle Ownership in Various Asian Developing Countries.

States/ Cities in Asian Developing Countries	GDP per capita (USD)[a]	Car Ownership per 1,000 inhabitants[a]	Motorcycle Ownership per 1,000 inhabitants	Motorcycle Fatalities per 100,000 inhabitants[e]
Bangkok	8,216	330	206[c]	5.4
Hanoi	2,788	18	107 [c]	4.7
Jakarta	3,975	203	196 [c]	2.2
Sarawak	10,776	206[b]	196 [b]	6.4[b]
Kuala Lumpur	13,816	314	230 [b]	4.6
Taipei	30,942	253	532 [d]	10.6

Source: [a] Kodukula (2011); [b] Own calculation using data for the year 2008 from Department of Statistics, Malaysia (DOSM, 2017a) (2017); [c] Senbil et al. (2007); [d] Hsu et al. (2003) [e]Abdul Manan and Várhelyi (2012).

The selection of Sarawak as a case study area was undertaken to understand the determinants of car and motorcycle ownership and use as no similar study has thus far been conducted from the context of a city or state in an Asian developing country, particularly with the inclusion of psychological factors as the explanatory variables. In comparison with other states in Malaysia, Sarawak is the fourth most populous state after Selangor, Johor and Sabah, and had a population of 2.47 million in 2010 (DOSM, 2010). Based on the statistics, the total population of Sarawak grew by 19 per cent from 2000 to 2010. Hence, this study is imperative considering that the rising population in the area would indicate that direct demand for private vehicles, particularly cars and motorcycles (Potoglou and Kanaroglou, 2008), is also likely to grow. During this period, car ownership showed a growth of 144 per cent, while motorcycle ownership showed a growth of 85 per cent.

The selection of specifically urban areas in Sarawak for the disaggregate model is driven by the size of the urban population, which reached 53.8 per cent in 2010, up from 48.1 per cent in 2000, out of the total population. Technically, the rise in the urban population is due to rural-urban and urban-urban migration, which are driven by income and job opportunities. Tey (2014) suggested that the pull factors driving migration are because of

industrialisation as well as enhanced infrastructure and amenities (road services). This means that car and motorcycle ownership is higher in urban areas compared to rural areas; this is in contrast to Dargay (2002), who stated otherwise. It seems possible that this is because of the inadequate public transport in developing countries compared to developed countries, as Dargay (2002) used UK data. According to a study by Borhan et al. (2019), a number of reasons were identified as to why the public bus is a less attractive model of transport in Putrajaya Malaysia. These included factors such as (i) a lack of service during off-peak hours, (ii) the frequency and punctuality of buses, and (iii) accessibility to public transport. These factors lead to dependency on a private mode of transport.

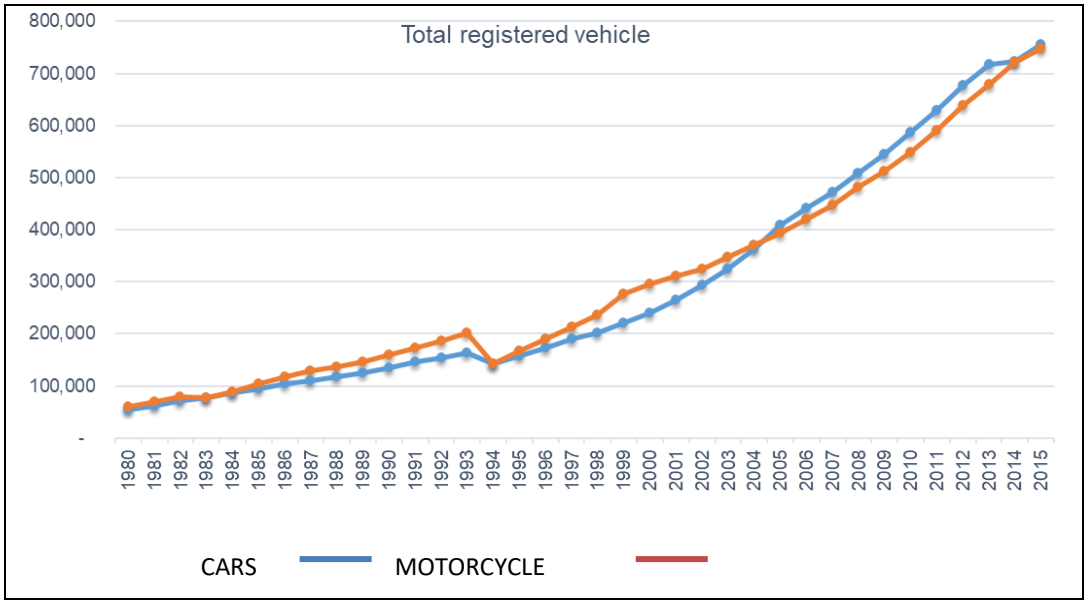
In a study by Kamba et al. (2007), they found that high traffic congestion and delays are the main factors discouraging car users from using public transport in Kuala Lumpur. The study also identified factors that encourage the use of cars, including (i) less travel time, (ii) desirable routes not covered by public transport, and (iii) infrequent public transport service. On the other hand, the continuous high level of motorcycle growth is triggered by three main factors according to Senbil et al. (2007), including (i) tropical or sub-tropical climate regions, (ii) promising economic and institutional infrastructure alongside adequate industrial capacity, and (iii) high-density urban forms and insufficient road space in certain areas.

Currently, car and motorcycle ownership in Sarawak are rather high, at 336 cars per 1000 inhabitants and 329 motorcycles per 1000 inhabitants, although this is not as high as the national average (480 cars per 1000 inhabitants and 467 motorcycles per 1000 inhabitants) (Source: Author’s own calculation using 2010 data). The significant increase in both car and motorcycle ownership implies that a continuous rise will lead to negative externalities, such as traffic congestion, accidents and environmental pollution. To deal with traffic issues, the relationship between car ownership and motorcycle ownership should also be examined by understanding the household owning behaviour in the case study area. Sarawak, in particular, is an appropriate case study area with a high car and motorcycle ownership in the case of an Asian developing country.

Private vehicle ownership in Malaysia, a developing country, is among the highest in the world. In the decade from 2008 to 2017, Malaysia experienced a substantial increase in vehicle ownership, namely 70 per cent for total registered cars and 55 per cent for total registered motorcycles, both considerably higher than the population increase of 16 per cent (CEIC, 2019). In terms of motorcycles per capita, Malaysia is ranked second after Vietnam, with 332 motorcycles per 1000 population (Sultan et al., 2016). In 2010, the country ranked behind Indonesia as the eighteenth country in terms of the number of registered cars in the world. However, in terms of the global motorisation rate, Malaysia ranked thirty-sixth in 2011, with 334 cars per 1000 inhabitants, while Brunei ranked fifth, with 696 cars per 1000 inhabitants. The statistics show that Malaysia has a very high level of private motorisation for both cars and motorcycles.

Despite its statistical significance, very few works of literature are found on car and motorcycle ownership in Malaysia, particularly for the latter, which suggests that further research is needed. For this reason, Sarawak in particular is selected as the case study site. Other than its economic contribution to Malaysia (refer to Section 3.2.1), the high level of car ownership, as shown in Table 3.2 and Figure 3.6, justify choosing Sarawak as the case study site for the thesis. Overall, all states in Malaysia are found to have a very high level of private car ownership (Figure 3.9); this is supported in the case of Sarawak, which has experienced a substantial rise over the past few decades, as depicted in Figure 3.6. There was an increment of 61 per cent of total registered cars, and 68 per cent of total registered motorcycles from the period of 2008 to 2017 (CEIC, 2019).

The increment is found to be lower for cars but higher for motorcycles during the same period in comparison with the overall Malaysian statistics. Presumably, both modes of transport are seen as having equal importance in the road users' travel activities as Figure 3.6 indicates that there is no substantial difference between the number of registered cars and motorcycles. This raised questions as for whether cars and motorcycles are complementary or substitutes in the case of Sarawak.

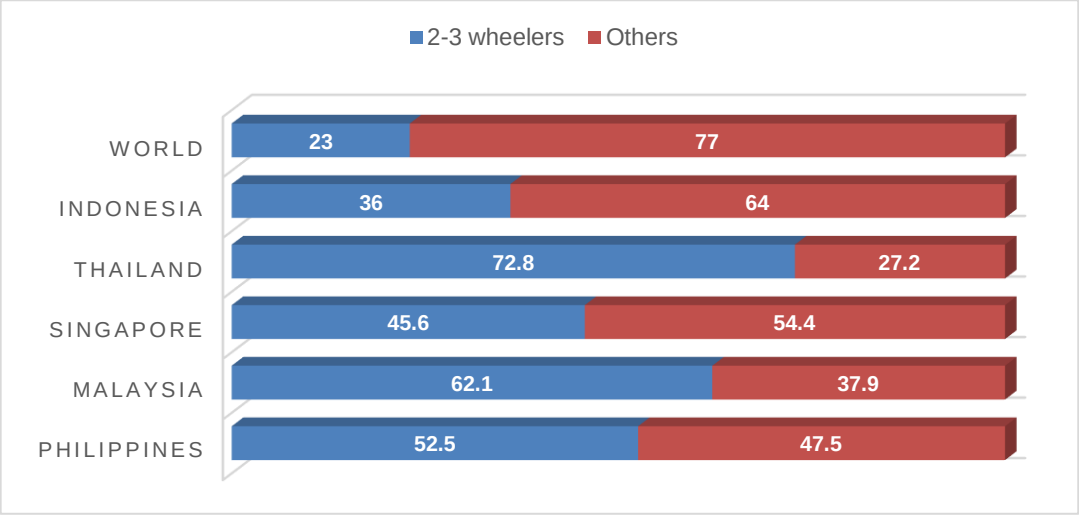


Source: Department of Statistics, Malaysia (DOSM, 2019). The number of vehicles is given in units.

Figure 3. 6 Total Registered Vehicles in Sarawak (1980-2015).

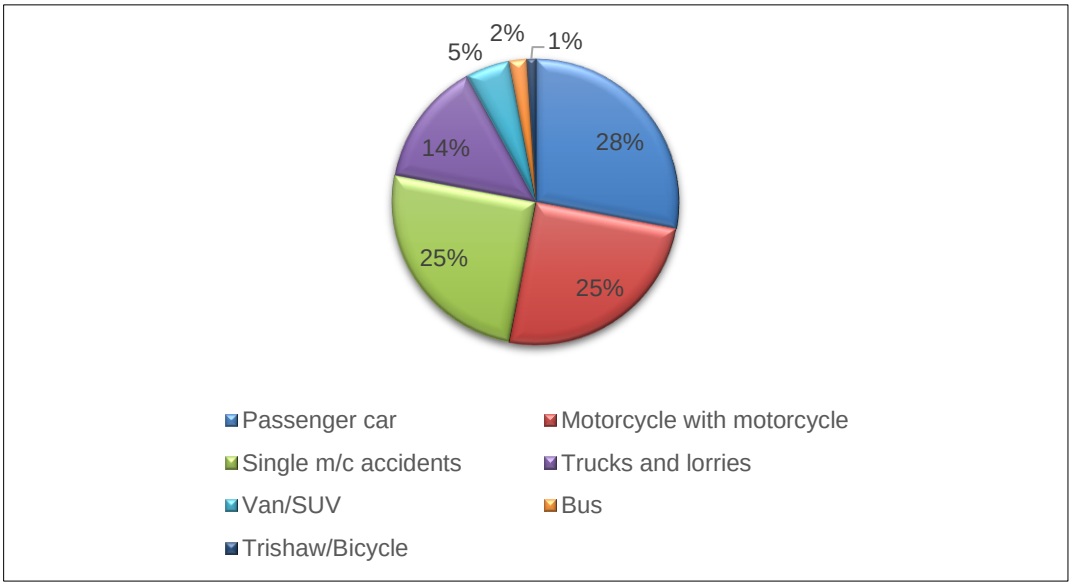
One of the concerning transport-based negative externalities in Asian developing countries is the problem of road accidents. Based on the World Health Organization (WHO, 2015), approximately 90 per cent of worldwide road traffic accidents take place in low- and middle-income countries, with approximately 74 per cent coming from low-income countries. Furthermore, the populations of these countries account for roughly 54 per cent of global vehicle ownership. According to the WHO (2015), the negative externalities, specifically traffic accident fatalities, are commonly caused by motorcycle or three-wheelers. These figures are found to be very high, particularly in the Asian developing countries such as Thailand, Malaysia and the Philippines (Figure 3.7). Malaysia recorded 62.1 per cent of traffic accident fatalities as being by two or three-wheelers, which is very high compared to the world average of 23 per cent. However, Thailand has the highest traffic accident fatality rate in the ASEAN region, with 72.8 per cent. The gravity of the issue is becoming a regional matter, considering the continuously rising level of car and motorcycle ownership in these countries. According to Abdul Manan and Várhelyi (2012), motorcycles contributed the most to road fatalities in Malaysia. Furthermore, they stated that the fatality rate per distance travelled in 2004 was 32.2 fatalities per billion kilometres for motorcycles compared to cars at 8.39 fatalities per billion kilometres. This is very alarming considering the rising level of motorcycle ownership over the past few decades (refer to Figure 3.6). In addition, they also highlighted that 61 per cent of accidents

occur in rural areas, while 39 per cent accidents occur in urban areas. Figure 3.8 presents the distribution of motorcycle fatalities by collision according to vehicle type in 2013. Passenger cars accounted for the highest percentage of collisions, at 28 per cent. This is followed by motorcycle on motorcycle collisions, with 25 per cent of collisions. About 25 per cent of collisions were single motorcycle accidents that did not involve other vehicles. Finally, trucks and lorries contributed to 14 per cent of collisions.



Source: World Health Organization (WHO, 2015).

Figure 3. 7 Traffic Accident Fatalities in ASEAN Countries by Mode of Transportation in Percentage (2013).

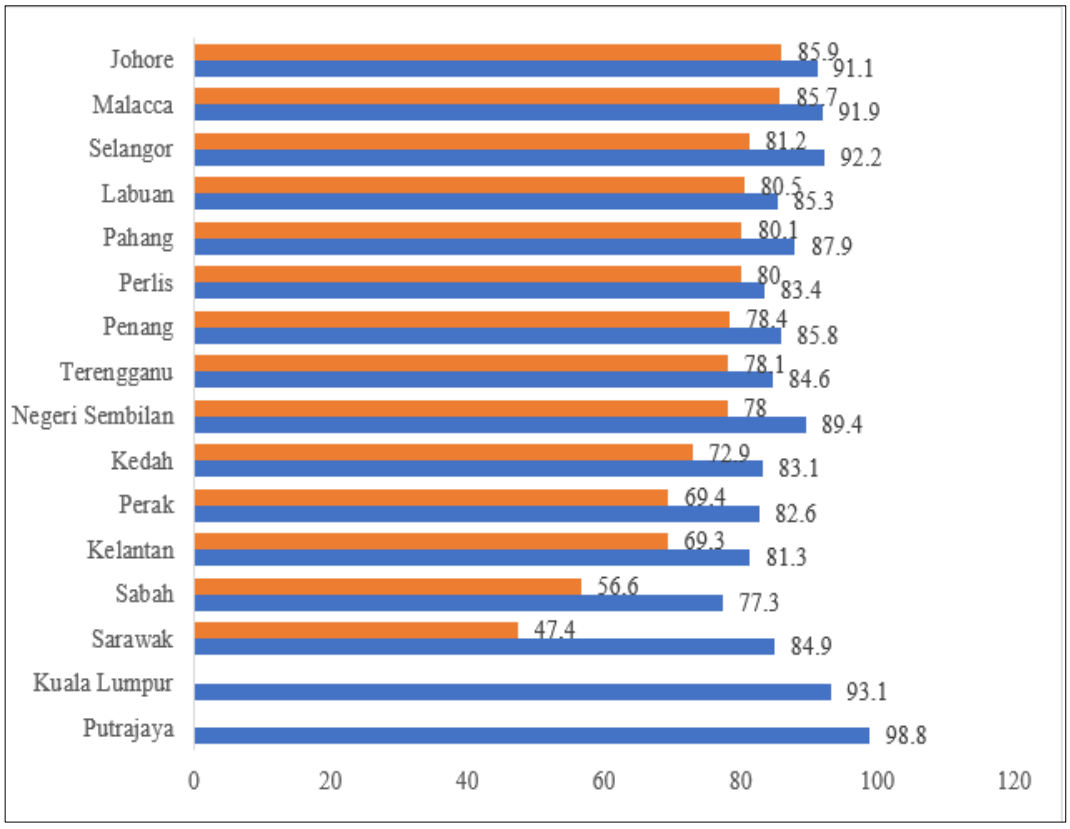


Source: Abdul Manan and Varhelyi (2012).

Figure 3. 8 Motorcycle Fatalities by Collision with Vehicle Type.

3.2.3 Car Ownership in Malaysian Urban and Rural Areas

In addition to the interdependency between car and motorcycle ownership, it is necessary to compare the level of motorisation from urban and rural perspectives. Figure 3.9 shows the percentage of car ownership in Malaysian rural and urban areas by states. Overall, it is evident that there is a high level of car ownership in all Malaysian states, and Sarawak is no exception. The highest level of car ownership is in Kuala Lumpur and Putrajaya, with 98.8 per cent and 93.1 per cent, respectively. Figure 3.9 also indicates that some of the urban regions in Sarawak are more car-dependent than some of the other urban regions in the state. Compared to other states, Sarawak shows the most significant difference between car ownership in urban vs rural areas, with 84.9 per cent and 47.4 per cent, respectively.



Source: Department of Statistics Malaysia (DOSM, 2016).

Figure 3. 9 Percentage Household Car Ownership in Malaysian Rural and Urban Areas (2014).

The difference in the standard of living between urban and rural areas causes car ownership to be higher in urban areas as rural residents are less likely to be able to afford the cost of owning and maintaining a car. A lower income in

rural areas might be attributed to the engagement in low-productivity and low-income jobs, either in agricultural activities or as low-skilled factory and construction workers and low-grade government employees (Shari and Osman, 1996).

3.2.3.1 Cost of Motorisation

According to Kasipillai and Chan (2008), the factors that contribute to the growing number of vehicles in Malaysia are population size, disposable income, fuel subsidies and decentralisation. Other than that, other contributing variables are the existence of several car assembly facilities and the participation of Malaysia in car production. Furthermore, the establishment of domestic car manufacturers, such as PROTON and PERODUA, has strengthened the car market as the locally produced cars are exempted from import duties, which are approximately between 140 per cent and 300 per cent (Mohamad and Kiggundu, 2007). Therefore, although imported cars are costly, users can be able to purchase locally made cars at a lower cost. However, individuals from a lower income level, particularly those in the rural areas, may opt for the motorcycle as their mode of transport.

Dargay (2002) stated that the rising cost of the car as a mode of transport poses a considerable economic burden for rural households. Therefore, given the low income of rural households and the rising cost of motoring, it is understandable that there is very low car ownership compared to urban Sarawak and Malaysia in general. In addition, Tanninen (2013) indicates that smaller cities are associated with car payment difficulties, and this has also been demonstrated in the research by Lim and Siew (2017), which highlighted that borrowers who reside in rural areas tend to have more car loan defaults compared to those in urban areas.

3.2.3.2 Road Transport Infrastructure

Apart from the cost of motorisation, road transport infrastructure is another factor that has led to a high level of car ownership in Sarawak's urban areas. The increasing road expansion further substantiates the growth in car and motorcycle ownership. An example is the construction of the Pan Borneo Highway, which stretches over 2,083 km connecting Sarawak, Sabah and Brunei. This project provides not only better road infrastructure for the inter-

state (Sabah-Sarawak) and inter-country (Malaysia-Brunei) networks but also allows for an improved connection between urban and rural areas within Sarawak, hence encouraging motorisation.

According to Cervero (2013), the concentration of wealth in main cities has paved ways for the concentration of public infrastructure developments, which includes automobiles and road lengths. This may align with the current road infrastructure (or lengths) in rural areas, which are not all at full/good capacity to accommodate the car usage, leading to lower demand for car ownership. As there is high car ownership in urban areas compared to rural areas, the case study site of this thesis will be focusing on the determinants of car and motorcycle ownership and use in urban Sarawak.

Based on the Department of Statistics Malaysia (DOSM, 2016), the length of the road network in Malaysia in 2000 was 66 thousand km. By 2009, the total road length in the country had increased by 104 per cent to 135 thousand km, while the length of paved roads rose by 116 per cent. Approximately 80 per cent of the total road network is paved throughout Malaysia. Naidu (2008) explains that the main intercity roads in Peninsular Malaysia are generally two or multiple-lane dual carriageways. Moreover, the 869 km North-South Expressway from Padang Besar (Thailand border) to Johor Bahru (Southern Peninsular Malaysia) is one of the examples of significant road network development in the country. Also, the private sector is much involved in the construction of intercity and urban roads, such as the Build-Operate-Transfer (BOT) projects and toll roads.

Major constructions in building and improving the road network have been undertaken in Sarawak. In 2009, the length of the road network had increased by more than 200 per cent to 20 thousand km from the year 2000, when there had been only 6 thousand km in the road network. Furthermore, the road surface type in Sarawak was 73 per cent paved in 2009, representing an approximately 298 per cent increment from 2000 and indicating a significant improvement in road network construction. In Sarawak, the high level of private motorisation is not just for car ownership but also for motorcycle ownership. In terms of the road infrastructure, the highly dense and narrow conditions of the roads in general discourage car driving in the CBD.

Furthermore, it is not difficult to search for parking spaces for motorcycles as less area is required compared to cars (Tuan, 2015). In the case of Sarawak, car users need to place a paid coupon ticket for parking in their cars, which implies a cost that is not required for motorcycle users. Therefore, road users tend to prefer motorcycles as they are easier and less costly in terms of parking areas compared to cars. The disparity in terms of road network development also contributes to a higher level of motorisation in urban areas. In rural areas, certain places are highly inaccessible via road, which leads to another mode of transport, including water transport, walking and motorcycle. Therefore, car ownership is lower in rural areas compared to the urban areas in Sarawak.

3.2.3.3 Congestion and Inadequate Public Transport

Statistically, motorcycles are one of the predominant modes of transport in Asian developing countries such as Indonesia, Thailand, Vietnam, and Malaysia. Meanwhile, motorcycle demand in developed countries is essentially based on leisure purposes and as a status symbol rather than as a form of transport (Jamson and Chorlton, 2009). This condition is different from Asian developing countries, which favour motorcycles as their main transport mode for numerous reasons, such as manoeuvrability on congested roads, low purchasing price, and fuel-efficiency (Hsu et al., 2003). Motorcycles are considered as the main mode of transport for Asian developing countries due to the underdeveloped road infrastructure and restricted access to particular parts of the country, specifically rural areas (Sohail et al., 2006; Abuhamoud et al., 2011). In Sarawak, motorcyclists can best commute during peak hours when the traffic is highly saturated. However, the drawbacks can include very few designated lanes for motorcycles and the risk of accidents as there are currently no regulations or designated lanes for heavy good vehicle road access in Sarawak.

Based on a study by Rasagam (1999), the insufficient capacity, poor dependability and low quality of public transport are the key issues that lead towards a greater dependency on private-based transportation. In the case of Sarawak, the low service level for public transportation is one of the motives for utilising a private mode of transport, such as motorcars and motorcycles. Lim et al. (2007) supported this and explained that public buses are considered as the less preferred mode of transportation in Sarawak as the

public buses system is regarded as poor and needs to be improved in terms of its punctuality and reliability. Public buses are the only public mode of transport available in Sarawak. Therefore, issues such as a lack of public transport services and quality, in terms of, e.g., the number of routes, availabilities of bus stops, and the frequency of buses, may prevent road users from riding buses as this may negatively influence their daily travel activities. Another notion for high car ownership in urban Sarawak in particular is the car-dependent culture.

3.2.3.4 Car-Dependent Culture

Another issue highlighted is the rising car-dependent culture, which causes a continuous rise in the car ownership demand. Tseu (2006) explains that the high dependency on private-based vehicles is because of the behaviour of the Sarawakians' themselves, who prefer to commute with private modes of transport rather than use public transportation. Tseu (2006, pp. 1) mentions the "car dependency in the city of Kuching, where rapid motorisation in the last thirty years and the spread of low-density suburban settlement patterns have seriously undermined and diminished the role of public transport and created unacceptable social and physical environmental problems". Tseu further elaborates that the progress in Sarawak towards a more car-oriented culture has caused a shift to cars as this is considered the more reliable and efficient mode of transport.

3.2.4 Vehicle Usage

When there is a continuous rise in economic activities, complemented with a car-oriented transport infrastructure, higher car dependency generally leads to higher value for kilometres travelled by road users. For the Malaysian case, each state may have different transport infrastructure. Table 3.3 presents the annual vehicle kilometres travelled according to the states in Malaysia in 2013. The yearly average car kilometres travelled (AAKT) was recorded as 24,129 km in 2013, whereby there was an increment of 26 per cent from the value of 19,135 km in 2007 (Shabadin et al., 2017). As one of the largest states in terms of its economic contribution and activities, Selangor recorded the highest average kilometres travelled, with 28,575.90 km, while Sarawak recorded an average of 20,737.40 km per annum. It is noted that the state of Johor recorded the lowest AAKT, with 16,342.30 km, despite being the state with the second highest number of registered cars. The lower values of VKT

might be due to various transport infrastructure and built-environment aspects in some states. For instance, some states may have lower VKT as the travel destinations are close and easy to access.

Table 3. 3 Annual Vehicle Kilometres Travelled (VKT) by States in Malaysia (2013).

State	AAKT (km)	Registered Cars	VKT
Perlis	25,953.00	21,229	550,956,237
Kedah	22,692.90	300,868	6,827,567,437
Penang	20,979.80	1,024,197	21,487,448,221
Perak	24,933.10	699,651	17,444,468,348
Selangor	28,575.90	1,037,243	29,640,152,244
Federal Territory	25,569.80	3,442,319	88,019,408,366
Negeri Sembilan	24,619.60	312,156	7,685,155,858
Melaka	23,551.50	310,169	7,304,945,204
Johor	16,342.30	1,339,446	21,889,628,366
Pahang	27,919.10	346,939	9,686,224,635
Kelantan	22,601.50	273,140	6,173,373,710
Terengganu	23,461.20	188,275	4,417,157,430
Sabah	22,821.20	556,699	12,704,539,219
Sarawak	20,737.40	683,244	14,168,704,126
Total	24,129.10	10,535,575	254,213,942,733

Source: Shabadin et al. (2014). AAKT: Average annual kilometre travelled. VKT: Vehicle Kilometres Travelled.

Interestingly, minimal data on private vehicle use are found in Malaysia although there is a very high level of car and motorcycle ownership for the country. State-based data are also only available for certain years, which suggests that further research needs to be conducted to understand the factors driving such a high level of motorisation.

3.3 Chapter Conclusion

This chapter discussed the case study site, which is Sarawak, Malaysia, from four main perspectives: (i) The socio-economic characteristics, (ii) the level of motorisation, (iii) car ownership in Malaysian urban and rural areas, and (iv) vehicle usage. Based on the socio-economic characteristics of the case study site, it is noted that the rise in economic development has led to job creations and growth in travel needs. Other features can be observed from the statistical evidence on the level of motorisation. First, private-based motorisation, specifically cars and motorcycles, is considered as the most used mode of transport in Malaysia and all its states, including Sarawak. Sarawak is considered as one of the states with a very high level of private vehicle ownership of both cars and motorcycles. It is also noted that Sarawak has the most substantial gap between rural and urban car ownership levels among all states. Second, there is a very high level of private vehicle ownership, which is comparable with other developed countries. Third, there has been an increment in car usage in Malaysia, and Sarawak is considered as having among the highest annual car use levels (annual VKT) compared to the other states in the country. This chapter also briefly discussed some of the factors that contributed to the high private vehicle ownership in Sarawak, which includes the cost of motorisation, road transport infrastructure, congestion and public transport availabilities. For the next chapter of the thesis, the research methodology is discussed in terms of modelling car and motorcycle ownership and use, both at the aggregate and disaggregate levels.

Chapter 4

Research Methodology

4.1 Introduction

While the previous chapter presented the literature review on vehicle ownership and use modelling, the purpose of this chapter is to introduce the research methodology for modelling the aggregate data and disaggregate data. This chapter is divided into five main sections. First, Section 4.2 explains the flow of the thesis for both the aggregate and disaggregate model in alignment with the objectives of the study. Section 4.3 describes the modelling of the aggregate data, which entails the justifications for the selected model. Hereby, this section discusses the methodology for the model of selection for the aggregate data, namely the vector error correction model (VECM), which is estimated using the time series data. The section also includes all testing procedures conducted, including the unit root test, cointegration test and the VECM itself. This section also discusses the time series data and model specifications. Section 4.4 explains the conceptual framework of the disaggregate model, which includes the hypothesis of the model. Section 4.5 elaborates on modelling the disaggregate data, which entails the justifications for the model of selection and describes its methodology, which is the partial least squares-structural equation modelling. Finally, Section 4.6 summarises the entire chapter and the expectations from the adopted research methodology.

4.2 Flow of the Thesis

This section describes the research flow of this thesis, as depicted in Figure 4.1. Each of the main four objectives relate to (I) aggregate data modelling and (II) disaggregate data modelling. Further explanation on both models is given in the following sub-sections.

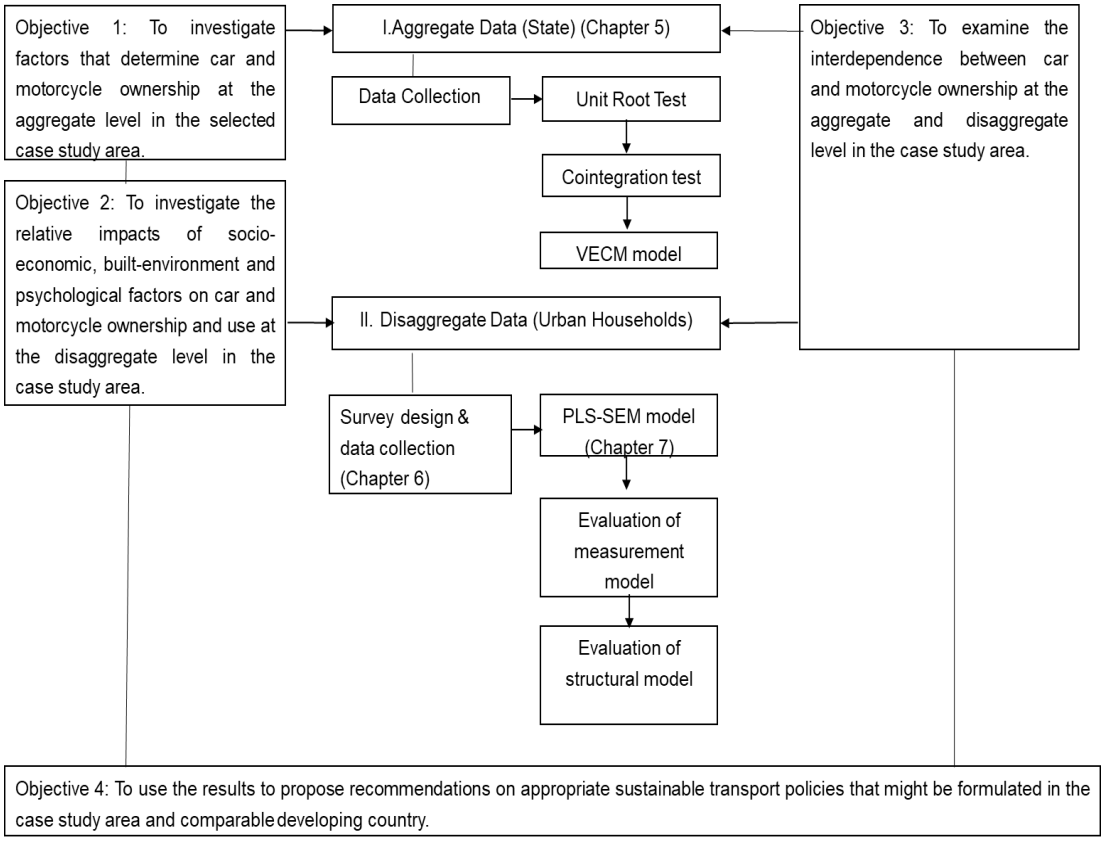


Figure 4. 1 Research Methodology Flowchart.

4.2.1 Summary of Modelling the Aggregate Data

This section discusses the summary of modelling the aggregate data based on the research methodology flowchart in Figure 4.1. First, the research objectives along with the research questions are identified to shape the suitable research method for the thesis. After this, relevant past studies are reviewed in the literature review. Following that, the literature review provides the thesis with details regarding relevant studies on private vehicle ownership in terms of the modelling approaches, theoretical background and determining factors. Following the identification of the research questions, the case study site is later introduced, and its selection is justified in the case study chapter. As the gaps in the studies are identified in the literature review, the analysis used in the thesis is divided into two main parts. The first analysis in the thesis is the aggregate modelling, which includes the unit root test, cointegration test and finally the vector error correction model. The outcome of this model includes the long-run car and motorcycle ownership model, which also integrates the interdependency between both modes at the aggregate model.

4.2.2 Summary of Modelling the Disaggregate Data

This section discusses the summary of modelling the disaggregate data based on the research methodology flowchart. The second part of the analysis applies the disaggregate data modelling, which utilises disaggregate data based on a case study-survey approach. For this data, a transport-based survey is conducted and distributed to households in urban Sarawak. A pre-pilot and a pilot survey are also conducted to prepare for the actual survey. A PLS-SEM model is used to analyse the joint model of car and motorcycle ownership and use. This includes the evaluation of the measurement model and the evaluation of the structural model. This model also analyses the interdependency between car and motorcycle ownership at the disaggregate urban level. Finally, the output produced is discussed, and policy recommendations are made to answer the objectives and the research question of the thesis.

4.3 Modelling Aggregate Data

4.3.1 Justification for Applying VECM

This section discusses the relevant methods pertaining to modelling aggregate data. The discussion is focused on the time series models, which are described in Figure 4.2. Figure 4.2 shows the selection of the time series aggregate model. The selection of the time series model firstly depends upon the stationarity of the models. Time series variables which are stationary at level may apply the ordinary least squares (OLS) regression. Time series variables which are not stationary at level but are stationary at first difference may proceed with the Johansen and Juselius cointegration test. Time series variables which are cointegrated may proceed with error correction models, while non-cointegrated variables may proceed with the vector autoregressive (VAR) model. Mixed variables (Stationary at I(0), I(1)) may proceed with the autoregressive distributive lag (ARDL) model.

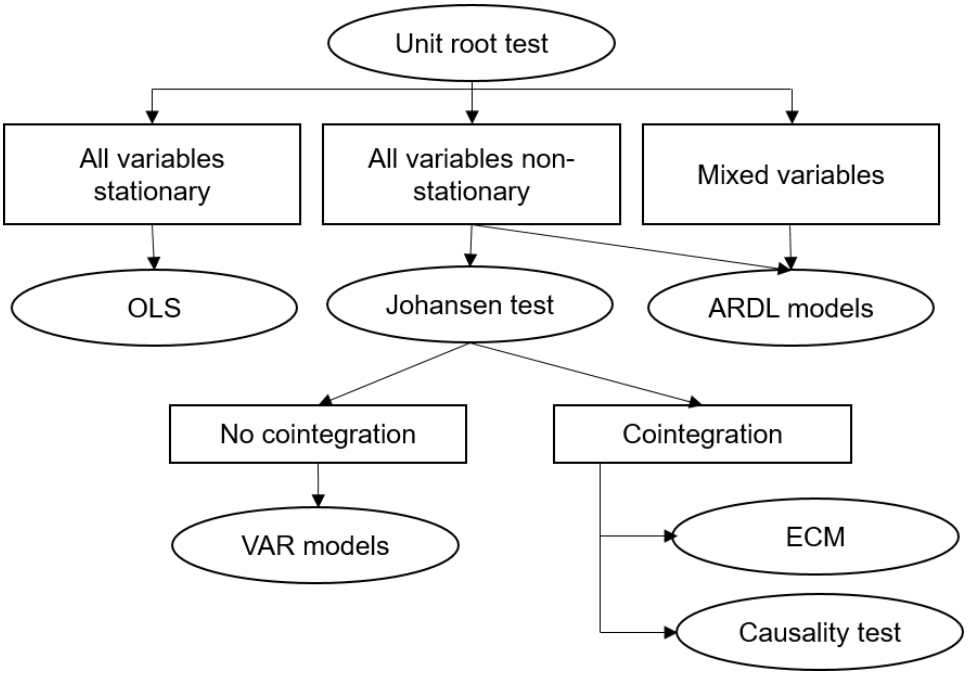


Figure 4. 2 The Selection of the Time Series Aggregate Model.

Source: Shrestha and Bhatta (2018). OLS: Ordinary Least Squares; VAR: Vector Autoregressive; ARDL: Autoregressive Distributed Lags; ECM: Error Correction Models.

It is noted that there are few studies on private vehicle ownership in Malaysia. In Sarawak particularly, no studies have been conducted to date on private vehicle ownership and use and their determinants. Therefore, the time series aggregate based modelling is conducted to obtain an overview to understand the factors that influence car and motorcycle demand over time. As there is insufficient aggregate based statistical data on vehicle use in Sarawak, the research only concentrates on the determinants of private vehicle ownership rather than private vehicle use. Considering that limitation, the selected variables for the models are based on the data available for the case study area.

Time series data are considered to be stationary based on the assumption made in general economic theory. This denotes that mean and variance are constant and the covariance between the two points relies on the time distance between them. The failure to achieve these may cause the problem of non-stationarity (Wooldridge, 2009).

This implies that the concept of stationarity is fundamental when it comes to time series analysis. The issue in time series-based data is the possibility to produce spurious output whereby trend and stationarity are not estimated or taken into consideration (Hendry and Juselius, 2000). In a typical regression, there might be a possibility of producing spurious output in the case where trends and stationarity are not considered or estimated. This causes a significant regression relationship between the dependent and independent variables affected by a similar underlying trend, which is a false (spurious) relationship. An outcome which is spurious may lead to an overstated and unreliable fit of the model.

Therefore, it is decided that the vector error correction model (VECM) is best suited to analysing the aggregate time series modelling in this thesis. It is noted that the main advantage of VECM includes the ability to have a reasonable interpretation of long-term and short-term equations. In addition, Maysami and Koh (2000) asserted that the model could be used to examine the dynamic co-movement between the variables and also the process of adjustments to achieve a long-term equilibrium. The following section explains the time series data required for the model.

4.3.2 Methodology: Vector Error Correction Model

The vector autoregressive model (VAR) is a multivariate autoregressive model proposed by Sims (2006), whereby the past values of the dependent variable and the past values of other variables are regressed in a system. The VAR captures the dynamic interrelationships between variables in a system. The VECM is a restricted VAR model wherein variables are cointegrated (Verbeek, 2008). The VECM can be used to obtain both long-run and short-run dynamics adjustment and the correct disequilibrium that may shock the whole system.

The aims of using the VECM in the study are (1) to acquire a long-run cointegration matrix which represents the long-run equilibrium relationship among the variables; (2) to acquire the short-run coefficient matrices which incorporate the short-run adjustment parameter of each variable with another variables; and (3) to acquire the error correction term (ECT). This study uses three main procedures to analyse the relationship between the variables. Firstly, two unit root tests (Augmented Dickey-Fuller and Phillip–Perron tests) are used to test the unit root presence or otherwise. Next, the Johansen and

Juselius cointegration test is applied to recognise the presence of cointegrating vectors. Thirdly, the VECM is utilised to estimate the long-run relationship between the variables. Finally, the Granger Causality test is used to identify the short-run causal relationship among the variables (Source: Verbeek, 2008; Shrestha and Bhatta, 2018). The overall stages in aggregate modelling are presented in Figure 4.2, while the steps in VECM are presented in Figure 4.3.

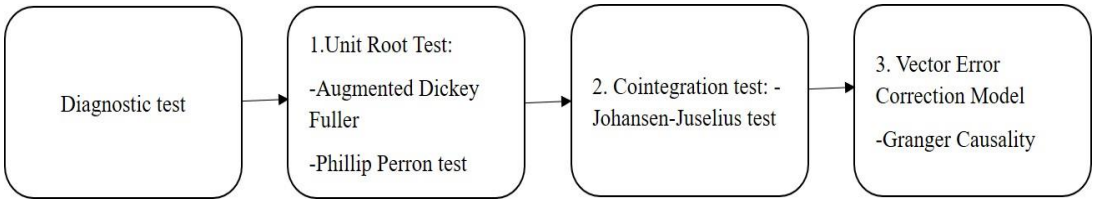


Figure 4. 3 Steps in VECM.

4.3.3 Time Series Data and Model Specifications

4.3.4 Time Series Data Sources

For the aggregate modelling, annual time series data of six variables were collected during the period of 1980 to 2018. The models include variables such as cars per capita (CAR), motorcycles per capita (MOTOR), real gross domestic product per capita (RGDP) (Johansson and Schipper, 1997; Romilly et al., 1998), employment (EMP) (Paravantis and Sambracos, 2006), fuel price (FP) (Bradburn and Hyman, 2002; Dargay et al., 2007), and road length (ROAD) (Ingram and Liu, 1999). These variables were selected based on previously mentioned studies on private vehicle ownership using aggregate time series modelling. Due to the expected limited availability of data, the data are selected from 1980 to 2018. Table 4.1 presents a description of the data.

Table 4. 1 List of Variables.

Variable	Description	Source
RGDP	Real Gross Domestic Product per capita	Department of Statistics (DoS, 2019)
CAR	Total number of cars per capita	Department of Statistics (DoS, 2019)
MOTOR	Total number of motorcycles per capita	Department of Statistics (DoS, 2019)
EMP	Total number of people employed	Department of Statistics (DoS, 2019)
FP	RON97 price (2010 constant price) in USD	Ministry of Domestic Trade, Co-operatives and Consumerism (2019)
ROAD	Road length in kilometer (km)	Department of Statistics (DoS, 2019)

4.3.5 Specification of the long-run vehicle demand model

Some literature on car and motorcycle ownership demand, such as Romilly et al. (1998), Bradburn and Hyman (2002), Dargay (2010), and Fouquet (2012). included variables such as income, price of fuel, road length and the level of employment to examine the effect of socio-economic and built-environment factors on vehicle ownership demand. Changes in income are anticipated to positively influence vehicle demand. Subsequently, income signifies the economic condition of citizens, whereby the accumulation of wealth would make people better off and, therefore, create greater car and motorcycle demand. Furthermore, the cost of travelling is a key component in vehicle demand in addition to fuel price, which is utilised as the proxy for the cost of transportation. Hence, this study assumes that a surge in the fuel price could contribute to lowering the travelling frequency, which produces negative elasticity for the demand for road-based vehicles. Other variables, for instance, road length, which measures the accessibility, are considered as built-environment factors and are assumed to show a positive sign towards car and motorcycle ownership (Law et al., 2015). The level of employment is also considered in the model as it shows the necessity of travel or how work purposes affect the need to travel. The variable is expected to yield a positive sign. Consequently, by considering the variables presented in the literature and the data availability in Sarawak, the proposed car and motorcycle ownership model in Sarawak is as shown in Equations 4.1 and 4.2. All data collected were transformed into natural logarithm to enable the long-run elasticity estimation. CAR_t and $MOTOR_t$ serve as the dependent variables for Equations 4.1 and 4.2, respectively. CAR_t, $MOTOR_t$, $RGDP_t$, FP_t, $ROAD_t$, and EMP_t are the explanatory variables in year t, u_t is the error term, and

coefficients β_1, β_2, β_3, β_4 and β_5 are the long-run elasticities to be estimated. The interdependency between car and motorcycle ownership depends on the coefficient of β_1 for respective equations.

$$lnCAR_t = \beta_0 + \beta_1 . lnMOTOR_t + \beta_2 . lnRGDP_t + \beta_3 . lnFP_t + \beta_4 . lnROAD_t + \beta_5 . lnEMP_t + u_t$$

(Equation 4.1)

$$lnMOTOR_t = \beta_0 + \beta_1 . lnCAR_t + \beta_2 . lnRGDP_t + \beta_3 . lnFP_t + \beta_4 . lnROAD_t + \beta_5 . lnEMP_t + u_t$$

(Equation 4.2)

The long-run elasticity and causal relationship between motorcycle ownership, car ownership, GDP per capita, price of fuel, road length and the level of employment in Sarawak are examined using the VECM. The VECM equations are presented in Equation 4.3 and Equation 4.4 in Section 4.3.8. The output of the estimation will be further elaborated in the succeeding section.

4.3.6 Unit Root Test

Before conducting the unit root tests, several diagnostic tests are conducted to detect the presence of serial correlation, heteroscedasticity and normality among the variables. The stability tests (CUSUM and CUSUMSQ test) are also conducted to examine the parameters' stability (Pesaran, 1997). The CUSUM test examines the systematic changes in the regression coefficient, while CUSUMSQ identifies abrupt changes based on the constancy of the regression coefficient. The cumulative sum test identifies systematic changes in the regression coefficients, while the cumulative sum of squares test detects sudden changes from the constancy of the regression coefficients (Ravinthirakumaran et al., 2015). The study continues with the unit root test in the presence of satisfactory diagnostic tests.

Firstly, two unit root tests, specifically the Augmented Dickey-Fuller (Dickey and Fuller, 1979) and the Phillips–Perron (Phillips and Perron, 1988) tests are used to test whether the variables are stationary or not. Generally, the null hypothesis for both tests indicates the presence of a unit root (non-stationary), while the alternative hypothesis indicates no presence of a unit root, which means the variables are stationary. In the estimations, we utilise variables that show that as the size of the sample rises, the sample variances converge to population (Verbeek, 2008). In the case of non-stationarity, the variances of the variables are considered as ill-defined because they do not fluctuate around a constant mean, which leads to the widely known issue of spurious regression. Spurious regression occurs when estimators and test statistics are misleading (Verbeek, 2008), leading to an incorrect conclusion of the model. The hypotheses for the Augmented Dickey-Fuller (ADF) and Phillips–Perron unit root tests are as follows:

H0: Non-stationary (has a unit root)

H1: Stationary (no unit root)

4.3.7 Cointegration Test

The process of stationarity is imperative when dealing with ordinary least squares (OLS). This is because the assumptions of constant variances and means need to be fulfilled to conduct OLS. Variables which are tested as non-stationary using the above-mentioned unit root tests need to be tested using a different method, that is, the Johansen and Juselius cointegration test (Johansen and Juselius, 1990). The Johansen and Juselius cointegration test involves trace statistics and maximum eigenvalue statistics. The presence of the cointegrating vector in the Johansen and Juselius test indicates that a long-run equilibrium relationship exists (Verbeek, 2008) or in other words, the variables move together in the long run. This test will also determine whether the vector autoregressive (VAR) model or vector error correction model (VECM) should be used in the study. VECM will be used in the case of cointegration, while VAR will be used in the case of no cointegration. The hypotheses for both trace and maximum eigenvalue statistics are as follows:

H0: No cointegration (No long-run relationship)

H1: Cointegration exists (A long-run relationship is present)

4.3.8 Vector Error Correction Model

A vector autoregressive (VAR) model is defined as the dynamic evolution of several variables driven from their shared history (Verbeek, 2008). The vector error correction model (VECM) is a restricted VAR which indicates the presence of cointegration, specifically the long-run relationship among the variables. The VAR model, however, does not capture these long-run relationships. Subsequently, a lagged error correction term (ECT) can be found in the VECM, which is derived from the long-term cointegrating relationship (Pojanavatee, 2014). In addition, the Granger causality test is conducted to identify the causality among the variables. The following equation represents the VECM in the case of a cointegration for the car and motorcycle model.

$$\Delta LNCAR_t = \alpha_0 + \sum_{i=1}^{m} \beta_{1,i} \Delta LNCAR_{t-i} + \sum_{i=1}^{m} \beta_{2,i} \Delta LNMOTOR_{t-i} + \sum_{i=1}^{m} \beta_{3,i} \Delta LNRGDP_{t-i} + \sum_{i=1}^{m} \beta_{4,i} \Delta LNFP_{t-i} + \sum_{i=1}^{m} \beta_{5,i} \Delta LNROAD_{t-i} + \sum_{i=1}^{m} \beta_{6,i} \Delta LNEMP_{t-i} + \theta_1 ECT_{t-1} + \varepsilon_{1t}$$

(Equation 4.3)

$$\Delta LNMOTOR_t = \alpha_0 + \sum_{i=1}^{m} \beta_{1,i} \Delta LNMOTOR_{t-i} + \sum_{i=1}^{m} \beta_{2,i} \Delta LNCAR_{t-i} + \sum_{i=1}^{m} \beta_{3,i} \Delta LNRGDP_{t-i} + \sum_{i=1}^{m} \beta_{4,i} \Delta LNFP_{t-i} + \sum_{i=1}^{m} \beta_{5,i} \Delta LNROAD_{t-i} + \sum_{i=1}^{m} \beta_{6,i} \Delta LNEMP_{t-i} + \theta_1 ECT_{t-1} + \varepsilon_{1t}$$

(Equation 4.4)

Where Δ indicates the lag operator; α_0, β_s are the estimated coefficients; m is the optimal lag length, ε_t is the residual; θ measures the response of LNCAR or LNMOTOR to departure from equilibrium. ECT measures the speed of adjustment if there is a deviation in the long-run equilibrium; it will be corrected by short-run adjustments. This will be shown by an ECT that is negative and statistically significant. In testing whether LNRGDP does not Granger cause LNCAR or LNMOTOR, H_0: β_3, i = 0 for all i. The rejection of H_0 shows that LNRGDP causes LNCAR or LNMOTOR.

4.4 Conceptual Framework of the Disaggregate Model

The rising level of private-based motorisation in Asian developing countries has caused various negative externalities, such as traffic congestion, road accidents and air pollution. To mitigate these issues, there is a need to investigate the set of factors that influence car and motorcycle decision-making so that an appropriate set of policies can be developed. Socio-economic and built-environment factors are widely known to be the general determinants of vehicle ownership and use. However, Maltha (2016) has pointed out that the influence of traditional factors (e.g. socio-economic factors) has diminished over the past years. One of the many factors is due to the role of the psychological factors, which are often left out in much of the literature. Therefore, a plethora of studies have suggested the inclusion of psychological factors (Bagley and Mokhtarian, 2002; Schwanen and Mokhtarian, 2005) in determining vehicle decision-making. According to McFadden (2001), “attitude” serves a crucial role in explaining transport decision-making.

It is also evident that the inclusion of psychological factors in private vehicle ownership and use models provides an understanding of the uncertainties that vary in individual travel behaviour. While some research has been carried out on the role of psychological factors in car ownership and use, there have been few empirical investigations into their role as a determining factor in private vehicle ownership and use in an integrated model or a single framework which includes motorcycle ownership and use. Considering that integrated psychological-based theories of the theory of planned behaviour (TPB) and the norm activation model (NAM) are adopted to construct the conceptual framework for the car and motorcycle ownership and use model, the conceptual framework used for the disaggregate model is depicted in Figure 4.4 and Figure 4.5, providing a view of the model that goes from general to specific.

The general conceptual framework in the thesis is depicted in Figure 4.4. In the general overview of the conceptual framework, the three gaps being addressed by the thesis are highlighted:

(1) The psychological determinants of motorcycle ownership and use;

(2) The interdependency between car and motorcycle ownership; and

(3) An integrated model of car and motorcycle ownership and use. (Refer to Chapter 2.)

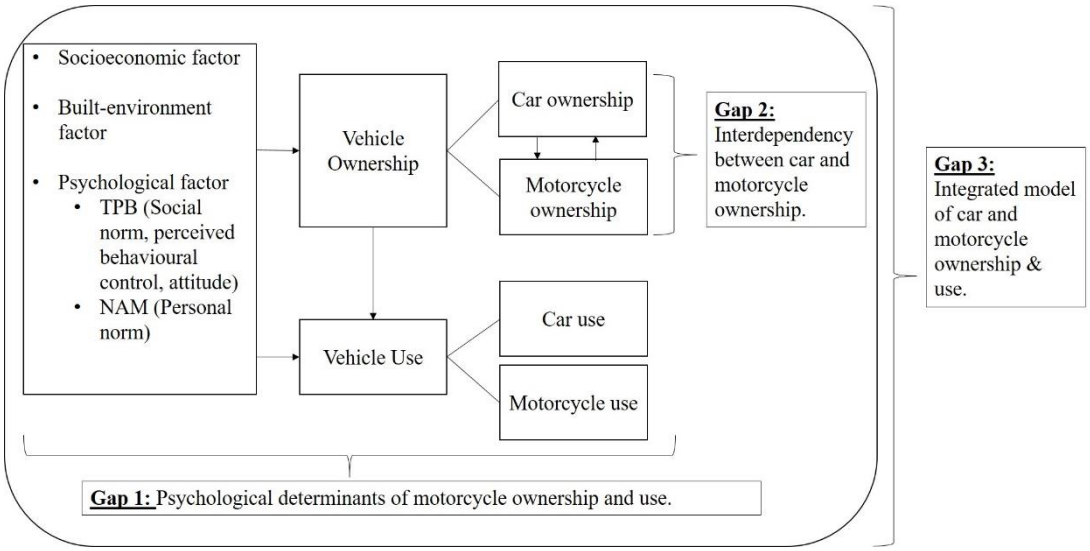


Figure 4. 4 Conceptual Framework (General).

To further understand the conceptual framework, a more specific conceptual framework is introduced in Figure 4.5. The conceptual framework presented can be viewed based on the endogenous (dependent) variables and the exogenous (independent) variables within the rounded rectangle. On the left-hand side (LHS) and the right-hand side (RHS) are the three main determinants or independent variables (exogenous variables), which are the psychological factors (on the LHS) and the socio-economic and built-environment factors (on the RHS). Each component of the factors is within the dotted rounded rectangle. The dependent variables (endogenous variables) are in the middle part of the conceptual framework, which consists of car and motorcycle ownership and use. Further explanation of the hypothesised model of the study will be presented in the following sections.

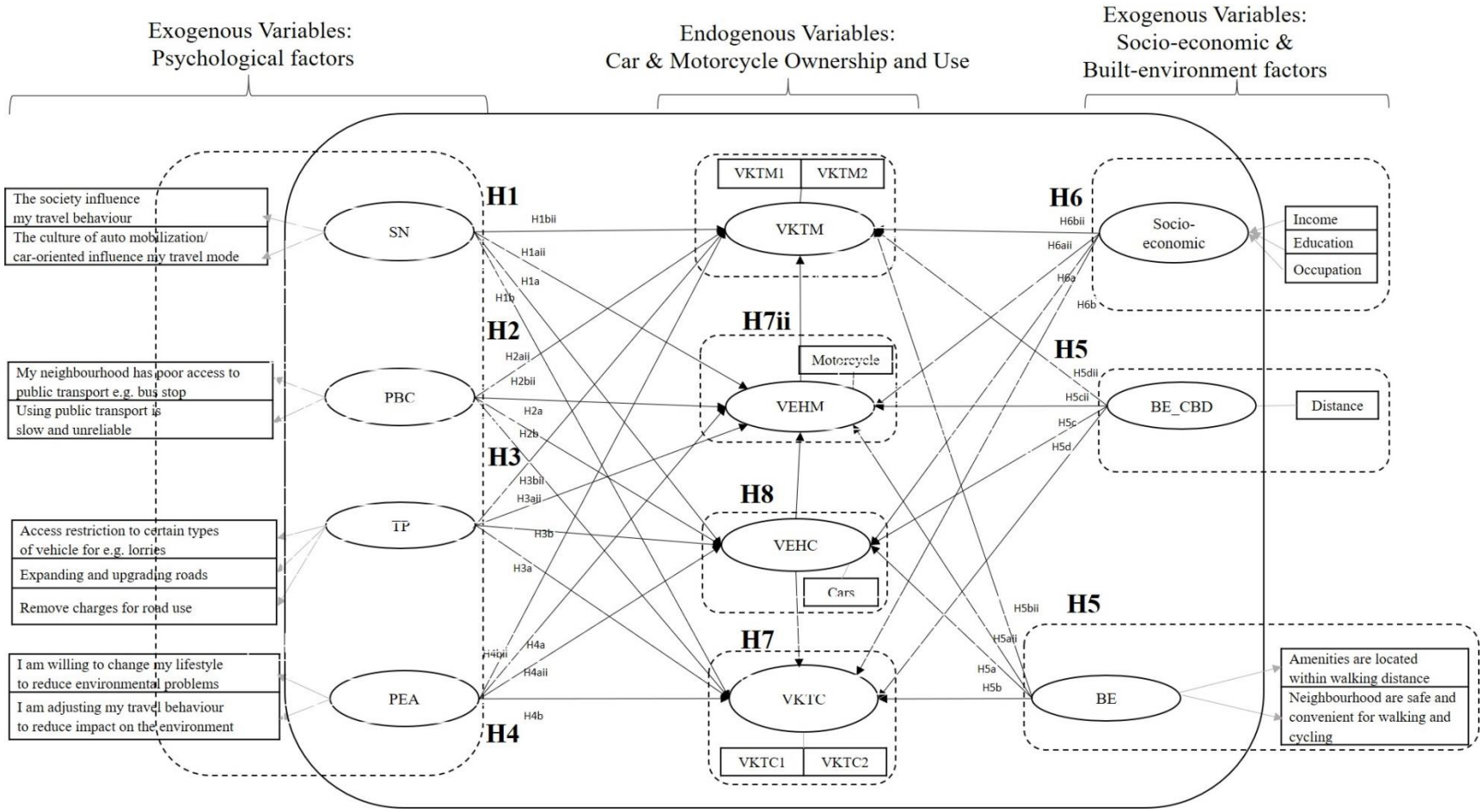


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Figure 4. 5 Conceptual Framework.

4.4.1 Psychological Factors as Determinants of Car and Motorcycle Ownership and Use

Based on the theoretical approaches reviewed in Chapter 2, the hypothesised relationship investigated in the disaggregate model revolves mainly around the integration of two main theories, which are the theory of planned behaviour and the norm activation model (NAM) for the psychological determinants in addition to the socio-economic and built-environment determinants. Therefore, the psychological determinants for the proposed structural model of car and motorcycle ownership and use include four main psychological factors, which are social norms, perceived behavioural control and attitude towards transport policy driven from TPB; and pro-environmental attitude representing personal norms from NAM. A number of hypotheses are developed based on the previous literature (refer to Chapter 2) in order to conduct an empirical analysis of the proposed model using PLS-SEM. The specific hypotheses are presented in the following sections.

4.4.2 Social Norms

The first hypothesis of the proposed conceptual model (refer to Figure 4.4 and Figure 4.5) relates to the role of social norms in influencing car and motorcycle ownership and use. A number of studies from both developed and developing countries (e.g. Japan, Indonesia and China) have shown that there is a positive relationship between social norms and car ownership (Belgiawan et al., 2017; Liu et al., 2017). The indicators which represent the social norms in the conceptual framework are based on the two statements measured using a five-point Likert-scale (from (1) Strongly disagree to (5) Strongly agree): (1) The society influences my travel behaviour; and (2) The culture of auto mobilisation/car-oriented influences my travel mode. For this conceptual framework, by highlighting the role of society and a car-oriented culture, it is expected that social norms have direct positive effects on private vehicle (e.g. cars and motorcycle) ownership and usage.

Based on indicator (1), the term society may refer to the inner circle, mostly family, friends, acquaintance and colleagues (with persistent social interaction), and how the perceived expectations influence an individual to own and use a car. On the other hand, the second indicator for the hypothesis, indicator (2), involves the role of an auto-dependent culture in influencing car and motorcycle ownership and use. Culture may refer to the “set of basic

values, beliefs, norms and related behaviours that are studied by the members of society". In addition, culture is learned and has a long-lived impact on the individual's behaviour. In this sense, an individual may conform to a culture which is practised by the majority of the society, whereby car-owning represents a hegemonic culture as they fear that non-conformity may lead to social exclusion. The specific (H1) hypothesis is as follows:

H1a: There is a significant positive relationship between social norms and car ownership.

H1aii: There is a significant positive relationship between social norms and motorcycle ownership.

H1b: There is a significant positive relationship between social norms and car VKT.

H1bii: There is a significant positive relationship between social norms and motorcycle VKT.

4.4.3 Perceived Behavioural Control

Another construct used in the conceptual framework derived from TPB is perceived behavioural control (PBC), which is defined as the degree to which a person feels capable of performing a particular behaviour. In this thesis, PBC is considered as the psychological factor representing the ease of commuting by a person who has better control using other modes of transport, which can be a reason to reduce private vehicle ownership and use. For example, good access to public transport will lead people to use more public transport to reach their intended destination rather than using cars. PBC is a component in TPB which may be the hindrance or motivation to pursue specific action, in this case, vehicle ownership and use.

Based on the PBC construct, it can be seen that the indicators are constructed to determine the other mode of transport, in this case, the poor public buses services in Sarawak, may encourage private vehicle ownership and use. Issues with poor public bus services in Sarawak include: (1) No bus schedule; (2) no proper bus fare schedule; (3) long waiting times; and (4) long distance to bus stops, among others. Heath and Gifford (2002) found that PBC significantly and positively influences university students to use the bus. This is supported by Harland et al. (1999).

It is expected that PBC may positively influence private vehicle ownership and use in Sarawak. Hence, after considering many factors, the presented indicators for PBC include: (1) My neighbourhood has poor access to public transport (e.g. bus stop); and (2) Using public transport is slow and unreliable. These indicators should not be mistaken with built-environment factors as they focus solely on the perceived level of difficulty that come with using other competing modes of transport instead of private-based transport. Indicator (1) is used to show the possibility for respondents to have access to other modes of transport, in this case, buses. Indicator (2) indicates the difficulties of taking another mode of transport in terms of the services offered. It is assumed that the higher the level of perceived difficulties in taking the bus, the more people tend to opt for private-based vehicles, such as cars or motorcycles, which have a higher level of perceived ease. Therefore, the hypothesis regarding PBC (H2) is as follows:

H2a: There is a significant positive relationship between perceived behavioural control (PBC) and car ownership.

H2aii: There is a significant positive relationship between perceived behavioural control (PBC) and motorcycle ownership.

H2b: There is a significant positive relationship between perceived behavioural control (PBC) and car VKT.

H2bii: There is a significant positive relationship between perceived behavioural control (PBC) and motorcycle VKT.

4.4.4 Attitude

Another component of TPB that is incorporated in the conceptual framework is “attitude”, which is defined as a global assessment of how favourable a specific behaviour is perceived. In our conceptual framework, attitude refers to the degree to which an individual favours or does not favour the idea of car-commuting. Attitude based on TPB relates to the instrumental, symbolic affective or social orderliness. However, in the framework, attitude is based on the instrumental motives, that is, the functional attributes perspective. The indicators used in the attitudinal factor, which are extracted from Bamberg et al. (2011), include: (1) Expanding and upgrading roads; (2) access restriction to certain types of transport (e.g. lorries, HGVs); and (3) removing charges for road use. Higher attitudinal scores suggest greater favouritism towards the

functionality of infrastructure, which is driven by private vehicle-based transport policies. For example, indicator (1) suggests that a higher functionality of road infrastructure will encourage a more convenient car commuting experience. Tennøy et al. (2019) states that road expansion is the cause of land-use sprawl, which leads to traffic congestion (high car use). Adding to this, Cervero (2003) explains that traffic growth is driven by faster travel speed and land-use shifts, namely the extension of freeway lanes. Byun et al. (2017) further support this by highlighting the induced demand, whereby road expansion may lessen travel time but, in turn, influence people to travel more (greater car use). Therefore, it is expected that the attitude towards transport policy may encourage greater car and motorcycle ownership and use.

Meanwhile, according to indicator (2), access restriction (e.g. HGVs) leads to a safer road environment and less potential for traffic fatalities for private based vehicles. More detailed explanation on access restriction can be based on several criteria, that is, level of emissions, level of noise, the weight of the vehicle, level of occupancy, days in a week, time of day and quota for VKT on a certain area (Pojani and Stead, 2015). This so-called command and control policy can be implemented in accordance with a particular condition. HGV restrictions, for example, may be implemented at a certain point of time on a given day, for example, during peak hours to avoid conflict with cars and motorcycles commuting to work. As reported by Moridpour et al. (2015), HGVs have physical and psychological effects on their surroundings due to the physical and operational attributes. In many developing Asian countries, there is an unregulated yet substantial number of HGVs roaming freely without any restrictions being imposed on them. Furthermore, most HGVs in these countries cause traffic accidents and potential traffic safety reduction, especially when they manoeuvre in and share driving lanes with conventional cars and motorcycle. Therefore, it is expected that attitude towards transport policy has a positive association with car and motorcycle ownership and use.

In addition, indicator (3) claims that transport incentives in the form of removed toll charges lead to greater car ownership and use as this reduces the cost to travel. This is supported by Jakobsson et al. (2000), who show that when travelling cost increases (whether by fuel price or car kilometre charges), the trips taken may also change. Individuals may reduce their car use and even opt for another mode of transport, for example, bus, walking or cycling. Fu and

Gu (2014), in their analysis, found that eliminating tolls in urban China can lead to excess vehicles on the road, more VKT and significant increments in terms of emissions. According to Schuitema et al. (2010), pricing policy applies whenever there are more drastic changes to the prices. It is expected that the removal of vehicle charges may increase vehicle ownership and use. The hypothesis (H3) is as follows:

H3a: There is a significant positive relationship between attitude and car ownership.

H3aii: There is a significant positive relationship between attitude and motorcycle ownership.

H3b: There is a significant positive relationship between attitude and car VKT.

H3bii: There is a significant positive relationship between attitude and motorcycle VKT.

4.4.5 Pro-Environment

In contrast with social norms from TPB, personal norms, as in the norm activation model (NAM), point out the explicit norms and the underlying moral motives rather than the individual's personal interest (Nayum and Klöckner, 2014). Considering this, a pro-environment factor based on NAM's altruistic behaviour is integrated into the model. The determinants of car use can be guided by two main theories, which are TPB and NAM. This is supported by some studies from the developed world which integrate both theories (Harland et al., 1999; Bamberg et al., 2007; Klöckner and Blöbaum, 2010; Liu et al., 2017). On the other hand, there have been very few studies that integrate TPB and NAM using developing countries as the case study (Setiawan et al., 2015). While this thesis does not utilise the entire NAM in the framework, it does adopt the pro-environmental value, which relates to the acknowledgement of individuals' concern for the environment and their moral obligations to reduce the environmental impact by controlling their travel behaviour.

In the attempt to examine the outcome resulting from an environmentally concern behaviour, these indicators are developed: (1) I am willing to change my lifestyle to reduce environmental problems; and (2) I am adjusting my travel behaviour to reduce my impact on the environment. These indicators

are adapted and modified from studies by Bamberg et al. (2007), Abrahamse et al. (2009b) and Liu et al. (2017). Higher scores suggest higher personal norms. A study by Bamberg and Schmidt (2015) found that personal norms have a negative relationship towards the intention to use a car, and this is supported by Liu et al. (2017) in that personal norms have a positive relationship to reduce car usage. The study by Abrahamse et al. (2009b), on the other hand, provides evidence that personal norms have a direct negative relationship with using the car to commute and a positive relationship with the intention to reduce car use to commute. Their indicators emphasise the moral obligation and guilt in terms of the impact that car commuting has on others. Personal norm according to NAM takes on a different view of altruistic behaviour, that is, giving up on personal advantage to preserve the environment or for the sake of protecting people from the consequences of environmental degradation.

Based on the indicators, the relationship between personal norms should be significant in explaining vehicle ownership and use in the case where they are aware of the consequences and feel responsible for the impact of these consequences. That is, a person who has a high degree of personal norms tends to have environmental knowledge, which leads to pro-environmental behaviour as a result of their moral obligations towards others. The difference with social norms are that personal norms are personally driven by their self-value and guilt for the effect that the environmental consequences would have on others, rather than being influenced by other individuals; in other words, it is an internalisation of the norm. For indicator (1), an individual who realises the effect of environmental problems may opt for a more environmentally friendly lifestyle as they are aware of the aftermath and are morally obliged to not harm others. In particular, indicator (2) suggests a change of travel behaviour, for instance, commuting by bus rather than car, which means that they are sacrificing their convenience (e.g. lack of personal space) and freedom (e.g. the obligation to follow bus schedules). The extent of personal norms can be seen by the higher degree of moral obligation to have a pro-environmental lifestyle while giving up on personal gains, which is depicted in a significant and negative association with car and motorcycle ownership and use.

It is also evident that travel behaviour can be altered by letting individuals realise the negative effects caused by high car ownership and usage. If the

awareness of negative consequences and the sense of guilt felt due to their consumption is raised, individuals may also willingly reconsider their travel decisions, which may be in the form of less car ownership or use. Therefore, the hypothesis regarding PEA (H4) is as follows:

H4a: There is a significant negative relationship between pro-environmental behaviour and car ownership.

H4aii: There is a significant negative relationship between pro-environmental behaviour and motorcycle ownership.

H4b: There is a significant negative relationship between pro-environmental behaviour and car VKT.

H4bii: There is a significant negative relationship between pro-environmental behaviour and motorcycle VKT.

4.4.6 Built-Environment

While the built-environment factor has been widely applied in an array of studies, this thesis specifically investigates the role of the built environment based on two perspectives, namely subjective and objective perspectives. In a study by Banerjee and Hine (2016), they operationalised built-environment factors into two parts, namely urban form factors, which consist of distance to the city centre, as well as attitude and preference factors, which consist of sustainable transport-oriented and residential preferences. Following that, the built-environment factor based on Figure 4.5 is perceived from the objective and subjective measurements. The objective measurement of the built environment is operationalised using distance to CBD, while the subjective measurement is based on the attitudinal aspects of the built environment as perceived by individuals.

For this thesis, the indicators for attitude towards the built environment are: (1) Amenities are located within walking distance; and (2) the neighbourhood is safe and convenient for walking and cycling. These indicators are selected based on the ease of an individual to gain access to social and economic gains at a certain proximity without relying on cars or motorcycles. Safety and security measures also determine the way a person or individual travels. For example, in a neighbourhood with a high crime rate and where it is unsafe to cycle, it would be more likely for people to opt for cars to commute as the

feeling of being threatened by the surrounding becomes a deterrent for them to walk and cycle. Banerjee and Hine (2016) used indicators such as "near to amenities" and "good street lighting" among the measures for the physical neighbourhood properties in terms of the ease for household travel according to vehicle miles driven. It is expected that there is a negative relationship from the attitude towards the built environment based on the conceptual framework. The hypothesis (H5) for this subjective factor is as follows:

H5a: There is a significant negative relationship between attitude towards the built environment and car ownership.

H5aii: There is a significant negative relationship between attitude towards the built environment and motorcycle ownership.

H5b: There is a significant negative relationship between attitude towards the built environment and car VKT.

H5bii: There is a significant negative relationship between attitude towards the built environment and motorcycle VKT.

Meanwhile, the indicator for accessibility, which is derived objectively, relates to the distance to the city centre, which is an important necessity for individual travel activities. The individual is expected to commute via walking or cycling to the amenities provided that these amenities are located within walking distance, and thereby lower vehicle ownership and use. Destination accessibility, specifically local accessibility, is defined by Handy (1993) as the distance from home to the nearest store. According to Banerjee and Hine (2016), the provision of infrastructure lessens with increasing distance from the city centre and a better provision of infrastructure is associated with living in the city, and thus leading to less vehicle kilometres travelled. As stated by Van Acker and Witlox (2010), accessibility is an imperative feature of the built environment that refers to the capacity to reach a certain activity or location using a combination of different travel modes. The previous literature has indicated that accessibility has a negative relationship with car ownership. (Simma and Axhausen, 2003; Gao et al., 2008; Banerjee and Hine, 2016). Simma and Axhausen (2003) elucidate that individuals who live in a neighbourhood in close proximity to amenities such as shops and schools within walking distance tend to take more walking trips and less car trips.

It is noted that there is no best approach to measure accessibility as there are diverse conditions and underlying factors which necessitate different methods. These can be found in the studies conducted by Black and Conroy 1977), Handy and Niemeier (1997), and Geurs and van Wee (2004). In this study, we apply one of the criteria from Geurs and van Wee (2004), which is the land-use component. According to Geurs and van Wee (2004), the component of land use reflects the system of land-use, which consists of: "(a) the amount, quality and spatial distribution opportunities supplied at each destination (jobs, shops, health, social and recreational facilities, etc.), (b) the demand for these opportunities at origin locations (e.g. where inhabitants live), and (c) the confrontation of supply of and demand for opportunities, which may result in competition for activities with restricted capacity". Therefore, the hypothesised relationship between the built environment (objective) and ownership and use are as follows:

H5c: There is a significant positive relationship between the built environment (BE_CBD) and car ownership.

H5cii: There is a significant positive relationship between the built environment (BE_CBD) and motorcycle ownership.

H5d: There is a significant positive relationship between the built environment (BE_CBD) and car VKT.

H5dii: There is a significant positive relationship between the built environment (BE_CBD) and motorcycle VKT.

4.4.7 Socio-Economic Variables

Several studies investigating vehicle ownership and use have identified the socio-economic factor as the main determinants for both aggregate (Romilly et al., 1998; Dargay and Gately, 1999; Fouquet, 2012) and disaggregate models (Whelan, 2007; Nolan, 2010). The socio-economic factor is an important determinant in an array of studies as it represents the economic capacity, social power, and social prestige of an individual. The socio-economic construct in this conceptual framework is operationalised using indicators such as income, education and occupation. As specified by Lorant et al. (2003), the socio-economic factor generally consists of an individual's income, education and occupation. Some other studies also utilised these

factors in measuring the socio-economic factor (Klöckner et al., 2013; Hsieh and Huang, 2014; Khoo and Ong, 2015).

The higher the socio-economic status of the household, the better the standard of living, enabling them to own more vehicles and drive more. Those who are in the higher income groups are expected to have, in general, a higher level of car ownership (Dargay et al., 2007; Whelan, 2007). Higher disposable income leads the individual to have more budget to purchase a private-based vehicle. As mentioned by Pearman and Button (1976), individuals who are better off tend to purchase first-hand vehicles and at a more frequent rate. In contrast, those with lower disposable income have a higher likelihood to purchase second-hand cars or select cheaper private vehicle options, such as a motorcycle.

Education level is also considered as an important determinant towards car ownership. An individual with a higher education is likely to work in a specialised job and is expected to be more involved in long-distance commuting and, therefore, higher car usage (Boarnet and Sarmiento, 1998; Krizek, 2003). There may be an association between education level and low-carbon mobilisation and there are claims that tertiary-based educated individuals may have greater emissions linked to transport compared to those who did not achieve such a level of education. Furthermore, Büchs and Schnepf (2013) identified that education is one of the main determinants for high emissions from transport, even after income is controlled. This high emissions from transport are probably attributed to high car ownership and use.

Another indicator of the socio-economic factor is employment, which also contributes to car ownership and use. Maltha et al. (2017) further elaborate that employment or working status are related to a higher ownership of cars. Clark et al. (2016) suggest that a change in employment most likely changes the choices available for a journey. This is because workplace location changes relative to home may also alter the work-journey schedule and may lead to the acquisition of more cars. Also, Abenoza et al. (2017) have identified that those who are unemployed and on parental leave might experience lower private vehicle use and are thus considered as “inactive travellers”. Furthermore, low-income earners have a low level of car ownership, with

many of them having limited access to transport, and they may consider inexpensive travel options, such as buses (which is identified as a spatial disadvantage), which restricts the locations and availability of employment type. The socio-economic factor has been shown to have a positive effect on travel behaviour (annual mileage) (Banerjee and Hine, 2016). Therefore, it is expected that the socio-economic factor positively affects vehicle ownership and annual mileage. The hypothesis (H6) is as follows:

H6a: There is a significant positive relationship between socio-economic factors and car ownership.

H6aii: There is a significant positive relationship between socio-economic factors and motorcycle ownership.

H6b: There is a significant positive relationship between socio-economic factors and car VKT.

H6bii: There is a significant positive relationship between socio-economic factors and motorcycle VKT.

4.4.8 Vehicle Ownership and Use

According to Dargay (2001), there is some evidence that supports that the procurement of car leads to a prolonged pattern of entrenched car use, that is, a high dependency on the car as the mode of transport. The study shows that while car ownership increases due to an increase in income, for a decrease in income, households will retain their level of car ownership, which to allow for some sets of travel demand patterns. Households with cars undertook more trips and travelled greater distances compared to those without a car. This is supported by Van Acker and Witlox (2010), who highlight that car ownership has a considerable effect on car use and added that people tend to use cars once they own them. Moreover, Dieleman et al. (2002) elucidate that car ownership causes higher car use for longer distances, that is, by owning a car, people tend to live far from their offices compared to those without cars. In this thesis, there is a direct relationship between vehicle ownership and use. The hypothesis (H7) is as follows:

H7: There is a significant positive relationship between number of cars owned and car VKT.

H7ii: There is a significant positive relationship between number of motorcycles owned and motorcycle VKT.

4.4.9 Car and Motorcycle Ownership Interdependency

Based on the aggregate time series data, the car and motorcycle ownership rates are found to increase together. Hence, we assume that there is a complementary relationship between car and motorcycle ownership (Sanko et al., 2009; Chen et al., 2013). Based on these studies, it is hypothesised that an increase in car ownership may lead to an increase in motorcycle ownership. The interdependency between car and motorcycle ownership is hypothesised (H8) as below:

H8: There is a significant positive relationship between the levels of car ownership and motorcycle ownership.

4.5 Modelling Disaggregate Data

4.5.1 Justification for using PLS-SEM

This section discusses the relevant methods pertaining to modelling disaggregate data. For the disaggregate model, this thesis adopts structural equation modelling (SEM) to investigate the determinants of car and motorcycle ownership and use. SEM is a second-generation technique which enables the use of a large number of variables. As compared with the first-generation techniques, for example exploratory factor analysis, multiple regression and logistic regression, SEM is able to analyse multiple dependent and independent variables at the same time. In addition, SEM allows the inclusion of latent variables which cannot be measured directly in the model. While a more advanced discrete choice model (for example, the hybrid choice model) is able to integrate the latent variables as the independent variables, incorporating a large number of latent variables may result in issues such as no clear behavioural interpretation by the model (Ben-Akiva et al., 2002) . This leads to the discussion of the two main structural equation models, namely the covariance based-structural equation model (CB-SEM) and the partial least squares-structural equation model (PLS-SEM), which are described in Table 4.2.

For the disaggregate model, PLS-SEM is applied as it is the model that fulfils the research gaps identified in Figure 4.4. Figure 4.4 presents the three gaps in the studies for the disaggregate model, including (1) the psychological determinants of motorcycle ownership and use, (2) an interdependency between car and motorcycle ownership, and (3) an integrated model of car and motorcycle ownership and use. Following this, several reasons are identified to justify the usage of the PLS-SEM method for the disaggregate model.

The use of PLS-SEM over CB-SEM is highlighted based on the following four main perspectives. (1) First, the research goals of PLS-SEM are to predict the key determinants and it is used for exploratory studies or the expansion of an existing theory. The aim of CB-SEM is to test a theory or compare a theory with an alternative theory. (2) Second is the epistemic relationship among the latent variables and its indicators. That is, PLS-SEM can utilize both formative and reflective indicators while CB-SEM basically applies reflective indicators. (3) Third, the model complexity for PLS-SEM is very complex and comprises a large number of variables and indicators (Henseler et al., 2014). PLS-SEM works effectively with sample data that is complex in nature, while CB-SEM merely allows for a small to medium number of variables. (4) Fourth, PLS-SEM is able to handle relatively low sample sizes, which is the opposite of CB-SEM. The sample size has major implication for the distribution of sample. It is frequently ascertained that smaller samples lead to distributions that are non-normal. This is due to insufficient estimation of the data dispersion, which leads to a curve that is non-normal. CB-SEM can only be used under the circumstance of normal data distribution. PLS-SEM is applied for the disaggregate model as it can cater for non-normally distributed data (Monecke and Leisch, 2012). (refer to Table 4.2).

Table 4. 2 Comparison of CB-SEM and PLS-SEM.

Criterion	PLS-SEM	CB-SEM
(1) Objectives	-The aim is to predict the key determinants. -If the study is exploratory or extension of an existing theory.	The aim is for theory testing and compare a theory with other alternative theories.
(2) Epistemic relationship among variables	Can be modelled with both formative and reflective variables.	Can be modelled with reflective variables.
(3) Model complexity	Large number of variables and indicators.	Small to medium number of variables and indicators.
(4) Sample Size	If the sample size is relatively low.	If the sample size is large and meets the data distribution requirements.

Source: Chin and Newsted (1999); Hair et al. (2011).

4.5.2 Methodology: Partial Least Squares-Structural Equation Model (PLS-SEM)

The previous section operationalizes the conceptual framework used in this thesis with a special focus on the psychological factors. In regards to the conceptual framework, a partial least squares-structural equation model (PLS-SEM) is applied to predict or identify the key drivers for vehicle ownership and use in Sarawakian urban households. This thesis applies PLS-SEM to analyse the hypothesised model in this thesis. The structural equation model (SEM), or CB-SEM, is “a technique to specify, estimate and evaluate models of linear relationships among a set of observed variables in terms of a generally smaller number of unobserved variables” (Shah and Goldstein, 2006). SEM is prominently used in the area of social sciences, particularly in operational and marketing research. However, due to the direction of this thesis, which is to predict key target constructs, and due to the exploratory nature of the research, PLS-SEM is utilised. Furthermore, covariance-based SEM aims to test a theory or compare theories with an alternative theory. For a study which incorporates an extension of an existing theory that is exploratory, covariance-based SEM is unsuitable. Hence, PLS-SEM is recommended as it can be used particularly for exploratory studies where there are data limitations in

terms of non-normal data distribution and also smaller sampling size than could be fulfilled using covariance-based SEM (Hair et al., 2011).

PLS-SEM is a component-based approach developed by Wold (1982) and Lohmöller (1989). PLS-SEM is a simultaneous combination of principal component analysis, path analysis and regression to evaluate theory and data. The objective of PLS-SEM is to calculate the estimated coefficient (path coefficient) that maximises the value of R^2 for the targeted endogenous constructs (dependent variable). Its main feature involves theory development (extension of existing theory) and an explanation of construct prediction. PLS-SEM maximises the endogenous variables' explained variance through the estimation of the partial model relationship in an iterative sequence of OLS regressions.

PLS-SEM is designed to estimate the relationship between the dependent variable (endogenous factor) and the independent variables (exogenous factors) (Ramayah et al., 2016). It is a method of regression which enables the factors' identification, that is, the linear combination of the independent variables (exogenous factors) which best model the dependent variable (endogenous factor). PLS-SEM estimations start with the calculations of case values in which "unobservable variables are estimated as exact linear combinations of their empirical indicators" (Fornell and Bookstein, 1982, pp. 441). Later, the estimations are made based on the weights used to determine these case values to ensure that the case values capture the variance of the exogenous variables in determining the endogenous variables (Garthwaite, 1992). In summary, the general idea of PLS-SEM begins with the weight relations which associate the indicators with the respective variable. Secondly, the case value calculation for unobserved variables is based on the indicators' weighted average. Third, the parameter for the structural relationship (structural model) is determined based on the case value, which is used in the regression equations (Fornell and Bookstein, 1982), resulting in several path coefficients.

PLS-SEM consists of two primary components: (i) The structural model, which shows the relationship (path) between the latent variables; and (ii) the measurement model, which shows the relationship between the indicators and the latent variables. Figure 4.6 presents the paths, which are the hypothesised

relationship between the factors from latent variables A & B to C (ovals), which represents the structural model. The rectangular boxes for latent variable A, B, and C represent the indicators for the respective variables. The relationship between one latent variable to another variable is shown in (hypothesised) arrows, while the relationship between each latent variable and its indicators can be seen through the dotted arrow from the oval-shaped latent variable towards the rectangular boxes. The relationship between the latent variable A, B, and C with the respective indicators are assessed using measurement models. There are two types of measurement models: (i) The formative model; and (ii) the reflective model. Referring to Figure 4.6, (A) represents a reflective model, which is represented by a variable which has observed measures that are impacted by the underlying unobservable variables.

Meanwhile, (B) represents a formative model which comprises a composite multiple measure. PLS-SEM depends on a non-parametric bootstrap procedure to assess the coefficients for their significance. Based on bootstrapping, a huge number of subsamples (for example, bootstrap samples) are drawn from the original sample with replacement (randomly from the population of the sample).

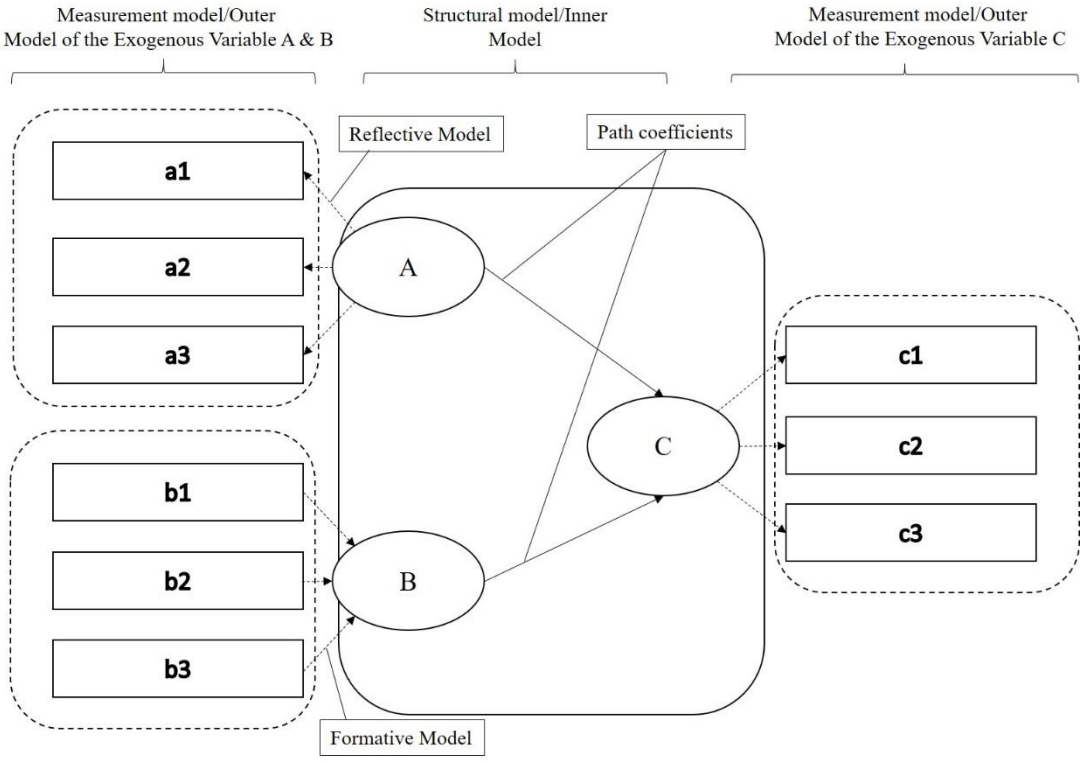


Figure 4. 6 PLS-SEM**.**

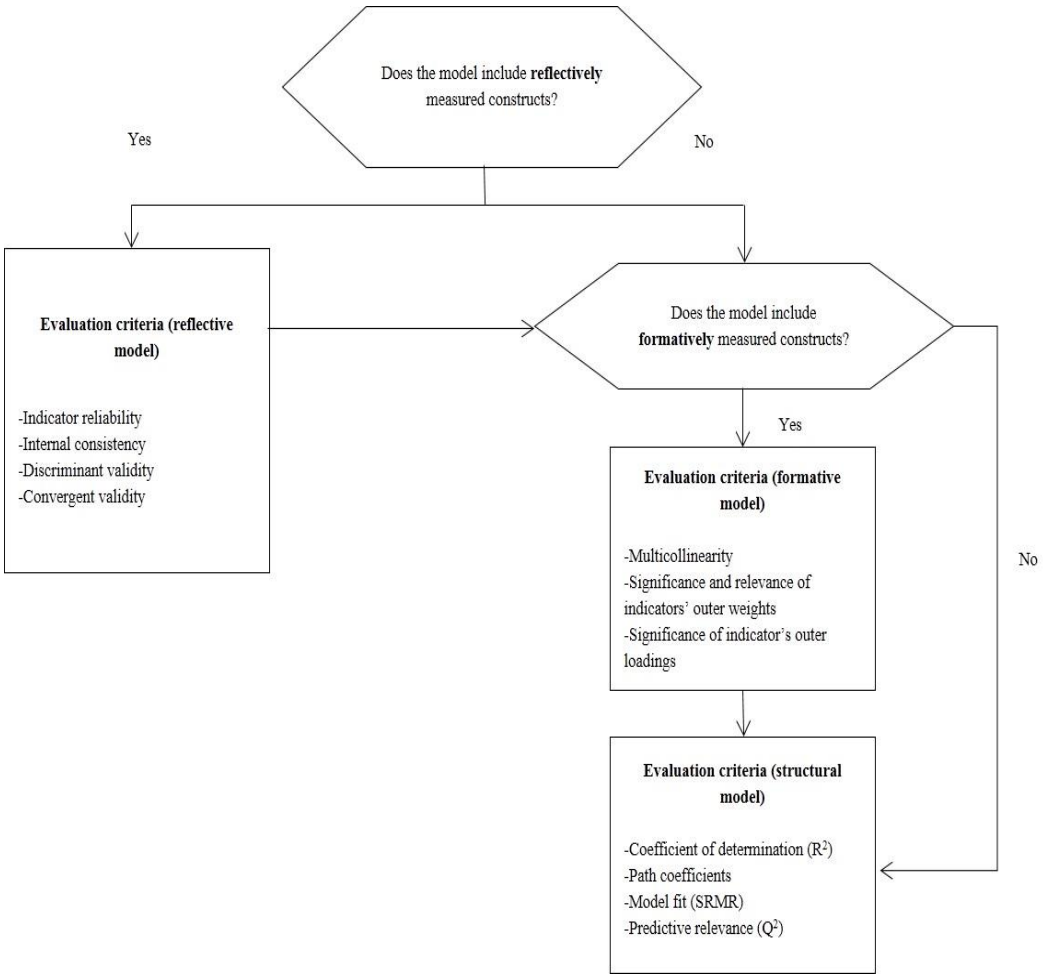
4.5.3 Model Validations

There are two important steps of PLS-SEM evaluation stages, including the evaluation of the measurement model and the evaluation of the structural model. According to Chin (1998), PLS-SEM includes a two-stage process in the model assessment. The first stage involves the measurement model (outer model), while the second stage involves the structural model (inner model). The measurement model relies on the condition whether the model includes a reflective model or formative model or both (Sarstedt et al., 2014). Therefore, it is compulsory to distinguish between the reflective and formative models in order to proceed with the evaluation.

The evaluation of the measurement model includes the reflective model assessment and the formative model assessment. The reflective model assessment involves four assessment criteria, which are the internal consistent reliability, individual reliability, convergence validity and discriminant validity. The main aim is to ensure the reliability and validity of the respective indicators to the given constructs. The formative model assessment is conducted to assess whether the indicators fully represent the domain of the respective formative construct. This includes the determinant of the assessment of the construct multicollinearity and the assessment of the significance of the formative indicators.

Following that, the assessment of the structural model is conducted after the indicators are found to be valid in representing the constructs of the model. The assessment of the structural model involves the assessment of the significance and relevance of the structural model relationship through the bootstrapping procedure, which calculates the path coefficient and the t-values for the loadings. Bootstrapping is a “resampling technique that draws a large number of subsamples from the original data (with replacement) and estimate models for each subsample” (Sarstedt et al., 2014). Later, the model’s predictive accuracy is generated via the coefficient of determination (R^2). In other words, R^2 calculates the amount of variance in endogenous constructs (dependent variable), which can be explained by the entire exogenous constructs (independent variables). Later, the predictive relevance, Q^2, is obtained via the blindfolding technique. The blindfolding technique is “a resampling technique that systematically deletes and predicts every data point of the indicators in the reflecting measurement model of the

endogenous construct" (Ramayah et al., 2016). Finally, the goodness of fit for PLS-SEM is measured through the standardized root mean square residual (SRMR). SRMR is measured to avoid the model misspecification by measuring the average magnitude of discrepancy between the observed and expected correlations. Figure 4.7 shows the PLS-SEM evaluation stages. The formulations for the PLS-SEM evaluation stages are attached in Appendix C.



Source: Adapted from Sarstedt et al. (2014) and Urbach and Ahlemann (2010).

Figure 4. 7 PLS-SEM Evaluation Stages.

4.6 Chapter Conclusion

This chapter discussed the overall research methodology applied in the thesis. For that purpose, two main research methodologies were applied, namely the vector error correction (VECM) model and the partial least squares-structural equation model (PLS-SEM). In this chapter, the vector error correction

(VECM) model is justified as the model for the aggregate car and motorcycle ownership model. This chapter involves the justifications of PLS-SEM being used for the analysis of the disaggregate model and the model validations. The analysis involves two main stages, which are the: (i) the measurement model, and (ii) the structural model. Later, the conceptual framework is explained, which involves the determinants of car and motorcycle ownership and use from the socio-economic, built-environment and psychological factors' perspectives.

According to the conceptual framework depicted in Figure 4.4, three gaps are specifically highlighted, which are (1) the psychological determinants of motorcycle ownership and use, (2) the interdependency between car and motorcycle ownership, and (3) an integrated model of car and motorcycle ownership and use. Subsequently, a detailed description of the conceptual framework is presented in Figure 4.5. Based on these gaps, PLS-SEM is introduced as the best model that can capture the entire gaps that are highlighted in the conceptual framework in Figure 4.4. The following chapter discusses the aggregate analysis of car and motorcycle ownership using the vector error correction model (VECM).

Chapter 5

Aggregate Analysis of Car and Motorcycle Ownership

5.1 Introduction

A high level of private motorisation is the root cause of several negative externalities, including traffic congestion, safety risks and pollution (air, noise, and light pollution). These negative externalities may have dangerous consequences for society. In the previous chapter, it was noted that there is a very high level of motorisation in Malaysia compared to other countries. Nevertheless, very few studies have been conducted on private vehicle ownership, of both cars and motorcycles, in the country. The case study site, i.e. the state of Sarawak, has a considerably high level of private vehicle ownership in relation to other states in Asian developing countries (Table 3.2) and the trend is expected to increase for many decades (Figure 3.6). Hence, there is a need to identify the causes that lead to car and motorcycle ownership in the long run, which leads to the intertemporal study. The method used in the intertemporal study of car and motorcycle ownership determinants is discussed in Section 4.3. For that purpose, a time series analysis, specifically the vector error correction model (VECM) is conducted to understand the nature of the relationship between private vehicle ownership and its determinants in Sarawak.

Section 5.2 outlines the results of the aggregate data analysis for both car and motorcycle ownership in Sarawak using annual time series data from 1980 to 2018 by applying VECM. This includes Section 5.2.1, which presents the results for the data diagnostic test, and Section 5.2.2, which presents the unit root test results. Section 5.2.3 explains the cointegration test results, while Section 5.2.4 and Section 5.2.5 explain the short-run and long-run relationships between the said variables for both the car and motorcycle ownership model. Following that, Section 5.3 presents the discussion for the entire chapter, and finally, Section 5.4 summarises the overall VECM chapter.

5.1.1 Vector Error Correction Model (VECM)

Based on section 4.3, VECM is utilized to study the intertemporal variation of car and motorcycle ownership in Sarawak. The time period covered in the models encompasses annual time series data from 1980 to 2018. This includes two main dependent variables, namely the total number of cars per capita (CAR) and the total number of motorcycles per capita (MOTOR), which represent the two main models as presented in equation 4.1 and equation 4.2. The main aim of these two models is to identify the long-run determinants of car and motorcycle ownership in Sarawak. Meanwhile, the independent variables for the respective car and motorcycle models consist of real gross domestic product per capita (RGDP), employment (EMP), fuel price (FP) and road length (ROAD).

The aggregate models also aim to identify the interdependency between car and motorcycle ownership at the aggregate level. Prior to conducting the VECM analysis, several diagnostic tests are conducted to check if the data or variables face any serial correlation, heteroscedasticity and normality issues. After conducting the diagnostic tests, the unit root test is conducted to see whether the time series data possesses unit roots, which are considered as non-stationary. The concept of stationarity is important as it indicates that the mean, variance and autocorrelation are constant over time, which is important to predict the future trend (in this case, the long-run relationship). Non-stationary variables lead to misleading conclusions (spurious regressions), which can be handled by first differencing. The time series data that are non-stationary at level require first differencing, which is the transformation of, for example, the first difference of RGDP at period t is equal to $RGDP_t$ - $RGDP_{t-1}$. Following that is the cointegration test, which assesses the existence of long-run relationships among the variables. Finally, the VECM model indicates the long-run elasticity between the dependent and independent variables as well as the error correction term (ECT), which measures the rate of convergence to the long-run equilibrium as well as the short-run causal analysis.

5.2 Results of the VECM

5.2.1 Diagnostic Test

As mentioned in Section 5.1.1, a series of diagnostic tests is crucial to test the data for the aggregate models. Appendix B (I) show the details of the diagnostic tests conducted to check for the serial correlation, heteroscedasticity and normality of the variables used in the car and motorcycle ownership model. The diagnostic tests were proven to be satisfactory for the motorcycle ownership model based on the results in Table 5.8. Based on the car ownership model results shown in Table 5. 7, it is evident that the model does not suffer from serial correlation and heteroscedasticity. In addition, the estimated residuals were found to be normally distributed and as the cumulative sums had fallen within the two-standard deviation band, the models were found to be relatively stable. These results permit the VECM to be conducted as the overall diagnostic results for the car and motorcycle ownership model were found to be satisfactory, which allows for the unit root test to be conducted. Hence, the unit root test is conducted in the following section to test for the stationarity of the data used in the models.

5.2.2 Unit Root Test

As a prologue to the Johansen and Juselius' cointegration and the VECM in Sections 5.2.3, 5.2.4 and 5.2.5, respectively, the variables for both motorcycle and car ownership models were tested for stationarity. For this reason, two main unit root tests, namely the Augmented Dickey-Fuller (ADF) test and the Phillips–Perron (PP) test, as discussed in the previous chapter, were applied to determine the stationarity of the variables at level and first difference. As mentioned in Section 4.3.1, the problem with non-stationary time series data indicates the problem of a spurious regression relationship. The results for the variables' unit root tests are presented in Table 5.1.

Table 5. 1 Unit Root Test.

	Augmented Dickey-Fuller		Phillip–Peron	
Variables	**Level**	**First Difference**	**Level**	**First Difference**
lnCAR	-2.03	-6.12**	-2.01	-6.38**
lnMOTOR	-0.97	-6.80**	-3.12	-9.79**
lnRGDP	-1.74	-5.49**	-1.79	-5.51**
lnROAD	-2.01	-5.96**	-2.12	-5.96**
lnFP	-1.90	-5.42**	-1.90	-5.45**
lnEMP	-2.41	-10.19**	-2.38	-9.18**

Notes: ** represent 5 % level of significance.

Based on the ADF test, the null hypothesis of no unit root can be rejected at level (raw data before first difference) for all variables for both the ADF and Phillip–Perron test. This indicates that the data have non-stationary, which means that the mean, variance and autocorrelation are not constant over time. Following the non-stationarity at level, the unit root tests are then tested at the first difference (for example, $RGDP_t$ - $RGDP_{t-1}$) for all variables. On the contrary, all the variables were found to be stationary after first differencing, which indicates that they were integrated at I (1) and are non-spurious. Similarly, the results indicated that the null hypothesis containing the unit root had failed to be rejected for all variables at a level under the PP test. For variables at the first difference, it was found that the null hypothesis was rejected at the first difference. This indicated that the variables were integrated at order 1. The findings indicating the same order of integration allow for the Johansen and Juselius' cointegration test to take place in Section 5.2.3.

5.2.3 Cointegration Test

The cointegration test was applied to determine the type of model to be applied for the analysis. Specifically, the Johansen and Juselius' test was performed to test for the existence of a cointegrating relationship in both motorcycle and car ownership models in order to identify whether there is a long-run relationship or otherwise. The presence of cointegration shows that the series move together in the long-run or that there is a long-run relationship for the model, which allows the VECM model to be conducted. The cointegration test results for the car and motorcycle ownership model are

presented in Table 5.2. According to the cointegration test results, both the null hypothesis of no cointegration for trace statistics and the Max-Eigen are rejected. This shows that the car and motorcycle ownership model has two cointegrating vectors, which implies that the variables do not drift apart and share a common stochastic relationship in the long-run.

Table 5. 2 Johansen and Juselius Cointegration Test Results.

H0:	H1:	Trace Statistics	Critical Value	Max-Eigen Statistic	Critical Value
r=0	r=1	127.28**	95.75	55.65**	40.08
r≤1	r=2	71.63**	69.82	35.18**	33.88
r≤2	r=3	36.45	47.86	17.23	27.58
r≤3	r=4	19.22	29.80	11.38	21.13
r≤4	r=5	7.84	15.49	6.21	14.26
r≤5	r=6	1.62	3.84	1.62	3.84

Notes: (**) denotes rejection of the hypothesis at the 5%. The letter “r” represents the number of co-integrating equations. The critical values are based on Osterwald-Lenum (1992).

Overall, the Johansen and Juselius test findings show that both the motorcycle and car ownership models have two cointegrating vectors from the Trace and Max-Eigen statistics. The outcome also shows that the assumption of non-causality between the variables is to be ruled out and that a long-run relationship is present in both models. Therefore, this allows for the VECM to be conducted to identify the long-run and short-run relationships for the models in Sections 5.2.4 and 5.2.5.

5.2.4 Aggregate Car Ownership Model

As the results of non-causality are rejected according to the Johansen Juselius cointegration test in Section 5.2.3, the VECM can be analysed. The results for the VECM for the car ownership model are presented in Table 5.3, Table 5.5, and Figure 5.1. The elasticities in the long run were measured by the variables β1, β2, β3, β4 and β5 (refer to Equations 4.1 and 4.3). In general, elasticity measures the responsiveness of the percentage change of one variable to the percentage change of another variable. Since all variables are in logarithms, the cointegration relationship implies the long-run elasticity of

the explanatory variables with regards to car ownership. The VECM is utilised to capture the dynamics of the long-run equation in the time series.

The results for the normalised long-run equation for the car ownership model is shown in Table 5.3. It is evident that all variables are statistically significant at the 5% level, except for road length. The long-run car ownership elasticities with respect to RGDP per capita and level of employment were 1.56 and 3.59, respectively, while negative elasticity was identified for fuel price (-1.06). The results also show a long-run substitution relationship between car and motorcycle ownership (-0.56).

Table 5. 3 Long-Run Car Ownership Model Estimations.

(a) The long-run car ownership model

$lnCAR_t$	= - 3.86	- 0.56$lnMOTOR_t$	+ 1.56$lnRGDP_t$	+ 0.07$lnROAD_t$	- 1.06$lnFP_t$	+ 3.59$lnEMP_t$
(t-stat)		(11.75)**	(-15.26)**	(-1.57)	(13.21)**	(16.60)**

$R^2 = 0.51$

Notes: The figure in parenthesis (…) denote as t-statistics. ** represent 5% level of significance.

5.2.5 Aggregate Motorcycle Ownership Model

The results for the VECM for the motorcycle ownership model are presented in Table 5.4 and Table 5.5 and Figure 5.1. Based on the long-run equation in Table 5.4 for the motorcycle ownership model, it is shown that all variables are statistically significant at the 5% level. According to the results, it is found that the long-run motorcycle ownership elasticities with respect to RGDP per capita and employment are 2.76 and 6.37, respectively. Negative elasticities were identified in the case of fuel price (-1.88). The results also show a long-run substitution relationship between car and motorcycle ownership (-1.77).

Table 5. 4 Long-Run Motorcycle Ownership Model Estimations.

(b) The long-run motorcycle ownership model

$\ln MOTOR_t$	= - 6.85	- 1.77$\ln CAR_t$	+ 2.76$\ln RGDP_t$	+ 0.12$\ln ROAD_t$	- 1.88$\ln FP_t$	+ 6.37$\ln EMP_t$
(t-stat)		(17.02)**	(-15.70)**	(-1.59)	(13.38)**	(-15.36)**

$R^2 = 0.57$

Notes: The figure in parenthesis (...) denote as t-statistics. ** represent 5% level of significance.

According to Table 5.4, the value of ECT, which is the error correction term, was shown to have an expected coefficient that is negative with the significant t-statistics value which matches the outcome (-0.27 for the motorcycle ownership model; -0.13 for the car ownership model). The magnitude of these coefficients indicates that the speed of adjustment varies between these two models. In particular, it takes 27 per cent adjustment in a year for the motorcycle ownership model and 13 per cent per year for the car ownership model to adjust to the long-run equilibrium due to short-run disturbances. This indicates that motorcycle ownership has a faster speed of adjustment to correct disequilibrium compared to car ownership. Such results show that in the case of any shocks in the market (for example fuel hikes), motorcycle ownership adjusts faster than car ownership to achieve long-run equilibrium. The VECM short-run causal relationship results for car and motorcycle ownership are presented in Figure 5.1. Based on the results, there is a unidirectional short-run causal relationship from RGDP to both car and motorcycle ownership.

Table 5. 5 Short-Run Causality Results Based on VECM – Motorcycle and Car Ownership Model.

Dependent variables	Independent variables: χ^2 statistics of lagged 1st differenced term						Ect_{t-1} coefficient (t-stat)
	ΔlnMOTOR	ΔlnCAR	ΔlnRGDP	ΔlnROAD	ΔlnFP	ΔlnEMP	
ΔlnMOTOR	-	0.49	0.73**	0.44	0.89	0.05	-0.27** (-3.21)
ΔlnCAR	0.20	-	2.44**	0.13	0.11	0.31	-0.13** (-2.14)
ΔlnRGDP	0.66	0.35	-	1.15	0.21	0.02	0.11 (1.45)
ΔlnROAD	0.10	0.10	0.07	-	0.13	0.03	0.37 (1.90)
ΔlnFP	0.48	0.26	0.09	0.84	-	0.09	0.10 (0.89)
ΔlnEMP	0.51	0.88	1.01	0.66	1.31	-	0.05 (1.72)

Note: ** denotes significant at 5% significant level. The figure in parenthesis (…) denote as t-statistics and the figure in the squared brackets […] represent as p-value.

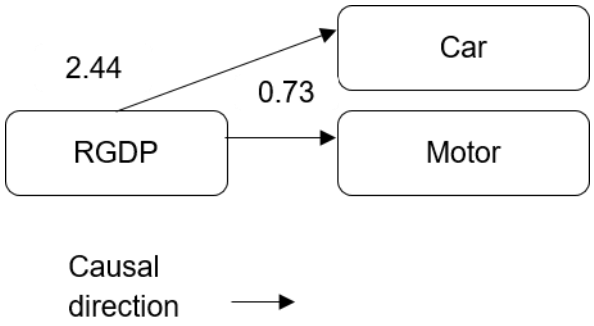


Figure 5. 1 Short-run Causal Relationship of Car and Motorcycle Ownership. Note: The numbers on/near the arrows are χ^2 values.

5.3 Discussion of the Significant Findings

A summary of the VECM results for the car and motorcycle ownership model are presented in Table 5.6. The outcomes show that there are four main determinants of vehicle ownership, which are RGDP, fuel price, level of employment and ownership of another private mode of transport. Among the determinants, level of employment is shown to have the largest effect on both car and motorcycle ownership. All determinants have similar expected signs in accordance with the past literature.

Table 5. 6 Summary of the VECM for the Car and Motorcycle Ownership Models.

	Long-run elasticity		**Long-run elasticity**
Car Ownership Model		**Motorcycle Ownership Model**	
Constant	3.86		6.85
Car Ownership	-0.56** (Substitution)	**Motorcycle Ownership**	-1.77** (Substitution) Tuan (2011) "long-run substitution" [-0.24 in Malaysia; -0.15 in Japan]
Income	1.56** Johansson and Schipper (1997), Romilly et al. (1998), and Goodwin et al. (2004) [1]; Chin and Smith (1997) [0.916]	**Income**	2.76** Duffy and Robinson (2004) [3.8];
Fuel price	-1.06** Johansson and Schipper (1997) [-0.1]; Goodwin et al. (2004) [-0.25]	**Fuel price**	-1.88**
Road length	0.07 Law et al. (2015)	**Road length**	0.12 Law et al. (2015)
Employment	3.59**	**Employment**	6.37**

Notes: ** denotes significant at 5% significance level. Elasticity in square brackets [ ].

5.3.1 Car and Motorcycle Interdependency

This study has been able to identify the determinants of car and motorcycle ownership at the aggregate level for a state in a developing country with a high level of car and motorcycle ownership. First, the results indicated that there is a substitution relationship between cars and motorcycles in the long run (-0.56 from motorcycle to car ownership; -1.77 from car to motorcycle ownership). This shows that there is a more elastic relationship from car to motorcycle ownership. Based on the outcome, as the number of car ownerships increases, in the long run, it is highly likely that there will be a leap from motorcycle to car ownership. The negative relationship between both modes is aligned with the results from Tuan (2011). However, the relationship presented in the results are more elastic (-1.77) than that presented by Tuan

(2011) [-0.24 for Malaysia; -0.15 for Japan]. It is evident that there is a long-run dependency between car and motorcycle ownership in Malaysia, as demonstrated at the country and at the state level (Sarawak). The stronger relationship at the state aggregate level compared to the country aggregate level indicates that there might be lower car and motorcycle dependency in other states in Malaysia, which might be triggered by other transport options such as public buses and train. In the context of Sarawak, specifically Kuching city, cars have been identified as the most popular mode of transport across age, income and occupation groups (Lim et al., 2007). This is due to issues in public buses services, such as punctuality, reliability, availability of bus schedules, bus route frequency and the cleanliness. The results also indicated that there is a stronger dependency between car and motorcycle ownership in Sarawak compared to a developed country. Japan has been recognized for its well-known *shinkansen* (bullet train), trains, subway and buses, which provide clean, reliable, punctual and comfortable public transport services for the users. This can be seen from the modal split of passenger transport in Tokyo, Japan, in 2003 (Fujimoto, 2008). Although there is a sizeable share for passenger cars (33 per cent), the remaining shares of the modal split refer to other alternative modes, including Japan railways (25 per cent), private railways (23 per cent), subway (13 per cent) and buses (6 per cent). This outcome could also be attributed to different transport infrastructure and services options (aside from public buses and train), which might be due to better walking and cycling facilities provided in a developed country compared to a developing country. In the case of a city in a developing country, Putrajaya, Malaysia, the implementation of walkability is still low (Hashim et al., 2017). Considering that Malaysia is a hot climate country, the failure to provide shade for pedestrians and cyclists discourages people from walking and cycling. Hashim et al. (2017, p. 104) further elaborated the main reasons for limited bicycle usage, including a “lack of appropriate infrastructure, lack of promotion, not enough cycle lane, cycle lane not well designed, and lack of maintenance”.

Cars and motorcycles have different features. Motorcycles are less expensive and have lower maintenance costs compared to cars. Households consider owning motorcycles at lower income levels and as they gain more income, they purchase cars and might even consider selling their motorcycles to purchase more cars. The similar relationship (substitution) between car and motorcycle ownership at the aggregate country (Malaysia) and aggregate

state level (Sarawak) triggers the needs to further extend the study using a cross-sectional study at the disaggregate urban level, which is presented in Chapters 6 and 7.

5.3.2 Income as a Determinant of Car and Motorcycle Ownership

It is known that as income rises, individuals tend to purchase vehicles to realise their needs to travel (Bradburn and Hyman, 2002; Dargay, 2010). For car ownership elasticity with respect to income, it was shown that the elasticity in the long run is 1.56, which slightly higher than Johansson and Schipper (1997), Romilly et al. (1998), and Goodwin et al. (2004), who predicted that a 1 per cent increment in income would lead to an approximately 1 per cent increment in vehicle ownership. The elasticity is almost similar with that of a neighbouring country, Singapore, which showed an elasticity of 0.916 in a study by Chin and Smith (1997). The output indicates that the income elasticity of Sarawak is higher than that in developed countries. The people in Sarawak have a high dependency on cars because in comparison to developed nations, the state is still lacking in terms of public transport infrastructure and services.

Motorcycles are considered as the key mode of transport for commuters with a low to middle income in Sarawak. The primary reason behind the continuous high motorcycle demand is the vehicle's advantages, such as a smaller engine size compared to that of cars (Hsu et al., 2003). Based on the outcomes, income elasticity is found to be lower in comparison with the results of Duffy and Robinson (2004), who studied motorcycle demand in the UK and obtained elasticity values of 3.80 (data period: 1964-2000). The consequence of income in Sarawak for motorcycle demand is found to be significant and elastic in the long run; this can be explained by assuming that with greater wealth, households tends to purchase more motorcycles for other purposes, for example as a symbol of prestige and for recreational purposes. Similar relationship is also found in the short-run indicating income to be significantly important determinant to own either car and motorcycle in short- and long-run.

According to the results, as income increases, people are encouraged to own more private-based vehicles, either cars or motorcycles. Road users prefer a private mode of transport as it assures them shorter travel times, flexibility and comfort compared to public transport (Borhan et al., 2019). It is evident that

people perceive motorcycle as a less expensive private mode of transport compared to cars. Therefore, the results show that changes in income have a greater effect on changes to motorcycle ownership compared to car ownership.

5.3.3 Fuel Price as a Determinant of Car and Motorcycle Ownership

It was also expected that fuel price could influence vehicle ownership (Dargay et al., 2007). The results found that car ownership in Sarawak is less sensitive to changes in fuel price, with an elasticity value of -1.06, compared to motorcycle ownership, with an elasticity value of -1.88. These relate with motorcycle as the first option for private vehicle owners due to its affordability. As those who purchase motorcycles may come from a lower economic background than those who purchase cars, the rise in fuel price affects the former more than the latter. Any fuel price changes are known to have more influence towards motorcycle ownership compared to car ownership. This can be explained by assuming that the motorcycle is the first option in terms of a less expensive private vehicle; thus, households tend to abort their intention to purchase more motorcycles with the anticipation of a rising fuel price.

The results for car and motorcycle ownership elasticity with respect to fuel price were greater for both models compared to Johansson and Schipper (1997), with an elasticity value of -0.1, and Goodwin et al. (2004), with an elasticity value of -0.25. The effect of fuel price on vehicle ownership may vary based on different markets. Given similar increases in absolute fuel price, people from a country with a higher fuel tax (for example, the UK) may face a lower overall fuel price percentage change compared to those from a lower fuel tax country. Hence, this influences the consumer perception of more significant changes of vehicles in a lower fuel tax country in comparison with a high fuel tax country.

5.3.4 Employment as a Determinant of Car and Motorcycle Ownership

The long-run elasticity of car ownership and motorcycle ownership with respect to employment is significant and highly elastic at 3.59 and 6.37, respectively. This is supported by Hanly and Dargay (2000), who indicated

that a rise in employment leads to a rise in vehicle ownership. A number of previous studies using time series aggregate models have included unemployment rate in their models. However, the variable has been shown to be insignificant in studies by Romilly et al. (1998) and Paravantis and Sambracos (2006). Employed individuals commonly have more income and hence have the ability to own cars and motorcycles. However, the relationship between employment and motorcycle ownership was found to be higher than car ownership. This is because of the motorcycle's affordability as the best first transport mode to commute, particularly for new workers (Hsu et al., 2003). The situation usually occurs in many Asian developing countries where there is a high dependency on motorcycle ownership. This again leads to the case of Sarawak, in which the purchasing power is still very low, causing motorcycles to be the first option of private vehicle purchase compared to cars. Nonetheless, people switch their mode of transport from motorcycle to cars for many reasons, such as an improved standard of living or the expansion of family size.

5.4 Chapter Conclusion

In order to identify the determinants (long-run elasticities) of private vehicle ownership, particularly car ownership and motorcycle ownership in Sarawak, this chapter of the thesis presented the output of the vehicle ownership model that was analysed using the vector error correction model (VECM). In summary, the results found that real GDP, fuel price and employment are significant in explaining car ownership and motorcycle ownership demand in the long run.

Based on the outcome of the analysis, it was found that there are similarities and dissimilarities between how the determining variables (real GDP, fuel price, road length and employment) influence vehicle ownership (in terms of long-run elasticities) between the car ownership model and the motorcycle ownership model, and also between developed and developing countries. The differences are mainly due to the diverse socio-economic backgrounds and transport infrastructure availability between developed and developing countries. For instance, in the case of Sarawak, lower-income people resort to motorcycles as their main mode of transport instead of taking public buses, cycling or walking. This is due to the lack of efficient bus services, for example,

inadequate public bus frequency and punctuality and improper provision of bus schedules to the public. Cycling and walking are less preferred due to the poor cycling and walking conditions, complemented by the weather factor of the year-round hot tropical climate in Sarawak. As few studies have been conducted in the context of Asian developing countries utilizing the same techniques to estimate vehicle ownership, it is challenging to provide a comparison on the effect of these variables towards vehicle ownership in the long run.

Apart from the above-mentioned discussions, the outcome of this study sheds light on the interdependency between car and motorcycle ownership in the long run at the aggregate level. Firstly, there is a negative and elastic relationship from car ownership towards motorcycle ownership compared to the relationship from motorcycle ownership towards car ownership. This indicates that people are highly likely to shift from owning motorcycles to cars in the long run. Secondly, there is a similar substitution relationship between car and motorcycle ownership in the country at the aggregate level (Malaysia, as studied by Tuan, 2011) and at the state aggregate level (Sarawak). However, the relationship is stronger at the state aggregate level. Motorcycles are considered as an important mode of transport in developing countries for several reasons, including low purchase cost, low cost of maintenance and easy manoeuvring on the road. In contrast, there are significantly fewer motorcycles in developed countries compared to developing countries as motorcycles are generally considered recreational. Following this, the third result shows that there is a similar substitution relationship between car and motorcycle ownership with that of a developed country, specifically Japan (Tuan, 2011). However, the relationship is inelastic in the case of the developed country, which is due to the existence of other viable modes of transport. While it is true that socio-economic factors significantly influence people to own more cars or motorcycles, there are other factors which are yet to be explored that cannot be explained using aggregate data. These may include the integration of individual preferences, such as the psychological factors as the determinants of car and motorcycle ownership, specifically in urban areas. Therefore, the following chapter is presented to further support the role of the disaggregate study through the survey design, data collection and descriptive analysis of the disaggregate data.

Chapter 6

Survey Design, Data Collection and Descriptive Analysis of the Disaggregate Data

6.1 Introduction

The past decade has seen the growing importance of disaggregate based data in comparison with aggregate based data, particularly in capturing individual specific preference travel behaviour. In Chapter 4, aggregate based modelling was conducted as there is no extant research on travel behaviour in Sarawak. The aggregate based studies provide a basic understanding of factors influencing car and motorcycle ownership. Meanwhile, the previous literature on disaggregate vehicle ownership modelling has not addressed the determinants of motorcycle ownership and use in much detail. Such expositions are unsatisfactory because in Asian developing countries (for instance, Malaysia), the rise in motorcycle ownership parallels the rising trend in car ownership. Despite the continuous increase in motorcycle ownership in these regions, aside from the limited number of studies, the relevant research has consistently been conducted primarily from the perspective of socio-economic and built-environment factors. Little is known about the role of psychological factors in explaining motorcycle ownership and use.

Furthermore, while studies in vehicle ownership have only focused on car and motorcycle ownership as well as car ownership (motorcycle ownership) and use in separate models, there are very few quantitative analysis examining the interdependencies between car and motorcycle ownership jointly with car and motorcycle use in a single framework. This indicates the need to investigate the nature of the relationship between car and motorcycle ownership and understand how psychological factors influence ownership and use. Following this, the chapter is divided into a few parts. First, the survey design is presented in Section 6.2, which describes the survey-based research and questionnaire setup for the thesis. Section 6.3 presents the sampling method of the survey, which includes the sample selection process and the calculation of the sampling. Next, Section 6.4 explains the survey evaluation, which entails the pre-pilot and pilot study. In Section 6.5, the

sample characteristics are outlined, and the survey response are presented. Furthermore, the socio-economic and travel behaviour characteristics as well as the psychological factors are discussed. Finally, Section 6.6 sets out to summarise the entire chapter.

6.2 Survey Design

6.2.1 Survey-Based Research

Survey-based research was conducted to collect data for the proposed model for the study, whereby a self-administered paper-based survey was utilised in. Sarawak does not have an existing travel-based survey database and transport experience-related survey. The survey was produced in two languages, namely English and Malay, for the convenience of the respondents. Participants were given a package containing all the necessary information pertaining to the research, which included all the important details regarding the questionnaire:

- 1 x Household information and transportation options form
- 4 x Personal attitudinal survey on transport
- 1 x Cover letter
- 1 x Information sheet
- 1 x Envelope for returning the completed surveys

This study used a paper-based self-administered survey rather than a web-based survey for several reasons:

- Difficulties in obtaining e-mail addresses of households in Sarawak. While it might have been possible to obtain e-mail addresses for certain government and non-government offices, these conditions may have led to selection bias. Although internet access is increasing among the population, the Sarawakian people are not familiar with online surveys. Hence, there is a possibility that they would have been reluctant to fill in a survey. Alternatively, if they had filled in a survey, then they might not have fully completed it or there might have been a lower response rate as the responses would have been from those who had internet access and were interested in answering the survey. As there are enumerators, the paper-based survey increased the response rate compared to using internet-based survey. According to Lupu

and Michelitch (2018), local enumerators which have familiar traits (ethnicity) may have a positive effect on survey responses. The households were identified using the addresses provided by the Department of Statistics Sarawak for the Official Household Survey.

6.2.2 Questionnaire Setup

The structure of the conceptual framework is described in Figure 4.4 and Figure 4.5 and consists of several hierarchical construct models to operationalise the complex relationship that links the factors influencing private vehicle ownership and use. In this model, there are four main endogenous variables (dependent variables), which are car ownership, motorcycle ownership, car use and motorcycle use. Three main groups of determining factors or exogenous variables (independent variables) are identified, namely socio-economic, built-environment and psychological factors. Psychological variables include attitude towards transport policy, perceived behavioural control, social norms and pro-environment factor. The conceptual framework, as previously described, assists in the questionnaire setup for the disaggregate model. The survey descriptions are shown in Table 6.1.

Table 6. 1 Surveyed Data Description.

	Variables	**Items**	**Description**
Dependent Variables			
VKT (VKTC, VKTM)	Vehicle Kilometres Travelled	Average annual vehicle kilometres travelled for either cars or motorcycles	Categorical Scale: 1≤10,000km; 2=10,001-20,000km; 3=20,001-30,000km; 4=30,001-40,000km; 5≥40,001km
VEH (VEHC, VEHM)	Vehicles	Number of vehicles owned in a household for either cars or motorcycles	Categorical Scale: 1,2,3 4>5
Independent Variables			
Socio-economic	Socio-economic	Income	Categorical Scale: 1=<RM1,000; 2=RM1,000-RM2,000; 3=RM2,001-RM3,000;

			4=RM3,001-RM4,000; 5=>RM5,000
		Education	Categorical Scale: 1=Primary school; 2=High school; 3=Bachelor's degree; 4=Master's degree; 5=PhD
		Occupation	Categorical Scales: 1=Unemployed/housewife; 2= Student; 3=Private sector; 4=Public sector; 5= Business owner
Built-environment factors (The items are based on the responses to statements in the descriptions)			
BE_CBD	Accessibility	Distance from house to city centre (km)	Categorical Scale: 1=<10; 2=10-19km; 3=20-29km; 4=30-39km; 5=>40km
BE	Accessibility	My neighbourhood is safe and convenient for walking and cycling	Likert Scale: 1=Strongly disagree; 2=Disagree; 3=Undecided; 4=Agree; 5=Strongly agree
		Amenities are located within walking distance.	Likert Scale: 1=Strongly disagree; 2=Disagree; 3=Undecided; 4=Agree; 5=Strongly agree
Latent Psychological Variables (The items are based on the responses to statements in the descriptions)			
TP	Attitude towards transport policy (Reflective construct)	Expanding and upgrading roads. Charges for road use. Access restrictions for certain types of vehicles (e.g. lorries).	Likert Scale: 1=Strongly disagree; 2=Disagree; 3=Undecided; 4=Agree; 5=Strongly agree
PEA	Pro-environment	I am adjusting my travel behaviour to reduce my impact on the environment.	Likert Scale: 1=Strongly disagree; 2=Disagree; 3=Undecided; 4=Agree; 5=Strongly agree

	(Reflective construct)	I am willing to change my lifestyle to reduce environmental problems.	
PBC	PBC	My neighbourhood has poor access to public transport services.	Likert Scale: 1=Strongly disagree; 2=Disagree; 3=Undecided; 4=Agree; 5=Strongly agree
	(Reflective construct)	Using public transport is slow and unreliable.	
SN	Social norm	Society influences my travel behaviour	Likert Scale: 1=Strongly disagree; 2=Disagree; 3=Undecided; 4=Agree; 5=Strongly agree
	(Reflective construct)	The culture of auto mobilization/car-oriented influences my travel behaviour	

6.3 Sampling Method

6.3.1 Sample Selection Process

While the previous section described the survey questions, this section of the thesis presents the sampling method used for the research. Figure 6.1 shows the sampling process for the thesis, while Table 6.2 shows the socio-demographic characteristics of the districts in Sarawak. This thesis used stratified random sampling, which involves the following:

(i) The selection of chosen districts, which are Kuching, Kota Samarahan, Miri and Sibu. The chosen districts are based on the socio-demographic characteristics of the households in Sarawak. First, the districts are chosen based on the main criteria, such as having the highest average household monthly income, which is Miri (RM6,525), Kuching (RM6,281), Kota Samarahan (RM6,232) and Sibu (RM5,386). The selection assumes that the divisions with the highest income may have high levels of car and motorcycle ownership, which suits the purpose of the disaggregate model. The selection

of Kuching and Kota Samarahan is further strengthened as these have the largest population density, with 183.9 inhabitants per sq km and 60.3 inhabitants per sq km, respectively. Kuching is the administrative centre of Sarawak and consists of high-tech industry, finance, tourism, service and education. As an education hub in Sarawak, Kota Samarahan is also known for its medical, agriculture and plantation industry. Another district, which is Sibu, is also selected as a district with a high number of people (302,300, third after Kuching and Miri) and also a high number of households (50,318, second after Kuching). The main economic activities in Sibu are ship-building, tourism, plantation and education. The economic factor, land size, number of households, population size and population density in these four districts are an indication of the high level of travel activities and demand, and therefore were the main criteria for choosing the sample.

(ii) The choice of sampling urban households in this thesis is due to the huge gap between urban and rural household car ownership, which indicates potential high car-based travel activity. In addition, the selection considers the difficulties (time and cost) which may be incurred when involving rural households. The process of reaching the rural areas in question may have presented a high risk for the researcher, thereby excluding the households from rural areas in this research. Smaller districts are not sampled due to limited transportation options and to avoid problems with non-meaningful sampling.

(iii) The household respondent is randomly identified from the household database (Number of households: 1,900 households) from the Department of Statistics Sarawak (2010). The calculation of random sampling after stratifying the four urban districts is shown in Section 6.3.2.

Table 6. 2 The Socio-demographic Background of the Sampled Sarawak Districts.

Districts	Mean Monthly Household Income (RM)	Industry	Population	Area (km)	Population Density (per sq km2)	Number of House holds
Kuching	6,281	Administrative centre, High-tech industry, finance, tourism, service, education	771,600	4,195	183.9	131,908
Kota Samarahan	6,232	Education, medical, agriculture, plantation	176,400	2,928	60.3	16,448
Sibu	5,386	Ship-building, tourism, plantation, education	302,300	8,278	36.5	51,898
Miri	6,525	Plantation, petrochemical, manufacturing, tourism, education	380,600	26,777	14.2	66,634
Sri Aman	4,154	Agriculture, plantation	66,790	2,323	28.8	15,866
Betong	3,495	Agriculture, plantation	68,100	2,493	27.3	12,927
Sarikei	4,012	Agriculture, fishing, plantation	58,021	985	58.9	13,220
Mukah	4,297	Timber processing, agro-processing, sago plantation	46,100	2,536	18.2	8,962
Bintulu	5,046	Petrochemical, plantation	189,146	7,220	26.2	40,226
Kapit	3,707	Logging, coal	56,053	15,595	3.6	12,862
Limbang	4,555	Agriculture, tourism	48,186	11,620	4.1	10,476

Source: Department of Statistics Malaysia (DOSM, 2017b).

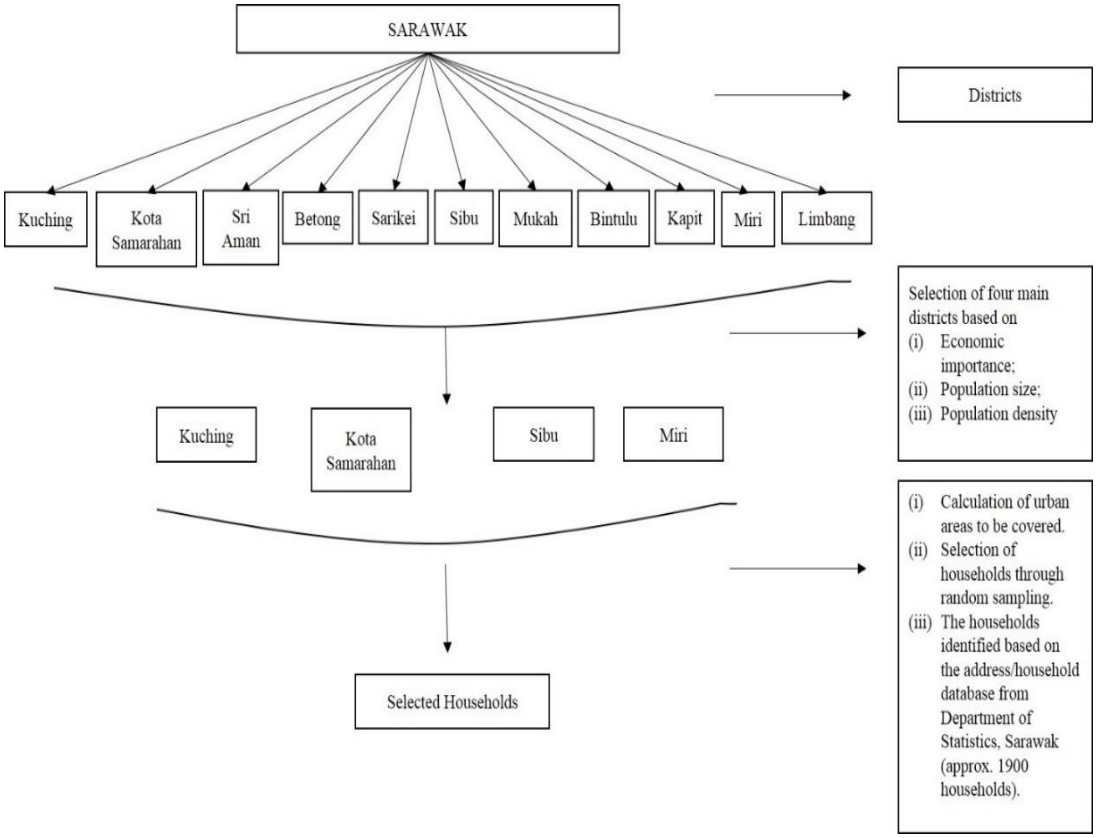


Figure 6. 1 Flow Chart of the Sampling Process.

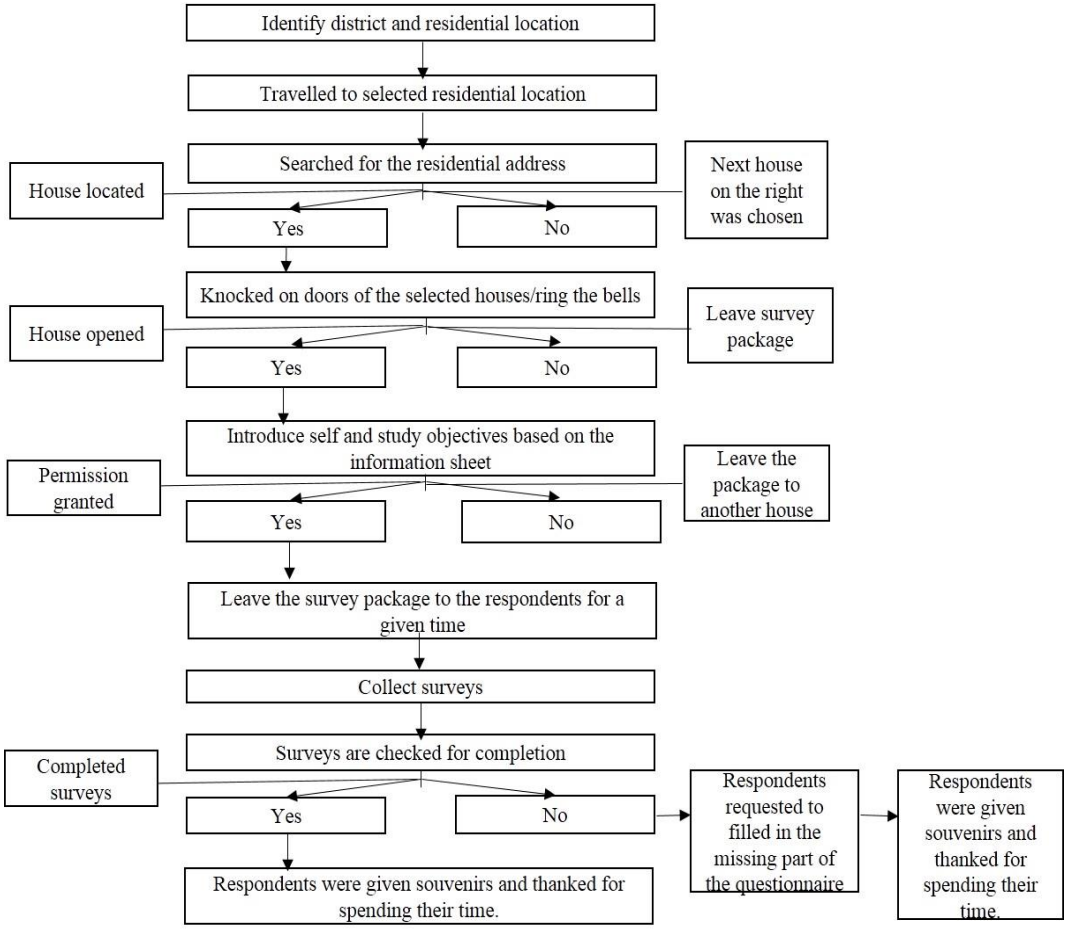


Figure 6. 2 Flow Chart of the Data Collection Process.

Figure 6.2 shows the flow chart of the data collection process for the four chosen districts in Sarawak. Data collection was undertaken by the researcher and a group of trained research assistants. The individual households were identified based on the address from the database of the Department of Statistics Sarawak, which consisted of approximately 1900 households. The research assistants were trained in how to locate the residence and persuade the participants to take part in the survey. They were also briefed prior to each survey distribution day. Each of the survey packages contained an information sheet, and the targeted participants were briefed with the aims and details of the research. The package also notified that those who filled in the survey were considered to have given their consent to participate in the research and that there was a date of withdrawal if they chose not to participate. The research assistant collected the surveys at the given point of time, and upon collecting the surveys, they checked whether they had been completed or not.

6.3.2 Calculation of the Sample Size

Based on the identification of the selected districts in Section 6.3.1, this section explains the calculation of the random sampling of urban households in Sarawak. The sample size calculation was based on the stratified random sampling method. The main advantage of applying stratified random sampling is that it enables the main population characteristics in the sample to be captured. Stratified random sampling provides a smaller estimation error and higher precision in comparison with simple random sampling. Previously, the income factor determined the selection of districts in Sarawak for the disaggregate model. Next, the urban areas of the selected districts are used as the relevant strata, considering the substantial gap between urban and rural car ownership. This is because, by stratifying these urban districts, the sample produced is more representative of the urban districts in Sarawak and thus relevant for the research (refer to Table 6.3).

Table 6. 3 Number of Households Based on Strata in Sarawak Main Districts (2010).

	District	Rural	Urban	Total
(a)	Kuching	15,166	116,742	131,908
(b)	Kota Samarahan	3,923	12,525	16,448
(c)	Sibu	8,438	43,460	51,898
(d)	Miri	16,316	50,318	66,634
	Total	43,843	223,045	266,888

Source: DOSM (2010).

The research sampling was based on random sampling.

$n = [(z^2 * p * q) + ME^2] / [ME^2 + z^2 * p * q / N]$

where

	Value/Formula	**Definition**
n = sample size	*unknown*	
z = critical value	*1.96*	*the point (or points) on the scale of the test statistic beyond which we reject the null hypothesis, derived from the level of significance α of the test.*
p = proportion value	*0.5*	*parameter that describes a percentage value associated with a population*
q =	*1- p = 0.5*	
ME (Margin of error) =	*0.04*	*amount of random sampling error in a survey's results* (Gilliland and Melfi, 2010).
N = Population size	*223,045*	*A group of individuals of the same species occupying a particular geographic area*

The main strata comprised the main districts in Sarawak, which are Kuching, Kota Samarahan, Miri and Sibu. A random sampling calculation was later conducted to determine the sample size for the survey. The formula was used as the population size is known. As the proportion size is unknown, the population is set to 0.5, which yields a conservative size of the sample that

will ensure better precision. As precision is based on standard error, a small standard error indicates more precise sample estimates, and vice versa. The equation for the total sample size is:

$n = [(1.96^2) \times 0.5 \times 0.5 + 0.04^2] / [0.04^2 + (1.96^2) \times 0.5 \times 0.5 / 223{,}045] = 0.96^2/0.002 = 481$

The total sample size required for the research was a minimum of 481 households. This needed to be divided based on the size of every district in order to obtain the number of households that needed to be sampled for every district. For that reason, the general equation is as follows:

$n_i = \frac{district\ population}{N} \times n.$

$n_a = \frac{116{,}742}{223{,}045} \times 481 = 251.76 \approx 252$	$n_c = \frac{43{,}460}{223{,}045} \times 481 = 97.72 \approx 98$
$n_b = \frac{12{,}525}{223{,}045} \times 481 = 27.01 \approx 28$	$n_d = \frac{50{,}318}{223{,}045} \times 481 = 108.51 \approx 109$

Rounding up the district sample size gives the number of households to be sampled in every district: 252 in (a) or Kuching, 28 in (b) or Kota Samarahan, 98 in (c) or Sibu, and 109 in (d) or Miri (the total of summation is 483, which is slightly greater than sample size as a results of rounding). Based on Watt et al. (2002), 33 per cent is the average response rate for a paper-based questionnaire. Their research comparing a non-face-to-face paper-based survey against a non-face-to-face online survey indicated that the response rate was 33 per cent for the former and 32 per cent for the latter. Considering the high response rates received by several studies, which were in the range of > 50 per cent (Cook et al., 2000; Nair et al., 2005), the 33 per cent response rate is perceived as quite low, raising questions as to whether the survey was properly handled in a face-to-face environment. However, there are a few considerations that should not be taken lightly, including the following: (1) Sarawak and Malaysia have no official travel-based survey, hence the survey was set up at a lower response rate; (2) there is an official socio-economic survey that is only conducted every five or ten years, which indicates how rare

official surveys are conducted. Therefore, each sample size for the district was divided by 0.33, resulting in a larger sample size and allowing for non-responders. Considering that there is no official travel/transport-based survey in Malaysia, the researcher decided to follow the low response rate of 33 per cent to describe a worst-case scenario. A previous study by Lupu and Michelitch (2018) also stated that there is still inadequate empirical knowledge on the response rate to surveys in developing countries.

$n_a = \frac{252}{0.33} = 763.6 \approx 764$	$n_c = \frac{98}{0.33} = 296.97 \approx 297$
$n_b = \frac{28}{0.33} = 84.8 \approx 85$	$n_d = \frac{109}{0.33} = 330.3 \approx 331$

In total, 1,477 (based on calculation) surveys needed to be distributed to households in the Kuching, Kota Samarahan, Sibu and Miri districts in Sarawak.

6.4 Survey Evaluation

6.4.1 Pre-Pilot Study

In this thesis, a pre-pilot test and a pilot test were undertaken before the actual survey was conducted. The pre-pilot and pilot tests were conducted using a self-administered paper-based questionnaire. The pre-pilot test was carried out to identify the problems in the language, tone, structure and design of the survey to be used in the pilot survey. The pre-pilot test was targeted at various University of Leeds students from Malaysia to confirm whether the presentation of the attributes was understandable for the respondents. The main reason for the pre-pilot test being conducted in the University of Leeds was to identify the adequacy of the survey in general, for instance the clarity and sequence of instructions and questions, the length and understandability of questionnaire, and rating scales of the questionnaire. Twenty surveys were distributed, and 19 responded (95 per cent). The pre-pilot response time was approximately three weeks after the survey was distributed. From the pre-pilot test, a few points were taken into considerations. These included:

- The language usage was too technical for some respondents with various educational backgrounds.

- The translation of the local language was incomplete.
- The structure and design of the survey was found to be difficult to navigate. The survey needed proper numbering and sections.

As a result, careful improvements were made to ensure that the language was easy to understand by consulting a Malaysian English teacher. The Likert scale was also standardised for each of the questions that contained agreement/disagreement question. The questions were re-organised page by page and the numbering was done properly. Each page was also later numbered.

6.4.2 Pilot Study

As an addition to the reason mentioned above, several issues were pointed out to justify the pilot test in Sarawak, including providing fieldwork training for the enumerators, estimating the monetary cost and time required for the respondents to complete the questionnaire, and identifying the suitability of the questionnaires' contents in the Sarawak context. Before commencing with the actual survey, the pilot test was deployed to improve the survey by obtaining additional information from the smaller size of the sample of respondents to further understand the survey instrument, wording, and measurement and to identify any ambiguity in the questions. This was to ensure that the questions in the questionnaire would be understood by the respondents in the context. The pilot test was conducted in Sarawak using the rule of thumb of five to ten per cent of the expected sample size, whereby the questionnaire was in two languages (English and Malay Language). The targeted respondents came from the Kuching district, the capital of Sarawak. The pilot was conducted from December 2015 to January 2016. Research assistants were involved in the distribution and the collection of the survey.

Kuching was selected as the pilot test location as the district is the most developed and it has the highest population and number of households (refer to Table 6. 2). Sixty-five pilot surveys were distributed to urban households in the Kuching district area using the paper-based self-administered survey. Based on the sampling calculation, a number of 39 respondents, which is 5 per cent of 764 respondent, needed to be distributed for the pilot test. However, 65 pilot surveys were distributed. As a result, a total of 55

respondents returned the survey, but only 51 surveys could be used (response rate: 78 per cent). A number of factors were considered to produce the high response rate. That may include the fact that, as a result of time constraints, the selection of respondents by the research assistant may have been done on familiar territory to reduce the risk of non-response.

Issues that were observed among the respondents in the pilot questionnaire include:

- Content of the survey, namely understanding the questions in the survey as well as terms and the sequence of the questions. For example, the distance travelled per annum might be mistaken with total car mileage. The distance travelled per annum is the total kilometres travelled by cars (and motorcycle) in the households within a year, while the total car mileage is the overall kilometres that the car has travelled in its life. Some participants suggested that some questions are too similar with other questions, for example “I am concerned about environmental issues” and “I am an environmentally aware person”.

- Length of the survey: Other participants also found that the survey was very difficult to fill in and the questionnaire was too lengthy. They pointed out that because of this, the survey consumed a lot of their time, which was longer than the expected 15-20 minutes as written on the information sheet. The number of questions was thus reduced to avoid the survey becoming too lengthy. Since the respondents rarely participated in surveys, they might have taken more time to fill in the survey. The initial length for the survey was six pages and it was later shortened to five pages. [It is noted that the official household survey is conducted every 6-10 years, including in Sarawak (refer to Appendix E).]

6.5 Sample Characteristics

6.5.1 Survey Response and Completion Rate

Table 6.4 shows the response and completion rate of the survey for four districts in Sarawak, namely Kuching, Kota Samarahan, Sibu and Miri. A total of 1,477 surveys were distributed to the respective districts. An overall response rate of 66 per cent were received, in which the Kota Samarahan

response rate was highest at 88 per cent. This is followed by Miri with 75 per cent; Kuching with 70 per cent and Sibu with 63 per cent. However, after thorough assessment, the overall completion rate was 47 per cent, with the highest completion rate from Kota Samarahan at 79 per cent. This was followed by Miri with 50 per cent, Sibu with 45 per cent and Kuching with 42 per cent.

Table 6. 4 Survey Response and Completion Rate.

	District	Sample Total	Response	Response Rate (%)	Completed	Completion Rate (%)
(a)	Kuching	764	462	70	321	42
(b)	Kota Samarahan	85	75	88	67	79
(c)	Sibu	297	186	63	135	45
(d)	Miri	331	247	75	165	50
	Total	1,477	970	66	688	47

6.5.2 Socio-Economic and Travel Behaviour Characteristics

The data collection took place between February and September 2016 in four urban districts of Sarawak, namely Kuching, Kota Samarahan, Miri and Sibu. Table 6.5 presents the household characteristics for this sample of urban households and compares them with official local and national statistics where possible. Car ownership statistics indicate that there is a very high level of car ownership in the study area. With 93 per cent of the households owning a car, car ownership is much higher than the 85 per cent reported by the DoS. Meanwhile, the level of motorcycle ownership is much lower in urban Sarawak, at only 48 per cent. This shows that a car can be considered as the primary mode of transport while a motorcycle is considered as a secondary mode of transport. The distribution of gross monthly household income is comparable to the income distribution in the Sarawak region, as reported by the Department of Statistics (2015). Only the lowest income category is slightly under-sampled. Most of the respondents (97 per cent) had completed their tertiary education with an undergraduate college/polytechnic diploma (62 per cent) as their major type of education. Most of the respondents were doing clerical work (57 per cent), and there was also a high percentage for medium

to high-skilled employment (34 per cent) and low semi-skilled employment (9 per cent).

Table 6. 5 Sample Characteristics for Urban Households in Sarawak.

Household Info (n=688)				
	Source			
	Survey (2016)[a]		**Department of Statistics (DoS), Sarawak, Malaysia (2015)[b]**	
Number of Cars Owned	**Frequency**	**Percentage**	**Frequency**	**Percentage**
0	45	6.54	43,260	15.1
1	205	29.80		
2	252	36.63		
>3	186	27.04		
≥1	643	**93.46**	**243,232**	**84.9**
Max	7			
Number of Motorcycles Owned			**Department of Statistics, Sarawak, Malaysia (2010)[c]**	
0	358	52.04	195,273	68.16
1	193	28.05	71,508	24.96
>2	137	19.91	19,711	6.88
>1	330	**47.96**	**91,219**	**31.84**
Max	5			
	Researcher's Own Survey (2016)		**Department of Statistics, Sarawak (DoS), Malaysia (2015)[b]**	
Monthly Household Income	**Frequency**	**Percentage**	**Frequency**	**Percentage**
<RM2000	103	15	55,293	19
RM2001-RM3000	114	17	46,698	16
RM3001-RM4000	138	20	50,996	18

RM4001-RM5000	88	13	34,379	12
RM5001-RM6000	55	8	24,352	9
RM6001-RM7000	41	6	17,763	6
>RM7001	149	22	57,012	20

Survey

Education	**Frequency**	**Percentage**
Primary & high school	22	3
College/ Polytechnic Diploma	428	62
Undergraduate degree	195	28
Masters	35	5
PhD	8	1
Employment	**Frequency**	**Percentage**
Housewife, unemployed, retired	28	4
Semi-skilled workers, machine operators	36	5
Clerical	389	57
Medium business and minor professional (executive)	199	29
Major business and professional	36	5
Distance to CBD	**Frequency**	**Percentage**
<5	147	21.4
5≤CBD<10	177	25.7
10≤CBD<15	140	20.3
15≤CBD<20	74	10.8

20≤CBD<25	150	21.8
	688	

*The frequency for monthly household income and house tenure is calculated based on Department of Statistics, Sarawak, Malaysia (DOSM, 2010) number of urban households. (n=286,492)

a Researcher's Own Survey (2016).

b Source: Department of Statistics Malaysia DOSM (2010)

c Source: Department of Statistics Malaysia (DOSM, 2015)

When comparing with international statistics, car ownership in Malaysia itself was 439 vehicles per 1,000 inhabitants in 2015 (WHO, 2015). This figure is almost as high as in developed European countries, such as Denmark and Finland with around 490 vehicles per 1,000 inhabitants. Sarawak's car ownership was 280 vehicles per 1,000 inhabitants while motorcycle ownership was 277 vehicles per 1,000 inhabitants in 2015. Figure 6.1 puts the high levels of car ownership in Malaysia into context by distinguishing between urban and rural areas. The highest levels of car ownership in urban areas are found in Kuala Lumpur and Putrajaya. In both cities, 93 per cent and 99 per cent of households own at least one car, respectively. In the state of Sarawak, 85 per cent of households own at least one car in the urban areas, but only 47 per cent do so in rural areas. Sarawak has the highest urban-rural gap in car ownership compared to the other states.

The discrepancy between rural and urban car ownership is mainly attributed to the average income difference between urban and rural households. The average gross monthly income in 2016 for urban households in Sarawak was RM 6,548, which is higher (almost double) than the average monthly income of rural households of RM 3,695 in Sarawak.

The difference in the standard of living between urban and rural areas causes car ownership to be higher in urban areas as rural residents are less likely to be able to afford the cost of owning and maintaining a car. A lower income in the rural areas might be attributed to the engagement in low productivity and low-income jobs, either in agriculture in the rural areas or low-skilled factory and construction workers and low-grade government employees (Shari and Osman, 1996). According to Dargay (2002), the increasing cost of using a car as a mode of transport cause a significant economic impact for households in the rural areas. Hence, it is reasonable that car ownership is substantially low

in comparison with urban Sarawak and Malaysia considering rural households with low income and the rising cost of motoring. Furthermore, Tanninen (2013) elucidates that smaller-sized cities are related with difficulties in car payment and this has also been shown in the study by Lim and Siew (2017), which explained that borrowers living in rural areas are most likely to have greater car loan defaults in comparison with those in urban areas. This leads to higher car ownership in urban areas compared to rural areas.

Based on a study by Cervero (2013), the concentration of wealth in the main cities has paved the way for the concentration of public infrastructure developments, which includes public buses and roads. This may align with the current road infrastructure (or length) in the rural areas, which do not all have full/good capacity to accommodate the car usage, leading to lower demand for car ownership. Considering this, the thesis specifically targets the investigation of car ownership among urban households. Overall, it is evident that there is a high level of car ownership in Malaysia, and Sarawak is no exception. However, it should be noted that it is possible that the targeted urban regions in Sarawak are more car-dependent than some of the other urban regions in the state.

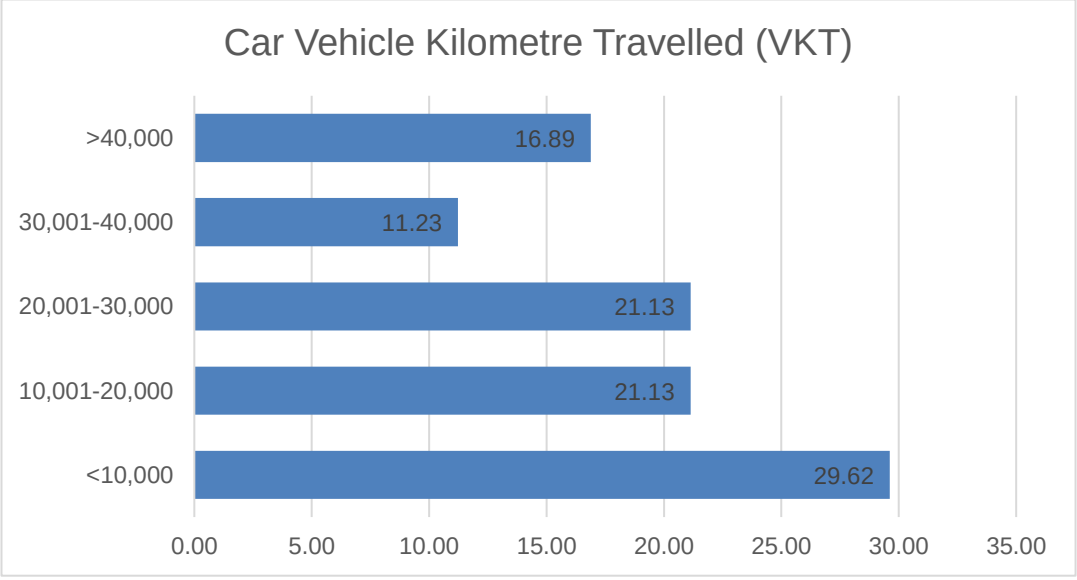


Figure 6. 3 Average Annual Vehicle Kilometres Travelled (VKT) via Car (n=688) by Sarawakian Urban Households.

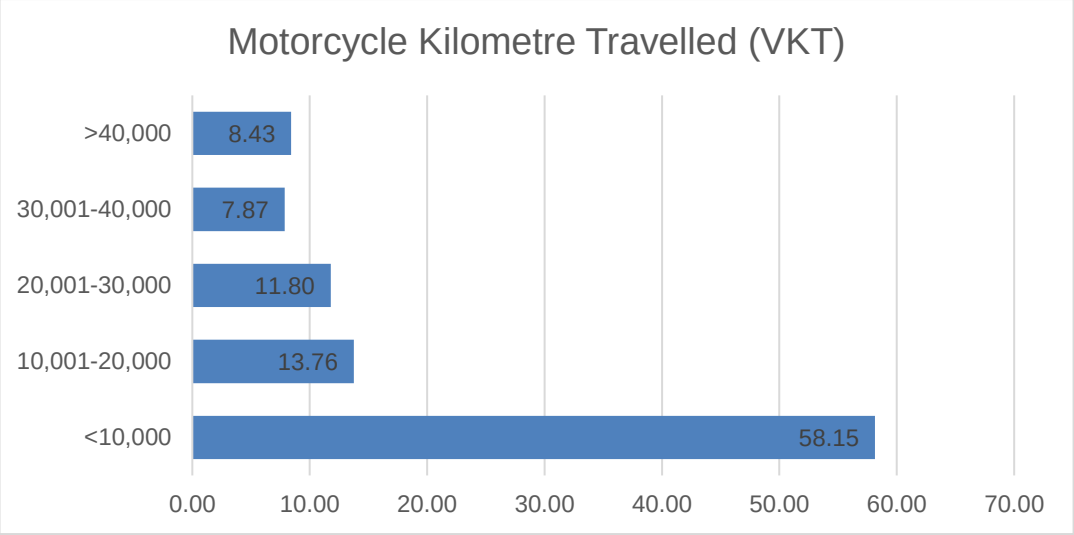


Figure 6. 4 Average Annual Vehicle Kilometres Travelled (VKT) via Motorcycle (n=688) by Sarawakian Urban Households.

The above figures are the average car VKT and motorcycle VKT per annum for urban Sarawak in percentages. These were recorded based on the total estimated annual average VKT for vehicles in each household (n=688). Based on Figure 6.3, it is noted that the biggest category for car VKT is from <10,000 km per annum, with 30 per cent, while the smallest is in the category 30,001-40,000 km per annum, with 11 per cent. This shows that although there is high car ownership, people do not drive that much and have a repetitive work-based driving behaviour as work is considered to be the main travel purpose. According to the author's calculation, the group mean is approximately 28,000 km per annum for the vehicles in the household. This indicates that there is a moderate car usage although car ownership is high per household. Surprisingly, this is comparable with the average annual car distance travelled recorded in the U.S., which was approximately 26,363 km per household in 2017 (FWHA, 2017) for vehicles in the household. The reason for the moderate VKT despite high car ownership is attributed to the trends in urban Sarawak, namely owning different cars based on their functionality. For instance, different cars served different functions or purposes, whereby some are mainly used for work purposes on the weekdays while other cars may serve for leisure purposes at the weekends, depending on the type of car. The cars which are used regularly are those which are the most convenient and economical (lower cc). For example, using a smaller car makes it easier to commute in town, easier to park and it is more fuel-efficient.

On the other hand, cars which are used for leisure during the weekend are cars that have more unique specifications. An example is luxury cars, which represent a status symbol, however, due to the high maintenance costs and due to the desire to preserve the condition of the car, owners rarely use them on a daily basis. Similarly, four-wheel drive (4WD) cars are reserved for long journeys to visit hometowns in rural areas, which may have very poor road conditions. Another reason is the low resale value as Malaysia does not have any vehicle scrappage schemes, unlike in developed countries such as the United Kingdom, Germany and Japan. Therefore, it is not compulsory or advantageous to scrap old unused cars. Hence, rather than selling old cars, owners tend to opt to keep them instead. Added to this are the options provided by the local financial institutions. Car loans are easy to obtain, particularly for domestic cars, which are less expensive compared to imported cars as these have an import duty of 70% (which is among the highest in the world) on top of the car price.

Meanwhile, Figure 6.4 shows the motorcycle VKT per annum for vehicles in each household, and it is apparent that the biggest VKT category is from <10,000 km per annum, with 58.15 per cent, while the smallest is in the 30,001-40,000 km per annum category. Based on the author's calculation, the group mean is approximately 9,830 km per annum for vehicles in the household. According to Shabadin et al. (2014), the annual average for all cars VKT for Sarawak is 20,37.40 km (Table 3.3), which is lower than the average total VKT in Malaysia, at approximately 38,239 km per annum. The annual average all car VKT is considered lower than the author's calculation as it may encompass the overall data, which includes urban and rural counterparts of Sarawak. It can also be said that motorcycles have a lower annual VKT in comparison with annual car VKT in the case of Sarawak. Despite the simultaneous rise in car and motorcycle ownership in Sarawak, evidently in terms of usage, this is not the case for vehicle kilometres travelled. Referring to Table 6.5, 84.9 per cent of the urban households owned at least a car while only 31.84 per cent of the urban households owned at least a motorcycle. This is because the motorcycle is considered secondary private transport compared to cars in urban Sarawak. We can assume that considering a simultaneous rise at the national level, there might be higher motorcycle ownership in rural areas. Lower motorcycle ownership in urban areas contributes to lower VKT.

With changes in the socio-demographic or family structure of a household, for example, an increase in income or the family expansion, in urban Sarawak, the main mode of transport changes from motorcycle to car. This relates to the functionality of the motorcycle. Those with larger families tend to use more cars compared to motorcycles to commute, particularly families with infants and small children as it is not safe or secure to have them as passengers of a motorcycle.

In addition, there exist concerns regarding the risk of motorcycle usage for long-distance purposes. Malaysia is among the countries with the highest rate of motorcycle deaths per 100,000 inhabitants in Asia (Abdul Manan, 2015). It is also noted that motorcycle users are more vulnerable due to the nature of the road environment, the causes of crashes and the severity of injury outcomes compared to other road users. Therefore, lower motorcycle VKT may be attributed to the characteristic of the motorcycle itself, namely that it is not suitable for long-distance travel due to safety and security concerns.

6.5.3 Psychological Factors

Although socio-economic factors are generally the main determinants of vehicle ownership and usage, it is important to include the role of human psychological factors as part of the determinants of travel behaviour. This is because not all human beings react similarly based on their socio-economic characteristics, thus offering dissimilar and interesting insights into their travel decision-making. Recent findings indicate that psychological factors have gained importance in determining car ownership and usage (Maltha et al., 2017; Belgiawan et al., 2017; Nishihara et al., 2017). As the above statistical evidence has shown the socio-economic factors characterising the private-based travel behaviour in urban Sarawak, this section describes psychological factors based on the conceptual framework in Section 4.4. These factors are based on the theory of planned behaviour (TPB) and the norm activation model (NAM); considering that, a number of factors are identified based on these theories, namely social norms, attitude, perceived behavioural control and personal norms. Later, a number of indicators are obtained to represent each of these psychological factors. The selection of these indicators can be referred to as the operationalization of the conceptual framework in Section 4.4.

Notes: Five-point Likert scale of (1) Strongly Disagree; (2) Disagree; (3) Neutral; (4) Agree; and (5) Strongly Agree on the respective psychological factors, specifically on attitude towards transport policy, pro-environment, perceived behavioural control, social norms and built environment.

Figure 6. 5 Psychological Based Indicators.

Figure 6.5 shows several psychological indicators based on TPB and NAM, which are later used based on the PLS-SEM evaluation of measurement model. The respondents' feedbacks on the respective indicators are as follows:

- Attitude towards transport policy

In the attitude towards transport policy, several questions are included to represent the respondents' attitude towards the acceptance of transport policy. In general, the respondents agreed on most of the policies, including "Lowering speed limit", "Road incentives", "Access restrictions", and "Invest in

additional walking and cycling infrastructure". The "Expanding and upgrading roads" question had the highest acceptance and a strong acceptance percentage, at 40 per cent and 53 per cent each, which indicates that there is a very critical need in developing more roads or improving the current roads in Sarawak and this has the main priority above other policies. Aside from that, 43 per cent were found to strongly disagree to charges for road use, which indicates that the majority of the respondents are not very fond of being monetarily charged for using the road.

As expected of a car-dependent state, there is an extremely high agreement with expanding and upgrading the road network in Sarawak. Moreover, in contrast, people are against an act of limiting car commuting, namely implementing toll payments. Their agreement with road expansion is notably higher compared to their agreement with designated lanes and also the restriction of heavy goods vehicles on the road. This is because the respondents' decisions are apparently based on what benefits them the most as individuals. Although such policies could benefit them somehow, their role as car users is predominant in decision-making as they consider the improvement of road conditions have more significant effects compared to the other policies. The restriction on heavy goods vehicles (HGV) may affect the general public indirectly in terms of reducing accidents or reducing the road defects caused by them. However, it may not affect those people commuting in the areas with very few HGVs passing by, as such vehicle types are usually located in areas under development (e.g. construction sites) rather than the city centre/CBD.

- Social norms

On the other hand, there are three indicators based on social norms. Fifty-two per cent of the respondents agreed that "It is unsafe to cycle in my city according to the society"; 46 per cent agreed that "The culture of auto-mobilisation influences my travel mode"; and 58 per cent agreed that "The society influences my travel behaviour". According to Figure 6.5, the surrounding population has a particular effect on people's commuting behaviour. It is possible that some people are influenced by observing the behaviour of their surroundings and what people around them are doing, in this case owning cars. Conformity happens when a person's perception is influenced by what other people are doing or expecting. If a significant share

of the society initiates car dependence, this might turn into a larger trend or lifestyle as people tend to consider or adhere to the expectations of others. Strang and Soule (1998) mention that individual behaviour is a function of the perceived existence of previous adopters of a person's social system. People's interaction within their society, including how they connect with their family, friends and colleagues, determines their decision-making, how they value their surroundings, and the lifestyle or culture they believe relates to transport decision-making. The perceived social pressure of car-dependence based culture pushes people to include private-based vehicles, specifically cars, as part of their lifestyle.

- Perceived behavioural control

Meanwhile, the perceived behavioural control (PBC) questions/indicators are based on the ease/difficulty of accessing public transport in urban Sarawak; in this case, there is excellent access to bus services. Among the respondents, a high percentage ranged from strongly disagree to neutral is found in terms of whether using buses is fast and reliable and also comfortable and safe. This indicates that the respondents are generally unsure about how they perceive the public transport services, which indicate the existing ambiguity on buses as a mode of transport. This shows that some people are also unconcerned about public transport as in the urban areas, a car is considered as their primary mode of transport. The reason may be that although there is good access to public transport, some of the neutral respondents might not have had any experience with taking a bus as they have only ever experienced car or motorcycle rides. The results also indicated that there is a high level of agreement towards the respondents' neighbourhood has good access to public transport. Although there is good access to public transport (buses), it is noted that significant upgrades in terms of both the bus conditions and facilities are required in Sarawak.

- Pro-environment behaviour (personal norms)

Another group of questions is based on pro-environment behaviour. There is a mixed feeling from the respondents regarding their opinions towards the environment. For instance, there is a very high level of agreement for "I buy environmentally friendly product" at 52 per cent; "I am willing to change my lifestyle to reduce the environmental problems" at 55 per cent; and "I am concerned about the environment and climate change" at 56 per cent.

However, there is also a high percentage of the neutral answer to the question “Environmental protection measures should be enacted”. There is a willingness to change, and to trade-off, current lifestyles, but the respondents show that they still hesitate when it comes to actual legal actions involving the environment.

Based on the results, there is a very high agreement that people are very concerned about the environment and climate change. However, there is a considerable gap between their willingness to change their lifestyle (higher agreement) compared to changing their travel behaviour to reduce the impact on the environment. CO_2 emissions caused by cars are among the highest contributors to anthropogenic pollution in Malaysia, and hence, changes in travel behaviour are deemed necessary. People are found to be in conflict with their values (or they attempt to position themselves as green individuals) and also the way they behave, given their limited travel options. Unlike developed countries, the current public transport facilities are still insufficient or not in their best condition. Some people consider changing their travel behaviour as a substantial sacrifice in their lives because they would need spend a considerable amount of travel time commuting to and from work if they opted for public buses, as a result of inefficient public transport. Furthermore, difficulties such as limited bus schedules and transit availabilities add to the difficulties in commuting using public buses.

In a different scenario, a developed country which has high car ownership, such as the U.S., has opted for changes in technology to deal with the environmental concerns, such as using catalytic converters, cleaner fuels and electric/hybrid vehicles to continue their driving patterns. Unlike the U.S., Sarawakian people may have lower income and are less able to purchase electric/hybrid cars (usually imported and expensive). Furthermore, there are very few facilities that cater for such cars in Sarawak, which increases the cost of maintenance as a whole. For instance, charging stations for battery-powered electric vehicles are only available at the respective car dealers, service centres and a few limited locations.

- Built environment

For perception towards the built environment, although there is a high percentage of agreement for “My neighbourhood is safe and convenient for

walking” at 46 per cent, there is a very high percentage of disagreement for “Sustainable mode of transport (bus, cycling, walking) facility is available in the neighbourhood” and “Amenities within walking distance”. This may indicate that although it is safe and convenient to walk around the neighbourhood, there are limitations in terms of other travel options (walking, cycling, and buses) and there are also long distances to reach amenities. Furthermore, there are very few cycling and walking facilities compared to road infrastructure (for example, car lanes), causing people to opt for the car.

6.6 Chapter Conclusion

The chapter firstly outlined the survey design, which included the survey-based research and the questionnaire setup. Next, the sampling method was presented, including the sample selection process and the calculation of the sample. The sample was selected in the urban areas due to the high level of car ownership and also other limitations, such as time and cost constraints. Furthermore, the selection of districts was mainly based on the socio-economic factors, particularly the average monthly household income in Kuching, Kota Samarahan, Sibu and Miri. The survey evaluation was based on the pre-pilot test, conducted at the University of Leeds, and the pilot test, conducted in one of the selected districts. Based on the actual survey conducted, it appears that there is a very high level of car ownership at the urban level. Subsequently, the next chapter presents the analysis and results of PLS-SEM for the disaggregate model of car and motorcycle ownership and use employed in this thesis.

Chapter 7

Disaggregate Analysis of Car and Motorcycle Ownership and Use

7.1 Introduction

The previous chapter discussed the survey design, data collection and descriptive analysis of the disaggregate data. Following that, this chapter describes the analysis and discussions of the PLS-SEM model for the car and motorcycle ownership and use model. Section 7.2.1 presents the evaluation of the measurement model while Section 7.2.2 discusses the evaluation of the structural model. Finally, Section 7.3 summarises the chapter.

7.2 Analysis and Discussion of PLS-SEM

Following the description of the socio-economic, psychological and travel behaviour characteristics of the respondents of the survey, this section presents the analysis and discussions of the determinants of car and motorcycle ownership and use using partial least squares-structural equation modelling. According to the conceptual framework (Figure 4.4 & 4.5), there are three main gaps introduced in the study, namely (1) the psychological determinants of motorcycle ownership and use; (2) the interdependency between car and motorcycle ownership; and (3) the determinants of car and motorcycle ownership and use in a city-region which has the dual characteristics of being situated in a developing economy but with very high car and motorcycle dependence.

To bridge these gaps, a complex model incorporating four main dependent variables, namely car ownership (VEHC), motorcycle ownership (VEHCM), car VKT (VKTC) and motorcycle VKT (VKTM), is introduced, with each representing a sub-model. The socio-economic, built-environment and psychological factors are then analysed against these four sub-models within

a joint model (PLS-SEM). In identifying the interdependency between car and motorcycle ownership, three models are analysed. Model 1 consists of a base model. Model 2 consists of a hypothesis (H8: There is a significant positive relationship from car ownership to motorcycle ownership), while Model 3 consists of a hypothesis (H8: There is a significant positive relationship from motorcycle ownership to car ownership). PLS path models only allow for recursive relationships and, therefore, Model 2 and Model 3 are constructed to test the relationship. The PLS-SEM model for Models 1, 2 and 3 involves a two-step process, which is (i) the evaluation of the measurement model and (ii) the evaluation of the structural model, which is presented in the following sub-sections.

7.2.1 Evaluation of the Measurement Model

This section presents the evaluation of the measurement model. This evaluation is essential to ensure that all the indicators (refer to Figure 4.5) in the conceptual model well represent the latent psychological constructs, which include pro-environment behaviour (PEA), attitude towards transport policy (TP), social norms (SN), perceived behavioural control (PBC) and perception towards the built environment (BE). The indicators are assessed using testing criteria, such as composite reliability, indicator loadings, discriminant validity and average variance extracted (AVE) (C(I) Stage 1: Assessment of measurement model) for a discussion of these test statistics and (C(II) Stage 2: Assessment of structural model on the output of the evaluation of measurement model) to determine if they can fit into the model. Based on the results in Appendix C, a number of indicators are evaluated to ensure that they are fit to represent the latent (reflective) psychological constructs. Initially, a number of 20 indicators were tested to represent the latent psychological constructs, and only 11 indicators were retained. Next, the formative model was tested and the results are shown in Appendix C. This indicates that there is no problem of collinearity for the indicators of the formative constructs. Therefore, by looking at the results, all the indicators for the formative constructs are retained and can further be used along with the reflective constructs in the evaluation of the structural model. The following section presents the outcome for the structural model.

7.2.2 Evaluation of the Structural Model

This section presents the evaluation of the structural model following the evaluation of the measurement model. The evaluation of the structural model is done to test the hypothesised relationship in the conceptual model (Figure 4.5). The main aim of this section is to identify the socio-economic and psychological determinants for vehicle ownership and use (car and motorcycle) in a joint model. Table 7.1 presents the PLS-SEM results for Model 1, Model 2 and Model 3, consisting of the sign, magnitude and significance for the coefficients for each of the sub-models. Models 1 to 3 are comparable in terms of their structure. Each of the models has four sub-models explaining four dependent variables, namely (i) car ownership (VEHC); (ii) motorcycle ownership (VEHM); (iii) car vehicle kilometres travelled (VKTC); and (iv) motorcycle vehicle kilometres travelled (VKTM).

Model 1 serves as the base model and explains the relationship between the socio-economic, built environment and psychological variables, and the four dependent variables. Its structure is compatible with Figure 4.5 (conceptual framework). Models 2 and 3 extend the base model by including the interaction effects between VEHC and VEHM. Model 2 examines whether VEHC influences VEHM, whereas Model 3 reverses this causal relationship and examines whether VEHM influences VEHC.

First, the preferred model is selected based on the evaluation of the structural model using the value of goodness of fit using the standardized root mean square residual (SRMR). Based on Henseler et al. (2014), the SRMR value can be used to assess the goodness of fit measure to avoid model misspecification. Model 2 is selected as the preferred model as it has the lowest SRMR. A model is considered to have a perfect fit if the value of SRMR is 0 while it has a good fit if the SRMR value is < 0.08 and 0.10 (Hu and Bentler, 1998). Based on Table 7.1, the SRMR values for all the three models are of a good fit, and the values are almost similar. Model 2 is chosen as the preferred model as there is high car ownership in Sarawak, which justifies regarding it as the primary mode of transport whereas motorcycle is considered as the secondary mode of transport for urban households. This includes an interaction effect explaining the extent to which car ownership as the primary mode of transport influences motorcycle ownership. We proceed with the interpretation of the Q^2 value describing the predictive relevance of a

large complex model. The Q^2 value for Model 2 shows that a value which is greater than 0 is acceptable/satisfactory, and this means that the independent variables can thoroughly explain the dependent variables in the model. The test also indicates that the path model with high predictive relevance is considered to have a small prediction error.

Following this, the path coefficient based on Model 2 is obtained to estimate the relationship from the determining variables towards the dependent variables using a bootstrapping procedure. Since PLS-SEM involves a non-parametric test, a bootstrapping method is involved in acquiring the precision of its estimates. The explanation of the PLS-SEM coefficient is based on four sub-models, namely VEHC, VEHM, VKTC and VKTM in Section 7.2.2.1 to Section 7.2.2.4, respectively.

Table 7. 1 PLS-SEM Results.

Hypothesis		Model 1 Base Model		Model 2 Car → motorcycle ownership		Model 3 Motorcycle→ Car Ownership	
		Path coeff.		Path coeff.		Path coeff.	
	Sub Model: VEHC						
H1a	SN→ VEHC	**0.093**	**	**0.093**	**	**0.087**	**
H2a	PBC→ VEHC	0.010		0.010		0.002	
H3a	TP→ VEHC	0.025		0.025		0.036	
H4a	PEA→ VEHC	**-0.143**	***	**-0.143**	***	**-0.134**	***
H5a	BE→ VEHC	-0.022		-0.022		-0.009	
H5c	BE_CBD →VEHC	-0.023		-0.023		-0.025	
H6a	SE→ VEHC	**0.361**	***	**0.361**	***	**0.479**	***
H8	VEHM →VEHC					**0.144**	***
	Sub Model: VEHM						
H1aii	SN→ VEHM	0.027		0.012		0.027	
H2aii	PBC→ VEHM	0.055		0.053		0.055	
H3aii	TP→ VEHM	**0.073**	**	**0.085**	**	**0.073**	**
H4aii	PEA→ VEHM	**-0.074**	*	**-0.083**	*	**-0.074**	*
H5aii	BE→ VEHM	**0.088**	**	**0.089**	**	**0.088**	**
H5cii	BE_CBD →VEHM	0.011		0.015		0.011	
H6aii	SE→ VEHM	**-0.069**	***	**-0.122**	***	**-0.069**	***
H8	VEHC →VEHM			**0.260**	***		

	Sub Model: VKTC									
H1b	SN→ VKTC	0.03			0.03			0.03		
H2b	PBC→ VKTC	-0.032			-0.032			-0.032		
H3b	TP→ VKTC	**0.088**	**		**0.088**	**		**0.088**	**	
H4b	PEA→ VKTC	0.019			0.019			0.019		
H5b	BE→ VKTC	-0.022			-0.022			-0.022		
H5d	BE_CBD →VKTC	0.054			0.054			0.054		
H6b	SE→ VKTC	**0.093**	***		**0.093**	***		**0.093**	***	
H7	VEHC →VKTC	**0.451**	***		**0.451**	***		**0.451**	***	
	Sub Model: VKTM									
H1bii	SN→ VKTM	0.022			0.022			0.022		
H2bii	PBC→ VKTM	-0.043			-0.043			-0.043		
H3bii	TP→ VKTM	**0.071**	**		**0.071**	**		**0.071**	**	
H4bii	PEA → VKTM	-0.03			-0.03			-0.03		
H5bii	BE→ VKTM	0.006			0.006			0.006		
H5dii	BE_CBD →VKTM	**0.054**	**		**0.054**	**		**0.054**	**	
H6bii	SE→ VKTM	0.007			0.007			0.007		
H7ii	VEHM → VKTM	**0.569**	***		**0.569**	***		**0.569**	***	
		R^2_{adj}	Q^2	SRMR	R^2_{adj}	Q^2	SRMR	R^2_{adj}	Q^2	SRMR
	VEHC	0.178	0.163	0.077	0.178	0.163	0.072	0.154	0.140	0.076
	VEHM	0.035	0.028		0.088	0.075		0.035	0.028	
	VKTC	0.253	0.126		0.253	0.126		0.253	0.126	
	VKTM	0.337	0.123		0.337	0.123		0.337	0.123	

Bold***: p<0.01; bold**: p<0.05; bold*: p<0.10

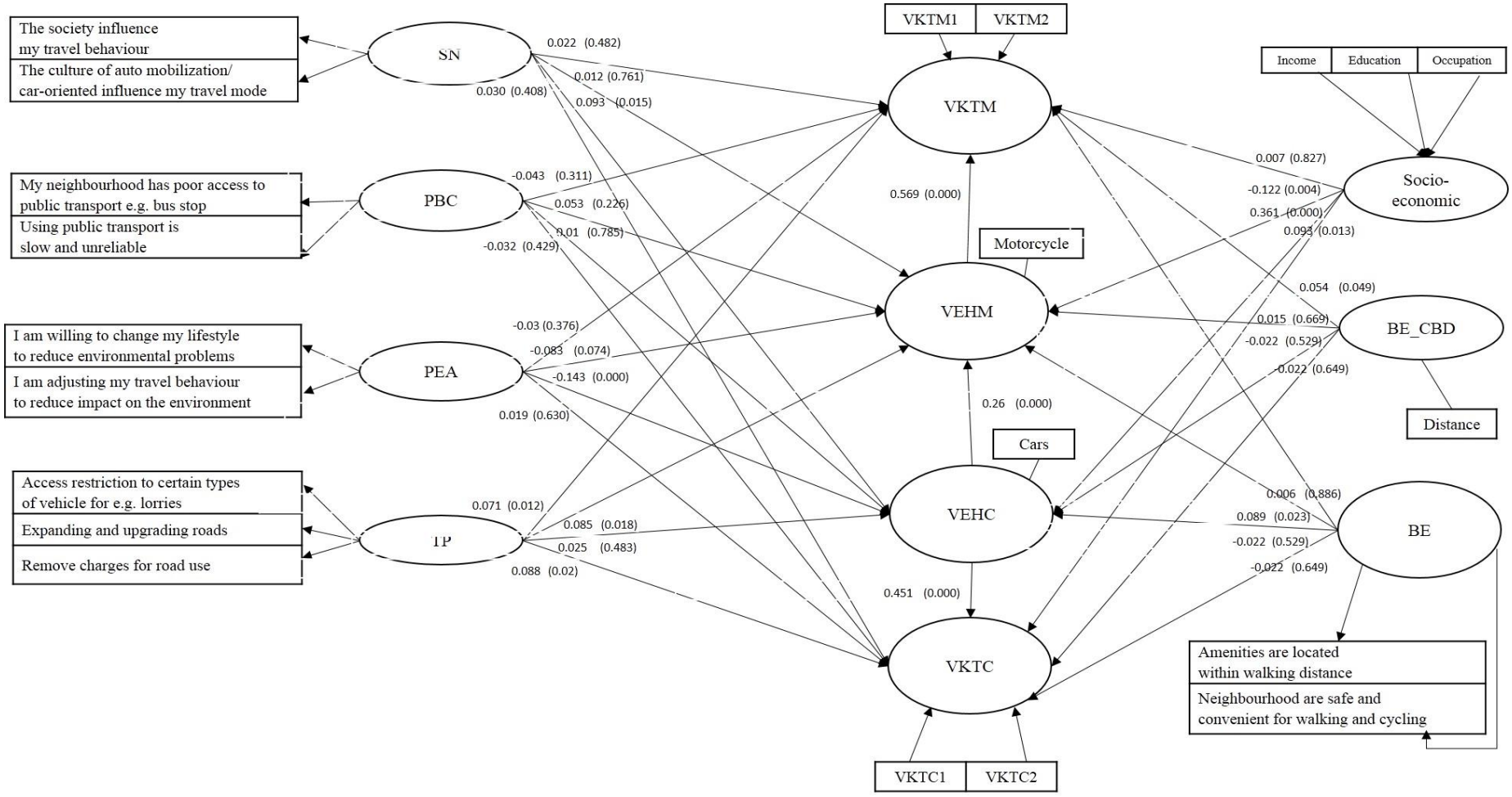


Figure 7. 1 PLS-SEM results.

7.2.2.1 Car Ownership Sub-Model (VEHC)

Based on sub-model VEHC in Table 7. 2, it is found that three hypotheses are supported, which are H1a: There is a significant positive relationship between social norms and car ownership (β = 0.093**); H4a: There is a significant negative relationship between pro-environment behaviour and car ownership (β = - 0.143***); and H6a: There is a significant positive relationship between socio-economic factors and car ownership (β = 0.361***).

Table 7. 2 Summary of Hypothesis for the Car Ownership Sub-Model.

H:	**Hypothesis**	**Outcome**
H1a	*There is a significant positive relationship between social norms and car ownership.*	*Supported*
H2a	*There is a significant positive relationship between perceived behavioural control and car ownership.*	*Not Supported*
H3a	*There is a significant positive relationship between attitude towards transport policy and car ownership.*	*Not Supported*
H4a	*There is a significant negative relationship between pro-environment behaviour and car ownership.*	*Supported*
H5a	*There is a significant negative relationship between attitude towards the built-environment and car ownership.*	*Not Supported*
H5c	*There is a significant positive relationship between the built environment (BE_CBD) and car ownership.*	*Not Supported*
H6a	*There is a significant positive relationship between socio-economic factors and car ownership.*	*Supported*

- *H1a: There is a significant positive relationship between social norms and car ownership*.

Based on the results in Table 7. 1 and Figure 7. 1, there is a significant positive relationship between social norms and car ownership (β = 0.093**). The result is supported by Gaker et al. (2010), Ozaki and Sevastyanova (2011), and

Goetzke and Weinberger (2012). It is evident that individuals are affected by others' behaviour within their peer group. The circumstantial impact is where the attribute of that particular group may affect the behaviour of an individual. As suggested by Gaker et al. (2010), the probability of car ownership is influenced by the people of a similar socio-economic group and by physical neighbours. That means that in a society with high car-dependence, it is very likely that individuals may own a car as they are surrounded by other individuals who own a car.

The significance of social norms as the determinant of car ownership represents the power of society and culture (car dependence) in transport decision-making. As auto-mobility has been ingrained in the life of modern society, the nature of activities being conducted by the society as a whole revolves around locations that are accessible by car, which causes social exclusion of those who do not have a car. Although the distinct nature of car-dependence might be ambiguous in the sense of whether the society itself influences car dependence or the location itself is inaccessible, causing people to commute using cars, the active encouragement of society in car ownership is driven by many factors. First is the instrumental value of the transport itself, whereby cars are considered as representing travel independence, which is not obtained through another mode of transport. Numerous amenities in Sarawak are very difficult to reach without cars. This is influenced by changes in the distribution of employment, patterns of shopping, social interactions, industrial priorities and town-planning. For instance, society is encouraged to own a car to enable people to have access to these amenities by car. Government offices and shopping complexes in Sarawak, for instance, provide numerous parking places rather than installing walking or cycling areas, while the availability of public transport access causes the society to opt for cars rather than another mode of transport. In this sense, auto-mobility coerces society to juggle the multifaceted, contingent and delicate nature of time and also social life patterns by owning a car, which provides the freedom and flexibility to commute from one place to another.

- *H4a: There is a significant negative relationship between pro-environment behaviour and car ownership.*

Based on the results, there is a significant negative relationship between pro-environment behaviour and car ownership (β = - 0.143***). In this case, the

pro-environment factor has a significant negative influence, thus reducing car ownership. Those who possess environmental knowledge will initiate their sense of awareness and responsibility to perform a behaviour that brings lesser harm to others. This is supported by Flamm (2009) and Abrahamse et al. (2009). Flamm (2009) suggested that environmental concerns may have a very significant impact on society, particularly on environmentally related domains such as travel mode choices. Flamm (2009) further adds that individuals who are pro-environment have a higher probability of having knowledge of the environmental effects of owning vehicles.

The pro-environment factor relates to personal norms from the norm activation model (NAM), which suggests the important role of moral obligations, that is, the extent to which individuals are personally obliged to perform certain behaviours. Behaviour based on individual personal norms may lead towards feelings of guilt when the person did not act based on their personal norms. Individuals who realize the effects of their behaviour towards the environment have a greater sense of moral obligation to reduce their car ownership compared to those who do not. Therefore, this leads to a sense of responsibility for the potential negative effects (e.g. air pollution from car commuting). Hence, those who realize the effects may engage in altruistic behaviour, that is, a willingness to behave in a way that brings advantage to others.

Based on the results, it is also indicated that pro-environmental behaviour has greater influence on car ownership compared to social norms for urban Sarawak. The result is supported by Liu et al. (2017). This shows that an individual is less affected by what others tell them in comparison to their personal obligations towards certain behaviour. Furthermore, pro-environmental behaviour is found to be significant for car ownership instead of car VKT. This indicates that while it is easier to control their car ownership, it is harder to change their repetitive behaviour, that is, their car use. An explanation of this can be found in Gatersleben et al. (2002, p. 338), who explained that “environmental attitudes are most strongly related to behaviours that do not have a high impact on people's daily lives (e.g. waste management, political behaviour, food purchase...) than to behaviours with a high psychological and financial impact (e.g. transport and energy use...)”. While this shows that there is a likelihood that individuals who are pro-environment reduce their car ownership, it is worth noting that there is a high

dependence on car and motorcycle ownership in Sarawak due to the poor and limited availabilities of public transport services and infrastructure. Therefore, we can assume that individuals respond less likely in terms of their repetitive behaviour, as depicted by car users.

- *H6a: There is a significant positive relationship between socio-economic factors and car ownership.*

Based on the results, there is a significant positive relationship between socio-economic factors and car ownership (β = 0.361**). The result is supported by Clark (2007), Wong (2013), Sanko et al. (2014), Belgiawan et al. (2016) and Hsieh et al. (2017). The significance of the relationship is aligned with the results from the aggregate model (Chapter 5). Socio-economic factors refer to the social and economic features that influence what status individuals or groups have within a particular society. The socio-economic factors based on the conceptual framework include income, education and employment status. Income level influences the ability of households' finances to own a vehicle. Those who are wealthier tend to purchase more than one car.

Previous studies (as mentioned above) have supported that there is higher car ownership among the higher income groups. Since there is a very high car dependence, particularly in the urban Sarawak, the car is perceived as the most reliable mode of transport, and hence there is very high car ownership compared to non-car ownership. For lower-income households, they tend to purchase cars at a lower price or second-hand cars, while those from higher income households tend to purchase more and better-quality cars. This is because those with higher income could afford and have greater access to services, such as car financing or loans compared to those with a lower income.

Education level is essential in determining higher car ownership. Those with a higher education tend to have more cars as it reflects the material and intellectual capabilities of particular households. The knowledge and skills obtained via the level of education may affect a person's cognitive ability in transport decision-making. Those with a higher level of education tend to own cars as they are very selective in choosing their vehicle to commute. The car is considered the most reliable mode of transport in terms of safety, security and time-management aspects. Households with higher education levels tend

to have more knowledge of these aspects; hence, owning cars would be a practical and beneficial option in their daily travel activities.

Employment relates to social standing in society. This is reflected in an individual's social networking, control and autonomy. More skilled workers, specifically for those from medium to major business owners, for instance, reflect a higher social standing, whereby owning more cars shows a social privilege compared to from less-skilled workers, who are considered underprivileged. Furthermore, lower skill workers, for example, machine operators, tend to work in manufacturing plants, which provide hostel-type accommodation located within the facility or free transport such as buses. The lowest skill group, such as retirees, tend to have lower car ownership as they tend to remain with their old car or depend on their other family members (e.g. children) to commute. Retirees tend not to own more cars as they are less likely to be able to afford the financing of the new cars (in terms of loan approval due to old age) and the ability to maintain their cars.

Previous studies have found that individuals with a higher level of education have better access to job opportunities compared to those with a lower income. Those who are employed may need cars as this is considered a reliable mode of transport, providing shorter commuting times and a flexibility not supported by public transport. Furthermore, Gurley and Bruce (2005) also suggest that personal transport may provide the ability to work during non-traditional hours and in higher paying jobs.

7.2.2.2 Car Use Sub-Model (VKTC)

Based on sub-model VKTC in Table 7. 3, it is found that three hypotheses are supported, which are H3b: There is a significant positive relationship between attitude towards transport policy and car VKT (β = 0.088**); H6b: There is a significant positive relationship between socio-economic factors and car VKT (β = 0.093**); and H7: There is a significant positive relationship between car ownership and car VKT (β = 0.451**).

Table 7. 3 Summary of Hypotheses for the Car VKT Sub-Model.

H:	Hypothesis	Outcome
H1b	*There is a significant positive relationship between social norms and car VKT.*	*Not Supported*
H2b	*There is a significant positive relationship between perceived behavioural control and car VKT.*	*Not Supported*
H3b	*There is a significant positive relationship between attitude towards transport policy and car VKT.*	*Supported*
H4b	*There is a significant negative relationship between pro-environmental behaviour and car VKT.*	*Not Supported*
H5b	*There is a significant negative relationship between attitude towards the built environment and car VKT.*	*Not Supported*
H5d	*There is a significant positive relationship between the built environment (BE_CBD) and car VKT.*	*Not Supported*
H6b	*There is a significant positive relationship between socio-economic factors and car VKT.*	*Supported*
H7	*There is a significant positive relationship between car ownership and car VKT.*	*Supported*

- H3b: *There is a significant positive relationship between attitude towards transport policy and car VKT*.

Based on the results, only one psychological factor is found to be significant. There is a significant positive relationship between attitude towards transport policy and car VKT (β = 0.088**). The result is supported by Thorpe et al. (2000), Beale and Bonsall (2007), and Abrahamse et al. (2009). The results are in contrast with Van and Fujii (2011), who stated that attitude is less significant for a high car use country. According to Parkany et al. (2004), an individual's attitude towards travel significantly influences the amount of travel they demand. In our case, the policies constructed are made to encourage car use, such as (1) expanding and upgrading roads; (2) access restriction to certain types of transport (e.g. lorries, HGVs); and (3) removing charges for

road use. These transport policies are evidently aimed at encouraging the salient beliefs that cognitively encourage car use. In this sense, a positive attitude towards better road infrastructure provides a favourable condition for driving, which increases car use. Similarly, with fewer HGVs, people feel more at ease while driving, and this may encourage other non-work trip purposes as they feel more secure and safe on the road. The removal of road charges also promotes higher car usage as it lifts the monetary burden from the car user. Moreover, this extrinsic incentive provided by the government changes the overall attitude, which leads car users to enjoy travelling more but with lesser costs.

It is evident that policies that target influencing car use should be aimed at the segment of the market that is being encouraged to alter car use (Beirão and Cabral, 2007). The lability in attitude is expected for individuals who have less commitment to a certain attitude or when encountering an information conflict. As suggested by Beale and Bonsall (2007), lability takes place within people who are exposed to marketing show a reassessment of attitudes. For instance, transport policy that encourages the positive effect of marketing material on other modes of transport (e.g. buses) may influence their attitude through the message contained in marketing, which is considered as self-relevant. That is, by using salient statements regarding the fares, travel times, and convenience of the bus system, one may convince individuals to reduce their car use.

Different measures in transport policy may be used to achieve different targeted outcomes. This model purposely examines the current situation in urban Sarawak, which involves transport policies that lead to a positive attitude towards car use. It is evident that attitude towards transport policy provides push and pull measures that cause individuals to favour certain components of the policy. In our model, the indicators used are a combination of both pull and push measures that encourage car use. According to Steg and Sievers (2000), a push measure can make car use less rewarding while a pull measure targets enhancing other travelling options. Thus, the outcome of the results also justifies the effectiveness or favouritism towards certain policy-specific beliefs. In addition to the above, it is worth noting that attitude towards transport policy is the only psychological factor that influences car use. The pro-environment determinant from NAM and other factors in TPB are not significant in explaining car VKT in urban Sarawak.

- H6b: *There is a significant positive relationship between socio-economic factors and car VKT*.

The results also show that there is a positive and significant direct relationship from the socio-economic construct towards car VKT (β = 0.093**). This supports the hypothesis stating that the socio-economic condition has a more considerable influence on car use (Lai and Lu, 2007; Dargay et al., 2007; Banerjee and Hine, 2016).

Higher income group households tend to have higher car use. That is, households with more significant income have greater travel demands related to not only work but also non-work purposes. This is because higher income households can afford to participate in more non-work activities compared to lower income households, including leisure activities (e.g. shopping, holiday trips). Lower income households' travel activities may concentrate mainly on work (or study) purposes as they are limited by their budgetary constraints. Hence, this leads to more travel by cars compared to those from lower income groups. Similar to car ownership, those from a higher education level tend to engage in more travel activities. Greater income and educational attainment further enhance the affordability of households to own a vehicle, encouraging them to purchase more vehicles and hence increasing their vehicle use. Higher VKT for urban households results from highly educated individuals (Boarnet and Sarmiento, 1998; Van Acker and Witlox, 2010). This causes higher car usage due to their demand for travel activities. Level of employment influences car use as those who are in the minor professional to professional group tend to have a more specialised occupations, which are usually focused in the CBDs or technology parks located far from suburban housing. Manufacturing operators tend to work in facilities which provide accommodation due to strict working hours. This leads them to have limited access outside the facilities and they only have the opportunity to travel outside the facility at designated times (free time only during the weekend, and some facilities may also operate on Saturdays). Those who are retired or unemployed travel for non-work purposes, and this may include leisure activities. These activities may not be as demanding or as laborious compared to the activities of those who are employed. Hence, employed or more skilled people tend to involve themselves in more long-distance commuting, which leads to higher car use.

- *H7: There is a significant positive relationship between car ownership and car VKT*.

Based on the VKTC sub-model path analysis results, it is shown that there is a moderate, positive and significant relationship from the number of cars (VEHC) towards the VKTC (β = 0.451**). Car access tends to be associated with longer travel distances (Mokhtarian et al., 2001; Giuliano and Dargay, 2006; Hunecke et al., 2007). According to Van Acker and Witlox (2010b), households that own many cars are more likely to have higher car usage. This is because of high car reliance, in which larger household size leads to longer travel distances. It is shown that higher income households can afford to own many cars and therefore have a higher car use. Thus, it is crucial to explore the direct impact of socio-economic factors and car ownership on car use. Evidently, the results show that car ownership has a greater impact compared to the socio-economic factors. This suggest that once people own a car, they are more likely to use it often. Hence, it is important for policymakers to focus on measures that regulate the ownership and operation of cars.

7.2.2.3 Motorcycle Ownership Sub-Model (VEHM)

This section represents the determinants for the motorcycle ownership sub-model. Model 2 is selected under the consideration that motorcycle ownership is considered secondary compared to car ownership. Based on sub-model VEHM in Table 7. 4, it is found that five hypotheses are significant, which are H3aii: There is a significant positive relationship between attitude towards transport policy and motorcycle ownership (β = 0.085**); H4aii: There is a significant negative relationship between pro-environmental behaviour and motorcycle ownership (β = - 0.083*); H5aii: There is a significant positive relationship between attitude towards the built environment and motorcycle ownership (β = 0.089**); H6aii: There is a significant positive relationship between socio-economic attributes and motorcycle ownership *(β = -0.122***);* H8: There is a significant positive relationship between car ownership and motorcycle ownership (β = 0.260***).

Table 7. 4 Summary of Hypothesis for the Motorcycle Ownership Sub-Model.

H:	**Hypothesis**	**Outcome**
H1aii	*There is a significant positive relationship between social norms and motorcycle ownership.*	*Not Supported*
H2aii	*There is a significant positive relationship between perceived behavioural control and motorcycle ownership.*	*Not Supported*
H3aii	*There is a significant positive relationship between attitude towards transport policy and motorcycle ownership.*	*Supported*
H4aii	*There is a significant negative relationship between pro-environmental behaviour and motorcycle ownership.*	*Supported*
H5aii	*There is a significant negative relationship between attitude towards the built environment and motorcycle ownership.*	*Not Supported*
H5cii	*There is a significant positive relationship between the built environment (BE_CBD) and motorcycle ownership.*	*Not Supported*
H6aii	*There is a significant positive relationship between socio-economic factors and motorcycle ownership.*	*Not Supported*
H8	*There is a significant positive relationship between car ownership and motorcycle ownership.*	*Supported*

- *H3aii: There is a significant positive relationship between attitude towards transport policy and motorcycle ownership*.

Interestingly, there are two psychological factors that influence motorcycle ownership, including attitude towards transport policy and the pro-environment factor. Based on the results, there is a significant positive relationship between attitude towards transport policy and motorcycle ownership (β = 0.085**). The significance of the result is in contrast with Chen and Lai (2011). This shows that the push and pull measures, as reflected by the indicators, encourage higher motorcycle ownership.

Compared to cars, motorcycles are a better option in evading problems with traffic congestion as they are smaller (than cars) and tend to be more manoeuvrable. As there is an access restriction on lorries, there are lesser negative externalities, which may include fewer road accidents that due to the threat of lorries. Although motorcycles have less visual restrictions than cars, they do have a higher risk of accident and death due to their exposure. Lorries are responsible for many road accidents and deaths per year in many countries. Studies have found that the percentage volume of lorries on the road is a key determinant of the crash severity, even in the event of the lesser volume of traffic. By restricting lorries for certain zones/areas, this reduces the probability of road accidents, particularly for motorcyclists, who have a higher exposure. Furthermore, providing more roads and including motorcycle lanes, will able motorcyclists to avoid being affected by heavy goods vehicles. Ample space requirement would be a beneficial effort by the government in terms of designing motorcycle facilities to curtail such traffic safety issues, particularly for a country with a high level of motorcycle ownership. The removal of road use charges is especially beneficial for motorcycles considering their position as the secondary private mode of transport after cars. Such effort from the government would enable those from lower income in particular to afford not only owning motorcycles but also bearing the additional costs associated with travelling, specifically highway tolls.

- *H4aii: There is a significant negative relationship between pro-environmental behaviour and motorcycle ownership.*

Model 2 also indicates that for sub-model VEHM, there is a negative and significant relationship from PEA towards motorcycle ownership (β = - 0.083*). In comparison with the VEHC sub-model, the VEHM sub-model seems to

have a smaller effect running from PEA. The low effect from PEA towards VEHM is because a large number of motorcyclists come from the lower income group. While walking, cycling and using public transport are considered as more environmentally friendly transport options, those using motorcycles are limited by the nature of their travel patterns. This may include complex working hours or journeys that are not accommodated for by these environmentally friendly transport options and are restricted by their income. A motorcycle is often preferred as the mode of transport as it is the cheaper option for personalised mobility when purchasing and maintenance costs are taken into consideration. Therefore, two conditions may influence this situation. First, pro-environmental behaviour may influence (reduce) the number of motorcycles owned, but this is restricted by the fact that motorcycles are purchased by those who have lower income. While considering the incurred cost of acquiring a motorcycle, those at the lower income level may purchase a motorcycle at the lowest price or maybe even second-hand motorcycle. These cheaper options may not have catalytic converters to reduce the pollution being emitted. Although it is more pro-environmental to own motorcycles with such features, the income factor always comes first and, hence, there is a lower effect from the PEA factor.

- *H5aii: There is a significant negative relationship between attitude towards the built environment and motorcycle ownership.*

This may be further explained by the relationship between BE and VEHM (β = 0.089**), which does not support the hypothetical negative relationship. Indicators for BE include: (i) Amenities are located within walking distance, and (ii) the neighbourhoods are safe and convenient for walking and cycling. These indicators are expected to reduce vehicle ownership as a result of shorter distances and enhanced safety and convenience while walking and cycling. However, as the society is used to commuting via vehicles, it is expected that for shorter distances, they may also opt for motorcycle ownership.

Many other reasons contributed to this condition. Firstly, the motorcycle is considered as the best choice for the first vehicle in many Asian developing countries, particularly for individuals who have just entered the labour force. This includes the lower purchasing and maintenance costs compared to cars, which become more preferred as individuals reach a more stable source of

income (Leong and Sadullah, 2007). They further suggest that motorcycles are also preferable for many reasons, such as (i) avoiding traffic congestion; (ii) cost-saving, e.g. free-of-charge or low-priced parking rates especially in buildings within city areas compared to cars; (iii) less parking space required compared to cars; and (iv) inefficient public transport.

- *H6aii: There is a significant positive relationship between socio-economic attributes and motorcycle ownership*.

Based on the results, it is found that SE does not support the hypothesis of a positive relationship towards VEHM. The path coefficient exhibits a rather negative, significant and weak relationship towards motorcycle ownership (β = -0.122***), which explains that people tend to reduce their motorcycle ownership as their income increases. While the result is supported by Yamamoto (2009) and Chen and Lai (2011), it is in contrast with the aggregate model. The results may differ as the aggregate model focuses on both urban and rural Sarawak, while the disaggregate model is focused mainly on urban Sarawak. Therefore, this creates a disparity between urban and rural demand for motorcycle ownership whereby, in general, the high motorcycle ownership in Sarawak might be due to the contribution from the rural counterparts. The socio-economic variable is shown to have a strong positive relationship towards car ownership, while the socio-economic variable indicates a negative relationship towards motorcycle ownership. This means that owning a motorcycle is considered secondary by urban households, whereby households tend to own motorcycle when they have a lower income (e.g. first-time employee), but as they gain a higher income and socio-economic achievements, they tend to purchase more cars, while some may also own motorcycles for leisure purpose. This is where the motorcycle is considered more of an accessory rather than as the main mode of transport to commute.

Wen et al. (2012) also found similar results and point out that due to the low purchasing cost of motorcycles, many low-income households can afford to purchase inexpensive motorcycles while households with a higher income prefer to have more cars compared to motorcycles. However, those who have greater income, and thus tend to own more cars, may also own motorcycles (not for necessity but because they can afford to do so). Another interpretation can be explained by Law et al. (2015), who elucidate that motorcycle ownership may increase with income at a lower socio-economic level but

decrease with higher level socio-economic conditions. Higher income households tend to buy cars as they can afford the cost of travelling/commuting, while households with lower income can only purchase motorcycles as these can be obtained at lower costs.

The negative relationship indicates there is a difference between Sarawak as a whole and urban Sarawak in terms of education level. In urban Sarawak, those with a higher education tend to own cars rather than motorcycles. As explained in Section 7.2.2.1, the car is considered as the most reliable form of private transport. As those with a higher educational attainment tend to have better material and intellectual capabilities in society, they are more particular in relation to the features of their private mode of transport. Motorcycles for example, are cheaper and easier to manoeuvre compared to cars. However, motorcycles have less safety and security features and are thus less practical in comparison with cars. Similarly, regarding employment, those with better job attainment tend to prefer to own cars compared to motorcycles, as owning cars represents prestige in society. Hence, with higher social status, an individual becomes less likely own a motorcycle or consider a motorcycle as their main mode of transport.

- *H8: There is a significant positive relationship between car ownership and motorcycle ownership.*

Therefore, from Model 2, the strongest relationship can be seen from VEHC towards VEHM (β = 0.260***). The relationship indicates the dependency between car ownership and motorcycle ownership, as depicted by Model 2. As PLS-SEM is a recursive model which does not allow for a two-way relationship between variables, the comparison is drawn based on the similar model and structure (Model 3), which is differentiated by the arrow between these two variables. It is possible to compare this with the relationship from VEHM towards the VEHC sub-model in Model 3 (β = 0.144***).

This output means that there is a complementary relationship between car ownership and motorcycle ownership. In contrast with most findings in the Asian developing world, namely substitution relationships (Hsu et al., 2007; Yamamoto, 2009; Chiou et al., 2009; Anastasopoulos et al., 2012; Gómez-Gélvez and Obando, 2014), the complementary relationship between car and motorcycle ownership is supported in studies by Chen et al. (2013) and Sanko

et al. (2014). As previously suggested, the motorcycle is considered as being secondary to the car. However, the demand for motorcycle rises as households with high car ownership consider owning more motorcycles for purpose other than commuting, for example, leisure and study. Therefore, although there is negative relationship between socio-economic factors and motorcycle ownership, it is likely that households with car ownership will purchase more motorcycles.

7.2.2.4 Motorcycle Use Sub-Model (VKTM)

Based on sub-model VKTC in Table 7. 5, it is found that three hypotheses are supported, which are H3bii: There is a significant positive relationship between attitude towards transport policy and motorcycle VKT (β = 0.071**); H5dii: There is a significant positive relationship between the built environment (BE_CBD) and motorcycle VKT (β = 0.054**); and H7ii: There is a significant positive relationship between motorcycle ownership and motorcycle VKT (β = 0.569***).

Table 7. 5 Summary of Hypothesis for the Motorcycle VKT Sub-Model.

H:	**Hypothesis**	**Outcome**
H1bii	*There is a significant positive relationship between social norm and motorcycle VKT.*	*Not Supported*
H2bii	*There is a significant positive relationship between perceived behavioural control and motorcycle VKT.*	*Not Supported*
H3bii	*There is a significant positive relationship between attitude towards transport policy and motorcycle VKT.*	*Supported*
H4bii	*There is a significant negative relationship between pro-environmental behaviour and motorcycle VKT.*	*Not Supported*
H5bii	*There is a significant negative relationship between attitude towards the built environment and motorcycle VKT.*	*Not Supported*

H5dii	*There is a significant positive relationship between the built environment (BE_CBD) and motorcycle VKT.*	*Supported*
H6bii	*There is a significant positive relationship between socio-economic factors and motorcycle VKT.*	*Not Supported*
H7ii	*There is a significant positive relationship between car ownership and motorcycle VKT.*	*Supported*

- H3bii: *There is a significant positive relationship between attitude towards transport policy and motorcycle VKT.*

Based on the results, only one psychological factor is found to be significant. There is a significant positive relationship between attitude towards transport policy and motorcycle VKT (β = 0.071**). The relationship is similar with car VKT (β = 0.088**). The restrictions on certain types of vehicles increase the number of motorcycles on the road as they lessen the number of risks, such as road accidents and deaths due to encounters with heavy goods vehicles. On the other hand, road charges can decrease motorcycle usage. As motorcycle ownership is determined by income, road charges such as tolls may lead to a reduction in motorcycle usage. The effect is low, but it implies that there might be some reductions in motorcycle VKT, perhaps in terms of the number of trips or the use of more environmentally friendly options, such as walking for short-distance trips.

- H5dii: *There is a significant positive relationship between the built environment (BE_CBD) and motorcycle VKT.*

Based on the results, the relationship between BE_CBD and motorcycle VKT (β = 0.054**) is supported. BE_CBD represents the distance of households to the city centre and the further the distance to the city centre, the higher the VKTM, which supports the hypothesis of Bagley and Mokhtarian (2002). This denotes that the motorcycle is important in terms of commuting among Sarawakian urban households, as people may select their residential location based on their attitudes and preferences. There is only a small effect from BE_CBD compared to a strong effect, as supported by Zegras (2010) on auto use. Based on Ewing and Cervero (2010), the amenities and other attractions are located at the CBD, which means that the further the distance to the CBD, the higher the number of kilometres travelled. However, BE_CBD does not

have any significant relationship towards vehicle ownership and use of cars. This might be due to job sprawl, which relates to the expansion of the population away from CBD through the process of suburbanization and the encouragement of car-dependent communities in urban Sarawak.

- H7ii: *There is a significant positive relationship between motorcycle ownership and motorcycle VKT*.

It is found that VEHM is the main determinant for VKTM (β = 0.569***). The result is supported by Chen and Lai (2011). This indicates that motorcycle VKT is mainly contributed to by motorcycle ownership. Finally, the last sub-model in table 7.5 is based on VEHM sub-model. Socio-economic factors prove to have no significant effects on motorcycle VKT, unlike car ownership. This is because income does not have any direct effects on the use of motorcycles; instead, the motorcycle kilometres driven value is mainly determined by the number of motorcycles owned. As explained in Section 7.2.2.2, similar to car VKT, this shows that owning a motorcycle will increase the likelihood of travelling by motorcycle.

7.3 Chapter Conclusion

This chapter presented the descriptive statistics of the determinants of car and motorcycle ownership and use. The survey results from urban households in Sarawak are reported featuring a number of questions, including socio-economic, built-environment and psychological factors. The psychological factors are based on two main theories, namely the theory of planned behaviour and the norm activation model. Four sub-models are obtained using the partial least squares-structural equation model (PLS-SEM): (i) The car ownership sub-model; (ii) car VKT sub-model; (iii) motorcycle ownership sub-model; and (iv) motorcycle VKT sub-model. Based on the result of the car ownership sub-model, social norm, pro-environment and socio-economic factors are identified as the determining factors. Based on the result of the car VKT sub-model, attitude towards transport policy, socio-economic factors and car ownership are identified as the determining factors. Meanwhile, the motorcycle ownership sub-model indicated that the attitude towards transport policy, pro-environment, socio-economic, built-environment and car ownership factors are significant determinants. Finally, the attitude towards transport policy, built-environment (CBD) and motorcycle ownership factors

are supported as the determinants for motorcycle VKT. Based on the results, it is shown that psychological factors are significant in explaining ownership and use. Contrary to the aggregate model, there is a negative effect from the socio-economic factors towards motorcycle ownership. The results are noteworthy in the sense that the sample for the disaggregate model was acquired only from urban households whereas the aggregate model data covered the whole of Sarawak (rural and urban areas). Based on the results, it is noted that pro-environmental behaviour, which is based on NAM's personal norms, influences both car ownership and car VKT, while social norms only influence car ownership. This indicates that other people may influence an individual in terms of the number of cars they own; however, in terms of usage, it depends on the person themselves by taking into consideration their personal moral obligations. It is also evident that there is an interdependency between car and motorcycle ownership. While it is found that there is a negative relationship between the socio-economic factors and motorcycle ownership, complementarity occurs in the case where households that own many cars might consider owning motorcycles for various travel purposes. Overall, the results provide an overview of the determinants of car and motorcycle ownership and use in a city-region that has the dual characteristics of being located in a developing country but with a high level of reliance on private-based vehicles.

Chapter 8

Conclusions

8.1 Introduction

This thesis investigates the determinants of car and motorcycle ownership and use in a city-region which has the dual characteristics of being situated in a developing economy but also having very high car and motorcycle dependence. The rise of car and motorcycle ownership in Sarawak, a state in Malaysia, has caused severe congestion, accidents, and environmental and accessibility issues, particularly in urban areas. Inadequate access to public transport plays an important role in this high dependency. This case study context investigates some important gaps in the literature relating to car and motorcycle ownership. Firstly, it is commonly assumed that those with lower incomes tend to purchase motorcycles while those with higher incomes tend to own cars. Hence, both types of vehicles are usually considered as substitutes.

In the case of Sarawak, however, the simultaneous rise of car and motorcycle ownership challenges this perspective on the interdependency. Secondly, the demand for private vehicle ownership and use is typically investigated using socio-economic and built-environment factors. There are limited studies on the role of human psychological factors towards private vehicle ownership and use, especially with regard to motorcycles. Moreover, most studies have been conducted in the context of the developed world. Understanding the interrelationships between the variables is of significant importance to policymakers to effectively strategize their key initiatives as well as to ensure that the policies are suitable with respect to the context and nature of the population of interest.

8.2 How the Research in this Thesis Addresses the Objectives

8.2.1 Objective One: To Investigate Factors that Determine Car and Motorcycle Ownership at the Aggregate Level in the Selected Case Study Area.

An aggregate approach using a vector error correction model (VECM) is applied to investigate the determinants of car and motorcycle ownership using time series data at the state level. Based on the aggregate modelling in Chapter 5, the VECM analysis shows that gross domestic product (GDP), fuel price and level of employment are significant determinants of car and motorcycle ownership. The findings show that as the standard of living rises, both car and motorcycle demand increases. However, the intertemporal effects differ from the cross-sectional effects. This is because there is a negative relationship from the socio-economic factor towards motorcycle ownership for urban households in Sarawak. This suggest that there is a different socio-economic background in Sarawak as a whole compared to the urban part of Sarawak, whereby the higher income urban Sarawak tends to have fewer motorcycles and more cars. This is suggested despite the negative relationship with fuel price; the high vehicle ownership is encouraged by the government's fuel subsidies as well as flexible vehicle financing schemes. We also found that motorcycle ownership is more sensitive to the fuel price compared to car ownership, which shows that the changes in price have a greater influence on motorcycle owners. The finding of the current study is not consistent with Lai and Lu (2007), who suggested that cars are more sensitive to the fuel price compared to motorcycles.

8.2.2 Objective Two: To Investigate the Relative Impacts of Socio-Economic, Built-Environment and Psychological Factors on Car and Motorcycle Ownership and Use at the Disaggregate Level in the Case Study Area.

A disaggregate model is developed in Chapters 5 and 6 by applying partial least squares-structural equation modelling (PLS-SEM) using cross-sectional urban household data, thereby answering the first and third research gaps. For this purpose, a travel behaviour survey was conducted for a sample of 688 urban households in Sarawak, allowing the study to gather not only socio-economic and built-environment factors but also a large number of psychological determinants. The latter were based on the theory of planned

behaviour (TPB) and the norm activation model (NAM), from which social norms, perceived behavioural control, attitudes and pro-environment motives were measured.

For the disaggregate modelling, the PLS-SEM analysis outcomes are separated by four main sub-models, which are:

(1) The car ownership sub-model, indicating that the socio-economic, pro-environment and social norms factors are significant determining factors. The significance of the pro-environment (representing personal norms) and social norms factors validates the importance of integrating both TPB and NAM, which represents the effect of self-interest and pro-social concerns in car ownership reduction. This indicates that people behave in accordance with how other people behave within their circle (e.g. family, friends etc.) as well as the prevailing culture of car dependence in the society. Surprisingly, the role of the pro-environment factor has a greater effect compared to social norms, which captures the influence from the society. The altruistic behaviour of individuals, which means giving up personal advantages for the sake of the environment, has a greater influence in reducing car ownership, which suggests that soft policy measures, for example, education and awareness on the environment, may increase the impact of regulating car ownership.

(2) The motorcycle ownership sub-model indicates that the socio-economic, built-environment, attitude towards transport policy and pro-environment factors are significant determinants of motorcycle ownership. The results show that better socio-economic status reduces the number of motorcycles, which means that people will opt for cars as their primary mode of transport. The motorcycle is preferred as the mode of transport for lower income individuals due to its inexpensiveness and lower maintenance costs. That also explains why the socio-economic factor has a greater influence than attitude towards transport policy and the pro-environment factor. Unlike car ownership, social norms have no effect on motorcycle ownership. This means that an individual does not need to conform to society because they are more driven by their affordability to own a motorcycle. The significance of the pro-environment factor in lowering motorcycle ownership highlights the importance of moral obligations driven by the feeling of self-guilt due to the negative consequences, such as air pollution, of having too many motorcycles as well as the problem of traffic congestions, especially in the case of

developing Asian countries. Attitude towards transport policy also has a significant influence in determining motorcycle ownership. This indicates that a policy that is structured with the aim of influencing private-based transport may assist in controlling the motorcycle ownership specifically by embedding environmental values and improving the infrastructure of other modes of transport (e.g. public buses).

(3) The car use sub-model indicates that the car ownership, socio-economic and attitude towards transport policy factors are significant in explaining car use. Better socio-economic conditions encourage people to gain access to cars and to drive more beyond merely going to work, including for leisure purposes. The pro-environment factor has a significant effect on car ownership but no effect on car use. This is because changing one's repetitive behaviour is much more difficult than changing purchase decision-making. Among the psychological factors, only attitude towards transport policy is significant, which shows that policies can be altered to be in favour of car use reduction. For instance, price regulations (e.g. road charges) may add costs for the travel journey and may thus reduce car use.

(4) The motorcycle use sub-model indicates that motorcycle ownership, distance to city centre, and attitude towards transport policy affect motorcycle use. Unlike the other sub-models, the socio-economic factor does not show any significant influence on motorcycle use. This is because although there is generally a high motorcycle ownership in Sarawak, motorcycle use may be low in comparison to car use. Distance to CBD shows a significant relationship with motorcycle use. This suggests that having amenities and other attractions located near the CBD causes higher motorcycle use. Similar to the car use model, attitude towards transport policy is significant in influencing car use. For example, policies that restrict motorcycles on sidewalks may discourage motorcycle use.

8.2.3 Objective Three: To Examine the Interdependence Between Car and Motorcycle Ownership at the Aggregate and Disaggregate Levels in the Case Study Area (Refer to Sections 5.3.1 and 7.2.2.3).

Using PLS-SEM (Chapter 7), the model also found a complementary relationship between car and motorcycle ownership, which shows that the demand grows together rather than the two being alternatives to each other, which answers research gap 2. This may be due to the important functionality of both cars and motorcycles in the households, which serve different travel purposes in commuting. The results indicate that policies to promote other sustainable modes of transport (e.g. public buses) may be effective considering high car and motorcycle ownership in the case of developing countries. Unlike the cross-sectional effects, the intertemporal effects show that there is a substitution relationship between car and motorcycle ownership. Based on the results, it is evident that the interdependency between car and motorcycle ownership is not similar at the aggregate and disaggregate levels.

8.2.4 Objective Four: To Use the Results to Propose Recommendations on Appropriate Sustainable Transport Policies that Might Be Formulated in the Case Study Area and Comparable Developing Country.

(Refer to Section 8.3.2)

8.3 Implications of the finding

8.3.1 Theoretical Implications

The outcomes of the study have two implications for the theory in the context of car and motorcycle ownership and use. First, the thesis was able to contribute to the knowledge by conducting the study in the case of a developing country with high vehicle ownership. This is because most previous studies were conducted in developed countries, such as European countries and the USA. Also, the research fills the literature gap by providing empirical evidence to support the integration of the theory of planned behaviour (TPB) and the norm activation model (NAM) in explaining private vehicle ownership. Elements from both TPB (social norms) and NAM

(personal norms as depicted by the pro-environment factor) are found to be statistically significant in explaining car and motorcycle ownership. This is consistent with the previous findings from Abrahamse et al. (2009) and Liu et al. (2017). The outcome suggests that more studies should incorporate the integration of both TPB and NAM, particularly for vehicle ownership in Asian developing countries.

Secondly, the findings of the thesis have identified that the most critical determinant for car ownership are social norms and the pro-environment factor in the context of a developing Asian country. This is slightly different from the developed countries, where studies have shown perceived behavioural control and the attitudinal factor to be most important determinants (Abrahamse et al., 2009; Liu et al., 2017). Meanwhile, the thesis has indicated that the attitude and pro-environment factors are the most critical determinants of motorcycle ownership. However, attitude towards transport policy is the only significant psychological factor found in the case of car and motorcycle use. Overall, one reasonable conclusion, following the outcome of the results, is that different ‘types' of factor could apply to different domains of behaviour. The factors that reflect norms were mainly successful in explaining ownership, whereas vehicle use was better explained by individual considerations, specifically attitude. Therefore, policies aimed at reducing ownership should be targeted at the moral obligation to bring about change. On the other hand, a norm-based factor is not significant as car and motorcycle use are repetitive behaviour. The study indicates that it is very hard to alter norms unless there is a better optional mode of transport, such as buses. This can fill in the literature gaps, which can be used to further understand the development of the car and motorcycle ownership and use model in future studies.

8.3.2 Policy Recommendations

8.3.2.1 Transport Infrastructure and Public Transport Reform

This section provides suggestions in answering the fourth objective of the thesis, which is “To use the results to suggest how acceptable sustainable transport policies might be formulated in developing countries”. The thesis assists by informing cities in developing Asian countries which have a high car and motorcycle dependence regarding acceptable, sustainable transport policies that can be applied in the respective countries.

First, considering the significance of attitude towards transport policy for both car and motorcycle use, there is a need for policymakers to re-assess the current transport infrastructure and provide necessary improvements related to government aims. For instance, since there is a very high reliance on motorcycle ownership and use, this means that there are rising negative externalities, such as traffic congestion as well as safety and security issues (e.g. collisions with HGVs and cars). Therefore, one of the suggestions is to provide a designated lane for motorcycles and other vehicles. As many of the accidents involve HGVs and motorcycle, it is imperative to also have designated lanes for motorcycles and HGVs and to impose restrictions on HGVs access, for example, providing time limits in accessing certain parts of the cities. This is a command and control measure that is less costly and easy to apply, particularly for low-income or developing countries. Considering the continued rise in motorization and serious congestion issues, it is crucial to revisit current road transport policies in the case of Asian developing countries.

Second, unless the government implements public transport reform, there will be a continuous high car ownership per capita in urban Sarawak. Although there is a sizeable level of agreement among the respondents on access to public buses, there is a more than 50 per cent level of disagreement to neutral in terms of speed and convenience. Based on the observations, the current public bus system and services are still insufficient/ineffective. Policymakers need to improve the bus infrastructure, including improving public bus stops as well as equipping them with bus schedules, route numbers and state-of-the-art safety features (e.g. CCTV, emergency phones). In terms of bus services, the government needs to be stringent in terms of the compliance with the rules, regulations and services offered by bus operators. This includes improving the bus schedules, the number of routes, fares standardisation, ticketing system, designated seats for disabled, elderly and pregnant women, enhancing the user experience (increasing comfort and convenience) and safety features, such as CCTV. There were also complaints in terms of the buses not arriving on time and not arriving at the specified destination. In this case, the government should closely monitor bus performances in terms of the bus flow of movement. Another option of monitoring is by improving the technology used by bus operators. In this sense, it is imperative for bus operators to ensure that they are equipped with an application which enables users to purchase bus tickets and monitor the estimated time of arrival and

geo-location of the buses. Public transport such as buses in Asian developing countries tends to be a secondary mode of transport compared to private-based vehicles. Therefore, it is highly suggested to recognize the flaws and deficiencies of public transport in order to have a better understanding from the demand side. By upgrading the current public transport infrastructure and services, this may shift users from private-based vehicles to public transport to overcome the issues of congestion due to high vehicle dependence in Asian developing countries.

8.3.2.2 Technology Integration

It is noted that the pro-environment factor influences both car and motorcycle ownership but not use. Intervention on environmental knowledge is not sufficient without intervention, especially for repetitive behaviour in car and motorcycle use. In this case, we highlight the integration of technology in cars and motorcycles. The element of technological integration in car and motorcycle ownership may include the strict enforcement of electric vehicles or fuel-efficient vehicles, which are considered as being pro-environment as they emit less harmful pollution. To achieve this, the government plays a crucial role encouraging vehicle users through a series of pull measures, such as providing incentives in the form of subsidies which reduce the vehicle price as well as tax exemption and ease of financing. In addition, it is important that charging facilities are widely available for the convenience of the users. Developed countries have more well-equipped and state-of-the-art electric vehicle or fuel-efficient vehicle facilities as well as several incentives that are in line with encouraging more environmentally friendly behaviour, a situation which is in contrast with most developing Asian countries. This condition concludes that the development of the electric vehicle or fuel-efficient vehicle infrastructure is still at its infancy. While it is known that Asian developing countries have a high reliance on cars and motorcycle, it is important to focus on encouraging the purchase and use of such eco-friendly private vehicles. This is because shifting to a different mode of transport (e.g. buses) may be difficult for them as it involves changing one’s repetitive behaviour.

8.3.2.3 Enhance Knowledge and Improve Knowledge Dissemination

One of the implications of these findings is that pro-environment factors should be incorporated when dealing with car and motorcycle-based policies. Based on the output, the pro-environment factor is significant in explaining lower car

ownership but not car use. The high resistance to reducing car use as a result of repetitive behaviour might be a chain that is difficult to break, which suggests that policymakers should concentrate more on providing sufficient education as well as implementing various marketing techniques (online and offline) to create awareness and instil a responsibility among the public. In particular, one course of action is strengthening the environmental knowledge in relation to vehicle efficiency, which might increase the demand for energy efficient vehicles (EEV), which will, in turn, reduce the harmful pollution of the environment.

In 2014, the National Automotive Policy was established to produce EEV within Malaysia to make the country a regional EEV hub by 2020, and such particulars are widely available on the internet and various car dealers. However, there is still vagueness in how the information is distributed and understood among vehicle users. Based on the results, the effect on travel behaviour is driven by the two main forces or psychological factors in this study, whereby one is the personal norms. Meanwhile, knowledge of the environment creates awareness, which later translates into action. It is duly noted that the altruistic side of the individual is nurtured through education. It is also imperative that environmental knowledge is instilled in the school curriculum at a very young age – a step that is not yet fully present in the local education system. In other words, the current education system should be revised to ensure that students receive sufficient knowledge and exposure regarding environmental protection.

8.3.2.4 Land Authorities and Transport Authorities

Malaysia has developed the National Transport Policy (2019-2030), which provides a strategic direction to achieve an efficient, integrated and sustainable transport system for ministries at the federal and state levels (MOT, 2018).

The NTP was developed with the following objectives:

- Create a conducive ecosystem for the transport industry to enhance productivity and competitiveness
- Facilitate seamless movement of goods to boost trading activities and ease of doing business
- Provide mobility that meets the expectations of people and promotes inclusivity
- Increase modal share for public transport
- Deliver an intelligent, safe and secure transport system
- Ensure efficient and sustainable use of resources and minimise environmental pollution

While there is a country-level strategic policy being implemented by the government, the situation might differ at the state level. This is due to different socio-economic and built-environment factors as well as the transport needs, which differ from one state to another. On top of the Malaysian National Transport Policy (2019-2030), the state government of Sarawak is currently planning to develop its own integrated transport master plan to cater to the transport demand in Sarawak (Lumandan, 2019). It is important that the domestic aspect of transport demand is understood and interpreted into the government aims and preferences. These aims and preferences serve as the initiation points in realising the advancement of capitals into real outcomes to achieve the provision of sustainable transport in the long run. It is noted that there is no official transport-based survey at the country and state levels. Hence, this study could be the point of reference to identify the factors that contribute to car and motorcycle ownership and use at the state and country levels.

A number of policy recommendations are suggested for the land and transport authorities in Sarawak. Firstly, it is recommended to design more road networks that can accommodate all modes of transport, including non-motorized transport (e.g. infrastructure for pedestrians and cyclists), as well as ensure better access to public transportation. This is because the current demand for car and motorcycle ownership is high and is expected to continue to increase in the long run as there are limited alternatives with which to travel. Secondly, it is recommended to establish a taskforce that brings together all the individual stakeholders (Ministry of Infrastructure Development and Transportation, Land and Survey Department, academics, companies and consultants). This taskforce would work to synergize the links between stakeholders, identify issues with the current transport system (e.g. traffic congestion and road maintenance), provide solutions, and continuously

monitor any progress on the relevant issues. Thirdly, it is recommended to provide transport databases at the state level, particularly at the disaggregate household or individual level. The main reason for this is the absence of a transport-based survey at the national and state levels. Some parts of this thesis provide the determinants for car and motorcycle ownership and use which are investigated at the aggregate state level (intertemporal) and disaggregate (cross-sectional) level in the urban area which are beneficial for local transport authorities policy-making. Interestingly, the study incorporate not only the socio-economic and built-environment factors but also psychological factors which are useful to study the behaviour of road users. Such database is imperative to continuously monitor the progress and challenges of the transport system in Sarawak.

8.4 Limitations

The first limitation of this thesis is related to the population sample used to estimate the proposed PLS-SEM model and the sample that can be used. Although this study aims to identify the determinants of vehicle ownership and use in a developing country, the data collected are only from urban households. Thus, the data collected may not fully represent the aim of investigating a developing country. This is because during the survey collection, the research encountered issues related to time and monetary constraints. It was impossible to collect data from both urban and rural households given the limited timeframe. Furthermore, there exists a very high level of risk in collecting data in the rural areas of a developing country due to safety and security concerns. Usually, to collect more data, more monetary cost should be incurred, and this could pose budgetary issues for the research as there is limited funding to conduct the survey. Nevertheless, it is imperative to be cautious and ensure that a satisfactory sample size is obtained to ensure that valid and reliable outcomes are achieved in producing an applicable conclusion to the thesis.

The second limitation is the fact that the disaggregate model only investigates the direct relationship between the variables and does not include the indirect relationship between them. A potential limitation that needs to be addressed is that the model did not examine the relationship between the socio-economic variables and any of the psychological factors. This is important as the socio-

economic determinants may influence the psychological factors. Since the sample was collected from urban districts in Sarawak, the psychological factors represent an urban population in a developing country, and thus may differ from the rural counterparts. Considering that, the psychological factors may not represent Sarawak as a whole.

The third limitation is the measurement of the psychological factors. There is a wide range of measures for psychological factors, specifically, the one adapted from TPB and NAM, and no single measure is ideal as it is subject to the area of the study. There is a possibility that there are certain indicators that are not included as part of the determining factor. Furthermore, as only very limited studies have been conducted in the case of motorcycle ownership and use, there might be some indicators that need to be addressed that are not incorporated in the study.

The fourth limitation is from the perspective of the aggregate data. That is, no data on rural and urban car and motorcycle ownership were available for the study. It is of interest to capture the intertemporal effect in general as well as from the point of view of the rural and urban perspective. Furthermore, there are no data on vehicle use that can be used to compare the effect at the aggregate level with that at the disaggregate level.

8.5 Further Appropriate Work

First, the thesis uses data from 688 urban households in Sarawak. Future research could apply a similar modelling framework with a larger sample that includes rural households as the sample for the analysis and then conduct a comparative analysis. This may offer a different insight for policymakers to devise future policies for two different demographic backgrounds. Furthermore, more built environment-based indicators could be used, such as density, diversity and design (for example, average street width or numbers of pedestrian crossings) to complement the study as the determining factors to refine the overall model.

Second is the exploration of the indirect relationship among the variables in the proposed travel behaviour model. In addition, moderating variables (for

example, age and gender) could also be used in the model. In addition, a similar study could also be conducted based on two different timelines (pre- and post- survey). This would show whether there are changes in the impact of the psychological factors on behaviour over a period of time.

Third is to test the relationship between the socio-economic variables and the psychological variables. It would be interesting to see whether the impact of higher socio-economic status, for example, leads people towards more pro-environmental behaviour.

Fourth is to include habits and other psychological factors as the determinant of car and motorcycle ownership and use. Other theories could also be used to obtain a different take on the psychological factors from a different perspective.

Fifth is to include more variables to represent the built environment. While it is evident that psychological factors serve as one of the main determinants of car and motorcycle ownership and use in the thesis, it is interesting to see how different built-environment indicators may influence car and motorcycle ownership and use.

Sixth, it would be interesting to conduct an intertemporal study of the interdependency between car and motorcycle ownership at the aggregate level in Malaysia and compare different states in Malaysia. This would provide an insight into whether all states have similar or different interdependencies between the ownership of both vehicles.

Finally, since the thesis only employed a quantitative-based analysis, it is suggested to use a mixed-method approach which integrate quantitative and qualitative analysis. This is because a qualitative method, such as interviews and focus group discussions, would offer better insights considering that an official transport-based survey has never been conducted in Sarawak before. A mixed-method approach would add value as respondents would be able to express their individual opinions regarding the issues in far greater detail.

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List of Abbreviations

3SLS	:	Three Stage Least Squares
ADF	:	Augmented Dickey-Fuller test
ARDL	:	Autoregressive Distributed Lags
ATT	:	Attitude
AVE	:	Average Variance Extracted
BOP	:	Bivariate Ordered Probit
CAFÉ	:	Corporate Average Fuel Economy
CAO	:	Passenger cars per 1000 people
CBD	:	Central Business District
CB-SEM	:	Covariance Based-Structural Equation Model
CO_2	:	Carbon dioxide emissions
DOS	:	Department of Statistics
ECM	:	Error Correction Model
ECT	:	Error correction term
EPU	:	Economic Planning Unit
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
HGV	:	Heavy Goods Vehicles
MAO	:	Motorcycles per 1000 people
MDCEV	:	Multiple Discreet Continuous Extreme Values
MNL	:	Multinomial Logit Model
NAM	:	Norm Activation Model
OLS	:	Ordinary Least Squares
ORP	:	Ordered Response Probit
PP	:	Phillips–Perron test
PBC	:	Perceived Behavioural Control
PLS-SEM	:	Partial Least Squares Structural Equation Model

PN	:	Personal norm
SN	:	Social norm
SRMR	:	Standardized Root Mean Square Residual
SURE	:	Seemingly Unrelated Regression
TPB	:	Theory of Planned Behaviour
TW	:	Two-wheeler
VAR	:	Vector Autoregressive
VECM	:	Vector Error Correction Model
VEHC	:	Car ownership model
VEHM	:	Motorcycle ownership model
VKT	:	Vehicle Kilometres Travelled
VKTC	:	Car use model
VKTM	:	Motorcycle use model
VMT	:	Vehicle Kilometres Travelled

Appendix A

Summarised literature review

Author	Country/ Case study	Aggregate/ Disaggregate	Socio economic factors	Built-environment factor	Psychological Factors	Inter dependency
Car ownership						
(Reza and Spiro, 1979)	USA	A	/			
(Witt and Johnson, 1986)	UK	A	/			
(Romilly et al., 1998)	Great Britain	A	/			
(Dargay and Gately, 1999)	UK	A	/			
(Fouquet, 2012)	UK	A	/			
(Prevedouros and An, 1998)	Asian countries	A	/			
(Button et al., 1993)	Low income countries	A	/			
(Whelan, 2007)	Great Britain	D	/			
(Ritter and Vance, 2013)	Germany	D	/			
(Nolan, 2010)	Ireland	D	/			
(Kumar and Krishna Rao, 2006)	India	D	/			

(Chamon et al., 2009)	India	D	/			
(Boarnet and Sarmiento, 1998)	Portland, USA	D	/	/		
(Potoglou et al., 2008)	Canada	D	/	/		
(Van Acker and Witlox, 2010)	Ghent, Belgium	D	/	/		
(Li and Zhao, 2017)	Beijing, China	D	/	/		
(Ao et al., 2018)	Sichuan, China	D	/	/		
(Fujii and Gärling, 2003)	Kyoto, Japan	D	/	/	/	
(Wu et al., 1999b)	Xi'an , China	D	/	/	/	
(Choo and Mokhtarian, 2004)	San Francisco Bay, USA	D			/	
(Van and Fujii, 2011)	Japan, Thailand, China, Vietnam, Indonesia, the Philippines	D			/	
(Lois and Lopez-Saez, 2009)	Spain	D			/	
(Nishihara et al., 2017)	Japan	D			/	
(Belgiawan et al., 2014)	China, Indonesia, Japan, Lebanon, Netherland	D	/	/	/	

	s, Taiwan, and USA					
(Handy et al., 2005)	Northern California, USA	D	/	/		
Motorcycle ownership						
(Prabnasak and Taylor, 2008)	Medium size Asian city	A	/			
(Pongthanaisawan and Sorapipatana, 2010)	Thailand	A	/			/
(Duffy and Robinson, 2004)	U.K.	A	/			
(Law et al., 2015)	80 countries	A	/			
(Burge et al., 2007)	U.K.	D	/			
(Wedagama, 2009)	Bali	D	/			
(Hsu et al., 2007)	Taiwan	D	/			/
(Leong and Mohd. Sadullah, 2007)	Penang State, Malaysia	D	/			
(Gopisetty and Srinivasan, 2013)	Chennai, India	D	/			
(Dash et al., 2014)	India	D	/			
(Lin and Yang, 2009)	Taipei, Taiwan	D	/	/		
(Herwangi, 2018)	Jogjakarta, Indonesia	D	/	/		
(Yamamoto, 2009)	Osaka; Kuala	D	/			/

	Lumpur, Malaysia					
(Sanko et al., 2014)	Kuala Lumpur, Bangkok, Nagoya	D	/			/
(Chiou et al., 2009)	Taiwan	D				/
(Senbil et al., 2007)	Indonesia, the Philippines, Kuala Lumpur	D	/	/		/
(Gómez-Gélvez and Obando, 2014)	Greece, Colombia	D	/			/
Car use						
(Wheaton, 1982)	42 countries	A	/			
(Small and Dender, 2007)	USA	A	/			
(Hymel et al., 2010)	USA	A	/			
(McMullen and Eckstein, 2012)	USA	A	/			
(Tanner, 1983)	OECD countries	A	/			
(Emrath and Liu, 2008)	USA	D	/			
(Akar and Guldmann, 2012)	USA	D	/	/		
(Woldeamanuel and Kent, 2014)	California, USA	D	/	/		
(Boarnet, 2004)	Portland, USA	D	/	/		

(Zegras, 2007)	Santiago de Chile	D	/	/		
(Handy et al., 2005)	North California, USA	D	/	/		
(Bagley and Mokhtarian, 2002)	San Francisco Bay, USA	D	/	/	/	
(Banerjee and Hine, 2016)	Northern Ireland	D	/	/	/	
(Steg and Sievers, 2000)	Netherland	D			/	
(Choocharukul and Fujii, 2007)	Thailand	D			/	
(Choocharukul et al., 2008)	Thailand	D	/	/	/	
Motorcycle use						
(Senbil et al., 2006)	Jabatobek, Indonesia	D	/	/		
(Shirgaokar, 2016)	India	D	/	/		

Appendix B

Diagnostic test and stability test results

B(I) Diagnostic test

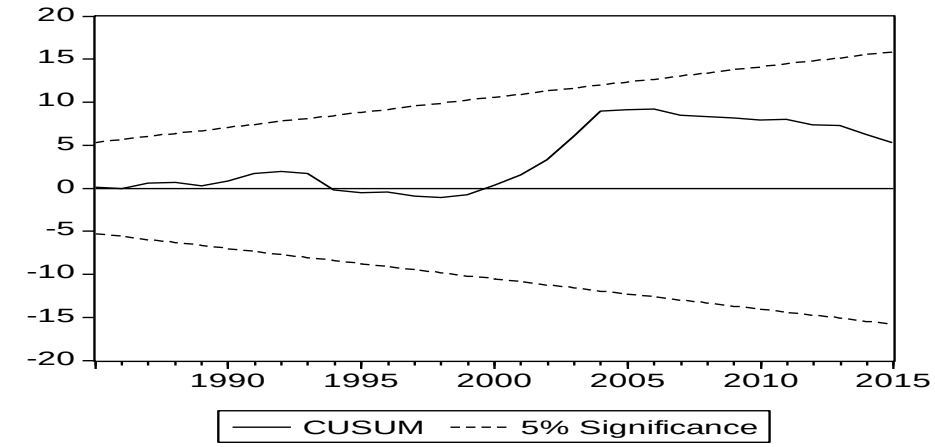
Table 5. 7 Diagnostic Test Results for Car Model.

Test	H_0	Probability	Decision
VEC Residual Serial Correlation test	No serial correlation at lag order h	0.8108	Do not reject H_0
VEC Residual Heteroscedasticity	Residuals are homoscedastic	0.1137	Do not reject H_0
VEC Residual Normality test	Residuals are multivariate normal	0.7886	Do not reject H_0

Table 5. 8 Diagnostic Test Results for Motorcycle Model.

Test	H_0	Probability	Decision
VEC Residual Serial Correlation test	No serial correlation at lag order h	0.1510	Do not reject H_0
VEC Residual Heteroscedasticity	Residuals are homoscedastic	0.1290	Do not reject H_0
VEC Residual Normality test	Residuals are multivariate normal	0.8684	Do not reject H_0

B(II) Stability test



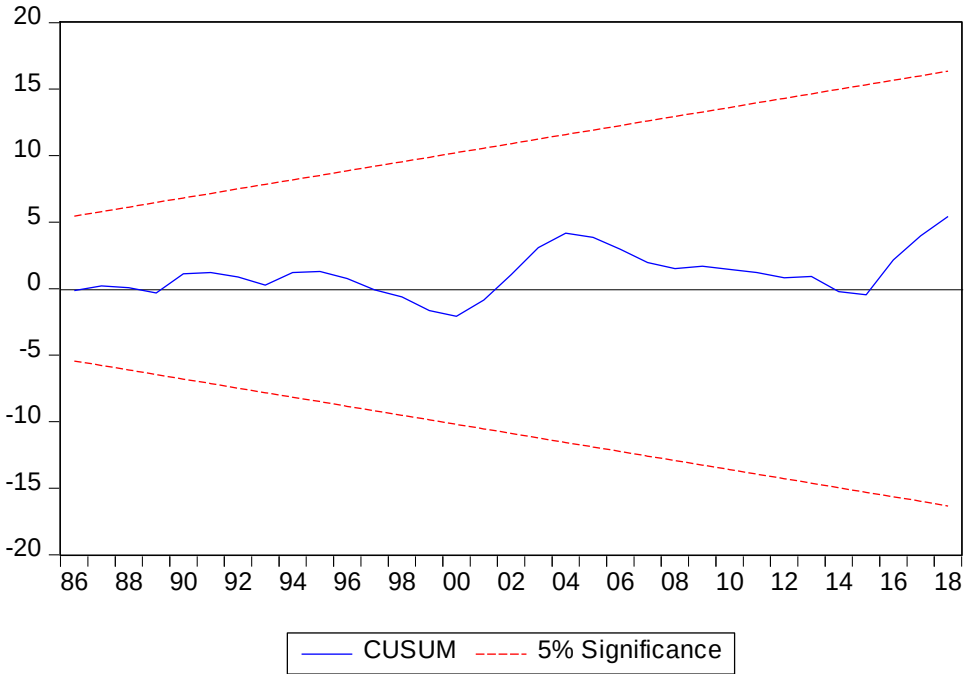


Figure 5. 2 Plot of CUSUM test (Car).

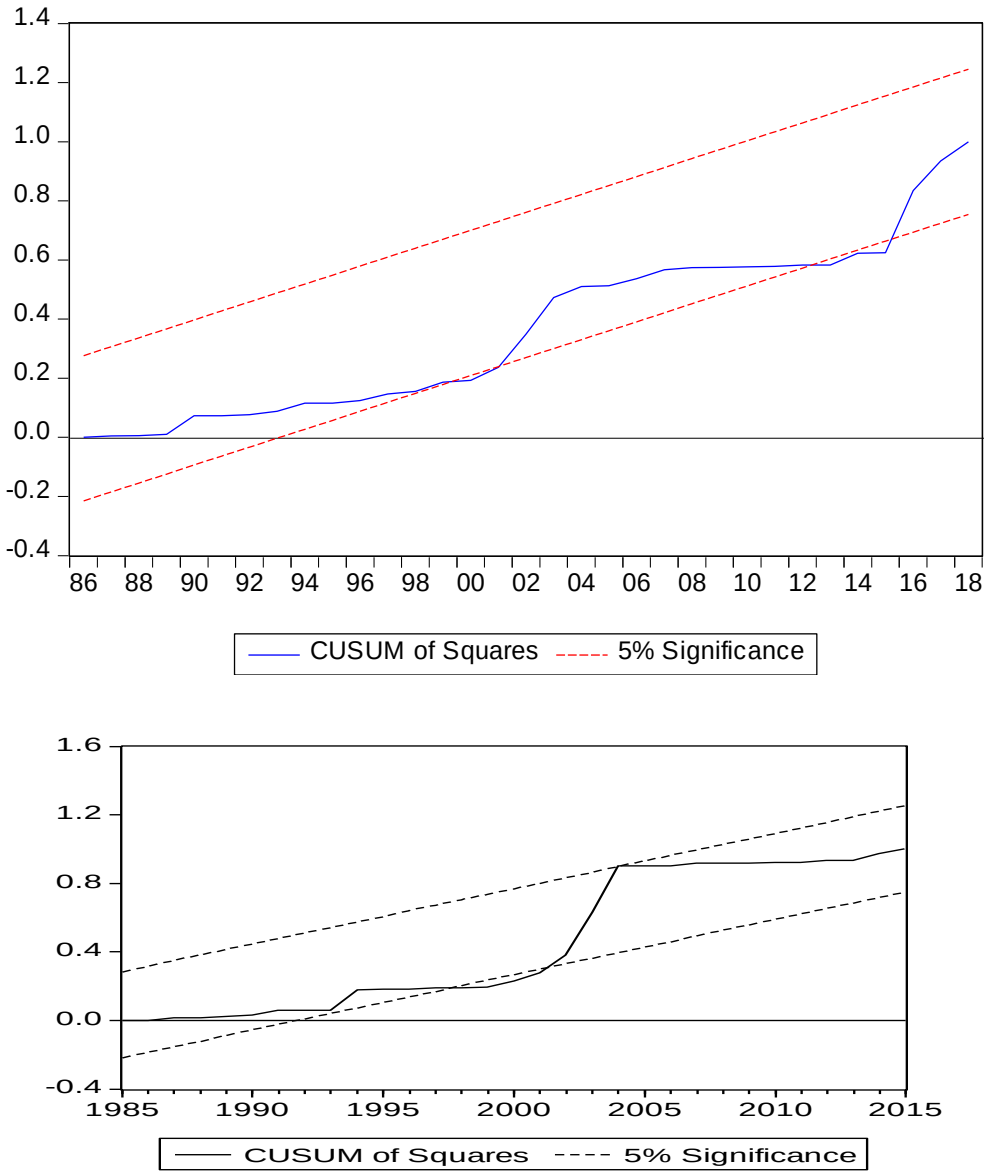


Figure 5. 3 Plot of CUSUM Square test (Car).

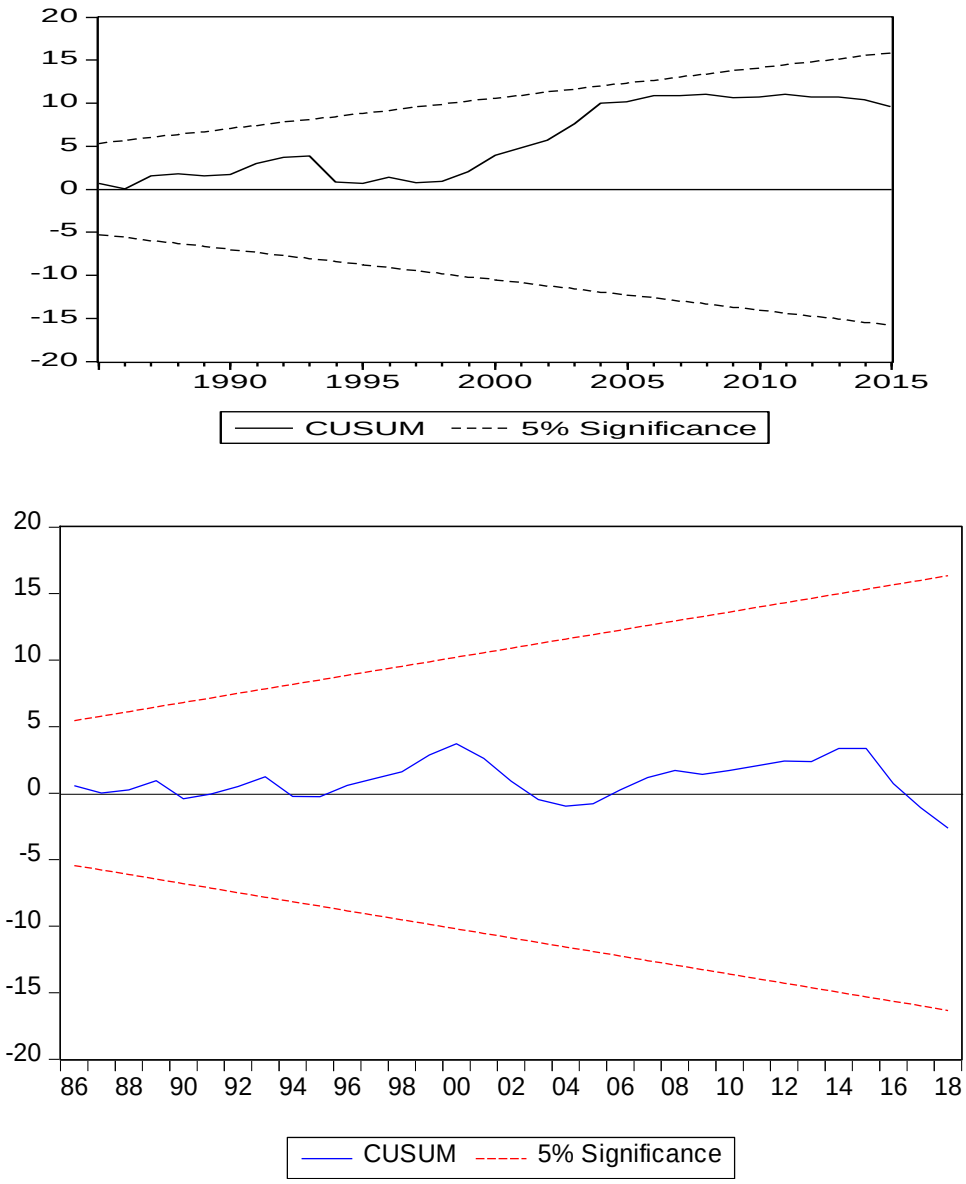


Figure 5. 4 Plot of CUSUM test (Motorcycle).

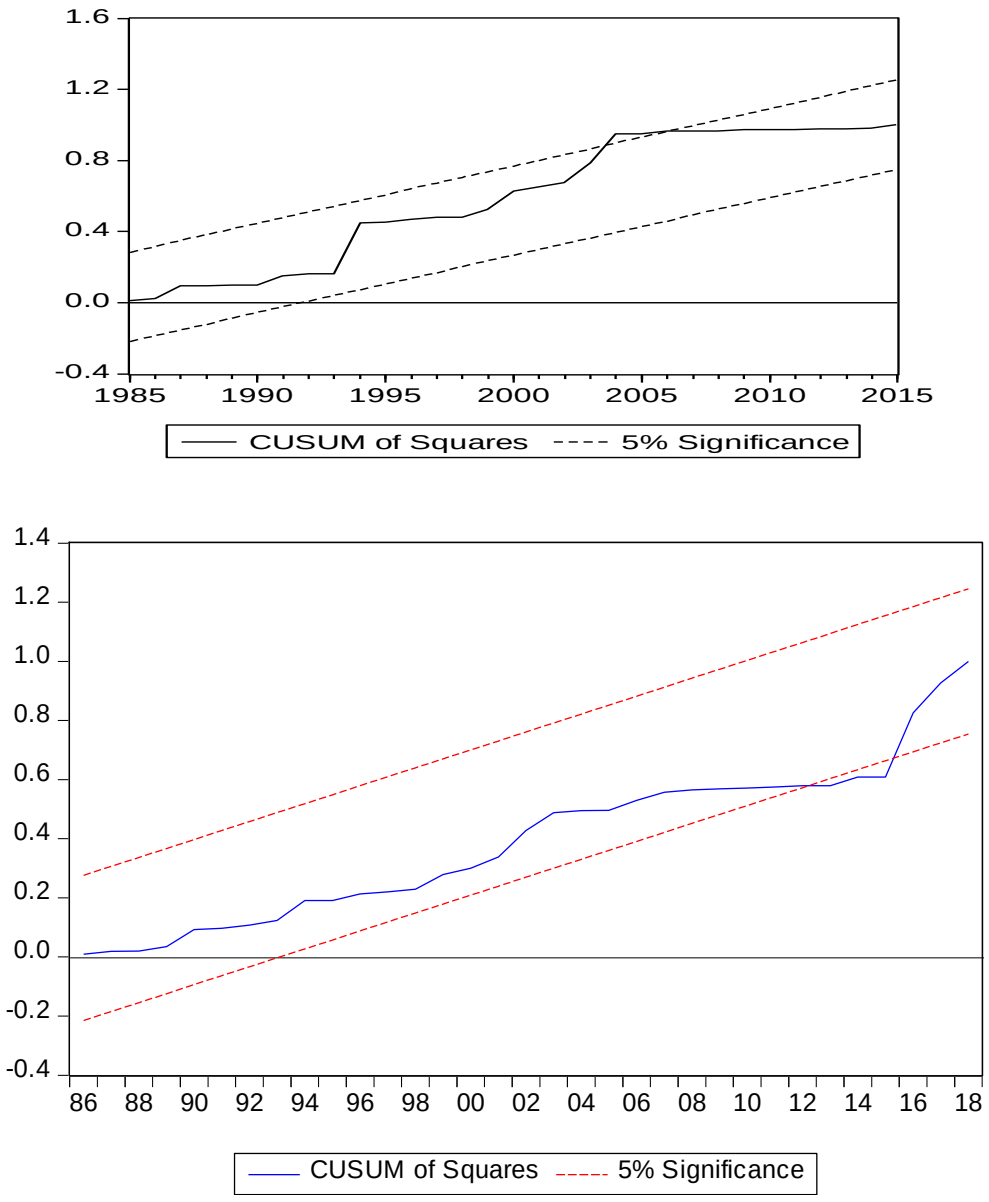


Figure 5. 5 Plot of CUSUM Square test (Motorcycle).

Appendix C

PLS-SEM Methodology

C(I) Stage 1: Assessment of measurement model

The outer model measurement/assessment model consist of two sub-models namely; reflective measurement model and formative measurement model. The reflective measurement model can be assessed using the following criteria; Indicator Reliability, Internal Consistency Reliability, Convergent Validity and Discriminant Validity.

Reflective measurement model

Assessment of individual item reliability

Convergent validity

Convergent validity measures the “extent to which a construct converges in its indicators by explaining the items’ variance (Sarstedt et al., 2014). The criterion of convergent validity is measured using Average Variance Extracted (AVE) suggested by Fornell & Larcker (1981). The formula is calculated as following:

$$AVE = \frac{(\sum {\lambda_i}^2)}{\sum {\lambda_i}^2 + \sum_i var(\varepsilon_i)}$$

Where λ_i is the component loading to an indicator and var(ε_i) = (1-λ_i^2) in case of standardized indicator. The AVE value of at least 0.50 indicates the condition of sufficient convergent validity which shows that 50 per cent of the variance of its items is explained by the construct (Sarstedt et al., 2014).

Discriminant validity

In PLS-SEM, discriminant validity measures to which extent different constructs differ from one another (Urbach & Ahlemann, 2010). There are two measures of discriminant validity which are the Fornell-Larcker criterion and cross loadings. According to the Fornell-Larcker criterion (Fornell & Larcker, 1981), it is a requirement for a latent construct to share more variance with its assigned indicators than with any other latent construct. In this case, the AVE for each latent construct should be more than the squared correlations with all other latent constructs. The second criterion is an indicator's loading which is associated with its latent construct should be greater than its own loading with all the remaining constructs (Hair et al., 2011).

Reliability analysis (Internal consistency reliability)

The traditional measure of reliability is Cronbach alpha (CA) in which greater value of alpha assumes that all indicators under the similar construct possessed the same range (Cronbach, 1951). The following is the estimation of Cronbach alpha:

$$\propto \frac{N - \bar{r}}{1 + (N - 1) - \bar{r}}$$

Where N is equal to the number of items and $\bar{r}$ is the average inter-correlation among items (average of all Pearson correlation coefficients between the items)

Composite reliability is the alternative measure to Cronbach alpha as it is deemed more appropriate since Cronbach alpha tend to underestimate the internal consistency reliability in PLS-SEM's latent construct. Furthermore, composite reliability takes into consideration that indicators have different loadings. (Henseler et al., 2009) The formula to calculate composite reliability score is as follows:

$$\rho_c = \frac{(\sum \lambda_i)^2}{(\sum \lambda_i)^2 + \sum_i var(\varepsilon_i)}$$

Where ρ_c is the composite reliability score and λ_i is the component loading of each item to a latent variable and var(ε_i) = (1-λ_i^2). The composite reliability values between 0.6 and 0.7 are considered acceptable in the case of exploratory research while between 0.7 and 0.95 are considered satisfactory to good (Hair et al., 2014).

Formative measurement model

A formative measurement model evaluation criterion requires a different approach than the one applied in the reflective measurement model (Sarstedt et al., 2014). The concept of internal consistency reliability and convergent validity are not meaningful when involving the formative measurement model. (Henseler et al., 2009; Urbach & Ahlemann, 2010) There are two measures in assessing the formative measurement model; (1) Indicator validity and (2) Construct validity (Urbach & Ahlemann, 2010). The evaluation of indicator weights (Chin, 1998; Lohmoller, 1989) and collinearity should be taken into considerations in assessing indicator validity.

Indicator weights

Indicator weights significance can be obtained by running a bootstrapping procedure. Bootstrapping procedure is “a resampling technique that draws a large number of subsamples (typically 5000) from the original data (with replacement) and re estimates the model for each subsample”. These subsamples allow the computation of bootstrap standard error which then results in the calculation of t-values and p-values for each indicator weights. The following are the criteria to determine the significance of the weights: (Sarstedt et al., 2014) If the weight is statistically significant, the indicator is retained

- If the weight is non-significant but the indicator’s loading is 0.50 or higher, the indicator is still retained, provided that theory and expert judgment support its inclusion.
- If the weight is non-significant and the loading is low (i.e., below 0.50), the indicator should be deleted from the measurement model.

Multicollinearity

High levels of multicollinearity could result in the indicator's information to be redundant thus causing it to be nonsignificant (Hair et al., 2011). In order to check for multicollinearity, the variance inflation factors are calculated among the formative indicators. The VIF indicates the extent to which an indicator's variance is explained by other indicators in the same construct (Urbach & Ahlemann, 2010) VIF can be calculated using the following formula:

$$VIF = \frac{1}{1 - R_i^2}$$

Construct validity: Nomological validity and interconstruct correlation

In the case of measuring the construct validity for formative measurement model, nomological validity and interconstruct correlations are taken into account. Nomological validity is defined as "the relationship between formative index and other constructs in the path model, which are sufficiently well known through prior research, should be strong and significant" (Jorg Henseler et al., 2009). Therefore, the relationship between formative construct and other constructs are expected to be strong and significant as expected from previous literatures (Urbach & Ahlemann, 2010). The final measure in construct validity for formative measurement model is the interconstruct correlations. It is expected that the correlations between formative construct and other constructs are less than 0.70 to signify that the constructs are different from one another (Urbach & Ahlemann, 2010).

C(II) Stage 2: Assessment of structural model

Coefficient of determination (R^2)

The assessment of structural model takes place after the construct measures are confirmed to be valid and reliable. PLS-SEM differs than CB-SEM in a way that it does not have a single goodness of fit metric for the overall model. Instead, PLS-SEM relies on the explanatory power of the model in testing the research hypothesis (Aibinu & Al-Lawati, 2010).The coefficient of determination (R^2) of the endogenous latent construct is the essential criterion in evaluating the inner path model. Chin (1998) stated that R^2 values of approximately 0.67, 033 or 0.19 are considered as substantial, moderate or week. Accordingly, the R^2 is expected to exhibit at least a substantial level if the endogenous latent construct depends on several exogenous latent construct.

Predictive relevance (Q^2)

Predictive relevance according to Urbach & Ahlemann (2010), calculates Q^2 which measures the relevance of a block of manifest variables. The predictive relevance, Q^2 can be measured using non-parametric Stone-Geisser test. The measured Q^2 describe how well the values being observed are reconstructed by the model and the estimation of its parameters. Q^2 with positive values indicate that the predictive relevance for the model with respect to the constructs. Negative Q^2 values show that the predictive relevance for the model is lacking.

$$Q^2 = 1 - \frac{\sum_k E_{jk}}{\sum_k O_{jk}}$$

Goodness of fit

The goodness of fit (GoF) criteria that is applied using PLS-SEM path model for this thesis is the standardized root mean square residual (SRMR). SRMR is suggested by Henseler et al. (2014) as a GoF measure in order to avoid misspecification issue in the mode. According to Ramayah et al. (2016), SRMR is defined as the difference between observed correlation and the model implied correlation matrix. A good fit based on Hu and Bentler (1999) is a value of SRMR less than 0.10 or 0.08.

Path coefficient

Henseler et al. (2009) describes the individual path coefficient as standardized beta coefficients of ordinary least squares regressions. In PLS-SEM, the path coefficients among the latent construct are analysed in terms of their sign, magnitude and significance. Paths which exhibit contrary signs or nonsignificance to expectations does not support pre-postulated hypothesis. A nonparametric bootstrap procedure is applied since PLS-SEM does not presume the distribution to be normal. The bootstrapping method is a procedure which a huge number of sub-samples (e.g. suggested 5000) are acquired from the original sample with replacement to determine the bootstrap standard which later provide an approximate t-values for significance which tested for the structural path coefficient (Ramayah et al., 2016). The rule of thumb for bootstrapping procedure is to ensure that the number of sub-samples should be greater than the observation. It is suggested that the magnitude between two latent constructs should exceed 0.010 to give certain impact within the (Urbach & Ahlemann, 2010). Table 4.3 summarizes the stages and indices in PLS-SEM.

Table 4. 3 Summaries of Stages and Indices in PLS-SEM.

Stage One: Assessment of Measurement Model		
Step 1: Measurement of Reflective Model		
	Assessment	Name of Index & Guidelines
Step 1.1	Internal Consistency	<u>Composite Reliability (CR)</u> CR > 0.90 (Not desirable) 0.7 < CR < 0.9 (Satisfactory) CR < 0.6 (for exploratory studies)
Step 1.2	Indicator Reliability/ Factor Loadings	<u>Indicator Loadings</u> Loadings should be > 0.708 Loadings > 0.4 acceptable if other loadings have high score loadings to complement AVE and CR

Step 1.3	Convergent Validity	Average Variance Extract (AVE) AVE > 0.5
Step 1.4	Discriminant Validity	Fornell-Larcker's Criterion The square root of AVE of a construct > correlations between the construct and other construct in the model
Step 2: Measurement of Formative Model		
Step 2.1	Collinearity among indicators	Variance Inflation Factor (VIF) VIF < 5 or VIF < 3.3 (no collinearity)
Step 2.2	Significance of outer weights	The outer weights results from bootstrapping should have significant p-value
Step 2.3	Significance of outer loadings (if outer weights is not significant)	The outer loadings results from bootstrapping should be > 0.5 and have significant p-value
Stage Two: Assessment of Structural Model		
Step 1	Assessment of Goodness of Fit	Standardized Root mean Square Residual (SRMR) SRMR < 0.08 or SRMR < 0.10 are considered a good fit
Step 2	Path Coefficient and total effects	p-value < 0.100, 0.05, 0.01
Step 3	Coefficient of Determination (R^2)	Cohen (1989) 0.26 – Substantial 0.13 – Moderate 0.02 – Weak

Step 4	Stone-Geisser Q^2 Predictive Relevance	Q^2 > 0 indicates that exogenous constructs have predictive relevance on endogenous constructs

Source: Ramayah et al. (2016); Hair et al. (2014).

Appendix D

PLS-SEM results

Evaluation of reflective measurement model

Table 7. 6 Evaluation of Reflective Measurement Model.

Indicators	BE	PBC	PEA	SN	TP
Access restriction to certain types _of vehicle for e.g. lorries					0.776
Expanding and upgrading roads					0.614
Remove charges for road use					0.732
Amenities are located _within walking distance	0.918				
Neighbourhood are safe and _convenient for walking and cycling	0.603				
I am adjusting my travel behaviour _to reduce impact on the environment			0.835		
I am willing to change my lifestyle _to reduce environmental problems			0.704		
My neighbourhood has poor access to _public transport e.g. bus stop		0.599			
Using public transport is _slow and unreliable		0.862			
The culture of auto mobilization/_car-oriented influence my travel mode				0.67	
The society influence _my travel behaviour				0.81	
Composite reliability (CR)	0.744	0.704	0.746	0.71	0.752
Average Variance Extracted (AVE)	0.603	0.551	0.596	0.552	0.505

Table 7. 7 Discriminant Validity.

	BE	PBC	PEA	SN	TP
BE	**0.79**				
PBC	-0.091	**0.727**			
PEA	0.129	-0.229	**0.77**		
SN	-0.043	0.252	-0.102	**0.713**	
TP	0.057	0.125	-0.045	0.115	**0.69**

The results shown in Table 7.7 establish the measurement model's validity. The evaluations for the model measurement validity is made to ensure that all psychological latent constructs well represent the model. For latent psychological construct loadings of minimum value of 0.60 are retained following the factor analysis of the outer model. For convergent validity, the model satisfies the Average Variance Extracted (AVE) of more than 0.50 and for the case of composite reliability, the value is greater than 0.70. The discriminant validity established in Table 7.7 also indicate that the square root of AVE is higher than the correlation with other latent psychological constructs.

Evaluation of formative measurement model

Table 7. 8 Evaluation of Formative Measurement Model.

	Items	Outer Weights	t Statistics	Outer Loadings	t Statistics	VIF
Socio economic	Income	0.850	16.138	0.932	26.869	1.060
	Employment	0.005	2.058	0.501	1.989	1.010
	Education	0.371	4.175	0.558	7.086	1.051
VKTC	VKTC1	0.063	2.787	0.598	3.564	1.143
	VKTC2	1.021	42.462	0.998	16.333	1.143
VKTM	VKTM1	0.607	10.889	0.851	23.751	1.214
	VKTM2	0.579	9.789	0.834	22.703	1.214

For formative constructs in Table 7.8, tests for multicollinearity satisfies the VIF for the indicators which are all less than 5 in this thesis. Hence, overall results for evaluation of measurement model shows that all the indicators presented are satisfactory.

Appendix E

Survey

SECTION I: Household Information and Transportation Options Form

Please complete the questions below for **ALL** adult (age 18 years old above) occupants in your property during the time of the survey. Some questions are relevant to **ALL** members of the household. Section I contain two pages which can be answered either in BM/BI while section II contain four pages in dual language.

1. What type of property do you live in?

☐ *Flat/Apartment*

☐ *Single storey-terraced*

☐ *Single storey-semi detached*

☐ *Double storey-terraced*

☐ *Double storey-semi detached*

☐ *Bungalow/Detached*

2. How many bedrooms does the property have?

☐ *0*

☐ *1*

☐ *2*

☐ *3*

☐ *4 or more. Please specify:* _____

3. What is the tenure status of the property?

☐ *Rented*

☐ *Shared ownership*

☐ *Privately owned*

4. How many people in total living in this household?

[ ]

5. How many children are living in this household of the following age?

6. How many motorcars are owned by the household altogether?

☐ *0*

☐ *1*

☐ *2*

☐ *3*

☐ *4 or more. Please specify:* _____

7. How many motorcycles are owned by the household altogether?

☐ *0*

☐ *1*

☐ *2*

☐ *3*

☐ *4 or more. Please specify:* _____

8. How many bicycles are owned by the household altogether?

☐ *0*

☐ *1*

☐ *2*

☐ *3*

☐ *4 or more. Please specify:* _____

9. How far is your house from the city centre?

[ ] *km*

Age of children	*Please tick (√)*	*Number of children*
No children		
1-6 years		
7-9 years		
10-12 years		
13-15 years		
16-17 years		

10. How far is your house from the nearest public transport stop?

_____ ***km***

11. ***What is your monthly gross household income?***

☐ ***<RM1,000***

☐ ***<RM2,000***

☐ ***RM2,001-RM3,000***

☐ ***RM3,001-RM4,000***

☐ ***RM4,001-RM5,000***

☐ ***RM5,001-RM6,000***

☐ ***RM6,001-RM7,000***

☐ ***>RM7,000***

12. What are the features of the motorcars that your household currently owned? Please fill in the following box for the FOUR most regularly used car in the house.

	Car1	Car2	Car3
Make: (e.g. Toyota)			
Model (e.g. Vios)			
Year of production:			
Fuel type: (e.g. RON95)			
Please tick (√) on the estimated annual distance travelled PER YEAR for each given car (km):	(_)0-10,000 (_)10,001-20,000 (_)20,001-30,000 (_)30,001-40,000 (_)>40,000	(_)0-10,000 (_)10,001-20,000 (_)20,001-30,000 (_)30,001-40,000 (_)>40,000	(_)0-10,000 (_)10,001-20,000 (_)20,001-30,000 (_)30,001-40,000 (_)>40,000
Vehicle total kilometre driven (km): [Refer to car odometer readings] →			

13. What are the features of the motorcycle that your household currently owned? Please fill in the following box for the FOUR most regularly used motorcycle in the house.

	Motor cycle1	Motor cycle 2	Motor cycle 3
Make: (e.g. Honda)			
Model: (e.g. XR650L)			
Year of production:			
Fuel type: (e.g. RON95)			
Please tick (√) on the estimated annual distance travelled PER YEAR for each given motorcycle (km):	(_)0-10,000 (_)10,001-20,000 (_)20,001-30,000 (_)30,001-40,000 (_)>40,000	(_)0-10,000 (_)10,001-20,000 (_)20,001-30,000 (_)30,001-40,000 (_)>40,000	(_)0-10,000 (_)10,001-20,000 (_)20,001-30,000 (_)30,001-40,000 (_)>40,000
Vehicle total kilometre (km): [Refer to motorcycle odometer readings] →			

Horse power (in cc):			
MAIN purpose of this car: (for e.g. work/ study/leisure)			
How many years do you own this car?			
New:			
Second-hand:			
Purchase price			
Horsepower			
Safety			
Reliability			
Styling			
Seating capacity			
Load capacity			
Re-sale value			
Fuel economy			

Horse power (in cc):			
MAIN purpose of this motorcycle: ***(for e.g. work/ study/leisure)***			
How many years do you own this motorcycle?			
New:			
Second-hand:			
Purchase price			
Horsepower			
Safety			
Reliability			
Styling			
Re-sale value			
Fuel economy			

SECTION II: Attitude towards Transport Survey 2016: The Case of Sarawak, Malaysia

Please complete **ALL** the questions below for adult (age 18 years old above only) occupants in your property. Section II contain **THREE** pages.

*Sila lengkapkan **KESEMUA** soalan tersebut untuk penghuni dewasa (berumur 18 tahun ke atas sahaja) di kediaman anda. Seksyen II merangkumi **THREE** mukasurat.*

A. Respondent's Personal details		
14. Gender/*Jantina*:	☐ Male/ *Lelaki* ☐ Female/ *Perempuan*	
15. Age/*Umur*:	☐ 18-20 ☐ 21-30 ☐31-40 ☐ 41-50 ☐ 51-60 ☐ >60	
16. District/Daerah:	☐ Kuching ☐ Kota Samarahan ☐ Miri ☐ Sibu ☐Other, please state/*Lain, Sila nyatakan:*_____	
17. Employment status/ *Status pekerjaan*:	☐ Housewife or Homemaker/*Suri rumahtangga* Unemployed/*Menganggur*; Retired/*Pesara* ☐ Semi-skilled works, machine operators *Pekerja separa mahir/ pengendali mesin* ☐ Clerical / *Kerani* ☐ Medium business/Minor professional *Perniagaan Sederhana/Separa profesional*	☐ Major business/ Professional *Perniagaan Skala Besar / Profesional* ☐ Other, please state/*Lain, Sila nyatakan:*_____
18. Education/ *Pendidikan*:	☐ Primary school/*Sekolah rendah* ☐ STPM/Diploma/Matric ☐ Bachelors degree/Ijazah Sarjana Muda	☐ Masters degree/Ijazah Sarjana ☐ PhD ☐ Other, please state/*Lain, Sila nyatakan:*_____
19. How long have you lived in the property? *Berapa lamakah anda*		

tinggal di kediaman ini?

20. Please fill in the relevant information.

Sila isi maklumat yang berkenaan.

Driving license	(__)Yes (__)No	Motorcycle license	(__)Yes (__)No
How many years have you been driving cars?		How many years have you been riding motorcycles?	

22. On average, please indicate *(V)* how long it would take you to travel to your MAIN TRAVEL DESTINATION (e.g. home to work or school) by each of the following travel methods?

Sila semak (V) secara purata, berapakah masa diambil bagi PERJALANAN UTAMA (Dari rumah ke tempat kerja atau tempat pengajian) bagi kaedah perjalanan tersebut?

YOUR MAIN TRAVEL PURPOSE (__) Work (__)Study (__)Leisure

TUJUAN UTAMA PERJALANAN ANDA (__) Kerja (__)Belajar (__)Riadah

Travel method/ *Kaedah perjalanan*	Not available	<20 minutes	21-40 minutes	41-60 minutes	61-90 minutes	>90 minutes	Don't know
a)Car Alone/ *Kenderaan sendiri*							
b)Carpool/ *Kongsi kenderan*							
c)Motorcycle/*Motosikal*							
d)Public transport/ *Kenderaan awam*							
e)Cycling/ *Berbasikal*							
f)Walking/*Berjalan kaki*							
g)Others/*Lain-lain*							

B. Please CIRCLE the number that best describes your opinion. ***Sila BULATKAN angka yang dapat menggambarkan pendapat anda dengan tepat.***					
PSYCHOLOGICAL FACTORS TOWARDS CAR AND MOTORCYCLE OWNERSHIP AND USE					
To what extent do you accept the following psychological factors towards car and motorcycle ownership and use? ***Apakah anda bersetuju bahawa penyataan tersebut mempengaruhi sikap anda terhadap pemilikan dan penggunaan kereta dan motosikal ?***	Strongly Do Not Accept *Sangat Tidak Setuju*	Does Not Accept *Tidak Setuju*	Undecided *Tidak pasti*	Accept *Setuju*	Strongly Accept *Sangat Setuju*
24. Expanding and upgrading roads. *Melebarkan dan menaiktaraf jalanraya.*	1	2	3	4	5
25. Charges for road use (for example tolls). *Caj bagi penggunaan jalanraya (contohnya tol).*	1	2	3	4	5
26. Invest in additional walking and cycling infrastructure. *Mengimplementasikan lebih banyak infrastruktur berjalan dan berbasikal.*	1	2	3	4	5
27. Access restrictions for certain types of vehicles (for example Lorries). *Sekatan akses bagi sesuatu jenis kenderaan (contohnya lori)*	1	2	3	4	5
28. Road Incentives *Insentif jalanraya.*	1	2	3	4	5
29. Lowering speed limits. *Had laju yang lebih rendah.*	1	2	3	4	5
30. I am concerned about the environment and climate change. *Saya sangat mengambilberat tentang isu alam sekitar dan perubahan cuaca.*	1	2	3	4	5
31. I am willing to change my lifestyle to reduce environmental problems. *Saya sanggup mengubah cara hidup untuk mengurangkan masalah alam sekitar.*	1	2	3	4	5
32. Environmental protection measures should be enacted. *Langkah-langkah perlindungan alam sekitar harus digubal.*	1	2	3	4	5
33. I am not adjusting my travel behavior to reduce my impact on the environment. *Saya tidak mengubah tingkahlaku perjalanan saya untuk mengurangkan impak terhadap alam sekitar.*	1	2	3	4	5
34. I buy environmental friendly products. *Saya membeli produk yang mesra alam sekitar.*	1	2	3	4	5
35. My neighborhood are safe and convenient for walking and cycling. *Kawasan kejiranan mempunyai akses yang baik untuk servis pengangkutan (contohnya pengangkutan awam seperti perhentian bas)*	1	2	3	4	5
24. Amenities are located within walking distance. *Kemudahan awam terletak dalam jarak berjalan kaki.*	1	2	3	4	5
25. Sustainable modes of transport (e.g. bus, cycling and walking) facility is available in the neighbourhood. *Mod pengangkutan mampan (contohnya bas, berbasikal dan berjalan kaki) terdapat di kawasan kejiranan.*	1	2	3	4	5
26. Using public transport is comfortable and safe *Menggunakan pengangkutan awam adalah selesa dan selamat.*	1	2	3	4	5
27. Using public transport is slow and unreliable. *Menggunakan pengangkutan awam adalah perlahan dan tidak boleh dipercayai.*	1	2	3	4	5
28. My neighborhood has good access to public transport. *Kawasan kejiranan mempunyai kemudahan baik untuk pengangkutan awam (cth.bas).*	1	2	3	4	5
29. There is a lot of crime in my neighborhood. *Terdapat banyak kegiatan jenayah di kawasan kejiranan saya.*	1	2	3	4	5
30. The society influencesmy travel behavior. *Masyarakat mempengaruhi tingkah laku perjalanan.*	1	2	3	4	5
31. The culture of motorization or auto-mobilization influences my travel behavior. *Budaya motorisasi atau mobilisasi auto mempengaruhi perilaku perjalanan saya.*	1	2	3	4	5