Understanding the Factors Influencing Public Transport Mode Choice in Taiwan

Thesis submitted to University College London for the degree of Doctor of Philosophy

By

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Declaration

I, Chien-Pang Liu, confirm that the work presented in the thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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ABSTRACT

Promoting public transport use, which has become an important part of government strategies to reduce carbon emissions from the transport sector worldwide, requires a good understanding of the factors that influence public transport mode choice including the policy implementation process. Previous studies have identified a range of factors influencing public transport use while few have brought all these factors together in a single study. Additionally, few studies have sought to understand public transport mode choice and public transport policy implementation processes in East and Southeast Asian countries. This is of concern as conditions in East and Southeast Asia are significantly different from those in many parts of the Western world with typical features of higher population density, a higher proportion of motorbike use and evolving governance structures.

This study explores public transport policy implementation and public transport mode choice in Taiwan – a country that bridges East and Southeast Asia. A number of interviews with transport policymakers and planners were conducted to understand how the current governance structure impacts public transport policy implementation. A conceptual model was developed based on the COM-B model (Capability, Opportunity, Motivation-Behaviour) proposed by Michie et al (2011) which allows a comprehensive range of factors influencing travel mode choice to be considered. This conceptual model was tested using a variety of modelling approaches including multi-level regression analysis and structural equation modelling. The study finds the relationships between objective and subjective walking environment measures, walkability and walking to access public transport, and gives evidence that the COM-B model can apply to public transport mode choice. It was also found that land use variables have a stronger relationship with intention to use public transport for motorbike user than car users and has a greater effect at the trip destination than at the trip origin.

The key factors influencing public transport policy implementation identified in this study can be a good reference for Southeast Asian countries if they are going to implement public transport plan. From the results obtained by the analysis of capability, opportunity and motivation influence travel mode choice, implementing effective strategies and build up a well-function public transport service to ensure a favoured environment for public transport over motorbike and car use is critical for a sustainable future.

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Chapter 1 **INTRODUCTION**

1.1 Background

Radical climate change is of major concern internationally because of its potentially catastrophic effects. The IPCC (International Panel on Climate Change, 2007) have concluded that climate change is almost certainly man-made, with carbon emissions from the burning of fossil fuels being one of the main culprits. In order to reduce carbon emissions, promoting public transport use in accordance with land-use and transport planning has become part of the mitigation strategies for policymakers (International Panel on Climate Change, 2007).

Public transport services are lifelines to work, education, leisure and tourism, especially for those who do not or cannot drive, low income households, people with disabilities, students or the elderly (Social Exclusion Unit, 2003). Likewise, public transport is an important tool to address car dependency, and the urban congestion and air quality concerns associated with car dependency (Currie and Wallis, 2008). In many circumstances, the provision of public transport is only possible at a financial loss (Currie and Rose, 2008). Many studies (Litman, 2011, Currie and Wallis, 2008, Chapman, 2007, Commission for Integrated Transport, 2005, General Accounting Office, 2001) have shown that improving bus-based public transport is a more cost-effective and flexible option compared with rail investment.

Creating well-used transport services requires a good understanding of how factors influence demand for public transport and travel mode choice (Banister, 2011, Litman, 2013). Many studies have focused on North America as a case study, such as Seattle (Frank et al., 2008), San Francisco Bay Area (Cervero and Duncan, 2006), North Carolina (Rodríguez and Joo, 2004), Boston (Zhang, 2004), Portland (Rajamani et al., 2003) and Maryland (Cervero, 2002). Other studies based on Western Europe and Australia, such as Sydney (Tsai, 2013, Hensher, 2002), the Netherlands (Limtanakool et al., 2006, Schwanen et al., 2004, Dieleman et al., 2002), Southeast England (Titheridge and Hall, 2006), Italy (Laura Eboli and Gabriella Mazzulla, 2007), German (Bamberg et al., 2003) and Portugal (Beirao and Beirão, 2007). The previous studies in North America, Western Europe and Australia can offer important lessons for Southeast Asian countries. The course of urban and transport development of the Southeast Asian countries, however, is much different than that of their North America and Western Europe counterparts. Only few studies have reported on East and Southeast Asian countries' public transport use, Taiwan (Lin and Yang, 2009, Chen and Chao, 2011, Chen and Lai, 2011), Malaysia (Nurdden et al., 2007) and Hong Kong (Zhang, 2004). This is of concern as a study by Nijkamp and Pepping (1998), which compared a number of studies from across Europe, concluded that study location significantly affected the results of the demand elasticity. Since conditions in Southeast Asia are significantly different from those in many parts of the Western world, this suggests results from studies of these areas may not be applicable to the East and Southeast Asia.

The features of East and Southeast Asian cities are high density and mixed land-use, with rapid motorisation. The population density on the Asian continent was 135 persons per square kilometre in 2012; this is nearly five times that for Europe as a whole (at 32 persons per square kilometre), and about ten times that of North America which was 16 persons per square kilometre in 2012 (Department of Economic and Social Affairs, 2012). The United Nations (Department of Economic and Social Affairs, 2011) forecasts that 22 out of 38 mega-cities expected to exist in 2025 will be located in Asia-Pacific region. In addition, the average level of urbanization in Southeast Asia is expected to rise from their current low levels to something approaching levels in America and Europe (currently 89% and 82% respectively (Department of Economic and Social Affairs, 2012)) by 2050. For example, China is expected to rise from 51% in 2011 to 77% in 2050 (United Nations, 2011). It is also expected that the population in Asia will rise to over 5 billion, or nearly 55% of the world population by 2050 (Department of Economic and Social Affairs, 2012). Due to this rapid urbanization and motorization, (the annual number of passenger cars sold in Asia rose from 14.5 million in 2005 to 30.1 million in 2012 (Statista), Asian cities have been facing the phenomena of 'the paradox of intensification' (Melia et al., 2011) whereby increasing urban density could lead to reduced vehicle miles travelled and promote public transport and active modes use but environmental conditions could also become worse through the concentration of heavy traffic.

A high percentage of motorbike ownership and use is another important feature for Southeast Asian countries. The motorbike plays an important role in road transport in some of the Southeast Asian counties. As can be seen in Table 1.1, in Malaysia, Thailand, Indonesia, Cambodia, Laos, Vietnam, and Taiwan as well, the proportion of motorbikes to all motorised vehicles were greater than 40% (Ak et al., 2006). The market share for motorbike is about 50% in Taiwan (Department of Statistics, 2015a). Feng and Sun (2012) summarised the reasons why the motorbike is so popular in some Asian countries. The reasons include low-cost transport mode option, easy to manipulate in narrow roads, high mobility and accessibility (Feng and Sun, 2012). Journeys made by motorbike tend to be unaccompanied, short-distance and multi-leg trips (Chang and Wu, 2008). Most previous studies on motorbike use were concerned with safety issues (Hsu et al., 2003, Manan and Várhelyi, 2012, Davoodi et al., 2012, Kieling et al., 2011). Hence, there is an unanswered question - is there a fundamental different relationship between land use and travel behaviour when a high proportion of motorbike use is present in the modal split?

Table 1.1 The proportion of two-wheeled vehicles to motorised vehicles

Country	Population density (people per sq. km)	Vehicles	Motorbikes	% of motorbikes
Taiwan	660	21,400,863	13,661,719	63.8%
Brunei	80	244,727	6,855	2.8%
Singapore	7,807	711,043	134,767	19.0%
Myanmar	83	467,350	172,568	36.9%
Philippines	338	4,292,000	1,617,000	37.7%
Malaysia	92	12,868,930	5,859,195	45.5%
Thailand	133	25,100,000	17,800,000	70.9%
Indonesia	142	24,994,890	18,800,000	75.2%
Cambodia	88	447,428	336,502	75.2%
Laos	31	278,384	223,088	80.1%
Vietnam	296	12,054,000	11,379,000	94.4%

Source: Ak et al. (2006), Department of Statistics (2015b), and The World Bank (2017)

Taiwan, which is located in East Asia, is categorized as an Asian high-income country with compact cities and a high propensity for car and motorbike ownership (Barter, 1999). Taiwan has a total area of 36,192 km^2, a population of greater than 23 million and a population density of 649 persons/km^2 (Ministry of the Interior, 2014).

Taiwan has similar land-use and transport patterns to many other East and Southeast Asian countries. The country owns a dense road network with a road density of 1,181m per km^2 (Ministry Of Transportation and Communications, 2014b) and a diverse public transport system, which includes bus, metro, rail and high speed rail. Total car and motorbike ownership is 94 vehicles per 100 persons (Ministry Of Transportation and Communications, 2014b).

Car and motorbike ownership has steadily increased over the past two decades along with the GDP growth in Taiwan (see Figure 1.1). Motorbike and car ownership per thousand people increased from 368 and 174 in 1992 to 649 and 309 in 2012 respectively. Over the same period, the GDP per capita increased from US$ 10,778 in 1992 to 21,308 in 2012. On the other hand, public transport, especially bus, had gradually lost its competitive advantage compared with the car and motorbike in Taiwan. Bus annual patronage decreased from 1,550 million in 1992 to around 1,039 million in 2009, dropping by about 33% (see Figure 1.1).

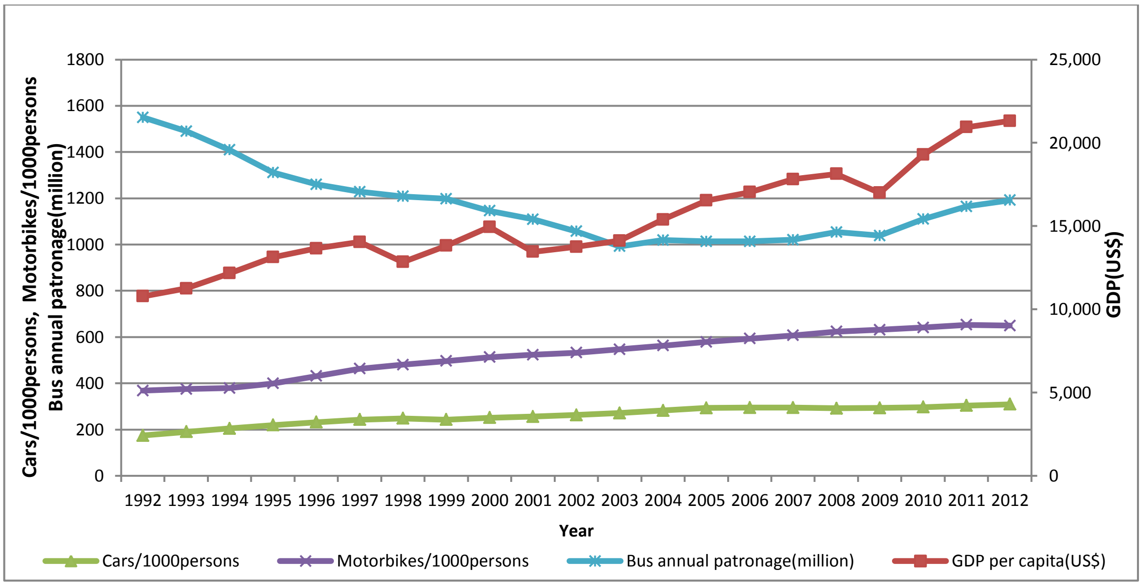


Figure 1.1 Vehicle ownership, bus patronage and GDP trends (up to 2012)

Unsurprisingly, motorbike enjoys the greatest market share (47%) among all the modes of transport (Department of Statistics, 2015a) (see Figure 1.2). This is followed by car (25%) and public transport (16%). The market share of non-motorised transport and public transport is totally about 27.5% in Taiwan in 2012 (see Figure 1.2).

Declining public transport patronage and market share, and increasing private vehicle ownership and usage have caused severe traffic and environmental problems in Taiwan (Institute of Transportation, 2011a, Ministry Of Transportation and Communications, 2012a). Carbon dioxide emissions from road transport increased from 19.8 million tons in 1992 to 32.7 million tons in 2009, an increase of about 44% (Institute of Transportation, 2011a). About 86% of carbon dioxide emissions from the road transport sector are caused by private road vehicles (Ministry Of Transportation and Communications, 2012a).

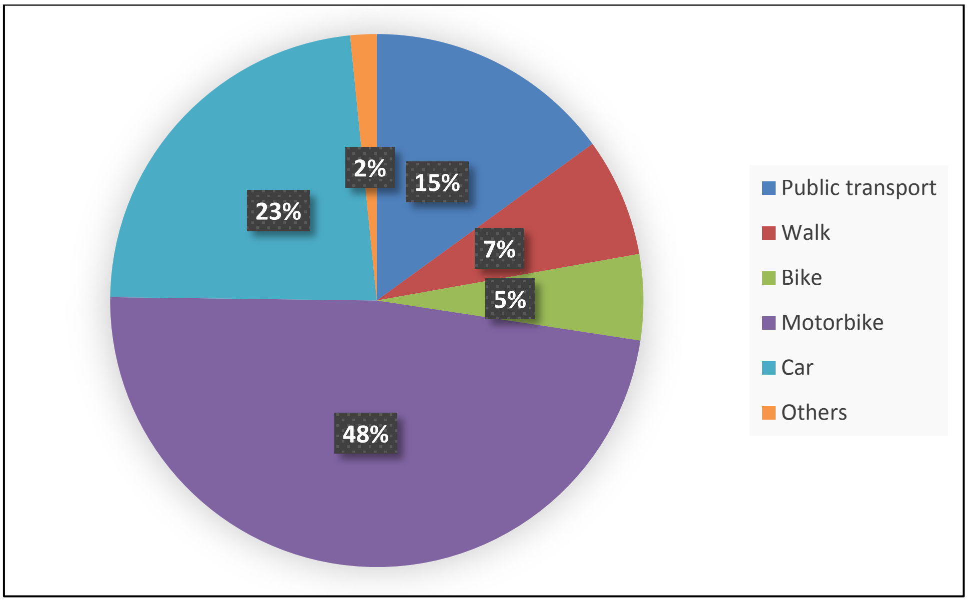


Figure 1.2 Modal split in 2012 [Department of Statistics (2013)]
Note: modal split is measured by passenger-trips.

In 2010, the Taiwanese Ministry Of Transportation and Communications (MOTC) launched the National Road Public Transport Plan (NRPTP) to try to change mode choice behaviour towards road public transport and to increase road public transport patronage (Ministry Of Transportation and Communications, 2010a). The plan was granted an annual implementation budget of US$ 166 million. The NRPTP sets two key objectives: to increase bus patronage by 5% annually, and to raise public transport market share to 18% by 2016, to 20% in the mid-term (by 2020), and to 30% in the long-term (by 2025) (Ministry Of Transportation and Communications, 2010a, Ministry Of Transportation and Communications, 2012c).

The implementation of NRPTP has reversed the declining trend of bus patronage but the objectives have not been met. The bus patronage increased from 1,039 million in 2009 to 1,239 million in 2014 but reduced slightly to 1,221 million in 2015 (Table 1.2). The objective of an annual bus patronage increase of 5% was only attained in 2010, the first year of NRPTP implementation. Over the following four years, bus patronage increased at a rate lower than the desired 5%; the size of the increases decrease each year from 4.91% in 2011 to 1.57 in 2014, until finally in 2015 bus patronage decreased by 1.5% compared with the previous year.

Public transport market share increases steadily between 2009 and 2014, but by less than 1% annually (Table 1.2). By 2014 public transport market share had reached 16%.

Based on the increases achieved in previous years, the possibility of increasing public transport market share by a further 2% in 2 years to 2016 seems low. It seems that the short-term target, at least, for public transport market share is unlikely to be met. Hence, this raised the question why the targets of the public transport policy have not been attained after several years of policy implementation with aggressive government investment?

Table 1.2 Bus patronage and public transport market share trends

Year	Bus patronage (1000 passengers)	% of bus patronage increase	Bus market share (%)	Public transport market share (%)
2009	1,038,779	--	8.1	13.4
2010	1,109,829	6.84	8.2	13.9
2011	1,164,297	4.91	8.2	14.3
2012	1,191,741	2.36	9.0	15.0
2013	1,220,056	2.38	8.6	15.2
2014	1,239,178	1.57	8.6	16.0
2015	1,220,590	-1.50	N/A	N/A

Sources: (Department of Statistics, 2010, Department of Statistics, 2011, Department of Statistics, 2012, Department of Statistics, 2014, Department of Statistics, 2015a, Department of Statistics, 2013), (Ministry Of Transportation and Communications, 2014b)

The passing of a policy does not guarantee success on the ground if that policy is not implemented well. This is particularly the case for rapid emerging economies such as Taiwan has being undergoing a lot of change in terms of governance moving from very top-down and centralized approach to a more democratic, localized and bottom-up approach (Bagley and Mokhtarian, 2002). Public transport policy implementation may require consensus about the objectives from all the stakeholders, sufficient implementation resources, a well-designed implementation mechanism and outcomes monitoring , characteristics of implementation agencies, the attitudes of implementers, bureaucratic discretion in implementation, and economic, social and political conditions (Winter, 2003). Fewer studies have explored the phenomenon of public transport policy implementation.

Understanding the factors influencing public transport policy implementation is not enough. The target of the NRPTP is to change travellers' behaviour towards public transport. Following the public transport policy implementation analysis, examining the factors influencing public transport mode choice is another critical issue in this study. A number of previous studies have focused on the impact of factors such as: socio-demographic characteristics (Stead and Marshall, 2001, Hensher, 2002), public transport provision and service attributes (Paulley et al., 2006), built environment (Ewing and

Cervero, 2001, Ewing and Cervero, 2010), walkability (Olszewski and Wibowo, 2005), and attitudes and intentions (Bamberg et al., 2007).

Several studies have used a number of different behavioural frameworks to look at public transport mode choice such as NDM (normative decision-making) Model (Klöckner, 2004), TPB (theory of planned behaviour) (Bamberg et al., 2003), MOA (motivation, opportunity and ability) (Thøgersen, 2009). These behavioural frameworks have identified some specific psychological constructs such as pro-environment value, attitudes, subjective norms, perceived behavioural control, perceived moral obligation and intentions that exist complex relations with travel mode choice behaviour. However, the NDM and TPB models only consider the effects of psychological factors on travel behaviour. The MOA contains psychological factors, individual's skills and knowledge and extrinsic conditions while the MOA model did not deliver a comprehensive coverage that can apply to every intervention that has been or could be developed (Michie et al., 2011).

The COM-B (Capability, Opportunity and Motivation – Behaviour) Model, a relatively new behaviour framework proposed by Michie et al. (2011), comprehensively considers the relationships between psychological constructs – motivation, individual's characteristics – capability, extrinsic factors – opportunity and performing a specific behaviour. COM-B model is gaining popularity in health and a couple of other study areas, particularly with regard to policy design. That is one of the thing it has been designed for policymakers to help them think through problems. The advantage of the COM-B model is that the model is comprehensive, coherent and linked to an overarching model of behaviour (Michie et al., 2011). All the various theories that are mentioned will be considered in great depth in the literature review chapter.

The COM-B model assumes that individual's travel mode choice behaviour may be co-determined by his/her capability and motivation and opportunity (extrinsic conditions) (Michie and Johnston, 2012). Capability refers to individual's practical ability to choose from his/her transport mode alternatives in the context of his/her personal characteristics, social background and economic circumstances (Sen, 1997). Opportunity refers to all the factors that lie outside the individual that make choosing public transport possible such as land use, public transport provision and walking environment (Michie et al., 2011). Motivation refers to all those brain process that energize and direct use of public transport such as individual's attitudes, social pressure of using public transport (subjective norm), perceptions of ease or difficulty of using public transport (perceived behaviour control), perceived moral obligation and intentions to use public transport (Michie et al., 2011, Bamberg et al., 2003). This study adopts the COM-B model because the model provides a comprehensive coverage of travel mode choice behaviour and considers the full range of understanding the factors influencing to travel mode choice. This is an important basis for the policy makes to design effective interventions in switching travel mode choice behaviour to public transport use in the future.

Fewer studies have brought together capability, opportunity and motivation to examine their influence on travel mode choice at a disaggregate level. Most previous studies on travel mode choice adopted only one or two of the three aspects. Frank et al. (2008), Zhang (2004), Titheridge and Hall (2006) and Cervero (2002) looked at the influence of land use and socio-demographic characteristics (opportunity and capability) on mode choice. Thøgersen and Møller (2008), Bamberg et al. (2003) and Chen and Chao (2011) examined the effects of attitudes, perceived behavioural control and subjective norms on intentions and travel mode choice. Hence, can a novel conceptual model linking capability, opportunity and motivation make an important contribution to understanding mode choice behaviour? These models are discussed further in Chapter 2.

Walking is the most common and natural transport modes to access to and egress from public transport (Olszewski and Wibowo, 2005). The level of walking environment may influence public transport use (Olszewski and Wibowo, 2005). Previous studies found that built environment had significant influence on walking activities (Saelens and Handy, 2008, Shay et al., 2003, Handy et al., 2002). Walking environment can be measured objectively and subjectively (McCormack et al., 2007). Objective measures of walking environment build on measurable built environment data (De Vries et al., 2007, Owen et al., 2007) while subjective measures of walking environment build on self-reported perceptions of walking environment (Cerin et al., 2010, Leslie et al., 2005). There is a lack of evidence which shows the relationships between objective measures and subjective measures of the walking environment and walking behaviour. Alfonzo (2005) asserted that the objective walking environment is an important indirect determinant of walking behaviour, which operates via its impact on the cognition of walking environment (Alfonzo, 2005). Ewing and Handy (Ewing et al., 2006) suggested that perceptions of the walking environment are influenced by physical features for walking, amongst other things, and determine overall perceived walkability and walking behaviour. Very few studies have incorporated both objective measures and subjective measures of walking environment to examine their relationships and impacts on walking behaviour (Vernez Moudon et al., 2007) . Hence, is there a better understanding the relationship between walking environment and walking behaviour by bringing together objective measures and subjective measures of walking environment?

1.2 Research questions and roadmap of the thesis

1.2.1 Research questions

Research question 1 (RQ1): To explore why after 6 years of policy implementation of the Taiwanese NRPTP (National Road Public Transport Plan), the objectives are not being attained - what are the key factors which have contributed to the plan's poor outcomes?

Research question 2 (RQ2): To understand if is there a fundamentally different relationship between public transport provision and travel mode choice in the context of Taiwanese high population density and mixed land use.

Research question 3 (RQ3): To understand if are there fundamentally different relationships between land-use factors at different geographic scales and travel mode choice behaviour in the context of Taiwanese high percentage of motorbike usage.

Research question 4 (RQ4): Can a structural model linking objective measures and subjective measures of walking environment to explain walk for public transport behaviour perform better than existing models in understanding walking environment and walking behaviour?

Research question 5 (RQ5): Can a novel conceptual model linking capability, opportunity and motivation make an important contribution to understand mode choice behaviour?

1.2.2 Roadmap of this study

Taiwan has faced declining public transport usage over the past decades. The Taiwanese government introduced the NRPTP in 2010 in order to increase public transport patronage and market share. Although the plan has reversed the declining trend for public transport patronage, the plan's objectives have not been attained. This study explores important issues affecting NRPTP policy implementation and examines the complex relationships between sociodemographic characteristics, built environment, public transport provision, attitudes and intentions, and their impacts on travel mode choice behaviour in Taiwan. The results may also give some policy implications for East and Southeast Asian countries with similar transport situations as Taiwan.

In the following paragraphs, the roadmap of the thesis chapters is presented.

Chapter 2 broadly review the literature about the theories of behaviour models, the factors affecting public transport mode choice as well as the key issues for policy implementation. In terms of the theories of behaviour models, the theory of planned behaviour, MOA (motivation, opportunity and ability) model and the COM-B (capability, opportunity and motivation – behaviour) model are discussed. In terms of factors affecting public transport mode choice, this study reviews previous literatures about factors, which are categorised as capability, opportunity and motivation, influence public transport mode choice. Then, a conceptual model linking capability, opportunity and motivation, and public transport mode choice is proposed.

Chapter 3 discusses the methodologies and datasets being used in this study. Two surveys are conducted in this study including a qualitative survey of interview and a quantitative online survey. Additionally, an existing survey data, 2011 Taiwanese mode choice behaviour data is used. The descriptive statistics of the quantitative data are presented. In terms of methodologies, both qualitative and quantitative methods are adopted in this study. The epistemology of the overall approach covering the strength and weakness of qualitative and quantitative methods and the reasons of the choices of methods are discussed. Then, the literatures of the methodologies being used: thematic analysis, multilevel multinomial logit (MNL) model, structural equation model (SEM) and generalised structural equation model (GSEM), are reviewed.

Chapter 4 to Chapter 8 adopt qualitative and quantitative methods to look into the Research Question 1 to 5 respectively. Chapter 4 uses qualitative thematic analysis to explore the reasons why after 6 years of policy implementation of the Taiwanese NRPTP, the objectives are not being met (RQ1). This chapter describes the overview of the NRPTP and discuss the main themes in policy implementation. Then the analysis results draw some important insights for future public transport policy implementation in this chapter. In Chapter 5, a quantitative method of conditional logit model is adopted to examine the relationships between public transport provision and travel mode choice in the context of Taiwanese high population density and mixed land use (RQ2). Chapter 6 focuses on the analysis of land use influencing travel mode choice behaviour in Taiwan (RQ3). The key premise in this chapter is that in the context high population density, highly mixed land use and high percentage of motorbike usage in Taiwan, there might be a fundamentally different relationship between land use and travel mode choice compared with previous studies in North America and Western Europe. Multilevel multinomial models are used in order to accommodate spatial autocorrelation and spatial heterogeneity issues involved in land use and travel behaviour analysis. In Chapter 7, a structural equation model (SEM) is adopted to link objective measures and subjective measures of walking environment to explain walk for public transport behaviour (RQ4). The key premises in this chapter are that individual's perceptions of the walking environment are determined by the objective measures of walking environment. In addition, individual's overall perceived walkability and walking behaviour are determined by individual's perceptions of the walking environment. Chapter 8 bring together capability, opportunity and motivation into travel mode choice analysis to understand that can a novel conceptual model linking capability, opportunity and motivation make an important contribution to understand mode choice behaviour (RQ5). Exploratory factor analysis is adopted to identify the unobserved latent variables and structural equation model (SEM) and generalised structural equation model (GSEM) are used to examine the complex relationships between capability, opportunity and motivation, and travel mode choice behaviour.

Chapter 9 discusses the major findings and the limitations of this study, presents this study's contributions, and draws some policy implications. Then the conclusions of this study are presented.

Chapter 2 **LITERATURE REVIEW**

This chapter proposes model for travel mode choice behaviour towards use public transport by reviewing the literatures of theory of behaviour change models, the factors of affecting use of public transport, subjective and objective measures of walking environment. In addition, this chapter reviews the factors influence policy implementation.

2.1 Theory of behaviour models

In order to make the most use of public transport and reduce the dependence on private vehicle, the theory of change travel mode choice behaviour from private car and motorbike to public transport should be considered. Several behaviour theories have been proposed, name a few such as the Norm Decision-making Model (NDM) also named Norm Activation Model (NAM) (Schwartz and Howard, 1981), and Theory of Planned Behaviour (TPB) (Ajzen, 1991) and MOA (motivation, opportunity and ability) model (Thøgersen, 2009). TPB is the most common model being used in transport studies to examine the effects of interventions on travel behaviour change (Bamberg et al., 2003, Chen and Chao, 2011, Chen and Lai, 2011, Thøgersen and Møller, 2008, Heath and Gifford, 2002). TPB however has its limitations – personal characteristics and extrinsic conditions are not considered in TPB - when applied to travel behaviour studies. For the most recently, Michie et al. (2011) proposed a method of behaviour change model, which is |Capability, Opportunity and Motivation – Behaviour model (COM-B). This study combines both theory of COM-B and TPB to propose a travel mode choice behaviour model.

1. The theory of planned behaviour (TPB)

The theory of planned behaviour (TPB) is based on the concept that intention is a central factor affecting behaviour (Ajzen, 1991, Ajzen, 2005). TPB assumes that all motivational factors leading to the individual’s behaviour are captured by and mediated *via* the behavioural intention. Behavioural intention is influenced by attitudes toward the behaviour, subjective norms, perceived moral obligation (PMO) and perceived behavioural control (PBC) (see Figure 2.1) (Ajzen, 1991, Chen and Tung, 2014). TPB models have been adopted by several studies of travel mode choice behaviour (Heath and Gifford, 2002, Bamberg and Schmidt, 2003, Bamberg et al., 2007, Haustein and Hunecke, 2007). Several previous studies adopted meta-analysis have provided good support for the TPB (Ajzen, 2005). The correlations for the prediction of intentions from the motivational factors were found to range from 0.63 to 0.71 (Ajzen, 2005).

Some previous studies have found that the impact of individual's environmental concern on performing a particular environmental friendly behaviour was through situation-specific beliefs and attitudes (Bamberg, 2003, Chen and Tung, 2014). Bamberg (2003) reviewed some previous studies and assumed that pro-environment value, which is a general attitudes on environment concerns and value, had an indirect influence on specific environmental behaviour intentions and specific environmental behaviour. Chen and Tung (2014) & Bamberg (2003) gave the evidence that pro-environment value did not have significant direct impact on behaviour intentions and behaviour itself but exerted strong direct impacts on situation-specific beliefs and attitudes.

Attitudes reflect the overall evaluation, which are positive or negative, of the particular behaviour, and are based on expectancy beliefs about the likelihood that behaviour results in particular consequences, and desirability of those consequences, that in turn may affect one's behaviour (Steg, 2005, Parkany et al., 2004). Studies in social psychology have found that attitudes theory, and its relationship with behaviour, can help to understand the decision-making process underlying mode choice. Attitudes are typically broken down into three basic and associated components: cognitive (linked to knowledge), affective (related to emotions) and behavioural components (translated into conduct) (Parkany et al., 2004, Domarchi et al., 2008). In addition, in social psychology, measuring intention rather than desires is the way to understand the correlation between attitudes and behaviour.

Subjective norms 'refer to the perceived social pressure to perform the behaviour, and are based on perceptions of expectations of relevant reference groups concerning the behaviour and the motivation to comply with these reference groups' (Steg, 2005). The intention of choosing public transport may be affected by subjective norms, which refers to social pressure or social approval or disapproval of the behaviour, or by descriptive norms, which refers if the behaviour is typical or normal by most people doing in a given situation (Heath and Gifford, 2002, Bamberg et al., 2007).

Perceived moral obligation (PMO) or personal norms refers to internalize and accept social norms. Personal norm is the key component in Schwartz's Model of Normative Decision-making (NDM), which explain that the perception of moral obligation is caused by activated personal norms which are internalized social norms. Some previous studies have found the association between perceived moral obligation and intentions towards travel mode choice behaviour (Klöckner, 2004, Matthies et al., 2006, Bamberg et al., 2007).

Perceived behavioural control (PBC) refers to an individual's perception of the ease or difficulty of performing the behaviour of interest. PBC may depends on past experience with the behaviour, and also depends on information collecting from others (acquaintances and friends) about the perceived ease or difficulty of performing the behaviour in question (Ajzen, 2005). PBC can also serve as a proxy of actual behavioural control (Ajzen, 1991). Hence, In TPB, PBC plays as roles of predictor for both intentions and behaviour (see Figure 2.1). Ajzen (1991) claimed that TPB can be used to explain the complexities of intentional social behaviour.

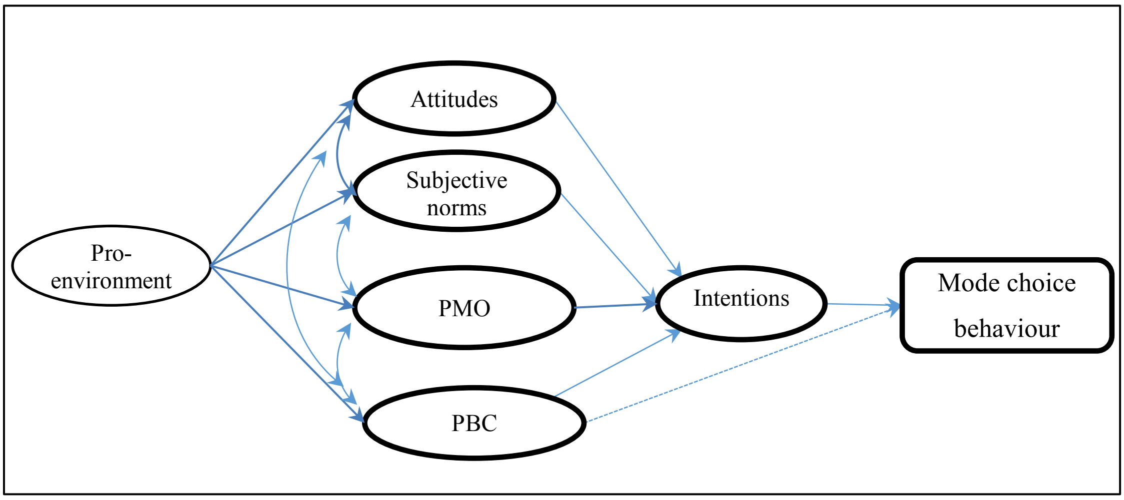


Figure 2.1 Theory of planned behaviour
[Ajzen (2005), Bamberg (2003), Chen & Tung (2014)]

2. MOA (motivation, opportunity and ability) model

Thøgersen (2009) expanded TPB model to MOA (motivation, opportunity and ability) model. The MOA model assumes that whether an individual performs a specific behaviour (e.g. use public transport) or not is partly voluntary and therefore depends on individual's motivation (Thøgersen, 2009). However, motivation is a requirement but not the sufficient condition to perform the behaviour. Ability and opportunity influence the individual's decision to perform a specific behaviour as well. Ability refers to knowledge, skills and resources needed to perform the behaviour. Opportunity refers to extrinsic conditions that may impede or facilitate the behaviour (see Figure 2.2) (Thøgersen, 2009).

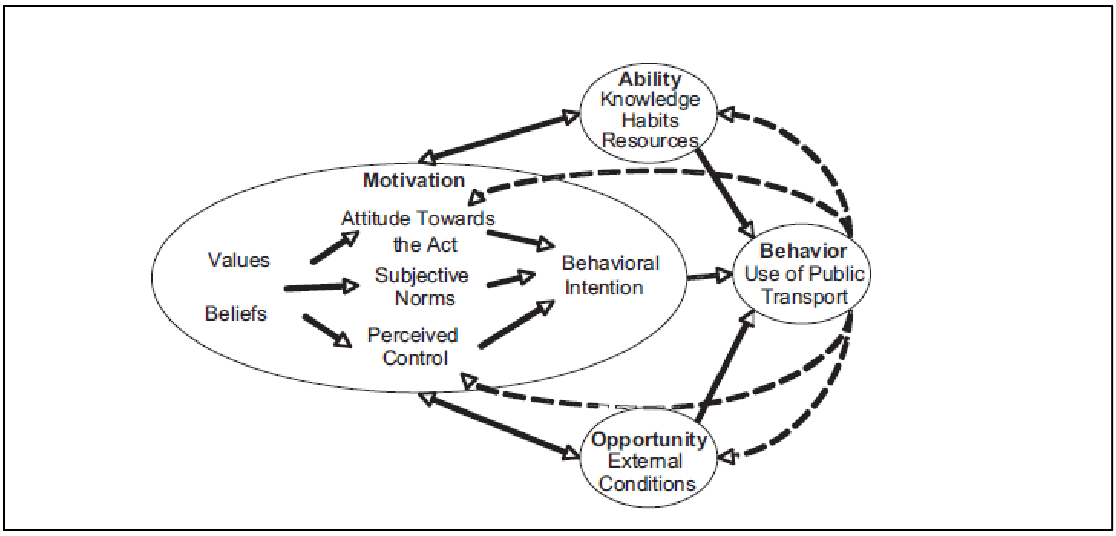


Figure 2.2 MOA model
[Thøgersen (2009)]

3. Capability, Opportunity and Motivation – Behaviour (COM-B) model

The COM-B model (Michie et al., 2011), which involves the interaction between capability which refers to the individuals' psychological and physical capacity to engage in the activity concerned, opportunity which refers to all the factors that lie outside the individual that make the behaviour possible or prompt it, and motivation which refers to all those brain processes that energize and direct behaviour, including habitual processes, emotional responding and analytical decision-making, to generate behaviour were proposed by Michie et al. (2011).

The difference between MOA model and COM-B model lies in the difference between ability and capability. By definition, capability is usually defined as the feature of being capable of something. Ability is a word that pertains to being able. Ability is much nearer to describe individual's talents, skills or level of expertise whereas capability is used to describe practical ability, which is a form of limitation for individuals to perform a specific behaviour. In the analysis of travel mode choice behaviour, individual's practical ability of using the alternative modes of transport is of the main concerns. Hence, this study adopts COM-B model to analyse the travel mode choice behaviour.

Individual's capability is defined by Sen (1993) as 'the alternative combinations of functionings the person can achieve, and from which he or she can choose one collection.' Michie et al. (2011) defined capability as the individual's psychological and physical capacity to perform the behaviour concerned, concerns about having the necessary knowledge and skills. Capability refers to what people are actually able to do and to be. The alternative combinations of functionings the person can achieve is reflected in the person's capability set. Sen (1993) mentioned that 'the capability of a person depends on a variety of factors, including personal characteristics and social arrangement'. This study adopts personal socio-demographic characteristics as proxies of capability because a person's socio-demographic characteristics may affect his/her freedom of travel mode choice. For instance, as a person grows older, the physical constraints make him/her more willing to use public transport rather than private vehicle. In addition, a person who owns car or motorbike (tools) is more capable to use car or motorbike. Mental aspect of capability relates to education and occupation. Financial aspect of capability relates to income. For example, higher income people are more capable of owning a car and using car as transport mode.

Opportunity refers to all the factors that lie outside the individual that make the behaviour possible or prompt it (Michie et al., 2011). Applying opportunity to travel mode choice behaviour towards use public transport, it is related to public transport provision, land-use and accessibility. 'Accessibility is defined as the potential of opportunities for interaction' (Hansen, 1959). Hence, accessibility is similar to opportunity which is affected by the supply side of public transport service quality and the demand side the situation of land-use.

Several previous studies used TPB as the basic framework to analyse individual's motivation in travel behaviour studies (Bamberg and Schmidt, 1999, Thøgersen, 2009) while there are some difference between motivation and intention. Motivation refers to an inner state that leads and energises human behaviour (Jang et al., 2009). Motivation in COM-B model is to bridge the relations between motivational factors, intentions to use public transport and travel mode choice behaviour. Motivation refers to 'brain processes to energize or direct behaviour' (Michie et al., 2011), which indicate the reasons why the individual intends to have the action. For example, the individual traveller may think he/she wants to use public transport because most of his/her friends have already been using this form of transport. The 'want to use public transport' is the intentions and the 'because most of his/her friends have already been using public transport' is the motivation. Hence, motivational factors relate to the factors prior to intention such as pro-environment values, attitudes, subjective norms, perceived behavioural control (PBC) and perceived moral obligation (PMO). Intention which is an outcome of a mental process that leads to an action is the immediate antecedent to behaviour (Jang et al., 2009, Ajzen, 2005).

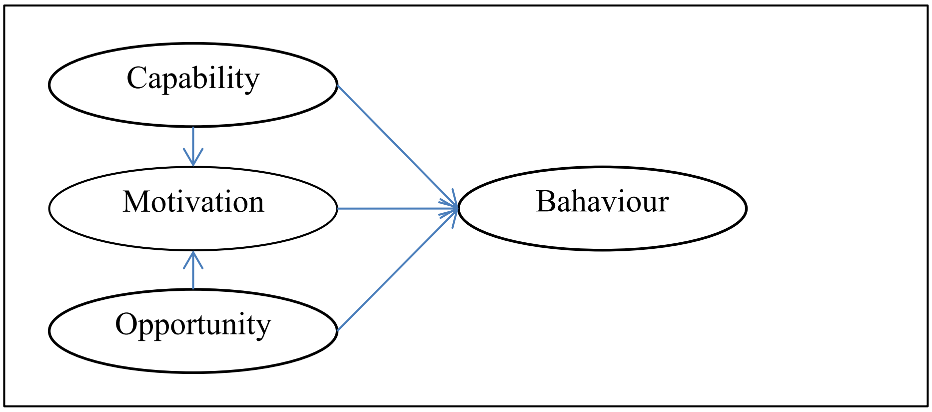


Figure 2.3 The COM-B model
[Michie et al. (2011)]

2.2 Factors affecting public transport mode choice

This section reviews previous literatures studying about factors, which are categorised as capability, opportunity and motivation, influence public transport mode choice.

2.2.1 Capability: socio-demographic characteristics

Social exclusion has been an increasing important study about the limitations of the ability to use modes of transport for activities (Titheridge and Solomon, 2008, Titheridge et al., 2014). Sociodemographic characteristics such as no car, low income, no job, poor housing and aging were part of the reasons that limited individuals' transport capacity and caused social exclusion (Titheridge et al., 2014, Titheridge and Solomon, 2008). Hence, this study uses sociodemographic characteristics as the proxy variables of capability.

Several studies have found that socio-economic characteristics might have a significant and important role in affecting travel behaviour (Cao et al., 2007, Limtanakool et al., 2006, Handy et al., 2006). Dieleman et al (2002) found that residential environments and socio-economic characteristics had equal importance for mode choice for the Netherlands. Stead (2001) analysed the effects of land-use and socio-economic characteristics on the travel distance in the UK and found that socio-economic characteristics had about a half of explanatory power in the travel distance while land-use variables applied up to one third of explanatory power in the travel distance (Stead, 2001). Antipova et al. (2011) stratified socio-economic characteristics into two levels – household level, and neighbourhood level – to examine its relation with travel distance and time by multilevel regression model and found that socio-economic characteristics at both levels reported significant effects on commuting behaviour. Bottai et al. (2006) also adopted multilevel model and found that age and gender had effects on travel behaviour, such as daily trip frequency and trip distance.

Stead and Marshall (2001) reviewed previous land-use and travel behaviour studies and contended that the effects of socio-economic characteristics, such as income, car ownership, household size, age, gender, education, personality type, employment type, work status, driver licence and attitudes, on travel behaviour should be considered in land-use and travel behaviour analysis.

2.2.2 Opportunity

Opportunity is the extrinsic conditions that affect individuals' travel mode choice. The extrinsic conditions may include public transport service availability, affordability and accessibility. Previous studies about the effects of these factors on the use of public transport are reviewed in the following.

1. Service availability and quality

There have been several studies exploring the relationships between service availability, quality and mode choice. Most early studies focused on measuring the operating performance, covering the efficiency and effectiveness, as the audit tools for authorities (Fielding et al., 1985, Chu et al., 1992) . However, passengers' perception of service quality based on the demand side aspects is different from the authorities' perception of operating performance which concerns more on supply side, and more crucial in order to promote bus service and ridership. Several studies have progressed on the measurement of bus service quality from a users' standpoint (Hensher, 2002, Laura Eboli and Gabriella Mazzulla, 2007, Beirao and Beirão, 2007, Eboli and Mazzulla, 2008a, dell'Olio et al., 2011, Rojo et al., 2012). In addition, the results of the analysis recognized the weights or ranks of the attributes. Frequency, reliability, cleanliness, travel time, bus stop facilities and seats availability are the highly ranked attributes for service quality (Hensher et al., 2003, Laura Eboli and Gabriella Mazzulla, 2007, Beirao and Beirão, 2007, Eboli and Mazzulla, 2008a, Eboli and Mazzulla, 2008b, dell'Olio et al., 2011, Tyrinopoulos and Antoniou, 2008, Rojo et al., 2012). The most common used attributes of measuring public transport service quality are the following.

1) Cleanliness;
2) Driver or personnel attitudes;
3) Frequency or waiting time;
4) Fare or cost affordability;
5) Information at the stops/stations;
6) Reliability;
7) Stops/stations availability;
8) Stops/stations facilities;
9) Seats availability or occupancy;
10) Travel time.

2. Interchange between or within modes

Interchange within and between modes results in time spent on waiting, time spent transferring between vehicles, inconvenience and increased risks, which can affect travel demand. Interchange can be seen as a penalty for passengers (Wardman, 2000). On the other hand, for public transport operation, interchange can increase efficiency and expand the accessible opportunities. Hence, the UK Government's White Paper (DETR, 1998) states that 'quick and easy interchange is essential to compete with the convenience of car use'. In the UK, the average equivalent penalty, including walking and waiting times necessary to effect an interchange, is 21 min IVT (in-vehicle time) on a bus trip and 37 min IVT on a train trip (Paulley et al., 2006).

3. Public transport accessibility

Public transport accessibility refers to the extent to which individuals can access to spatial distributed activities (opportunities) by public transport. Murray et al. (1998) divided public transport accessibility into access to and from public transport stops or stations from origins and to destinations, and accessibility by public transport or network accessibility. Access to public transport refers as 'the opportunity for system use based upon proximity to the service and its cost' (Murray et al., 1998). Therefore, access to public transport and to the destinations concerns with not only the distances between the service points to the origins and destinations but also the cost affordability and temporal availability. Accessibility by public transport or network accessibility denotes as 'the suitability of the public transport network to get individuals from their system entry point to their system exit location in a reasonable amount of time' (Murray et al., 1998).

4. Access distance and mode, travel speed and travel distance

Access mode means public transport users' choice of mode access to public transport stops/stations. Travel speed and travel distance play an important role influencing the choice of access mode in three ways. First, the distance between two public transport stops or stations increase if the speed of the public transport increase, resulting in relatively long access and egress distances. Second, passengers using faster modes of public transport tend to travel longer distances, therefore would willing to accept longer access and egress distances. Finally, faster modes of public transport tend to attract people from a longer distance because of their high potential of travel-time savings (Martens, 2004).

According to the past studies above mentioned, walking and cycling might consider as the major access modes for public transport for shorter range of urban trips. If further regarding the transport system in Taiwan, motorbike might also need to be included in the alternatives of access mode for public transport. As for the long range and faster public transport such as rail, inter-city bus and high speed rail, the access modes should consider not only walking, cycling and motorbike but also bus and car for intermodal transport needs.

5. Public transport stops/stations' service areas

Despite there are some alternatives of access modes of choice for public transport, walking is one of the most important transport mode for access to public transport. Walking provides basic mobility for all people whatever their social status, especially for those who are transportation disadvantaged (people with disabilities, older people, children, and people with low income). The International Charter of Walking recognizes that the promotion of walking can contribute to social inclusion (Walk21, 2006). In addition, walking can increase rates of physical activity and improve public health. Litman (2003) contended that the economic value of walkability has long been underestimated as the significant social benefits are often ignored or overlooked, such as public cost savings from reducing traffic jams due to a shift from motorized transport to walking, improving community liveability and improving public health.

The main indicators for access to public transport stops or stations and destinations are measured using proximal walking distances from different public transport facilities such as bus, metro, tram and train stops/stations. Several studies have adopted accessible threshold distances of 400 metres for bus stops and underground stations, which equates to a 5 min walk, of 800 metres for train stations (Murray et al., 1998, Murray, 2001, Wu, 2005, Murray, 2003, Currie, 2010). Transport for London's PTALs (Public Transport Accessibility Levels) defined the maximum walk time as 8 minutes or distance of 640 metres for buses and the maximum walk time as 12 minutes or distance of 960 metres for rail, underground and light rail services (London, 2010). The Public Transport Capacity and Quality of Service Manual (Kittelson et al., 2003) supported 400 metres walking distance to bus stops.

Individuals' sociodemographic characteristic, extrinsic walking environment and public transport service level affect walking distance to public transport. The Public Transport Capacity and Quality of Service Manual (Kittelson et al., 2003) claimed walk distance access to public transport stops/stations should be accounted for such as age, grades, lacking sidewalks, poorly maintained sidewalks, lacking street lighting, and crossing safety. In addition, Alshalalfah and Shalaby (2007) studied the correlation between various characteristics of public transport service, socio-economic characteristics and walk access distance to public transport services in the city of Toronto, Canada, and found that passengers were willing to walk longer distance for high frequency routes than low frequency routes. El-Geneidy et al. (2014) adopted multilevel regression model to analyse walk distance access to public transport service and found that neighbourhood, household and individual trip and route characteristics influence walk distance access to public transport service. The study suggested that walk distance access to public transport stops/stations should also account for the type and quality of service being offered (El-Geneidy et al., 2014).

6. Network accessibility

Public transport frequency or waiting time is another important issue relating to temporal component of accessibility. Due to the variation of public transport frequency between peak-hour, inter-peak and weekend, the average waiting varies between different time of day and day of week. Currie (2010) & Delbosc and Currie (2011) studies adopted weekly number of mode of public transport as the waiting time variable while ignored the frequency variation. Curtis (2011) study used inter-peak frequency as impedance variable for measuring public transport accessibility because that if less frequent inter-peak services can be compatible with private car, peak hour services are even better. However, the waiting time depends on the frequency when the trip happens, and the time of the trip happen might depend on the purpose of the trip. Regarding the network accessibility, whether the destinations are reachable also depend on public transport network. In addition, the travel time should include the time of transfer and stop time.

7. Land-use

Land-use has been seen as an important factor influencing travel behaviour. The density of development, diversity of land uses and design features (layout or form) of the built environment – the 3Ds (Cervero and Kockelman, 1997) – have been found to influence travel distances, trip frequencies and mode choice.

Density provides us a mean of understanding land use or urban form. Newman and Kenworthy (1989) found an exponential relationship between gasoline use and density, which was a proxy of urban form represented by population density and job density. The research suggested strategies of re-urbanization and reorientation of transport priorities in order to reduce automobile dependence and gasoline consumption. Newman and Kenworthy (1991) observed that a density of 30 persons per hectare

(3,000 persons per km^2) could be a threshold to reduce automobile dependence. Frank and Pivo (1994) also found that public transport use and walking had the highest and nonlinear relationships with urban form, which was measured by population and employment density. Moreover, Kenworthy and Laube (1999) extended to analyse the relationships between transportation, land-use and economic factors and found that the higher public transport oriented cities were wealthier than the most auto-dependent cities. The study also showed a positive relationship between density and public transport usage.

Land-use mixed measures the variation of land use types, including offices, shops, restaurants, banks, and other activities, within a given geographic area (Cervero, 1989, Pivo, 1994). Rowley (1996) expressed that the indispensable conditions for generating prosperity diversity including multi-function land use, short blocks, and composition buildings. Pivo (1994) found a positive relationship between land-use mix and public transport use for both work trips and shopping trips. Cervero (1996) used binomial logit model to test the effects of mixed land-use and density on travel demand and found that the residential density had a stronger effect than mixed land use on mode choice.

Newman and Kenworthy (1996) contended the importance of urban connectivity which means higher density and mixed land-use along with high-quality public transport. Highly connect urban structure can help to reduce automobile dependence and increase public transport usage. Besides the density and mixed land-use factors, Kitamura et al. (1997) added public transport accessibility and the presence of sidewalks into the model and found that these factors all had significant effects on trip rates and mode choice. This study gave contribution to the research of land-use and transportation by expanding representing factors. These factors' effects on the travel behaviour were significant but less strong than attitudes factors.

Cervero(1997) added neighbourhood design factors relating to the characteristics of the streets, pedestrian and cycling provision and the site design, into the model. This study was to analyse the 3Ds' effects that are density, diversity and design, upon the travel behaviour. The results of the regression model showed the causal relationship that a denser, mixed-use and pedestrian-friendly design could deter automobile dependence, vehicle mile travel per capita and encourage non-motorized travel, although some of the 3D's variables had not quite high effects on the travel demand.

Dieleman et al (2002) found that residential environments and socio-economic characteristics had equal importance for mode choice for the Netherlands. Zhang's (2004) study showed land-use variables had significant but slight effects on mode choice for Boston and Hong Kong. In addition, Titheridge and Hall (2006) analysed the relationships between travel-to-work patterns and socio-economic and land-use characteristics in South East England. The study found that the density could give impetus to public transport use, cycling and walking, and shorter travel distances.

The results of land-use and transportation interaction were specific to where the study examined but might not be transferable to other cities. Ewing and Cervero (2010) used meta-analysis method weighted the average elasticities of public transport use with respect to density, diversity and design, see Table 2.1. Lin and Yang (2009) found that building density and employment density for density variable, housing-job balance, housing-retail balance for diversity variable, and road density and grid-network for design variable had significant effects on trip rates and private vehicle use for Taipei.

Table 2.1 Summary of the elasticity of land-use variables adapted from Ewing and Cervero (2010)

Land-use variables	Representative variables	Weighted average elasticity of public transport use
Density	Household/population density	0.07
	Job density	0.01
Diversity	Land-use mix (entropy)	0.12
Design	Intersection/street density	0.23
	Percentage of 4-way intersections	0.29

The effects of land-use factors on public transport usage overlap. Therefore, a study adopting only a single factor tends to exaggerate land-use's effects (Litman, 2005). However, a study adopting sophisticated land-use factors should be wary about the colinearity between the factors.

Although most of the previous studies' results supported the idea that compact and diverse (mixed-use) development could reduce travel distance, frequency and time and promote public transport use, the effects of land-use factors on travel behaviour have been found to be quite varied (Ewing and Cervero, 2001, Ewing and Cervero, 2010).

For example, the role of density in reducing travel distance, travel time and car dependency, and increase public transport use, has been demonstrated in several previous studies (Tsai, 2013, Lin and Yang, 2009, Cervero and Duncan, 2006, Rajamani et al., 2003, Zhang, 2004, Kenworthy and Laube, 1999). However, its impact on public transport demand has been disputed. Ewing and Cervero (2010) showed that the value of elasticity of density to public transport trips was huge, ranging from the highest at 0.41 to the lowest at -0.2.

Badoe & Miller (2000), Crane (2000) and Stead (2001) discussed that there are three reasons why the past studies on the effects of land-use on the travel behaviour were arguable and what were the research gaps. Firstly, the use of zonal-aggregate data ignored the variation of disaggregate features. Secondly, the geographic scale affects the results. The measures of land-use variables at neighbourhood level or area level influence the sensitivity of land-use variables on travel behaviour, and therefore, get various study results. In addition, the studies of land-use and travel behaviour interaction only concerned the demand side effects. However, there are other supply side factors or traveller's characteristics affecting the travel behaviour, such as socio-economic characteristics, public transport service availability and quality. Stead (2001) analysed the effects of land-use and socio-economic characteristics on the travel distance in the UK and found that socio-economic characteristics had about a half of explanatory power in the travel distance while land-use variables applied up to one third of explanatory power in the travel distance. Finally, more rigorous and integrated research methods are needed to analyse the complex interaction between land-use and transportation and improve the transferability of the analysis' findings (Badoe and Miller, 2000, Crane, 2000, Stead and Marshall, 2001).

8. Walking environmental factors and walk for public transport

Walking is the most common and natural forms of physical activity and transport modes. It is also the most important transport mode for public transport to connect the last mile (Olszewski and Wibowo, 2005). Most public transport journeys include an element of walking both to and from the bus stop or metro/railway station, and possibly at interchange points.

Walking environment can be measured objectively and subjectively. The relationships between (objective or subjective measures of) the walking environment, walking behaviour have been a popular area for research over the last decade (Frank et al., 2010, Leslie et al., 2007, Owen et al., 2007, Saelens et al., 2003a, Saelens et al., 2003b, Leslie et al., 2005) both within the fields of transport and health. Within transport studies, additional attention has been paid to the effects of the walking environment on the mode choice of walking either walking to access public transport or walking to destination. However, walking behaviour has been neglected in most travel mode choice studies (Lai and Lu, 2007, Aditjandra et al., 2012, Cervero, 2002). Where walking is considered in mode choice studies, it is often treated as being an option for all trips (Zhang, 2004, Frank et al., 2008). However there are many factors which make walking difficult, if not impossible, for many trips (Alfonzo, 2005). These include trip distance and individual characteristics such as health and disability. Rodríguez and Joo (2004) assumed that walking is not an option for a traveller if his/her trip distance too long, and used a 6.45 km one-way distance as the cut off point for walking as an available mode.

A behaviour of choosing walking over other modes of transport represents the results of an interaction between the person and the walking environment (Sallis et al., 2006) amongst other factors. Alfonzo (2005) and Ewing and Handy (Ewing et al., 2006, Ewing and Handy, 2009) have asserted that perceived environmental factors are mediators between physical environment features, and overall walkability and walking behaviour. An individual’s overall perception of walkability determines their walking behaviour (Ewing et al., 2006, Ewing and Handy, 2009). Kremers et al. (2006) also argued that the impact of neighbourhood environmental attributes on physical activity may be mediated through environmental cognitions.

An individual’s socio-demographic characteristics such age, gender, income, household motorised vehicle ownership have been found to affect their walking behaviour. (Pivo, 1994, Frank et al., 2008). These factors may influence both the affordances the perceive within the environment and how these combine into perceived overall walkability but may also influence walking behaviour through other mechanisms relating to, for example, motivations and intentions (Sallis et al., 2006, Alfonzo, 2005) and the availability of alternatives to walking (Alfonzo, 2005).

2.2.3 Motivation towards public transport

Motivation towards public transport contains the factors which represent an inner state that leads and energises the use of public transport. These factors are pro-environment value, attitudes, subjective norms, perceived moral obligation (PMO) and perceived behavioural control (PBC). Likewise, motivation towards public transport contains intention to use public transport, which is an outcome of a mental process that is immediate antecedent to travel mode choice behaviour.

1. Intentions

Several previous studies have shown that intention is a good predictor for travel mode choice behaviour (Bamberg et al., 2003, Thøgersen, 2009, Chen and Lai, 2011). Chen and Lai (2011) used a combination of TPB and discrete choice model to examine the effects of psychological factors (including intentions), socio-demographic characteristics and mode attributes on motorbike use behaviour in Taiwan. The results showed that intentions statistically significantly predicted motorbike use behaviour, and the impacts of psychological factors (intentions and habits) were higher than socio-demographic characteristics (Chen and Lai, 2011). Bamberg et al. (2003) concluded that travel behaviour was a reasoned behaviour because decision-making of travel behaviour was statistically significantly affected by intentions, which were determined by attitudes, subjective norms and perception of behavioural control. Thøgersen (2009) study showed that an intervention of offering a free month travel card led to a significant increase in commuting by public transport, and this effect was mediated through an increase in intentions toward public transport.

2. Attitudes

Many studies have been explored the relationship between attitudes and travel behaviour (Kitamura et al., 1997, Parkany et al., 2004, Steg, 2005, Vredin Johansson et al., 2006, Beirão and Sarsfield Cabral, 2007, Domarchi et al., 2008, Murray et al., 2010). Attitudes are measured by the evaluation of service quality, such as the need for time saving and flexibility with sensitive to costs and stress or as intention to use alternative modes of transport, or environmental desires and public transport perceptions (Kitamura et al., 1997, Parkany et al., 2004). Parkany et al. (2004) found that attitudes significantly influenced travel behaviour on route choice. Kitamura et al. (1997) categorized attitudes into 8 factors (pro-environment, pro-public transport, suburbanite, automotive mobility, time pressure, urban villager, pro-road construction, workaholic) relating to urban life and found that attitudes had stronger effects on travel behaviour than land-use. Vredin Johansson et al. (2006) found that attitudes towards flexibility, comfort and pro-environment had effects on the individual's mode choice behaviour. Beirão and Sarsfield Cabral (2007) used qualitative method to explore attitudes towards public transport and private car, and found that attitudes towards public transport was an important determinant for mode choice. Improving the image and level of service of public transport can increase potential users' intention to use public transport. Habib et al. (2011) found that reliability and convenience of public transport service had higher effects on traveller's attitudes towards public transport than comfort. Murray et al. (2010) tested what caused the differences on attitudes, which was measured by public transport prejudice scores, towards public transport in New Zealand, and found that not only the quality of service of public transport but also social norm influenced the attitudes towards public transport. The previous research showed that attitudes towards public transport were also influenced by socio-economic characteristics, such as age and income (Habib et al., 2011) and segmented by population groups, such as public transport users, non-users and potential users (Beirão and Sarsfield Cabral, 2007, Domarchi et al., 2008, dell'Olio et al., 2011).

3. Subjective norms

Heath and Gifford (2002) showed that descriptive norms were significant predictors on public transport use. It implied that most other people doing the specific behaviour had significant effects on individuals' intention to do the specific behaviour. Steg (2005) found that the effects of descriptive norms (behaviour of others) on mode choice were higher than family expectations and self-arousing. Additionally, subjective norms significantly related to personal norms, which refers to an individual's conviction that action in a certain way is right or wrong, and both asserted effects on the intention to use public transport (Bamberg et al., 2007). Therefore, both subjective and descriptive norms seems having relations to public transport use.

4. Perceived moral obligation (PMO)

Several previous studies suggested that adding personal feelings of moral obligation can effectively improve the explanatory power of the TPB (Chen and Tung, 2014, Chen and Tung, 2009). Chen and Tung (2009) extended TPB by adding moral norm factor to examine the effects on consumers' recycling intentions and results provided a better prediction of intentions. Another study also showed that including perceived moral obligation into TPB resulted a better understanding of consumers' intention to visit green hotels (Chen and Tung, 2014).

5. Perceived behavioural control (PBC)

Several studies have examined the effects of PBC on intentions and travel behaviour (Bamberg et al., 2003, Haustein and Hunecke, 2007, Heath and Gifford, 2002, Chen and Lai, 2011, Chen and Chao, 2011). Chen and Chao (2011) adopted TPB and the technology acceptance model to understand the effects of PBC and habits on switching intentions towards public transport for car and motorbike users in Taiwan. The results showed that effects of PBC on intentions was only statistically significant for motorbike users but not significant for car users (Chen and Chao, 2011). Another study on the effects of PBC, attitudes, subjective norms and habits on motorbike use intentions in Taiwan also found that the PBC was the most influential factor on intentions (Chen and Lai, 2011). Haustein and Hunecke (2007) found that PBC exerted significant directly influence on the choices of environmentally friendly modes of transport (walk, bike and public transport) and indirectly *via* intentions, the effects of PBC on the choices of environmentally friendly modes of transport is greater than intentions.

Except capability, opportunity and motivation influence travel mode choice, the design of public transport policy and the approaches used in public transport policy implementation also influence travel behaviour towards public transport. The following section reviews the studies of policy implementation and summarise the factors influence the outcomes of policy implementation.

2.2.4 Policy implementation

Policy implementation studies examine the 'gap' between what was planned and what occurred as a result of a policy (Schofield, 2001). Policy implementation is a delivery process that turns a policy into practice. As Sabatier and Mazmanian (1980) stated 'Implementation is the carrying out of a basic policy decision'. Policy implementation plays a decisive role, affecting whether the policy is successful or not. It can be seen as an interaction process between making objectives and carrying out those objectives. In addition, policy implementation is, after a policy decision has been made, the process of bringing together necessitated resources in a cohesive way to carry out or accomplish the established objectives (Pulzl and Treib, 2006). Policy decision-making cannot be detached from policy implementation (Cerna, 2013). Likewise, policy will not be accomplished without a proper policy implementation design (Cerna, 2013). Therefore, the passing of a policy does not guarantee success on the ground if that policy is not implemented well.

There are three main themes that have developed in the policy implementation literatures: implementation methods, the implementation factors affecting the outcomes, and the stakeholders and their relationships (Schofield, 2001). These are discussed in turn below.

1. Implementation methods

Three main implementation methods or approaches have been identified within the literature: top-down (forward mapping), bottom-up (backward mapping), and synthesis approaches (Sabatier, 1986, Matland, 1995, Pulzl and Treib, 2006, O'Toole, 2000, Fiorino, 1997, Winter, 2009).

Top-down implementation begins often with central government or the policy-maker (Sabatier, 1986). Policy implementation is the hierarchical execution of centrally defined policy intentions (Sabatier, 1986). Top-down theory emphasises statute formulation and central government control, with central government supervising the actions of implementers (Fiorino, 1997, Pressman and Wildavsky, 1984).

The bottom-up approach assumes essentially the converse of the top-down approach. Dispersed and decentralized decisions, flexibility, and discretion are the basic rules for the bottom-up approach (Fiorino, 1997). The focus is on ‘the specific behaviour at the lowest level of the implementation process that generate[s] the need for a policy’ (Elmore, 1979). Bottom-up theory starts by mapping the network of actors at the bottom of the implementation chain and asks them about goals, strategies, activities, and contacts (Sabatier, 1986). It then uses the contacts to develop a stakeholders’ network covering local, regional, and national actors involved in the relevant governmental or non-governmental programmes (Sabatier, 1986). Bottom-up theory does not draw as clear a line between policy decision makers and policy implementers as top-down theory. This provides a mechanism for moving street-level-bureaucrats from the role of implementers to the role of policy-makers in both the public and private sectors.

Both top-down and bottom-up have faced some criticisms (Matland, 1995, Pulzl and Treib, 2006, Sabatier, 1986, Sabatier, 2005). Top-down approaches have been criticised for neglecting the knowledge and expertise of the street-level bureaucrats and for lacking tolerance of diversity (Matland, 1995). On the other hand, bottom-up approaches have been criticised for overemphasising the level of local autonomy, and for inconsistent accountability of the policy controller. In addition, a bottom-up approach can be a slow and potentially costly way to accomplish change (Fiorino, 1997). It costs huge amount of time to form stakeholder groups, assemble basic information about a problem, agree on issues and pilot projects, evaluate the effects of pilots, and transfer lessons to other groups (Fiorino, 1997).

A synthesis approach focuses on combining a top-down and a bottom-up approach.(Matland, 1995). For a policy with a high level of conflict about the goals or intent of that policy and high uncertainty about which actions will achieve those goals, where a top-down approach cannot be imposed and where a bottom-up approach would be far too risky and unfocused (Matland, 1995), then neither top-down nor bottom-up approaches are appropriate and a synthesis approach may be the answer . The precise mix of top-down and bottom-up will depend on how the policy designer wishes to deal with potential policy conflicts and uncertainties (Matland, 1995).

2. Policy implementation factors

Several studies have asserted that implementation outcomes are affected by factors such as policy objectives, policy resources, organizational communication processes, characteristics of implementation agencies, economic, social and political conditions, the attitudes of implementers and bureaucratic discretion in implementation (Schofield, 2001, Gornitzka et al., 2005, Van Meter and Van Horn, 1975, Winter, 2003). Figure 2.4 summarizes the relationships between all these factors. Each of the factors are discussed in more detail below.

- Policy standards and objectives: Policy objectives are the starting point for the analysis of implementation processes. As Pressman and Wildavsky (1984) said ‘implementation cannot succeed or fail without a goal against which to judge it’.

Whether a policy has clear, unambiguous and consensus goals is important for policy implementation (Gornitzka et al., 2005).

- Policy resources: Resources could be in the form of funds or other incentives, which facilitate the administration of a programme (Gornitzka et al., 2005). Inadequate resources input will make it difficult for the policy objectives to be achieved (Van Meter and Van Horn, 1975, Gornitzka et al., 2005).
- Organizational communication and behaviour: This represents different degrees of commitment and coordination among and within the organizations related to a policy (Winter, 2009). Early understanding, and having agreement with the policy among these organizations can increase motivation to make the implementation successful (Winter, 2009).
- Characteristics of the implementing agencies: This factor consists of both the formal structural features of implementing organizations and the informal attributes of their personnel. Van Meter and Van Horn (1975) mentioned the competence (knowledge and skills) and size of an agency's staff, and the degree of hierarchical control of processes within the implementing agencies.
- Economic, social and political conditions: These form important framework conditions for implementation and include public opinion, supportive socio-economic context and political conditions (Winter, 2009).
- Attitudes of implementers: This includes the will and interests of those responsible for implementing the policy (Winter, 2003). Experience has shown that key persons in an organization can be very influential in the success or failure of a reform (Gornitzka et al., 2005, Van Meter and Van Horn, 1975). The attitudes of implementers are affected by policy resources, economic, social and political conditions, organizational communication and behaviour, and characteristics of the implementing agencies (Van Meter and Van Horn, 1975).

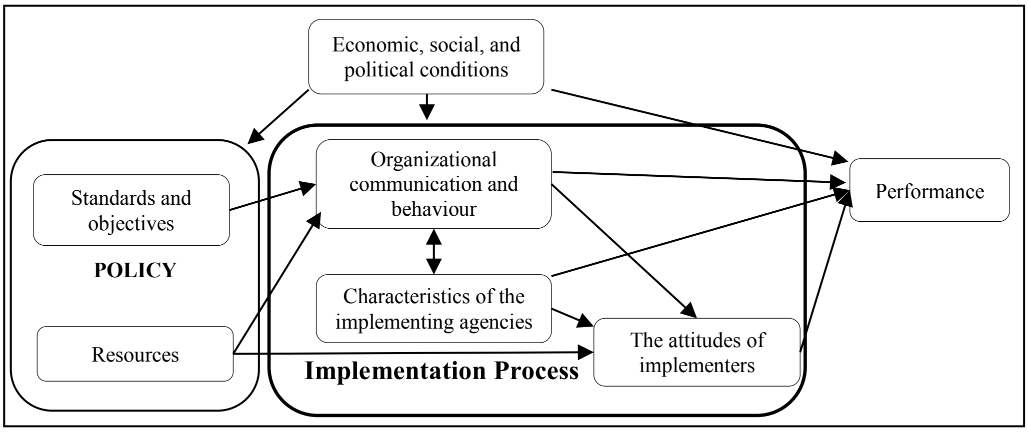


Figure 2.4 Policy implementation model
[Van Meter & Van Horn (1975), Gornitzka et al. (2005), Winter (2003)]

3. Stakeholders

The third key theme in the policy implementation literature relates to the involvement of stakeholders inside and outside of the implementation agencies. Successful policy implementation relies heavily on understanding the internal and external stakeholders and their relationships (O'Toole, 2000). O'Toole Jr (2009) categorized governmental relations into four types: vertical intergovernmental relations, horizontal intergovernmental relations, regulatory relationships between government and the private sector, and contracting ties with the private sector. Vertical intergovernmental relations refers to the level of command and control, and compliance relationships, between the higher tier government and its subordinate ones, as set by statutes. Horizontal intergovernmental relations refer to the extent of collaborative relationships between government agencies and departments. Regulatory relationships are those where the government has rights by statute to permit, oversee, suspend or cancel the operation of a specific service. The rights and obligations of a contracting relationship is set by, and builds on, the contracts between government and private sector organisations.

4. Implementation of transport policies

There have been a number of studies that have examined the implementation of transport policy (Fraser et al., 2006, Lutsey and Sperling, 2008, Schreurs, 2008, Lumsdon and Tolley, 2001, May et al., 2003, Noordegraaf et al., 2014). Noordegraaf et al. (2014) used content analysis to study the factors influence road pricing policy implementation in six places and identified 6 generic implementation factors: general political support, general public support, information campaign, various actor perceptions, characteristics of the transport system and marketing the scheme. Fraser et al. (2006) showed that including frontline target groups at an early stage of the decision-making process, through community participation, played a key role in the successful formulation of sustainability indicators. Lutsey and Sperling (2008) and Schreurs (2008) found that decentralizing decisions about climate change measures led to better outcomes. Lumsdon and Tolley (2001) and Gaffron (2003) studied the effects of local authorities' involvement in national walking and cycling policies' implementation in the UK. Both studies highlighted the importance of local authorities' attitudes, and that a high level of commitment within the local authorities led to a sustained and consistent implementation. May et al. (2003) concluded that public and political acceptability, financial barriers and technical feasibility contribute to the success or failure of implementation of transport policy in a study of decision making requirements for the formulation of sustainable urban land use. Reviewing previous studies on transport policy implementation, it shows that there is a lack of studies of this nature looking at road public transport (bus) policy implementation.

2.3 Proposed model for travel mode choice behaviour towards use public transport

1. Capability

Capability is categorised as physical, mental and financial aspects. Physical aspect of capability relates age, children in household, household size, drivers' licence and car ownership. For instance, as a person grows older, the physical constraints make him/her more willing to use public transport rather than private vehicle. Likewise, age and gender exerted some impacts on travel behaviour (Bottai et al., 2006, Mercado and Páez, 2009). In addition, a person who owns car or motorbike (tools) is more willing to use car or motorbike rather use than public transport. Children in household may also affect an individual's travel mode choice capability because parents have the responsibility to take and pick up children to and from school (and other places). Mental aspect of capability relates to education and occupation. Financial aspect of capability relates to income. For example, lower income people may not afford to own a car or use car because of financial limitation. Figure 2.5 shows the capability factors relates to travel mode choice behaviour towards use public transport.

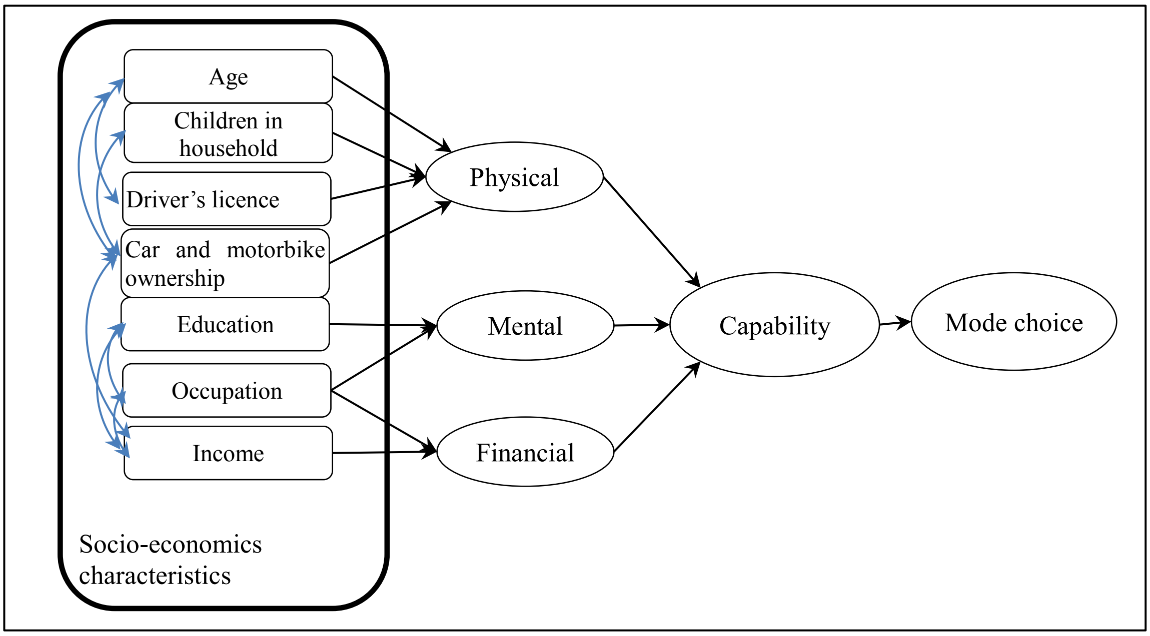


Figure 2.5 Capability factors relates to travel mode choice behaviour towards use public transport

2. Opportunity

Opportunity is similar to accessibility which is affected by the supply side of public transport service quality and the demand side the situation of land-use. In addition, there is an interaction between public transport service availability/quality and land-use. Figure 2.6 shows the opportunity factors relates to travel mode choice behaviour towards use public transport.

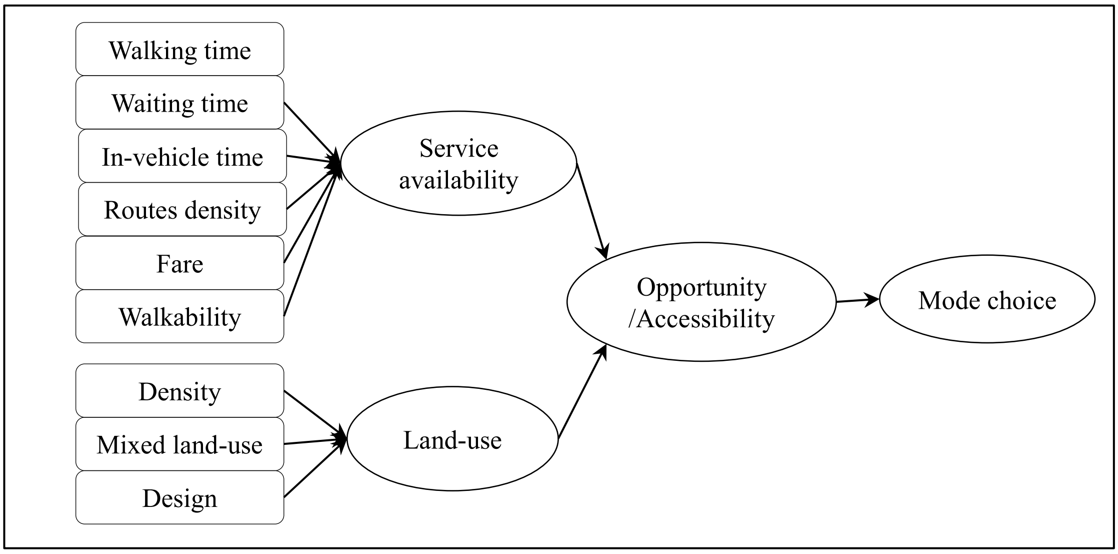


Figure 2.6 Opportunity factors relates to travel mode choice behaviour towards use public transport

3. Motivation

The motivational factors: pro-environment value, attitudes, subjective norms, perceived moral obligation (PMO), perceived behavioural control (PBC) and intentions, were developed by the theory of planned behaviour (TPB) (Ajzen, 1991) and its extended model (Chen and Tung, 2014, Heath and Gifford, 2002). The theory of planned behaviour (TPB) model and its extended model have been the commonly used basic frameworks to explain travel behaviour intentions and travel behaviour (Chen and Chao, 2011, Chen and Lai, 2011, Thøgersen, 2009, Bamberg et al., 2003, Heath and Gifford, 2002). Chen and Tung (2014) & Heath and Gifford (2002) extended TPB model by adopting perceived moral obligation (PMO), and environmental concerns and value to enrich the explanatory power for intentions. Pro-environment value, attitudes, subjective norms, PMO, PBC are treated as antecedent of intentions to use public transport, as shown in Figure 2.7. In terms of PBC, it refers to an individual's judgement about ease or difficulty in using public transport and it is assumed to reflect past experience as well as expected impediments and obstacles for using public transport. PBC can also serve as a proxy for actual behaviour control and contribute to the prediction of mode choice behaviour, as shown in Figure 2.7(Ajzen, 1991).

Pro-environment value is assumed to be related to the intentions of using public transport indirectly, which is mediated by attitudes, subject norm and PMO in the motivation towards public transport model, as shown in Figure 2.7. Most of the previous studies reported disappointing results, which showed low to moderate relationships between environmental concerns and behaviour. Bamberg (2003) reviewed some previous studies and assumed that pro-environment value, which is a general attitudes on environment concerns and value, had an indirect influence on specific environmental behaviour intentions and specific environmental behaviour. Chen and Tung (2014) & Bamberg (2003) gave the evidence that pro-environment value did not have significant direct impact on behaviour intentions and behaviour itself but exerted strong direct impacts on situation-specific beliefs and attitudes.

For example, imagine two people A and B in which A has higher environmental concerns and values than B. With all other conditions the same, person A may report higher evaluation on attitudes towards public transport and perceived moral obligation of using public transport than person B under the same public transport service level due to person A's higher pro-environmental value. In terms of subjective norms, person A may report higher evaluation on subjective norms over public transport than person B because his/her pro-environment value let him/her have more sensitivity on the social pressure to use public transport than person B. Likewise, person A may report easier to use public transport than person B because his/her pro-environmental value let him/her have higher tolerance on using public transport.

This study also assumes that there are some interactions between attitudes, subjective norms, PMO and PBC (Figure 2.7). Individual's attitudes may exert some impact on perceptions of behavioural control over public transport (PBC). Perceptions of moral obligation (PMO) may be affected by social pressure (subjective norms) and perceptions of behavioural control (PBC).

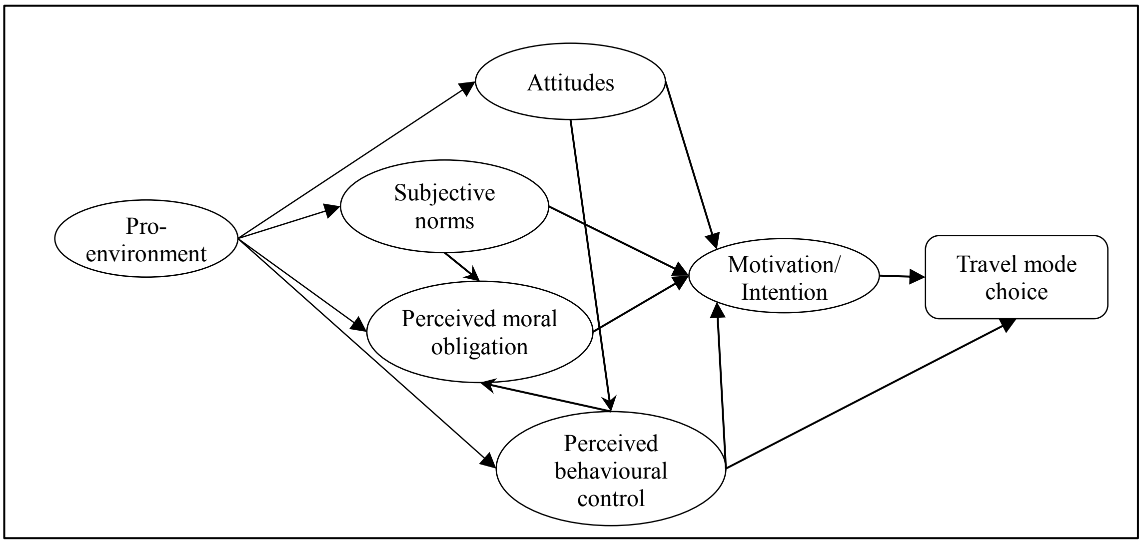


Figure 2.7 Motivation factors relates to travel mode choice behaviour towards use public transport

Integration of the capability, opportunity and motivation factors, the proposed model for travel mode choice behaviour towards use public transport is shown as Figure 2.8. There are interactions between capability and motivation, and opportunity and motivation.

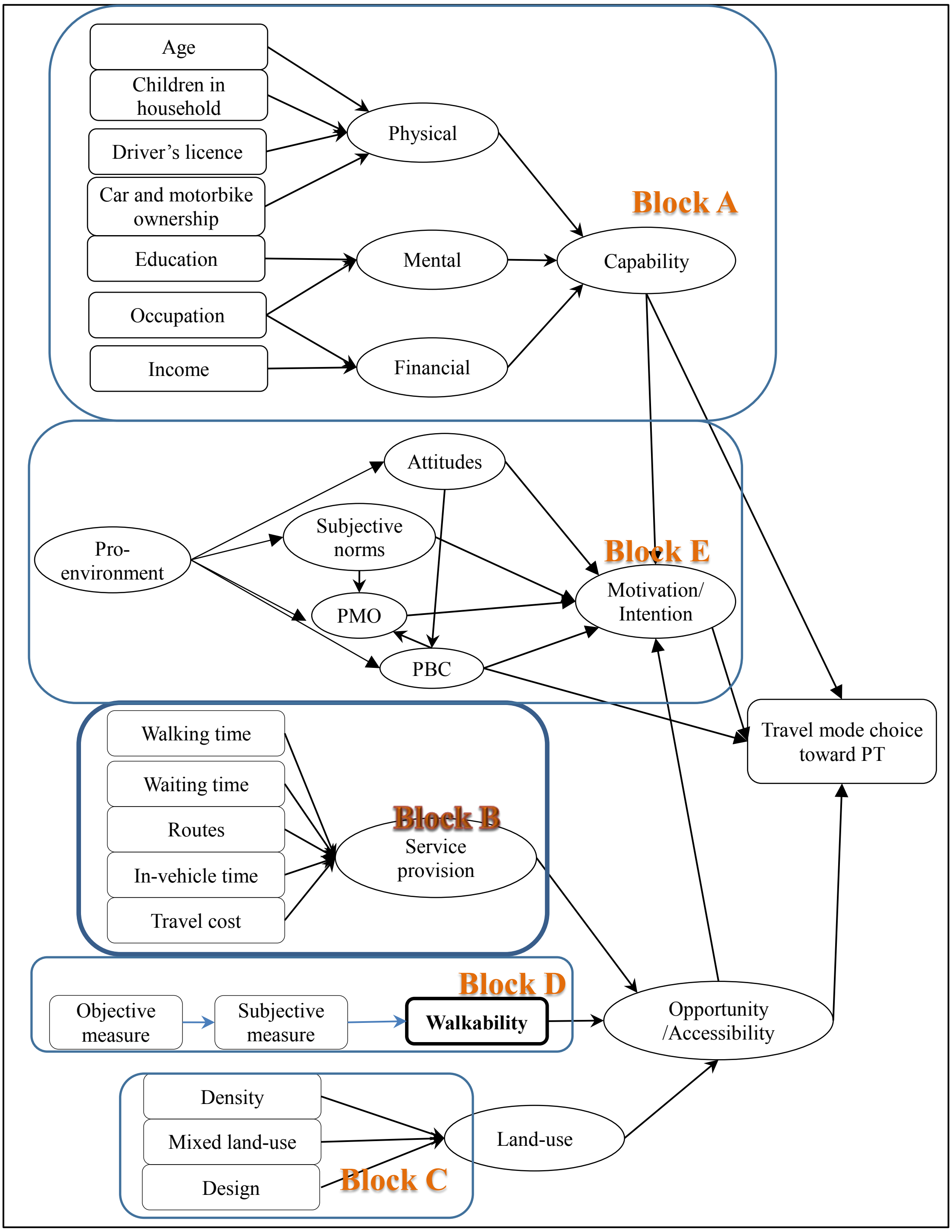


Figure 2.8 Proposed model for travel mode choice behaviour towards use public transport

The linkages of research questions and the conceptual model proposed in Figure 2.8 are explained as following.

As can be seen in Figure 2.8, the relationships between Block B, public transport provision, and travel mode choice behaviour accounting for socio-demographic characteristics, Block A, are to solve the Research Question 2 (RQ2) in Chapter 1, which is to understand that is there a fundamentally different relationship between public transport provision and travel mode choice in the context of Taiwanese high population density and mixed land use. The objectives of RQ2 are to examine the impacts of public transport provision such as the number of bus stops, bus frequency and metro stations, and service quality attributes such as walking time, waiting time, in-vehicle and travel cost on travel mode choice between car, bus, metro, motorbike and train accounting for the sociodemographic characteristics such as age, income, vehicle ownership, car and motorbike driver's licence, and household car and motorbike ownerships.

The relationships between Block C, land use, and travel mode choice behaviour accounting for socio-demographic characteristics, Block A, are to explore the Research Question 3 (RQ3) in Chapter 1 (Figure 2.8), which is to understand that is there a fundamentally different relationship between land-use factors at different geographic scales and travel mode choice behaviour in the context of Taiwanese high percentage of motorbike usage. There two objectives for RQ3. First is to examine land use variables such as population density, job density, mixed land use and grid like street pattern, across trip origin and trip destination influence travel mode choice between car, motorbike and public transport. Second is to examine the land use variables at different geographic scales (district and county) influence travel mode choice between car, motorbike and public transport.

Block D, objective and subjective measures of walking environment, and its relation with walking behaviour are to answer the Research Question 4 (RQ4) in Chapter 1, which is that can a structural model linking objective measures and subjective measures of walking environment to explain walk for public transport behaviour perform better than existing models in understanding walking environment and walking behaviour?. The objectives of RQ4 are to examine to what extent objective walking environment factors influence subjective measures of walking environment factors, and to what extent subjective measures of walking environment factors influence overall perceived walkability and walking for public transport.

The relationships between Block E, intention to use public transport, and travel mode choice behaviour, and also the interactions with Block A, B, C and D are to answer the

Research Question 5 (RQ5) in Chapter 1 (Figure 2.8), which is that can a novel conceptual model linking capability, opportunity and motivation make an important contribution to understand mode choice behaviour. There three objectives for RQ5. First is to examine the effects of motivational factors – pro-environment value, attitudes, subjective norms, perceived moral obligation and perceived behaviour control – on intentions to use public transport. Second is to examine the impacts of capability and opportunity on motivation. The third objective is to analyse the impacts of capability, opportunity and motivation on travel mode choice between car, motorbike and public transport.

Public transport policy implementation plays an important role for encouraging public transport use although it is not contained in the proposed conceptual model in Figure 2.8. Public transport policy implementation study is to solve the Research Question 1 (RQ1), which is to explore the reasons why after 6 years of policy implementation of the Taiwanese NRPTP (National Road Public Transport Plan), the objectives are not being attained - what are the key factors which have contributed to the plan's poor outcomes. The objectives of RQ1 is to explore the factors in the policy implementation process including policy implementation approach, consensus about the objectives, policy resources, organizational communication and the attitudes of implementers influence the attainment of public transport policy.

2.4 Summary

1. Adopting TPB and COM-B, a travel mode choice behaviour towards public transport model including capability, opportunity and motivation has been proposed in Figure 2.8. The objectives for the five research questions raised in Chapter 1 are also identified by reviewing previous literatures.
2. Walking is the key mode of transport access to and from public transport. Walking environment can be measured by objective indicators and subjective indicators while very few studies have examined the relationship between objective and subjective measures of walking environment. There is a need to explore the association between objective measures and subjective measures of walking environment and the effects on walking behaviour, especially for walking access to public transport.

3. In terms of the effects of capability, opportunity and motivation on travel mode choice behaviour, most of previous studies only examined either one or two of the three aspects while very few study has examined comprehensively the associations between intentions, opportunity and capability, and their influence on travel mode choice behaviour toward public transport.
4. For policy implementation, the literature showed that implementation approach, policy objective, resources, organizational communication and behaviour, characteristics of implementing agencies, attitudes of implementers, and stakeholders are potential factors affecting outcomes of policy implementation.

Chapter 3 **METHODOLOGY**

This chapter introduces the datasets and methodologies used in this study in order to solve the five research questions raised in Chapter 1 (Section 1.2).

The datasets include two specially design surveys for this study and a number of secondary datasets. The specially designed surveys are a qualitative interview survey concerning policy implementation processes, and an online survey of motivation and attitudes towards public transport and walking. Other datasets utilised in this study include the 2011 Travel Mode Choice Behaviour Survey, transport networks GIS data and land use GIS data.

Due to the complex relationships between the factors influencing public transport policy implementation, and between capability, opportunity, motivation and travel mode choice behaviour, mixed methodologies are adopted in this study. Methodologies used in this study include qualitative thematic analysis, multinomial logit model (MNL), multilevel MNL model, multinomial cross-classified MNL model, structural equation model (SEM) and generalized structural equation model (GSEM).

The Research Question 1 (RQ1), which is to understand the factors influence public transport policy implementation, is answered by using qualitative interview data and thematic analysis method. The objectives of RQ1 is to explore the factors in the policy implementation process including policy implementation approach, consensus about the objectives, policy resources, organizational communication and the attitudes of implementers influence the attainment of public transport policy.

The Research Question 2 (RQ2), which is to examine the influence of public transport supply and socio-demographic characteristics on travel mode choice, is answered by using 2011 Travel Mode Choice Behaviour data, land use GIS and public transport provision data and applies a multinomial logit model (MNL). The objectives of RQ2 are to examine the effects of public transport provision including the number of bus stops, bus frequency and metro stations, and public transport service attributes walking time, waiting time, in-vehicle time and travel cost on travel mode choice accounting for sociodemographic characteristics.

The Research Question 3 (RQ3), which is to explore the land use at different geographic scales and across trip origins and destinations influence travel mode choice, is answered by using 2011 Travel Mode Choice Behaviour data and land use GIS, and adopting multilevel MNL model and multilevel cross-classified MNL model. The objectives of RQ3 are to examine to the land-use variables: population density, job density, mixed land use, percentage of four-way intersections and cul-de-sac, across trip origin and trip destination, and at different geographic scales: district and city/county on travel mode choice behaviour.

The Research question 4 (RQ4), which is to examine the influence of objective and subjective measures of walking environment on walk for transport behaviour, is answered by using online travel survey data and land use GIS data and adopting structural equation model (SEM) and generalized structural equation model (GSEM) in Chapter 7. The objectives of RQ4 are to examine to what extent objective walking environment factors influence perceived walking environment factors, and to what extent perceived environmental factors influence overall perceived walkability and walking as a mode choice.

The Research Question 5 (RQ5), which is the influence of capability, opportunity and motivation on travel mode choice, is answered by using the datasets of online travel survey data, land use GIS data and public transport provision data, and methodologies of structural equation model (SEM) and generalized structural equation model (GSEM). The objectives of RQ5 are to explore the latent motivational factors: pro-environment value, attitudes, subjective norms, perceived moral obligation (PMO) and perceived behavioural control (PBO), and their impacts on intentions to use public transport; and to what extent capability and opportunity influence on motivation; and to what extent capability, opportunity and motivation influence on travel mode choice behaviour.

3.1 Data and methodologies used in the following analysis

Table 3.1 shows the datasets and methodologies used to answer the five research questions listed in Section 1.2, and how these map onto the chapter structure (Chapter 4 to Chapter 8) of this thesis. The following sections describe the datasets and methodologies used in this study.

Table 3.1 Mapping research questions with datasets, methodologies and chapters

Research question	Datasets	Methodology	Thesis chapter
RQ1: To explore why after 6 years of policy implementation of the Taiwanese NRPTP (National Road Public Transport Plan), the objectives are not being attained - what are the key factors which have contributed to the plan's poor outcomes?	1. Qualitative interview data.	Thematic analysis	**4**
RQ2: To understand that is there a fundamentally different relationship between public transport provision and travel mode choice in the context of Taiwanese high population density and mixed land use.	1. 2011 Travel Mode Choice Behaviour Survey; 2. Public transport provision data; 3. Land use GIS data.	Multinomial logit model	**5**
RQ3: To understand that is there a fundamentally different relationship between land-use factors, at different geographic scales and travel mode choice behaviour in the context of Taiwanese high percentage of motorbike usage.	1. 2011 Travel Mode Choice Behaviour Survey; 2. Land use GIS data.	Multilevel MNL model & multilevel cross-classified MNL model	**6**
RQ4: Can a structural model linking objective measures and subjective measures of walking environment to explain walk for public transport behaviour perform better than existing models in understanding walking environment and walking behaviour?	1. Online motivation and walking environment survey data; 2. Land use GIS data.	Structural equation model (SEM) & Generalized SEM	**7**
RQ5: Can a novel conceptual model linking capability, opportunity and motivation make an important contribution to understand mode choice behaviour?	1. Online motivation and walking environment survey; 2. Public transport provision data; 3. Land use GIS data.	Structural equation model (SEM) & Generalized SEM	**8**

3.2 Epistemology in this study

This study adopted with mixed research methods from the pragmatism. The pragmatism proposed different perspective while there are incompatibility between positivism and social constructivism (Creswell, 2013). The pragmatic paradigm is not committed to any one system of philosophy and reality. This applies to mixed methods research in that inquirers draw liberally from both quantitative and qualitative assumptions when they engage in their research. Individual researchers have a freedom of choice. Researchers are free to choose the methods, techniques, and procedures of research that best meet their need and purposes. Pragmatists do not see the world as an absolute unity. In a similar way, mixed methods researchers look to many approaches for collecting and analysing data rather than subscribing to only one way (e.g., quantitative or qualitative). Pragmatism opens the door to multiple methods, different paradigms, and different assumptions, as well as different forms of data collection and analysis (Creswell, 2013).

The study flowed from inductive research (qualitative method) to deductive research (quantitative methods). The inductive research in this study tried to observe and understand the public and private partnership behaviour in order to increase public transport patronage. The deductive researches in this study tried to test the effectiveness of the variables influencing public transport mode choice.

Constructivism or socio constructivist is typically seen as an approach to qualitative research, which refers to an interpretative method of collecting and analysing data to explore and explain a phenomenon (Creswell, 2013). Qualitative research describes an event in its natural being (Abusabha and Woelfel, 2003). It is a subjective way to look as life as it is lived and an attempt to explain the studied behaviour (Walsh, 2003). This type of approach typically refers to a range of data collection and analysis techniques that use purposive sampling and semi-structured, open-ended interviews (Choy, 2014). Rather than design an experiment and artificially control the variables, qualitative researchers use anthropological and ethnographic methods to study the participants. Instead of providing a broad view of a phenomenon that can be generalised to the population, qualitative research seeks to explain a current situation and only describes that situation for that group.

On the other hand, quantitative research design is empirical in nature; it is also seen as the positivist or scientific paradigm. The paradigm ensures validity by the process of rigorous clarification, definition or use of experiments (Atieno, 2009). Quantitative research establishes statistically significant conclusions about a population by studying a representative sample of the population (Creswell, 2013). The population consists of the entire group being studied. If chosen properly, the sample will be statistically identical to the population and conclusions for the sample can be inferred to the population. Quantitative research is also described by the terms ‘empiricism’ and ‘positivism’ (Carr, 1994). Positivists believe that reality is stable and can be observed and described from an objective viewpoint without interfering with the phenomenon being studied (Creswell, 2013).

Philosophical worldviews of the positivist and the constructivist can distinct between qualitative and quantitative methods (Creswell, 2013). Positivists hold a deterministic philosophy in which causes (probably) determine effects or outcomes. Thus, the problems studied by positivists reflect the need to identify and assess the causes that influence outcomes, such as found in experiments. Positivist assumptions have represented the traditional form of research, and these assumptions hold true more for quantitative research rather than qualitative research. Positivists view that Sociology should be studied in a scientific manner. On the other hand, constructivists hold a different paradigm. Constructivism or interpretivism believe that society cannot be treated as a science, and it is typically seen as an approach to qualitative research (Creswell, 2013). Social constructivists believe that individuals seek understanding of the world in which they live and work. Individuals develop subjective meanings of their experience – meanings directed toward certain objects or things. These meanings are varied and multiple, leading the researcher to look for the complexity of views rather than narrowing meanings into a few categories or ideas. Scientific approaches are not suitable for the study of society because everyone is different with different views and attitudes.

3.2.1 The strengths and weaknesses of quantitative and qualitative research methods

Both quantitative and qualitative research methods have their own strengths and weaknesses. The quantitative research methods have several significant advantages. First, it can be administered and evaluated quickly. There is no need to spend time at the organisation prior to administering the survey, and the responses can be tabulated within a short timeframe. Second, numerical data obtained through this approach facilitates comparisons between organizations or groups, as well as allowing determination of the extent of agreement or disagreement between respondents (Choy, 2014). Third, quantitative research is considered more reliable than qualitative research (Carr, 1994). This is because a quantitative approach aims to control or eliminate extraneous variables within the internal structure of the study, and the data collected can also be assessed by standardised testing. Quantitative studies decrease the chances people’s responses or behaviours being affected or influenced by the outside researcher. Fifth, quantitative methods allow for generalizability when data are drawn from fairly large random samples (Ratnesar and Mackenzie, 2006). Finally, quantitative methods can produce results that are solid, unlike an opinion and common sense answer (Ratnesar and Mackenzie, 2006).

The strengths of quantitative research can, however, also be weaknesses. Many important characteristics of people and communities including both rich and poor, for example, identities, perceptions, and beliefs cannot be meaningfully reduced to numbers or adequately understood without reference to the local context in which people live (Carr, 1994, Choy, 2014). In addition, human behaviour naturally comes with emotional responses which are difficult to digitalise. In terms of validity, the weakness in quantitative research is that the more tightly controlled the study, the more difficult it becomes to confirm that the research situation is like real life (Carr, 1994).

Qualitative research methods have several advantages. First, qualitative methods that allow researchers to explore the views of homogeneous as well as diverse groups of people help unpack these differing perspectives within a community (Choy, 2014). Second, qualitative methods have the ability to probe for underlying values, beliefs and assumptions (Yauch and Steudel, 2003). To gain a full appreciation of an organization, it is necessary to understand what is driving their behaviour. In addition, qualitative approach design is broad and open-ended, allowing participants to raise issues that matter most to them (Yauch and Steudel, 2003).

The major disadvantages associated with qualitative research methods are (a) the process is time-consuming, and (b) important issue could be overlooked (Yauch and Steudel, 2003). All researchers' interpretations are subjective and limited. Hence personal experience and knowledge influence the observations and conclusions. Also, because qualitative inquiry is generally open-ended, the participants have more control over the content of the data collected. The other critic to qualitative approach is that it results in data which is not objectively verifiable (Choy, 2014). Hence, the findings from qualitative methods cannot be extended to wider populations with the same degree of certainty that quantitative analyses can.

3.2.2 The choices between quantitative and qualitative methods and generation issues

Qualitative method was chosen to study the Research Question 1: To explore why the Taiwanese NRPTP objectives are not being attained. This was because this analysis related to explore the phenomenon within the NRPTP policy implementation. Multiple stakeholders were involved in the NRPTP policy implementation. The analysis tried to understand the feelings and perceptions about the NRPTP policy and to generate ideas to improve the NRPTP policy implementation. Hence, a qualitative approach was chosen to solve Research Question 1.

Quantitative methods were chosen to solve the Research Question 2, 3, 4 and 5. This was because these research questions were all related to the identification of factors that influence an outcome (mode choice behaviour). Most of the factors: public transport provision, land use and objective walking environment, are observable variables. Numerical techniques (e.g. exploratory factor analysis) have been used to identify some of the unobservable factors (subjective walking environment and attitudes towards public transport) (Lin and Moudon, 2010, Thøgersen, 2009). These analyses tried to find the correlations between the observable variables and the outcomes. Hence, quantitative methods were chosen to solve Research Question 2, 3, 4 and 5.

Quantitative studies results have the strength of generalization while qualitative results may not. Quantitative methods were used to answer the RQ2, RQ3, RQ4 and RQ5. The results can be generalized because the validity and reliability of the study processes. In terms of qualitative research of RQ1, due to the very small purposive samples and without statistically representative of the whole population in question, the results may not be generalizable.

3.3 Datasets used

Survey involves the use of standardised questionnaires or interviews to collect the required information in a systematic manner. Two surveys were conducted in this study including a qualitative survey of interviews and a quantitative online survey. Additionally, an existing survey data, 2011 Taiwanese mode choice behaviour data, was used in this study. The data sources and descriptive statistics are as follows.

3.3.1 Qualitative interview data

The purpose of the interviews was to explore opinions on public transport policy implementation and the factors contributing to its successes and failures, which is research question 1 (**RQ1**). The interviews were conducted by the author of this study. The author had worked in local authority in Taiwan for more than 13 years and has worked for central government for more than 3 years. The past working experience and the training in PhD study help the author deeply understand the processes of public transport policy implementation and have sufficient knowledge and skills to conduct the qualitative study.

3.3.1.1 Ethical and relational considerations

The research should be conducted ethically in order for it to result in benefit and minimise risk of harm. The potential risk of harm in a study might include physical, psychological, social, economic or legal harm (Creswell, 2013). Ethical and relational considerations are to prevent the potential risk of harm.

The major ethical issues in conducting research contain are: a) informed consent, b) beneficence – do not harm, c) respect for anonymity and confidentiality, d) respect for privacy (Marianna, 2011). The first issue that arose in the research related to informed consent, which means that a person knowingly, voluntarily and intelligently, and in a clear and manifest way, give his consent (Marianna, 2011). Prior to the consent form, individual should be informed on the possible risks and benefits of the research. Free and informed consent needs to incorporate an introduction to the study and its purpose as well as an explanation about the selection of the research subjects and procedures that will be followed (Orb et al., 2001).

The second issue is beneficence – do not harm, which refers to the Hippocratic "be of benefit, do not harm"(Marianna, 2011). This principle refers to that researches are expected to provide the participants with an outline of the risks and benefits involved to the participants of the study. In qualitative research, it is often difficult to predict the balance of risks to benefits (Marianna, 2011). However, researchers have an obligation to anticipate the possible outcomes of an interview or observation and to weigh the benefits and the potential harm (Houghton et al., 2010).

The third issue is respect for anonymity and confidentiality (Marianna, 2011). Anonymity refers to the subject's identity cannot be linked with personal responses. Confidentiality means that researchers have to well manage private information in order to protect the subject's identity (Marianna, 2011). With regards to individual participants, researchers may need to use pseudonyms and to be selective when describing defining characteristics of participants that could reveal their identities (Houghton et al., 2010).

The final issue is respect for privacy, which refers to the freedom an individual has to determine the time, extent and general circumstances under which private information will be shared with or withheld from others (Marianna, 2011). An invasion of privacy happens when private information such as beliefs, attitudes, opinions and records, is shared with others, without the individual's knowledge or consent (Marianna, 2011).

There are some measures these ethical issues in this study's qualitative survey. Firstly, the purpose of the qualitative interview and the benefit of the qualitative study were informed to the interviewers at the beginning of the interview. After well explanation of the benefits of the interviews, all the interviewees were asked to consent the interviews. The interviewer commenced the questions after the interviewers accept. In addition, the interviewees can end the interviews at any time (Please see Appendix A).

In terms of respecting anonymity and confidentiality, the identities of the participants were replaced by pseudonyms at data coding stage. The pseudonyms allowed readers to recognise the types of organizations the participants belong to but kept their identities secretly, for example, CG represents that the participant works at central government and LA refers to that the participant works at local authority. In order to keep all the interview records confidentiality, all the files are encrypted (VeraCrype encryption software is used) and stored in the author's personal hard drive.

With respect to privacy, the participants' private information will not be revealed or shared with others. The participants' privacy is highly respected in this study. All the audio records and data coding files are stored with encryption. The pseudonyms are used to provide enough information for the analysis without revealing any personal identity.

Another issue raised is that the author of this qualitative study has abundant career experience on the topic, what the advantages and disadvantages are. The advantages of this are the author understands the scope of the topic and who are the stakeholders involved in the survey. The author can easily contact to the key persons in the stakeholder organizations. During the interview progressing, the author can partner with the participants and ask some follow-up open-ended questions to extract more underlying information from the participants. Furthermore, the author's background can help the interpretation of the data because the author positions himself in the research to acknowledge how his interpretation flows from the participants' personality, cultural and historical experiences. However, there are some potential risks resulted from the author's experience. Firstly, some important issue could be overlooked due to the author's preconceived judgements (Yauch and Steudel, 2003). Secondly, the author's interpretations are subjective and may be limited. Hence personal experience and knowledge influence the observations and conclusions.

3.3.1.2 Data collection

In order to understand the influence of policy implementation on use of public transport, 13 in-depth interviews were conducted. The 13 participants were purposively selected, which covered nearly all the stakeholders for the public transport policy implementation including central government, local authorities, NRPTP (Taiwanese National Road Public Transport Plan) joint office, bus companies and academic institutions (see Table 3.2). A relationship has been established between the author and the participants due to past working experience involving in the policy implementation of Taiwanese National Road Public Transport Plan (NRPTP), which was launched in 2010. The participants well understood the reason the author conducted the survey and was willing to give contribution to this study of public transport policy implementation and to the policy implementation of Taiwanese National Road Public Transport Plan (NRPTP).

The purposely selected participants, who came from diverse backgrounds and play important roles in the public transport policy implementation, have the potential to provide rich, relevant and diverse data pertinent to the research question. All the invited 13 participants were directly involved in the NRPTP policy implementation (Table 3.2). No participation invitation was refused because a relationship has been established between the author and the participants prior to the study. The participants in central government include staff in the Ministry Of Transportation and Communications (MOTC) and Directorate General of Highways (DGH), which they have been responsible for the NRPTP policy implementation for more than 5 years until 2016. The participants in the local authorities include 1 from a city/county, which is categorised as high population density and high public transport market share, 3 from cities which are categorised as high population density and low public transport market share, and 2 from cities/counties which are categorised as low population density and low public transport market share (Table 3.2). Some of the participants from local authorities have worked experience in central government and different categorised cities/counties. Three bus companies' general managers, which operate bus routes in three different areas in Taiwan, were interviewed. All the participants had been in their position related to the NRPTP for at least 3 years.

Table 3.2 General information about the interviewees

Code	Features	Role in NRPTP implementation
CG1	MOTC, Central government	Policymaker , sets up policy guidance
CG2	DGH, Central government	Implements policy guidance and determines budget allocation
LA1	Local authorities, high population density and high public transport market share local authority	Local Implementing agency
LA2	Local authorities, high population density and low public transport market share local authority	Local Implementing agency
LA3	Local authorities, high population density and low public transport market share local authority	Local Implementing agency
LA4	Local authorities, high population density and low public transport market share local authority	Local Implementing agency
LA5	Local authorities, low population density and low public transport market share local authority	Local Implementing agency
LA6	Local authorities, low population density and low public transport market share local authority	Local Implementing agency
AU1	NRPTP joint office,	Assists DGH and helps local authorities to initiate projects
AU2	Academic institution,	Government consultant
AU3	Bus company, operator	Frontline implementing agency
AU4	Bus company, operator	Frontline implementing agency
AU5	Bus company, operator	Frontline implementing agency

The interviews were semi-structured. 6 questions were developed in the question guide based on the literature review in section 2.5 in Chapter 2 that the factors affecting policy implementation may include policy objectives, policy resources, organizational communication, characteristics of the implementing agency, attitudes of implementers and implementation approaches (Figure 3.1). The interview guidance is as in Appendix A. Not all participants were asked all 6 questions; follow up questions were included to extract further information as necessary. The interview guidance aims to elicit information on policy implementation method and factors(as can be seen in Appendix A). The connection between main topics and the question guide is as shown in Figure

3.1. Most of the questions were covered by two or three topics because policy implementation is a continuous process related to all the topics and their interactions (McLaughlin, 1987). For example, the question of 'can you tell me what you understand the key NRPTP objectives to be' was related to policy objectives setting and if central government communicated the objectives to the stakeholders well.

The interviews took place in January and February 2016. Interviews lasted from 30 minutes to an hour and all the interviews used online calls. Chinese language was used in the interviews. The interviews were audio recorded, transcribed and analysed using thematic content analysis to categorise the main themes

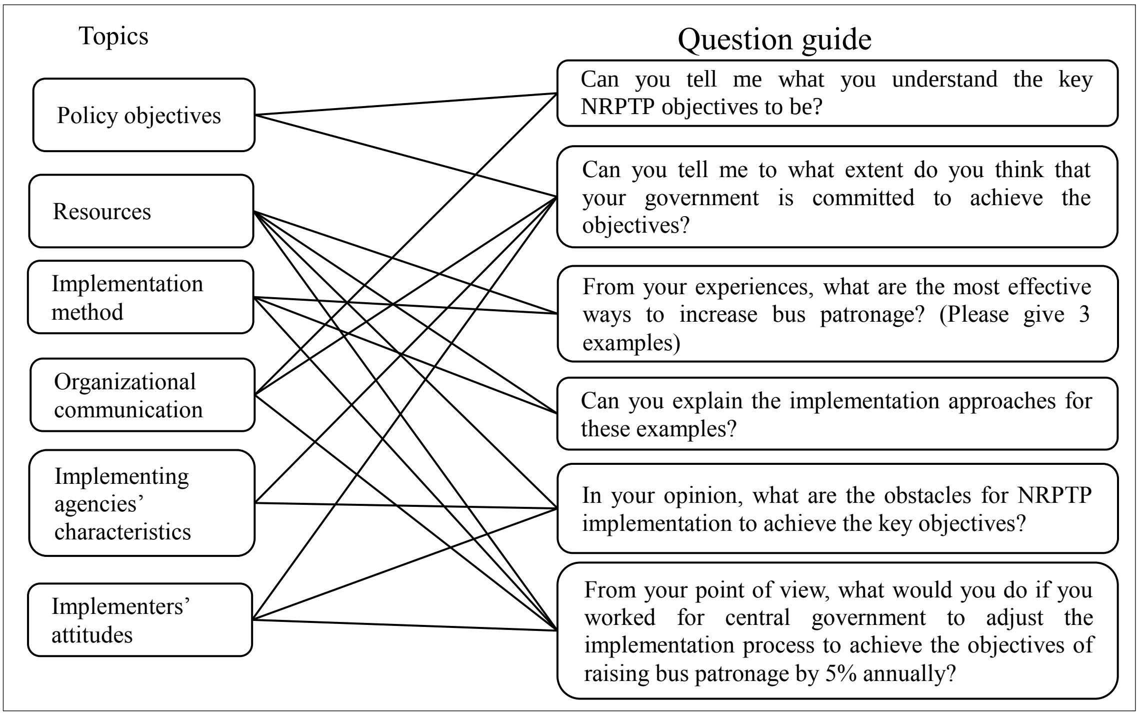


Figure 3.1 Relations between main topics and question guide

3.3.1.3 Interview data preparation and analysis

A cross-language thematic analysis was conducted because the language used in data collection (Mandarin) and report writing (English) were different. The analysis processes included familiarisation with the data, Mandarin verbatim transcriptions, theme searching, translation into English, coding text, reviewing themes, and result writing (Creswell, 2013). The first phase of familiarisation with the data involved listening and re-listening the data to become immersed and intimately familiar with its content. In order to familiar with the data, the author listened to each of the interviews' audio records at least twice.

The second stage involved cross-language translation. The first step was transcription of the interviews in Mandarin. The audio records of all the interviews were transcribed verbatim in Mandarin because the language used in the interviews is Mandarin (See Appendix B as an example). Then important passages and phrases were excerpted and translated into English with coding of themes. In order to understand and extract all the important information from the interviews, the author then re-read the Mandarin transcriptions and marking additional passages and phrases. These additional pieces of text were then translated into English and given a code according to the themes they belonged to. MS Excel was used in the English coding process because the dataset in this thematic analysis was relatively small. The Excel table records the excerpted passages and phrases, the respondent pseudonym, themes and theme codes (See Appendix C).

The third stage involved examining the text closely, line by line, to facilitate a micro analysis of the data. This was where themes began to emerge by organising items relating to similar topics into categories. There were some things drawn from the literature reviews, these were implementation approach, policy standards and objectives, policy resources (Van Meter and Van Horn, 1975, Gornitzka et al., 2005, Winter, 2003); essentially, the characteristics of the implementing agencies and attitudes of implementers. Some distinct themes emerged; these were lack of information about what works in switching travel mode choice, implementation mechanism and mayoral commitment.

The fourth stage involved trawling back through the data examining how information was assigned to each theme to evaluate its current meaning. After going back through a second time, the author was confident that no further information could be extracted. The final time the author went through, no new themes emerged. All the themes identified were stable.

Lost meaning is an issue that needed to be considered in the translation process. Qualitative research seeks to study meanings in subjective experience. The relation between subjective experience and language is a two-way process; language is used to express meaning, but language also influences how meaning is constructed (van Nes et al., 2010). Qualitative research is considered valid when the distance between the meanings as experienced by the participants and the meanings as interpreted in the findings is as small as possible (Polkinghorne, 2007). In addition, the findings should be communicated in such a way that the reader of the publication understands the meanings as it was expressed in the findings, originating from data in the source language (van Nes et al., 2010).

A number of measures were put in place to avoid meaning loss, however there may still be some residual risk of meaning losts. The Mandarin language, which is the author's native language, was used in the interviews. Hence, there is no problem for the author to understand the narrative experience expressed by the interviewees even if the interviewees used some metaphors. The interviews were conducted in the fourth year of the author's PhD study. More than two years British study experience helped the author to better manage the English language to reduce the risk of meaning lost in translation. In addition, the findings have been explained and discussed with the author's supervisor, which is a native English speaker, to make the writings understand by the readers. All the processes tried to interpret and explain the findings as close as possible to the participants' expressions.

3.3.2 Online motivation towards public transport and walking environment survey

Data can be collected by self-enumeration and interviewer-assisted (personal interviews or telephone interviews) (Bhattacherjee, 2012). Self-enumeration method is chosen because it is relatively easier to administer and cheaper than interviewer-assisted methods. In addition, this survey asks respondents to report their travel behaviour, attitudes towards public transport and the cognition on walking environment. A well-structured and easy to follow questionnaire can be designed. With self-enumeration, the respondent completes the questionnaire without the assistance of an interviewer. Self-enumeration methods require a very well-structured, easy to follow questionnaire with clear instructions for the respondent. There are a variety of ways that the questionnaire can be delivered to and return by the respondent: by post or facsimile, electronically (including the Internet) or by an enumerator (Bhattacherjee, 2012).

Every survey method has its own advantages and disadvantages (See Table 3.3). The choice of survey methods needs to consider data quality, collection costs, length of collection period, response rate and sampling bias (Bhattacherjee, 2012). In terms of interviewer-assisted methods, data can be collected by face-to-face interviews and telephone interviews. The advantages of face-to-face interview are that it has the highest response rates and lowest refusal rates, allowing for longer, more complex interviews, highest response quality and lowest sampling bias among all the survey methods (Szolnoki and Hoffmann, 2013). The disadvantages of face-to-face interviews are that it is the most costly mode of administration, with longer data collection periods and qualified interviewer concerns.

Compared with face-to-face interviews, telephone survey is less expensive, has a shorter data collection period and affords better control and supervision of interviewers (Szolnoki and Hoffmann, 2013). In addition, the response rates and data quality for telephone survey is better than self-enumeration methods: mail survey and online survey. The disadvantages for telephone survey are that it has potential bias against households without telephones and unlisted numbers, and non-response, especially for the younger generation which are used to use mobile phone instead of landline (Szolnoki and Hoffmann, 2013). In addition, through a telephone survey it is difficult to administer questionnaires on sensitive or complex topics compared with face-to-face interviews. Although interviewer-assisted methods enjoy many advantages, they are not pragmatic for this study considering the place to survey (Taiwan), costs to administer and period of collection. Mail surveys are advantageous in that they are unobtrusive (Bhattacherjee, 2012).

Mail surveys are expensive to administer and they tend to have a quite low response rate at about 10-15% (Bhattacherjee, 2012). Additionally, mail surveys take a long period to complete and the quality of response is difficult to control. Most of respondents tend to ignore survey request. The returned questionnaire may not be valid due to missing answers in it. Hence, the researcher must continuously monitor responses as they are being returned, track and send reminders to non-respondents repeated reminders.

Compared with interview-assisted survey, telephone survey and mail survey, online surveys have several advantages. They are easier and inexpensive to administer. Online survey shortens length of collection period. It is convenient for respondents to answer the questions to their schedule, at their pace, and they can even start a survey at one time, and complete it later. Results are instantly recorded in an online database. Considering costs, period of collection and response rate, the survey of motivation towards public transport and walking environment uses online self-enumeration method to collect the data. Hence, online survey is chosen among a variety of self-enumeration and interviewer-assisted methods to deliver and collect questionnaires.

There is a problem of limited coverage for online surveys. There are some sections of the population did not have access to Internet. Although Internet access is growing, there are still many individuals not covered, and if those without Internet access differ on key measures from those with Internet access, the resulting estimators will be biased. For example, if wealthier households are more likely to have Internet access, then a survey about household assets that is based exclusively on the Internet will produce income estimates that are too high (Lohr, 2008). Inaccessible Internet may not be a problem in Taiwan due to well-constructed Internet infrastructure (Taiwan Network Information Centre, 2017). Among all the households in Taiwan, about 88% have access to the Internet (Taiwan Network Information Centre, 2017). However, the digital divide may be a problem in this study's online survey. Some studies have reported the 'digital divide' between rural and urban (Cho et al., 2003, Hindman, 2000, Fong, 2009). In order to reach more respondents in rural areas, the author tried to send more invitations to people living in rural cities and counties in Taiwan and asked the respondents to forward the invitations to rural residents. Additionally, some groups in the population were difficult for the author to reach such as young adults and seniors. The author tried to ask his family, friends and colleagues to forward the invitation email to especially these groups.

Table 3.3 Comparison of survey methods

	Online	*Mail*	*Phone*	*F/F**
Cost	Cheap	High	Fair	High
Speed	Fast	Moderate	Fast	Slow
Response rate	High	Low	Fair	High
Burden on respondent	High	High	Fair	Low
Length of Questionnaire	Short	Long	Fair	Long
Sensitive questions	Poor	Good	Fair/good	Fair
Lengthy answer choices	Poor	Poor	Fair	Very good
Complexity of Questionnaire	Poor	Poor	Good	Very good
Quality of response	Poor	Poor	Good	Very good
Possibility of interviewer bias	None	None	Moderate	High
Sampling bias	Poor	Moderate	Good	Very good

*F/F: face-to-face survey

3.3.2.1 Question design

1. Motivation over public transport

Motivation towards public transport contains five aspects: pro-environment value, attitudes, subjective norms, perceived moral obligation (PMO), perceived behavioural control (PBC), and intentions towards public transport according to literature review in Chapter 2. All these factors are unobserved directly. This study adopted some observed indicators to measure these latent factors (Ajzen, 2005, Chen and Tung, 2014, Bamberg et al., 2007, Chen and Lai, 2011, Bamberg et al., 2003). The first block in this study's travel behaviour questionnaire contains the following indicators.

a. Pro-environment value

The purpose of pro-environment factor is to understand the respondents' awareness of and responsibility for the environmental problems caused by the climate change, global warming, and car and motorbike use. There are 8 questions as the indicators to measure pro-environment value (see Table 3.4).

Table 3.4 Indicators for pro-environment value

No	Questions	Scale	Reference
PE1	I am very concerned about environmental issues	5-likert scale, strongly disagree to strongly agree	(Nilsson and Küller, 2000, Bagley and Mokhtarian, 2002, Kitamura et al., 1997)
PE2	We will all need to make sacrifices in our lifestyles to reduce environmental problems		
PE3	The effects of climate change are too far in the future to really worry me		
PE4	The so called 'environmental crisis' facing humanity has been greatly exaggerated		
PE5	I would be prepared to pay more for environmentally-friendly products		
PE6	If things continue on their current course, we will soon experience a major environmental disaster		
PE7	Technological advances will solve many environmental problems		
PE8	There is an urgent need for something to be done about the environmental pollution caused by car and motorbike use		

b. Attitudes towards public transport

There are five indicators to measure the public's general preference for taking public transport (see Table 3.5). The attitudes' questions are designed to understand if the participants are satisfied with using public transport. Likewise, the questions ask if using public transport is convenient, reliable and cheap for everyday routes.

Table 3.5 Indicators for attitudes towards public transport

No	Questions	Scale	Reference
AT1	For me, to take public transport for everyday routes would overall be	5-likert scale, extremely bad to extremely good	(Bamberg et al., 2007, Ajzen, 2006, Chen and Lai, 2011)
AT2	In the past year, using public transport is a satisfying experience	5-likert scale, strongly disagree to strongly agree	
AT3	For me, using public transport for everyday routes is convenient		
AT4	For me, using public transport for everyday routes is reliable		
AT5	For me, using public transport for everyday routes is cheap		

c. Subjective norms over public transport

Subjective norms over public transport, which refers to the perceptions of social pressure to use public transport, are measured by three indicators to understand social pressure or preference to use public transport (see Table 3.6).

Table 3.6 Indicators for subjective norms over public transport

No	Questions	Scale	Reference
SN1	Most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence	5-likert scale, extremely bad to extremely good	(Ajzen, 2006, Bamberg et al., 2003, Ajzen, 2005, Bamberg et al., 2007, Chen and Lai, 2011)
SN2	Most people who are important to me think that I should use public transport instead of car and motorbike for daily travel from my current place of residence	5-likert scale, strongly disagree to strongly agree	
SN3	Most of my friends and relatives use public transport regularly		

d. Perceived moral obligation (PMO) and perceived behavioural control (PBC) towards public transport

Perceived moral obligation (PMO) refers to the perceptions of moral obligation to use public transport and perceived behavioural control (PBC) towards public transport refers to what extent it is easy or difficult to use public transport (see Table 3.7).

Table 3.7 Indicators for PMO and PBC

	Questions	Scale	Reference
PMO	Regardless of what other people do, because of my own values/principles I feel an obligation to use public transport instead of the car and motorbike for everyday trips	5-likert scale, extremely weak to extremely strong	(Chen and Tung, 2014)
PBC	For me, using public transport for everyday routes is	5-likert scale, extremely difficult to extremely easy	(Anable, 2005, Ajzen, 2006, Bamberg et al., 2003, Chen and Lai, 2011)

e. Intention to use public transport

Intention to use public transport, which refers to the perceptions of motivation to use public transport, is measured by two indicators (see Table 3.8).

Table 3.8 Indicators for intentions to use public transport

	Questions	Scale	Reference
IN1	How likely is it, that in the next 6 months you will use public transport for everyday routes	5-likert scale, very unlikely to very likely	(Ajzen, 2006, Ajzen, 1991, Bamberg et al., 2003, Bamberg et al., 2007, Chen and Lai, 2011)
IN2	My intention to use public transport for everyday routes is	5-likert scale, extremely weak to extremely strong	

2. Subjective measure of walking environment

The second block in the questionnaire is walkability. Previous studies have identified that perceptions of walking environment is associated with opportunities within walking distance, streets connectivity, streets barriers, streets hazards, crime safety, aesthetics, and the distance to facilities (Saelens et al., 2003b, Leslie et al., 2005, Cerin et al., 2009). All these perceived walking environmental indicators except the category of distance to facilities are measured by 5-likert scale; the overall perceived walkability is measured by 7-likert scale (see Table 3.9).

Table 3.9 Indicators for perceptions of walking environment

Categories	No.	Observed measurements	Measurement	Reference
Walking opportunity	WO1	There are many places to go within easy walking distance	5-likert scale, strongly disagree to strongly agree	(Cerin et al., 2009, Leslie et al., 2005)
	WO2	Convenient stores are within easy walking distance		
	WO3	It is easy to walk to a public transport stop (bus, metro or train)		
Street connectivity	SC1	The distance between intersections is usually short (150 metres or less)	5-likert scale, strongly disagree to strongly agree	(Cerin et al., 2009, Leslie et al., 2005)
	SC2	There are many alternative routes for getting from place to place		
	SC3	There are sidewalks on most of the streets in my neighbourhood		
	SC4	There are motorbike parking on the streets and sidewalks blocking the way		
	SC5	There are 'hawkers' and shops on the streets and sidewalks blocking the way		
Traffic safety	TS1	There are crosswalks and pedestrian signals on intersections	5-likert scale, strongly disagree to strongly agree	(Cerin et al., 2009, Leslie et al., 2005)
	TS2	There are so much traffic along nearby streets that it makes difficult or unpleasant to walk in my neighbourhood.		
	TS3	The speed of traffic on most nearby streets is usually slow (40 km/hr or less)		
	TS4	Most drivers exceed the speed limits while driving in my neighbourhood		
Crime safety	CS1	There is high crime rate in my neighbourhood	5-likert scale, strongly disagree to strongly agree	(Cerin et al., 2009, Leslie et al., 2005)
	CS2	There is unsafe to go on walks during at night due to high crime rate		
	CS3	The streets in my neighbourhood do not have many dead-end streets (cul-de-sac)		
Aesthetics	AE1	There are trees along the streets in my neighbourhood	5-likert scale, strongly disagree to strongly agree	(Cerin et al., 2009, Leslie et al., 2005)
	AE2	There are many attractive natural sights in my neighbourhood		
	AE3	My neighbourhood streets are well lit at night		
Distances to services	WT1	Walking time to the nearest convenient store	Estimated walking time: 1) less than 5 mins, 2) 6-10 mins, 3) 11-15 mins, 4) 16-20 mins, 5) 21-30 mins, and 6) 30 mins and over	(Cerin et al., 2009, Leslie et al., 2005)
	WT2	Walking time to the nearest bus stop		
	WT3	Walking time to the nearest supermarket		
	WT4	Walking time to the nearest primary school		
	WT5	Walking time to the nearest post office/ bank		
	WT6	Walking time to the nearest breakfast restaurant		
	WT7	Walking time to the nearest park		
Overall perceived walkability	OPW	Generally, how satisfied do you think your neighbourhood walking environment	7-likert scale, extremely dissatisfied to extremely satisfied	

3. Travel behaviour

Travel behaviour questions include the major mode of transport used for commuting trips, business trips and visiting/shopping trips. For commuting trips, further questions about travel time and travel cost were included. If respondents choose public transport as major mode of transport for commuting trips, further questions about the choices of mode of transport and travel time access to public transport and egress from public transport to destinations were included. Additionally, respondents also asked to report waiting time for public transport and numbers of transfers.

4. Socio-demographic characteristics

Questions about socio-demographic characteristics include gender, age, education, monthly income, occupancy, car and motorbike driver's licence ownerships, household size, numbers of children in household, numbers of car and motorbike in household.

3.3.2.2 Internet-based data collection

An unrestricted self-selection survey method was used for this survey, in other words the survey was open to the public to participate in. Participants could fill the questionnaire using any electronic device, including desktop computers, laptops, tablets and mobile phones, which can access the internet and open the web link. A snowball sampling method was used; the questionnaire web link was sent to contacts in Taiwan through email, Facebook and online chat apps; these contacts were asked both to complete the questionnaire and to forward the web link to their friends in Taiwan. The survey took place in July and August 2015. A total of 1,619 effective responses were collected. The responses covered all of the 19 cities and counties in Taiwan.

3.3.2.3 Issues on Internet-based survey

The use of Internet as a tool to collect data has become very popular in the recent years due to the features of lower costs, faster turnaround and more completeness compared with mail surveys (Benfield and Szlemko, 2006, Luo, 2009). The cost of setting up Web questionnaire is much cheaper than other equivalents. The cost savings of online survey compared with mailing survey include costs of printing, two-way postage, data entry, handling and tracking. In addition, the cost of Internet survey will keep flat if sample size increases (Benfield and Szlemko, 2006). In terms of turnaround, several studies have shown that the response speed of Internet surveys were significantly faster than postal surveys (McDonald and Adam, 2003, Truell et al., 2002). McDonald and Adam (2003) study showed that 40% of responses *via* Internet-based survey were received in the first 24 hours, and more than 85% of responses were received within 7 days. Truell et al. (2002) study showed that the average response period was 9.22 days for Internet-based survey compared with 16.43 days for postal survey. Several studies also found that the response completeness for Internet-based surveys were better than postal surveys (Truell et al., 2002).

Internet-based survey however has some shortcomings such as non-representative of Internet samples and some technical issues. Non-representative of Internet sampling is one of the major disadvantages for Internet-based survey. Internet users tend to be younger, more educated, and affluent (Luo, 2009). Hence, elders and people with less income, and people with less education are more likely to be underrepresented in Internet-based surveys (Luo, 2009). In terms of technical issues, several studies noted that the screen display by different electronic devices such as desktop computers, laptops, smart phones and tablets may vary (Truell et al., 2002). The survey questions show on the screen for different devices may be affected such as text wrapping, font size and style, image alignment, placement, sizes, and colour (Truell et al., 2002). Zhang (2000) reported some problems on Internet-based survey such as survey layout on low-resolution monitors, going back to previous parts of the survey, printing a completed survey, and loading the survey from low-speed Internet connections.

Some measures have been introduced to avoid the shortcomings of Internet-based survey. Firstly, in order to increase senior and younger people to participate the survey, the author especially sent email and message to friends to invite their parents to fill the questionnaire. Likewise, the email also sent to friends whose was teaching at high school in Taiwan to invite their students to fill the questionnaire.

Secondly, in order to avoid duplicate filling in or irrational filling in the questionnaire. The IP addresses of the electronic devices, which were used to fill in the questionnaire, were recorded. The same IP address can only answer the questionnaire once. The times the respondents started and finished the questionnaire were also recorded. After pre-survey in July 2015 for about 40 respondents, all the respondents expressed that the time period of filling in the questionnaire less than 5 minutes were irrational. Hence, this study excluded the data, which the time period of filling in the questionnaire were less than 5 minutes.

Finally, the pre-survey asked the respondents to use different electronic devices to finish the survey to understand if all the accessible electronic devices have friendly interface for respondents to fill in the questionnaire. In terms of low-speed internet connections, due to the advanced development in wifi and 4G infrastructure in communication industry, no respondents replied the problem of low-speed internet connection.

3.3.2.4 Comparing the sample and the population

Comparing the sample to the population of Taiwan (Table 3.10), the percentage of males in the sample (55.7%) is higher than for the whole population (49.9%) (Taiwan Ministry of the Interior, 2015). In terms of age, the sample has a higher percentage of people aged between 25-54 (80.5%) as compared to the population (57.3%) (Table 3.11). The percentage of those aged 15-24 and aged 55 and over in the sample (11.9% and 7.6% respectively) are lower than for the whole population (17.5% and 25.2% respectively) (Taiwan Ministry of the Interior, 2015). This is perhaps because senior people were less likely to use the Internet, required to fill in the online questionnaire (Willis and Tranter, 2006). This means that males and those aged between 25-54 are over represented in the sample; females, and those aged 15-24 and aged 55 and over are underrepresented. However, as the focus of this study is on understanding individual behaviour rather than predicting behaviour for the population this is not of major concern.

Table 3.10 Compare gender ratio between the sample and the population

	Percentage difference between sample and population	The sample		The population	
		Observed frequency	Percentage	Actual frequency	Percentage
Female	-5.8	717	44.3	11,769,664	50.1
Male	+5.8	902	55.7	11,706,976	49.9
Total	--	1,619	100.0	23,476,640	100.0

Data source: (Taiwan Ministry of the Interior, 2015)

Table 3.11 Compare age distribution between the sample and the population

	Percentage difference between sample and population	The sample		The population	
		Observed Frequency	Percentage	Actual Frequency	Percentage
Age 14-18	-5.5	32	2.0	1,435,157	7.5
Age 19-24	-0.1	160	9.9	1,925,604	10.0
Age 25-34	+6.1	395	24.4	3,513,586	18.3
Age 35-44	+14.2	549	33.9	3,796,203	19.7
Age 45-54	+2.9	359	22.2	3,711,938	19.3
Age 55-64	-9.9	112	6.9	3,228,999	16.8
Age 65-79	-7.4	12	0.7	1,614,440	8.4
Total	--	1619	100.0	19,225,927	100.0

1. Data source: (Taiwan Ministry of the Interior, 2015).

Table 3.12Compare city/county distribution between the sample and the population

City/county	Population density (persons/km^2)	Percentage difference between sample and population	The sample		The population	
			Frequency	Percentage	Frequency	Percentage
Chaiyi City	4,540	-0.6	9	0.6	270,883	1.2
Chiayi County	267	-1.7	10	0.6	524,783	2.3
Hsinchu City	3,478	+0.8	44	2.7	431,988	1.9
Hsinchu County	382	+0.5	45	2.8	537,630	2.3
Hualian County	72	-0.9	8	0.5	333,392	1.4
Ilan County	209	-0.7	21	1.3	458,777	2.0
Kaohsiung City	933	+2.1	229	14.1	2,778,992	12.0
Keelung City	2,813	+0.1	27	1.7	373,077	1.6
Miaoli County	310	-1.8	9	0.6	567,132	2.4
Nantou County	125	-1.6	10	0.6	514,315	2.2
NewTaipei City	1,926	+9.4	429	26.5	3,966,818	17.1
Pingtung County	303	-2.5	19	1.2	847,917	3.7
Taichung City	1,225	-4.3	119	7.4	2,719,835	11.7
Tainan City	836	-3.3	77	4.8	1,884,284	8.1
Taipei City	10,049	+12.2	387	23.9	2,702,315	11.7
Taitung County	62	-0.3	12	0.7	224,470	1.0
Taoyuan City	1,726	-3.8	83	5.1	2,058,328	8.9
Yunlin County	518	-1.8	19	1.2	705,356	3.0
Zhanghua County	1,070	-1.8	62	3.8	1,291,474	5.6
Total	639	--	1,619	100.0	23,191,766	100.0

Data source: (Ministry of the Interior, 2014)

3.3.2.5 Descriptive statistics

As can be seen in Table 3.13, about 85% of respondents had car or motorbike driver's licence. Monthly income ranged from US$ 333 and under to US$3,334 and over. Middle income group (monthly income US$ 1,333-2,000) had the highest percentage of all income groups. In terms of household car and motorbike ownerships, more than 80% of the respondents had at least one car and motorbike in household respectively. The percentage of households with at least one motorbike was similar to the data from the Taiwanese Household Income and Expenditure Survey- 83% household owned at least one motorbike while the percentage of households with at least one car is higher than the data from the Taiwanese Household Income and Expenditure Survey- 59% household owned at least one motorbike(Directorate General of Budget Accounting and Statistics, 2014). About half of respondents (45.6) had children aged under 18 in the household.

Table 3.13 Socio-demographic statistics

Items	Categories	Frequency	Percentage
Car driver's licence	No	253	15.6
	Yes	1366	84.4
Motorbike driver's licence	No	239	14.8
	Yes	1380	85.2
Monthly income (US $[1])	<=333	138	8.5
	334-666	58	3.6
	667-1,333	377	23.3
	1,333-2,000	436	26.9
	2,001-2,666	272	16.8
	2,667-3,333	100	6.2
	3,334 and over	139	8.6
	Missing	99	6.1
Household car ownership	0	305	18.8
	1	876	54.1
	2	352	21.7
	3	71	4.4
	4 and more	15	.9
Household motorbike ownership	0	271	16.7
	1	547	33.8
	2	434	26.8
	3	217	13.4
	4 and more	150	9.3
Children (aged under 18) in household	No	880	54.4
	Yes	739	45.6

1. Exchange rate US$: NT$ (New Taiwan Dollars)=1:30

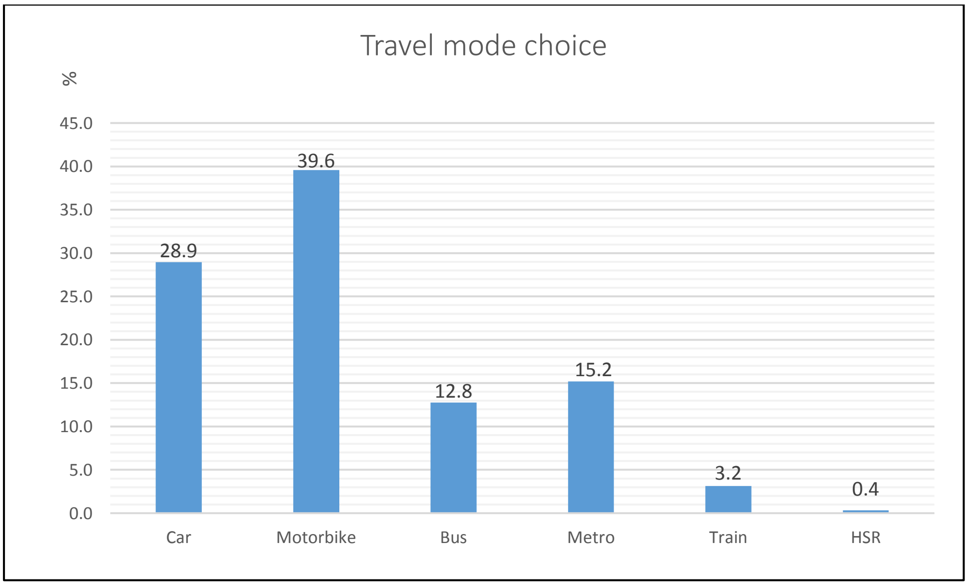


Figure 3.2 Travel mode choice for online survey data

3.3.3 2011 Taiwanese Mode Choice Behaviour Survey data

This study uses the 2011 Taiwanese Mode Choice Behaviour Survey to study the influence of public transport provision and land use variables on travel mode choice behaviour, which are RQ2 and RQ3. The survey was originally collected for the project of 'Evaluation and feedback on benefits of promoting public transport development policy – analysis of changes in mode choice behaviour and establishment of decision support systems', which was initiated by Taiwanese Institute of Transportation (Institute of Transportation, 2011b).

3.3.3.1 Questionnaire

Household travel survey was the main method to design the questionnaire. There are four parts in the questionnaire as the following.

1. Trip features

The respondents were asked to report the trip features of their most frequent trips. Trip features include trip purpose, trip frequency per week, companions of the trip, trip origin (district), trip destination (district), departure time of day and return time of day.

2. Travel mode choice

Respondents need to report what mode of transport they chose. If private vehicle (car, motorbike and bike) was chosen, respondents were asked to report walking time to access the chosen modes, in-vehicle time, searching time for parking space, parking cost and fuel cost. If public transport (bus, metro, rail and taxi) was chosen, respondents were asked to report walking time to public transport stop/station, waiting time, in-vehicle time and fare cost.

3. Satisfaction on modes of transport

Eleven indicators were adopted to measure four latent factors in this part. The four latent factors, which are convenience, reliability, safety and comfortability are related to respondents' satisfaction with each mode of transport. Five-likert scale was used to assess these 11 indicators.

4. Socio-demographic characteristics

Socio-economic characteristics include individuals' gender, age, education, occupancy, wage, car and motorbike driver's licence, households' car, motorbike and bike ownership, household size, number of children in household, and household income.

3.3.3.2 Data collection

The survey was implemented by postal survey in 2011 between September and October. Due to inaccessible to the overall household addresses in Taiwan as the sampling population, the postal survey used registered car and motorbike addresses data in

Taiwan as sampling population. There are about 8 million households in Taiwan (Taiwan Ministry of the Interior, 2015), and the total amount of registered car and motorbike are about 7 million and 15 million respectively.

In order to understand travel mode choice behaviour for both vehicle (car and motorbike) owner and non-vehicle owner, two questionnaires were sent to the chosen households – one questionnaire for the designated vehicle owner and another for non-vehicle owner in the household who was aged 15 and over.

The expected effective sample size was 5,000 respondents. Stratified random sampling was used. The expected sample size depends on the population of the city/county, as shown in Table 3.14. The 19 cities/counties in Taiwan was classified into three city types: Taipei metropolitan area, sub-main cities/counties and rural counties according to their population and socio-economic features (Chiou et al., 2013). The expected sample size for each type is 1,930 for Taipei metropolitan area, 2,024 for sub-main cities/counties and 1,046 for rural cities/counties respectively.

There were totally 100,000 questionnaires distributed (50,000 for vehicle owner and 50,000 for non-vehicle owner) and 6,860 samples were collected (6.9% return rate). Excluded incomplete questionnaires, and bike and taxi trips, 5,355 effective samples were used in this study's analysis. The chi-square test (Chi-square=0.070) show that the effective samples and expected samples for the 19 cities/counties were no significant difference at 95% confidence level.

The gender ratio and age distribution for sample and population are compared in Table 3.15 and Table 3.16. The gender ratio difference between the sample and population is quite small (Table 3.15). In terms of age, the distribution for age groups between 25-54 in the sample is slightly higher than the population.

Table 3.14 Expected sample size and effective sample size

Name	City types	Population (2011)	Expected samples	Effective samples
Taipei City*	A	2,607,428	568	616
New Taipei City*	A	3,873,653	845	1065
Keelung City	A	388,321	85	85
Taoyuan City*	A	1,978,782	432	589
Taichung City*	B	2,635,761	575	536
Tainan City*	B	1,875,406	409	470
Kaohsiung City*	B	2,770,887	604	627
Hsinchu City	B	411,587	90	94
Changhua County	B	1,312,467	286	247
Chiayi City	B	273,861	60	66
Hsinchu County	C	510,882	111	161
Miaoli County	C	561,744	123	135
Nantou County	C	530,824	116	96
Yunlin County	C	722,795	158	135
Chiayi County	C	547,716	119	87
Pingtung County	C	882,640	193	143
Ilan County	C	461,625	101	107
Hualian County	C	340,964	74	67
Taitung County	C	232,497	51	29
	Total	22,919,840	5000	5355

Table 3.15 Gender ratio between the sample and the population

	Percentage difference between sample and population	Sample		Population	
		Observed Frequency	Percentage	Actual Frequency	Percentage
Female	-1.1	2,622	49.0	11769664	50.1
Male	+1.1	2,733	51.0	11706976	49.9
Total	--	5,355	100.0	23476640	100

Source: Taiwan Ministry of the Interior (2015)

Table 3.16 Age distribution between the sample and the population

	Percentage difference between sample and population	Sample		Population	
		Observed Frequency	Percentage	Actual Frequency	Percentage
10to 14	-3.4	127	2.4	1,157,807	5.8
15-24	-2.7	682	12.7	3,110,907	15.5
25-34	+6.3	1,273	23.8	3,513,586	17.5
35-44	+4.6	1,255	23.4	3,796,203	18.9
45-54	+2.9	1,143	21.3	3,711,938	18.4
55-64	-4.0	642	12.0	3,228,999	16.0
65	-3.7	233	4.4	1,614,440	8.0
Total	--	5,355	100.0	20,133,880	100.0

Source: Taiwan Ministry of the Interior (2015)

3.3.3.3 Limitations of the survey data

The 2011 Taiwanese Travel Mode Choice Survey data has some limitations due to the questionnaire design and household mail sampling. Firstly, the trip features data collected from the survey was that only most frequent trips reported by respondents but not include all trips made by them. This means that commuting trips and school trips were likely to be overrepresented in the dataset and social and leisure trips are likely to be underrepresented (Department of Statistics, 2012). Some of the tour features, such as stops or transfers within the trips are not reported in the survey.

Secondly, non-coverage sampling error may occur because some households' addresses were excluded on the mailing list (Dillman, 1991). Only those households owned at least one car or at least one motorbike were in the sampling population. The statistics in 2011 showed that 59.1% out of all households owned at least one car and 83.0% out of all households owned at least one motorbike in Taiwan (Directorate General of Budget Accounting and Statistics, 2014). Although the penetration rates for car and motorbike, especially motorbike, are quite high, there was still small percentage of households that did not own any car and motorbike which were excluded in the sampling population. Their travel mode choice behaviour was ignored in the survey.

Thirdly, the potential bias arises because the inconsistence between the sampling target: individual, and household. Households were sampled as intermediary units of the sampling target: individuals in this survey. This survey did not adopt any approach of within household sampling. From the comparison of gender ratio and age distribution between sample and population (Table 3.15 and Table 3.16), the difference is small. Hence, the bias from not doing household sampling is not an important issue.

3.3.3.4 Descriptive statistics

Descriptive statistics for gender, age, monthly income, education, car and motorbike driver's licence can be seen in Table 3.17. The percentage of male to female was 48.8% to 51.2%, which was similar to the population (male: female = 49.9 : 50.1, (Taiwan Ministry of the Interior, 2015)). Aged 25-34 had the highest percentage (24.2%) among all the age groups. Monthly income between US$ 667-1333 had the highest percentage (33.2%) among all the income groups and the lowest income group (monthly income US$ 333 and under) was the second highest proportion (Table 3.17). In terms of education level, about half of the respondents had bachelor's degree and more than 85% of respondents enjoyed high school education level and higher. In terms of car and motorbike driver's licence, about 79% and 86% of all the respondents had car driver's licence and motorbike driver's licence respectively (Table 3.17).

Table 3.17 Descriptive statistics of socio-demographic characteristics

Items	Categories	Frequency	Percentage
Gender	Male	2614	48.8
	Female	2741	51.2
Age	10-14	122	2.3
	15-24	653	12.2
	25-34	1297	24.2
	35-44	1276	23.8
	45-54	1141	21.3
	55-64	638	11.9
	65 and over	228	4.3
Monthly income (US$[1])	333 and under	1294	24.2
	334-666	560	10.5
	667-1333	1780	33.2
	1334-2000	1016	19.0
	2001-2666	406	7.6
	2667-3333	150	2.8
	3334 and over	149	2.8
Education	Middle school and under	709	13.2
	High school	1589	29.7
	Bachelor degree	2549	47.6
	Master degree	469	8.8
	Doctoral degree	39	0.7
Car driver's licence	Yes	4211	78.6
	No	1144	21.4
Motorbike driver's licence	Yes	4624	86.3
	No	731	13.7

1. Currency exchange rate: US$:NTW$(New Taiwan Dollars)=1:30

Descriptive statistics for household characteristics such as household income, car and motorbike ownerships, children in household can be seen in Table 3.18. Household monthly income between US$ 1001-1666 had the highest percentage (22.4%) among all the household income groups. This is followed by household monthly income between US$ 2334-3333 (21.7%). In terms of household car and motorbike ownerships, one car in the household was the largest proportion (57.5%), and two motorbikes in household was the largest proportion (34.3%) compared with other car and motorbike ownership groups respectively (Table 3.18). About 90% and 92% of respondents had at least one car and motorbike in the household respectively. These numbers are higher than the data of Taiwanese Household Income and Expenditure Survey, which showed that 59.1 % and 83.0% of household owned at least one car and motorbike respectively (Directorate General of Budget Accounting and Statistics, 2014). This is caused by the samples of 2011 Taiwanese Mode Choice Survey were extracted from car and motorbike registered addresses data. Hence, households with car and motorbike ownerships will be overrepresented in the survey. About half of the respondents had children (aged under 18) in household.

Table 3.18 Descriptive statistics of household characteristics

Items	Category	Frequency	Percentage
Household monthly income (US$[1])	1000 and under	702	13.1
	1001-1666	1201	22.4
	1667-2333	924	17.3
	2334-3333	1162	21.7
	3334-5000	861	16.1
	5001-6666	284	5.3
	6667 and over	221	4.1
Household car ownership	0	530	9.9
	1	3080	57.5
	2	1356	25.3
	3	292	5.5
	4 and over	97	1.8
Household motorbike ownership	0	426	8.0
	1	1400	26.1
	2	1838	34.3
	3	1033	19.3
	4 and over	658	12.4
Children (aged under 18) in household	Yes	2544	47.5
	No	2811	52.5

1. Currency exchange rate: US$:NTW$(New Taiwan Dollars)=1:30

Figure 3.3 and Figure 3.4 show trip purposes and travel model choice. In terms of trip purposes, more than half of all trips (58.5%) were work trips. About 20% of all trips were visiting and shopping trips. This is followed by about 12% of school trips (Figure 3.3). In terms of travel mode choice, about half of all trips (46.9%) used motorbike as transport mode (Figure 3.4). This is followed by car (32.5%). About 21% trips used public transport (Figure 3.4).

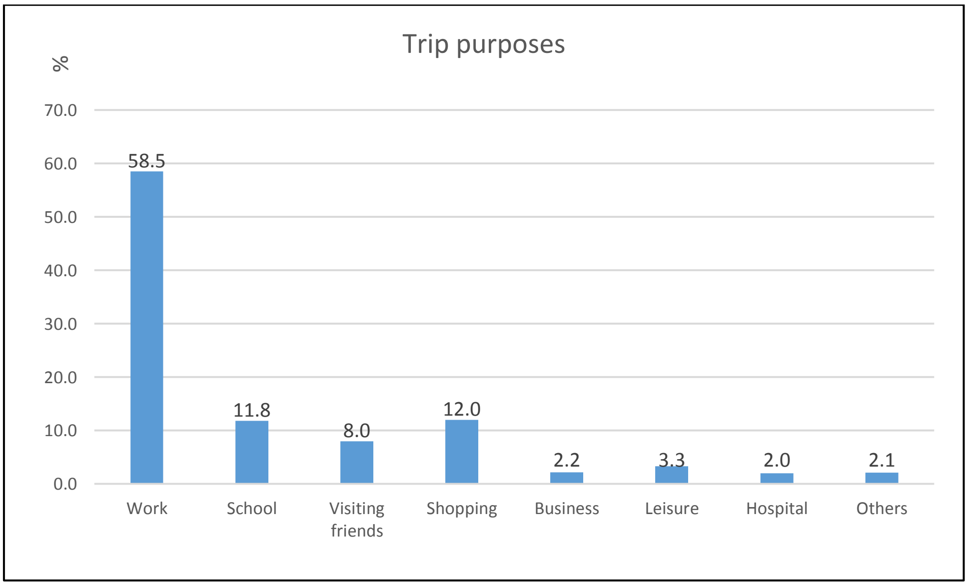


Figure 3.3 Trip purpose

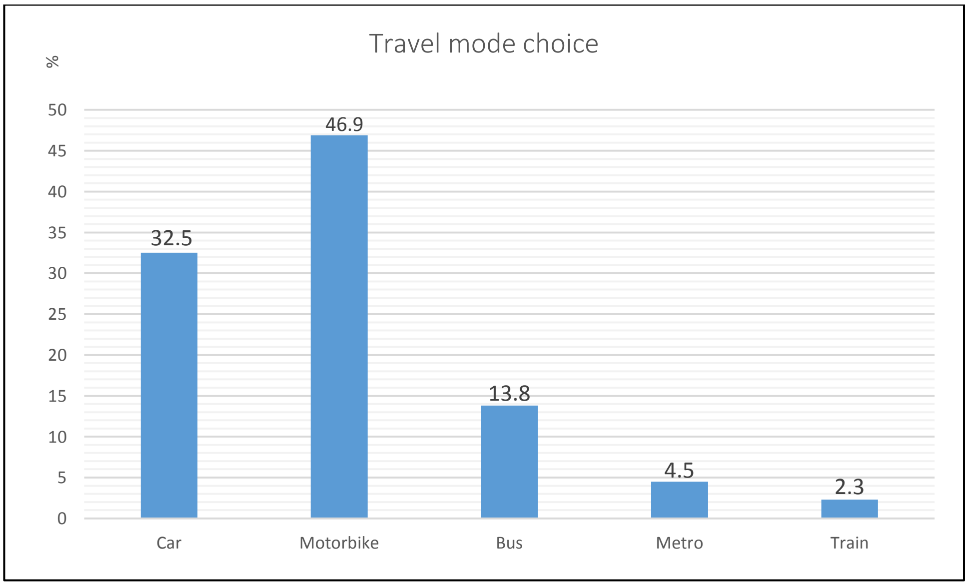


Figure 3.4 Travel mode choice

3.3.4 Supplementary data

Some GIS data and analysis, which ArcGIS 10.1 is used, are conducted in this study. The GIS data which include topographic data, road network, public transport network, land use and points of interests were described as the followings.

Road network and street pattern data was drawn from the Traffic Network Digital Map database under Taiwanese National Geographic Information System (TNGIS) (Institute of Transportation, 2009). The Traffic Network Digital Map includes the digital data of all the roads with width wider than 6 metres in Taiwan. The database was built in 2001 and kept periodically updating. This study used the version of 2009 updated road network GIS data (Institute of Transportation, 2009).

Bus networks' GIS data were collected from Directorate General of Highways (DGH), which is responsible for intercity bus management, and the 19 city/county governments, which are responsible for local bus management. The bus network data includes bus routes and bus stops GIS data, and the frequencies of all the bus networks.

The GIS maps of rail systems including metro, intercity rail and high-speed rail were drawn from the Traffic Network Digital Map database (2009) under TNGIS. The GIS data include the routes and stations of metro, intercity rail and high-speed rail.

Land use data includes population density, job density, land use mix, and road network and street pattern. The land use mix data is drawn from the Taiwanese National Land Surveying and Mapping Centre, which provide land use data for each village at a resolution of 1/25,000. Population density data was drawn from the socio-demographic database under Taiwanese National Geographic Information System (TNGIS) (Ministry of the Interior, 2014), which provide the areas and population for each village. Job density data was drawn from 2011 Industry, Commerce and Service Census Data (Directorate-General of Budget Accounting and Statistics, 2014), which provide the numbers of employers for each village. Village is the smallest administrative unit in Taiwan.

Land use mix GIS data was collected from National Land Surveying and Mapping Centre, Taiwan. The land use types are divided into night categories including agricultural, forest, transport, river, residential, recreational, commercial/industrial, government/institutional, and mining land-use with a resolution of 1/25,000.

Street patterns data, which include percentage of 4-way intersections and numbers of cul-de-sac, were drawn from the road network GIS data. ArcGIS 10.1 was used to extract the street pattern data. The procedures of getting 4-way intersections are first to open the road networks from the Traffic Network Digital Map database. Then, exclude highways, expressways, and the roads without breaks at underpasses and overpasses from the road networks. The third step is to run Feature Vertices to Point in ArcGIS to identify the intersections. The type of the point data show the intersection types of the points. The 4-way intersections are the points type number 4 and the cul-de-sac is the points with type number 1.

3.4 Methodologies

3.4.1 Thematic analysis

Thematic analysis is a method to formalize the identification and development of themes within data (Thomas and Harden, 2008, Braun and Clarke, 2006).

Deductive approaches are used in the study of public transport policy implementation. Deductive approach is used when the structure of analysis is operationalised on the basis of previous knowledge and studies. The purpose of deductive approach is theory testing (Elo and Kyngäs, 2008). The deductive approach starts with existing theoretical frameworks or models that drive the different aspects of analysis (Hernandez and Titheridge, 2015). This study reviewed the theoretical models for policy implementation in Chapter 2.5 understanding the potential factors influence policy implementation. Then, apply the theoretical frameworks into public transport policy implementation.

3.4.2 Measures of walking environment

Walking environment can be measured objectively and subjectively. According to the ecological model of walking (Sallis et al., 2006, Alfonzo, 2005), an individual's interaction with the walking environment is through a cognition process (Alfonzo, 2005, Ewing and Handy, 2009, Sallis et al., 2006). An individual's perceptions of the walking environment may be influenced by his/her reaction to the physical (objective) walking environment (Alfonzo, 2005). People may differ with respect to the affordances they perceived within the environment. For example, within the same setting such as street block length, presence of sidewalks and sidewalks widths, one individual may perceive the physical walking environment has met his/her need for connectivity, whereas another person may not. An individual's perceived walking environment - subjective measure of walking environment - determines their perceived overall walkability and walking behaviour (Alfonzo, 2005, Ewing and Handy, 2009, Ewing et al., 2006).

Objective walking environment measures attempt to capture urban form and urban design using data either collected in the field (Hoehner et al., 2005, De Vries et al., 2007) or from existing spatial and land use databases (Frank et al., 2010, Lee and Moudon, 2006, Frank et al., 2005). Proximity and connectivity are the most frequently captured built environmental features in studies of walking behaviours (Frank et al., 2010, Leslie et al., 2007, Owen et al., 2007, Saelens et al., 2003a, Frank et al., 2005). Proximity, which is similar to accessibility, refers to opportunities to access different activities by walking (Leslie et al., 2007, Saelens et al., 2003a, Frank et al., 2010). Proxy measures frequently used to represent proximity are density (population density or dwelling density) and the level of land use mixing (Leslie et al., 2007, Frank et al., 2010). Connectivity measures the directness and convenience of the pathways between households and destinations (Saelens et al., 2003a, Leslie et al., 2007, Frank et al., 2010). Proxy measures of connectivity are often based on street layout measures such as the density of intersections, average length of road segments and the numbers of cul-de-sacs (Frank et al., 2010, Leslie et al., 2007, McGinn et al., 2007). Comfort, safety, and neighbourhood aesthetics tend to be captured using measures such as sidewalk widths, percentage of sidewalks present, traffic volumes, traffic speeds, numbers of road traffic collisions, numbers of street lights, presence of graffiti and the numbers of trees along sidewalks (Boehmer et al., 2006, McGinn et al., 2007, Rodríguez and Joo, 2004, Vernez Moudon et al., 2007, Alfonzo, 2005).

Subjective measures of the walking environment are self-reported perceptions of the walking environment usually obtained from survey questionnaires (Saelens et al., 2003b, Leslie et al., 2005, Cerin et al., 2009, Cerin et al., 2010, McGinn et al., 2007, Cerin et al., 2008, Lin and Moudon, 2010). The Neighborhood Environment Walkability Scale (NEWS) and its abbreviated forms, NEWS-A, is one of the frequently used survey instruments for capturing perceptions of the walking environment (Cerin et al., 2010, Cerin et al., 2009, Cerin et al., 2007, Cerin et al., 2006, Leslie et al., 2005, Saelens et al., 2003b, Cerin et al., 2008). Participants are asked to rate their neighbourhood (local environment) for a number of different factors, including land use mix, street connectivity, infrastructure for walking, neighbourhood aesthetics, traffic hazards, and crime safety (Cerin et al., 2010, Cerin et al., 2009, Cerin et al., 2007, Cerin et al., 2006, Leslie et al., 2005, Saelens et al., 2003b, Cerin et al., 2008). Chiang and Weng (2012) used NEWS-A to examine the association between subjective measures of the walking environment, and walking duration and walking frequency in Taiwan and found statistically significant relationships between them.

Several studies have examined the correlations between objective measures of the walking environment and perceptions of walking environment and have found only low agreement between the objective measures and the perceived walking environment factors tested (Boehmer et al., 2006, McGinn et al., 2007, Gebel et al., 2009, McCormack et al., 2007, Cerin et al., 2008). This is hardly surprising given subjective measures of walking environment capture individuals' reactions, which reflect their perceptions of an affordance for a particular need (Alfonzo, 2005) and thus are varied from person to person, whilst objective measures do not. For example, under the same objective measures of walking environment, an individual who prefers walking may perceive a high level of walkability, whereas another person who is accustomed to using a private vehicle may perceive a low level of walkability. Cerin et al. (2008), however, found associations between objective measures of dwelling density, intersection density, land use mix and net retail area with perceived measures of residential density, land use mix, access to services and walking infrastructure, traffic safety, traffic speed.

Although several recent studies have used both objective and perceived walking environmental factors in their analysis, most of them only examined the correspondence between objective measures and self-reported perceptions of walking environmental factors. Few studies have incorporated both objective measures of walking environmental features and perceived environmental factors with walkability and walking behaviour. This is required if we wish to test the ecological walking behaviour model proposed by Sallis et al. (2006) and Alfonzo (2005), that walking-decision making is a cognition process of individual interaction with objective walking environment. There is currently a lack of an evidence to verify this model. Past studies (Sallis et al., 2006, Alfonzo, 2005, Ewing et al., 2006) have suggested that subjective measures of the walking environment seem to act as mediators between objective measures of the walking environment, and walkability and walking behaviour, however very few studies have tested this conceptual model.

3.4.3 Multilevel multinomial logit (MNL) models

Several previous studies have stressed that the analysis of the impacts of land use on travel behaviour often involves hierarchically structured data (Overmars and Verburg, 2006, Jones and Duncan, 1996). A hierarchy refers to units grouped at different levels. In the analysis of the effects of land use factors on travel behaviour, individuals' travel behaviour data and zonal area data, such as land-use, often have the features of hierarchical clustering (Bhat, 2000). For example, in a travel mode choice context, individuals are clustered in households and households in districts and districts in cities/counties. Multilevel MNL models are used to analyse the effects of land use across trip origin and destination, and at different geographic scales on travel mode choice due hierarchical features for land use data.

When analysing the effects of land-use on travel behaviour, the influence of urban context on travel behaviour is not restricted to a single geographical scale. Geographic scales for land use and travel behaviour studies has been seen as one of the important issues (Verburg et al., 2004, Crane, 2000). Boarnet and Crane (2001) asserted the importance of examining different scales of geography when studying the link between land-use and travel behaviour. The land-use at different scales has different influence on dependent variables. For example, Boarnet and Crane (2001) tested the effects of land-use (population density, retail employment density and service employment density) at census block group level and zip code level on trip demand, and the results showed that land-use variables only had significant effects on trip demand if measured at zip code level.

There are also a number of issues that can result when disaggregate or spatially-continuous data is summarised using geographical zones. Badoe and Miller (2000) contended that zonal-aggregated data in land-use and transportation interaction studies flatten the variance of land-use variables. Moreover, Snellen et al. (2002) contended that the aggregation of data results in fewer values for fewer units of observation, inclining to reducing the power of statistical analysis. In addition, such studies might also suffer from the ecological fallacy if doing inference of individual behaviour from the results of aggregation analysis (Antipova et al., 2011). The problems of geographic scale and aggregation are also known as the Modifiable Areal Unit Problem (MAUP) (Green and Flowerdew, 1996, Spielman and Yoo, 2009). The geographic scale problem refers to the variation in results obtained when data for one set of areal units is progressively aggregated into fewer or larger zones for analysis. Moreover, aggregation problem refers to the variation in results obtained from different ways of subdividing geographical space at the same scale (Green and Flowerdew, 1996). On the other hand, disaggregation implies that the sample size is arbitrarily increased and results in rejecting null hypothesis more easily (Snellen et al., 2002). Likewise, the variability between places might be ignored by the disaggregate analysis (Antipova et al., 2011).

Due to the features of hierarchical structured data in the integration analysis of land-use and travel behaviour, travel behaviour is not only affected by within group factors but also affected by between group factors at higher level. Multilevel modelling technique can recognize between group differences by allowing intercept and slope varied randomly. On top of that, random intercept and slope can be explained by between group factors at higher level. The effects of variables at various levels are adopted simultaneously in the modelling process.

Jones and Duncan (1996) discussed the requirements of a modelling approach relating to geography and people, and their interactions. Generally, there are three most important requirements. Firstly, both people and places make a difference. Hence, individual characteristics and place features should be considered simultaneously in a model. Secondly, a model should consider the effects of place heterogeneity. For example, the heterogeneity between households and neighbourhoods might assert some effects on individuals' travel behaviour. Thirdly, a model should take into account the interactions between different levels (Jones and Duncan, 1996). Schwanen et al. (2004) also asserted that land use variables at various geographical scales should be linked to travel behaviour analysis because the influence of the urban context on travel behaviour is not restricted in a single geographical level. The multilevel model fits for the requirements aforementioned (Antipova et al., 2011, Jones and Duncan, 1996) to deal with geographic scale problem.

Several studies have suggested that the multilevel modelling method can accommodate these hierarchical features of land use within travel behaviour modelling, and can accommodate zone differences and different geographic scales (Hong and Goodchild, 2014, Overmars and Verburg, 2006, Jones and Duncan, 1996). Multilevel models can accommodate spatial autocorrelation, spatial heterogeneity, higher-level context, and simultaneous handling of the micro-scale of individuals and the macro-scale of places (Bhat, 2000). Traditional single-level multinomial logit models (MNL) and nested logit (NL) models ignore between group variations and can lead to an inferior data fit (Bhat, 2000). However, only a few studies have adopted a multilevel modelling method to study land use and travel behaviour interrelationships (Ding et al., 2014, Hong and Goodchild, 2014, Antipova et al., 2011, Li et al., 2005, Schwanen et al., 2004, Snellen et al., 2002, Bhat, 2000).

Multilevel multinomial logit models are extended from multinomial logit (MNL) models to deal with hierarchical data of land use. The logit family of models have been perceived as the vital toolkits for studying discrete choices. This section introduces the methodologies of multinomial logit (MNL) model and then extends to multilevel MNL model.

3.4.3.1 Multinomial logit (MNL) models

MNL model is used to study the influence of public transport provision on travel mode choice, which is RQ2. The basic assumption of MNL models is that choice probability is deriving from utility-maximizing behaviour (Train, 2009). Each alternative in the choice set, such as travel modes of transport has its own linear utility function depending on the attributes of the alternative. Individuals make their choice decision by assuming to select the transport mode that yield the highest utility. Because of unobserved factors influence individual's preference, the utility function is composed of a systematic component and a random component. The utility function can be expressed as the following.

$$U_{it} = V_{it} + \varepsilon_{it} \qquad \textit{(Equation 3.1)}$$

$$V_{it} = \beta_{i0} + \beta_{im} x_{mt} \qquad \textit{(Equation 3.2)}$$

where U_{it} is the true utility of the alternative i to the decision maker t,

V_{it} is the deterministic or observable portion of the utility estimated by the analyst,

ε_{it} is the error or the portion of the utility unknown to the analyst,

β_{i0} is the alternative constant for alternative i,

β_{im} is the parametre for x_m variable in alternative i,

x_{mt} is the value of the m attribute for individual i.

By assuming that the random terms of the utility functions are independent and identically

Gumbel-distributed, the multinomial logit model framework used for estimating the probability of mode *(i)* for person *(n)* is expressed as:

$$Prob(i) = \frac{exp(V_i)}{\sum_{j=0}^{J} exp(V_j)} \;, \; j=0,\ 1,\ 2,\ldots,\ J. \qquad \textit{(Equation 3.3)}$$

where $Prob(i)$ is the probability of the decision-maker choosing alternative i and

V_j is the observable component of the utility of alternative j.

The elasticity can be obtained as (Train, 2009)

$$E_{ix_m} = \beta_{im} \widehat{x_m} (1 - Prob(i)) \qquad \textit{(Equation3.4)}$$

3.4.3.2 Multilevel MNL models

The multilevel MNL model is based on a MNL model with linear utility function. It allows the intercept of the utility functions to vary randomly over clusters. The utility function of the multilevel MNL model includes two parts, a fixed part and a random part. In order to capture the spatial heterogeneity, two random terms (combined as the random part) are included in the utility functions. The fixed part of the model includes variables at individual level and higher level.

Assuming a three-level multilevel MNL model (individual-level denotes i, district-level denotes j, and city/county-level denotes k), the predict function can be expressed as

$$U_{ijk} = \beta_{0jk} + \beta_{ijk}x_{ijk} + \epsilon_{ijk}, \qquad \textit{(Equation 3.5)}$$

where U_{ijk} is the utility function between car, motorbike and public transport and x_{ijk} is the individual-level's explanatory variables such as gender, age, monthly income, car driver's licence, motorbike driver's licence, children in household, trip purpose and trip distance in this study. β_{0jk} is district-level specific intercepts which reflects the variance between districts. β_{ijk} represents coefficients for x_{ijk} . ϵ_{ijk} is the individual-level residual terms.

If β_{0jk} is allowed to vary across districts and adds district-level contextual variables to explain the variance of β_{0jk} (between districts variance), then district-level model can be expressed as following:

$$\beta_{0jk} = \gamma_{00k} + \gamma_{01k}\omega_{jk} + \zeta_{0j} \textit{ (district-level model)}, \qquad \textit{(Equation 3.6)}$$

where γ_{00k} is city/county-level specific intercepts, ω_{jk} is district-level explanatory variables, and γ_{01k} is coefficients for the district-level explanatory variables. ζ_{0j} is the district-level random terms representing spatial heterogeneity between districts.

If γ_{00k} is allowed to vary across city/county and adds city/county-level contextual variables such as density, land use mix, road length and bus operation length to explain the variance of γ_{00k} (between city/county variance), then city/county-level model can be expressed as following:

$\gamma_{00k} = \pi_{000} + \pi_{001}\theta_k + \psi_{00k}$ *(city/county-level model),* *(Equation 3.7)*

Where π_{000} is city/county-level specific intercepts, θ_k is city/county-level explanatory variables, and π_{001} is coefficients for the city/county-level explanatory variables. ψ_k is the city/county-level random terms representing spatial heterogeneity between city/county.

Substituting the city/county level model and district-level model for the coefficients γ_{00k} and β_{0jk} in equation (4) and equation (3) into the individual-level model in equation (2), we obtain the reduced form as following:

$U_{ijk} = \pi_{000} + \beta \ \ x_{ijk} + \gamma_{01k}\omega_{jk} + \pi_{001}\theta_k + \zeta_{0j} + \psi_k + \epsilon_{ijk}$ (*Equation 3.8)*

Where, $\pi_{000}$is constant of the function. $\beta \ \ x_{ijk} + \gamma_{01k}\omega_{jk} + \pi_{001}\theta_k$ is fixed part of the function. And $\zeta_{0j} + \psi_k + \epsilon_{ijk}$ is random part of the function. Random terms at different levels are independent. Random terms at district-level and city/county-level are assumed to be normally and identically distributed, and random terms at different levels are independent.

$\zeta_{0j}^m \sim N\left(0, \sigma^2_{\zeta_{0j}^m}\right), \psi_{00k}^m \sim N\left(0, \sigma^2_{\psi_{00k}^m}\right)$ *(Equation 3.9)*

The random terms at individual-level, ϵ_{ijk}, are independent and identically distributed with Gumbel (type 1 extreme value) distribution with a variance (σ_ϵ^2) of $\pi^2/6$ (Train, 2009). Then the choice probability is as Equation 3.3.

3.4.3.3 ICC (Intra-class correlation)

The intra-class correlation coefficient (ICC) refers to the proportion of between group variance to total variance (Snijders, 2012). It is also equal to the correlation between values of two randomly drawn individuals in the same, randomly drawn group (Snijders, 2012). ICC is calculated by dividing the between-group variance by the total variance. The between-group variance in this study means the mode choice behaviour difference between districts or city/county. The ICC values for empty models (a model that only adopts random effects without any explanatory variables) of linear regression models often range between 0.10 and 0.25 (Snijders, 2012). A greater ICC value for empty model indicates that adoption of the multilevel model is meaningful.

3.4.3.4 Multilevel modelling studies in transport field

Multilevel modelling techniques have been used in several travel studies. Most of these studies used a model form with a linear structure and continuous dependent variables, such as travel distance, travel time, vehicle miles travel (VMT) and trip frequency (Antipova et al., 2011, Bottai et al., 2006, Li et al., 2005, Schwanen et al., 2004, Snellen et al., 2002). Schwanen et al. (2004) employed a four-level (individual, household, residential and regional) multilevel regression model to analyse the influence of urban form on mode choice, travel time and travel distance for commuters in the Netherlands. Snellen et al. (Snellen et al., 2002) studied the relationships between individual level socio-demographic characteristics, neighbourhood level land-use variables, and mode choice for frequently conducted activities. They found that urban land use variables only had a modest influence on the dependent variable. Antipova et al. (Antipova et al., 2011) used a two-level (individual and neighbourhood) multilevel modelling method to analyse the impact of land use on commuting distance and time. Li et al. (Li et al., 2005) also used a two-level (neighbourhood and residential) multilevel model. They analysed the relationship between built environment and walking activity for senior people. Nevertheless, only limited attention has previously been given to applying multilevel models to discrete responses.

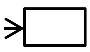
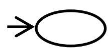
3.4.4 Structural equation model (SEM) and generalized structural equation model (GSEM)

Research question 4 and 5 are answered by adopting the methodologies of structural equation model (SEM) and generalized structural equation model (GSEM). Structural Equation Modelling (SEM) is a methodology that combines multivariate models, such as multiple regression analysis, factor analysis, and simultaneous equation modelling to test and explain complex relationships between observed (also called measured) and unobserved (also called latent) variables and relationships between two or more latent variables. It is quite common used in psychological, economical and behavioural studies (Bamberg et al., 2003, Chen and Chao, 2011, Chen and Tung, 2014), for example, Thøgersen (2009) adopted SEM to analysed the influence of unobserved psychological factors: attitudes, subjective norms, perceived behavioural control on behaviour intentions and use of public transport behaviour. Both research questions 4 and 5 relate to multiple and interrelated relationships between several independent and dependent variables. Additionally, some dependent variables are independent variables for other dependent variables. Hence, this study uses SEM and GSEM to examine the complicated associations in research question 4 and 5.

There are three major advantages for SEM (Kline, 2011, Hair et al., 2009). Firstly, SEM can estimate a set of multiple and interrelated relationships between one or more independent variables and one or more dependent variables. Secondly, both of independent and dependent variables can be observed variables or unobserved concepts. SEM accounts for the measurement error in the estimation process. Lastly, due to the above advantages, SEM is a method to deal with a systematic set of relationships by providing a consistent and comprehensive explanation of phenomena. However, SEM is an exemplification of a theory. Therefore, a theory should be prior to the structural equation models. Without a theoretical support, the proved causal relationships from SEM remain correlated relations (Kline, 2011, Hair et al., 2009).

There are two major components in the SEM: 1) structural model and 2) measurement model. Due to complexity of the model, structural equation models are often visualized by a graphical path diagram, which draws the relationships of the two major components based on theory and hypothesis.

3.4.4.1 Path diagram

A path diagram is a visual representation of a model (Figure 3.5). It makes up of boxes and circles, which are connected by arrows, describing the full set of relationships among the model’s constructs (Skrondal and Rabe-Hesketh, 2004). Generally, rectangle or square box represents observed variable and circle or ellipse represents latent variable. Straight line with single headed arrow signifies the causal relationships in the model and curve line with double-headed arrows signifies covariance or correlation.  represents measurement error existing only in measurement model.  represents residual of the latent endogenous construct existing only in structural model for latent endogenous variables (Skrondal and Rabe-Hesketh, 2004).

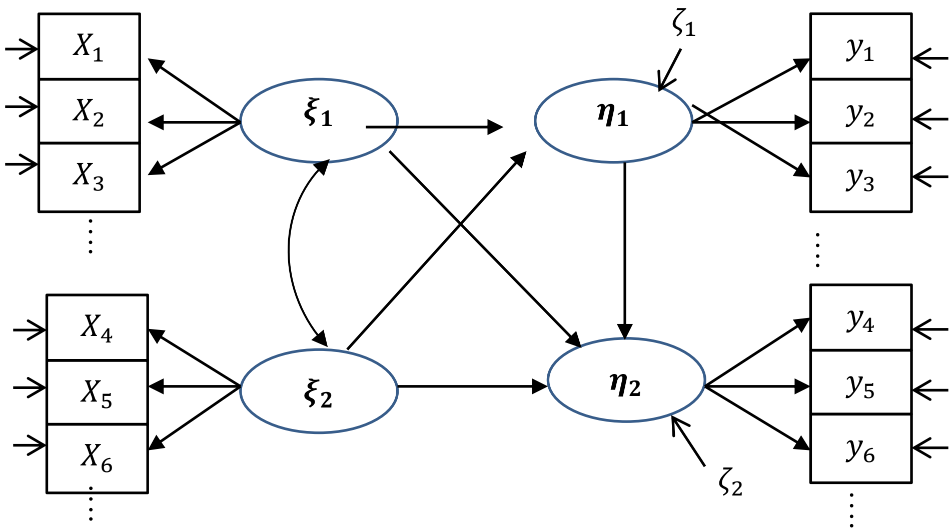


Figure 3.5 Path diagram for structural equation model
[Skrondal and Rabe-Hesketh (2004)]

3.4.4.2 Measurement model

Measurement model is to specify measurement relationships between observed variables and latent variables and to evaluate how well the observed variables measure latent variables (Hair et al., 2009). The measurement model looks like factor analysis to analyse the observed variables' loading on factors. The major difference is that, for SEM, the researchers have to specify which variables are associated with each construct during the phase of model building. However, there is little or no requirement for factor analysis to specify the relationships between observed variables and factors. Therefore, measurement model analysis is confirmatory factor analysis (CFA) to test the model's consistence with the observed data.

Yet, CFA measurement model has it limitation, and exploratory factor analysis (EFA) can also be used in measurement model instead (Asparouhov and Muthén, 2009, Marsh et al., 2009). The CFA measurement modelling requires researchers specify where each indicator is influenced by, generally, a single factor, based on theory and prior analysis, there is no cross-loadings (Asparouhov and Muthén, 2009, Marsh et al., 2009, Marsh et al., 2010). However, a measurement instrument often has many small cross-loadings that are well motivated by either substantive theory or by the formulation of the measurements. The CFA approach of forcing many or all cross-loadings at zero causes that models often do not fit the data well and there is a tendency to rely on extensive model modification to find a well-fitting model, which is often aided by the use of model modification indexes (Asparouhov and Muthén, 2009, Marsh et al., 2010, Marsh et al., 2009). In this situation, Browne (2001) advocated exploratory factor analysis rather than confirmative analysis. Hence, this study uses exploratory factor analysis to identify the latent variables.

3.4.4.3 Structural model

The structural model is defined as 'a set of one or more dependence relationships linking the hypothesized model's constructs' (Hair et al., 2009). The relations involve causal and correlation relationships among independent and dependent variables. Figure 3.5 illustrates causal relationships between ξ_1 and η_1, η_2, and ξ_2 and $\eta_1, \eta_2,$ and η_1 and η_2 . In addition, there is covariance between ξ_1 and ξ_2, without a causal interpretation. Based on the structural model, it forms a series of structural equations for each dependent variable.

Structural model is apparently similar to multiple regression models. Each endogenous variable, such as the dependent variable in multiple regression models, can be written as a regression equation relationship with independent variables, which are the constructs with arrows pointing to the endogenous construct. The major difference, also seen as an advantage, for SEM is that endogenous variables can act as an independent variable in another relationship.

3.4.4.4 Goodness-of-fit (GOF) for SEM

Model assessment is to measure the extent to which a specified model fit for the observed covariance matrix among the indicator variables. Several most common used goodness-of-fit indices for SEM are introduced as the following.

Root Mean Square Error of Approximation (RMSEA), Root Mean Square Residual (SRMR) and Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) are the most common used GOF indices for SEM (Thøgersen, 2009, Chen and Chao, 2011). RMSEA includes the degree of freedom and the sample size tries to correct possibly false computed by chi-square GOF index (Hair et al., 2009). The cut-off values for RMSEA are 0.05 and 0.08. The SRMR is an absolute measure of fit and is defined as the standardized difference between the observed correlation and the predicted correlation (Hair et al., 2009). It is a positively biased measure and that bias is greater for small N and for low df studies. Because the SRMR is an absolute measure of fit, a value of zero indicates perfect fit. The SRMR has no penalty for model complexity. A value less than .08 is generally considered a good fit. The Comparative Fit Index (CFI) is an index to test the incremental fit progress of a model (Hair et al., 2009). TLI compares the normed chi-square values of the null and specified model. The values of CFI and TLI are between 0 and 1, and the values near 1 represent good model fit. The cut-off values are above 0.9 (Hair et al., 2009). The formulas of RMSEA, CFI and TLI are as the following.

$$\text{RMSEA} = \sqrt{\frac{(x^2 - df_k)}{(N-1)}} \qquad \textit{(Equation 3.10)}$$

$$\text{CFI} = 1 - \frac{(x_k^2 - df_k)}{(x_N^2 - df_N)} \qquad \textit{(Equation 3.11)}$$

$$\text{TLI} = \frac{[\left(\frac{x_N^2}{df_N}\right) - (\frac{x_k^2}{df_k})]}{[\left(\frac{x_N^2}{df_N}\right) - 1]} \qquad \textit{(Equation 3.12)}$$

where the subscript N denotes values associated with the statistical null model, k refers to degrees of freedom.

3.4.4.5 Integrating latent variables in choice model and generalized structural equation model (GSEM)

The purpose of adopting integrated latent variables in choice model is to include latent variables such as walking environmental factors and attitudes factors, which are not observable directly, into analysis. Ben-Akiva et al. (1999) proposed integrated choice and latent variable model as shown in Figure 3.6. The model framework consists of two components: a choice model component and a latent variable model component. The latent variable model component, on the top right of Figure 3.6, is to identify unobserved latent variables by the observed indicators. The individual's utility u for each alternative is assumed to be a latent variable because of the unobservable latent variables (η). The latent variable model and choice model are expressed as the followings.

Latent variable model consists two equations.

$$y = \Lambda\eta + \epsilon \qquad \textit{(Equation 3.13)}$$

$$\eta = \Gamma S + \zeta \qquad \textit{(Equation 3.14)}$$

Where Equation 3.13 is to measure unobserved latent variables (η) by observed indicators (*y*). Equation 3.14 is the relationship between exogenous observable variables (S) and latent variables (η). ϵ and ζ are measurement errors.

Choice model consists of utility measurement function and multinomial logit function. Equation 3.15 is the utility function comprising of individual specific attributes (*S*) and latent variables (η). ε is unobserved random errors. Then, the choice model can be estimated by multinomial logit probability function as Equation 3.3.

$$u_j = \beta_j S + \gamma_j \eta + \varepsilon_j \qquad \textit{(Equation 3.15)}$$

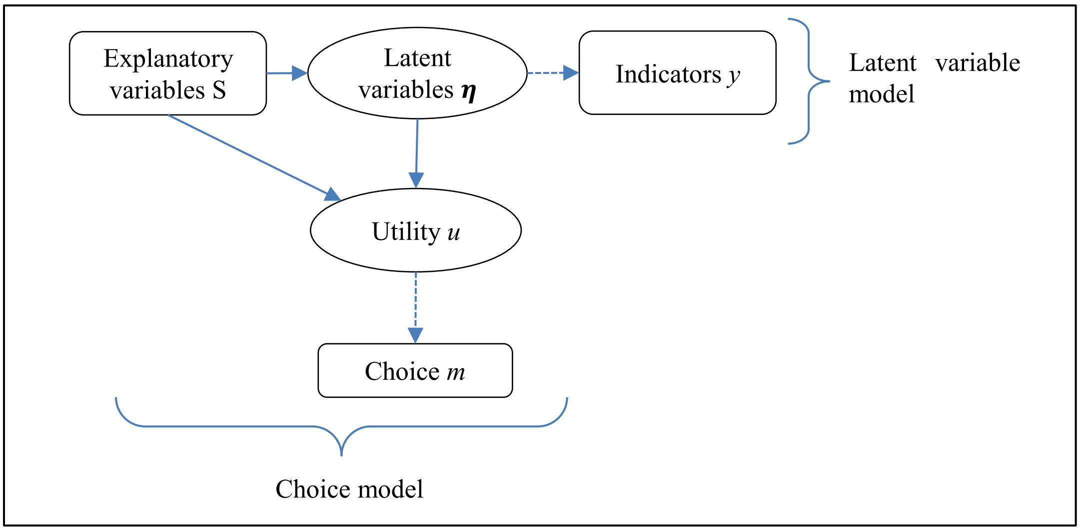


Figure 3.6 Integrated choice and latent variable model
[(Ben-Akiva et al., 1999)]

Generalized structural equation model (GSEM) is adopted the estimate the integrated choice and latent variable model. Integrated choice and latent variable model include measurement of latent variables and structural relationships exogenous variables, latent variables and utility function. Generalized structural equation model (GSEM) in Stata v.13 allows dependent variable as categorical choices and use multinomial logit link function to estimate the results. The estimation is performed in two steps where the latent variable model is estimated first and then the discrete choice model is estimated. This sequential estimation process is less cumbersome compared to simultaneous estimation process.

Several recent studies on travel mode choice have incorporated latent variable into discrete choice model in order to understand how psychological factors such as attitudes and perceptions influence decision-making (Kamargianni et al., 2014, Vredin Johansson et al., 2006, Raveau et al., 2010, Kim et al., 2014). Ben-Akiva et al. (1999) proposed integrated choice and latent variable model which include the components of latent variable model and choice model. The model not only incorporates unobserved psychological factors (latent variables) but also examine the interaction between observed explanatory variables and latent variables (Ben-Akiva et al., 1999). Vredin Johansson et al. (2006) used a sequential approach, where latent variables were estimated first and then the discrete choice model was estimated, to incorporated latent variables of attitudes and environmental friendly personality into discrete choice model. The interactions between socio-demographic characteristics and latent variables were also examined in the study (Vredin Johansson et al., 2006). Raveau et al. (2010) tested two approaches: a sequential approach – latent variables were built before integrated into discrete choice model – and a simultaneous approach – latent variables were built along with discrete choice model – to examine the effects of safety, accessibility, comfort and reliability (latent variables) on travel model choice. The results showed that there is no statistical evidence that the estimation results from sequential approach and simultaneous approach were different (Raveau et al., 2010). Hence, this study uses sequential approach to estimate the SEM and GSEM model, which latent variables are extracted by using exploratory factor analysis and then estimate the structure model of SEM and GSEM

3.5 Progression of This Study

This study was originated because the Taiwanese NRPTP (National Road Public Transport Plan) has been introduced for years and the outcome looked not as well as it was expected. The purposes of the NRPTP are to increase public transport patronage and market share. Hence, the study started from understanding what trigger a higher possibility of public transport usage.

At the first stage, 2011 Taiwanese Mode Choice Behaviour Survey data was used to analyse the influence of public transport provision and land use on travel mode choice behaviour. The results showed that only considering public transport provision and land use had its limitation in explanation on travel mode choice behaviour.

At the same time, travel behaviour theories were also reviewed by the author. Then the conceptual model of this study was building up and the motivational factors were also raised interests to the author. There was a need to collect more information on travel mode choice and the psychological factors. In addition, walking environment might facilitate public transport mode choice. The objective walking environment data (mostly GIS data) has been collected in the stage of land use and travel mode choice behaviour analysis. The relationships between objective measures of walking environment, subjective measures of walking environment and walking access to public transport could be disentangled if the survey included the information on the perceptions of walking environment. Hence, an online survey was conducted in July 2015 to collect information on motivation towards public transport and walking environment. The collected data was used to solve the structural relations between objective, subjective measures of walking environment and walking behaviour, and also to solve the structural relations between capability, opportunity and motivation, and travel mode choice.

Following the understanding the micro-level individual's travel mode choice behaviour, the study tried to understand macro-level issues – public transport policy implementation. Then the study conducted a qualitative survey in January 2016 to interview the participants selected from all the stakeholders related to the NRPTP implementation.

3.6 Overviews of Taiwan

This study uses Taiwan as a case study area. Taiwan is an island country with an area of about 36,000 km^2, a population of more than 23 million, and population density of 649 persons/km^2 (Taiwan Ministry of the Interior, 2015). This section introduces Taiwanese administrative divisions, surface public transport systems and modal split.

Taiwan, a tropical island, is located in the East Asia across the Taiwan Strait to China. Up north is Japan and South Korea and down south to the Philippines, Malaysia and Indonesia. The shape of Taiwan looks roughly like a tobacco leaf, which is 394 kilometres (245 miles) long and 144 kilometres (89.5 miles) wide at its broadest point (Figure 3.7).

3.6.1 Hierarchical administrative divisions

There are four hierarchical administrative divisions in Taiwan, which are village, district, city/county and the whole island from smallest scale to the largest. Village is the basic unit of Taiwanese administrative subdivision. Villages are clustered in district; and districts are clustered in city/county.

There are 7,710 villages clustered in 352 districts, and clustered in 19 cities/counties in Taiwan. Hence, the average area and population of a village are 4.7 km^2 and 3,017 persons respectively. The average area and population of a district are 102 km^2 and 66,000 persons respectively. The average area and population of a city/county are 1,895 km^2 and 1,236,000 persons (Ministry of the Interior, 2014).

About 70% of the island is covered with rugged, densely forested mountains. The Central Mountain Range is the most outstanding topographical highlight of the country. This mountain chain extends for 270 km and splits the island into two from north to south. About 240 peaks rise above 3000 metres. Mountain Jade (Yushan) is the tallest peak of the island at 3952 metres. In many area of the East side of Taiwan's coast, the cliffs drop into the ocean, creating some of Taiwan's most spectacular scenery.

About 96% of population lives in the west coast of the island and the east coast of the island is the least populated place of the island (Table 3.19). Most of the plain areas are located in the west coast. Hence, the main metropolises are located in the west coast. There are 6 metropolises: Taipei City (capital city), New Taipei City and Taoyuan City, which are located in the northern Taiwan, Taichung City (in central Taiwan), Kaohsiung City and Tainan City (in southern Taiwan). The 6 metropolises contain about 70% of all the population in Taiwan, as seen in Table 3.19. Cities/counties in northern Taiwan, by and large, have higher population density and greater public transport market shares than those in other parts of the island.

Note not all the local authorities (city/county government) have a local transport authority (Table 3.19). Most of the counties without a local transport authority are those with low population density and low public transport market shares, such as Hualian County, Taitung County, Ilan County, Pingtung County, Chiayi County and Yunlin County

3.6.2 Surface public transport systems

Surface public transport systems in Taiwan include high-speed rail (HSR), intercity rail, intercity bus, metro, and city bus, as shown in Figure 3. Taiwan high-speed rail, which runs along the west coast of Taiwan, with an operation length of 345km, started operation in Jan, 2007. The Taiwanese intercity railway, which is operated by the MOTC, has an operation length of about 1,085km, and covers both east and west coasts. Intercity bus networks are regulated and licenced by central government – the Directorate General of Highways (DGH), and operating by private bus companies. Metro systems operate in 3 cities: Taipei, New Taipei and Kaohsiung. Local bus networks are regulated and licenced by the local authorities (city/county governments) and operating by private bus companies.

As can be seen in Figure 3.7, public transport networks are concentrated in the west coast of Taiwan because most of the population (about 96%) live in this area. The Central Mountain Range, which penetrates the island from the north down to the south, divides the island into two. High density of bus networks, high-speed rail (HSR), intercity rail and metro networks are served in the west coast.

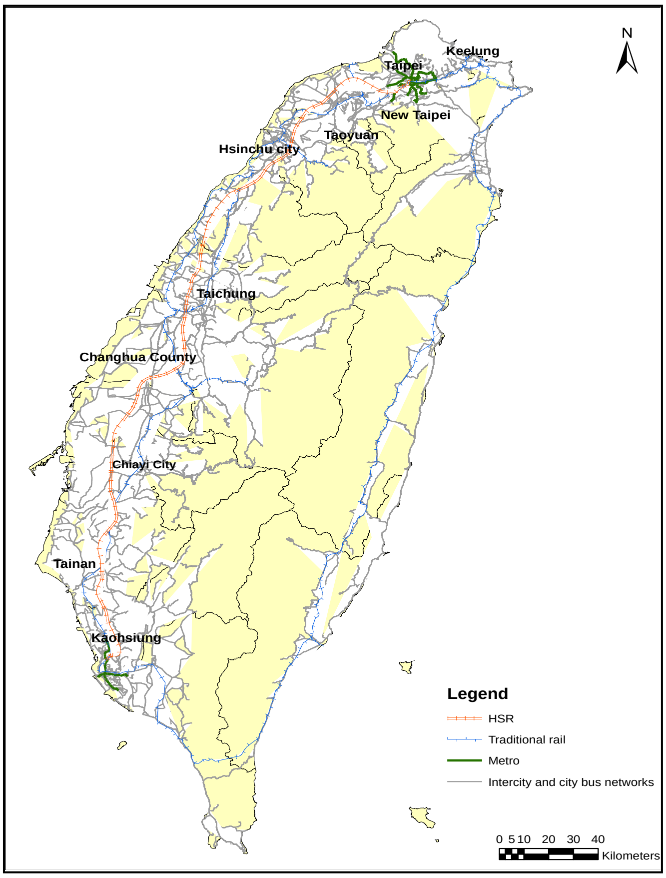


Figure 3.7 Surface public transport systems in Taiwan

3.6.3 Modal split

Public transport market shares for cities/counties were quite varied (Table 3.19). The average public transport market share in Taiwan was 13.9% in 2010. Taipei City (capital city) enjoyed the highest public transport market share (37.6%). Cities and counties in northern Taiwan, by and large, had higher public transport market shares than other cities/counties in Taiwan (Table 3.19).

The 19 cities/counties were divided into three categories: A) Taipei metropolitan area, B) sub-main cities/counties, C) rural counties, according to population density and public transport market share (Chiou et al., 2013), as can be seen in the urban types column in Table 3.19. There are four cities in Taipei metropolitan area (category A) including Taipei City, New Taipei City, Keelung City and Taoyuan City, which enjoy higher population density compared to other cities/counties in Taiwan (Table 3.19). Sub-main cities/counties (category B) include 6 cities/counties: Hsinchu City, Taichung City, Changhua County, Tainan City, Chiayi City and Kaohsiung City, which are higher population density and lower public transport market share compared to other cities/counties (Table 3.19). Rural counties (category C) include 9 counties: Hsinchu County, Miaoli County, Nantou County, Yunlin County, Chiayi County, Pingtung County, Ilan County, Hualian County and Taitung County, which are lower population density compared to other cities/counties(Table 3.19).

Table 3.19 Characteristics of cities/counties

Name	Location	Urban types	Population	Population density	Public transport market share (2010)	Local Transport Authority
Taipei City*	Northern Taiwan	A	2,706,030	10,049	37.6%	Yes
New Taipei City*		A	3,966,052	1,926	25.9%	Yes
Keelung City		A	372,787	2,813	31.9%	Yes
Taoyuan City*		A	2,086,081	1,726	11.8%	Yes
Hsinchu County		C	539,173	382	8.0%	Yes
Hsinchu City		B	432,860	3,478	6.1%	Yes
Taichung City*	Central Taiwan	B	2,731,500	1,225	6.8%	Yes
Miaoli County		C	565,704	310	7.6%	No
Changhua County		B	1,289,274	1,070	4.6%	No
Nantou County		C	511,518	125	5.1%	No
Yunlin County		C	701,898	518	4.2%	No
Tainan City*	Southern Taiwan	B	1,885,376	836	4.8%	Yes
Chiayi County		C	521,591	267	5.5%	No
Chiayi City		B	270,896	4,540	3.3%	Yes
Kaohsiung City*		B	2,778,835	933	6.0%	Yes
Pingtung County		C	843,981	303	5.2%	No
Ilan County	Eastern Taiwan	C	458,313	209	6.2%	No
Hualian County		C	332,424	72	3.9%	No
Taitung County		C	223,189	62	3.8%	No
	Whole Taiwan		23,217,482	649	13.9%	

'*' : the 6 metropolis in Taiwan

Data sources: Taiwan Ministry of the Interior (2015), Department of Statistics (2010)

3.7 Summary

1. This chapter presents that in order to solve the five research questions raised in Chapter 1, multiple datasets and mixed methodologies are used in this study.
2. Two specifically designed surveys, including a qualitative interview and an online survey, are conducted in this study. The qualitative interview data and thematic analysis method are used to analyse the factors influence public transport policy implementation (RQ1). The purposive interviews covered 13 experienced participants selected from central governments, local authorities, bus companies and academic institutions.
3. The online motivation towards public transport and walking environment survey along with structural equation model (SEM) and generalized structural equation model (GSEM) are used to solve the research question 4 and 5 (RQ4 & RQ5). Due to unobservable features of the motivational factors and walking environmental factors, the survey adopted observable indicators from previous studies to obtain the unobserved factors. Although the descriptive statistics of the collected 1319 samples are not similar to the population, this is not major concern as this study is on understanding individual behaviour.

4. The 2011 Taiwanese Mode Choice Behaviour Survey data along with multinomial logit (MNL) model, multilevel MNL model and multilevel cross-classified MNL model are used to answered the research question 2 and 3 (RQ2 & RQ3). Adopting multilevel MNL model and multilevel cross-classified model are because the hierarchical data structure exists in land use data. The multilevel methodologies can accommodate spatial autocorrelation and spatial heterogeneity, higher-level context, and handling of the micro-scale of individuals and the macro –scale of places.
5. This chapter also overview the transport system situations in Taiwan, which is the case study area of this study. The major difference for transport situation in Taiwan compared with North America and Western Europe is that Taiwan enjoys quite high proportion of motorbike usage, which is similar to some of the Southeast Asian countries. About 50% trips used motorbike as mode of transport. Due to the declining public transport patronage, the National Road Public Transport Plan (NRPTP) was launched in 2010 in Taiwan in which the objectives are to increase bus patronage by 5% annually, and to raise public transport market share to 18% by 2016. In terms of geographic scale for the land use analysis, this study uses three hierarchical administrative divisions in Taiwan, which are village, district and city/county from the smallest scale to the largest.

Chapter 4 **ANALYSIS OF FACTORS INFLUENCING PUBLIC TRANSPORT POLICY IMPLEMENTATION**

This chapter addresses the Research Question 1 (RQ1), which is to explore the reasons why after 6 years of policy implementation of the Taiwanese NRPTP (National Road Public Transport Plan), the objectives are not being attained - what are the key factors which have contributed to the plan's poor outcomes. The objective of this chapter is to explore the factors in the policy implementation process including policy implementation approach, consensus about the objectives, policy resources, organizational communication and the attitudes of implementers influence the attainment of the public transport policy.

There are six sections in this chapter. The first section describes the main themes in policy implementation. This is followed by the section of methodology. The third section gives an overview of the Taiwanese National Road Public Transport Plan (NRPTP). The fourth section presents the thematic analysis. The fifth section delivers the results, and the final section summarises the findings.

4.1 Main themes in policy implementation

As can be seen in Figure 4.1, the literature review of this study (Section 2.3) has shown the factors influence policy implementation include policy objectives, policy resources, organizational communication and behaviour, characteristics of the implementing agencies, attitudes of implementers, and economic, social and political conditions (Winter, 2003, Gornitzka et al., 2005, Van Meter and Van Horn, 1975). On top of that, policy implementation approach and stakeholders involved in policy implementation are also concerned in policy implementation study. Implementation approach mainly include top-down, bottom-up and synthesis approaches (Sabatier, 1986, Matland, 1995, Pulzl and Treib, 2006, Winter, 2009). This chapter follows these main topics in policy implementation to examine what factors affect the attainment of the NRPTP objectives.

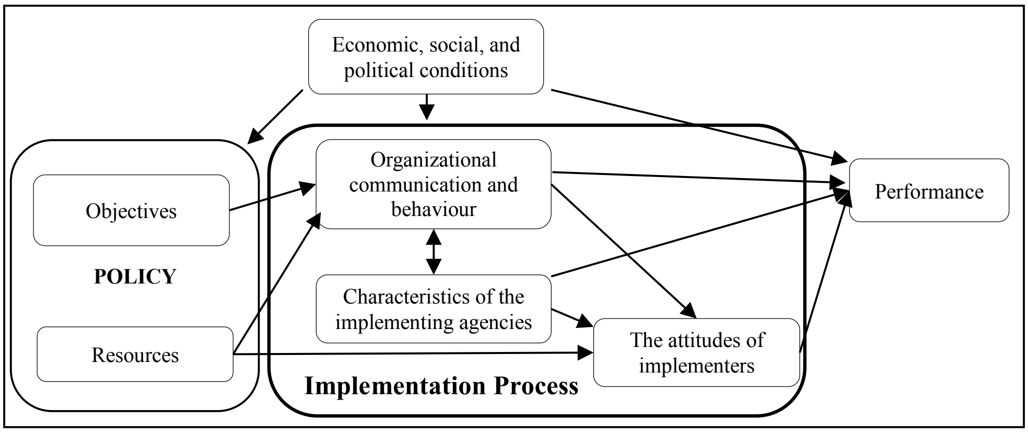


Figure 4.1 Policy implementation model
[Van Meter & Van Horn (1975), Gornitzka et al. (2005), Winter (2003)]

4.2 Methodology

This chapter uses the implementation of Taiwanese National Road Public Transport Plan (NRPTP) as study. A special designed interview data and qualitative thematic analysis were used to look into the 6 years of public transport policy implementation in Taiwan. Thirteen in-depth interviews were conducted covering nearly all the stakeholders for the public transport policy implementation including central government, local authorities, NRPTP joint office, bus companies and academic institutions.

4.3 Overview of the NRPTP

In 2010, the Taiwanese Ministry Of Transportation and Communications (MOTC) launched the National Road Public Transport Plan (NRPTP) to try to change mode choice behaviour towards road public transport and to increase road public transport patronage (Ministry Of Transportation and Communications, 2010a). The NRPTP sets two key objectives: to increase bus patronage by 5% annually, and to raise public transport market share to 18% by 2016, to 20% in the mid-term (by 2020), and to 30% in the long-term (by 2025) (Ministry Of Transportation and Communications, 2010a, Ministry Of Transportation and Communications, 2012c).

4.3.1 Pre NRPTP

Prior to the implementation of the NRPTP in 2009, only about US$43 million was invested annually in road public transport by central government (Directorate-General of Budget Accounting and Statistics, 2005, Lan et al., 2006, Ministry Of Transportation and Communications, 2010a). This amount is about a quarter of the NRPTP annual budget (US$166 million).The Directorate General of Highways (DGH) was responsible for implementing the budget. Most of the US$ 43 million budget was used to subsidise non-commercial bus services and for old buses replacement (Ministry Of Transportation and Communications, 2012b). This very limited budget was not enough to cover all of the deficit arising from operating non-commercial bus services (The Control Yuan, 2010). As a result, during 2006 and 2007, many operating companies applied to central government to remove non-commercial rural bus services from the bus market (The Control Yuan, 2010, Lan et al., 2006). Only a small part of the budget was used to subsidise replacement of old buses and for bus infrastructure refurbishment.

4.3.2 The NRPTP

As mentioned in section 1, the National Road Public Transport Plan (NRPTP) was launched in 2010 to address environmental problems associated with rising car and motorbike ownership, and to ensure access to services and facilities for those who do not have access to private transport (Ministry Of Transportation and Communications, 2010a). The NRPTP focuses on increasing bus patronage and increasing public transport market share. The first plan was approved in 2010. It covered a 3-year period, 2010 to 2012, and was granted an implementation budget of US$ 500 million (National Development Council, 2009). The plan was extended and amended in 2012, and was granted US$666 million to cover a 4-year period (2013-2016) (Executive Yuan, 2012a). A 4-year period (2017-2020) extension plan, which has been proposed by the MOTC, is currently under review (Directorate General of Highways, 2016b).

4.3.3 NRPTP strategies and implementation process

Under the two granted periods (2010-2016), the NRPTP is implemented year by year with an annual budget of about US$ 166 million (Ministry Of Transportation and Communications, 2010a, Ministry Of Transportation and Communications, 2012c).

The NRPTP budget comes from the Directorate General of Highways (DGH). Funding is distributed to local authorities through a bidding process. The local authorities produce annual road public transport proposals, applying to Directorate General of Highways (DGH) for NRPTP subsidy. The spending of the NRPTP budget is regulated so that recurrent expense such as subsidies to provide fare discounts cannot exceed 50% of capital expense such as public transport infrastructure refurbishment and introduction of new buses (National Development Council, 2015). Thus this ensures a minimum of two thirds of the NRPTP budget is spent on capital investment.

The DGH evaluates the annual road public transport proposals and draws up a NRPTP budget allocation plan, which is presented to the MOTC for approval. The local road public transport proposals are essentially bidding documents, submitted to central government, which set out the local authorities' plans for public transport in their area and how much money is requested from central government to help implement these (Ministry Of Transportation and Communications, 2011a). At the beginning of each new year, the DGH announces its NRPTP guidance to the local authorities. This guidance contains the NRPTP strategies, a list of major projects to be subsidized through the NRPTP, the rules for initiating annual local road public transport proposals, and the required contents of the annual local road public transport proposals (Directorate General of Highways, 2014). But the NRPTP guidance did not disclose the key objectives of raising bus patronage and public transport market share (Directorate General of Highways, 2014).

The NRPTP guidance has, to date, included four key strategies: 1) creating 'top-notch' cities and counties, 2) infrastructure refurbishment, 3) protection of basic mobility rights, and 4) provision of incentives for raising bus patronage (Directorate General of Highways, 2014).

The 'top-notch' strategy involves the implementation of effective projects in those cities and counties with a high potential for increasing public transport accessibility and patronage (Road Public Transport Plan Office, 2011). High potential cities/counties are identified as those with a high population density (above the average of approximately 650 persons/km^2) but with a low public transport market share (lower than the average of 13.9% in 2010) (see Figure 4.2). The high potential cities/counties include Chiayi City, Taichung City, Hsinchu City, Taoyuan City, Changhua County, Kaohsiung City and Tainan City. These 'top-notch' high potential cities/counties would be offered help and advice to draw up their annual road public transport proposals (Road Public Transport Plan Office, 2011).

The aim of the second strategy - infrastructure refurbishment - was to update the bus system infrastructure, and hence to improve the public image of the bus systems. Projects under this strategy include: transport smart card systems integration, installing bus real time information systems, introducing low floor buses, and speeding up the replacement of old buses (Ministry Of Transportation and Communications, 2012d).

The third strategy - basic mobility rights protection - was mainly focused on non-commercial rural bus services. The projects approved under this strategy included sustaining rural services by offering sufficient subsidy to cover operational deficits, and subsidizing the construction of bus shelters in rural areas (Ministry Of Transportation and Communications, 2012d).

The fourth strategy – provision of incentives for raising bus patronage – is a new strategy, which was introduced in the NRPTP guidance in 2014 (Directorate General of Highways, 2014), to encourage local authorities to raise bus patronage numbers. Under this programme, central government set up local authority targets for increasing annual bus patronage which rise each year (Directorate General of Highways, 2015). A proportion of the NRPTP subsidy budget is reserved for distribution to those local authorities whose bus patronage numbers exceed these targets.

The rules for initiating annual road public transport proposals in the NRPTP guidance listed two important requirements that local authorities need to comply with (Directorate General of Highways, 2014). Firstly, local authority should provide match funding, which is at least 10% of the total budget need in the annual road public transport proposal. Secondly, local authorities should propose annual performance indicators. However, there is no performance monitoring mechanism written into the NRPTP guidance (Directorate General of Highways, 2014).

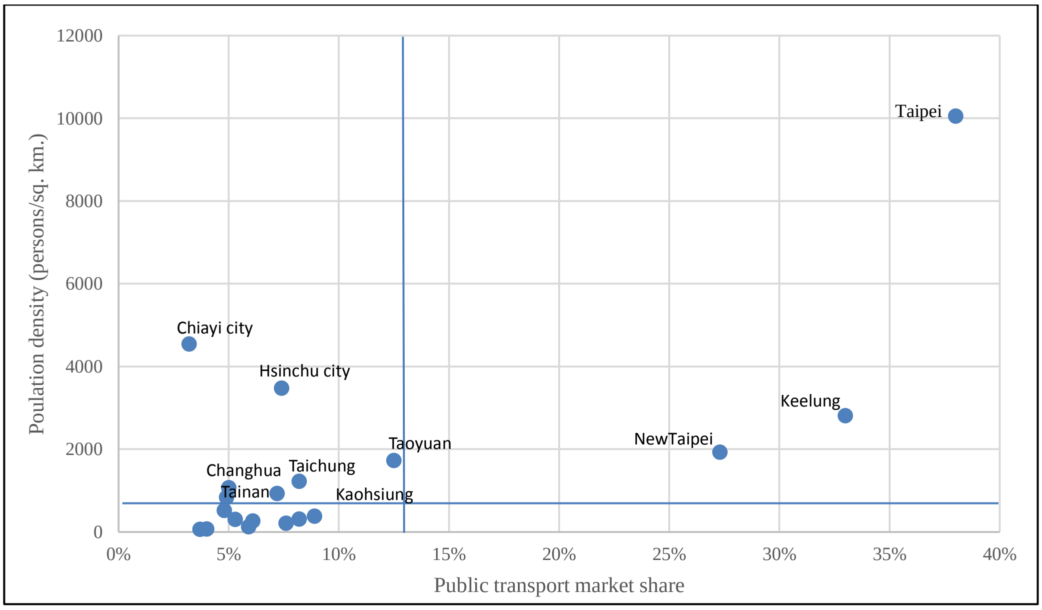


Figure 4.2 Population density and public transport market share
[Ministry of the Interior (2014), Department of Statistics (2011)]

4.3.4 Stakeholders in NRPTP (National Road Public Transport Plan) Implementation

As shown in Figure 4.3, the main bodies for NRPTP implementation are the Directorate General of Highways (DGH) and the city/county governments (local authorities). Other stakeholders include MOTC, Institute of Transportation (IOT), NRPTP office, bus companies, academic institutions, transport consultant companies, and the general public.

Vertical intergovernmental relationships exist between MOTC and Directorate General of Highways (DGH), and MOTC and Institute of Transportation (IOT) (Ministry Of Transportation and Communications, 2016). DGH and IOT are both subordinated to the Ministry of Transportation and Communications (MOTC) (Ministry Of Transportation and Communications, 2016). MOTC is the formulator and decision-maker for NRPTP policy and budget allocation. DGH is responsible for motor vehicles administration and the management of the intercity bus service (Directorate General of Highways, 2016a). Hence, DGH is the NRPTP implementing agency in central government. IOT is responsible for studying transport policies and offering advice to MOTC (Institute of Transportation, 2016). Hence, the IOT provides consultant and research & development functions to the MOTC for NRPTP implementation. A horizontal intergovernmental relationship exists between DGH and IOT (Ministry Of Transportation and Communications, 2016), which means DGH can request IOT's help or advice for NRPTP implementation.

The NRPTP office, which is a quango, was set up specifically to help the DGH with NRPTP implementation. DGH has periodically contracted academic institutions and transport consultancy firms to supply staff to the NRPTP office to help deal with NRPTP administration. Some academic institutions and transport consultancy companies have participated in the NRPTP through contracts with the local authorities and central government to give planning and consultancy services.

Regulatory relationships exist between the governments (central and local) and bus companies (Ministry of Justice, 2016). Bus companies are regulated either by local authorities or by DGH depending on the type of bus route (Ministry of Justice, 2016). City bus routes, which operate within a specific city or county administrative boundary, are regulated and licenced to operate by local authorities (Ministry of Justice, 2016). Intercity bus routes, which operate across city and county boundary, are regulated and licenced to operate by DGH (Ministry of Justice, 2016).

The general public is the target group of NRPTP implementation from a customer-oriented perspective. The aim of NRPTP implementation is to attract the public to switch their mode choice towards public transport, especially bus (Ministry Of Transportation and Communications, 2010a, Ministry Of Transportation and Communications, 2012c).

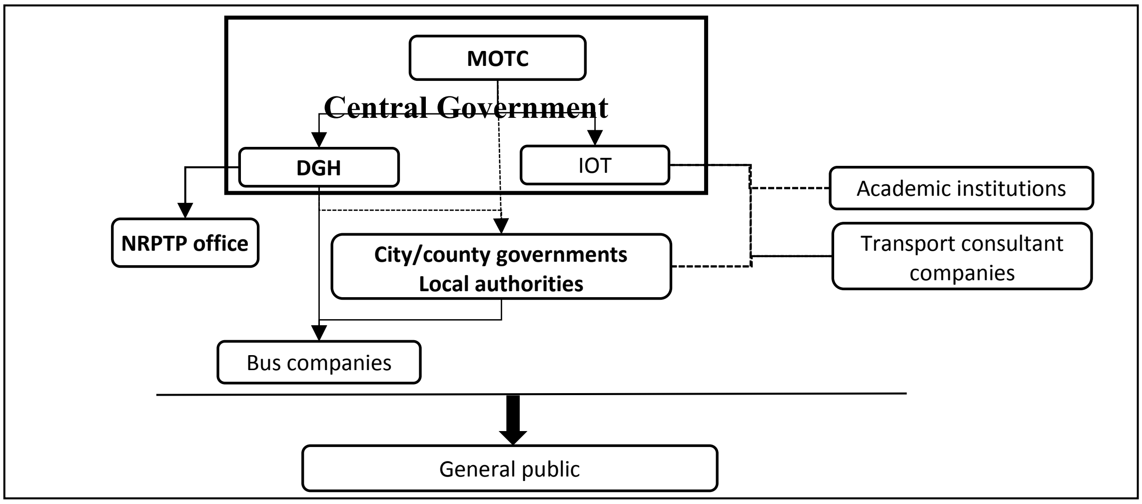


Figure 4.3 Stakeholders in NRPTP implementation

4.3.5 Key NRPTP implementation outcomes

Positive change has occurred in the public transport market in Taiwan since NRPTP implementation began in 2010 despite the key objectives not having been attained. In terms of infrastructure, the percentage of low floor buses to total buses in Taiwan increased sharply to 47% in 2015 from just 7% in 2009 (Directorate General of Highways, 2016b). Also, 3 different smart card systems, which are issued by three different companies and operate in three different areas, have been integrated through a multi-card validator (Ministry Of Transportation and Communications, 2010b, Ministry Of Transportation and Communications, 2011b, Ministry Of Transportation and Communications, 2012d, Ministry Of Transportation and Communications, 2013, Ministry Of Transportation and Communications, 2014a, Ministry Of Transportation and Communications, 2015). The integrated multi-card validators have also been extended from the bus system to the metro, intercity rail and high-speed rail systems. This means that passengers can now use any one of the three types of smart card when travelling across the whole of Taiwan. One hundred and eighteen new bus routes have been created and 492 new buses have been added to the fleet, expanding bus networks all over Taiwan Island (Ministry Of Transportation and Communications, 2010b, Ministry Of Transportation and Communications, 2011b, Ministry Of Transportation and Communications, 2012d, Ministry Of Transportation and Communications, 2013, Ministry Of Transportation and Communications, 2014a, Ministry Of Transportation and Communications, 2015). This has greatly improved access to and accessibility of the bus systems in Taiwan (Directorate General of Highways, 2016b). In addition, 30 new local bus terminals has been finished or are under construction (Ministry Of Transportation and Communications, 2010b, Ministry Of Transportation and Communications, 2011b, Ministry Of Transportation and Communications, 2012d, Ministry Of Transportation and Communications, 2013, Ministry Of Transportation and Communications, 2014a, Ministry Of Transportation and Communications, 2015).

As for NRPTP budget allocation, most of the NRPTP resources are invested in key cities/counties under the ‘top-notch’ strategy. As can been seen in Figure 4.4, Taichung city, Tainan city, Kaohsiung city, Hsinchu city, and Chiayi city, which are the main cities/counties identified as having high population density and low public transport market share, have been allocated a higher percentage of NRPTP budget between 2010 and 2015 than would be expected given the proportion of population located in these cities (Ministry Of Transportation and Communications, 2010b, Ministry Of Transportation and Communications, 2011b, Ministry Of Transportation and Communications, 2012d, Ministry Of Transportation and Communications, 2013, Ministry Of Transportation and Communications, 2014a, Ministry Of Transportation and Communications, 2015). This means that the resources allocation has followed the strategies been set up in NRPTP.

As discussed in section 1, the public transport market share for the 19 cities/counties has followed an upward trend over the five years (2010-2014) of NRPTP implementation (Figure 4.5). Taichung city was distributed the largest proportion of the NRPTP budget (28.6%) (Figure 4.4), and the public transport market share for Taichung city has steadily risen to 10% in 2014 from 6% in 2009 (Figure 4.5) (Department of Statistics, 2010, Department of Statistics, 2011, Department of Statistics, 2012, Department of Statistics, 2014, Department of Statistics, 2015a, Department of Statistics, 2013). Likewise, Kaohsiung city was distributed 17.1% of the NRPTP budget and here the public transport market share has increased to 8.2% in 2014 from 5.7% in 2009 (Department of Statistics, 2010, Department of Statistics, 2011, Department of Statistics, 2012, Department of Statistics, 2014, Department of Statistics, 2015a, Department of Statistics, 2013).

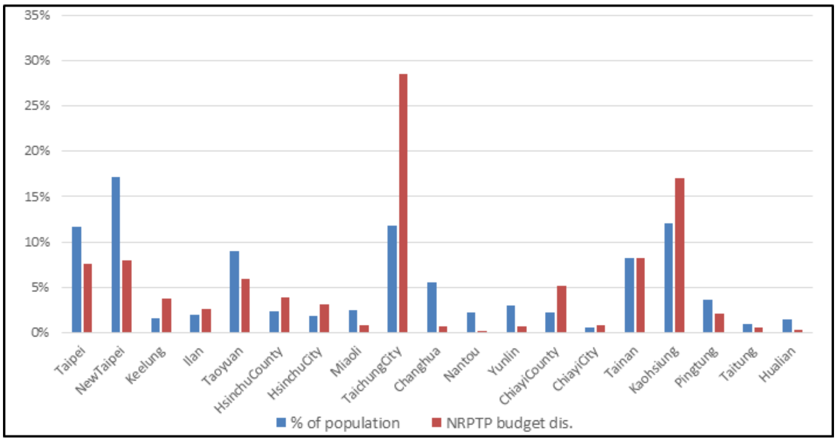


Figure 4.4 Budget and population distribution
[Ministry Of Transportation and Communications (2010b), Ministry Of Transportation and Communications (2011b), Ministry Of Transportation and Communications (2012d), Ministry Of Transportation and Communications (2013), Ministry Of Transportation and Communications (2014a), Ministry Of Transportation and Communications (2015)]

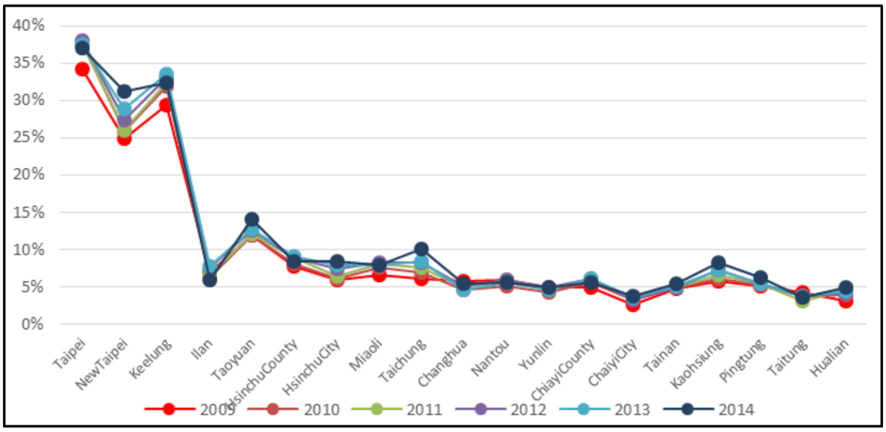


Figure 4.5 Public transport market share between 2009 and 2014
[Department of Statistics (2010), Department of Statistics (2011), Department of Statistics (2012), Department of Statistics (2013), Department of Statistics (2014), Department of Statistics (2015a)]

4.4 Analysis

By and large, interviewees felt that the six years of NRPTP implementation had made two major contributions. First, NRPTP policy implementation has raised some of the local authorities' awareness of and attention to local bus services. Second, NRPTP policy implementation has restored the general public's and bus operators' belief that public transport is in the mainstream of Taiwanese transport policy. However, some problems with the policy implementation have made it difficult for the key objectives to be met.

4.4.1 Consensus on policy objectives

Most of the implementers in local authorities and bus companies did not have a clear understanding of the objectives of the NRPTP, although they were aware of part of its content. Some of them knew about the objective of increasing public transport patronage but did not know exactly the size of the desired increase. Some listed the goals of particular programmes in local road public transport proposals, as NRPTP objectives, such as maintaining rural bus services, introducing low floor buses, and speeding up the rate of old bus replacement.

LA1: "NRPTP's objectives are to improve rural bus service, introducing green buses…"

LA6: "NRPTP's objectives are to subsidize specific types of public transport projects under central government's guidance…, also to encourage local government to dedicate resources to public transport."

There was a lack of a consensus about attaining key objectives of the NRPTP. Most of the local authorities did not think that they could raise bus patronage by 5% every year. The reason which was most frequently mentioned by the participants as to why the objectives cannot be achieved is because the cities/counties have not had local road public transport plans. Some of the local authorities mentioned that they initiated annual road public transport proposals routinely without assessing their transport needs and whether the proposed programmes can increase bus patronage or not.

LA2: "Raising annual public transport patronage by 5% have not been our goal. We [City government] *do not have a local transport policy and public transport plan…the annual local road public transport proposal was initiated randomly without plan or vision."*

LA6: "We have not thought about the objective of increasing bus patronage by 5% per year….We will wait until we get a longer-term local public transport plan. Then, follow the plan to increase bus patronage gradually."

4.4.2 Lack of information about what works in switching travel mode choice

Several participants from local authorities expressed that it is imperative to understand what the better public transport strategies, which adapt to local public transport conditions and land use, are in switching travel mode choice behaviour towards public transport. Without clear strategies and an action plan for local authorities, their local road public transport proposals cannot have a breakthrough achievement in raising bus patronage numbers and public transport market share.

LA2: "Lack of public transport strategies, the road public transport proposals can only be initiated routinely. We are not sure whether the programmes in the proposal can raise public transport patronage or not."

LA4: "We do not have local strategies in public transport development. This impedes us to propose our road public transport proposal."

4.4.3 Implementation method

Participants felt that implementing programmes using a bottom-up implementation method was a more effective way to increase bus patronage numbers. Frequent answers about which programmes were more effective at raising bus patronage included the introduction of new bus routes or networks, introduction of express bus routes, offering bus fare discounts, and increasing bus frequencies. These programmes tend to be implemented in a more bottom-up method because local authorities have more knowledge about local public transport needs. This indicates that central government may need to loosen NRPTP guidance to allow local authorities to implement more adaptive road public transport programmes to raise bus patronage numbers.

LA3: "Free bus service, bus network adjustment and creating arterial bus routes, creating express bus routes are the three effective ways to increase bus patronage"

LA4:"The implementation method should use bottom-up, but central government needs to motoring proposals and outcomes."

4.4.4 Outcomes monitoring and implementation mechanism

Some respondents from local authorities with job experience in central government expressed concerns that, so far, there is no monitoring mechanism to check if local authorities reach their annual goals at the end of year. The annual local road public transport proposals in consecutive years seem independent and discontinuous. There is no merit attached to last year's implementation outcomes. Each year, the NRPTP implementation process starts again with no reference to the last.

LA1: "Without a longer-term plan approved, when this year's subsidy has been implemented by local government, then it [this year's proposal] *is finished…"*

Several participants discussed a need to change the NRPTP implementation mechanism, suggesting that the implementation mechanism should require local authorities to submit longer-term (three or four-year) road public transport proposals and to strengthen their performance management. In addition, proposals should include annual action programmes and objectives. Central government would then approve the proposals and promise the requested subsidization for the 3-4 year period during which the following year's subsidization would be subject to previous year's outcomes. Then, central government would check whether the intended implementation outcomes have been attained year on year. If the previous year's outcomes have not met the objectives, central government may reduce this year's subsidization or even suspend the proposal.

LA1: "…for proposal [local road public transport proposal] *approval, the proposal should be longer than one year…" "If a 4-year proposal is approved, it is easier to check performance or whether the objectives have been attain or not."*

LA3: "There is a big problem with the implementation mechanism now…if the implementation mechanism is changed and local government are asked to produce a four-year proposal; there should be clear programmes and objectives for each year. Central government can approve a four-year proposal. The proposal and implementation outcomes can be tracked"

4.4.5 Characteristics of implementing agencies

Insufficient implementing capacity and skilled street-level-bureaucrats to produce and implement the annual local road public transport proposals were seen as major obstacles for NRPTP implementation. Some of the cities/counties still do not have a specific organization to deal with transport. This is viewed as resulting in some local governments not being able to keep transport expertise. In addition, there is considered to be too few (just one or two) staff in many local authorities to cope with the regulation of local bus services.

LA6: "…lack of manpower (only one member) limited the capacity to implement the NRPTP…"

AU1: "The problem we faced every year, the quality of the annual local road public transport proposals initiated by the local governments were not good enough, and also the total amount bid for NRPTP subsidy from local authorities is the same or even less than the NRPTP budget. So, it was difficult to choose good projects from them. …"

AU2: "…the county lacks the ability to produce a proposal [annual road public transport proposal], another county did not accept help from our team to draft their proposal because they lack manpower to execute it…"

4.4.6 Attitudes of implementers

Several participants expressed the problem that some cities/counties' willingness to produce a needed and good annual road public transport proposal is quite low. The street-level-bureaucrats are the implementers of the budget which they get from the NRPTP. Implementing the programmes included in their annual road public transport proposal could increase the work loading of these street-level-bureaucrats.

LA6: "…considering our implementation capacity, even if the central government would like to allocate more budget to us, we cannot execute it [NRPTP budget]*."*

AU1: "…there is only one member responsible for this project [NRPTP]*…unwilling to do it, so the quality of the proposal* [annual road public transport proposal] *is poor."*

4.4.7 Mayoral commitments

Lack of mayoral concern and commitment for road public transport is an obstacle for NRPTP implementation in some local authorities. Although most of the mayors have realized the importance of developing local bus services after six years of NRPTP implementation, mayoral commitment and support to dedicating more resources (manpower and finance) to the NRPTP still needs to rise.

CG2: "…counties such as..., have not paid attention to public transport…"

LA6: "The first support we need is from our mayor, then we can get more resources [in our government] *to progress bus service…"*

Several participants suggested that there is a need to exert more pressure on local leaders (mayors and directors of local transport authorities) to dedicate more local resources to bus services. The pressure may come from disclosing to the public an evaluation of public transport services for each local authority.

AU1: "We hope central government can set up local public transport indicators and survey cities/counties' public transport development, and then include these in the cities/counties' annual wellbeing evaluation, giving some pressure to local governments."

4.4.8 Inflexibility of budget spending

The inflexibility of NRPTP budget spending is associated with the resources issue. The inflexibility of NRPTP budget spending is divided into two aspects. First, NRPTP subsidy requires match fund from local governments, which is not affordable for some governments due to poor financial conditions.

LA5: "I asked our county government to provide the match funding for subsidizing non-commercial bus routes. But the county government did not agree."

Second, the ratio of capital expense and current expense in NRPTP budget is limited to 2 to 1, which means that expenditure within the NRPTP for recurrent items such as fare discount incentives, cannot exceed one third of the total budget.

LA3: "….There is a need to relax the limitation of the ratio of capital expense and current expense."

4.5 Results

Passing a public transport policy does not guarantee the success of the policy if the public transport policy is not well implemented. Reviewing the problems faced over the past six years' public transport policy implementation for NRPTP, this chapter summarises 6 recommendations that may help to attain a more successful public transport policy implementation. Table 4.1 summarise the main themes resulted from this chapter's analysis.

Table 4.1 Summary of the main themes in analysis

Main themes	Description
Consensus on policy obectives	• The implementing agencies did not clearly understand the objectives; • Some of the implementing agencies did not think they can attain the objectives.
Lack of information about what works in switching travel mode choice	• Lack of information about what the better public transport strategies are in switching travel model choice towards public transport.
Implementation method	• Bottom-up implementation approach seems to be a more effective way to increase bus patronage.
Outcomes monitoring and implementation mechanism	• It was difficult to monitor implementation outcomes with a year by year bidding process; • Lack of monitoring mechanism might be solved by asking for longer-term local public transport proposals.
Characteristics of the implementing agencies	• There was insufficient implementation capacity in local authorities; • A lack of skilled street-level-bureaucrats was a major obstacle for local NRPTP implementation.
Attitudes of implementers	• Some cities/counties lacked a willingness to implement the NRPTP.
Mayoral commitments	• Some local mayors were not committed to local bus services development.
Inflexibility of budget spending	• The NRPTP budget required local governments to find match funding, which can be difficult; • The ratio of capital expense and current expense constraint within NRPTP budget limited what can be achieved

Building a consensus on the policy objectives among central government and local authorities should be an important task. Some local authorities not only did not clearly understand the key objective of raising bus patronage numbers but also did not believe they can achieve the objective, for example raising bus patronage by 5% annually. Central government should improve intergovernmental communication with local authorities and bus companies to make sure that they all keep the objectives in mind and desire to achieve them.

There is a need to study what works in terms of public transport provision, land use and psychological effects in switching private vehicle users to public transport. Local authorities' road public transport proposals should adapt to local land use and public transport development. A better understanding the effects of land use and public transport provision on travel mode choice behaviour provide information for local authorities to initiate road public transport proposal which is fitted to their needs.

Mayoral commitment and provision of supporting resources to local transport authorities are critical for public transport policy implementation. Evaluating local public transport services and disclosing the results to the public could be an approach to increase mayoral commitment to public transport.

The implementation mechanism should be designed so that the local public transport proposal and bidding process is done once every four years and covers a mid-term local public transport plan. In addition, a performance monitoring mechanism should be built in. Once a mid-term, for example 4-year, local transport plan is approved, the 4-year subsidy should be simultaneously promised to the local authority. This can help local authorities to make longer-term public transport plans and would ensure continuity in consecutive years. In addition, the central government can then effectively monitor the progress of the implementation.

The guidance for public transport policy implementation should clearly disclose the objectives of the policy and ask local authorities to propose clear performance indicators which link to the public transport policy objectives. The content of the NRPTP guidance now only describes how to initiate the annual local road public transport proposal and lists the projects included in the NRPTP subsidy. The guidance may need to be revised to introduce the objectives of the policy, announce the criteria for approving local proposals, and require local authorities to set up performance indicators.

Adequate and supporting resources for local authorities are important. Lack of manpower is the most frequent problem faced by local authorities, affecting the attitudes of the public transport policy implementers. There is a disparate capacity within local authorities to deal with transport business. Most of the high-density cities/counties have local transport authorities while most low-density cities/counties do not (see Table 1.2). The central government could allocate some of the subsidy to help local authorities, especially those who do not have a local transport authority, to set up a local policy implementation office by recruiting some transport expertise. Providing sufficient manpower to local authorities may improve their attitudes towards policy implementation. In terms of subsidy, the match funding requirement and the spending limitation with regards to the ratio of capital expenditure to current expenditure should not be obstacles for policy implementation. Central government should remove these obstacles and help local authorities to implement all the measures which can raise public transport patronage.

4.6 Summary

1. This chapter used qualitative thematic and interview data to identify 8 important themes in NRPTP policy implementation in Taiwan. These are: 1) Lack of understanding of policy objectives within implementing agencies; 2) Lack of information about what works in switching travel mode choice; 3) Patchy local public transport proposals; 4) Centralised implementation approach; 5) Insufficient implementing capacity; 6) Insufficient skilled street-level-bureaucrats; 7) Lack of mayoral commitments; 8) Inflexibility of budget spending.
2. According the work in this chapter suggested that building a consensus among all the stakeholders on the policy objectives, better understanding local public transport needs, better implementation mechanism, more localised and bottom-up approach, mayoral commitments, characteristics of the implementing agencies, attitudes of implementers and sufficient resources were the key factors for a more successful public transport policy implementation.

Chapter 5 THE EFFECTS OF PUBLIC TRANSPORT PROVISION ON TRAVEL MODE CHOICE BEHAVIOUR

This chapter addresses the second research question (RQ2) which aims to understand that is there a fundamentally different relationship between public transport provision and travel mode choice in the context of Taiwanese high population density and mixed land use. If refers to the proposed model for travel mode choice behaviour towards use public transport in Figure 2.10, this chapter is to examine the relationships between Block B - public transport provision, Block A – socio-demographic characteristics, and travel mode choice behaviour (Figure 2.10).

The objectives of this chapter is to examine the impacts of public transport provision such as the number of bus stops, bus frequency and metro stations, and service quality attributes such as walking time, waiting time, in-vehicle and travel cost on travel mode choice between car, bus, metro, motorbike and train accounting for the sociodemographic characteristics such as age, income, vehicle ownership, car and motorbike driver's licence, and household car and motorbike ownerships.

The effects of built environment variable: density, which includes population density at trip origin and job density at trip destination on travel mode choice are also included in the analysis. Density relates to demand on public transport. The demand on public transport stimulates provision of public transport and affect travel mode choice behaviour. Discrete choice conditional logit model are adopted in this chapter's analysis.

There are four sections in this chapter. The following section describes the data used and the descriptive statistics. This is followed by presenting the model form of this chapter. The third section presents the estimation results. The final section concludes the findings of this chapter.

5.1 Descriptive statistics

Three data sources were used in this chapter's analysis: 1) 2011 Travel Mode Choice Behaviour Survey, 2) Public transport provision, 3) Population density and job density. The descriptive statistics of these data are as the followings.

5.1.1 Associations of socio-demographics and travel behaviour

The following part explains the descriptive statistics of 2011 Mode Choice Survey data, including the cross tabulations between gender, age, education and income, and mode choice. There were 5,764 samples collected from 2011 Mode Choice Survey; after removing incomplete responses, this gave a valid sample size of 5,485 individuals including travel mode choice of car, motorbike, bus, metro, train, bike and others.

Table 5.1 listed the cross table of gender and mode choice. It shows that male tended to drive car more than female, 29.7% for male and 23.4% for female. On the other hand, female inclined to use public transport more than male, 23.4% for female and 20.5% for male.

Table 5.1 Gender and mode choice

Unit: % of respondents

Mode of transport		Total	Female	Male
Car	driver	26.7	23.4	29.7
	passenger	5.0	5.8	2.8
Motorbike	driver	41.9	41.6	42.0
	passenger	3.8	3.8	2.2
Bus		14.4	16.3	14.5
Metro		3.8	5.0	3.7
Train		2.0	2.1	2.3
bicycle		1.8	1.4	2.2
Others		0.6	0.6	0.6

Data source: 2011 Mode Choice Behaviour Survey

As can be seen in Table 5.2, the respondents at the aged under 25 had the highest rate of public transport usage about 15-20%. Aged 25-34 had the highest percentage of motorbike usage, and aged 35-54 had the highest percentage of car usage. It seems that mode choice was shifting from public transport at the younger age to motorbike at aged 30s, then to car use at aged 40-50s.

Table 5.2 Age and mode choice

Unit: % respondents

Age Modes	10-14	15-24	25-34	35-44	45-54	55-64	>=65
Car	13.6	5.9	12.5	19.7	19.0	18.1	13.6
Motorbike	18.8	22.1	26.4	21.3	20.9	20.5	22.3
Bus	12.1	14.5	6.9	5.4	6.1	7.2	9.5
Metro	2.9	2.5	2.4	2.1	2.1	2.0	1.4
Train	0.4	1.9	1.2	0.9	0.9	1.1	0.8
Bicycle	1.8	3.0	0.3	0.3	0.5	0.9	1.6
Others	0.4	0.1	0.2	0.4	0.4	0.3	0.8

Data source: 2011 Mode Choice Behaviour Survey

As can be seen in Table 5.3, bus users are clustered in the lowest income group, which has a 24% bus usage rate for the most frequently made trips, compared with 10-14% in all other income groups. Motorbike use tends to be higher in the lower income groups. More than 50% of lower income respondents – whose income ranged between US$333-1,333 per month - commuted by motorbike. On the other hand, car use gradually increases as income increases. Nearly 60% of respondents with a monthly income of more than US$3,333 per month were car users.

Table 5.3 Personal income and mode choice

Unit: % of respondents

Monthly Income (US$)	<=333	334-666	667-1,333	1,334-19,99	2,000-2,666	2,667-3,333	>=3,334
Car	19.4	21.0	29.0	41.0	46.7	54.8	59.0
Motorbike	43.8	60.4	50.1	39.1	32.2	24.8	25.0
Bus	24.3	12.0	13.9	10.7	11.0	12.1	10.3
Metro	4.3	3.0	4.1	5.0	6.1	5.7	3.2
Train	3.5	1.8	1.5	2.5	1.6	1.3	1.9
Bicycle	4.2	1.7	0.8	0.8	1.2	1.3	0.0
Others	0.5	0.2	0.6	0.9	1.2	0.0	0.6

Data source: 2011 Mode Choice Behaviour Survey

Table 5.4 shows that car usage rate increased along with education level getting higher, and respondents with doctor degree had the highest car market share of 53.3%. On the other hand, respondents with master and doctor degree were less likely to use motorbike in comparison with other education groups. Bus had the highest market share, 21.1%, at the lowest education level.

Table 5.4 Education and mode choice

Unit: % of respondents

Education Modes	Primary or under	Secondary	College/University	Master	Doctor
Car	24.7	29.0	31.6	40.2	53.3
Motorbike	44.9	46.3	45.8	36.3	26.7
Bus	21.1	15.4	13.9	14.2	15.6
Metro	2.4	3.7	5.3	5.5	2.2
Train	2.0	2.4	2.2	2.2	2.2
Bicycle	4.4	2.3	0.8	1.2	0.0
Others	0.5	1.0	0.4	0.4	0.0

Data source: 2011 Mode Choice Behaviour Survey

Table 5.5 shows the relationship between trip purpose and mode choice. Basically, commuting to school trips had the highest percentage points of public transport usage, at about 34%. Business and tour trips had the highest percentage points of car usage, at about 45-47%. Work and shopping trips had the highest percentage points of motorbike usage, at about 49%.

Table 5.5 Trip purpose and mode choice

Unit: % trips

	Work	School	Visit friends	Shopping	Business	Tour	Hospital	Others
Car	32.2	18.5	40.1	29.6	47.5	45.7	39.3	30.3
Motorbike	48.9	41.2	38.3	49.8	30.3	33.6	32.6	49.5
Bus	11.5	23.5	13.0	12.1	11.1	14.3	19.1	14.1
Metro	4.3	6.0	3.8	5.0	5.1	5.0	0.0	3.0
Train	1.7	4.1	2.7	1.0	4.0	0.7	5.6	1.0
Bicycle	0.9	6.8	1.8	1.3	2.0	0.7	3.4	2.0
Others	0.5	0.0	0.3	1.2	0.0	0.0	0.0	0.0

Data source: 2011 Mode Choice Behaviour Survey

Table 5.6 shows the relationship between trip purpose and trip frequency. The row of the table, number of trip frequency, represents the number of return trips in one week. About 60% of trips' purpose is commuting, and education and shopping trips have about equal percentage point of 12%.

Table 5.6 Trip purpose and trip frequency

Unit: % of trips

Frequency Purpose	1	2	3	4	5	6	Over 6	Total
Commuting	17.5	2.3	2.7	2.7	47.6	23.0	4.2	58.9
Education	20.5	5.2	3.2	5.5	44.6	17.0	4.0	12.4
Visiting friends	47.7	22.1	13.0	6.8	5.3	3.2	1.8	8.0
Shopping	33.8	20.0	21.7	9.9	5.5	5.5	3.6	12.3
Business	30.3	19.7	17.2	5.7	13.1	9.8	4.1	2.2
Leisure	54.1	24.3	8.3	5.0	4.4	2.2	1.7	3.3
Hospital	52.7	17.3	16.4	10.9	0.9	0.9	0.9	2.0
Others	19.6	9.8	5.9	2.0	35.3	17.6	9.8	0.9

Data source: 2011 Mode Choice Behaviour Survey

Table 5.7 shows the relationship between vehicle ownership and travel mode choice. The vehicle owner means that the person at least owned one vehicle either car or motorbike. For non-vehicle owner, if they are car or motorbike users, that means they are car or motorbike passengers. For non-vehicle owners, they quite more depended on public transport (bus, metro and train) than vehicle owners. On the other hand, vehicle owners' car and motorbike usage rate were significantly higher than non-vehicle owners'. Therefore, vehicle owned or not may be an important factor influence mode choice behaviour.

Table 5.7 Vehicle ownership and mode choice

Unit: % of trips

	Non-vehicle owner	Vehicle owner
Car	21.1	39.3
Motorbike	38.3	51.6
Bus	24.2	5.7
Metro	8.5	1.5
Train	3.7	0.9
Bicycle	3.6	0.6
Others	0.5	0.4

Data source: 2011 Mode Choice Behaviour Survey

Table 5.8 shows the relationship between car and motorbike driver's licence, and mode choice. For the people without car or motorbike driver's licence, if they were car or motorbike users, that means they were car or motorbike passengers. Generally speaking, people without car or motorbike driver's licence, they are more likely to choose public transport and bicycle. The percentage points of choosing car as a mode of transport for car driver's licence owners, which were 36.6%, were double compared to people without car driver's licence, at 15.1%. Mode choice of motorbike use between people having motorbike driver's licence and without motorbike driver's licence had the similar pattern as car driver's licence.

Table 5.8 Car and motorbike driver licence and mode choice

Unit: % of respondents

	Car driver's licence		Motorbike driver's licence	
	No	Yes	No	Yes
Car	15.1	36.6	30.5	31.8
Motorbike	44.3	46.5	23.1	50.1
Bus	24.8	10.1	28.2	10.9
Metro	7.3	3.6	9.0	3.7
Train	3.0	1.8	2.8	2.0
Bicycle	5.3	0.8	6.1	1.1
Others	0.2	0.5	0.4	0.4

Data source: 2011 Mode Choice Behaviour Survey

Table 5.9 and Table 5.10 show the relationship between household car and motorbike ownership, and mode choice. Generally speaking, as the number of car or motorbike owned increasing, the car or motorbike usage rates increased. In terms of household car ownership, the percentage of car usage increases from 3.5% to more than a quarter if the household car ownership increase from none to one car. The percentage of car usage reaches to about 50% if there are more than two cars in the household. Likewise, the percentage of motorbike usage increases from about 12% to 36% if the household motorbike ownership increases from none to one motorbike The percentage of motorbike usage reaches 50% if there are two or more motorbike in the household. For the household without car or motorbike, public transport has not been there only travel mode choice. As can be seen in Table 5.9 and Table 5.10, for the no-car ownership households nearly 70% chose motorbike, and for the no-motorbike households about 57% chose car.

Table 5.9 Household car ownership and mode choice

Unit: % of respondents

	0	1	2	3	>=4
Car	3.5	28.1	44.4	49.1	52.1
Motorbike	69.4	48.0	36.5	33.0	38.0
Bus	15.8	14.3	11.3	14.8	5.6
Metro	6.3	5.5	2.4	0.9	1.4
Train	1.3	1.8	3.3	0.9	1.4
Bicycle	3.3	1.9	1.7	0.4	1.4
Others	0.5	0.4	0.4	0.9	0.0

Data source: 2011 Mode Choice Behaviour Survey

Table 5.10 Household motorbike ownership and mode choice

Unit: % of respondents

	0	1	2	3	4	5	>=6
Car	56.6	40.2	28.7	23.9	21.5	15.4	16.1
Motorbike	11.9	36.1	49.3	55.0	59.1	71.8	67.7
Bus	14.9	13.4	14.7	12.4	12.4	8.5	12.9
Metro	12.3	5.4	3.4	3.6	3.0	1.7	0.0
Train	1.7	2.4	1.8	2.3	2.3	2.6	3.2
Bicycle	2.3	1.9	1.9	2.1	1.5	0.0	0.0
Others	0.3	0.7	0.2	0.7	0.3	0.0	0.0

Data source: 2011 Mode Choice Behaviour Survey

5.1.2 Descriptive analysis for variables in conditional logit model

In order to recognise the impact of district-level variables, such as population density, job density and access to public transport, on individual mode choice behaviour, a conditional logit model, with a linear utility function and car as reference mode, was estimated using intra-city trips data collected from the 2011 Mode Choice Behaviour Survey and integrating district-level of density, access to public transport variables. Five modes of transport were considered to be available as the dependent variables: (1) car, (2) bus, (3) metro, (4) motorbike, and (5) train.

Table 5.11 and Table 5.12 summarised the variables description, hypothesized direction of relationships and descriptive statistics by different mode of transport. For socio-economic characteristics, there are 7 variables included in the mode, which are age, personal income, vehicle owned or not (0 for no vehicle owned, 1 for vehicle owned), car licence (0 for no car licence, 1 for having car licence), motorbike licence (0 for no motorbike licence, 1 for having motorbike licence), number of cars in household, number of motorbikes in household.

As for trip characteristics, there are four variables included in the model, which are walking time, waiting time, in-vehicle time and travel cost, which are treated as alternative specific variables in the model.

As for district's contextual variables, there are five variables included in the model, which are population density of the trip origin's district, job density of the trip destination's district, bus stops (number of bus stops at the trip origin's district), bus frequency (average bus frequency for bus routes at the trip origin's district), metro stations (number of metro stations at the trip origin's district).

The hypotheses of the conditional logit model are that socio-economic characteristics such as age, personal income, car and motorbike ownership, and car and motorbike driver licence exert negative effects on individuals' mode choice towards public transport. On the other hand, districts' factors such as density and public transport provision exert positive on individuals' mode choice towards public transport.

Table 5.11 Variables description and hypothesis for mode choice analysis

Type	Name	Variable description	Hypothesized direction of relationships refer to car			
			Bus	Metro	Motorbike	Train
Dependent variable	Mode choice	The alternatives include car, motorbike, bus, metro and train. Use car as reference category	N.A.	N.A.	N.A.	N.A.
Independent variable	Age	The age of the individuals chosen from the age categories .	-	-	-	-
	Personal income[1]	The respondents' income per month, unit: US$/ per month.	-	-	-	-
	Owned vehicle or not	Categorical variable to indicate if the respondents own vehicle (car or motorbike) or not. Marked 0 for no vehicle owned and 1 for vehicle owned.	-	-	-	-
	Car licence	Categorical variable to indicate if the respondents own car driver licence or not. Marked 0 for no car driver licence and 1 for with car driver licence.	-	-	-	-
	Motorbike licence	Categorical variable to indicate if the respondents own motorbike driver licence or not. Marked 0 for no motorbike driver licence and 1 for with motorbike driver licence.	-	-	+	-
	Number of cars in household	Number of car owned by the respondent's household. Unit: cars.	-	-	-	-
	Number of motorbike in household	Number of motorbike owned by the respondent's household. Unit: motorbikes.	-	-	+	-
	Walking time	Walking time access to the mode of transport in which the respondent chose. Unit: mins.	-	-	+/-	-
	Waiting time	Walking time for public transport (bus, metro and train) users. Unit: mins.	-	-	+/-	-
	In-vehicle time	The times spend in-vehicle (car, motorbike, bus, metro and train). Unit: mins.	-	-	-	-
	Trip cost	Trip cost for car and motorbike users include parking and fuel costs, for bus, metro and train users are fare costs. Unit: US$.	-	-	-	-
	Population density at origin	The total population of the district divided by the area of the district where the origin was located. Unit: persons/ per 10000 sq. metre	+	+	+/-	+
	Job density at destination	The total jobs of the district divided by the area of the district where trip destination was located. Unit: jobs/ per 10000 sq. metre	+	+	+/-	+
	Bus stops	Total number of hundreds of bus stops in the district where trip origin was located. Unit: 100 bus stops	+	+	+/-	-
	Bus frequency	Total bus frequencies in the districts divided by total number of bus routes in the district where trip origin was located. Unit: bus runs/per bus route	+	+	+/-	-
	Metro stations	Total number of metro stations in the district where trip origin was located.	+	+	+/-	-

[1] Exchange rate, US:NTW(New Taiwan dollars) = 1:30

Table 5.12 Descriptive statistics of variables for conditional logit analysis

Modes of Transport	CAR				BUS				METRO				MOTORBIKE				TRAIN			
Explanatory variables	Max.	Min.	Mean	Std.	Max.	Min.	Mean	Std.	Max.	Min.	Mean	Std.	Max.	Min.	Mean	Std.	Max.	Min.	Mean	Std.
Age	65.00	14.00	41.82	11.72	65.00	14.00	36.96	15.29	65.00	14.00	36.60	13.06	65.00	14.00	37.85	13.00	65.00	14.00	36.61	14.11
Personal income[2]	3333.33	333.33	1393.33	827.62	3333.33	333.33	903.33	693.96	3333.33	333.33	1150.00	764.97	3333.33	333.33	990.00	647.41	3333.33	333.33	1053.33	824.43
Owned vehicle or not	1.00	0.00	0.73	0.44	1.00	0.00	0.25	0.44	1.00	0.00	0.20	0.40	1.00	0.00	0.65	0.48	1.00	0.00	0.26	0.44
Car licence	1.00	0.00	0.89	0.31	1.00	0.00	0.56	0.50	1.00	0.00	0.62	0.49	1.00	0.00	0.78	0.42	1.00	0.00	0.68	0.47
Motorbike licence	1.00	0.00	0.85	0.36	1.00	0.00	0.68	0.47	1.00	0.00	0.68	0.47	1.00	0.00	0.92	0.27	1.00	0.00	0.80	0.41
Number of cars in household	5.00	0.00	1.62	0.77	5.00	0.00	1.25	0.75	3.00	0.00	1.02	0.55	5.00	0.00	1.18	0.77	4.00	0.00	1.41	0.66
Number of motorbike in household	8.00	0.00	1.70	1.14	6.00	0.00	2.01	1.14	5.00	0.00	1.66	1.20	8.00	0.00	2.41	1.17	5.00	0.00	2.00	1.18
Walking time	10.00	2.00	3.06	1.78	23.50	2.00	6.23	5.09	23.50	2.00	8.16	4.78	8.00	2.00	2.65	1.38	30.00	2.00	10.47	6.50
Waiting time	0.00	0.00	0.00	0.00	120.00	2.00	10.25	7.88	20.50	2.00	6.57	3.29	0.00	0.00	0.00	0.00	20.50	2.00	9.58	5.06
In-vehicle time	80.00	10.00	24.12	12.98	77.50	10.00	23.57	12.87	77.75	10.00	24.79	12.78	67.50	7.00	18.88	9.71	75.50	10.00	25.96	13.26
Travel cost	13.33	0.00	2.12	1.68	3.35	0.00	0.75	0.73	2.18	0.00	0.97	0.46	3.02	0.00	0.71	0.59	5.35	0.00	1.45	1.10
Population density	379.00	0.00	67.76	78.15	379.00	1.00	85.46	92.02	379.00	4.00	137.50	96.61	379.00	0.00	82.59	84.57	275.00	0.00	47.64	63.86
Job density at destination	334.40	0.02	30.06	34.35	334.40	0.14	72.13	48.72	334.41	1.02	69.68	51.89	334.41	0.06	37.13	37.82	122.94	0.04	32.69	40.03
Bus stops	2956.00	2.00	954.60	740.60	2956.00	11.00	1149.00	765.34	2956.00	36.00	1628.00	633.14	2956.00	0.00	1018.70	732.79	2621.00	2.00	753.00	687.46
Bus frequency	44.04	0.00	6.64	5.21	44.04	0.22	7.55	5.38	44.04	0.59	9.72	6.95	44.04	0.00	6.87	4.40	15.45	0.55	5.19	3.42
Metro stations	11.00	0.00	0.26	2.49	11.00	0.00	1.70	2.73	11.00	0.00	4.74	3.19	11.00	0.00	0.33	2.42	1.00	0.00	0.09	2.13

[2] Exchange rate, US:NTW(New Taiwan dollars) = 1:30

5.2 Model form

Conditional logit model was used to examine the effects of travel related factors, public transport provision, density on travel mode choice accounting for socio-demographic characteristics. The utility functions for car, motorbike, bus, metro and train are as the followings.

$$U_{car} = (\theta_{car}SD + \gamma_{car}PT + \delta_{car}D + \beta_1 WK_{car} + \beta_2 WT_{car} + \beta_3 VT_{car} + \beta_4 TC_{car}) + \varepsilon_{car} = V_{car} + \varepsilon_{car} \quad \text{(Equation 5.1)}$$

$$U_{MB} = \alpha_{MB} + \theta_{MB}SD + \gamma_{MB}PT + \delta_{MB}D + \beta_1 WK_{MB} + \beta_2 WT_{MB} + \beta_3 VT_{MB} + \beta_4 TC_{MB} + \varepsilon_{MB} = V_{MB} + \varepsilon_{MB} \quad \text{(Equation 5.2)}$$

$$U_{bus} = \alpha_{bus} + \theta_{bus}SD + \gamma_{bus}PT + \delta_{bus}D + \beta_1 WK_{bus} + \beta_2 WT_{bus} + \beta_3 VT_{bus} + \beta_4 TC_{bus} + \varepsilon_{bus} = V_{bus} + \varepsilon_{bus} \quad \text{(Equation 5.3)}$$

$$U_{metro} = \alpha_{metro} + \theta_{metro}SD + \gamma_{metro}PT + \delta_{metro}D + \beta_1 WK_{metro} + \beta_2 WT_{metro} + \beta_3 VT_{metro} + \beta_4 TC_{metro} + \varepsilon_{metro} = V_{metro} + \varepsilon_{metro} \quad \text{(Equation 5.4)}$$

$$U_{train} = \alpha_{train} + \theta_{train}SD + \gamma_{train}PT + \delta_{train}D + \beta_1 WK_{train} + \beta_2 WT_{train} + \beta_3 VT_{train} + \beta_4 TC_{train} + \varepsilon_{train} = V_{train} + \varepsilon_{train} \quad \text{(Equation 5.5)}$$

Where, MB denotes motorbike, SD denotes socio-demographic characteristics including age, monthly income, car and motorbike driver's licence (dummy variables), household car and motorbike ownerships. PT refers to public transport provision including bus stops, bus frequency and metro stations. WK, WT, VT and TC refer to walking time, waiting, in-vehicle time and travel cost (out of pocket cost) respectively.

Walking time (WK), waiting time (WT) and in-vehicle time (VT) are alternative-specific variables, which are varied across alternatives.

By assuming that random terms of the utility functions are independent and identically Gumbel-distributed, the modelling framework used for estimating the probability of choosing mode (*i*) for person (*n*) is given by:

$$Pr(ni) = \frac{exp(v_{ni})}{\sum_J exp(v_{nj})} \quad \text{(Equation 5.6)}$$

Where, *J* is the choice set of transport modes: car, motorbike, bus, metro and train.

5.3 Estimation results

5.3.1 Estimation results

The results of the estimated conditional logit model are shown in Table 5.13 and the model's goodness of fit (GOF) McFadden's R^2 is about 0.19. All the coefficients of the explanatory variables are as the expected directions. If compare the explanatory power between socio-economic characteristics and district factors, the explanatory power of district factors is a quarter of the explanatory power of socio-economic characteristics.

As for the influence of socio-economic characteristics on mode choice between car and public transport, individuals who are vehicle owner, having car licence and having more cars in household tend to use car more than bus, metro and train. High income users are less likely to choose bus than car; however, income is insignificant for metro.

This study found that land use variable at trip destination exerted more influence than at trip origin. Job density at the trip destination is statistically significant while population density is statistically insignificant for all the public transport modes in the model. Districts of trip destinations with higher job density are associated with higher percentage of public transport use.

In terms of public transport provision, increasing bus stops in districts might enable travellers to use the bus and metro service more than the car for their most frequent journeys. For metro service, increase bus frequency and metro service provision also have the effects of increasing mode choice behaviour towards metro.

5.3.2 Elasticity analysis

The last column in Table 5.13 shows the elasticity of the statistically significant variables. Elasticity is computed as the percentage of one variable in response to a 1% change of another variable. Not surprisingly number of cars in household had the highest negative elasticity among the sociodemographic variables for the mode choice of bus, metro and train compared to car. Hence, reduce household car ownership is the best way to encourage more use of public transport (bus, metro and train).

In terms of district variables' elasticity for the travel mode choice between bus and car, job density at trip destination had higher elasticity (0.32) than bus stops (0.26) for bus users, which indicate that the increase of 1% job density at trip destination can attract the higher percentage of bus use compared with the increase of 1% bus stops.

In terms of district variables' elasticity for the travel mode choice between metro and car, metro stations (1.09) had the highest elasticity, followed by bus stops (0.93) and job density (0.79), which indicate that the best ways to boost metro patronage is to add metro station and increase bus stops at trip origin, and raise job density at trip destination.

5.3.3 The value of travel time savings (VTTS)

According to the estimated coefficients of walking time, waiting time, in-vehicle time and trip cost, the value of travel time savings can be calculated by $\beta_{time}/\beta_{cost} \times 60_{mins}$. These estimated coefficients of cost and the various time components provide information on the value of walking time saving, waiting time saving and in-vehicle time saving, which means the extra cost that a person would be willing to pay to save time. All the signs of the coefficients for walking time, waiting time, in-vehicle time and trip cost, are negative means that they all act, as expected, disutility to travel behaviour.

Table 5.14 shows the estimated value of time savings. Walking time savings has the highest value, $8.9 per hour, following by waiting time savings, $5.7 per hour, and in-vehicle time savings, $2.4 per hour. The value of walking time savings is about three times to the value of in-vehicle savings and the value of waiting time savings is about two times to the value of in-vehicle time savings. As walking and waiting are mainly happened in using public transport, the measures to decrease walking and waiting time might be crucial for increasing people preference for public transport.

The estimated value of waiting time savings is similar to the average hour wage of all the respondents. Average monthly income for all the respondents was about US$ 1,130. If calculated the average monthly income to average hour wage by dividing monthly working hours – the legal working hours are 42 hours per week in Taiwan, the average hour wage was US$6.2. So, the values of waiting time savings (US$ 5.7/hr), walking time savings (US$ 8.9/hr) and in-vehicle time savings (US$ 2.4/hr) are about 0.92. 1.44

and 0.39 of the average hour wage respectively. In addition, the values of walking time savings and waiting time savings are 3.71 and 2.38 times of the value of in-vehicle savings respectively.

Table 5.13 Estimation results for conditional logit model

Transport modes	Explanatory Variables		B.	Std. dev.	Sig.	Odds Ratio	Elasticity
BUS	Intercept		9.25E-01	2.90E-01	***		
	Socio-economic factors	Age	-2.99E-03	4.52E-03			
		Monthly income	-1.27E-01	3.10E-02	***	0.88	-0.30
		Vehicle owned or not	-1.83E+00	1.38E-01	***	0.16	-0.39
		Car driver's licence	-8.62E-01	1.73E-01	***	0.42	-0.41
		Motorbike driver's licence	6.55E-02	1.76E-01			
		Number of cars in household	-5.92E-01	8.36E-02	***	0.55	-0.63
		Number of motorbikes in household	3.59E-01	5.63E-02	***	1.43	0.62
	District factors	Population density at trip origin	3.31E-05	8.94E-04			
		Job density at trip destination	5.13E-03	1.79E-03	***	1.01	0.32
		Bus stops	2.66E-04	9.44E-05	***	1.00	0.26
		Bus frequency	4.42E-03	1.23E-02			
		Metro stations	2.59E-02	2.86E-02			
METRO	Intercept		-1.22E+00	4.64E-01	***		
	Socio-economic factors	Age	-1.82E-02	7.47E-03	**	0.98	-0.63
		Monthly income	-4.11E-02	4.37E-02			
		Vehicle owned or not	-2.33E+00	2.29E-01	***	0.10	-0.44
		Car driver's licence	-4.82E-01	2.50E-01	*	0.62	-0.28
		Motorbike driver's licence	2.95E-02	2.51E-01			
		Number of cars in household	-9.40E-01	1.62E-01	***	0.39	-0.91
		Number of motorbikes in household	2.75E-01	9.10E-02	***	1.32	0.44
	District factors	Population density at trip origin	5.74E-04	1.15E-03			
		Job density at trip destination	1.20E-02	2.16E-03	***	1.01	0.79
		Bus stops	5.98E-04	1.49E-04	***	1.00	0.93
		Bus frequency	2.94E-02	1.47E-02	**	1.03	0.27
		Metro stations	2.42E-01	3.31E-02	***	1.27	1.09
MOTORBIKE	Intercept		9.35E-01	2.37E-01	***		
	Socio-economic factors	Age	-1.58E-02	3.62E-03	***	0.98	-0.31
		Monthly income	-1.70E-01	2.15E-02	***	0.84	-0.27
		Vehicle owned or not	-2.69E-01	1.01E-01	***	0.76	-0.09
		Car licence	-5.61E-01	1.46E-01	***	0.57	-0.23
		Motorbike Licence	1.07E+00	1.60E-01	***	2.92	0.52
		Number of cars in household	-7.86E-01	6.13E-02	***	0.46	-0.49
		Number of motorbikes in household	5.64E-01	4.22E-02	***	1.76	0.72
	District factors	Population density at trip origin	4.40E-04	6.88E-04			
		Job density at trip destination	4.37E-03	1.39E-03	***	1.00	0.09
		Bus stops	8.82E-05	7.14E-05			
		Bus frequency	-2.04E-02	1.03E-02	**	0.98	-0.07
		Metro stations	2.24E-02	2.24E-02			
TRAIN	Intercept		-8.89E-03	5.62E-01			
	Socio-economic factors	Age	-1.29E-02	9.63E-03			
		Monthly income	-7.71E-03	6.31E-02			
		Vehicle owned or not	-1.90E+00	2.92E-01	***	0.15	-0.48
		Car licence	-8.14E-01	3.52E-01	**	0.44	-0.54
		Motorbike Licence	5.86E-01	3.91E-01			
		Number of cars in household	-5.07E-01	1.66E-01	***	0.60	-0.70
		Number of motorbikes in household	2.48E-01	1.15E-01	**	1.28	0.49
	District factors	Population density at trip origin	-3.25E-03	2.60E-03			
		Job density at trip destination	1.00E-02	3.63E-03	***	1.01	0.32
		Bus stops	-1.37E-04	2.29E-04			
		Bus frequency	-8.98E-02	4.32E-02	*	0.91	-0.46
		Metro stations	-9.42E-02	8.51E-02			
	Walking time		-1.59E-02	8.13E-03	*		
	Waiting time		-1.31E-02	7.08E-03	*		
	In-vehicle time		-4.21E-03	2.03E-03	**		
	Travel cost		-3.49E-03	7.92E-04	***		

1. The reference category: CAR
2. Significant codes (Sig.): '***' P<0.01, '**' P<0.05, '*' P<0.1
3. McFadden R^2: 0.18842, Likelihood ratio test : chisq = 1631.4 (p.value = < 2.22e-16)

Table 5.14 Estimated value of time saving

Items	Value ($US/hour)[3]
Value of walking time saving	8.89
Value of waiting time saving	5.74
Value of in-vehicle time saving	2.43

5.4 Summary

1. This chapter examined the impacts of land use variables across trip origin and destination (population density at trip origin, job density at trip destination), access to public transport and socio-economic characteristics on mode choice behaviour for Taiwan, Southeast Asia.
2. The results showed that job density at trip destination plays a more important role than population density at trip origin for travel mode choice. This result is also reported by Ding et al. (2014).
3. With regard to public transport provision, the results found that bus stop, bus frequency and metro stations had statistically significant effects on encouraging metro use rather than car. The elasticity showed that add metro station and increase bus stops at trip origin are the better ways to attract metro use.
4. The value of travel time savings (VTTS) estimated by conditional logit model is $8.9 per hour for the value of walking time savings, $5.7 per hour for the value of waiting time savings, and $2.4 per hour for the value of in-vehicle time savings. Paulley et al. (2006) also reported that walking times to and from bus stops and stations were about 1.4 to 2.0 units of in-vehicle time by summarising 183 studies. The reason why the value of walking time is about 3.7 times of the value of in-vehicle time in Taiwan is perhaps because the weather is hot and humid. Walking is very unpleasant under this weather condition.
5. Walking and waiting are commonly happened in public transport. With regard to high value of walking time and waiting time, shortening walking time and waiting time when using public transport is critical for improving public transport's competitiveness compared with car and motorbike.

[3] Exchange rate, US:NTW(New Taiwan dollars) = 1:30

Chapter 6 **LAND USE INFLUENCE TRAVEL MODE CHOICE BEHAVIOUR**

This chapter addresses the Research Question 3 (RQ3) which aims to understand that are there a fundamentally different relationships between land-use factors at different geographic scales and travel mode choice behaviour in the context of Taiwanese high percentage of motorbike usage. If refers to the proposed model for travel mode choice behaviour towards use public transport in Figure 2.10, this chapter is to examine the relationships between Block C – land use factors, Block A – socio-demographic characteristics, and travel mode choice behaviour (see Figure 2.10).

There two objectives for RQ3. The first is to examine the land use variables at different geographic scales (district and city/county) influence travel mode choice between car, motorbike and public transport. The second is to examine land use variables across trip origin and trip destination influence travel mode choice between car, motorbike and public transport.

Multilevel MNL models are adopted in this chapter. In the analysis of the effects of land-use on travel behaviour, individuals' travel behaviour data and zonal area data, such as land-use, always have the features of hierarchical clustering or cross-classified structures. For example, in a travel mode choice context, individuals are clustered in households and households in home zones. In addition, if consider the effects of spatial contexts at trip origins and destinations, the clustered relationships become cross-classified, which means that individuals are both clustered in districts of trip origins and in districts of trip destinations. Traditional single level multinomial logit model neglects the within cluster variation and may lead to an inferior data fit. Multilevel models can accommodate spatial autocorrelation, spatial heterogeneity, higher-level context, and simultaneous handling of the micro-scale of individuals and the macro-scale of places. Several studies have suggested that multilevel modelling method satisfies the requirements of land-use and travel behaviour study, which places difference and data at different geographic scales should be accounted for (Overmars and Verburg, 2006, Jones and Duncan, 1996), while only few studies have adopted multilevel modelling method (Antipova et al., 2011, Li et al., 2005, Schwanen et al., 2004, Snellen et al., 2002, Bhat, 2000). Hence, this chapter used multilevel multinomial model and multilevel cross-classified model to examine the impacts of land-use variables at district-level and city/county level, and across trip origins and destinations on mode choice behaviour.

There are five sections in this chapter. The first section introduces the conceptual models of multilevel multinomial logit (MNL) model and multilevel cross-classified multinomial logit (MNL) model. The second section presents both of the model forms. This is followed by descriptive statistics of the data used in this chapter. The fourth section delivers the models' estimated results. The final section summarises the key findings of this chapter.

6.1 Multilevel conceptual model

In order to analyse the land-use variables' influence on mode choice behaviour, this chapter used Taiwanese 2011 Mode Choice Behaviour Survey Data to estimate two multilevel multinomial logit (MNL) models, which are multilevel MNL model and multilevel cross-classified MNL model.

The first model, which we expect there may be unobserved heterogeneity between individuals i and between districts j of trip origins, which are purely clustered. Therefore, a three-level multilevel multinomial logit model is adopted to capture the clustered variations, as shown in Figure 6.1.

As can be seen in Figure 6.1, socio-demographic characteristics and travel-related variables were included in the individual level. Socio-demographic characteristics included age, income, car and motorbike driver licence, household car and motorbike ownership. Travel-related factors included travel cost and OD distance. At the second level, district-level, land use variables: population density, job density, mix land use entropy, percentage of four-way intersections and numbers of cul-de-sac were adopted. At the city/county-level, density and land use mix entropy were adopted.

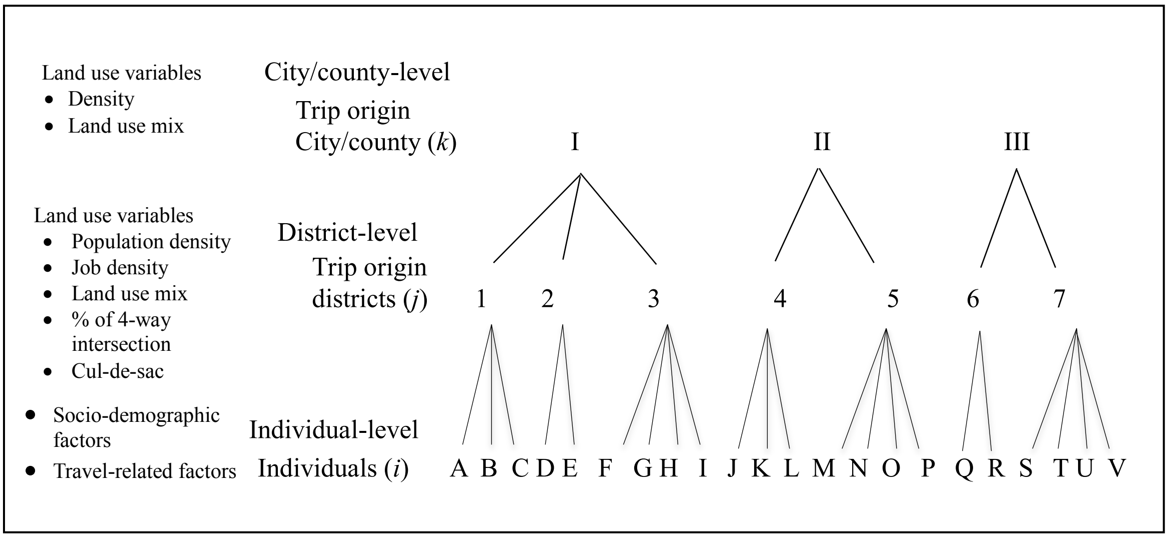


Figure 6.1 Three-level multilevel conceptual model

Figure 6.2 shows the conceptual model for multilevel cross-classified MNL model. The basic unit of analysis is the trip, as made by individuals. In order to extract the true spatial effects of land use on mode choice behaviour, the work in this chapter includes trip purpose of work and school, socio-demographic: personal monthly income, driver's licence for car and motorbike, and travel-related level of service variables: OD distance and travel cost, at the individual level as controlling factors.

This multilevel cross-classified MNL model is to examine the spatial heterogeneity across the trip origins and destinations. Districts are used as the spatial unit to accommodate the spatial heterogeneity across trip origins and destinations. Individual travellers are nested within districts. Travellers are cross-classified by home location (trip origin) and the district within which their trip ends (trip destination).

Household-level and neighbourhood-level are not included in this chapter's analysis because, for Taiwan's 2011 Mode Choice Behaviour Survey data, there were only two samples for each household, which were a vehicle-owner and a non-vehicle-owner. This sample size for each household is not enough to estimate the household heterogeneity. In addition, analysing the spatial heterogeneity at neighbourhood level and at district level (neighbourhoods clustered in districts) would involve examining the spatial heterogeneity of different geographical scale. This will add complexity to the model structure and will substantially increase the number of variables incorporated in the model. This chapter concentrates on the cross-classified relation across trip origins and destinations.

The model includes five variables - population density, job density, land use mix entropy, percentage of four-way intersections and numbers of cul-de-sac- to represent land use effects. These land use effects on mode choice behaviour were estimated at both trip origin level and trip destination level because these land use variables may play different roles for mode choice at trip origins from trip destinations. For population density and job density, Pivo (1994) found that population density at the trip origins and job density at the trip destinations played a role on influencing mode choice. Zhang (2004) also found that population density at the trip destinations had significant relationships with mode choice for both work and non-work trips. In order to understand the impacts of population density and job density at both trip origins and destinations on mode choice and to compare this chapter's results to previous results, the effects of population density and job density were estimated at both trip origins and trip destinations. The multilevel cross-classified model structure is shown as

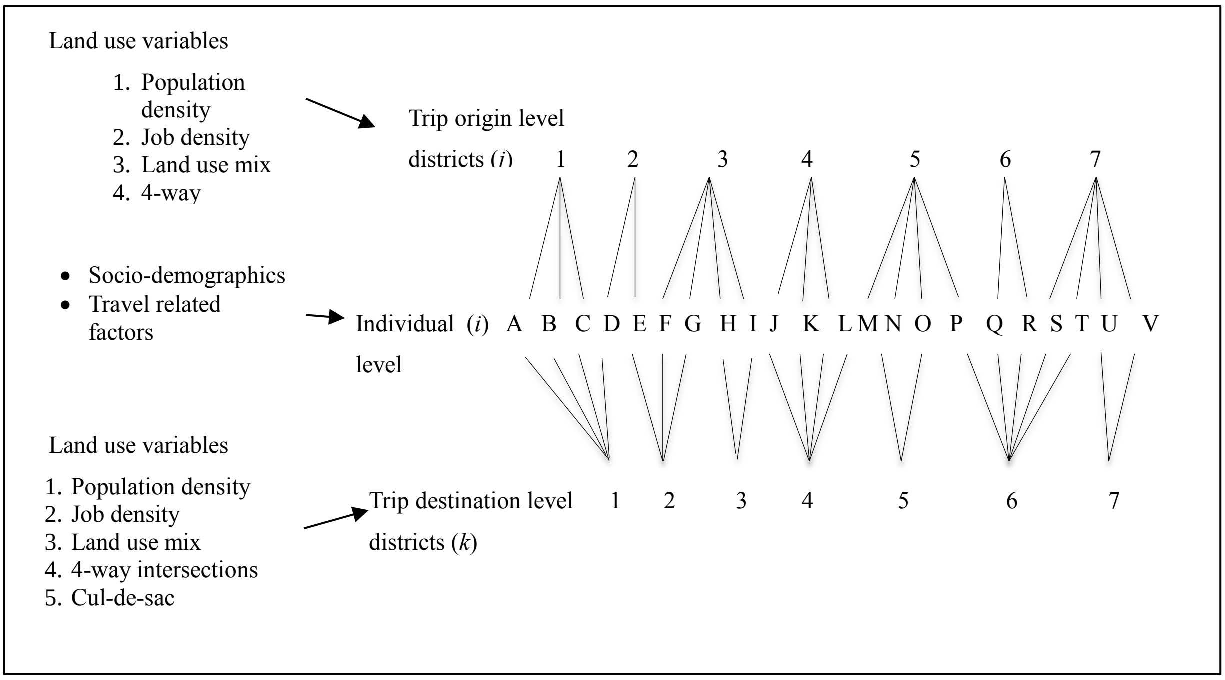


Figure 6.2 Multilevel cross-classified conceptual model

The discrete dependent variable of this chapter's analysis is mode choice (from car, motorbike and public transport). Increasing public transport use is an important policy goal within Taiwan's National Road Public Transport Plan (Executive Yuan, 2012b). Gaining a better understanding of the extent to which land use characteristics influence mode choice between car and public transport, and between motorbike and public transport can help decision-makers plan better land use and transport integration strategies to fulfil this policy goal. Hence, bus, metro and train were combined as public transport, and public transport was set as the of interest (reference) category.

6.2 Descriptive statistics

6.2.1 Travel behaviour data

The travel behaviour data used in this chapter is drawn from Taiwanese 2011 Mode Choice Behaviour Survey (Institute of Transportation, 2011b). Respondents were asked to report the features of their most frequent trip during a week. Trip features asked about included mode choice (among bus, metro, train, car and motorbike), trip purpose, trip frequency, trip origin and destination, travel cost, travel time, and service satisfaction. Travel cost refers to the out-of-pocket monetary cost of the trip. For car and motorbike users, this includes parking costs and fuel costs but nothing towards the cost of vehicle purchase, tax, insurance and maintenance. For public transport users, this cost equals the fare paid if respondents hold seasonal tickets such as monthly tickets, are asked to convert to single trip cost according to their monthly trips.

A number of socio-demographic characteristics (gender, age, education, job and wage, and whether they had a car and/or motorbike driver's licence) were also collected for each respondent. At the household level, data was collected on the number of cars, motorbikes and bicycles within the household, household size, the total number of driver's licences held, and household income.

After removing incomplete responses, and bike and other users, this gave a valid sample size of 5,356 individuals. Among all the trips, the trip origins covered 289 districts of all 348 districts and covered all 19 cities/counties in Taiwan. Within the sample, 20.5% of trips were made by public transport, 46.9% by motorbike, and 32.5% were by car. (Also see Figure 3.4)

It should be noted that the trip data used in this chapter's analysis only covers frequent trips reported by respondents and does not include all trips made by them. This means that commuting trips and school trips are likely to be over represented in the dataset and social and leisure trips are likely to be underrepresented. Some of the tour features, such as stops or transfers within the trips are not reported in the survey.

Table 6.1 show the relationships between sociodemographic characteristics and mode choices. In Taiwan, a greater proportion of males use the car, whilst a higher proportion of females use public transport. Use of the motorbike is evenly split between males and females. The samples' gender ratio of female to male is 50.6% to 49.4%. The chi-square test shows that we cannot reject the hypothesis that the samples' gender ratio is the same as Taiwan's population gender ratio of 49.9% to 50.1% (Taiwan Ministry of the Interior, 2015). Table 6.1 also shows that the groups of people aged under 14 and 15-24 have higher proportion to use public transport over car and motorbike. This maybe because people cannot have a car and motorbike driver's licence until the age of 18 in Taiwan due to the regulation. Car and motorbike users under age 18 are passengers driven by their parents or someone else. Aged 15 - 34 have the highest percentage of motorbike use, and aged 35 - 54 have the highest percentage of car use. This may reflect to people's mode shift from motorbike to car along with their age increase and social status changes. In addition, for occupancy, students have the highest percentage of choosing public transport compared to other occupancy.

The driver's licence ownership and children in household associate with mode choice, as shown in Table 6.1. The percentage of respondents who own car driver's licence and use car is more than twice as the percentage of respondents who do not own car driver's licence and use car as passengers. Likewise, the percentage of respondents who own motorbike driver's licence and use motorbike is about twice as the percentage of respondents who do not own motorbike driver's licence and use motorbike as passengers. Respondents with children (under 18) in households have much higher percentage of using car than respondents without children in household because the responsibility of transport their children.

Table 6.1 socio-demographics and mode choice

Gender	Mode choice	Frequency	Percent
Female	Car	841	30.7
	Motorbike	1294	47.2
	Public transport	606	22.1
	Total	2741	100.0
Male	Car	901	34.5
	Motorbike	1220	46.7
	Public transport	493	18.9
	Total	2614	100.0
Aged			
Under 14	Car	33	27.0
	Motorbike	49	40.2
	Public transport	40	32.8

	Total	122	100.0
15-24	Car	90	13.8
	Motorbike	329	50.4
	Public transport	234	35.8
	Total	653	100.0
25-34	Car	341	26.3
	Motorbike	712	54.9
	Public transport	244	18.8
	Total	1297	100.0
35-44	Car	520	40.8
	Motorbike	554	43.4
	Public transport	202	15.8
	Total	1276	100.0
45-54	Car	445	39.0
	Motorbike	493	43.2
	Public transport	203	17.8
	Total	1141	100.0
55-64	Car	245	38.4
	Motorbike	268	42.0
	Public transport	125	19.6
	Total	638	100.0
65 and over	Car	68	29.8
	Motorbike	109	47.8
	Public transport	51	22.4
	Total	228	100.0
Occupancy			
Student	Car	121	16.8
	Motorbike	327	45.3
	Public transport	274	38.0
	Total	722	100.0
Public servant	Car	281	43.8
	Motorbike	254	39.6
	Public transport	107	16.7
	Total	642	100.0
Technology industry	Car	199	37.5
	Motorbike	251	47.4
	Public transport	80	15.1
	Total	530	100.0
Financial industry	Car	68	34.5
	Motorbike	74	37.6
	Public transport	55	27.9
	Total	197	100.0
Business and service industry	Car	346	35.6
	Motorbike	463	47.6
	Public transport	163	16.8
	Total	972	100.0
Other service industry	Car	365	32.9
	Motorbike	564	50.8
	Public transport	181	16.3
	Total	1110	100.0
Housekeeper	Car	181	28.5
	Motorbike	325	51.3
	Public transport	128	20.2
	Total	634	100.0
Others	Car	181	33.0
	Motorbike	256	46.7
	Public transport	111	20.3
	Total	548	100.0

Car driver's licence owned or not	Yes=1	Car	1563	37.1%
		Motorbike	1971	46.8%
		Public transport	678	16.1%
		Total	4212	100.0%
	No=0	Car	179	15.6%

		Motorbike	544	47.6%
		Public transport	421	36.8%
		Total	1144	100.0%
Motorbike driver's licence owned or not	Yes=1	Car	1502	32.5%
		Motorbike	2333	50.4%
		Public transport	790	17.1%
		Total	4625	100.0%
	No=0	Car	240	32.8%
		Motorbike	182	24.9%
		Public transport	309	42.3%
		Total	731	100.0%
Children (age under 18) in household or not	Yes=1	Car	915	36.0%
		Motorbike	1130	44.4%
		Public transport	499	19.6%
		Total	2544	100.0%
	No=0	Car	827	29.4%
		Motorbike	1385	49.3%
		Public transport	600	21.3%
		Total	2812	100.0%

Table 6.2 shows the descriptive of income, household car ownership, household motorbike ownership, travel cost and OD distance compared with different mode choice groups. For personal income and household income per month, car users have the highest average income level (US$1,400 and US$2,900 for personal income and household income respectively) than motorbike (US$1,000 and US$2,400 for personal income and household income respectively) and public transport users (US$1,000 and US$2,700 for personal and household income respectively). For household car ownership and household motorbike ownership, car users have the highest average household car ownership (average 1.6 cars per household) than motorbike and public transport users. Also, motorbike users have the highest average household motorbike ownership (average 2.4 motorbikes per household) than other mode groups.

In terms of travel cost, car users have the highest average travel cost, US$2.3 compared with motorbike and public transport users. Travel cost refers to out of pocket cost, which includes fuel cost and parking cost for car and motorbike, and fare cost for public transport. The respondents who hold season tickets such as monthly tickets were asked to convert to single trip costs according to their monthly trips.

OD distance is included in this chapter's analysis is to examine the impacts of spatial distance between trip origins and destinations on mode choice behaviour. As precise origins and destinations were not known, it was calculated using the Euclidean distance between the trip origin district and trip destination district centroids. The district centroids were found by calculating the median centres, which minimize the overall Euclidean distance to the points of interests (POI) in each district. The POI data was supplied by Taiwanese Institute of Transportation, and included government offices, education facilities and public services. Trips that originated and ended within the same district were assigned an OD distance of 3 km. This distance (3km) is approximately half the average radius of the districts. Table 6.2 shows that car users have the longest average OD distance (8.8 km) ranging from about 1.2km to 166.8km and motorbike users have the shortest OD distance (6.3km) ranging from about 1.2km to 53.9km.

The distribution of OD distance for each mode reflects the service ranges for those modes. Table 6.2 shows that car enjoys the widest service range between the minimum of 1.2 km and maximum of 166.8 km than motorbike and public transport. Although there is some short trip use for cars, the average OD distance for car is the longest compared to motorbike and public transport. It seems that the car serves mainly for middle to long range trips. On the other hand, motorbike has the shortest average OD distance and smallest OD distance standard deviation, which means that motorbike may mainly serve for the shortest range trips due to the features of easy to use and free charging of parking in most cities in Taiwan. With trip distance increasing, travellers tend to use public transport and car instead of motorbike, possibly due to the increasing risks and discomfort for motorbike. In terms of public transport, the minimum OD distance is longer than that for motorbike and car, which may mean that for some short distance trips public transport users tend to walk or cycle rather than use public transport. The average OD distance for public transport is in between car and motorbike, which means that public transport may mainly cover the middle range trips in Taiwan. As trip distance increases, travellers would tend to use the car rather than public transport, possibly due the increasing in-vehicle time, transfers and waiting time. Although travel time was not included in the work in this chapter, the OD distance adopted in this chapter’s analysis can reflect the some of the features of car, motorbike and public transport.

Table 6.2 Income, motorised vehicle ownership and mode choice

	Items	Min.	Max.	Mean	Std. Deviation
Car	Personal income per month (US$ 1,000[4])	.3	3.3	1.4	.85
	Household income per month(US$ 1,000[1])	.7	7.50	2.9	1.79
	Household car ownership	0.0	6.0	1.6	.82
	Household motorbike ownership	0.0	8.0	1.7	1.19
	Travel cost (US$[1])	0	14	2.3	2.05
	OD distance	1.2	166.8	8.8	8.81
Motorbike	Personal income per month (US$ 1,000[1])	.3	3.3	1.0	.67
	Household income per month(US$ 1,000[1])	.7	7.5	2.4	1.58
	Household car ownership	0.0	6.0	1.2	.79
	Household motorbike ownership	0.0	8.0	2.4	1.20
	Travel cost (US$[1])	0	12.7	1.0	1.20
	OD distance	1.2	53.9	6.3	5.59
Public transport	Personal income per month (US$ 1,000[1])	.3	3.3	1.0	.76
	Household income per month(US$ 1,000[1])	.7	7.5	2.7	1.71
	Household car ownership	0.0	5.0	1.2	.75
	Household motorbike ownership	0.0	6.0	1.9	1.18
	Travel cost (US$[1])	0	6.7	1.0	0.98
	OD distance	1.7	50.9	7.7	6.77

6.2.2 Land use data

In this chapter, the impacts of land use factors on individuals' mode choice behaviour are examined at the district and city/county scale. There are 348 districts clustered in 19 cities/counties in Taiwan. The average area and population of the districts and cities/counties are 102 km2 and 66,000 residents for each district and about 1,800 km2 and 1,210,000 residents for each city/county respectively.

The trip origins of 5,356 samples used in this analysis were clustered in 285 districts of 348 districts and in all 19 cities/counties, and the trip destinations covered 293 districts in Taiwan. About 65% of all the trips had their origin and destination located in different districts.

The data from the Mode Choice Behaviour Survey is supplemented with land use data. The land use data is drawn from the Taiwanese National Land Surveying and Mapping Centre and the Traffic Network Digital Map database under Taiwanese National Geographic Information System (TNGIS), at a resolution of 1/25,000. A number of land use variables are estimated at the district level: population density, job density, land use mix entropy, and the percentage of 4-way intersections and the numbers of cul-de-sac. Figure 6.3 shows the land use measurements at district-level and city/county-level in Taiwan.

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[4] Exchange rate: US$:NT$(New Taiwan Dollar)=1:30

Table 6.3 gives the mean, standard deviation for the land use variables across the respondents' trip origin and destination districts, and cities/counties included in the model. For land use mix entropy, which indicates the extent of land use diversity, was calculated as Eq. (1) based on six land use categories: residential, commercial, industrial, government offices, educations, and hospital and social care buildings. Land use entropy ranges from 0 to 1 in which higher entropy value indicates that a more evenly distributed mix of land uses.

$$Land\ use\ mix\ entropy = -\sum_j P_j \times \frac{\ln(P_j)}{\ln(J)} \qquad \text{(Equation 6.1)}$$

Where P_j is the proportion of land use type j in the area, and J is the total number of land use types, which equals to 6.

The percentage of four-way intersections indicates the extent of grid-like street pattern (Cervero and Kockelman, 1997). The numbers of cul-de-sac in the district represents the street connectivity. These were extracted from the mapping data of Taiwanese Traffic Network Digital Map using ArcGIS 10.2 package. The road network included all the road types, such as provincial road, city/county road, and load road, except highways.

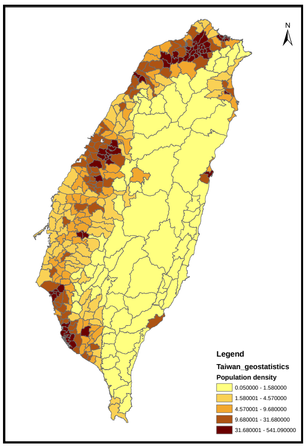
Population density and job density are adopted as explanatory variable at district-level either at trip origin or trip destination. At the city/county-level factor analysis was adopted to combine city/county's population density and job density into density variable. Most trips (81%) have their trip origins and destinations within the same city or county, and there is a high correlation between population density and job density (0.99) at this level. Thus it made sense to have a combined density measure at the city/county level.

The trip-related and socio-demographic variables adopted in this chapter's analysis were determined using a stepwise test to check if there were significant relations between the chosen variables and mode choice behaviour. The resulting variables selected to be included in the models were: trip purpose of work and school, and individual socio-demographic characteristics – age, gender, personal income, car driver's licence and motorbike driver's licence, children in household, and household car and motorbike ownerships as controlling factors. From the literature, these have been shown to be important determinants of mode choice.

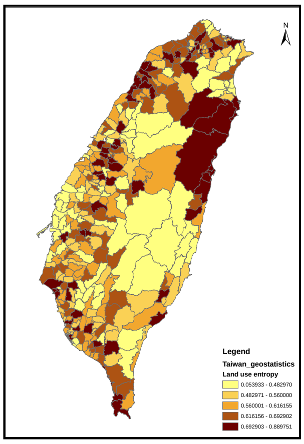
Table 6.3 Land use statistics for Taiwanese districts and city/county

Variables	Definition at district level	Trip origin districts		Trip destination districts		Cities/counties	
		Mean	SD	Mean	SD	Mean	SD
Population density	Population/area size(persons/ha)	83.77	96.62	86.64	97.07	22.59	28.39
Job density	Employment/area size(jobs /ha)	34.12	50.23	44.91	65.37	11.10	19.14
Land use mix entropy	Mixture of residential, commercial, industrial, government offices, educations, and hospital, social care buildings	0.65	0.11	0.65	0.11	0.66	0.04
% of 4-way intersections	Percentage of four-way intersections	0.22	0.07	0.23	0.09	--	--
Cul-de-sac	Numbers of cul-de-sacs	542.59	536.74	531.58	555.04	--	--
Density (city/county-level)	Factor analysis combines population density and job density at city/county level	--	--			0.00	1.00

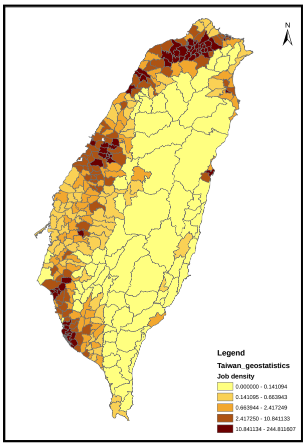
It should be noted that the population density, job density and numbers of cul-de-sac were standardised into z-scores for the purposes of the model estimation in order to obtain consistent results with other variables.



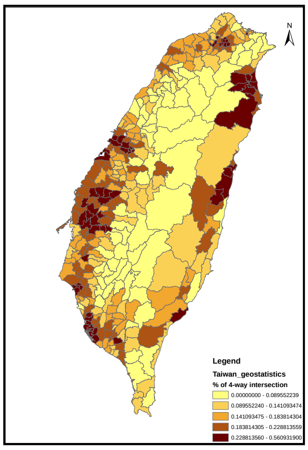
(a) Districts population density



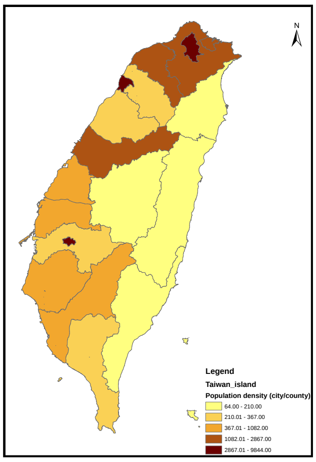
(b) Districts land use mix entropy



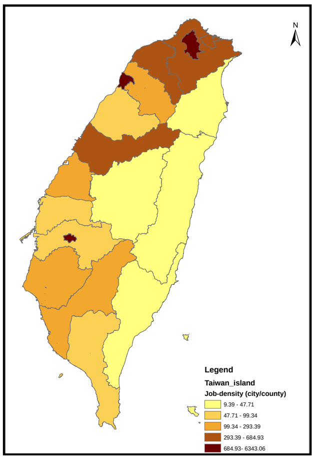
(c) Districts job density



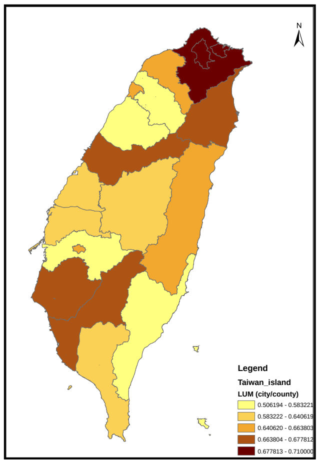
(d) District % of 4-way intersection



(e) City/county population density



(f) City/county job density



(g) City/county land use mix entropy

Figure 6.3 District and city/county land use features in Taiwan

6.3 Model form

6.3.1 Multilevel MNL model and multilevel cross-classified MNL model

Multilevel multinomial model and multilevel cross-classified MNL model is to capture the spatial heterogeneity at different geographical scales of district and city/county, and examine the impacts of land use variables at these geographical scales on travel mode choice behaviour. The multilevel MNL model allows the intercept of the utility functions to vary randomly over clusters. The utility function of the multilevel MNL model includes two parts, a fixed part and a random part. In order to capture the spatial heterogeneity, two random terms (combined as the random part) are included in the utility functions. The fixed part of the model includes individual level variables (trip-related, socio-demographic, and travel-related level of service variables), and land use variables at district-level and city/county-level.

Assuming a three-level multilevel MNL model (individual-level denotes i, district-level denotes j, and city/county-level denotes k), the utility function can be expressed as

$$U_{ijk} = \pi_{000} + \beta \ \ x_{ijk} + \gamma_{01k}\omega_{jk} + \pi_{001}\theta_k + \ \zeta_{0j} + \ \psi_k + \epsilon_{ijk} \qquad \text{(Equation 6.2)}$$

Where, $\pi_{000}$is constant of the function, $\beta \ \ x_{ijk} + \gamma_{01k}\omega_{jk} + \pi_{001}\theta_k$ is fixed part of the function. And $\zeta_{0j} + \ \psi_k + \epsilon_{ijk}$ is random part of the function. ω_{jk} is district-level explanatory variables, and γ_{01k} is coefficients for the district-level explanatory variables. ζ_{0j} is the district-level random terms representing spatial heterogeneity between districts. θ_k is city/county-level explanatory variables, and π_{001} is coefficients for the city/county-level explanatory variables. ψ_k is the city/county-level random terms representing spatial heterogeneity between city/county. Random terms at different levels are independent. Random terms at district-level and city/county-level are assumed to be normally and identically distributed, and random terms at different levels are independent.

$$\zeta_{0j}^{m} \sim N\left(0, \sigma^2_{\zeta_{0j}^{m}}\right), \psi_{00k}^{m} \sim N\left(0, \sigma^2_{\psi_{00k}^{m}}\right) \qquad \text{(Equation 6.3)}$$

The random terms at individual-level, ϵ_{ijk}, are independent and identically distributed with Gumbel (type 1 extreme value) distribution with a variance (σ^2_{ϵ}) of $\pi^2/6$ (Train, 2009).

Then a multinomial logit model form can be denoted as

$$\Pr\left(Y_{ijk} = m\right) = \frac{\exp(u_{ijk}^{m})}{\sum_{s=1}^{M} \exp(u_{ijk}^{s})} \quad \text{(Equation 6.4)}$$

The multilevel cross-classified MNL model allows the intercept of the utility functions to vary randomly across trip origins and trip destinations. The utility function of the multilevel cross-classified MNL model includes two parts, a fixed part and a random part. In order to capture the spatial heterogeneity across trip origins and trip destinations, three random terms – individual residuals, trip origin residuals and trip destination residuals - (combined as the random part) are included in the utility functions. The fixed part of the model includes individual level variables (trip-related, socio-demographic, and travel-related level of service variables), and land use variables at trip origin level and at trip destination level.

Assuming a three-level multilevel MNL model (individual level, trip origin level and trip destination level), the utility function can be expressed as

$$u_{ijk}^{m} = \pi_{000}^{m} + \beta_{1jk} x_{ijk}^{m} + \gamma_{01k}^{m} \omega_{jk} + \pi_{001}^{m} \theta_{k} + \mu_{0jk}^{m} + r_{00k}^{m} + \epsilon_{ijk}^{m} \quad \text{(Equation 6.5)}$$

Where, m is the set of alternatives (car, motorbike, public transport), and *i (i=1, 2, ...,I)* denotes individuals, which is nested in trip origin districts *j (j=1, 2, ...,J)* and in trip destination districts *k (k=1, 2, ..., K)*. π_{000}^{m} is constant of the function. $\beta_{1jk} x_{ijk}^{m} + \gamma_{01k}^{m} \omega_{jk} + \pi_{001}^{m} \theta_{k}$ is fixed part of the function. And $\mu_{0jk}^{m} + r_{00k}^{m} + \epsilon_{ijk}^{m}$ is random part of the function. x_{ijk}^{m} denotes the individual-level explanatory variables, ω_{jk} denotes level-2 (trip origin districts) explanatory variables, and θ_{k} denotes level-3 (trip destinations districts) explanatory variables. μ_{0j}^{m} and r_{00k}^{m} are random terms representing spatial heterogeneity parametres, which capture unobserved variations at trip origins and trip destinations, respectively. ϵ_{ijk}^{m} is a random term for the individual-level. Then a multinomial logit model form can be denoted as Equation 6.7.

However, the three-level multilevel multinomial model is not completely fit for this analysis in which data are impurely clustered between individuals and trip origin districts, and individuals and trip destination districts. Thus, a multilevel cross-classified multinomial model, which is a modified three-level multilevel multinomial model, is used.

The classification notation recognizes that cross-classified factors appear at the same level and thus has the same letter for the subscript representing them but is distinguished by numerical sub-subscripts ( ) as *(j1)* refers to the level of trip origin districts and *(j2)* refers to the level of trip destination districts (Browne et al., 2001). Therefore, the reduced form of the utility function for multilevel cross-classified multinomial models can be expressed as

$$u_{ijk}^{m} = \gamma_{000}^{m} + \beta_{1(j1,j2)}x_{i(j1,j2)}^{m} + \gamma_{0(j1)}^{m}\omega_{0(j1)}^{(2)} + \pi_{0(j2)}^{m}\theta_{0(j2)}^{(3)} + \mu_{00(j1)}^{m(2)} + \mu_{00(j2)}^{m(3)} + \epsilon_{i(j1,j2)}^{m} \quad \text{(Equation 6.6)}$$

Where, $\gamma_{000}^{m} + \beta_{1(j1,j2)}x_{i(j1,j2)}^{m} + \gamma_{0(j1)}^{m}\omega_{0(j1)} + \pi_{0(j2)}^{m}\theta_{0(j2)}$ is termed the fixed part of the model and $\mu_{00(j2)}^{m(3)} + \mu_{00(j1)}^{m(2)} + \epsilon_{i(j1,j2)}^{m}$ is termed the random part of the model.

In the fixed part of the model, $x_{i(j1,j2)}^{m}$ is an individual variable with slope coefficient $\beta_{1(j1,j2)}$, $\omega_{0(j1)}^{(2)}$ is a classification 2 variable with slope coefficient $\gamma_{0(j1)}^{m}$, and $\theta_{0(j2)}^{(3)}$ is a classification 3 variable with slope coefficient $\pi_{0(j2)}^{m}$. For random part of the model, $\mu_{00(j2)}^{m}$ and $\mu_{00(j1)}^{m}$ are random terms that capture unobserved variations at trip origins and trip destinations, respectively, and $\epsilon_{i(j1,j2)}^{m}$ is random term for individual-level, where $\mu_{00(j1)}^{m} \sim N\left(0, \sigma_{\mu_{00(j1)}^{m}}^{2}\right), \mu_{00(j2)}^{m} \sim N\left(0, \sigma_{\mu_{00(j2)}^{m}}^{2}\right)$.

The random terms at individual-level, ϵ_{ijk}, are independent and identically distributed with Gumbel (type 1 extreme value) distribution with a variance (σ_{ϵ}^{2}) of $\pi^2/6$ (Train, 2009).

6.3.2 ICC (Intra-class correlation)

The intra-class correlation coefficient (ICC) refers to the proportion of between group variance to total variance (Snijders, 2012). The index can represent the spatial heterogeneity of mode choice behaviour across districts (either trip origin district or trip destination district) and cities/counties, and can capture spatial autocorrelations among individuals within the same districts and cities/counties and recognise spatial heteroscedasticity (Ding et al., 2014). The ICC values for empty models (a model only adopts random effects without any explanatory variable) of linear regression models often range between 0.10 and 0.25 (Snijders, 2012). A greater ICC value for empty model indicates that adoption of the multilevel model is meaningful. Applying the notation for this chapter's analysis, the ICC for mode choice of car for multilevel MNL model can be expressed as

$$ICC^{car} = \frac{\sigma^2_{\zeta^{car}_{district}} + \sigma^2_{\psi^{car}_{city/county}}}{\sigma^2_{\zeta^{car}_{district}} + \sigma^2_{\psi^{car}_{city/county}} + \sigma^2_{\epsilon^{Car}}} \quad \text{(Equation 6.7)}$$

6.3.3 Estimation software

MLwiN (version 2.30), which was created by the Centre for Multilevel Modelling based in Bristol University, was used to estimate the results of all the models in this chapter. Only multinomial logit model can be estimated by MLwiN so far, which means that alternative specific variable is not allowed to be included in the model. Hence, travel time was not included in the models and travel cost was treated as individual-specific variable, which value did not vary across alternatives.

6.4 Results

This section presents the results of the model estimation. Six models were estimated. Model A and C are multilevel MNL models; Model D and F are multilevel cross-classified MNL models. Model B and Model E are single-level MNL models, which include district and city/county land use variables. The purposes of estimating the empty models – Model A and Model D – are to understand the ICC (Intra-class correlation) values for multilevel MNL model and multilevel cross-classified MNL model. Estimating single-level MNL models - Model B and Model E - are to compare the results with multilevel MNL model and multilevel cross-classified MNL model. The models' estimation was conducted using MCMC (Markov Chain Monte Carlo) procedures within the MLwiN package. These models were first run using restricted iterative generalized least square (RIGLS) to establish a prior distribution, follow by MCMC estimation using Gibbs sampling, with 2,000 burn in iterations and 300,000 iterations to get the posterior distribution.

6.4.1 Multilevel MNL model results

As can be seen in Table 6.4, Model A is null-models for multilevel MNL model with only intercept in the model. The purpose of Model A is to test the ICC values to see whether there is significant spatial heterogeneity or not. Model B is a single-level MNL model, which includes district-level and city/county-level explanatory variables within the same level. Model C is a 3-level multilevel MNL model which allowed intercepts to be varied randomly across district-level and city/county-level. This model includes travel-related attributes at the individual level, land use and public transport provision variables at district-level and city/county-level, and accounted for socio-demographic characteristics.

The reason for estimating Model A (null model) is to determine whether the adoption of a multilevel MNL model was justified. It depends on the significance of the spatial heterogeneity parametres representing the unobserved variations in utility functions and the level of ICC (intra-class correlation coefficients) values. Table 6.4 shows that all the spatial heterogeneity parametres for car and motorbike at district-level and city/county-level in Model A are significant. In addition, the ICC^{Car} and $ICC^{Motorbike}$ (intra-class correlation coefficient) across district-level and city/county-level, are 0.103 and 0.134, respectively, indicating that correlations for individuals at the same district and city/county are 10.3% and 13.4%, respectively. The high level of spatial heterogeneity at district-level and city/county-level implies that the spatial heterogeneity cannot be ignored and there is a need to adopt multilevel modelling technique to accommodate spatial issues of the work in this chapter.

With respect to the models' complexity and fit, the DIC (Deviance Information Criterion) (see Table 6.4) values suggest that Model C (Multilevel MNL model) is the best model among the three models. The DIC, which is the sum of the number of effective parametres (pD) and the deviance of MCMC, represents the model's complexity and fit, and may be used for comparing models(Spiegelhalter et al., 2002). The number of effective parametres refers to the complexity of a model and the deviance statistic refers to a model's fit. Since increasing complexity is trade-off by a better model's fit. Spiegelhalter et al. (2002) suggested that adds the model's fit (deviance of MCMC) and complexity (the number of effective parametres) to form the DIC (Deviance Information Criterion) for comparing models with the same structure or different structure. After adding spatial heterogeneity into the model, the DIC for model C reduced by around 43 compared with Model B. Although the number of effective parametres for Model C is 60 points higher than Model B, the deviance of MCMC for Model C, 9110.18, is about 102 points lower than Model B (Table 6.4).

The last column in Table 6.4 refers to the subtraction the absolute t-value for district-level and city/county-level variables in Model C from the absolute t-value for district-level and city/county-level in Model B. Most of the absolute t-values' difference between Model B and Model C are positive, except land use entropy at district-level for car and motorbike, and city/county-level for motorbike. In addition, comparing the coefficients' significant-level for density and % of 4-way intersection at district-level, these coefficients are significant at the 95% level in Model B but insignificant in Model C. This comparison provides evidence that, under the circumstances of high spatial autocorrelation, ignoring the spatial between-group difference by using a single-level discrete choice model (Model B) may exaggerate the coefficients' significance and lead to spurious results (Snijders, 2012, Snellen et al., 2002).

With respect to controlling factors of individual's socio-demographic factors and trip purpose in Model C, as shown in Table 6.4, Males tend to use motorbike more than public transport compared with females. Students are more likely to use public transport rather than car and motorbike compared to other occupation groups. Personal income shows opposite results between the mode choice of car and public transport, and motorbike and public transport. With increasing personal income, people are more likely to choose car over the public transport but would choose public transport over the motorbike. As for trip purpose, work and school trips are more likely to be made by public transport than by car while work trips are more likely to be made by motorbike than by public transport. Car and motorbike driver's licences also have significantly positive effects on car and motorbike use respectively.

With respect to household socio-demographic factors, households with children aged under 18 in the household tend to have a higher probability of car use than public transport use. Likewise, households with higher car or motorbike ownership are more likely to use the car or motorbike respectively (Table 6.4).

As for travel related attributes in Model C, as shown in Table 6.4, OD distance and travel cost have the opposite signs for people choosing between car and motorbike over public transport. With increasing OD distance, people tend to choose public transport rather than motorbike. On the other hand, higher travel costs intend to encourage car and motorbike use rather than public transport use.

After accounting for the controlling factors, the Model C results, as shown in Table 6.4, indicate that land use variables exert significant influence on mode choice behaviour. At the district-level, increasing population density and job density is significantly associated with a greater probability of choosing public transport over the car and the motorbike. On the other hand, the percentage of 4-way intersections – representing grid-like street pattern – shows strong association with motorbike and car use, which means that people in the districts with more gird-like street pattern tend to choose motorbike rather than public transport. Districts with more evenly distributed land uses – higher land use entropy values – tend to have more car use than public transport but tend to have more car and motorbike use than public transport (though not significant at the 95% level). In terms of the city/county-level, increasing density is associated with a higher probability of choosing public transport over the car and the motorbike, although the significant level for car is only at 90%.

The covariance of the random part refers to the correlation between car and motorbike use at district-level and city/county-level (Table 6.4). The positive covariance at district-level and city/county-level means that districts and city/ county in Taiwan have higher proportion of car use also have high proportion of motorbike use.

With respect to spatial heterogeneity (random terms), Model A, as shown in Table 6.4, shows that spatial heterogeneity parametres at district-level and city/county-level are at the level of significance of 90% and 95% respectively. It means that there is significant spatial heterogeneity (unobserved factors) influence mode choice behaviour between districts and cities/counties.

Table 6.4 Multilevel MNL model results

	Fixed Part	Model A Null Multilevel MNL model B	S.E.	t-value	Model B Single-level MNL model B	S.E.	t-value	Model C Multilevel MNL model B	S.E.	t-value	Absolute t-value in model B minus absolute t-value in Model C
Car	**Individual-level**										
	Intercept	0.63	0.10		-2.06	0.97	-2.12	-2.20	1.47	-1.50	
	Gender (Male=1)				0.14	0.09	1.54	0.15	0.09	1.69	
	Age under 14				0.58	0.33	1.78	0.59	0.33	1.75	
	Age between 15-24				**-0.55**	**0.23**	**-2.43**	**-0.57**	**0.23**	**-2.50**	
	Occupation (Student=1)				**-0.57**	**0.22**	**-2.59**	**-0.60**	**0.23**	**-2.58**	
	Monthly personal income (US$1,000)				**0.30**	**0.06**	**4.70**	**0.30**	**0.06**	**4.81**	
	Car driver's licence				**0.82**	**0.11**	**7.33**	**0.82**	**0.12**	**7.17**	
	Children (under 18) in Household				**0.36**	**0.09**	**4.07**	**0.36**	**0.09**	**4.01**	
	Household car ownership				**0.54**	**0.05**	**12.09**	**0.54**	**0.05**	**11.89**	
	Trip purpose (work=1)				-0.14	0.10	-1.35	-0.15	0.10	-1.46	
	Travel cost				**0.59**	**0.04**	**15.03**	**0.60**	**0.04**	**14.90**	
	OD distance				-0.01	0.01	-0.83	-0.01	0.01	-0.83	
	District-level										
	Population Density				-0.14	0.05	-2.80	-0.08	0.06	-1.33	1.47
	Job density				-0.04	0.06	-0.67	-0.03	0.07	0.42	0.25
	Land use mix entropy				-0.06	0.39	0.50	-0.06	0.47	-0.13	0.37
	% of four-way intersection				**3.85**	**0.83**	**4.64**	**2.01**	**1.03**	**1.95**	2.69
	No. of cul-de-sac				0.05	0.05	1.00	0.05	0.09	0.05	0.95
	City/county-level										
	Density				**-0.21**	**0.05**	**-4.20**	**-0.22**	**0.13**	**-1.69**	2.51
	Land use mix entropy				-1.03	1.41	-0.73	-0.24	2.47	-0.01	0.72
Motor-bike	**Individual-level**										
	Intercept	0.92	0.11		-2.72	0.82	-3.28	-2.88	1.54	-1.87	
	Gender (Male=1)				**0.17**	**0.08**	**2.13**	**0.18**	**0.08**	**2.23**	
	Age under 14				0.13	0.28	0.46	0.13	0.28	0.46	
	Age between 15-24				0.06	0.18	0.33	0.03	0.18	0.15	
	Occupation (Student=1)				**-0.52**	**0.18**	**-2.89**	**-0.54**	**0.18**	**-3.00**	
	Monthly personal income (US$1,000)				**-0.19**	**0.06**	**-3.11**	**-0.18**	**0.06**	**-2.97**	
	Motorbike driver's licence				**1.32**	**0.11**	**12.03**	**1.32**	**0.11**	**11.93**	
	Children (under 18) in Household				0.15	0.08	1.85	0.14	0.08	1.75	
	Household motorbike ownership				**0.35**	**0.03**	**12.93**	**0.35**	**0.03**	**12.32**	
	Trip purpose (work=1)				0.13	0.09	1.44	0.13	0.09	1.44	
	Travel cost				0.05	0.04	1.33	0.05	0.04	1.29	
	OD distance				**-0.04**	**0.01**	**-6.67**	**-0.04**	**0.01**	**-6.67**	
	District-level										
	Population density				-0.11	0.04	-2.75	-0.08	0.05	-1.60	1.15
	Job density				-0.04	0.05	0.80	-0.02	0.06	0.36	0.44
	Land use mix entropy				**0.56**	**0.35**	**1.60**	**0.68**	**0.41**	**1.65**	-0.05
	% of four-way intersection				**4.18**	**0.75**	**5.57**	**2.58**	**0.93**	**2.77**	2.80
	No. of cul-de-sac				0.05	0.05	1.00	0.06	0.08	0.75	0.25
	City/county-level										
	Density				**-0.21**	**0.05**	**-4.33**	**-0.24**	**0.11**	**-2.18**	2.15
	Land use mix entropy				1.38	1.22	1.13	1.92	2.04	0.94	0.19
Random part	City/county-level										
	$\sigma^2_{\psi^{car}_{00k}}$	0.15	0.07	2.25				0.12	0.07	1.77	
	$Cov(\sigma^2_{\psi^{car}_{00k}}, \sigma^2_{\psi^{motorbike}_{00k}})$	0.15	0.08	2.10				0.07	0.05	1.45	
	$\sigma^2_{\psi^{motorbike}_{00k}}$	0.21	0.09	2.33				0.10	0.05	1.80	
	District-level										
	$\sigma^2_{\zeta^{car}_{0j}}$	0.04	0.02	1.64				0.07	0.04	1.92	
	$Cov(\sigma^2_{\zeta^{car}_{0j}}, \sigma^2_{\zeta^{motorbike}_{0j}})$	0.00	0.02	0.13				0.03	0.03	1.30	
	$\sigma^2_{\zeta^{motorbike}_{0j}}$	0.04	0.02	1.91				0.03	0.02	1.53	
DIC (Deviance Information Criterion)		10988.85			9250.35			9207.75			
MCMC deviance		10903.69			9212.22			9110.18			
pD (the effective number of parametres)		83.69			38.13			97.58			

Bold numbers mean significant at level of 90%

6.4.2 Multilevel cross-classified MNL model results

The estimated results of multilevel cross-classified MNL models are shown in Table 6.5. Model D is an empty multilevel cross-classified MNL model to test the ICC values. Model E is a single-level MNL model, which includes district-level variables for both trip origins and destinations within the same level. Model F is a multilevel cross-classified MNL model which allowed intercepts to be varied randomly across trip origins and trip destinations. This model includes land use variables at both trip origin level and trip destination level and accounted for socio-demographic characteristics.

The reason for estimating Model D was to determine whether the adoption of a multilevel cross-classified modelling technique was justified (Table 6.5). Of all the spatial heterogeneity parametres representing the unobserved variations in utility functions for car and motorbike are statistically significant across trip origins and destinations. The ICC_{car} and $ICC_{motorbike}$ across trip origins and destinations are 0.170, and 0.145, respectively, indicating that the correlations for individuals at the same trip origins and destinations for car users and motorbike users are 17.0% and 14.5%, respectively. In addition, the $ICC_{O\text{-}car}$ and $ICC_{D\text{-}car}$, the correlations for car users at the same origins and destinations, are 0.055 and 0.114, respectively. The $ICC_{O\text{-}motorbike}$ and $ICC_{D\text{-}motorbike}$, the correlations for motorbike users at the same origins and destinations, are 0.055 and 0.090, respectively. The high proportion of spatial dependencies indicates that there is a need to adopt a multilevel modelling technique to accommodate the spatial issues in this chapter's analysis.

The last column in Table 6.5 refers to the subtraction between the absolute t-values in Model E and the absolute t-values in Model F. Most of the absolute t-values' difference for the land use variables across trip origins and destinations between Model B and Model C are positive. Also, comparing the coefficient's significant-level for population density at trip origin for car and at trip destination for motorbike in Model B and Model C, the coefficient is significant at the 95% level in Model B but insignificant in Model C. This comparison provides evidence that, under the circumstances of high spatial autocorrelations, ignoring the spatial between-group difference by only using a single-level discrete choice model may exaggerate the coefficients' significance and lead to spurious results (Snijders, 2012; Snellen et al., 2002).

With respect to the models' complexity and fit, the DIC (Deviance Information Criterion) (see Table 6.5) values suggest that Model F (multilevel cross-classified MNL model) is the best model among the three models. After adding spatial heterogeneity into the model, the DIC for model F reduced by around 31 compared with Model E. Although the number of effective parametres for Model F is about 113 points higher than Model B, the deviance of MCMC for Model F, 9026.4, is about 144 points lower than Model B (Table 6.5).

With respect to the controlling factors of socio-demographic characteristics and trip purpose in Model C, as shown in Table 6.5, personal income shows opposite results between the mode choice of car and public transport, compared with between motorbike and public transport. With increasing personal income, people are more likely to choose the car over public transport but would choose public transport over the motorbike. As for trip purpose, school trips are more likely to be made by public transport than by car, while work trips are more likely to be made by motorbike than by public transport.

With respect to the controlling factors of level-of-service in Model C, as shown Table 6.5, travel cost and OD distance have opposite signs for people choosing between car and motorbike over public transport. With increasing OD distance, people intend to choose public transport rather than the motorbike. Likewise, higher travel costs intend to encourage car and motorbike use rather than public transport use.

After accounting for socio-demographic and level-of-service factors, the Model C results (Table 6.5) indicate that land use variables exert significant influence on mode choice behaviour either on trip origins or on destinations. Increasing population density at trip origins is associated with a greater probability of choosing public transport over the car. The districts at trip origins with more grid-like street patterns, i.e. a higher percentage of 4-way intersections, significantly increase the probability of car and motorbike use compared with public transport use in Taiwan. At trip destinations, the results suggest that higher job density and mix land use increase the probability that people will take public transport rather than the car or motorbike. Job density shows significant and negative relationships for mode choice behaviour between car and public transport, and motorbike and public transport. Land use mix only shows significance significant (negative) relationship between car and public transport. The proportion of percentage of 4-way intersections shows significance significant (positive) relation between motorbike and public transport while shows insignificant between car and public transport.

Table 6.5 Multilevel cross-classified MNL model results

Dependent variable: mode choice of car, motorbike, and public transport (reference category)		Model D - Null model of multilevel cross-classified MNL model			Model E - MNL model			Model F - multilevel cross-classified MNL model			Subtract absolute t-value in Model B from absolute t-value in Model C
Explanatory variables		B	S.E.	t-value	B	S.E.	t-value	B	S.E.	t-value	
Fixed Part											
	Individual level										
	Intercept	0.651	0.065	10.010	-2.210	0.388	-5.696	-1.896	0.499	-3.800	
	Gender (male=1)				0.117	0.090	1.300	0.122	0.092	1.326	
	Aged under 14				0.542	0.331	1.637	0.528	0.338	1.562	
	Aged 15-24				**-0.561**	**0.224**	**-2.504**	**-0.626**	**0.231**	**-2.710**	
	Occupation (student=1)				**-0.560**	**0.226**	**-2.478**	**-0.558**	**0.230**	**-2.426**	
	Personal income				**0.311**	**0.063**	**4.937**	**0.319**	**0.066**	**4.833**	
Car	Car driver's licence				**0.809**	**0.114**	**7.096**	**0.799**	**0.116**	**6.888**	
	Children in household				**0.362**	**0.088**	**4.114**	**0.352**	**0.090**	**3.911**	
	Household car ownership				**0.543**	**0.044**	**12.341**	**0.539**	**0.046**	**11.717**	
	Trip purpose (work=1)				-0.105	0.098	-1.071	-0.126	0.101	-1.248	
	OD distance				-0.006	0.006	-1.000	-0.006	0.006	-1.000	
	Travel cost				**0.598**	**0.039**	**15.333**	**0.621**	**0.040**	**15.525**	
	Trip origin level										
	Population density				-0.061	0.050	-1.220	-0.045	0.062	-0.726	0.494
	Job density				-0.058	0.053	-1.094	-0.049	0.065	-0.754	0.340
	Land use mix entropy				0.331	0.437	0.757	0.329	0.527	0.624	0.133
	% of 4-way intersections				**3.138**	**0.963**	**3.259**	**2.518**	**1.124**	**2.240**	1.019
	No. of cul-de-sac				-0.020	0.078	-0.256	-0.038	0.091	-0.418	-0.162
	Trip destination level										
	Population density				0.012	0.052	0.231	0.019	0.072	0.264	-0.033
	Job density				**-0.193**	**0.044**	**-4.386**	**-0.192**	**0.067**	**-2.866**	1.520
	Land use mix entropy				**-1.034**	**0.445**	**-2.324**	**-1.285**	**0.608**	**-2.113**	0.211
	% of 4-way intersections				0.601	0.894	0.672	0.553	1.081	0.512	0.160
	No. of cul-de-sac				0.099	0.079	1.253	0.146	0.096	1.521	-0.268
	Individual level										
	Intercept	0.979	0.063	15.540	-2.003	0.365	-5.488	-1.902	0.412	-4.617	
	Gender (male=1)				**0.167**	**0.080**	**2.088**	**0.164**	**0.081**	**2.025**	
	Aged under 14				0.092	0.287	0.321	0.097	0.290	0.334	
	Aged 15-24				0.050	0.176	0.227	0.023	0.178	0.129	
	Occupation (student=1)				**-0.499**	**0.182**	**-2.742**	**-0.504**	**0.183**	**-2.754**	
	Personal income				**-0.179**	**0.062**	**-2.887**	**-0.175**	**0.064**	**-2.734**	
	Motorbike driver's licence				**1.313**	**0.109**	**12.046**	**1.323**	**0.110**	**12.027**	
Motorbike	Children in household				0.159	0.080	1.988	0.151	0.081	1.864	
	Household motorbike ownership				**0.349**	**0.027**	**12.926**	**0.351**	**0.028**	**12.536**	
	Trip purpose (work=1)				**0.184**	**0.089**	**2.067**	**0.177**	**0.090**	**1.967**	
	OD distance				**-0.038**	**0.006**	**-6.333**	**-0.038**	**0.006**	**-6.333**	
	Travel cost				0.059	0.040	1.475	0.070	0.041	1.707	
	Trip origin level										
	Population density				-0.053	0.042	-1.262	-0.051	0.051	-1.000	0.262
	Job density				-0.049	0.047	-1.043	-0.039	0.054	-0.722	0.321
	Land use mix entropy				0.606	0.401	1.511	0.671	0.455	1.475	0.036
	% of 4-way intersections				**2.752**	**0.862**	**3.193**	**2.408**	**0.985**	**2.445**	0.748
	No. of cul-de-sac				-0.034	0.075	-0.453	-0.055	0.081	-0.679	-0.226
	Trip destination level										
	Population density				0.066	0.044	1.500	0.066	0.054	1.222	0.278
	Job density				**-0.187**	**0.038**	**-4.921**	**-0.185**	**0.049**	**-3.776**	1.145
	Land use mix entropy				-0.071	0.409	-0.174	-0.150	0.454	-0.330	-0.156
	% of 4-way intersections				**2.431**	**0.792**	**3.069**	**2.430**	**0.904**	**2.688**	0.381
	No. of cul-de-sac				**0.122**	**0.075**	**1.627**	**0.151**	**0.083**	**1.819**	-0.192
Random Part	Trip destination level										
	σ^2_{D-car}	0.226	0.063	3.587				0.168	0.062	2.710	
	$cov(\sigma_{D-car}, \sigma_{D-motorbike})$	0.172	0.053	3.245				0.092	0.038	2.421	
	$\sigma^2_{D-motorbike}$	0.200	0.059	3.390				0.061	0.028	2.179	
	Trip origin level										
	σ^2_{O-car}	0.109	0.044	2.477				0.096	0.005	1.920	
	$cov(\sigma_{O-car}, \sigma_{O-motorbike})$	0.045	0.038	1.184				0.048	0.032	1.500	
	$\sigma^2_{O-motorbike}$	0.106	0.044	2.409				0.053	0.028	1.893	
DIC (Deviance Information Criterion)		10987.83			9214.07			9183.11			
MCMC deviance		10764.63			9170.09			9026.40			
pD (the effective number of parametres)		223.21			43.99			156.72			

Bold numbers mean significant at level of 90%

6.5 Summary

1. This chapter introduced a multilevel MNL model and multilevel cross-classified MNL model to explore unobserved spatial heterogeneity and the impact of land use variables at district and city/county level, and across trip origins and destinations on mode choice between car, motorbike and public transport. The results of this chapter add to the growing body of evidence that land use variables: density, mixed land use, and street design, apply influence on mode choice behaviour, after accounting for socio-demographic characteristics, trip purpose of work and school, travel distance, and travel cost. In addition, the model's fit for the multilevel MNL model and multilevel cross-classified MNL model are greatly improved compared to the traditional MNL model.
2. The results in this chapter found that the unobserved spatial heterogeneity do exert significant influence on mode choice behaviour. The model's fit of Model C and Model F improved by adopting unobserved spatial heterogeneity compared to Model B and Model E. In addition, by comparing the results of traditional single-level MNL model and multilevel MNL model, it provides further evidence that previous studies by adopting single-level MNL model, which neglected spatial dependency and spatial heterogeneity, to analyse the relationships between land and travel behaviour could exaggerate the sample size and cause misleading results (Snijders, 2012, Snellen et al., 2002). Therefore, for the studies related to hierarchical clustered features and hierarchical data structure, multilevel modelling techniques may be a better method leading to a more accurate results.
3. By and large, this chapter's results found that socio-demographic characteristics and travel-related attributes exert significant influence on mode choice behaviour. At the individual-level, age, personal income, car and motorbike driver's licence ownerships, travel cost and trip distance all affect individuals' mode choice between car and motorbike compared with public transport. With regard to the impact of household to individual, individuals with children (aged under 18) in households are more likely to choose car than public transport. Individuals with more cars or motorbikes in household tend to use more car or motorbike than public transport respectively.
4. As for the influence of land use variables at trip origins on travel mode choice between car and public transport, the results show that higher population density at district-level and higher population density and job density at city/county level

associate to higher probability of choosing public transport over the car while more grid-like street pattern intends to attract more car use rather than public transport. In terms of travel mode choice between motorbike and public transport, higher population density at district-level and city/county-level and job density at city/county-level also associate with choosing public transport over the motorbike while more diversified land uses and more grid-like street pattern associate to higher probability of motorbike use. Few studies have paid attention to the effects of land use on motorbike use.

5. As for the influence of land use variables at trip destinations on travel mode choice between car and public transport, the results show that higher job density and land use mix associate with higher probability of choosing public transport over the car. In terms of travel mode choice between motorbike and public transport, higher job density at trip destination will encourage public transport use while more grid-like street pattern or cul-de-sac intends to attract more motorbike use rather than public transport.

Chapter 7 SUBJECTIVE AND OBJECTIVE WALKING ENVIRONMENTAL MEASURES INFLUENCE WALKING BEHAVIOUR

This chapter addresses the fourth research question (RQ4) which aims to understand that can a structural model linking objective measures and subjective measures of walking environment to explain walk for public transport behaviour perform better than existing models in understanding walking environment and walking behaviour. If refers to the proposed model for travel mode choice behaviour towards use public transport in Figure 2.10, this chapter is to examine the relationship in Block D, which is the effects of objective measures of walking environment on subjective measures of walking environment, and their effects on perceived walkability and walking behaviour (see Figure 2.10).

There are two objectives for RQ4. The first is to examine to what extent objective walking environment factors influence subjective measures of walking environment factors. The second is to examine to what extent subjective measures of walking environment factors influence overall perceived walkability and walking for public transport.

Several studies have found evidence that the walking environment – whether captured using objective or subjective measures – exerts some influence on walking behaviour (Frank et al., 2010, Leslie et al., 2007, Chiang and Weng, 2012, Saelens et al., 2003b). A number of studies have also examined the correlations between the two types of measures (McGinn et al., 2007, Boehmer et al., 2006, Cerin et al., 2008). However, there is a lack of evidence which shows the relationships between objective measures and subjective measures of the walking environment and walking behaviour. Alfonzo (2005) asserted that the objective walking environment is an important indirect determinant of walking behaviour, which operates via its impact on the cognition of walking environment (Alfonzo, 2005). Ewing and Handy (Ewing et al., 2006) suggested that perceptions of the walking environment are influenced by physical features for walking, amongst other things, and determine overall perceived walkability and walking behaviour. Very few studies have incorporated both objective measures and subjective measures of walking environment to examine their relationships and impacts on walking behaviour (Vernez Moudon et al., 2007) .

There are four sections in this chapter. The first section proposes a conceptual model describing the relationship between objective measures and subjective measures of walking environment, overall perceived walkability, and walk for public transport behaviour. This is followed by describing the data collected for this chapter's study and the data analysis methods used. The third section presents the model estimated results. The final section summarises some important findings of this chapter.

7.1 Conceptual model for walking for transport

The walkability conceptual model underlying this chapter assumes that walking environmental perceptions and overall perceived walkability mediate between objective measures of the walking environment, and walking behaviour, as shown in Figure 1 (Alfonzo, 2005, Ewing et al., 2006, Ewing and Handy, 2009). Overall perceived walkability reflects an individual's overall assessment about the walking environment, which is determined by perceived environmental factors. Overall perceived walkability affects walking behaviour along with an individual's socio-demographic characteristics (Figure 7.1) and other factors which affect the mode choice set. Socio-demographic characteristics have been found to be important factors affecting travel mode choice (Frank et al., 2008, Rodríguez and Joo, 2004). The analysis in this chapter incorporates gender, age, income, household car ownership and household motorbike ownership in the model. An important constraint on walking as a mode choice is trip distance. In Taiwan, less than 5% of walk trips take more than 45 minutes to complete (Department of Statistics, 2015a).

Walking can be considered to consist of two main kinds of travel behaviour: walking to a destination (i.e. where the entire trip is made on foot) and walking to access public transport. The walking to destination could be more related to accessible activities within walking distance. Walking to public transport could influenced by whether there is a suitable public transport stop/station within walking distance as well as the walkability of the environment. Thus walking to the destination and walking to public transport need to be considered separately as they have different characteristics. The availability and relative attractiveness of alternatives to walking and walking to public transport also need to be considered.

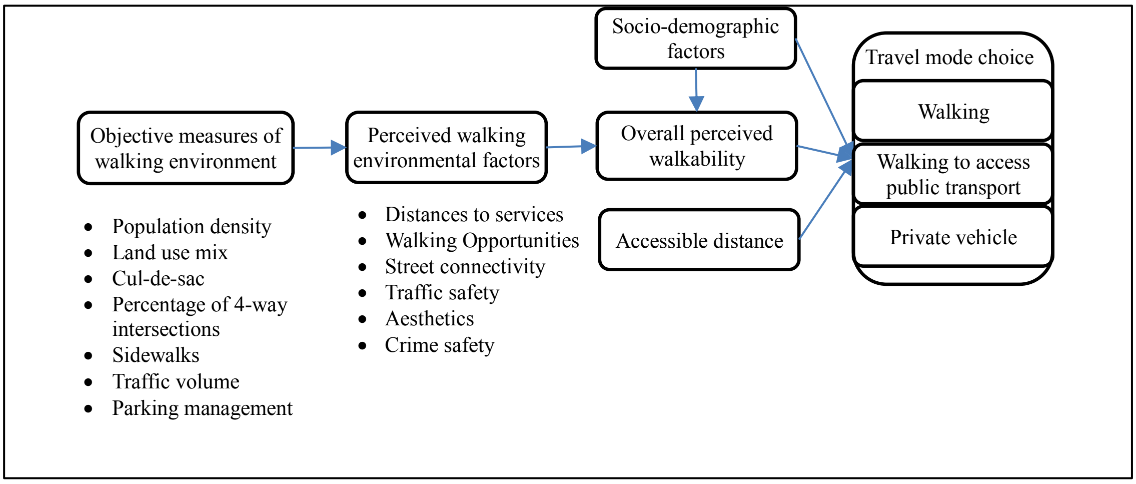


Figure 7.1 Conceptual model for walking for transport

7.2 Methodology

This section presents the data used in this chapter, describes the measures and variables extracted from the data, gives some descriptive statistics of the subjective measures and objective measures data, and describes the method used in data analysis. The analysis focuses on home-based commuting trips in Taiwan.

7.2.1 Data sources

Data on perceptions of walking environment, attitudes toward public transport, mode choice for commuting trips, and socio-demographic characteristics was drawn from an online survey of travel behaviour. An unrestricted self-selection survey method was used, in other words the survey was open to the public to participate in. Participants could fill the questionnaire using any electronic device, including desktop computers, laptops, tablets and mobile phones, which can access the internet and open the web link. A snowball sampling method was used; the questionnaire web link was sent to contacts in Taiwan through email, Facebook and online chat apps; these contacts were asked both to complete the questionnaire and to forward the web link to their friends in Taiwan. The survey took place in July and August 2015. A total of 1,619 effective responses were collected. The responses covered all of the 19 cities and counties in Taiwan.

Of the 1,619 valid responses, 1,031 were used in this chapter's analysis. Among the excluded 588 responses, 381 respondents' residences were located in the places (villages) where the land use data are not available. These excluded responses were from villages including military facilities. The other 207 excluded responses included travel mode choices reported as using private vehicles to access public transport (107), bike and taxi (35) and no reported commuting trips (65). Responses from children under the age of 15 were also excluded. The sample covered urban, suburban and rural environments and areas with population densities ranging from 0.03 to 1185.05 persons/hectare (Table 7.2).

As can be seen in Table 7.1, the socio-demographic statistics show that the respondents include genders, all age groups, all levels of education and all income groups in Taiwan. The proportion of males (57.3%) is somewhat greater than females (42.7%). About 85% of the respondents owned a car driver's licence or motorbike driver's licence. The monthly income of the sample ranged from less than US$333 to US$ 3,333 and over, and the proportion of respondents in the lowest income group is about the same as for the highest income group. Average household car ownership and motorbike ownership levels are 1.20 (standard deviation =0.80) and 1.65 (standard deviation=1.17) vehicles per household respectively (Table 7.1).

Table 7.1 Descriptive statistics for socio-demographics characteristics

Items	Freq.	Percentage
Gender		
Male	591	57.3
Female	440	42.7
Age		
15-24	115	11.2
25-54	856	83.0
55 and Over	60	5.8
Education		
High school and under	72	7.0
Bachelor	547	53.0
Master or higher	406	9.4
Missing	6	0.6
Car driver's licence		
Yes	881	85.4
No	150	14.6
Motorbike driver's licence		
Yes	895	86.8
No	136	13.2
Monthly personal income		
Under US$ 666	105	10.2
US$ 667-2666	725	70.3
US$ 2667 and over	150	14.6
Missing	51	4.9
Household car ownership		
0	168	16.3
1	556	53.9
2	247	24.0
3	48	4.7
4 and more	12	1.1
Household motorbike ownership		
0	174	16.9
1	338	32.8
2	283	27.4
3	140	13.6
4 and more	96	9.3

The objective measures were drawn from the Taiwanese Socio-economic Database (Ministry of the Interior, 2014), the Taiwanese National Land Surveying Database (National Land Surveying and Mapping Centre, 2008), and the Taiwanese Traffic Network Digital Map (Institute of Transportation, 2009) respectively. The GIS data was at a resolution of 1/25,000.

7.2.2 Objective measures

The objective built environment features were measured at the village scale. Village is the basic unit of Taiwanese administrative subdivision; under cities/counties and districts. The average area and population of a village in Taiwan are 4.7 km^2 and 3,017 persons respectively (Ministry of the Interior, 2014). Suppose that villages are circular in shape, then the radius of the average village would be about 1.2 km, which suggests it is reasonable to use village as the scale of analysis for walking environment features (Frank et al., 2005, Moudon et al., 2006, Frank et al., 2007). Four objective measures of walking environment attributes were calculated for each of the villages where respondents were located: population density, land use mix entropy, the percentage of 4-way intersections and the numbers of cul-de-sacs.

Table 7.2 shows the descriptive statistics of these objective measures of walking environment features. Land use mix entropy, which is to measure the extent of land use diversity in a village, was calculated using Eq. (1) based on six land use categories: residential, commercial, industrial, government offices, education, and hospital and social care buildings. Land use entropy ranges from 0 to 1, with higher entropy value indicate in a more evenly distributed mix of land uses. In order to reduce the varied ranges among these objective measures of walking environment factors, all the four factors were standardised into z-scores in the analysis.

$$Land\ use\ mix\ entropy = -\sum_j P_j \times \frac{\ln(P_j)}{\ln(J)} \qquad (1)$$

Where Pj is the proportion of land use type j in the area, and J is the total number of land use types, which equals to 6.

Table 7.2 Descriptive statistics of objective measures of built environment

	Obs.	Mean	Std. Dev.	Min	Max
Population density (persons/hectare)	1031	214.26	195.33	0.030	1185.05
Land use mix entropy	1031	0.41	0.19	0.004	0.88
Percentage of 4-way intersections	1031	0.25	0.13	0	0.75
Numbers of cul-de-sacs	1031	12.36	21.75	0	203.00

7.2.3 Subjective measures

The survey contained five categories of questions on perceptions of the walking environment, which were walking opportunities, street connectivity, aesthetics, traffic safety and distances to services. In total 21 questions were asked to measure perceptions of walking environment factors (Table 7.3). Except for distances to services, the questions used a 5-likert scale from strongly agree to strongly disagree to assess the walking environment attributes of a respondent’s neighbourhood. For questions where strongly agree and agree mean a positive walking environment, the 5-likert scale was coded as strongly agree: 5, agree: 4, neutral: 3, disagree: 2, strongly disagree: 1. For questions where strongly agree and agree mean a negative walking environment, such as SC4, SC5, TS2, TS4 in Table 2, the 5-likert scale was coded as strongly agree: 1, agree: 2, neutral: 3, disagree:4, strongly disagree:5. As for distances to services, the respondents reported estimated walking time (choices from less than 5 mins, 6-10 mins, 11-15 mins, 16-20 mins, 21-30 mins, and 30 mins and over) to their nearest facilities including convenient stores, bus stops, supermarkets, primary schools, post offices and banks, breakfast restaurants, and parks. The descriptive statistics for the perceptions of walking environmental indicators are shown in Table 7.3.

Among the likert-scale indicators in Table 7.3, the indicator WO2 had the highest average score, which indicates that the respondents were most satisfied with this indicator – convenient stores are within easy walking distance. This is consistent with WT1 indicator –walking time to the nearest convenient store – in distance to services, which had the shortest average walking time (Table 7.3).

Table 7.3 Descriptive statistics of perceived walking environmental indicators

Category	Code	Indicators	Ave.	Std. Dev.
Walking opportunities	WO1	There are many places to go within easy walking distance	3.87	1.10
	WO2	Convenient stores are within easy walking distance	4.29	0.91
	WO3	It is easy to walk to a public transport stop (bus, metro or train)	3.60	1.30
Street connectivity	SC1	The distance between intersections is usually short (150 metres or less)	3.84	1.00
	SC2	There are many alternative routes for getting from place to place	3.67	1.02
	SC3	There are sidewalks on most of the streets in my neighbourhood	3.22	1.27
	SC4	There are motorbike parking on the streets and sidewalks blocking the way	2.58	1.21
	SC5	There are 'hawkers' and shops on the streets and sidewalks blocking the way	3.03	1.19
Traffic safety	TS1	There are crosswalks and pedestrian signals on intersections	3.67	1.04
	TS2	So much traffic along nearby streets that it makes difficult or unpleasant to walk in my neighbourhood.	3.05	1.00
	TS3	The speed of traffic on most nearby streets is usually slow (40 km/hr or less)	2.98	1.03
	TS4	Most drivers exceed the speed limits while driving in my neighbourhood	2.78	1.01
Aesthetics	AE1	There are many trees along the streets in my neighbourhood	3.26	1.06
	AE2	There are many attractive natural sights in my neighbourhood	3.01	1.17
Distances to services	WT1	Walking time to the nearest convenient store is	5.80*	5.73
	WT2	Walking time to the nearest bus stop is	7.50*	6.97
	WT3	Walking time to the nearest supermarket is	12.04*	9.30
	WT4	Walking time to the nearest primary school is	11.71*	8.20
	WT5	Walking time to the nearest post office/ bank is	13.07*	9.64
	WT6	Walking time to the nearest breakfast restaurant is	6.53*	6.44
	WT7	Walking time to the nearest park is	9.39*	8.84

'*': the average walking time to nearest services estimated by the respondents.

7.2.4 Dependent variables

There are two dependent variables in the analysis. One is overall perceived walkability, another is travel mode choice. Overall perceived walkability plays roles as both a dependent variable and an independent variable. Overall perceived walkability acts as a dependent variable for the perceptions of walking environment factors; and it acts as an independent variable for travel mode choice (Figure 7.1).

7.2.5 Perceived overall walkability

The perceived overall walkability was self-reported using a 7-likert scale: extremely satisfied, satisfied, somewhat satisfied, neutral, somewhat dissatisfied, dissatisfied, and extremely dissatisfied, which were coded from 7 to 1 respectively. The average score and standard deviation of the sample for overall perceived walkability were 4.95 and 1.48 respectively.

7.2.6 Travel mode choice

The travel mode choice set includes walking, walking to access public transport and private vehicle (car and motorbike) for home-based commute journeys. Of the 1,031 responses, 6.1% chose walking to their destination; 22.2% chose walking to access public transport; and 71.8% chose private vehicle (Table 7.4).

Table 7.4 Travel mode choice

Transport modes	Freq.	Percentage
Walking to destinations	63	6.1
Walking access to public transport	228	22.2
Private vehicle	740	71.8
Total	1,031	100

7.2.7 Structural model

Based on the conceptual model (see Figure 7.1), Figure 7.2 presents the structural model. Subjective walking environmental factors and socio-demographic characteristics are assumed to influence overall perceived walkability; overall perceived walkability and socio-demographic characteristics are assumed to influence travel mode choice between walking (to destination), walking access to public transport and private vehicles.

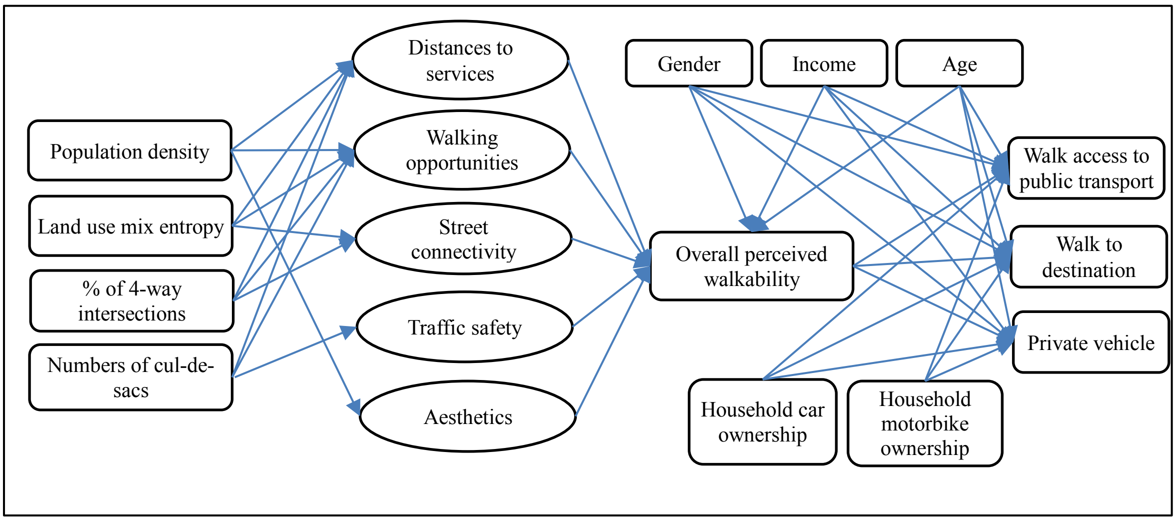


Figure 7.2 Model structure

7.2.8 Data analysis method

Data analysis was divided into two stages. The first stage used factor analysis to extract a set of perceptions of walking environment factors from the 21 indicators. The second stage used a generalized structural equation model (GSEM) to verify the hypothesis that objective measures of the walking environment influence subjective measures of the walking environment, and then subjective measures of the walking environment influence walkability and walking behaviour.

7.3 Results

7.3.1 Correlations between walking environmental indicators

The Cronbach's α for the 21 walking environmental indicators is 0.826, which exceed the acceptable level of 0.7 (Nunnally et al., 1978). This value indicates that the dataset of the walking environmental indicators is reliable and has adequate internal consistency.

As can be seen in Table 7.5, there are a substantial number of correlations greater than (+/-) 0.3, and there is no multicollinearity problem (no correlation greater than (+/-) 0.9). Hence, the dataset is suitable for factor analysis (Hair et al., 2009).

There are some significant cross correlations between indicators in different categories, which indicate that exploratory factor analysis may be a better approach than confirmative factor analysis to identify the latent factors (Asparouhov and Muthén, 2009, Marsh et al., 2009, Marsh et al., 2010, Browne, 2001). The work in this chapter tried to use confirmative factor analysis to identify the latent constructs of the measurement model. The goodness-of-fit was not well enough if fixing all cross-loading at zero. There is a need to do intensive measurement model modification by using modification indexes in order to get a measurement model which reach the requirements of goodness-of-fit. Browne (2001) contended as the following.

> Confirmative factor analysis procedures are often used for exploratory purposes. Frequently a confirmative factor analysis, with prespecified loadings, is rejected and a sequence of modifications of the model is carried out in an attempt to improve fit. The procedure then becomes exploratory rather than confirmatory. In this situation the use of exploratory factor analysis, with rotation of the factor matrix, appears preferable. (p. 113)

Thus, an exploratory factor analysis was used rather than confirmative factor analysis to identify the latent constructs between latent factors and walking environmental indicators.

Table 7.5 Correlations between walking environmental indicators

	WO1	WO2	WO3	SC1	SC2	SC3	SC4	SC5	TS1	TS2	TS3	TS4	AE1	AE2	WT1	WT2	WT3	WT4	WT5	WT6	WT7
WO1	1.00																				
WO2	0.64	1.00																			
WO3	0.56	0.47	1.00																		
SC1	0.45	0.47	0.48	1.00																	
SC2	0.47	0.37	0.37	0.51	1.00																
SC3	0.44	0.32	0.47	0.34	0.36	1.00															
SC4	-0.22	-0.23	-0.10	-0.17	-0.12	0.03	1.00														
SC5	-0.15	-0.15	-0.04	-0.10	-0.10	0.06	0.65	1.00													
TS1	0.43	0.41	0.43	0.36	0.32	0.52	-0.14	-0.06	1.00												
TS2	-0.12	-0.15	-0.09	-0.07	-0.04	0.03	0.40	0.41	-0.13	1.00											
TS3	0.16	0.15	0.14	0.10	0.15	0.23	0.08	0.08	0.16	0.13	1.00										
TS4	0.05	0.07	0.06	-0.01	0.07	0.13	0.29	0.30	0.04	0.35	0.49	1.00									
AE1	0.07	-0.01	0.15	0.03	0.07	0.35	0.13	0.15	0.19	0.10	0.17	0.12	1.00								
AE2	-0.05	-0.17	0.06	-0.06	0.02	0.26	0.21	0.24	0.06	0.11	0.14	0.12	0.66	1.00							
WT1	-0.46	-0.66	-0.34	-0.39	-0.27	-0.25	0.18	0.13	-0.34	0.12	-0.09	-0.06	0.05	0.19	1.00						
WT2	-0.39	-0.36	-0.51	-0.32	-0.19	-0.27	0.10	0.06	-0.32	0.08	-0.03	0.00	-0.02	0.06	0.49	1.00					
WT3	-0.55	-0.42	-0.39	-0.39	-0.35	-0.26	0.24	0.21	-0.32	0.10	-0.14	-0.04	0.06	0.15	0.53	0.46	1.00				
WT4	-0.47	-0.37	-0.35	-0.35	-0.30	-0.28	0.15	0.08	-0.30	0.02	-0.16	-0.08	-0.06	0.04	0.43	0.44	0.60	1.00			
WT5	-0.59	-0.44	-0.44	-0.36	-0.32	-0.30	0.19	0.15	-0.34	0.07	-0.10	-0.05	-0.01	0.10	0.54	0.53	0.66	0.60	1.00		
WT6	-0.47	-0.54	-0.33	-0.40	-0.27	-0.21	0.17	0.14	-0.27	0.11	-0.09	-0.05	0.12	0.22	0.71	0.46	0.57	0.53	0.55	1.00	
WT7	-0.41	-0.35	-0.32	-0.28	-0.26	-0.28	0.10	0.03	-0.27	0.00	-0.14	-0.10	-0.12	-0.01	0.46	0.38	0.45	0.41	0.48	0.40	1.00

7.3.2 Exploratory factor analysis for subjective measures of walking environmental indicators

Exploratory factor analyses were used to extract the perceived walking environmental factors. The Cronbach's Alpha for the 21 5-likert scale indicators is 0.718, which indicates that the dataset has adequate internal consistency (Nunnally et al., 1978). The index of Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) is 0.868 and Bartlett's Test of Sphericity is significant at $p<0.000$, which indicates that the 5-likert scales indicators dataset is suitable for factor analysis (Hair et al., 2009). Principal axing factoring method along with varimax rotation was used to extract five perceived walking environmental factors (Hair et al., 2009). As can be seen in Table 7.6, the five perceived walking environmental factors are named, using the features of their indicators, as distances to services, opportunities & street connectivity, on-street barriers, aesthetics and traffic safety. These accounted for 62.3% of total variance. Table 7.6 shows the factor loadings, with loadings less than 0.30 supressed (Hair et al., 2009).

Table 7.6 Rotated factor loading matrix

		Factor loading				
	Indicators	Distances to services	Opportunities & connectivity	On-street barriers	Aesthetics	Traffic safety
WT5	Walking time to the nearest post office/ bank	.723				
WT6	Walking time to the nearest breakfast restaurant	.702				
WT3	Walking time to the nearest supermarket	.697				
WT1	Walking time to the nearest convenient store	.654	-.301			
WT4	Walking time to the nearest primary school	.638				
WT2	Walking time to the nearest bus stop	.551				
WT7	Walking time to the nearest park	.537				
WO3	It is easy to walk to a public transport stop (bus, metro or train) from my home.	-.314	.624			
WO1	There are many places to go within easy walking distance of my home.	-.453	.613			
SC1	Distance between intersections in my neighbourhood is usually short (150 metres or less).		.596			
SC2	There are many alternative routes for getting from place to place in my neighbourhood.		.565			
SC3	There are sidewalks on most of the streets in my neighbourhood.		.563		.363	
WO2	Convenient stores are within easy walking distance of my home.	-.414	.550			
TS1	There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighbourhood.		.530			
SC5	There are 'hawkers' and shops on the streets and sidewalks blocking the way.			.834		
SC4	There are motorbike parking on the streets and sidewalks blocking the way.			.774		
TS2	So much traffic along nearby streets that it makes difficult or unpleasant to walk in my neighbourhood.			.487		
AE1	There are trees along the streets in my neighbourhood.				.794	
AE2	There are many attractive natural sights in my neighbourhood				.758	
TS4	Most drivers exceed the speed limits while driving in my neighbourhood.			.331		.780
TS3	Speed of traffic on most nearby streets is usually slow (40 km/hr or less).					.556

7.3.3 Correlation between objective and subjective measures of walking environment factors

The correlations in Table 7.7 show that overall perceived walkability tends to have higher correlations with subjective measures of walking environmental factors than objective measures of the walking environment. With the exception of Traffic safety, all the subjective measures of walking environment factors were significantly correlated to at least one objective measure of the walking environment.

Table 7.7 Correlations between walking environmental factors

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Objective measures	Population density (1)	1.00									
	Land use mix (2)	**-0.47**	1.00								
	% of 4-way intersection (3)	**0.29**	-0.09	1.00							
	Numbers of cul-de-sacs (4)	**-0.40**	**0.17**	**-0.27**	1.00						
	Overall perceived walkability (5)	**0.21**	-0.06	**0.12**	**-0.19**	1.00					
Subjective measures	Opportunities & street connectivity (6)	**0.28**	**-0.09**	**0.19**	**-0.19**	**0.42**	1.00				
	On-street barriers (7)	-0.08	**0.08**	**-0.10**	**0.09**	**0.12**	-0.03	1.00			
	Aesthetics (8)	**-0.13**	0.05	-0.03	0.06	**0.25**	0.05	0.05	1.00		
	Traffic safety (9)	0.03	-0.03	0.04	-0.02	**0.16**	0.03	0.08	0.05	1.00	
	Distances to services (10)	**-0.39**	**0.09**	**-0.23**	**0.34**	**-0.36**	**-0.22**	0.04	0.05	-0.05	1.00

Bold number denote correlation is significant at the 0.01 level (2-tailed)

7.3.4 Model results

Structural equation modelling (SEM) and generalized structural equation modelling (GSEM) with Stata 13.1 were used to estimate the path coefficients of the relationships between the constructs in the research model in Figure 7.2.

The estimation was divided into two stages. The first stage used SEM to estimate the paths in Figure 7.2 from objective measures of walking environmental factors to subjective measures of walking environmental factors and to overall walkability. The goodness-of-fit indices of the structural model were as follows: CFI = 0.95, TLI = 0.92, and RMSEA = 0.04. SRMR=0.03. The data shows a good fit with the hypothesized model structure. The second stage used GSEM to further include discrete choice between walking, walking access to public transport and private vehicle. The McFadden's pseudo R-squared for multinomial logit model is equal to 0.126.

The results of the structural equation model in Table 7.8 reveal that the path coefficients from population density, land use mix entropy, percentage of 4-way intersections and cul-de-sacs to the perceptions of distances to services and opportunities & street connectivity are all statistically significant and in the expected directions. Likewise, the path coefficients from land use mix entropy and percentage of 4-way intersections to on-street barriers are statistically significant and in the expected direction. The path coefficient from population density to aesthetics are statistically significant and in the expected direction.

The path coefficients from the subjective factors – distances to services, opportunities & street connectivity, aesthetics, on-street barriers and traffic safety – to overall walkability are all statistically significant and in the expected directions (Table 7.8). These results indicate that an individual's perceived overall walkability is determined by his/her perceptions of distances to services, opportunities & street connectivity, on-street barriers and traffic safety. Opportunities and street connectivity (0.382) exerts the highest impact on overall walkability followed distances to services (-0.317), by aesthetics (0.257), traffic safety (0.163) and then on-street barriers (0.142).

The coefficients' directions in Table 7.8 explain the relationships between objective and subjective measures of walking environment. People perceived shorter distances to services and greater walking opportunities and street connectivity if the environment has a higher population density, land use mix and percentage of 4-way intersections, and lower numbers of cul-de-sacs. People living in low population density neighbourhoods, which represent more rural places, tend to perceive better neighbouring aesthetics. Perceptions of on-street barriers are positively related to land use mix and negatively to the percentage of four-way intersections. This may be because higher land use mix in the neighbourhood means that many activities can be reached by walking. This potentially reduces the use of private vehicles and, hence reduces difficulties crossing roads and the amount of obstructive parking. On the other hand, a greater percentage of 4-way intersections represents a more grid-like street pattern which may be easier for motorbikes to access. Greater motorbike use may cause more severe on-street barriers, particularly with motorbikes being parked on sidewalks.

These results support this chapter's hypothesis that the objective measures of the walking environment are indirect determinants of walkability and walking behaviour, which operate via their impact on perceptions of the walking environment.

Gender and age exerted some influence on overall perceived walkability. Female and aged 55 and over had higher assessment on walkability then male and other age group respectively (Table 7.8).

Table 7.8 Structure model for objective and subjective walking environmental factors and walkability

	Coefficient	Std. dev.	t-value	Sig.
Distances to services <-				
Population density	**-0.335**	**0.035**	**-9.660**	**0.000**
Land use mix entropy	**-0.108**	**0.031**	**-3.540**	**0.000**
Percentage of 4-way intersections	**-0.088**	**0.028**	**-3.140**	**0.002**
Numbers of cul-de-sacs	**0.187**	**0.026**	**7.070**	**0.000**
Constant	0.010	0.027	0.370	0.714
Opportunities & street connectivity <-				
Population density	**0.252**	**0.034**	**7.520**	**0.000**
Land use mix entropy	**0.051**	**0.030**	**1.730**	**0.084**
Percentage of 4-way intersections	**0.080**	**0.027**	**2.960**	**0.003**
Numbers of cul-de-sacs	**-0.051**	**0.026**	**-1.980**	**0.048**
Constant	-0.032	0.026	-1.200	0.230
Aesthetics<-				
Population density	**-0.132**	**0.032**	**-4.110**	**0.000**
Land use mix entropy	0.010	0.031	0.330	0.740
Constant	0.021	0.028	0.750	0.451
On-street barriers <-				
Land use mix entropy	**0.079**	**0.028**	**2.820**	**0.005**
Percentage of 4-way intersections	**-0.070**	**0.027**	**-2.560**	**0.011**
Constant	0.020	0.028	0.710	0.481
Traffic safety<-				
Numbers of cul-de-sacs	-0.012	0.024	-0.500	0.615
Constant	-0.001	0.027	-0.050	0.963
Perceived overall walkability <-				
Distances to services	**-0.317**	**0.028**	**-11.400**	**0.000**
Opportunities & street connectivity	**0.382**	**0.031**	**12.420**	**0.000**
Aesthetics	**0.257**	**0.030**	**8.490**	**0.000**
On-street barriers	**0.142**	**0.030**	**4.750**	**0.000**
Traffic safety	**0.163**	**0.031**	**5.270**	**0.000**
Gender (female=0)	**-0.100**	**0.053**	**-1.890**	**0.059**
Aged 55 and over	**0.241**	**0.117**	**2.060**	**0.039**
Monthly income >= US$ 2,667	0.033	0.076	0.430	0.667
Constant	0.065	0.041	1.600	0.111

Table 7.9 shows the impacts on travel mode choice. Overall perceived walkability and most of the socio-demographic characteristics have statistically significant influence on the choices between walking to access public transport and private vehicles, and walking to the destination and private vehicles (Table 7.9). The impacts of overall walkability on walking to access public transport is about double the impacts on walking to destination (Table 7.9). The coefficient of overall walkability on walking to access public transport is statistically significant at a 95% level while the coefficient of overall walkability on walking to destination is statistically significant at a 90% level. In terms of socio-demographic characteristics, the aged 55 and over group are more likely to walk either to access public transport or to destinations than other age groups (significant at a 90% level). High household car and motorbike ownership are related a

low probability of walking in Taiwan. The more motorbikes in a household the less likely household members are to walk either to their destination or to access public transport (Table 7.9). Several studies have found that motorbike trip features are short distances and multi-trips (Chang and Wu, 2008). Hence they possibly offer more of an alternative to walking than the car.

Table 7.9 Walkability and -demographic characteristics influence walking behaviour

		Coefficient	Std. dev.	t-value	Sig.
Walking to access public transport	Overall walkability	**0.481**	**0.094**	**5.110**	**0.000**
	Gender (female =0)	-0.108	0.169	-0.640	0.524
	Monthly income >= 2,667	-0.223	0.243	-0.920	0.359
	Aged 55 and over	**0.652**	**0.335**	**1.950**	**0.052**
	Household car ownership	**-0.817**	**0.126**	**-6.480**	**0.000**
	Household motorbike ownership	**-0.646**	**0.089**	**-7.260**	**0.000**
	Constant	0.608	0.205	2.970	0.003
Walking to destinations	Overall walkability	**0.246**	**0.141**	**1.740**	**0.082**
	Gender (female =0)	0.001	0.272	0.000	0.998
	Monthly income >= 2,667	-0.312	0.411	-0.760	0.448
	Aged 55 and over	**0.824**	**0.494**	**1.670**	**0.096**
	Household car ownership	**-0.564**	**0.194**	**-2.910**	**0.004**
	Household motorbike ownership	**-0.362**	**0.132**	**-2.750**	**0.006**
	Constant	-1.254	0.327	-3.830	0.000

Table 7.10 shows the total effects - calculated from the significant relationships - that the objective measures and subjective measures of walking environment factors exert on overall walkability and travel mode choice. By and large, perceived walking environment factors exert greater effects on overall walkability and walking behaviour (Table 7.10). Population density has the greatest total effects on overall walkability and walking behaviour among the objective measures of walking environmental factors, following by numbers of cul-de-sacs (with negative effects), land use mix entropy and percentage of 4-way intersections. In terms of the effects of perceived walking environmental factors on overall walkability and walking behaviour, opportunities and street connectivity has the greatest total effect on overall walkability and walking behaviour, aesthetics, follow by distances to services, traffic safety and on-street barriers.

Table 7.10 Total effects of objective and subjective measures of walking environment on walkability

Factors	Effects on walkability	Effects to mode choice: walking to access public transport v private vehicle	Effects to mode choice: walking v private vehicle
Population density	0.169	0.081	0.042
Land use mix entropy	0.064	0.031	0.016
Percentage of 4-way intersections	0.058	0.028	0.014
Numbers of cul-de-sacs	-0.078	-0.038	-0.019
Distances to services	-0.317	-0.152	0.078
Opportunities and street connectivity	0.382	0.184	0.094
Aesthetics	0.257	0.124	0.063
On-street barriers	0.142	0.068	0.035
Traffic safety	0.163	0.078	0.040

7.4 Summary

1. The results of this chapter provide evidence to support the walkability conceptual model that objective measures of the walking environment exert indirect impacts on walkability and walking behaviour *via* perceptions of the walking environment.
2. This chapter provides insight into walking environments, walkability and walking behaviour. The results show that an individual's perceptions of distances to services, and opportunities & street connectivity are determined in part by population density, land use mix, percentage of 4-way intersections and numbers of cul-de-sacs. Moreover, perceptions of on-street barriers are partly determined by land use mix and percentage of 4-way intersections.
3. An individual's perceptions of distances to services, opportunities & street connectivity, on-street barriers and traffic safety are significant determinants for overall walkability accounting for sociodemographic characteristics. In addition, the perception of opportunity and street connectivity exerted the highest impact on the perceived overall walkability among all the subjective measures of walking environment factors.
4. Population density had the highest total effects on walking to access public transport and walking to destination among all the objective measures of walking environment factors. Likewise, opportunity and street connectivity exerted the highest total effects on walking to access public transport and walking to destination among all the subjective measures of walking environment factors.

Chapter 8 **CAPABILITY, OPPORTUNITY AND MOTIVATION INFLUENCE TRAVEL MODE CHOICE BEHAVIOUR**

This chapter addresses the fifth research question (RQ5) which aims to understand that can a novel conceptual model linking capability, opportunity and motivation make an important contribution to understand mode choice behaviour. If refers to the proposed conceptual model for travel mode choice behaviour towards use public transport in Figure 2.8, this chapter is to examine the relationships between Block E, intentions to use public transport, and travel mode choice behaviour, and also the interactions with Block A, B, C and D (see Figure 2.8). The conceptual model is summarised as Figure 8.1.

There four objectives for RQ5. First is to identify the latent factors: pro-environment value, attitudes, subjective norms, PMO, PBC and intentions, and their associations with city type and sociodemographic characteristics. Second is to examine the effects of motivational factors – pro-environment value, attitudes, subjective norms, perceived moral obligation and perceived behaviour control – on intentions to use public transport. Third is to examine the impacts of capability and opportunity on motivation. The fourth objective is to analyse the impacts of capability, opportunity and motivation on travel mode choice between car, motorbike and public transport.

There are seven sections in this chapter. The first section describes the data and methods used in this chapter; the second section describes the descriptive statistics of the variables and indicators; the third section uses factor analysis to extract the latent factors of the motivation towards public transport model; the fourth section analyse the associations of the factors in the motivation model with socio-demographic characteristics and different places. The fifth section presents the impacts of motivational factors on intentions to use public transport by using structural equation model (SEM). The sixth section examines the influence of capability, opportunity and motivation factors on travel mode choice behaviour by using generalized structural equation model (GSEM). The final section summarises the key findings of this chapter.

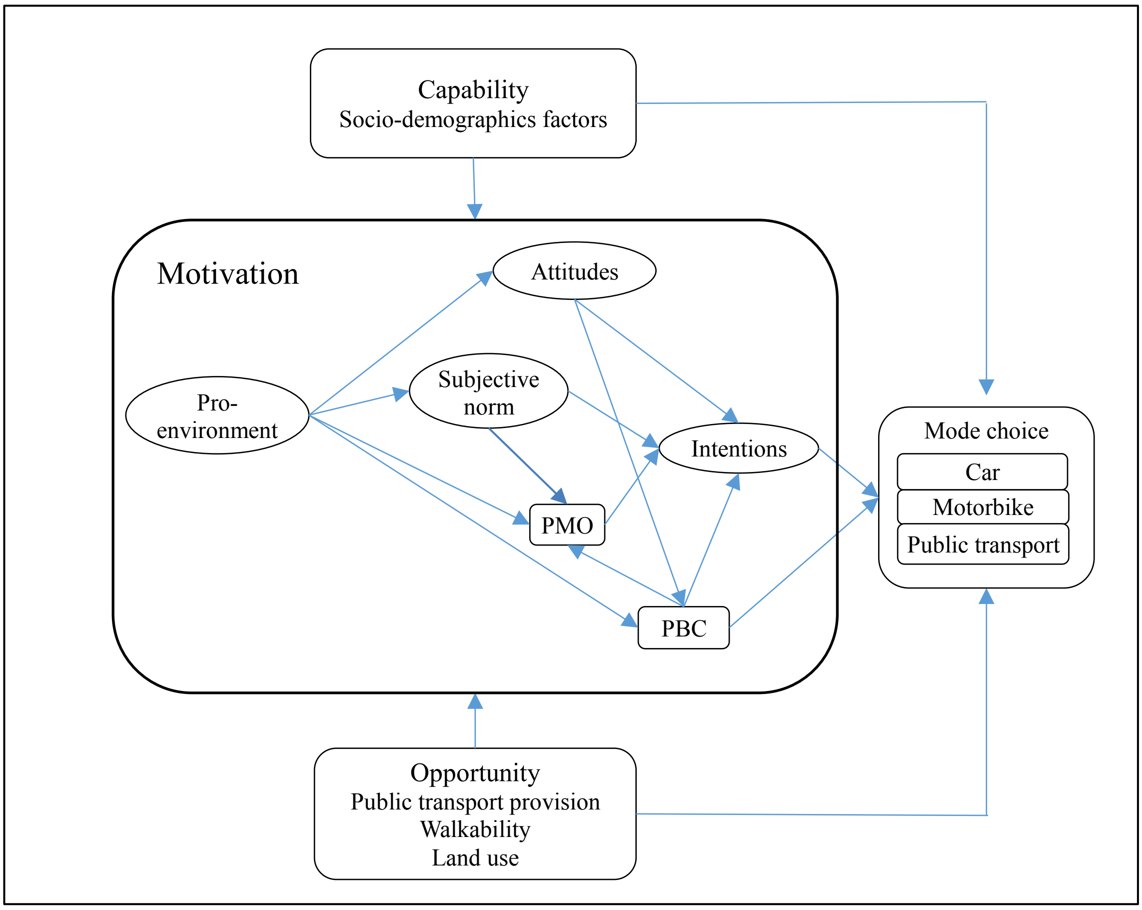


Figure 8.1 Summarised travel mode choice behaviour model

8.1 Methodology

An online survey data conducted by this study and mixed methodologies were used in this chapter's analysis. Exploratory factor analysis (EPA) was used to extract the unobserved latent variables. Structural equation model (SEM) and generalised structural equation model (GSEM) were used to analysed the effects motivational factors on intentions, and capability, opportunity and motivation on travel mode choice.

As mentioned in Section 2.1, sociodemographic variables are the proxy for capability. Capability variables include gender, age, income, education, car and motorbike driver's licence, household car and motorbike ownerships and children (aged under 18) in household. Opportunity variables include bus stop density, bus operation length, metro station, percentage of 4-way intersections, overall perceived walkability and walking time to public transport stop/station.

8.2 Descriptive statistics

8.2.1 Descriptive statistics of capability variables

Of all the effective samples, 1,427 samples was used in this analysis because 192 samples did not report commuting trips. The descriptive statistics for capability variables can be seen in Table 8.1. Of all the 1,427 samples, about 40% respondents reported using motorbike as commuting mode of transport, about 30% used car and public transport respectively (Table 8.1). If compare the samples' modal split with the modal split of Taiwanese National Travel Survey 2014 for commuting trips (car : motorbike : public transport = 23.6% : 53.9% : 25.7%) (Department of Statistics, 2015a), motorbike users were underrepresented in the sample while car and public transport users were overrepresented. This may be caused by the proportion of samples from metropolises such as Taipei City and New Taipei City were larger than the proportion of the population. These cities have higher public transport use rate and lower car use rate. However, as the focus of this study is on understanding individual behaviour rather than predicting behaviour for the population this is not of major concern.

Overall, female, aged 24 and under, aged 55 and over, lower education level, lower monthly income level, and without children in household tended to have higher possibility of using public transport (Table 8.1). Female had higher possibility (35.5%) of using public transport compared with male and male had higher possibility (44%) of using motorbike (Table 8.1). In terms of age, aged 24 and under, and aged 54 and over tended to use public transport more compared with other aged 25-54 (Table 8.1). Lower education level (high school and under) had the highest possibility to use public transport (40.2%) among all the education groups, and higher education level (master's and doctoral degree) had the greatest proportion (34.6%) of car use (Table 8.1). Lower income group (Monthly income <US$ 667) had the highest possibility (42.5%) of using public transport and higher income group (monthly income >= US$ 2,667) had the highest possibility (56.7%) of using car compared with other income groups (Table 8.1). Whether there are children (aged under 18) in household seems related to travel mode choice. Household without children tended to have higher possibility of using public transport (36.6%) and motorbike (43.2%) than household with children (Table 8.1).

By and large, car and motorbike driver's licence and household car and motorbike ownerships, which represent the capability of using car and motorbike, associated with travel mode choice (Table 8.1). The public transport usage rate for respondents without car driver's licence (57.8%) and without motorbike driver's licence (73.0%) were about double and triple to the respondents with car driver's licence (26.9%) and with motorbike driver's licence (25.1%) (Table 8.1). In terms of household car and motorbike ownerships, the proportion of public transport use decreased along with the increasing of household car and motorbike ownerships (Table 8.1).

Table 8.1 Modal split and socio-demographic characteristics

	Car (%)	Motorbike (%)	Public transport (%)
Total	28.9	39.6	31.5
Male	27.6	44.0	28.4
Female	30.7	33.8	35.5
Aged 14-24	5.3	50.6	44.1
Aged 25-54	31.7	39.5	28.8
Aged 55 and over	37.8	18.3	43.9
Education: high school and under	22.7	37.1	40.2
Education: bachelor's degree	25.7	47.1	27.2
Education: master's and doctoral degree	34.6	29.7	35.7
Monthly income < US$ 667	5.23	52.3	42.5
US$[1] 667<=Monthly income<US$ 2,667	27.4	44.0	28.6
Monthly income>=US$2,667	56.7	9.1	34.2
Children(aged under 18) in household: no	20.3	43.2	36.6
Children(aged under 18) in household: yes	38.7	35.6	25.7
Car driver's licence: no	5.6	36.6	57.8
Car driver's licence: yes	33.0	40.1	26.9
Motorbike driver's licence: no	24.9	2.1	73.0
Motorbike driver's licence: yes	29.6	45.3	25.1
Household car ownership: 0	1.2	50.0	48.8
Household car ownership: 1	25.2	40.8	34.0
Household car ownership: 2	55.0	27.8	17.2
Household car ownership: 3	49.3	40.3	10.4
Household car ownership: 4	60.0	40.0	0.0
Household motorbike ownership: 0	44.5	2.3	53.2
Household motorbike ownership: 1	32.2	31.6	36.2
Household motorbike ownership: 2	23.7	49.9	26.4
Household motorbike ownership: 3	24.1	57.6	18.3
Household motorbike ownership: 4	14.9	71.6	13.5

1. Exchange rate: US$: NTD (New Taiwan Dollar) = 1:30

8.2.2 Descriptive statistics for opportunity variables

Table 8.2, show descriptive statistics of the opportunity variables: land use mix entropy, percentage of 4-way intersections, walking time to public transport stop/station, bus operation length, bus stop density and overall perceived walkability for car, motorbike and public transport users.

Most of the opportunity variables are estimated at the district level: land use mix entropy, the percentage of 4-way intersections, bus operation length. Other opportunity variables such as bus stop density is measured at village level considering the accessible distance to bus stop, and walking time to public transport is used the perceived walking time collected from the online survey by this study.

Land use mix entropy was calculated based on six land use categories: residential, commercial, industrial, government offices, educations, and hospital and social care buildings. Land use entropy ranges from 0 to 1 in which higher entropy value indicates that a more evenly distributed mix of land uses.

Bus operation length was calculated by the length of the bus routes within the district multiply the weekday frequency of the routes. Including bus frequency can reflect the temporal bus accessibility. Hence, the bus operation length can be a proxy for spatial and temporal accessibility for bus service within a district.

Table 8.2 Descriptive statistics of opportunity variables

Variables		Mean	Std. dev.	Min.	Max.
Land use mix entropy (district)	Car	0.647	0.117	0.205	0.890
	Motorbike	0.644	0.113	0.054	0.853
	PT	0.650	0.092	0.228	0.890
% of 4-way intersections (district)	Car	0.214	0.075	0.034	0.561
	Motorbike	0.234	0.088	0.055	0.561
	PT	0.225	0.073	0.034	0.561
Bus operation length (district)	Car	2.16e+07	1.99e+07	6539	7.06e+07
	Motorbike	2.38e+07	1.99e+07	0	7.06e+07
	PT	3.60e+07	1.96e+07	0	7.06e+07
Bus stop density (Stops/per km^2, village)	Car	0.850	1.310	0	7.886
	Motorbike	1.086	1.417	0	10.891
	PT	1.912	1.968	0	17.919
Walking time to public transport stop/station	Car	8.840	8.138	3	35
	Motorbike	8.277	7.243	3	35
	PT	5.148	3.997	3	35
Overall perceived walkability	Car	4.828	1.498	1	7
	Motorbike	4.703	1.453	1	7
	PT	5.241	1.371	1	7

PT: public transport

8.2.3 Descriptive statistics of motivational indicators

As can be seen in Table 6.1, the constructs of motivation towards public transport contains five components including pro-environment value (PE1-PE7), attitudes towards public transport (AT1-AT5), subjective norms over public transport (SN1-SN3), PMO (perceived moral obligation of using public transport), PBC (perceived behaviour control for public transport) and intentions to use public transport (IN1 and IN2). Table

8.3 shows all the indicators this study adopted to measure the constructs of motivation towards public transport.

A 5-likert scale was used to for the respondents to measure these indicators, and the data are coded as strongly agree: 5, agree: 4, neutral (neither agree nor disagree): 3, disagree: 2, strongly disagree: 1. For questions, PE3 - the effects of climate change are too far in the future to really worry me, PE4 - the so called 'environmental crisis' facing humanity has been greatly exaggerated, and PE7 - technological advances will solve many environmental problems - were reversely coded, as strongly agree: 1, agree: 2, neutral: 3, disagree: 4, strongly disagree: 5. The higher the number indicates a more positive pro-environment value, as noted in the last column in Table 8.3.

As can be seen in Table 8.3 and Figure 8.2, generally, most of the respondents agree with the severe climate change and potentially caused environmental problem. All the indicators in the group of pro-environment value indicators except PE7 have a negative skewness. PE2 – we will all need to make sacrifices in our lifestyles to reduce environmental problems - has the highest mean score (4.39) and lowest standard deviation (0.609). PE7 - Technological advances will solve many environmental problems - has the lowest mean score (2.5) and highest standard deviation (0.985) in the group of pro-environment value indicators. From the histogram in Figure 8.2 and the positive skewness in Table 8.3, although most of the respondents agree that the climate change is an important issue, many others believe that technological advances will relieve the problem.

As for AT1-AT5 the indicators for measuring attitudes towards public transport (Table 8.3, Figure 8.2), Question AT1 - for me, (if) I can take public transport for everyday routes would overall be (very bad to very good) - has the highest mean score of 4.20 with a standard deviation of 0.876, which indicate that most of the respondents agree that it is a good thing if they can use public transport as everyday routes. Question AT2 - in the past year, using public transport is a satisfying experience, and AT3 - for me, using public transport for everyday routes is convenient - have the same lowest mean score of 3.57 with standard deviation of 0.937 and 1.046 respectively among the attitudes questions, which indicate that the respondents reported satisfaction and convenience for public transport service were not as well as their willingness to use public transport for a daily mode of transport.

As for the indicators (SN1-SN3) measuring subjective norms over public transport (Table 8.3 and Figure 8.2), SN1 - most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence) has the highest mean score (3.41) and lowest standard deviation (0.958). SN3 - most of my friends and relatives use public transport regularly - has the lowest mean score (3.01) and highest standard deviation (1.026). The skewness for SN2 and SN3 are close to 0, which means that the range of answers for both questions are about balance, as shown in Figure 8.2.

Perceived moral obligation and Perceived behaviour control are only measured by PMO and PBC respectively, as shown in Table 8.3 and Figure 8.2. PMO has the higher mean score (3.39) and lower standard deviation (1.027) compared with PBC (mean=2.94, SD=1.326). The gap between PMO and PBC means that the respondents feel that they are obliged to use public transport, however, some feel that it is difficult for them to use public transport as daily mode of transport.

Intentions to use public transport is measured by IN1 - how likely is it, that in the next 6 months you will use public transport for everyday routes (extremely unlikely to extremely likely), and IN2 - my intentions to use public transport for everyday routes is (extremely weak to extremely strong). The mean score and standard deviation for the indicators IN1 and IN2 are 2.85 and 1.335, and 2.91 and 1.163 respectively.

Table 8.3 Descriptive statistics for motivation towards public transport questions

No.	Items	Mean	Std. Dev.	Skewness	Kurtosis	Reverse code
PE1	I am very concerned about environmental issues.	4.22	.738	-.643	.134	No
PE2	We will all need to make sacrifices in our lifestyles to reduce environmental problems.	4.39	.609	-.840	2.003	No
PE3	**The effects of climate change are too far in the future to really worry me.**	4.09	.843	-1.068	1.390	Yes
PE4	**The so called 'environmental crisis' facing humanity has been greatly exaggerated.**	3.93	.930	-.949	.745	Yes
PE5	I would be prepared to pay more for environmentally-friendly products.	3.98	.722	-.843	1.801	No
PE6	If things continue on their current course, we will soon experience a major environmental disaster.	4.19	.735	-.967	1.763	No
PE7	**Technological advances will solve many environmental problems.**	2.50	.985	.478	-.481	Yes
PE8	There is an urgent need for something to be done about the environmental pollution caused by car and motorbike use.	4.35	.661	-1.135	3.075	No
AT1	For me, (if) I can take public transport for everyday routes would overall be (very bad to very good).	4.20	.876	-1.166	1.373	No
AT2	In the past year, using public transport is a satisfying experience.	3.57	.937	-.760	.436	No
AT3	For me, using public transport for everyday routes is convenient.	3.57	1.046	-.730	-.006	No
AT4	For me, using public transport for everyday routes is reliable.	3.63	.858	-.833	.904	No
AT5	For me, using public transport for everyday routes is cheap.	3.60	.970	-.627	-.040	No
SN1	Most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence.	3.41	.958	-.337	-.283	No
SN2	Most people who are important to me think that I should use public transport instead of car and motorbike for daily travel from my current place of residence.	3.11	.983	-.031	-.471	No
SN3	Most of my friends and relatives use public transport regularly.	3.01	1.026	-.057	-.734	No
PMO	Regardless of what other people do, because of my own values/principles I feel an obligation to use public transport instead of the car and motorbike for everyday trips.	3.39	1.027	-.421	-.289	No
PBC	For me using public transport for everyday routes is (extremely difficult to extremely easy).	2.94	1.326	.079	-1.222	No
IN1	How likely is it that in the next 6 months you will use public transport for everyday routes (extremely unlikely to extremely likely).	2.85	1.335	.086	-1.241	No
IN2	My intentions to use public transport for everyday routes is (extremely weak to extremely strong).	2.91	1.163	-.069	-.808	No

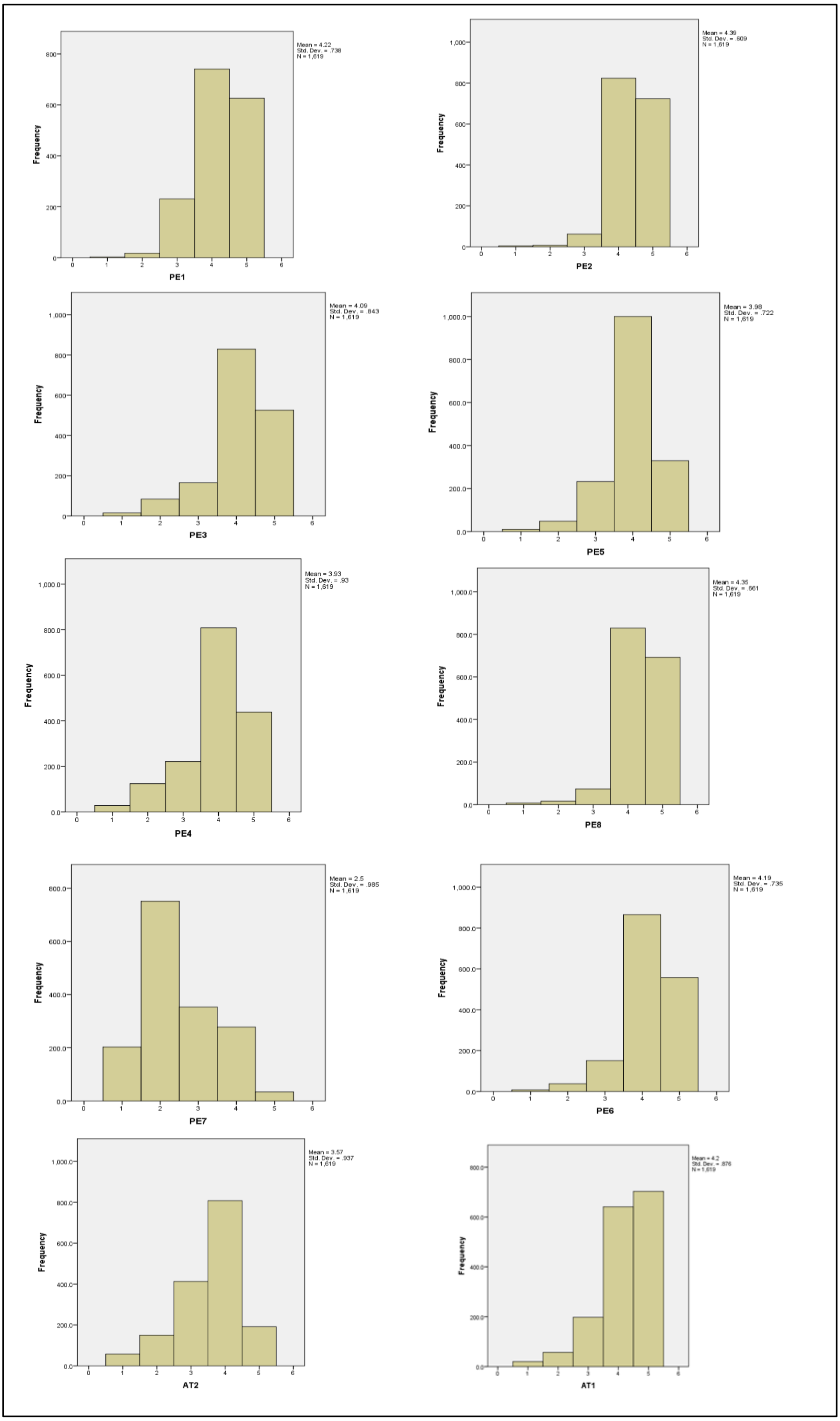


Figure 8.2 Histogram for motivation towards public transport questions

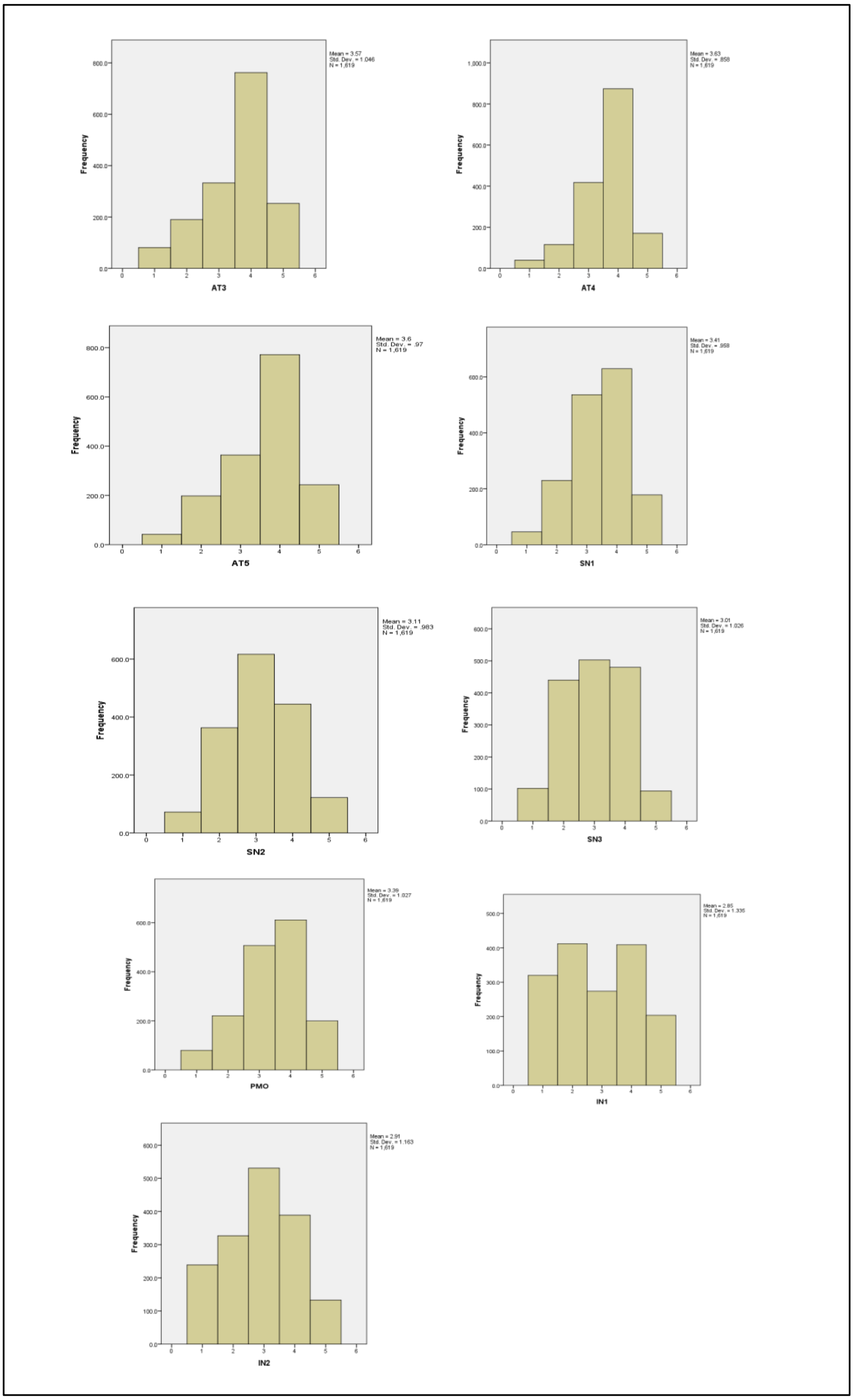


Figure 8.2 Histogram for motivation towards public transport questions (continue)

The Cronbach's α is 0.892, as shown in Table 8.4, which exceed the acceptable level of 0.7 (Nunnally et al., 1978). This value indicates that the dataset of motivation towards public transport indicators is reliable and has adequate internal consistency.

Table 8.4 Reliability statistics

Cronbach's Alpha	N of Items
.892	20

8.3 Exploratory factor analysis for motivation model latent factors

Exploratory factor analysis (EFA) rather than confirmative factor analysis (CFA) was used in identify the measurement model of SEM. The questionnaire adopted some related questions as indicators to measure the unobserved motivational factors: pro-environment value, attitudes, subjective norms, perceived moral obligation (PMO), perceived behavioural control (PBC) and intentions. As can be seen in Table 8.5, there are many cross correlations between indicators in different categories, which indicate that if CFA was used and fixing cross-loadings at 0 may cause a worse fit of a measurement model. Then, there is a need to do intensive model modification by using model modification indexes to find a well-fitting model. The process of model modification becomes exploratory rather than confirmatory. Hence, EFA was used to identify the measurement model, which is the latent constructs between motivational latent variables and the indicators (Asparouhov and Muthén, 2009, Marsh et al., 2010, Browne, 2001).

Sample size and the correlations between the indicators shows that the dataset is well for EFA, Sample size in this chapter's analysis,1,427 samples is much sufficient for doing exploratory factor analysis (Williams et al., 2012, Hair et al., 2009). As can be seen in Table 8.5. except PE7, there are a substantial number of correlations among the indicators greater than 0.3, and there is no multicollinearity problem (no correlations greater than 0.9) (Hair et al., 2009), which suggests that the dataset used in this analysis are suitable for EFA. Correlation matrix in Table 8.5 shows that PE7 may be irrelevant to other indicators. PE7 seems more likely to assess pro-technology value rather than pro-environment value. Therefore, PE7 is excluded in the factor analysis. Expand on this in meeting

Table 8.5 Correlation matrix for motivation towards public transport indicators

	PE1	PE2	PE3	PE4	PE5	PE6	PE7	PE8	AT1	AT2	AT3	AT5	AT5	SN1	SN2	SN3	PMO	PBC	IN1	IN2
PE1	1.00																			
PE2	.595	1.00																		
PE3	.489	.467	1.00																	
PE4	.412	.409	.605	1.00																
PE5	.382	.437	.360	.360	1.00															
PE6	.425	.474	.458	.500	.441	1.00														
PE7	-.001	.002	.061	.071	-.003	-.007	1.00													
PE8	.380	.458	.382	.343	.402	.430	-.089	1.00												
AT1	.274	.341	.272	.220	.307	.283	-.029	.418	1.00											
AT2	.154	.183	.146	.093	.214	.193	-.013	.184	.349	1.00										
AT3	.136	.198	.119	.116	.219	.182	-.037	.201	.357	.705	1.00									
AT4	.162	.214	.143	.112	.240	.189	-.046	.207	.349	.653	.668	1.00								
AT5	.164	.221	.170	.144	.226	.187	-.011	.248	.338	.418	.426	.438	1.00							
SN1	.172	.233	.136	.126	.235	.189	-.024	.249	.422	.420	.439	.405	.390	1.00						
SN2	.201	.220	.139	.137	.230	.179	-.051	.239	.356	.396	.439	.397	.377	.729	1.00					
SN3	.105	.140	.066	.085	.147	.107	-.035	.141	.265	.396	.460	.392	.318	.530	.546	1.00				
PMO	.340	.351	.288	.240	.353	.315	.022	.374	.546	.415	.439	.391	.388	.456	.486	.342	1.00			
PBC	.102	.149	.118	.082	.162	.102	-.002	.180	.398	.505	.567	.430	.358	.479	.474	.451	.514	1.00		
IN1	.154	.196	.154	.126	.217	.137	.024	.241	.441	.444	.493	.368	.354	.445	.452	.382	.563	.774	1.00	
IN2	.244	.284	.222	.200	.271	.194	.038	.297	.488	.377	.433	.345	.342	.439	.451	.325	.639	.644	.733	1.00

8.3.1 Exploratory factor analysis for pro-environment, attitudes towards public transport and subjective norms over public transport

Exploratory factor analyses were used to extract the perceived walking environmental factors. The index of Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) is 0.887 and Bartlett’s Test of Sphericity is significant at $p<0.000$, which indicates that the 15 5-likert scales indicators are suitable for factor analysis (Hair et al., 2009) (Table 8.6). Principal axing factoring method along with varimax rotation was used to extract five perceived walking environmental factors (Hair et al., 2009). As can be seen in Table 8.7, the three motivational factors are named, using the features of their indicators, as Pro-environment, attitudes and subjective norms. These accounted for about 60% of total variance. Table 8.7 shows the factor loadings, with loadings less than 0.30 supressed (Hair et al., 2009).

Table 8.6 KMO-MSA and Bartlett’s test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.887
Bartlett's Test of Sphericity	10119.826	13839.174
	105	153
	.000	.000

Table 8.7 Rotated factor loadings

		Factor		
		Pro-environment	Attitudes towards PT	Subjective norms over PT
PE3	The effects of climate change are too far in the future to really worry me.	.710		
PE2	We will all need to make sacrifices in our lifestyles to reduce environmental problems.	.703		
PE6	If things continue on their current course, we will soon experience a major environmental disaster.	.669		
PE1	I am very concerned about environmental issues.	.669		
PE4	The so called 'environmental crisis' facing humanity has been greatly exaggerated.	.667		
PE8	There is an urgent need for something to be done about the environmental pollution caused by car and motorbike use.	.576		
PE5	I would be prepared to pay more for environmentally-friendly products.	.557		
AT1	For me, to take public transport for everyday routes would overall be (Very bad to very good)	.372	.305	.321
AT3	For me, using public transport for everyday routes is convenient.		.796	
AT2	In the past year, using public transport is a satisfying experience.		.786	
AT4	For me, using public transport for everyday routes is reliable.		.752	
AT5	For me, using public transport for everyday routes is cheap.		.430	.305
SN1	Most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence.			.802
SN2	Most people who are important to me think that I should use public transport instead of car and motorbike for daily travel from my current place of residence.			.790
SN3	Most of my friends and relatives use public transport regularly.		.358	.536

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 4 iterations.

8.3.2 PMO, PBC and intentions to use PT

1. PMO (perceived moral obligation) and PBC (perceived behaviour control)

PMO and PBC are measured by the indicators: regardless of what other people do, because of my own values/principles I feel an obligation to use public transport instead of the car and motorbike for everyday trips, and for me using public transport for everyday routes is (extremely difficult to extremely easy) respectively. In order to pertain consistent result, standardised scores with mean 0 and standard deviation 1 for PMO and PBC are used in the model analysis.

2. Intentions to use PT

Intentions to use public transport is measured by two indicators: IN1 - how likely is it, that in the next 6 months you will use public transport for everyday routes.(extremely unlikely to extremely likely)- and IN2 -my intentions to use public transport for everyday routes is (extremely weak to extremely strong). The Cronbach's Alpha for the two indicators is 0.841, which suggests its adequate internal consistence. The extracted intentions to use public transport factor explained about 87% of total variance and each indicator has 73.2% variance explained by the intentions to use public transport factor.

8.4 The association of motivational factors with city types and socio-demographics

The aim of this section is to understand if there are associations between socio-demographic characteristics and the city types, and motivational factors. As can be seen in Figure 2.9, the travel mode choice behaviour model proposed by this study supposed that socio-demographic characteristics and opportunity exert some potential influence on motivation. The city types for 19 cities/counties in Taiwan are divided into three categories: A) Taipei metropolitan areas, B) sub-main cities, C) rural counties according to population density and public transport market share, see Section 3.2.3.2 (Chiou et al., 2013). One-way analysis of variance (ANOVA) was adopted to test if significant differences exist among the subgroups in the capability and opportunity variables for the perceived motivational factors: pro-environment, attitude towards public transport, subjective norms over public transport, PMO, PBC and intentions to use public transport among various groups.

8.4.1 Pro-environment value, and city types and socio-demographic characteristics

As can be seen in Table 8.8, the ANOVA test results show the city types and socio-demographic characteristics have a significant association with their awareness of the climate change and environmental problem at the 95% confidence level. Pro-environment values for subgroups of city types (p-value=0.000), gender (p-value=0.000), age (p-value=0.000), car driver's licence owned or not (p-value=0.009), monthly income (p-value=0.000), household car ownership (p-value=0.010), household motorbike ownership (p-value=0.013) and children in household or not (p-value=0.000) are significantly different (Table 8.8).

People who live in more rural areas are concerned more about the environmental issues than metropolitan areas (Table 8.8). Rural area respondents (mean score=0.246) have the highest mean score followed by sub main cities (mean score=0.022) and Taipei area (mean score=-0.061). The reason may be because that people in rural areas enjoy more green spaces and cleaner air and water than urban areas. So, they tend to have higher awareness of the climate change and environmental problems; they are happy to sacrifice more in order to mitigate environmental problems.

Gender, age and monthly income also have an effect on the attitude to climate change and environmental problems (Table 8.8). Female (mean score=0.146) had higher agreement that climate change is a serious problem than their male counterparts (mean score=-0.116). Likewise, people aged over 54 (mean score=0.546) tend to have higher agreement than younger people; the youngest group, which (age under 25) has the lowest mean score of -0.304 is the least caring age group with regards to climate change and environmental problems. In terms of income, the highest income group (mean score=0.190) tend to have higher agreement on climate change problem than other income groups.

Car and motorbike ownership and car driving capability have an effect on the attitude to climate change and environmental problems also (Table 8.8). People with car driver's licences (mean score=0.019) are more concerned about environmental problems than those without licences (mean score=-0.102). The reason may be because licence owners generally, have higher social status than non-car driver's licence owners. About 85% of the respondents owned a car driver's licence, and another 15% did not. Likewise, in terms of household car ownership, people with higher household car ownership tended to have higher agreement that climate change is a serious problem than households with lower car ownership, due to the higher social status for car owners. On the other hand, people with higher household motorbike ownership tended to have lower agreement (Table 8.8).

As for children in households (Table 8.8), people with children (mean score=0.092) tend to have higher agreement that climate change is a serious problem due to caring about their next generation's living conditions. Also, children have many chances to discuss environmental issues with their parents at home while these issues are also being taught in class. This increases parents' concerning about the environmental issues as well.

It is worth to notice that the three education levels did not have a clear trend relationship with the evaluation of pro-environmental values (Table 8.8) although there is no significant different pro-environmental evaluation for the three education levels. The group of bachelor's degree had the lowest score of pro-environmental values (this pattern also shows in other psychological construct in the following sections) compared with other education levels. This is in accordance with that bachelor's degree group had the highest percentage of private vehicle usage (72.8% of car and motorbike use) (Table 8.1). Either lower evaluation of pro-environmental values caused their higher private vehicle usage or the other way round.

Table 8.8 ANOVA test of pro-environment factor among various groups

Pro-environment factor					
Classification	Subgroups	Mean	F-value	*p*-value	Sig.
City types	Taipei metropolitan area	-.061	7.569	.001	***
	Sub main cities/counties	.022			
	Rural counties	.246			
Gender	Female	.146	33.183	.000	***
	Male	-.116			
Age	<25	-.304	31.282	.000	***
	25-54	-.004			
	>54	.546			
Education	High school (or under)	.059	1.031	.357	
	Bachelor degree	-.030			
	Master and PhD	.030			
Car driver's licence	No	-.102	3.708	.054	
	Yes	.019			
Motorbike driver's licence	No	.080	2.145	.143	
	Yes	-.014			
Monthly income (US$)	<1000	-.184	9.369	.000	***
	1000-3000	-.007			
	>=3000	.190			
Household car ownership	0	-.068	3.331	.010	*
	1	-.041			
	2	.107			
	3	.226			
	4 or more	.204			
Household motorbike ownership	0	.139	3.195	.013	*
	1	.030			
	2	-.036			
	3	-.076			
	4 or more	-.145			
Children (age under 18) in household	No	-.077	13.814	.000	***
	Yes	.092			

Level of significance: '***' p-value<0.000, '**' p-value<0.01, '*' p-value<0.05

8.4.2 Attitudes, and city types and socio-demographic characteristics

As can be seen in Table 8.9, the ANOVA test results show that the city types and socio-demographic characteristics have significant association with attitude towards public transport at the 95% confidence level. The reported attitude towards public transport for subgroups of city types (p-value=0.000), gender (p-value=0.000), age (p-value=0.029), car driver's licence owned or not (p-value=0.002), motorbike driver's licence owned or not (p-value=0.000), household car ownership (p-value=0.000) and household motorbike ownership (p-value=0.000) are significantly different (Table 8.9). Attitude towards public transport refers to the respondents past experience about public transport service convenience, service reliability, and their satisfaction.

As shown in Table 8.9, people living in Taipei area (mean score=0.220) reported higher evaluations for the public transport service than sub main cities (mean score=-0.257) and rural areas (mean score=-0.169) because people in Taipei area enjoy a superior public transport service. The reason that sub main cities received a lower average mean score than rural areas may be because that people in sub main cities expect as good a public transport service as Taipei area. However, the actual public transport service quality is not to their expectation in sub main cities.

As shown in Table 8.9, car and motorbike driving capability, and household car and motorbike ownerships make different attitudes towards public transport. The respondents without car driver’s licence (mean score=0.164) and without motorbike driver’s licence (mean score=0.342) reported more positive attitudes towards public transport than car driver’s licence owners (mean score=-0.030) and motorbike driver’s licence owners (mean score=-0.059) respectively. Likewise, higher car and motorbike ownership in households tended to have a lower evaluation for the public transport service (convenience, reliability and satisfaction) than households that had fewer car and motorbike owners, respectively.

Table 8.9 ANOVA test of attitude towards PT factor among various groups

Attitude towards PT factor					
Classification	Subgroup	Mean	F-value	*p*-value	Sig.
City types	Taipei metropolitan area	.220	56.502	.000	***
	Sub main cities/counties	-.257			
	Rural counties	-.169			
Gender	Female	.107	18.310	.000	***
	Male	-.085			
Age	<25	.054	3.553	.029	*
	25-54	-.026			
	>54	.187			
Education	High school (or under)	.030	1.249	.287	
	Bachelor degree	-.031			
	Master and PhD	.042			
Car driver's licence	No	.164	9.972	.002	**
	Yes	-.030			
Motorbike driver's licence	No	.342	41.100	.000	***
	Yes	-.059			
Monthly income (US$)	<1000	.035	1.703	.182	
	1000-3000	-.033			
	>=3000	.078			
Household car ownership	0	.085	7.441	.000	***
	1	.056			
	2	-.135			
	3	-.239			
	4 or more	-.751			
Household motorbike ownership	0	.211	10.363	.000	***
	1	.087			
	2	-.088			
	3	-.233			
	4 or more	-.108			
Children (age under 18) in household	No	.010	.214	.644	
	Yes	-.011			

Level of significance: '***' *p*-value<0.000, '**' *p*-value<0.01, '*' *p*-value<0.05

8.4.3 Subjective norms, and city types and socio-demographic characteristics

As can be seen in Table 8.10, the ANOVA test results show that the city types and socio-demographic characteristics have significant associations with subjective norms over public transport at the 95% confidence level. The reported subjective norms over public transport for subgroups of city types (p-value=0.000), gender (p-value=0.002), age (p-value=0.000), education (p-value=0.001), motorbike driver's licence owned or not(p-value=0.000), monthly income (p-value=0.000), household car ownership (p-value=0.000), household motorbike ownership (p-value=0.000) are significantly different (Table 8.10). Subjective norms over public transport refers to perceived social pressure to use public transport.

As shown in Table 8.10, people living in Taipei area (mean score=0.214) reported a highest subjective norms over public transport than sub main cities (mean score=-0.253) and rural areas (mean score=-0.148); the respondents living in sub main cities felt the least social pressure to use public transport.

Different gender, age, education and monthly income also make a difference reported social pressure to use public transport (Table 8.10). Females (mean score=0.076) reported higher subjective norms over public transport than males (mean score=-0.060). In terms of age, the subgroup of age over 54 (mean score=0.356) reported the highest subjective norms over public transport than other age groups, which means that people aged over 54 feel the highest social pressure to use public transport. In terms of education, the highest education group (mean score=0.098) reported the highest social pressure to use public transport compared with other education groups. In terms of monthly income, people with higher income reported higher social pressure to user public transport (Table 8.10).

Different ownerships of Household car and motorbike make different reported social pressure to use public transport (Table 8.10). Higher car and motorbike ownership in households reported lower subjective norms over public transport than lower car and motorbike ownership in household, respectively.

Table 8.10 ANOVA test of subjective norms over PT factor among various groups

Subjective norms over PT factor Classification	Group	Mean	F-value	*p*-value	Sig.
City types	Taipei metropolitan area	.214	55.056	.000	***
	Sub main cities/counties	-.253			
	Rural counties	-.148			
Gender	Female	.076	9.359	.002	**
	Male	-.060			
Age	<25	-.088	11.330	.000	***
	25-54	-.021			
	>54	.356			
Education	High school (or under)	.012	6.629	.001	**
	Bachelor degree	-.071			
	Masters and PhD	.098			
Car driver's licence	No	.087	2.883	.090	
	Yes	-.016			
Motorbike driver's licence	No	.372	50.429	.000	***
	Yes	-.064			
Monthly income (US$)	<1000	-.148	8.027	.000	***
	1000-3000	-.014			
	>=3000	.182			
Household car ownership	0	.044	8.262	.000	***
	1	.079			
	2	-.145			
	3	-.397			
	4 or more	-.273			
Household motorbike ownership	0	.240	12.932	.000	***
	1	.070			
	2	-.036			
	3	-.233			
	4 or more	-.248			
Children (age under 18) in household	No	.026	1.614	.204	
	Yes	-.031			

Level of significance: '***' p-value<0.000, '**' p-value<0.01, '*' p-value<0.05

8.4.4 PMO, and city types and socio-demographic characteristics

As can be seen in Table 8.11, the ANOVA test results show that the city types and socio-demographic characteristics have significant association with perceived moral obligation at the 95% confidence level. Perceived moral obligation for the subgroups of city types (p-value=0.000), gender (p-value=0.002), age (p-value=0.000), education (p-value=0.000), car driver's licence owned or not (p-value=0.042), motorbike driver's licence owned or not (p-value=0.000), monthly income (p-value=0.004), household car ownership (p-value=0.003), household motorbike ownership (p-value=0.000) are significantly different (Table 8.11). PMO refers to perceived moral obligation to use public transport.

As shown in Table 8.11, people living in Taipei area (mean score=0.091) reported highest perceived moral obligation than sub main cities (mean score=-0.119) and rural areas (mean score=-0.016), and the respondents living in sub main cities felt the least moral obligation to use public transport.

Gender, age, education and monthly income also make different perceived moral obligation to use public transport (Table 8.11). Females (mean score=0.087) reported higher PMO than males (mean score=-0.069). In terms of age, the subgroup of age over 54 (mean score=0.571) reported the highest PMO than other age groups, which means that people aged over 54 feel the highest moral obligation to use public transport. In terms of education, the most educated group (mean score=0.098) reported the highest PMO compared with other education groups. In terms of monthly income, higher income reported higher PMO (Table 8.10).

Car and motorbike driving capability, and household car and motorbike ownership make different perceived moral obligations to use public transport (Table 8.10). People without car and motorbike drivers' licence reported higher PMO than with car and motorbike drivers' licence, respectively. On the contrary, higher car and motorbike ownership in households reported lower PMO than lower household car and motorbike ownership, respectively.

Table 8.11 ANOVA test of PMO among various groups

PMO factor Classification	Group	Mean	F-value	*p*-value	Sig.
City types	Taipei metropolitan area	.091	8.039	.000	***
	Sub main cities/counties	-.119			
	Rural counties	-.016			
Gender	Female	.087	9.771	.000	***
	Male	-.069			
Age	<25	-.024	22.553	.000	***
	25-54	-.051			
	>54	.571			
Education	High school (or under)	.276	9.460	.000	***
	Bachelor degree	-.088			
	Master and PhD	.069			
Car driver's licence	No	.118	4.153	.042	*
	Yes	-.022			
Motorbike driver's licence	No	.436	55.053	.000	***
	Yes	-.075			
Monthly income (US$)	<1000	-.056	7.995	.004	**
	1000-3000	-.055			
	>=3000	.224			
Household car ownership	0	-.040	4.004	.003	**
	1	.075			
	2	-.083			
	3	-.338			
	4 or more	.016			
Household motorbike ownership	0	.315	16.827	.000	***
	1	.073			
	2	-.036			
	3	-.244			
	4 or more	-.379			
Children (age under 18) in household	No	-.043	3.491	.062	
	Yes	.051			

Level of significance: '***' *p*-value<0.000, '**' *p*-value<0.01, '*' *p*-value<0.05

8.4.5 PBC, and city types and socio-demographic characteristics

As can be seen in Table 8.12, the ANOVA test results show that city types and socio-demographic characteristics have significant association with PBC at the 95% confidence level. PBC for the subgroups of city types (p-value=0.000), gender (p-value=0.000), age (p-value=0.000), education (p-value=0.000), car driver's licence owned or not (p-value=0.000), motorbike driver's licence owned or not (p-value=0.000), monthly income (p-value=0.004), household car ownership (p-value=0.000), household motorbike ownership (p-value=0.000) and children in household (p-value=0.000) are all significantly different (Table 8.12).

People living in Taipei area (mean score=0.396) reported the highest PBC evaluation compared with sub main cities (mean score=-0.437) and rural areas (mean score=-0.404), Table 8.12. So, people living in Taipei area feel that public transport is more convenient than in other places.

Gender, age, education, monthly income and children in households also makes a difference to PBC (Table 8.12). Females felt that they can use public transport more easily than males. Those aged over 54 and under 25 reported that they can use public transport more easily than those aged between 25 and 54. In terms of education and monthly income, the lowest level of education and monthly income both reported the highest PBC evaluation, which means that they feel they can use public transport more easily than other subgroups. Furthermore, the respondents with children in households reported that it is more difficult for them to use public transport than without children in households (Table 8.12).

Car and motorbike driving capability and household car and motorbike ownership make different reported PBC either (Table 8.12). The respondents without car and motorbike driver's licence reported higher PBC evaluation than with car and motorbike driver's licence. Also, households with higher car and motorbike ownership reported lower PBC evaluation.

Table 8.12 ANOVA test of PBC factor among various groups

PBC factor Classification	Group	Mean	F-value	*p*-value	Sig.
City types	Taipei metropolitan area Sub main cities/counties Rural counties	.396 -.437 -.404	166.332	.000	***
Gender	Female Male	.106 -.084	14.497	.000	***
Age	<25 25-54 >54	.253 -.080 .452	23.651	.000	***
Education	High school (or under) Bachelor degree Master and PhD	.209 -.085 .077	7.693	.000	***
Car driver's licence	No Yes	.468 -.087	68.375	.000	***
Motorbike driver's licence	No Yes	.773 -.134	187.011	.000	***
Monthly income (US$)	<1000 1000-3000 >=3000	.172 -.060 -.045	4.962	.007	**
Household car ownership	0 1 2 3 4 or more	.294 .090 -.337 -.571 -.709	27.782	.000	***
Household motorbike ownership	0 1 2 3 4 or more	.395 .097 -.101 -.278 -.372	23.647	.000	***
Children (age under 18) in household	No Yes	.106 -.127	22.108	.000	***

Level of significance: '***' p-value<0.000, '**' p-value<0.01, '*' p-value<0.05

8.4.6 Intentions, and city types and socio-demographic characteristics

As can be seen in Table 8.13, the ANOVA test results show that the city types and socio-demographic characteristics have significantly association with intentions to use public transport at the 95% confidence level. Intentions to use public transport for the subgroups of city types (p-value=0.000), gender (p-value=0.000), age (p-value=0.000), education (p-value=0.000), car driver's licence owned or not (p-value=0.000), motorbike driver's licence owned or not (p-value=0.000), monthly income (p-value=0.026), household car ownership (p-value=0.000), household motorbike ownership (p-value=0.000) and children in household (p-value=0.035) are significantly different (Table 8.12).

As shown in Table 8.13, people living in Taipei area (mean score=0.246) have the highest intentions to use public transport, and the respondents living in sub main cities (mean score=-0.285) reported the lowest intentions to use public transport.

Gender, age, education, monthly income and children in household also make different intentions to use public transport (Table 8.13). Females (mean score=0.100) had a higher intentions to use public transport than males (mean score=-0.080). Also, people aged over 54 (mean score=0.603) reported highest intentions to use public transport compared with those aged under 25 (mean score=2.90) and aged between 25 and 54 (mean score=-0.062). In terms of education and monthly income, the lowest education level reported the highest intentions to use public transport while the highest monthly income group reported the highest intentions to use public transport. For the respondents with children in households, they reported significantly lower intentions to use public transport. This may be caused by the responsibility to transport their children to and from school (Table 8.13), which makes the commuting trips too complicated to use public transport.

Car and motorbike driving capability, and car and motorbike ownerships in household make different intentions to use public transport (Table 8.13). These all show the same associations with intentions to use public transport. You may have to shorten this by using abbreviations or acronyms as it is very difficult to judge whether you are referring to those that hold a licence or are car drivers - Car and motorbike driver's licence owners reported lower intentions to use public transport compared with non-car driver's licence and non-motorbike driver's licence. Likewise, the respondents with higher car and motorbikes in household reported lower intentions to use public transport compared with lower car and motorbike ownerships in household groups.

Table 8.13 ANOVA test of intentions to use public transport among various groups

Intentions to use PT factor Classification	Group	Mean	F-value	*p*-value	Sig.
City types	Taipei metropolitan area Sub main cities/counties Rural counties	.246 -.285 -.195	68.724	.000	***
Gender	Female Male	.100 -.080	15.466	.000	***
Age	<25 25-54 >54	.031 -.062 .603	30.798	.000	***
Education	High school (or under) Bachelor degree Master and PhD	.161 -.101 .109	11.606	.000	***
Car driver's licence	No Yes	.331 -.061	39.778	.000	***
Motorbike driver's licence	No Yes	.684 -.118	171.437	.000	***
Monthly income (US$)	<1000 1000-3000 >=3000	.039 -.044 .125	3.666	.026	*
Household car ownership	0 1 2 3 4 or more	.204 .059 -.220 -.456 -.309	15.017	.000	***
Household motorbike ownership	0 1 2 3 4 or more	.427 .094 -.092 -.313 -.396	32.759	.000	***
Children (age under 18) in household	No Yes	.044 -.053	4.453	.035	*

Level of significance: '***' p-value<0.000, '**' p-value<0.01, '*' p-value<0.05

The ANOVA test results give the evidence that capability and opportunity have potential influence on motivation as proposed by the COM-B model (Figure 2.5) (Michie et al., 2011). As can be seen in Table 8.14, most of the capability and opportunity variables are associated with the motivational factors. Especially for PBC and intentions to use public transport, both factors are potentially influenced by all the capability and opportunity variables adopted in this section. All the capability and opportunity characteristics except children in households have potential influence on PMO. In terms of city types, the mean scores for the six motivational factors among the Taipei area, sub main cities and rural areas are all statistically significantly different. In terms of socio-demographic characteristics, gender, age, household car and motorbike ownership have potential influence on all the 6 motivational factors.

Table 8.14 One-way ANOVA test summaries

Subgroups	PE	AT	SN	PMO	PBC	IT
City types	√	√	√	√	√	√
Gender	√	√	√	√	√	√
Age	√	√	√	√	√	√
Education		√	√	√	√	√
Car driver's licence		√		√	√	√
Motorbike driver's licence		√	√	√	√	√
Monthly income	√		√	√	√	√
Household car ownership	√	√	√	√	√	√
Household motorbike ownership	√	√	√	√	√	√
Children in household	√				√	√

1. '√' refers to that the mean scores of the subgroups is significantly different at 95% significance level;
2. PE: pro-environment values, AT: attitude towards public transport, SN: subjective norms over public transport, PMO: perceived moral obligation, PBC: perceived behaviour control, IT: intentions to use public transport.

8.5 Associations between motivational factors and intentions

Based on the conceptual model developed in Figure 8.1, this section examines the impact of the motivational variables: pro-environment value, attitudes, subjective norms, PMO, PBC, on intentions to use public transport and travel mode choice behaviour by adopting structural equation model (SEM) and generalized structural equation model (GSEM).

It should be noted that the variables and factors used in SEM and GSEM estimations were standardised into z-scores for the purposes of the model estimation in order to obtain consistent results.

8.5.1 Correlations of the motivational factors

As can be seen in Table 8.15, PBC had the highest correlation with intentions among all the motivational factors, and pro-environment had the lowest correlation with intentions. High correlations occurred between attitudes, subjective norms and PMO, and PBC, which implies that there are interactions between attitudes, subjective norms and PMO, and intentions. Likewise, there are potential interactions between attitudes and subjective norms, and PMO.

Table 8.15 Correlations between motivational factors

	Pro-environment	Attitudes	Subjective norms	PMO	PBC	Intentions
Pro-environment	1.00					
Attitudes	0.22	1.00				
Subjective norms	0.25	0.12	1.00			
PMO	0.41	0.41	0.47	1.00		
PBC	0.15	0.51	0.44	0.51	1.00	
Intentions	0.27	0.44	0.46	0.63	0.77	1.00

8.5.2 Motivational factors influence on intentions

There are three SEM models being estimated with a maximum likelihood estimation method. In the first model, this study estimated a whole sample model to test the hypothesis of the conceptual model. The second and third SEM models adopted car users and motorbike users in order to understand the different effects for car and motorbike users on intentions to use public transport.

Table 8.16, Figure 8.3, Figure 8.4 and Figure 8.5 report the estimated results. The goodness of fit (GOF) indices indicate that the proposed model fits the data well, RMSEA<0.06, CFI and TLI >0.9, SRMR<0.08 (Bartholomew et al., 2008) for both whole samples model and motorbike users except car users model.

For the whole sample model, as shown in Table 8.16 and Figure 8.3, the results confirm that environmental concerns and value (pro-environment) is an important antecedent determining an individual's intentions to use public transport. All the four paths direct from pro-environment factor to attitudes towards public transport, subjective norms over public transport, PMO and PBC are statistically significant. In other words, an individual's attitudes towards public transport, subjective norms over public transport, perceived moral obligation and perceived behaviour control are influenced by his/her environmental concerns and value. In addition, environmental concerns and value (pro-environment) exerts the highest impact on perceived moral obligation to use public transport (PMO) compared with attitudes, subjective norms and PBC. This means that individuals, who enjoy higher awareness of climate change and environmental problem, have higher perceived moral obligations to use public transport.

As can be seen in Table 8.16 and Figure 8.3, the paths of motivational factors: subjective norms, PMO and PBC to intentions to use public transport are statistically significant and in the expected direction. The results indicate that an individual's intentions to use public transport is determined by his/her subjective norms over public transport, perceived moral obligation and perceived behaviour control. About 73% of the total variance in intentions to use public transport factor is explained by the motivational factors, which indicate that this model enjoys a well explanatory power in predicting intentions to use public transport.

PBC is the most influential factor affecting the intentions to use public transport of all the motivational factors (Table 8.16), which implies that the individual's perceived easy or difficult to use public transport is the most important factor in the model influence his/her intentions to use public transport. PMO is also an indispensable factor in explaining intentions to use public transport (Table 8.16).

As can be seen in Table 8.16, Figure 8.4 and Figure 8.5, attitudes towards public transport is insignificant in the whole sample model; and shows opposite impacts on car and motorbike users' intentions to use public transport. Attitudes towards public transport is only statistically significant for motorbike users. This may be because travel mode choice behaviour is more like a habitual behaviour and car users have psychological ambivalence, which explain as the following.

There are two reasons to explain why attitudes was insignificant to intentions. Firstly, mode choice behaviour has become automatic behaviour, which means that habits are automatically triggered the mode choice (Gärling et al., 2001, Ronis et al., 1989, Aarts et al., 1998). Under this situation, attitudes towards public transport may become irrelevant in guiding behaviour when mode choice has developed into a habit (Gärling et al., 2001, Ronis et al., 1989, Aarts et al., 1998).

Secondly, ambivalence, which refers to 'holding conflicting feelings or beliefs towards one object (Gerd Bohner, 2002) may be able to explain why the attitudes towards public transport is not statistically significant for car users. The social status (income) for car users is higher than motorbike and public transport users. The social status makes car users pay more attention on climate change and environmental problems. So, they tend to give more positive attitudes for public transport use. However, car users may still enjoy driving. So, their intentions to use public transport could be lower than expected. As can be seen in Table 8.16 and Figure 8.4, the negative coefficient between attitudes towards public transport and intentions to use public transport gives evidence of the psychological ambivalence for car users.

In terms of the interactions within the motivational factors, the results showed that attitudes to public transport exerted high influence on PBC. This means that travellers who satisfy with public transport and feel that public transport is convenient, reliable and cheap, have higher perceived behavioural control over public transport (Table 8.16 and Figure 8.3). This pattern is the same for car users and motorbike users only models (Table 8.16, Figure 8.4 and Figure 8.5).

Of all the variance in intentions to use public transport for whole sample model, car users' model and motorbike users' model (Table 8.16), 72.7%, 69.3% and 75% were explained by the motivational factors respectively, which indicates that the motivational factors adopted in this analysis are good predictors for intentions.

In comparison to car users and motorbike users, pro-environment values exerted significantly effects on PBC for motorbike users but not significant for car users. This is perhaps because car users were higher income and education level. They tended to concern more about the environmental problems. But these environmental concerns did not affect their perceived easier to use public transport. On the other hand, subjective norms showed statistically significant influence on intentions to use public transport for car users but not for motorbike users. This may be because the higher social status for car users makes them concern more about the social pressure to use public transport. The social pressure may boost their intentions to use public transport.

Table 8.16 Structural model estimated results for intentions to use PT

Path	Model 1: Whole sample			Model 2: car users			Model 3: motorbike users		
	B	SD	Sig	B	SD	Sig	B	SD	Sig
PE → AT	0.22	0.026	***	0.18	0.051	***	0.25	0.041	***
PE → SN	0.25	0.025	***	0.25	0.044	***	0.21	0.038	***
PE → PMO	0.33	0.023	***	0.28	0.042	***	0.29	0.037	***
PE → PBC	0.05	0.025	*	0.02	0.004		0.09	0.029	**
AT → PBC	0.52	0.023	***	0.36	0.036	***	0.34	0.029	***
PBC → PMO	0.25	0.026	***	0.21	0.053	***	0.30	0.053	***
SN → PMO	0.30	0.026	***	0.36	0.047	***	0.34	0.042	***
AT → IN	0.01	0.018		-0.02	0.034		0.07	0.026	*
SN → IN	0.06	0.018	**	0.12	0.039	**	0.05	0.028	
PMO → IN	0.28	0.018	***	0.27	0.037	***	0.25	0.025	***
PBC → IN	0.52	0.018	***	0.46	0.041	***	0.42	0.034	***
Constant									
Total IN variance explained	72.7%			69.3%			75.0%		
Goodness of fit (GOF)	RMSEA=0.063, CFI=0.997, TLI=0.974, SRMR=0.018			RMSEA=0.069, CFI=0.994, TLI=0.956, SRMR=0.015			RMSEA=0.000, CFI=1.0, TLI=0.999, SRMR=0.006		
Sample size	1427			413			565		

PE: pro-environment value, AT: attitudes towards public transport, SN: subjective norms over public transport, IN: intentions to use public transport
Level of significance: p<0.000 '***', p<0.01 '**', p<0.05 '*'

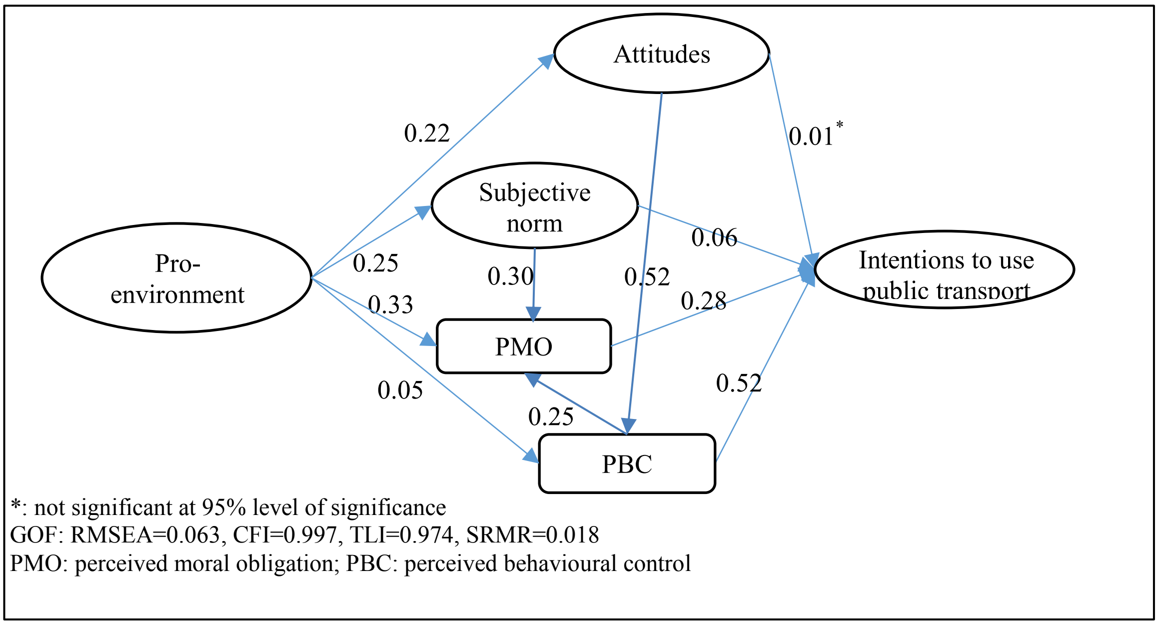


Figure 8.3 Intentions to use public transport estimated results: whole samples

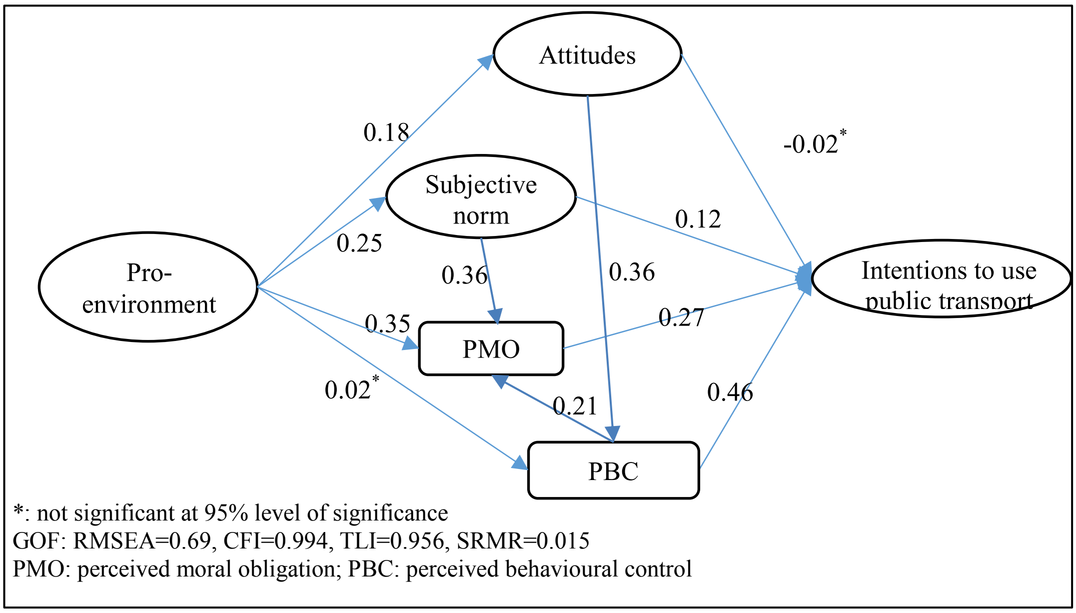


Figure 8.4 Intentions to use public transport estimated results: car users

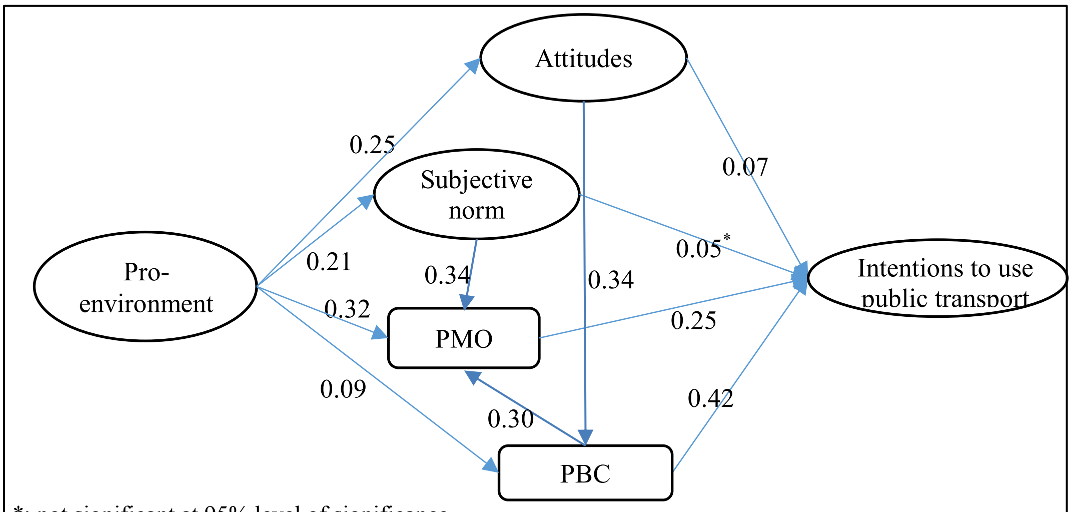


Figure 8.5 Intentions to use public transport estimated results: motorbike users

8.6 Influence of capability, opportunity and motivation on travel mode choice

8.6.1 Influence of capability and opportunity on motivational factors

As can be seen in Table 8.17 and Table 8.19, by and large, the estimation results verified the hypothesis that capability factors and opportunity factors exerted some influence on motivational factors. Additionally, capability, opportunity and motivation had statistically significant effects on mode choice behaviour.

Capability variables include gender, age, education, car driver's licence, motorbike driver's licence, children in household, household car ownership and household motorbike ownership.

Opportunity variables include land use variables such as land use mix entropy and percentage of 4-way intersections, and public transport provision variables such as bus stop density, bus operation length and metro station, and overall perceived walkability.

The estimation was divided into two stages. The first stage used SEM to estimate the paths in from capability and opportunity to motivation. The goodness of fit (GOF) indices of the structural model were as follows: RMSEA=0.069, CFI=0.914, TLI=0.743, SRMR=0.032. The data shows a good fit with the hypothesized model structure. The second stage used GSEM to further include discrete choice between car, motorbike and public transport. The McFadden's pseudo R-squared for multinomial logit model is equal to 0.451. This shows a good model's fit. Public transport is the reference category in order to understand the effects of the variables on the choices between car and public transport, and motorbike and public transport.

1. Effects of capability on motivational factors

Generally, Table 8.17 showed that the paths direct from capability factors to motivational factors were statistically significant and in the expected direction.

Age exerted significant effects on pro-environment value, PBC and intentions Table 8.17. Compared with aged between 25 and 54, aged under 24 tended to concern less about the problems of climate change and global warming. On the other hand, aged over 55 cared more about the problems of climate change and global warming (Table 8.17). In terms of PBC, both aged under 24 and aged over 55 expressed easier use of public transport compared with aged between 25 and 54. Intentions only showed significant for aged over 55. Aged over 55 ad higher intentions to use public transport compared with aged between 25 and 54 (Table 8.17).

Gender exerted significant effects on pro-environment value and attitudes (Table 8.17). Compared with male, female concerned more about the problems of climate change and global warming. In terms of attitudes toward public transport, female perceived less attitudes than male, which means that female felt that using public transport was less satisfying, convenient, reliable and cheap (Table 8.17).

Education exerted significant effects on pro-environment value, subjective norms, PMO, PBC and intentions (Table 8.17). Compared with education level of bachelor's degree, education level of high school and under perceived more concerns about environmental problems and had higher perceived moral obligation to use public transport. In terms of subjective norms, PBC and intentions, education level of master's degree and higher perceived higher social pressure to use public transport and felt easier to use public transport compared with education level of bachelor's degree. Hence, education level of master's degree and higher had higher intentions to use public transport (Table 8.17).

Car and motorbike driver's licence exerted significant effects on subjective norms, PBC and intentions (Table 8.17). Both car and motorbike driver's licence exerted negative effects on PBC, which means that car and motorbike driver's licence owners felt more difficult to use public transport. Motorbike driver's licence owners perceived less social pressure and intentions than non-owners to use public transport (Table 8.17).

Household car and motorbike ownership exerted significant effects on pro-environment value, subjective norms, PMO, PBC and intentions (Table 8.17). Both household car and motorbike ownerships exerted statistically negative significant effects on subjective norms and PBC, which means that respondents with more cars and motorbikes within household perceived lower social pressure and felt more difficult to use public transport. In terms of pro-environment value and PMO, the effects of household car and motorbike had different direction on the two factors. On the one hand, respondents with more household car ownership perceived more concerns about environmental problems and more moral obligation to use public transport. On the other hand, higher household motorbike ownership groups had less concerns about environmental problems and perceived less moral obligation to use public transport (Table 8.17).

Children in household exerted significant effects on PBC (Table 8.17). Individuals with children in household perceived more difficult to use public transport. This may be because they need to take their children to and from school and other places. They tend to have more multi-trips in their daily travel, which make them more difficult to use public transport (Table 8.17).

2. Effects of opportunity on motivational factors

As can be seen in Table 8.17, the paths direct from opportunity factors to motivational factors were statistically significant and in the expected direction.

Bus stop density, bus operation length and metro station within district showed significant associations with attitudes and PBC (Table 8.17). Likewise, perceived walking time to the nearest public transport stop/station had significant impact on PBC. Bus stop density within village refers to if people can easy access to bus service. The average areas of a village in Taiwan is 4.7 km^2 and the radius of a village is about 1.2

km if suppose that villages are circular in shape. Bus operation length in district refers to level of bus service including bus network and frequency. Metro station within district refers to if there is metro service available. All these three factors reflect the opportunity to use public transport. The results showed that higher bus stop density, bus operation length and with metro station within district all associated with higher attitudes and perceived easier to use public transport (Table 8.17). Bus stop density exerted strongest effects on attitudes and PBC among the opportunity variables, following by metro station within district.

Table 8.17 Structural model results

Path	Coef.	Std. dev.	t-value	Sig.
Pro-environment <-				
Gender (female=0, male=1)	**-0.290**	**0.050**	**-5.770**	**0.000**
Aged 55 and over	**0.385**	**0.103**	**3.720**	**0.000**
Aged 24 and under	**-0.273**	**0.107**	**-2.540**	**0.011**
Monthly income <=US$666	0.101	0.107	0.940	0.345
Monthly income > US$2,666	0.133	0.072	1.850	0.064
Education: high school and under	**0.262**	**0.101**	**2.600**	**0.009**
Education: master's degree and higher	0.051	0.051	1.000	0.318
Car driver's licence (yes=1)	0.090	0.079	1.130	0.258
Motorbike driver's licence (yes=1)	-0.029	0.079	-0.370	0.712
Household car ownership	**0.091**	**0.030**	**3.000**	**0.003**
Household motorbike ownership	**-0.054**	**0.022**	**-2.450**	**0.014**
Constant	0.018	0.096	0.180	0.855
Attitudes <-				
Pro-environment	**0.217**	**0.026**	**8.430**	**0.000**
Gender (female=0, male=1)	**-0.102**	**0.049**	**-2.090**	**0.037**
Aged 55 and over	-0.010	0.102	-0.100	0.922
Aged 24 and under	0.135	0.104	1.310	0.191
Monthly income <= US$666	0.008	0.103	0.080	0.935
Monthly income > US$2,666	-0.037	0.069	-0.540	0.591
Education: high school and under	-0.059	0.097	-0.600	0.548
Education: master's degree and higher	0.081	0.049	1.630	0.102
Car driver's licence (yes=1)	-0.123	0.074	-1.660	0.098
Motorbike driver's licence (yes=1)	-0.139	0.075	-1.840	0.066
Children (aged under 18) in household	0.025	0.046	0.530	0.595
Household car ownership	-0.039	0.032	-1.240	0.216
Household motorbike ownership	-0.029	0.022	-1.320	0.188
Bus stop density (village)	**0.734**	**0.271**	**2.710**	**0.007**
Bus operation length (district)	**0.096**	**0.027**	**3.580**	**0.000**
Metro station within district (yes=1)	**0.208**	**0.054**	**3.850**	**0.000**
Constant	0.193	0.101	1.910	0.057
Subjective norm <-				
Pro-environment	**0.229**	**0.025**	**9.080**	**0.000**
Gender (female=0, male=1)	-0.040	0.045	-0.900	0.369
Aged 55 and over	0.179	0.092	1.950	0.051
Aged 24 and under	0.022	0.102	0.220	0.828
Monthly income <= US$666	-0.071	0.102	-0.700	0.482
Monthly income > US$2,666	0.099	0.068	1.460	0.144
Education: high school and under	0.012	0.096	0.120	0.904
Education: master's degree and higher	**0.137**	**0.049**	**2.800**	**0.005**
Car driver's licence (yes=1)	-0.053	0.075	-0.710	0.478
Motorbike driver's licence (yes=1)	**-0.297**	**0.075**	**-3.940**	**0.000**
Household car ownership	**-0.128**	**0.029**	**-4.440**	**0.000**
Household motorbike ownership	**-0.049**	**0.021**	**-2.310**	**0.021**
Constant	0.478	0.091	5.250	0.000
PMO <-				
Subjective norm	**0.295**	**0.026**	**11.530**	**0.000**
PBC	**0.276**	**0.026**	**10.530**	**0.000**

Pro-environment	**0.318**	**0.024**	**13.450**	**0.000**
Gender (female=0, male=1)	0.042	0.044	0.960	0.338
Aged 55 and over	0.036	0.091	0.400	0.691
Aged 24 and under	0.041	0.093	0.440	0.656
Monthly income <= US$666	-0.054	0.092	-0.590	0.557
Monthly income > US$2,666	0.056	0.062	0.910	0.365
Education: high school and under	**0.312**	**0.087**	**3.570**	**0.000**
Education: master's degree and higher	0.057	0.045	1.270	0.204
Car driver's licence (yes=1)	0.031	0.069	0.440	0.658
Motorbike driver's licence (yes=1)	0.039	0.070	0.560	0.577
Household car ownership	**0.056**	**0.027**	**2.070**	**0.039**
Household motorbike ownership	**-0.054**	**0.019**	**-2.800**	**0.005**
Constant	-0.122	0.087	-1.400	0.161
PBC <-				
Attitudes	**0.417**	**0.023**	**17.960**	**0.000**
Pro-environment	**0.081**	**0.024**	**3.400**	**0.001**
Gender (female=0, male=1)	-0.038	0.045	-0.840	0.400
Aged 55 and over	**0.214**	**0.093**	**2.310**	**0.021**
Aged 24 and under	**0.190**	**0.094**	**2.020**	**0.043**
Monthly income <= US$666	-0.052	0.093	-0.560	0.575
Monthly income > US$2,666	-0.090	0.063	-1.440	0.151
Education: high school and under	0.088	0.089	0.990	0.324
Education: master's degree and higher	**0.149**	**0.045**	**3.310**	**0.001**
Car driver's licence (yes=1)	**-0.219**	**0.070**	**-3.150**	**0.002**
Motorbike driver's licence (yes=1)	**-0.427**	**0.071**	**-6.050**	**0.000**
Children (aged under 18) in household	**-0.129**	**0.040**	**-3.230**	**0.001**
Household car ownership	**-0.119**	**0.029**	**-4.150**	**0.000**
Household motorbike ownership	**-0.046**	**0.020**	**-2.310**	**0.021**
Overall perceived walkability	0.004	0.021	0.200	0.838
Walking time to stop/station	**-0.090**	**0.021**	**-4.360**	**0.000**
Bus stop density (village)	**0.548**	**0.236**	**2.320**	**0.020**
Bus operation length (district)	**0.055**	**0.023**	**2.350**	**0.019**
Metro station within district (yes=1)	**0.136**	**0.048**	**2.840**	**0.005**
Constant	0.672	0.093	7.250	0.000
Intentions <-				
Attitudes	0.012	0.019	0.650	0.514
Subjective norm	**0.052**	**0.019**	**2.770**	**0.006**
PMO	**0.274**	**0.018**	**15.270**	**0.000**
PBC	**0.502**	**0.020**	**25.630**	**0.000**
Gender (female=0, male=1)	0.003	0.030	0.110	0.915
Aged 55 and over	**0.130**	**0.063**	**2.080**	**0.037**
Aged 24 and under	-0.063	0.063	-1.000	0.317
Monthly income <= US$666	-0.001	0.063	-0.020	0.982
Monthly income > US$2,666	-0.045	0.042	-1.070	0.286
Education: high school and under	0.001	0.060	0.020	0.980
Education: master's degree and higher	**0.097**	**0.030**	**3.170**	**0.002**
Car driver's licence (yes=1)	-0.060	0.047	-1.270	0.203
Motorbike driver's licence (yes=1)	**-0.133**	**0.048**	**-2.790**	**0.005**
Children (aged under 18) in household	0.024	0.029	0.830	0.406
Household car ownership	-0.015	0.019	-0.810	0.417
Household motorbike ownership	**-0.027**	**0.013**	**-2.050**	**0.040**
Constant	0.171	0.060	2.870	0.004

Bold numbers mean significant at 90% level.

The estimated SEM model well explained intentions, PMO and PBC. As can be seen in Table 8.18, about 73% of variance of intentions to use public transport was explained by the model. More than 40% of variances for PMO and PBC were explained by the capability variables, opportunity variables and other motivational factors (Table 8.18). About 30% of variances of attitudes and subjective norms were explained by the capability variables, opportunity variables and other motivational factors (Table 8.18).

Table 8.18 Unexplained variance

Factors	Unexplained variance
Attitudes	0.719
Subjective norms	0.700
PMO	0.574
PBC	0.587
Pro-environment value	0.773
Intentions	0.267

8.6.2 Effects of capability, opportunity and motivation on travel mode choice

1. Effects of capability on travel mode choice

As can be seen in Table 8.19, capability factors showed statistically significant impacts on travel mode choice and in the expected direction. Sociodemographic characteristics are the proxies for capability. The results showed that age, income, education level, car and motorbike driver's licence owned, household car and motorbike ownerships and children in household had statistically significant influence on travel mode choice.

In terms of travel mode choice between car and public transport, the results showed that the capability of owning and using car plays an important role in choosing between car and public transport. Aged 24 and under, and lower income group (monthly income <= US$666) tended to choose public transport rather than car (Table 8.19). This is perhaps because these age and income group cannot afford to own or use car. On the other hand, individuals with car driver's licence or higher household car ownership had higher possibility to use car than public transport. Likewise, aged over 55 and higher income group (monthly income > US$ 2,666) tended to choose car as mode of transport rather than public transport. Moreover, education level of high school and under was more likely to choose car as a mode of transport than public transport (Table 8.19).

In terms of travel mode choice between motorbike and public transport, the capability of avoiding risks from traffic accidents plays an important role in choosing between motorbike and public transport. Individuals with higher education (education level of master's degree and higher) were more likely to choose public transport as a mode of transport rather than motorbike while education level of high school and under tended to choose more motorbike than public transport. Also, higher income group (monthly income > US$2,666) tended to choose public transport rather than motorbike (Table 8.19). This may be because motorbike is relatively high risk of traffic accident compared with other mode of transport (Hsu et al., 2003). Higher education and income groups are more concerns about the safety issue than other education and income groups. Individuals with motorbike driver's licence and higher household motorbike ownership tended to choose motorbike as a mode of transport than public transport (Table 8.19).

2. Effects of opportunity on travel mode choice

As can be seen in Table 8.19, opportunity exerted significant effects on travel mode choice. Land use and public transport provision variables are the proxies for opportunity. Public transport provision variables include bus stop density, bus operation length, metro station, and land use variables include land use mix entropy, percentage of 4-way intersections and perceived walkability. Except perceived walkability, other factors were in the expected direction.

In terms of travel mode choice between car and public transport, individuals, who enjoyed easier access to bus stop (higher bus stop density) and more bus network and frequency (higher bus operation length) were more likely to choose public transport as a mode of transport instead of car (Table 8.19).

In terms of travel mode choice between motorbike and public transport, more grid-like street pattern, which means higher percentage of 4-way intersections, tended to have more motorbike use than public transport while if there is metro station within district can encourage individual to use public transport than motorbike (Table 8.19).

3. Effects of motivation on travel mode choice

As can be seen in Table 8.19, the motivational factors, PBC and intentions, showed statistically significant impacts on travel mode choice and in the expected direction. PBC exerted stronger effects on the mode choice of car (-1.658) than of motorbike (-1.427) (Table 8.19). On the other hand, the intentions to use public transport exerted stronger effects on the mode choice of motorbike (-1.187) than of car (-0.828), which indicates that intentions to use public transport applies higher influence on motorbike users to shift their mode choice to public transport than car users (Table 8.19). So, boosting intentions to use public transport for motorbike users will have greater effects on behaviour change than car users (Table 8.19).

The results of this study showed that the effects of PBC on travel mode choice was stronger than intentions to use public transport while Bamberg et al. (2003) showed that intentions exerted stronger effects on travel behaviour than PBC. The reason perhaps is because this study covered urban areas, suburban areas and rural areas in Taiwan and the public transport provision for these areas are quite varied. This also reflects to the mean scores of PBC for Taipei metropolitan area, sub-main cities/counties and rural counties. As can be seen in Table 8.12, the mean score for PBC in Taipei metropolitan area was 0.396, and in sub-main cities/counties and rural counties were -0.437 and -0.404 respectively. On the other hand, intentions to use public transport showed less variance across Taipei metropolitan area, sub-main cities/counties and rural counties. The mean scores of intentions to use public transport for Taipei metropolitan area, sub-main cities/counties and rural counties are 0.246, -0.285 and -0.195 respectively (Table 8.13). The F-values for PBC among Taipei metropolitan area, sub-main cities/counties and rural counties was 166.3 much higher than intentions to use public transport (68.7) (Table 8.12, Table 8.13).

Table 8.19 Effects on travel model choice

Structure model for mode choice	B	Std. dev.	t-value	Sig.
Car <-				
PBC	**-1.658**	**0.171**	**-9.720**	**0.000**
Intentions	**-0.828**	**0.181**	**-4.590**	**0.000**
Gender (female=0, male=1)	-0.081	0.212	-0.380	0.702
Aged 55 and over	**0.677**	**0.399**	**1.700**	**0.090**
Aged 24 and under	**-1.605**	**0.605**	**-2.650**	**0.008**
Monthly income <=US$666	**-0.977**	**0.590**	**-1.660**	**0.098**
Monthly income >US$2,666	**0.594**	**0.283**	**2.100**	**0.036**
Education: high school and under	**1.502**	**0.494**	**3.040**	**0.002**
Education: master’s degree and higher	-0.025	0.223	-0.110	0.911
Car driver’s licence	**1.326**	**0.430**	**3.090**	**0.002**
Children (aged under 18) in household	**0.513**	**0.213**	**2.410**	**0.016**
Household car ownership	**1.045**	**0.112**	**9.320**	**0.000**
Land use mix entropy (district)	-1.139	1.070	-1.060	0.287
Percentage of 4-way intersections	0.050	0.117	0.430	0.668
Overall perceived walkability	**0.203**	**0.114**	**1.780**	**0.075**
Walking time to stop/station	-0.113	0.141	-0.800	0.424
Bus stop density (village)	**-2.561**	**1.337**	**-1.920**	**0.055**
Bus operation length (district)	**-0.269**	**0.130**	**-2.070**	**0.038**
Metro station within district (yes=1)	-0.366	0.288	-1.270	0.203
Constant	-1.159	0.888	-1.300	0.192
Motorbike <-				
PBC	**-1.427**	**0.164**	**-8.710**	**0.000**
Intentions	**-1.187**	**0.175**	**-6.770**	**0.000**
Gender (female=0, male=1)	0.195	0.205	0.950	0.340
Aged 55 and over	0.294	0.468	0.630	0.530
Aged 24 and under	-0.365	0.436	-0.840	0.403
Monthly income <=US$666	-0.010	0.440	-0.020	0.983
Monthly income >US$2,666	**-1.369**	**0.361**	**-3.800**	**0.000**
Education: high school and under	**0.933**	**0.464**	**2.010**	**0.045**
Education: master’s degree and higher	**-0.382**	**0.215**	**-1.780**	**0.075**
Motorbike driver’s licence	**3.350**	**0.625**	**5.360**	**0.000**
Children (aged under 18) in household	0.141	0.203	0.700	0.486
Household motorbike ownership	**0.654**	**0.074**	**8.900**	**0.000**
Land use mix entropy (district)	-1.096	1.053	-1.040	0.298
Percentage of 4-way intersections	**0.320**	**0.114**	**2.810**	**0.005**
Overall perceived walkability	0.137	0.110	1.250	0.211
Walking time to stop/station	-0.012	0.136	-0.090	0.927
Bus stop density (village)	-0.042	1.202	-0.030	0.972
Bus operation length (district)	-0.009	0.125	-0.070	0.942
Metro station within district (yes=1)	**-0.568**	**0.268**	**-2.120**	**0.034**
Constant	-2.179	0.984	-2.210	0.027

Reference category: public transport

Bold numbers mean significant at 95% level

McFadden’s pseudo R-squared=0.451

8.7 Summary

1. The results of this chapter gives the evidence to the proposed model for travel mode choice behaviour towards use public transport in Figure 2.8 (Chapter 2), which capability, opportunity and motivation exerted direct effects on travel mode choice and, additionally, capability, opportunity exerted indirect effects on travel mode choice *via* motivation. The results showed that the factors of capability, opportunity and motivation well explained travel mode choice behaviour with McFadden's pseudo R-squared=0.451.
2. Capability variables: gender, age, income, education, car and motorbike driver's licence owned, children in household, and household car and motorbike ownerships directly and indirectly influence travel mode choice. The indirect effects are mediated by motivational factors. Capable of owning and using car plays an important role in choosing between car and public transport. Capable of avoiding risks from traffic accidents plays an important role in choosing between motorbike and public transport.
3. Opportunity variables: bus stop density, bus operation length, metro station, perceived walking distance to stop/station, percentage of 4-way intersections directly and indirectly influence travel mode choice. The indirect effects are mediated by motivational factors. Bus density exerted the strongest effects on travel mode choice between car and public transport among all the opportunity variables, and metro station is the most important variable influence travel mode choice between motorbike and public transport. Likewise, bus stop density had the strongest effects on attitudes towards public transport and the perception of easy or difficult to use public transport (PBC) among all the opportunity variables.
4. In terms of motivation, PBC exerted the strongest impact on intentions to use public transport among attitudes, subjective norms, PMO and PBC. This result has also been reported in several studies (Bamberg et al., 2007, Chen and Lai, 2011, Chen and Tung, 2014). In addition, PBC had stronger influence on mode choice behaviour towards public transport than intentions to use public transport. PBC is statistically significantly affected by capability: age, education, car and motorbike driver's licence, and household car and motorbike ownerships, and opportunity: walking time to stop/station, bus stop density, bus operation length and metro station.
5. The estimation results showed that the motivation factors: pro-environment value, attitudes, subjective norms, PMO, PBC well explained the intentions to use public

transport. About 73% of variance of intentions to use public transport was explained by these factors. Ajzen (2005) stated that the multiple factors to predict the intentions were found to range from 63% to 71% by meta-analysis. Attitudes exerted statistically significant effects on intentions for motorbike users but not for car users (Table 8.16). Subjective norms exerted statistically significant effects on intentions for car users but not for motorbike users (Table 8.16). This is perhaps because the social status (higher income and education level) for car users were higher than motorbike users. Car users tended to give high evaluation to public transport while their intentions to use public transport seemed not highly correlate to their attitudes. In addition, the higher social status made car users more concerns about social pressure of using public transport.

Chapter 9 **DISCUSSION AND CONCLUSION**

9.1 Discussion

This thesis was designed to systematically look insight into the factors influence travel mode choice towards public transport in Taiwan which may give some policy implication for some East and Southeast Asian countries. The factors included qualitative aspects in the process of public transport policy implementation and quantitative aspects of capability, opportunity and motivation.

There were five research questions raised in Chapter 1 and a conceptual model for travel mode choice behaviour towards public transport was proposed in Figure 2.8 (Section 2.4) based on the COM-B model (Michie et al., 2011). The conceptual model drew out the relationships between capability, opportunity, motivation and travel mode choice. Sociodemographic variables were used as proxies for capability. Opportunity included three parts: public transport service provision, land use and walkability. Motivation contained the relationships between intentions to use public transport, pro-environment values, attitudes, subjective norms, PMO (perceived moral obligation) and PBC (perceived behavioural control). The RQ2, RQ3 and RQ4 were to separately analyse the three parts in opportunity: public transport provision, land use and walkability influencing travel mode choice accounting for sociodemographic variables (capability). The RQ5 brought together capability, opportunity and motivation to understand their influence on travel mode choice behaviour. Except capability, opportunity and motivation, public transport policy design and implementation also affected travel behaviour. Hence, RQ1 was to analyse the factors influencing public transport policy implementation.

This study of the policy implementation found the ‘gap’ between the Taiwanese NRPTP (National Road Public Transport Plan) policy and its implementation, and the gap caused the unattainable objectives of the Taiwanese NRPTP. In terms of implementation methods, top-down approach has dominated the NRPTP implementation. However, this approach was criticised by the local authority for neglecting the knowledge and expertise of the street-level bureaucrats and for lacking tolerance of diversity, which the criticisms are in accordance with previous studies (Matland, 1995, Pulzl and Treib, 2006, Sabatier, 2005, Sabatier, 1986). More bottom-up implementation approach was suggested for the NRPTP implementation to result a better outcome. This result is in accordance with previous transport policy implementation studies (Fraser et al., 2006, Lutsey and Sperling, 2008, Schreurs, 2008).

In terms of the factors influence the NRPTP implementation, all the 7 key factors identified in this study - 1: Lack of understanding of policy objectives within implementing agencies; 2: lack of information about what works in switching travel mode choice; 3: outcomes monitoring and implementation mechanism; 4: insufficient implementing capacity; 5: insufficient skilled street-level-bureaucrats; 6: lack of mayoral commitments; 7: inflexibility of budget spending - were related to will and capacity at the local authorities, and pressure and support from the central government (McLaughlin, 1987). The lack of understanding of policy objectives within implementing agencies, insufficient implementing capacity, insufficient skilled street-level-bureaucrats and lack of mayoral commitments caused low will and capacity at the local authorities. The lack of information about what works in switching travel mode choice, outcomes monitoring and implementation mechanism, and inflexibility of budget spending was due to lack of central government pressure and support (McLaughlin, 1987).

Noordegraaf et al. (2014) identified six generic implementation factors: general political support, general public support, information campaign, various actor perceptions, characteristics of the transport system and marketing the scheme. Building consensus among all the stakeholders on the policy objectives was consistence with various actor perceptions. Likewise, better understanding local public transport needs was in accordance with characteristics of the transport system, and mayoral commitment was similar to general political support. Attitudes of implementers can be seen as part of general public support for public transport policy implementation. More localised and bottom-up approach can facilitate policy implementation was also found in Fraser et al. (2006). Beyond these factors, this study found that it is important to build up an outcome monitoring mechanism to check if the performance reaches the objective.

This study results found that there is a fundamentally different relationship between land use factors at different geographic scales and travel mode choice behaviour in the context of Taiwanese high percentage of motorbike usage. This study found that the effect of grid-like street pattern (% of 4-way intersections) on travel mode choice in Taiwan is different from previous studies. Ewing and Cervero (2010) showed that the weighted average elasticity of public transport use with respect to % of 4-way intersections is 0.29, which means that grid-like street pattern improves public transport access by offering relatively direct routes and alternatives to travel along high-volume, high-speed roads due to parallel routes being available in a grid (Ewing and Cervero, 2001).The findings presented in Chapter 6 (Table 6.5) showed a significantly positive coefficient for car versus public transport, and motorbike versus public transport with respect to % of 4-way intersections across trip origin and destination which means that grid-like street pattern improves private vehicle users access by dispersing vehicular traffic and providing multiple routes to any destination (Ewing and Cervero, 2001). Especially for motorbike use, a grid-like street pattern both at trip origin and destination had strongly significant effects on encouraging motorbike usage instead of public transport.

This study results showed that the impact of population density on travel mode choice is perhaps due to other variables with which population density covaries. Density is the most important aspect among the 3Ds (Ewing and Cervero, 2001). Many studies showed a significantly positive impact of population density on public transport (Newman and Kenworthy, 1991, Frank et al., 2008, Zhang, 2004). However, the results in this study showed that there is no statistically significant impact of population density on public transport mode choice after accounting for public transport provision variables. The districts with higher population densities are related to higher bus frequencies and bus stop densities, and more metro stations. Higher possibility of public transport usage was perhaps caused by better public transport service but not higher population density.

This study's results highlight the different land use influence on car and motorbike over public transport. In terms of the effects of job density and land use mixed on travel mode choice at trip destination, both were associated with higher possibility of travelling by public transport instead of car and motorbike. The finding of land use effects on car is in accordance with previous studies from Ding et al. (2014), Chen et al. (2008) and Zhang (2004) but in the context of Southeast Asian country, while few studies have explored land use effects on motorbike. On the other hand, living in highly mixed land use area, and more grid-like street patterns either at trip origin or trip destination, traveller was more likely to use motorbike instead of public transport. As far as the author's knowledge, no study has ever explored the influence of land use on travel mode choice between motorbike and public transport.

The results of Chapter 6 also revealed that among the five land use variables: population density, job density, land use mix entropy, percentage of 4-way intersections and number of cul-de-sac at trip origin and trip destination, land use variables at trip destination played a more important role than at trip origin. Several previous studies also reported this consistence finding (Ding et al., 2014, Chen et al., 2008, Zhang, 2004). Job densities and land use mix at trip destinations were more important than population densities at trip origins (Ewing and Cervero, 2010).

Spatial heterogeneity and spatial autocorrelation due to hierarchical data structure in land use analysis were dealt in this study. Jones and Duncan (1996) contended that a modelling approach relating to geography and people was required to consider individual's characteristics and place features, the effects of place heterogeneity, and the interactions between different level of geographical scales. Several studies have suggested that multilevel modelling method can accommodate these hierarchical features and spatial issues in the analysis of land use and travel mode choice (Hong and Goodchild, 2014, Overmars and Verburg, 2006, Jones and Duncan, 1996). Due to the limitations of computing power and modelling techniques, less study has adopted multilevel discrete choice model. This study's findings added to the analysis of multilevel discrete choice model (Bhat, 2000, Ding et al., 2014, Hong and Goodchild, 2014). The different significant levels for traditional MNL model, and multilevel MNL model and multilevel cross-classified MNL model (See Table 6.4 and Table 6.5 in Section 6.4) indicated that including spatial heterogeneity and spatial correlation in the land use and travel behaviour study can reduce the likelihood of drawing misleading inference of the impacts of some land use factors, which is in accordance with Hong et al. (2014) and Ding et al. (2014). The calculated intra-class correlations (ICC) indicated that there were correlations among travellers living in the same district or going to the same district (destination).

The Modifiable Areal Unit Problem (MAUP) was explored in this study by adopting two different geographical scales (district and city/county). The MAUP has been discussed for decades in geography (Fotheringham and Wong, 1991, Jelinski and Wu, 1996). Conceptually, what is the most relevant geographic scale depends on which aspect of travel behaviour to be examined. Hong et al. (2014) showed the different effects of land use variables at 1-km buffer and TAZ (Traffic Analysis Zone) on VMT (Vehicle Mile Travel) by adopting multilevel regression models. This study showed that land use variables at district-level exerted more significant impact on travel mode choice than at city/county-level.

In terms of travel-related variables, the results in this study found that the ratios of the value of walking time saving (US$8.9/hr) and the value of waiting time saving (US$5.7/hr) to the value of in-vehicle time saving (US$2.4/hr) were 3.7 and 2.4. This ratio was higher than the meta-analysis results from Balcombe et al. (2004), which reported that walking time to and from bus stops and stations were about 1.4 to 2.0 units of in-vehicle time. Perhaps this was because the hot and humid weather in Taiwan makes it unpleasant for walking.

This study found that a structural model linking objectives measures and subjective measures of walking environment to explain walk for public transport behaviour performed better than existing models in understanding walking environment and walking behaviour. The previous studies only explored part of the relations such as the influence of objective measures of walking environment on walking behaviour (Frank et al., 2010, Leslie et al., 2007, Owen et al., 2007, Saelens et al., 2003a, Frank et al., 2005) or subjective measures of walking environment on walking behaviour (Saelens et al., 2003b, McGinn et al., 2007, Cerin et al., 2008, Leslie et al., 2005, Cerin et al., 2009, Cerin et al., 2010). These studies cannot explain how to build a better walking environment to boost the perceptions of walking environment and to encourage walking. The results from this study showed that living in the village with higher population density, mixed land use, percentage of 4-way intersections and lower numbers of cul-de-sacs, people tended to have higher perceptions of distance to services, opportunity & street connectivity and lower perception of on-street barriers. In addition, higher perceptions of subjective measures of walking environment led to higher perceptions of overall walkability. The higher perceptions of overall walkability encouraged people walking access to public transport and walking to destination. This result gave evidence to support the planning tool of transit oriented development which suggests that an urban environment with high densities, mixed and diversified land uses located within an easy walkable area around a transit stop can encourage walking and transit uses (Curtis et al., 2009, Hale and Charles, 2006, Wey and Chiu, 2013).

The study findings showed that a behaviour of choosing walking over other mode of transport represents the results of an interaction between the person and the walking environment. Several studies have examined the correlations between objective measures of the walking environment and subjective measures of walking environment, and found only low agreement between them (McGinn et al., 2007, Boehmer et al., 2006, Gebel et al., 2009, McCormack et al., 2007, Cerin et al., 2008). This study's analysis found that the correlations between objective measures of walking environment and subjective measures of walking environment was higher than the correlations between objective measures of walking environment and overall perceived walkability. The correlations support this study's assumption that the choice behaviour of walking or not is a cognition process. The objective walking environment affects individual's perceptions of walking environment, and individual's perceptions of walking environment affects his/her perception of overall walkability and walking behaviour (Alfonzo, 2005, Ewing et al., 2006, Ewing and Handy, 2009).

This study made an important contribution on understanding mode choice behaviour by introducing a novel conceptual model linking capability, opportunity and motivation, and travel mode choice. As can be seen in Figure 9.1, a complex behaviour model was estimated in this study. In addition, the interactions between capability, opportunity and motivation were examined. Most previous studies only considered the impact on motivational factors on travel mode choice and the interactions among the motivational factors (Bamberg et al., 2007, Chen and Chao, 2011). The results of the structural model found that capability, opportunity and motivation exerted direct effects on travel mode choice and capability and opportunity exerted indirect effects on travel mode choice *via* motivation. This results showed that the COM-B model (Michie et al., 2011) well-explained public transport mode choice behaviour.

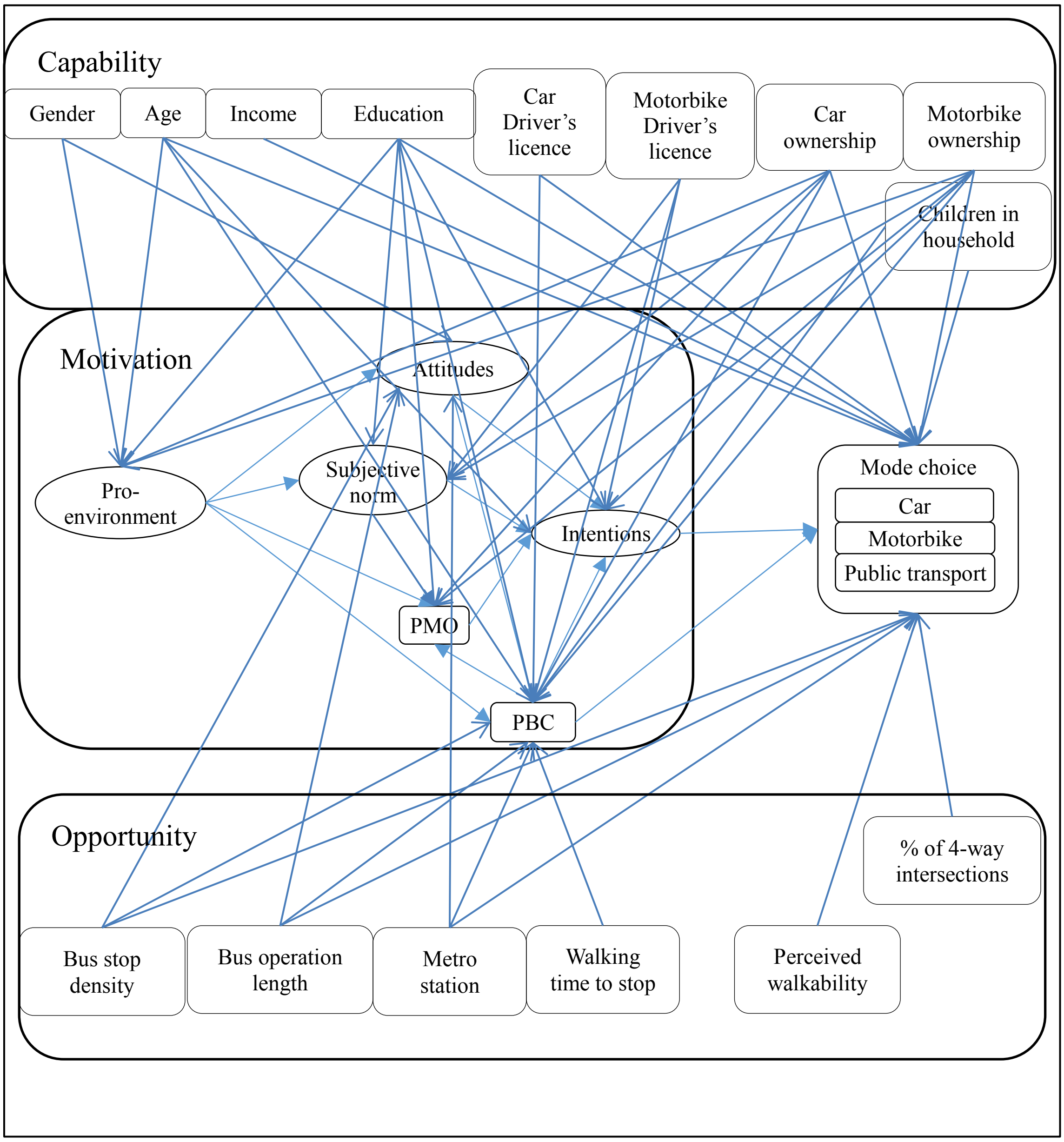


Figure 9.1 Final model estimated by this study

The conceptual model of capability, opportunity, motivation and travel mode choice behaviour in this study incorporated the cognitive process which has been identified as an important to the choice process. Ben-Akiva et al. (2002) developed hybrid choice models that go beyond the random utility model (RUM) to incorporate latent psychological construct, such as attitudes and intentions into choice model. Traditional discrete choice model directly mapped observed features of alternatives and observed characteristics of decision makers to overt choice behaviour (Temme et al., 2008, Morikawa et al., 2002). However, there is a growing of studies concerning about the decision maker's internal processes during preference formation and notably the role of factors that are not directly observable, such as attitudes, social norms and intentions, which are so-called 'black-box' in traditional discrete choice analysis (Temme et al., 2008, Ben-Akiva and Boccara, 1995, Morikawa et al., 2002, Ben-Akiva et al., 2002). In recent attempts to gain insight into the decision making process of the individual, traditional choice models have been enriched with constructions of latent variables (Ben-Akiva et al., 1999, Morikawa et al., 2002, Morikawa and Sasaki, 1998, Pendleton and Shonkwiler, 2001).This study specifically addressed the problem of unobservable, or latent, preferences in mode choice models. The study looked insights into the individual's decision making 'black box' and, thus, to help to set priorities in governmental policy and decision making by constructions of latent variables and mirroring the individual's preferences.

In terms of the explanatory power for intentions, about 73% of variance from the intentions to use public transport was explained by the motivational factors: pro-environment values, attitudes, subjective norms, PMO (perceived moral obligation) and PBC (perceived behavioural control). This explanatory power was slightly higher than Ajzen (2005) asserted of ranging from 63% to 71%. This is perhaps because the analysis in Chapter 8 added PMO as a predictor for intentions to use public transport.

With regard to capability, the results found that capable of owning a car (higher income and age) and capable of using a car (car driver's licence and household car ownership) played important roles in travel mode choice between car and public transport. Likewise, individuals who were capable of using a motorbike (motorbike driver's licence and household motorbike ownership) tended to use motorbike. However, individuals who were capable of avoiding risk from using motorbike (higher income and education level) tended to take public transport rather than motorbike.

In terms age and education, aged over 55 tended to have higher perception of environmental problems (pro-environment values), perceived easier to use public transport and higher intentions to use public transport. Female tended to more concern about environmental problems and have higher attitudes towards public transport. Education level at master's degree higher tended to perceive higher social pressure in using public transport, easier to use public transport and higher intentions to use public transport. In terms of opportunity influence motivation, bus stop density, bus operation length and metro station statistically affected individuals' attitudes towards public transport and perceptions of easier or difficult to use public transport (PBC).

The impact of age and income on travel mode choice between car, motorbike and public transport showed a particular mode choice behaviour evolution along with age and income moving in Taiwan. Most previous studies only considered the impact of age and income on mode choice between car and public transport (Ding et al., 2014, Bhat, 2000, Zhang, 2004, Donald et al., 2014), and the results showed that with the age and income increases people tended to shift travel mode choice from public transport towards car. The results in this study showed that with the age and income increases people tended to switch their travel mode choice from motorbike to public transport. However, people tended to switch their travel mode choice from public transport to car with increasing age and income.

The results found that interactions existed between the motivational factors. The empirical results showed that attitudes towards public transport statistically influenced PBC, and PBC and subjective norms exerted statistical influence on PMO. These indicate that increasing individual's attitudes can increase his/her perception easy use of public transport, and boosting social pressure and improving perceived behavioural control on public transport and encourage individual's perceived moral obligation over public transport use. These interactions were neglected by some of previous studies (Thøgersen, 2009, Chen and Lai, 2011, Lo et al., 2016).

In terms of motivation, the results found that PBC had the strongest effects on intentions to use public transport among attitudes, subjective norms, PMO and PBC. This finding was consistence with previous studies from Bamberg et al. (2007), Chen and Lai (2011) and Chen and Tung (2014). Moreover, PBC had stronger influence on travel mode choice than intentions to use public transport. This result was somewhat different from previous study (Bamberg et al., 2003). The reason is perhaps because this study covered whole island of Taiwan including urban areas, suburban areas and rural areas, and the public transport provisions for these areas were quite varied. Hence, the reported PBCs were quite varied, which increased its effects on travel mode choice.

9.1.1 Research contributions

This study contributed to understand the land use influence travel mode choice between motorbike and public transport while motorbike use has long been neglected by previous land use study (Ding et al., 2014, Chen et al., 2008, Zhang, 2004). The results in Chapter 6 showed that land use variables played a more important role for travel mode choice between motorbike and public transport than between car and public transport. Living in the district and city/county with higher population density, people were more willing to use public transport rather than motorbike. Likewise, higher job density at trip destination, people tended to take public transport. However, living in a highly mixed land use area and more grid-like street patterns (higher percentage of 4-way intersections) either at trip origin or trip destination, people were more likely to use motorbike rather than public transport. Additionally, more cul-de-sacs at trip destination tended to attract more motorbike use rather than public transport. This is because mixed land use and grid-like street pattern shorten trip distances and provide alternative routes for motorbike to access to destinations easier and more convenient.

This study makes a contribution to clarify the relationships between objective measures and subjective measures of walking environment, overall walkability and walking behaviour. The results of Chapter 7 confirmed the hypothesis that objective measures of walking environment exerted indirect impacts on walkability and walking behaviour *via* subjective measures of walking environment. This finding provided the evidence for the concept proposed by Alfonzo (2005) and (Ewing et al., 2006). Most previous studies analysed the correlations between objective measures and subjective measures of walking environment (McGinn et al., 2007, Boehmer et al., 2006, Cerin et al., 2008). Some previous studies tried to understand which are the most effective in capturing associations with walking for objective measures and subjective measures of walking environment (Lin and Moudon, 2010, Saelens et al., 2003a).

This study found that capability and opportunity had significant impacts on motivation while most previous studies neglected these effects (Chen and Chao, 2011, Lai and Chen, 2011, Bamberg et al., 2007, Chen and Lai, 2011). Unobserved latent variables such as attitudes, intentions, PBC, pro-environmental values, subject norms and PMO in this study can be predicted by observed capability and opportunity variables. Since unobserved latent variables cannot be easily forecasted, the relation of these constructs to observed capability and opportunity variables may aid in forecasting such variables.

The results found that motivational factors exerted different impacts on intentions to use public transport for car users and motorbike users. Motorbike users' intentions to use public transport were significantly affected by their attitudes on public transport while car users were not. Car users' intentions to use public transport were significantly affected by subjective norms while motorbike users were not. This provides information on that different marketing strategies should be designed for car users and motorbike users in order to improve their intentions to use public transport.

9.1.2 Policy implication

Some previous studies supported that the introduction of bus-based National Road Public Transport Plan (NRPTP) in Taiwan is a more cost-effective and flexible option compared with rail investment (General Accounting Office, 2001, Commission for Integrated Transport, 2005, Litman, 2011, Currie and Wallis, 2008). Although the key objectives of NRPTP have not been attained, the plan has reversed the declining trend in public transport patronage and market share in Taiwan. For the emerging economies in the Southeast Asian countries, rapid motorization has caused a continuous declining public transport market share and severe congestion problems in many urban areas (Parikesit and Susantono, 2012). These countries can learn from Taiwan to initiate bus-based public transport plan and inject more budgets on bus industry. In addition, the key factors influencing public transport policy implementation identified in this study can be a good reference if these countries are going to implement public transport plan.

Rapid motorisation, particularly in South East Asia, has emerged as a global concern given the region's cumulative population, rate of industrialisation, and large-scale urbanisation (Le Loo et al., 2015, Van et al., 2014). Some policy implications can be made based on the results of capability, opportunity and motivation influence travel mode choice. In a motorbike-dependent country, such as Taiwan and other Southeast Asian countries like Vietnam, the Philippines, Malaysia, Thailand and Indonesia, car and public transport are the alternate modes that motorbike users could switch to along with their age growth and income increase. Without good public transport service, motorbike users might be more likely to switch to car due to their consideration of convenience and comfort.

To promote greater use of public transport and less dependent on car and motorbike, an efficient public transport system is clearly needed. Taiwanese government has invested more budgets in public transport infrastructure through the NRPTP implementation. The question raised here is where and how to invest the budget can effectively facilitate public transport development. From the impact of opportunity on travel mode choice, the investment on public transport infrastructure should focus on the areas with higher density and diversity in land use, which refers higher job density and land use mix. Within these areas, the investment through increasing public transport provision, such as adding bus network densities and frequencies, and adding metro or light rail service can be leveraged by land use. On the other hand, the government's land use interventions should be placed in the areas with better public transport accessibility. The interventions can consider increase job density, land use mix, population density, and improve walking environment.

From the results obtained by the analysis of land use influence travel mode choice, it seems that, in Taiwan, motorbike use fits better with high density, diversified land use and grid-like street patterns than the car. Diversified land uses provide more opportunities for access to different activities. Likewise, a grid-like street pattern provides an easy access environment for the motorbike. Chang & Wu(Chang and Wu, 2008) characterised motorbike by shorter trip distances and a greater number of multi-stop trips compared to car use. Feng and Sun (2012) mentioned that motorbike provides better mobility and accessibility in comparison with poor and inconvenient road-based public transport system. In addition, motorbike offers a low-cost private mode option, in terms of purchasing as well as operation and parking. Furthermore, under the congested traffic condition, motorbike offers much needed flexibility in navigation through shortcut or spaces left between the road lanes. These factors contribute to the growth and popularity of motorbikes in Taiwan as well as other countries in Southeast Asia, such as Vietnam, the Philippines, Malaysia and Thailand (Feng and Sun, 2012).

For Southeast Asian countries with a high proportion of motorbike use such as Taiwan, maybe there is a need to implement some strategies to increase the inconvenience or the costs for motorbike use in urban area in order to make public transport more competitive compared to the motorbike. Although there may be an argument that the motorbike is preferable to the car in terms of environmental impact, and should therefore be encouraged in order to discourage growth in car use, the motorbike is a step into private motorised transport for people reaching the age of 18 enjoying the right to have driver’s licence. If people get used to using the motorbike as daily transport mode at the young age, many of them may well shift to car ownership as their income increases and they get older. Additionally, higher percentage of motorbike usage is related to higher traffic accidental injuries and fatalities (Feng and Sun, 2012). Therefore, implementing effective strategies to ensure the built environment favours public transport over motorbike use is critical for a sustainable future.

The strategies of reducing the dependence on motorbike may be through increasing motorbike purchasing cost and using cost. In terms of purchasing cost, upgrading vehicle standards keep the sale price up or prevent it from falling which in turn contributes to the management of motorbike ownership. In terms of using cost, introducing more stringent traffic safety regulations and initiating stronger enforcement against illegal driving behaviour would not only improve traffic safety but also help to restrain the growth of motorbike ownership. In addition, motorbike usage can be managed by charging for motorbike parking, regulating motorbike parking space, and prohibiting motorbike on major tunnels, bridges, expressways and highways.

Walking has been reported by many studies as the most natural and important mode to access public transport (Wibowo and Olszewski, 2005, Cervero, 2001). The results of this study suggest that increasing population density, land use mix, percentage of 4-way intersections and reducing cul-de-sacs can improve public’s perceived walking environment on opportunity & street connectivity, distances to services, on-street barriers and traffic safety. This can lead to better perceptions of overall walkability and encouraging walking to access public transport.

The results of this study showed that grid-like street pattern encouraged motorbike use instead of public transport, however, if one only considers the mode chosen by public transport users their mode to access to public transport, grid-like street pattern encouraged walking instead of private vehicle use. This is perhaps because motorbike is often used for multi-stop and short-distance journeys in Taiwan (Chang and Wu, 2008). A grid-like street pattern is easier for motorcyclists to access to multi-destinations within a single journey. In addition, a grid-like street pattern helps motorcyclists to avoid traffic congestion by running alternative routes. Furthermore, motorbike parking regulation is very loose in Taiwan. Motorcyclists can park motorbikes very close to destinations, which minimise walking distance. Hence, motorbike enjoys more benefits from a grid-like street pattern than public transport. On the other hand, for access to public transport, the places are surrounding public transport stops/stations and distances are relatively short, normally within 20-minute walk. In this circumstance, a grid-like street pattern improves street connectivity. In addition, a grid-like street pattern shortens street block distances and makes people easier to walk to intersections and cross streets to access to public transport stops/stations. Hence, a more grid-like street pattern (higher percentage of 4-way intersections) encourages walking to access to public transport.

In terms of the impact of motivation on travel mode choice, public awareness campaigns aiming to create a supportive public opinion climate for public transport use may be an important prerequisite for the effectiveness of measures targeting individual behavioural change.

For motorbike users, successful strategies in increasing their positive attitudes towards public transport, perceived moral obligation and perceived ease of use public transport can boost motorbike users' intentions to use public transport and lead to switch their mode choice from motorbike to public transport. The strategies may be through raising motorbike users' concerns about the climate change and their environmental consequences. In terms of car users, the strategies to increase their intentions to use public transport may through increasing perceived social pressure, perceived moral obligation and perceived ease of use on public transport.

Perceived ease of use public transport was found to have significant, strongest and positive effects on an individual's intentions to use public transport and travel mode choice behaviour. Furthermore, the perceived ease of use public transport was statistically significantly affected by public transport provisions. This indicates that build a well-functioning public transport system is a very important strategy in changing travellers' behaviour towards public transport. In terms of the effects of capability on

PBC, higher education level tended to perceived easier use of public transport. This is perhaps because higher-educated people enjoying higher income level are living in the places having better public transport accessibility and connectivity.

The culture difference between Taiwan and other Southeast Asian countries, such as Indonesia, Malaysia, Vietnam and the Philippines may limit the generation of this study's results to Southeast Asian countries (Le Loo et al., 2015). An individual's culture group may impact their transport choices by influencing their identity and the values that drive their attitudes and motivations to perform certain behaviour (Le Loo et al., 2015). In comparison with six Asian countries including Japan, China, Thailand, Indonesia, Vietnam and the Philippines, Van et al. (2014) found that people living in a higher income society like Japan perceived having a car as having a lower evaluation of social status compared to those in low-income countries. This is perhaps because it may be economically easier to own a car in higher income countries. The income levels in these countries had different attitudes and intentions on car and public transport (Van et al., 2014). Low and Gleeson (2001) found that culture change towards pro-environmentalism and sustainability and the rising acceptance of sustainable mode of transport within society, which indicated that culture norms may influence individuals' travel mode choice behaviour. Hence, this study's results may be limited in generalization to other Southeast Asian countries due to economic conditions and culture difference.

9.1.3 Limitations and future research

There are two sampling limitations in this study. First, a limitation of the works done in policy implementation was that there were only a small number of participants although the participants have covered nearly all types of stakeholders in NRPTP policy implementation. Future work could expand the number of participants to include views of the general public, including both bus users and non-bus users. Secondly, the dataset obtained from the online survey may exist sampling bias. The bias perhaps caused by digital gaps between young people and seniors, urban and rural areas. Future study may adopt other data collection method such as mail survey or interview to fix the sampling bias.

People who prefer to use public transit may self-select to live in more compact, more connected, mixed land use neighbourhoods, easy access to public transport and well-connected public transport networks and thus use transit more. In this case, the built environment and public transport provision do not have a direct relationship with travel behaviour. It is the residential choice that determines the travel behaviour. To solve this problem, more attitude data or other techniques are needed to control the self-selection bias.

Future study on land use influencing travel mode choice behaviour by adopting multilevel modelling techniques may use advanced model estimation method to include travel time and travel cost as alternative specific variables in the analysis. Travel time was not included in the analysis of land use influencing travel mode choice study and travel cost was treated as individual characteristics due to the limitation of model estimation. Future study may extend model estimation method to estimate multilevel conditional logit model which can contain alternative specific variables in the model.

There are some limitations for the walking environment study. Firstly, more aspects of the walking environment need to be incorporated. The four objective measures used cannot cover all the aspects of the built environment which influence people's subjective evaluation of the walkability of an area. Future study may include more detailed objective measurements such as the number of facilities within walking distance, sidewalks widths, presence of sidewalks, average street block length, traffic volume, traffic speed, street lighting and street trees. This will help to provide more information on how individuals react to the physical walking environment. Secondly, subjective measures of walking environment factors may not be the only mediators between objective measures of the walking environment, walkability and walking behaviour. People's attitudes and intention towards walking may be also associated with their perceptions of the walking environment and affect perceived walkability and walking behaviour (Chang and Shen, 2005). Third, similar to some previous studies (Frank et al., 2008, Zhang, 2004), this study assumed that walking is an available choice for all travellers. Some studies, however, have argued that including an unavailable choice in the traveller's choice set may cause biased results (Rodríguez and Joo, 2004). This raises the question: under what circumstances is walking considered not an option?

Finally, the quantitative analysis in this study used cross-sectional data. Cross-sectional analysis is sufficient to provide robust tests of the existence of a correlation between variables but it should be cautious about causal inference. In order to have a robust causal inference, a panel data analysis may be a solution in the future. Mobility as a service (MaaS) will be introduced in Taipei metropolitan area in 2017. It may be a good opportunity to do a comprehensive before and after study to explore what (capability, opportunity and motivation) trigger the behaviour change and to what extent.

9.2 Conclusion

Due to the complexity of the research questions, mixed methodologies (including MNL, multilevel MNL, multilevel cross-classified MNL, SEM and GSEM) and multiple datasets (including two specific designed surveys conducted by this study) were used in this study. The content of this study evolved from the observed features of alternatives and observed socio-demographic characteristics to the unobserved psychological factors, such as the perceptions of walking environmental measures, attitudes, intentions, perceived behavioural control, social norm, perceived moral obligation and pro-environmental values. The main findings were chapter specific and were summarised within the respective chapters. Chapter 4 – Analysis of factors influence public transport policy implementation - answered the RQ1. Chapter 5 – The effects of public transport provision on travel mode choice behaviour – answered the RQ2. Chapter 6 – Land use influence travel mode choice behaviour – answered the RQ3. Chapter 7 – Subjective and objective walking environmental measures influence walking behaviour – answered the RQ4. Chapter 8 – Capability, opportunity and motivation influence travel mode choice behaviour.

This study gave the evidence to COM-B model that capability, opportunity and motivation exerted direct effects on travel model choice and capability and opportunity also influence travel mode choice indirectly *via* motivation. The major findings in this study can be categorised by capability, opportunity and motivation.

In terms of motivation, motivation for public transport can be driven by capability and opportunity (Figure 9.1). The study found that capability: age, income, household car and motorbike ownership, car and motorbike driver’s license, number of car and motorbike in the household and children in household played significant roles in influencing motivation. In addition, bus stop density, bus operation length, metro station and walking time to public transport stop/station, all exerted statistically significant effects on motivation (Figure 9.1). The interactions between the motivational factors: pro-environmental values, attitudes, subject norm, perceived moral obligation, perceived behavioural and intentions, were examined in this study. The results showed that perceived behavioural control had stronger effects than intentions on public transport mode choice.

In terms of opportunity, the influence of public transport provision and land use on travel mode choice was examined in this study. The results added the evidence of land use effects on travel mode choice between motorbike and public transport. Land use exerted a different effects on motorbike compared to car. Living in highly mixed land use and more grid-like street pattern tended to have higher possibility of choosing motorbike instead of public transport. Additionally, this study found that land use variables played a more important role for mode choice between motorbike and public transport than between car and public transport. The results also showed that land use variable at trip destination had higher impacts on travel mode choice than at trip origin. Fourth, objective measures of walking environment exerted indirect effects on walkability and walking to access pubic transport *via* subjective measures of walking environment.

In terms of capability, socio-demographic characteristics played an important role in influencing individual's motivation and travel mode choice. Understanding the different effects socio-demographic characteristics having on motivation and travel mode choice provides the ideas to design specific public transport campaigns focusing on the target groups in order to effectively raise public transport usage.

Apart from the capability, opportunity, motivation and travel mode choice behaviour, public transport policy should not only consider its policy design but also its policy implementation. Eight important policy implementation factors were concluded in this study. This can give important reference for next period of Taiwanese NRPTP implementation in order to having a more successful implementation outcome.

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APPENDIX A: INTERVIEW GUIDANCE FOR TAIWANESE NRPTP POLICY IMPLEMENTATION

1. Introduction

   I want to thank you for taking the time accepting my online interview today. My name is Chien-Pang Liu and I would like to talk to you about your experiences participating in the Taiwanese National Road Public Transport Plan (NRPTP). This is part of my PhD study. I would like to evaluate the Taiwanese National Road Public Transport Plan policy implementation in order to capture lessons that can be used in the future. I hope the results of this study can give some helps for future NRPTP policy implementation.

   The interview should take less than an hour. I will be taping the session because I do not want to miss any of your comments. Although I will be taking some notes during the session, I cannot possibly write fast enough to get it all down. Because we are online and on tape, please be sure to speak up so that we do not miss your comments.

   All responses will be kept confidential. This means that your interview responses will only be used in this research and I will ensure that any information we include in our report does not identify you as the respondent. Remember, you do not have to talk about anything you do not want to and you may end the interview at any time.

   Are there any questions about what I have just explained?

   Are you willing to participate in the interview?

2. Questions

   Thank you for agreeing my interview. The questions will cover the aspects of policy objectives, resources, implementation methods, organizational communications, implementing agencies' characteristics and implementers' attitudes. The questions are open-ended. If you have any further comments, please feel free to tell me.

   Opening questions:

   1) Please tell me about what is your understanding about the Taiwanese NRPTP?
   2) How long have you been engaged in the NRPTP? What kind of organizations have you been engaged in the NRPTP?

   Core in-depth questions:

   3) Can you tell me what you understand the key objectives of Taiwanese NRPTP to be?

4) Can you tell me to what extent do you think your government is committed to achieve the objectives?
5) From your experience, what are the most effective ways to increase bus patronage? (Please give at least 3 examples)
6) Can you explain the implementation approaches for these examples?
7) In your opinion, what are the obstacles for NRPTP implementation to achieve the key objectives?
8) From your point of view, what would you do if you worked for central government to adjust the implementation process to achieve the objectives of raising bus patronage by 5% annually?

3. Closure

Is there anything more you would like to add?

I will be analysing the information you and others gave me. I will be happy to send you a copy of this study to review at that time, if you are interested.

Thank you for your time.

APPENDIX B: CHINESE INTERVIEW TRANSCRIPTION FOR LA3 (EXAMPLE)

Interviewer

這是一個研討會的論文，主要目的在探討公路公共運輸計畫他似乎再主要目標，再市佔率及運量成長目標均未達到，因此本論文主要再探討這目標為何未達到，在計畫執行時，中央與地方的角色及中央與地方對於計畫的認知，級應該如何調整才能達到目標。所以第一個問題要問你的是，你知道公路公共運輸計畫的目標嗎?

LA1

我知道，大目標是 2025 年要達到 30%，近期目標是 18%在 2020 年達到，他們好像訂一個 18%。

Interviewer

你知道每年運量要成長多少嗎?

LA1

運量每年要成長 5%

INTERVIEWER

大致上你講的目標都對，納你認為臺中市政府有朝向這個目標在推動嗎?有很積極嗎?

LA1

有有有，臺中這幾年運量成長了 140%，從 100 年到 104 年。

INTERVIEWER

所以你認為臺中是這幾年在運量成長最有效果的是哪些措施，可不可以舉三項?

LA1

舉三個項目，我的判斷，最主要的是免費公車，這是第一個，第一個是免費公車，第二個是路網調整，所謂路網調整就是把一些幹線，運輸幹線，主要路廊拉出來，譬如說臺灣大道，然後還有豐源路廊，這幾年都有一些幹線公車在跑，這幾年我們還有更優化，我們作了幾條幹線還有快捷公車，快捷公車包括從臺鐵車站到核心趨，還有核心區到附都心，到幾個附都心的幹線公車，納時後有推，然後還有推第三種類型的是走高快速道路的公車。

INTERVIEWER

納這些計畫都跟公路公共運輸計畫補助的經費有關嗎?

LA1

喔，有有關，免費公車大部分是市府出錢，光市府一年就出了 22 億元，補助部分大約 4 億多元。

INTERVIEWER

那路網調整根公路公共運輸計畫有關係嗎?

LA1

有，我們要申請新闢路線，這部分工運計畫有補助，補助新闢車輛，這部分業者就會有興趣。

INTERVIEWER

納這三項計畫是你們提出來的，還是跟中央的作業原則有甚麼關係?

LA1

免費公車是市府自己提的，納時後也跟中央曾取經費，但是中央不同意。納時後我也在中央，然後我下來才知道這個免費公車初期的特效藥還蠻重的，元擇上中央不補助免費公車，但是中央補助虧損，納這個部分也會到免費公車里面，不過免費公車的運價會含虧損補貼還有額外收入差額我們再補上去。所以中央在虧損補貼部分對免費公車有補助，旨是在政策上並沒有補助。

納第二個有關的是幹線公車，幹線公車事實上中央有幾個關聯性，他們鼓勵轉運站設置及新闢路線，納這幾個地方地方都可以運用，轉運中心社至因為涉及土地問題，我們現在才在推，未來也會跟中央申請補助。那幹線公車部分，就是由地方挑選出來後就可以申請新闢路線補助。

INTERVIEWER

有關執行方式，從上而下還是由下而上

LA1

它其實有分兩塊，一部分市政策引導型，初期的時候市政策引導型，這個政策就是優先著重在車輛汰換，來提升服務品質，這是政策引導部分，政策引導還有候車亭，我講的政策引導市 2010 年至 2012 年，2013 至 2016 是第二階段。第一階段著重車輛汰換還有候車亭，主要有四項，我觀察，另外就是虧損補貼，因為虧損補貼一直以來都不足，所以業者經營效率一直沒法全心投入，第四個就是計程車 DRTS 需求反應式服務，所以這四塊市交通部在第一階段投入的重點項目。

納這重點項目就引導地方政府在提案實就著重在這幾塊，我看以臺中為例，除了我們自己在支付的免費公車，我們的提案在前面所提的四項大概佔申請經費的八成，例如營運虧損補貼加上車輛汰換、後車亭及 DRTS 這幾項大概就佔八成左右經費。

納地方由下而上也有，地方也會提，就是地方一般的能力，提案能力除直轄市政府外，一般的提案能力都不強，所以而且，我覺得這可以從機制面來看，我覺得地方也會提案，但是地方提案從第一階段來看都不是那麼受到重視，就是中央有一些政策引導，雖然策略項目有很多項目可以提，但是主要還是針對剛剛提到那四項在提。納地方提案我覺得是受到基至面的影響，因為都市每年每年提，計畫都不是屬於長期性，所以他的整體性不是那麼足夠\，所以一方面是地方的能力不是那麼足夠，另一方面又是中央政策引導，基至沒有一個整體性的機制。有策略引導但是沒有機制引導。

你所謂的機制是甚麼

我舉例來講，每年每年都提，所以地方來講就會我今年要做幾個候車亭、虧損補貼要多少、新闢路現幾條，可是他不會考慮我四年對應中央四年的計畫，我四年要做哪些哪些，這就跟你第一個題目有關，為什麼很多現是 5%都達不到，因為計畫都市逐年在提，他的效果都很有限，那如果執行基至面要求一次要提四年的計畫，那四年就可以作很多事情，也可以對應到運量要成長 5%，還有市佔率要成長到到多少%，低地板公車的使用率要成長多少，那我一起提我就可以逐年達成那個目標，但是因為機制面沒有這樣的引導，策略面是有幾個策略在引導，但是機制面沒有引導，所以就變成地方在提案實就應付型的在提，如果又沒有一個能力強，地方專業又不足，就變成你要我提甚麼我就提甚麼，所以這種就是大部分的縣市都達不到那個效果。

INTERVIEWER

你剛剛提到 2013-2016 年的計畫在執行上有甚麼改變嗎?

他們後來就強調 1 加 3 的提案方式，也就是我只核定一年，但是你可以提 4 年的計畫，可是這個執行面還是沒有很具體，也就是你提 1 加 3，他也沒有辦法保證後面 3 年匯給

予補助。所以旨是我現在有一個 1 加 3，然後也沒有硬性規定，一班縣市政府也就還是提一年的計畫，想到甚麼就做甚麼。第二個就算我提一加三，中央也沒有給予保證，所以就沒有甚麼誘因，所以現在還是大家每年在爭取，提當年的計畫。

策略面已有明顯差異，第二階段在營運補貼部分改為績效補貼，在主軸部分也提出幹支線公車，喔，我記錯了，幹支線公車是第三階段 2017 年才提出來的，在第三階段。

INTERVIEWER

所以說這就是未來的，朝向調整路網，但在第二階段比較重要的是衝量計畫，你覺得中央政策引導利還是蠻強的

LA1

第二階段還有一個很重要的是著重顧問了，因為開始發現到地方的有些部分縣市的能力比較差，所以中央輔導顧問團的補助機制有出現。

INTERVIEWER

這個部分是誰在輔導?

LA1

就是公路總局有一個公共運輸專案辦公室，它們後來有結合地方的學校單位，在北部、中部及東部都有區域運輸研究中心。

INTERVIEWER

你從中央到地方，你覺得工運計畫的執行還有甚麼可以建議的?

LA1

我覺得有幾個面向，第一個還是在堤岸計畫層面上，還是要有一個整體計畫提出來，中央在推動這個計劃時，要漲我的是策略面及機制面，很多的計畫是因地制宜的，地方比較了解地方大眾運輸發展及地方需求，但是按照現在的機制是每年提的，所以是片段片段的，所以一定要有一個機制確保這四年的計畫，有點像美國的 MPO 的概念，區域的公共運輸計畫，四年的計畫一次提，那當然每年可以依預算限制予以調整經費，那這樣子地方政府才會有這樣的企圖心去提一個整體性計畫出來。我覺得這是關鍵，我覺得現在地方政府不會從四年去看一個這種中期的目標，只看一年，這一年我要做甚麼就做甚麼，那也就變成中央訂了很有企圖心的目標，但是地方在執行時跟中央的目標根本就脫節了，因為地方在擬計畫時根本沒再想到 4 年後會變成怎樣，那你說衝量 5%，你去叫雲林縣政府、嘉義市政府還有台東縣政府它們去衝量，他怎麼衝的出納 5%出來，所以這中央訂的目標與地方政府就有很大落差。每年在思考這個問題的話，從績效管理角度來看的話，就很薄弱。

第二個是人力的問題，人力也是中央到地方後才發現的問題，直轄市我們還算好，同仁還可以有，可是大部分同仁還是沒有一個整體性概念，比如說我們要有一個怎樣的目標及行動計劃，其實都比較欠缺。可是地方比較了解實質問題，比如說哪邊要設候車亭、你一條是黃金路線、那些點是熱點等，向台中現在也很流行大數據分析，可是這些資料如果沒有一個很有能力團隊來協助做出一個整體規劃，再依據這樣的整體計畫來提出行動計畫，對目標達成有幫助的計畫出來，那對於目標達成也是效益不大。可是地方政府在這個人力方便就欠缺很多。地方因為職等關係，因此在朝聘人力部分，就限制很多。這部分其實就必須要地方政府與地方的學研單位來協助。

INTERVIEWER

目前如您所提是地方政府的人力來看，可以提出治標的做法，但是沒辦法治本

LA1

對對，長期性結構性的解決方案不容易找出來。

INTERVIEWER

所以你覺得要怎樣解決這個地方人員每有整體計畫願景的問題

LA1

第一個是中央官員應該儘速下鄉，比如交通部在推動工運計畫的人員應該儘速到地方，我覺得這是實在的，到地方才發現在中央會有迷失，比如我在中央的時候推區域公共運輸，可是區域要整合，理論上沒有錯，譬如台中市是核心區，我應該要串聯彰化、南投，這兩個地方要發展公共運輸有其困難，因為它主要的場站高鐵站，及比較方便的運輸場站在台中，那它主要轉運節點要到台中來轉運，所以在公共運輸的發展方便，本來就應該從區域發展概念，那區域就要有人區來做區域整合，在中央就會想這區域整合很容易啊，你們就成立一個平台，大家就來談阿，但是事實上並不是這樣，這要有人出來當LEADER，你要當 LEADER 你必須要出錢、要有構想，還要讓利，所謂讓利就是跟人家合作提案時，要讓對方取得比較多的資源，那這樣人家才願意跟你配合，這個都是實務性問題，不是簡單的說妳們就一起整合提案就好，不是線畫一畫就好。所以第一個我建議是說在中央做規劃的，因為有策略規劃能力的都在中央，中央應該跟地方多交流，下來了解實務，地方比較欠缺的是有整體規畫概念的人，可是這個也不行，畢竟你不是在地你不了解在地的問題。第二個就是，你必須要有在地的學研單位，尤其是學校，或者是有一些顧問公司可以來協助在地做規劃，那就會是公部門有規劃的人才，在地也有學研單位做研究，本身在地的交通部門她又了解一些在地的一些問題可以提出問題，上面有一些解決方案或比較有創意的方法可以解決問題。那這樣才可以變成一個好的團隊，那這就是剛剛提到一個機制面，在機制面上可以引導計畫做整體性，還有人力，另外一個就是資源面，以往資源都是偏向於硬體資本門補助，比如車輛汰舊換新阿，可是對這種基礎研究，比如說我們獎的經常門這一塊就把關非常嚴格，比如說補貼阿，你適度的對於一些項免費公車這種有利基的措施，初期給予一些彈性，例如幹線公車，在新闢初期可以給予一些補貼，或是捷運、軌道系統阿，可以給予一些補貼，以增加客源，這些是以往中央在執行策略面沒有放鬆的，資源面其實經資們比例應該要做一些適度的調整，就是經常門的比例要適度比較彈性。

INTERVIEWER

要提高公共運輸使用，不外就是路網，讓大家很方便到達站位級很方便到達目的地，再來就是費率，費率部分，對於轉成補貼等等，一直都是管制比較緊的。有哪些計畫是你們想要做，但是工運計畫無法支持你們的?

LA1

目前看起來比較少這個部分，現在最大一部分就是免費公車、轉乘優惠等，類似這兩部份都是在地方編了很多經費，向轉乘優惠，向台北市政府，再轉乘優惠每年都編了很多錢，這是有需要拉，其他的都還好，現在工運計畫的彈性還蠻高的。

Interviewer

區域整合的部分，你對於現在區域研究中心的看法如何，他們是不是可以扮演好區域整合的腳色

LA1

我覺得很難拉，因為區域運輸研究中心不應該由中央來推動，應該由地方政府來推，我為什麼提到 MPO，像漢堡市等都有區域運輸研究中心，例如德國司圖特加，它們區域運輸研究中心完全由地方來籌組，美國甚至有法案來引導，然後地方來主導 MPO 成立，中央告訴地方如果你要申請經費，地方一定要有區域運輸中心，如果是這種模式，就是從計畫機制與資源面來誘導，如果這樣，台中市政府就會出來找彰化、南投或苗栗縣政府一起，爭取計畫經費，大家一起來爭取，然後就會找一個顧問性質的區域運輸研究中心，

這個中心可以是個地方整府調人、找顧問公司或學研單位，那這個才會真的跟地方整府合作，現在由上而下下來，中央不一定了解地方整府狀況，以台中市為例，目前主導區域運輸研究中心的是前台中市政府交通局局長，那這怎麼合作，實質問題就是這樣。

INTERVIEWER

你們現在台中市會面臨到人力不足問題嗎?

LA1

有阿，我們也是會有人力不足問題，因為我們現在工運處好像有 20 餘位同仁，相對我們幅員比較大，人數相對比較少一點，當然跟其他縣市相比，我們還是好一些。你如果要比一些我周邊彰化、南投苗栗等，我們當然好一些。

INTERVIEWER

你們未來有沒有計畫要調整組織人力

LA1

我們現在有提出來，要增加工運執行人力，當然這還受限於我們預算員額，我們希望公共運輸執行人力可以加倍。

INTERVIEWER

請問你對於公路公共運輸發展計畫執行，還有其他建議嗎?

LA1

沒有了，我想要提的意見都已經說明完了。

INTERVIEWER

好，那謝謝你的接受訪問，訪問的相關錄音檔及紀錄等都將予以保密，並且僅限於本研究的用途。謝謝您，再見。

LA1

好，再見。

APPENDIX C: EXCEL USED TO RECORD THE IMPORTANT DESCRIPTIONS AND CATEGORISE THE THEMES

	A	B	C	D	E	F	G	H	I	J	K	L
1	Respondent pseudonym	Interview Excerpt	Themes	Codes applied:	Consensus on policy objectives (1)	Lack of information about what works in switching travel mode choice (2)	Implementation method (3)	Outcomes monitoring and implementation mechanism (4)	Characteristics of implementing agencies (5)	Attitudes of implementers (6)	Mayoral commitments (7)	Resources
2				Total per code:	9	5	8	6	7	5	6	7
3	AU1	The problem we faced every year, the quality of the annual local road public transport proposals initiated by the local governments were not good enough, and also the total amount bid for NRPTP subsidy from local authorities is the same or even less than the NRPTP budget. So, it was difficult to choose good projects from them. …	Characteristics of implementing agencies	5					1			
4	AU1	"…there is only one member responsible for this project [NRPTP]…unwilling to do it, so the quality of the proposal [annual road public transport proposal] is poor.	Attitudes of implementers	6						1		
5	AU1	public transport indicators and survey cities/counties' public transport development, and then include these in the cities/counties' annual wellbeing evaluation, giving some pressure to local governments.	Mayoral commitments	7							1	
6	AU2	[annual road public transport proposal], another county did not accept help from our team to draft their proposal because they lack manpower to execute it	Characteristics of implementing agencies	5					1			
7	CG2	"…counties such as…, have not paid attention to public transport…"	Mayoral commitments	7							1	
8	LA1	NRPTP's objectives are to improve rural bus service, introducing green buses, low floor buses, building bus terminals and bus shelters.	Consensus on policy objectives	1	1							
9	LA1	year's subsidy has been implemented by local government, then it [this year's proposal] is finished. No mechnism to check if the local authorities obtained the objectives they had set up.	Outcomes monitoring and implementation mechanism	4				1				
10	LA1	"…for proposal [local road public transport proposal] approval, the proposal should be longer than one year…" "If a 4-year proposal is approved, it is easier to check performance or whether the objectives have been attain or not."	Outcomes monitoring and implementation mechanism	4				1				
11	LA2	have not been our goal. We [City government] do not have a local transport policy and public transport plan, to lead our public transport development, hence,the annual local road public transport proposal was initiated randomly without plan or vision.	Consensus on policy objectives	1	1							
		public transport proposals can only be initiated	Lack of									

工作表1 工作表2 工作表3

就緒 100%

APPENDIX D

From: Crouch, Spenser on behalf of Finance.Data Protection
Sent: 20 July 2015 10:13
To: Liu, Chien-Pang
Subject: 20150720 Email Confirm

Dear Chein-Pang Liu

Thank you for the application for Data Protection Registration.

I am pleased to confirm that this project is covered by the UCL Data Protection Registration, reference No Z6364106/2015/07/30, section 19, research: social research.

It is rarely necessary to store electronic personal data on portable devices such as laptops, USB flash drives, portable hard drives, CDs, DVDs, or any computer not owned by UCL. Similarly, manual personal data should not be regularly removed from UCL premises. In the case of electronic data, to minimise the risk of loss or disclosure, a secure remote connection to UCL should be used wherever possible.

Downloading personal data on to portable devices or taking manual personal data off-site must be authorised in writing by the Data Owner, who must explain and justify the operational need in relation to the volume and sensitivity of the data. The data must be strongly encrypted. Users should only store the data necessary for their immediate needs and should remove the data as soon as possible. To avoid loss of encrypted data, or in case of failure of the encryption software, an unencrypted copy of the data must be held in a secure environment. The Computer Security Team's guidance on encryption should be followed:

http://www.ucl.ac.uk/informationsecurity/itsecurity/knowledgebase/securitybaselines/encryption

Manual personal data and portable electronic devices should be stored in locked units, and they should not be left on desks overnight or in view of third parties.

In order to comply with the fifth data protection principle personal data should be securely destroyed when no longer required, with consideration for the format of the data. The Computer Security Team's guidance should be followed for electronic data: http://www.ucl.ac.uk/isd/common/cst/good_practice/secure_disposal_guidelines.

Personal data must not be disclosed unlawfully to any third party. Transfers of personal data to third parties must be authorised in writing by the data owner and protected by adequate contractual provisions or data processor agreements, agree with UCL's notification and must use safe transport mechanisms.

If not already done so, please provide copies of any information sheets and consent forms that you are using.

When all essential documents are ready to archive, contact the UCL Records Office by email records.office@ucl.ac.uk to arrange ongoing secure storage of your research records unless you have made specific alternative arrangements with your department, or funder.

Regards,

Spenser Crouch
Data Protection & Freedom of Information Administrator
Legal Services, Finance & Business Affairs, UCL | Gower Street | London | WC1E 6BT
Internal Address: 6th floor | 1-19 Torrington Place | London | WC1E 7HB

From: Liu, Chien-Pang
Sent: 13 July 2015 14:19
To: Finance.Data Protection
Subject: Apply to data protection for an online survey

Hi,
I am going to do an online survey by Opinio. This survey is part of my PhD study to understand Taiwanese attitudes towards the use of public transport and their perceived walking environment. The attached files are the data protection application form and the questionnaire.

Best wishes,

Chien-Pang Liu
Department of Civil, Environmental and Geomatic Engineering
Room 201, Chadwick Building
University College London
Gower Street, London WC1E 6BT
Cell phone:(44)07472136960

APPENDIX E: ON-LINE SURVEY OF ATTITUDES TOWARDS PUBLIC TRANSPORT USE AND PERCEIVED WALKING ENVIRONMENT

Q1: I have read and understood the above information, have had any questions answered satisfactorily, and I willingly consent to participate in this study.

○ Agree ○ Disagree

Part 1: Attitudes towards the use of public transport

A. Environmental awareness

Q2: The effects of climate change are too far in the future to really worry me.

○ Strongly disagree ○ disagree ○ Neutral ○ agree ○ Strongly agree

Q3: I am very concerned about environmental issues.

○ Strongly disagree ○ disagree ○ Neutral ○ agree ○ Strongly agree

Q4: The so-called 'environmental crisis' facing humanity has been greatly exaggerated.

○ Strongly disagree ○ disagree ○ Neutral ○ agree ○ Strongly agree

Q5: We will all need to make sacrifices in our lifestyles to reduce environmental problems.

○ Strongly disagree ○ disagree ○ Neutral ○ agree ○ Strongly agree

Q6: I would be prepared to pay more for environmentally-friendly products.

○ Strongly disagree ○ disagree ○ Neutral ○ agree ○ Strongly agree

Q7: If things continue on their current course, we will soon experience a major environmental disaster.

○ Strongly disagree ○ disagree ○ Neutral ○ agree ○ Strongly agree

Q8: Technological advances will solve many environmental problems.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q9: There is an urgent need for something to be done about the environmental pollution caused by car and motorbike use.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

B. Attitudes towards public transport use

Q10: For me, to take public transport (bus, metro, train) for everyday routes would overall be

○ Very bad ○ Bad ○ Neutral ○ Good ○ Very good

Q11: In the past year, using public transport is a satisfying experience.

○ Strongly disagree (Strongly disagree) ○ disagree
○ Neutral ○ agree
○ Strongly agree (Strongly agree)

Q12: For me using public transport for everyday routes is convenient.

○ Strongly disagree (Strongly disagree) ○ disagree
○ Neutral ○ agree
○ Strongly agree (Strongly agree)

Q13: For me using public transport for everyday routes is reliable.

○ Strongly disagree (Strongly disagree) ○ disagree
○ Neutral ○ agree
○ Strongly agree (Strongly agree)

Q14: For me using public transport for everyday routes is time efficient.

○ Strongly disagree (Strongly disagree) ○ disagree
○ Neutral ○ agree
○ Strongly agree (Strongly agree)

Q15: For me, using public transport for everyday routes is cheap.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q16: For me using public transport is the safest travel choice.

○ Strongly disagree (Strongly disagree) ○ Disagree
○ Neutral ○ Agree
○ Strongly agree (Strongly agree)

C. Subjective norm over public transport use

Q17: Most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence.

○ Strongly disagree (Strongly disagree) ○ disagree
○ Neutral ○ agree
○ Strongly agree (Strongly agree)

Q18: Most people who are important to me think that I should use public transport instead of car and motorbike for daily travel from my current place of residence.

○ Strongly disagree (Strongly disagree) ○ disagree
○ Neutral ○ agree
○ Strongly agree (Strongly agree)

Q19: Most of my friends and relatives use public transport regularly.

○ Strongly disagree (Strongly disagree) ○ disagree
○ Neutral ○ agree
○ Strongly agree (Strongly agree)

D. Personal norm and perceived behaviour control over public transport use

Q20: Regardless of what other people do, because of my own values/principles I feel an obligation to use public transport instead of the car and motorbike for everyday trips.

○ Strongly disagree (Strongly disagree) ○ disagree
○ Neutral ○ agree
○ Strongly agree (Strongly agree)

Q21: For me, using public transport can take me to all the places I want to.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q22: For me using public transport for everyday routes is

○ Extremely difficult (Extremely difficult) ○ Difficult
○ Neutral ○ Easy
○ Extremely easy (Extremely easy)

E. Intention to use public transport

Q23: My intention to use public transport for everyday routes is

○ Extremely weak (Extremely weak) ○ Weak
○ Neutral ○ Strong
○ Extremely strong (Extremely strong)

Q24: How likely is it, that in the next 6 months you will use public transport for everyday routes.

○ Extremely unlikely (Extremely unlikely) ○ unlikely
○ Neutral ○ Likely
○ Extremely likely (Extremely likely)

PART 2: Perceived walking environment

Q25: Convenient stores are within easy walking distance of my home.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q26: There are many places to go within easy walking distance of my home.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q27: It is easy to walk to a public transport stop (bus, metro or train) from my home.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q28: The distance between intersections in my neighbourhood is usually short (100 meters or less).

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q29: There are many alternative routes for getting from place to place in my neighbourhood. (I don't have to go the same way every time.)

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q30: There are sidewalks on most of the streets in my neighbourhood.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q31: There are motorbike parking on the streets and sidewalks blocking the way.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q32: There are 'hawkers' and shops on the streets and sidewalks blocking the way.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q33: The streets in my neighbourhood are hilly, making my neighbourhood difficult to walk in.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q34: There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighbourhood.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q35: There are so much traffic along nearby streets that it makes difficult or unpleasant to walk in my neighbourhood.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q36: The speed of traffic on most nearby streets is usually slow (40 kph or less).

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q37: Most drivers exceed the speed limits while driving in my neighbourhood.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q38: There is a high crime rate in my neighbourhood.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q39: The crime rate in my neighbourhood makes it unsafe to go on walks during at night.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q40: The streets in my neighbourhood do not have many dead-end streets.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q41: My neighbourhood is safe enough so that I would let a 10-yr-old boy walk around my block alone in the daytime.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q42: My neighbourhood streets are well lit at night.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q43: There are trees along the streets in my neighbourhood.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q44: There are many interesting things to look at while walking in my neighbourhood.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q45: There are many attractive natural sights in my neighbourhood (such as landscaping, views).

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

Q46: How long would it take to get from your home to the nearest convenient store if you walk to?

○ 1-5 min ○ 6-10 min ○ 11-20 min ○ 21-30 min ○ 30+ min ○ Don't know

Q47: How long would it take to get from your home to the nearest bus stop if you walk to?

○ 1-5 min ○ 6-10 min ○ 11-20 min ○ 21-30 min ○ 30+ min ○ Don't know

Q48: How long would it take to get from your home to the nearest supermarket if you walk to?

○ 1-5 min ○ 6-10 min ○ 11-20 min ○ 21-30 min ○ 30+ min ○ Don't know

Q49: How long would it take to get from your home to the nearest primary school if you walk to?

○ 1-5 min ○ 6-10 min ○ 11-20 min ○ 21-30 min ○ 30+ min ○ Don't know

Q50: How long would it take to get from your home to the nearest post office/ banks if you walk to?

○ 1-5 min ○ 6-10 min ○ 11-20 min ○ 21-30 min ○ 30+ min ○ Don't know

Q51: How long would it take to get from your home to the nearest breakfast restaurant if you walk to?

○ 1-5 min ○ 6-10 min ○ 11-20 min ○ 21-30 min ○ 30+ min ○ Don't know

Q52: How long would it take to get from your home to the nearest park if you walk to?

○ 1-5 min ○ 6-10 min ○ 11-20 min ○ 21-30 min ○ 30+ min ○ Don't know

Q53: How long would it take to get from your home to the nearest village recreation centre if you walk to?

○ 1-5 min ○ 6-10 min ○ 11-20 min ○ 21-30 min ○ 30+ min ○ Don't know

Q54: How long would it take to get from your home to your office/ school if you walk to?

○ 1-5 min ○ 6-10 min ○ 11-20 min ○ 21-30 min ○ 30+ min ○ Don't know

6. Generally assessment on neighbourhood walking environment

Q55: How longest would you like to walk from your home to nearby facilities (convenient stores, supermarket, school et. al)?

○ 1-5 min ○ 6-10 min ○ 11-15 min ○ 16-20 min ○ 21-30 min ○ Other

Please explain: (min)

Q56: Generally, how satisfied do you think your neighbourhood walking environment ?

○ 1Extremely unsatisfied ○ 2Quite unsatisfied ○ 3 Slightly unsatisfied ○ 4 Neutral
○ 5Slightly satisfied ○ 6Quite satisfied ○ 7 Extremely satisfied

PART 3: Trip characteristics

Thinking about travel you undertake on a daily or weekly basis, please tell us the main mode of travel you use most frequently for the following activities. Please only tick one box per activity. If an activity does not apply to you, please tick 'Not applicable'.

Q57: Travel to work

Car	Motorbike	Bus	Metro	Train
High speed train	Bike	Walk	Taxi	Not applicable

Q58: Travel to school

Car	Motorbike	Bus	Metro	Train
High speed train	Bike	Walk	Taxi	Not applicable

If for your **travel to work/school**, one of **public transport modes** (bus/ metro/ train/ high speed train) is selected, **please answer question 56-60**.

Q59: How do you get from home to the bus stop/ metro station/ train station?

○ Walk ○ Bike ○ Bus ○ Metro ○ Car ○ Motorbike
○ Other

Please explain:

Q60: How long does it take from your home to bus stop/ metro station/ train station?(min)

○ > 3 min ○ 3-5 min ○ 6-10 min ○ 11-15 min ○ 16-20 min ○ 21-25 min

Over 26 min, please fill how long:

[ ]

Q61: How long does it take to wait for a bus/ metro/ train at stop/ station?(min)

○ Less than 3 min ○ 3-5 min ○ 6-10 min ○ 11-15 min ○ 16-20 min
○ 21-25 min

Over 26 min, please fill how long:

[ ]

Q62: How do you get from the bus stop/ metro station/ train station to work/school ?

○ Walk ○ Bike ○ Bus ○ Metro ○ Car ○ Motorbike
○ Other

Please explain:

[ ]

Q63: Do you have to make any transfers for your travel to work/school from your home to office/ school?

○ No ○ Yes

How many transfers?

[ ]

Q64: How long does the total trip take, from the time you left home to the time you arrived at work/school (in minutes)?

[ ]

Q65: How much money does it cost for you to travel to work / school? (Including public transport ticket or parking cost and fuel cost)

Q66: Shopping / visiting friends and relatives

Car	Motorbike	Bus	Metro	Train
High speed train	Bike	Walk	Taxi	Not applicable

Q67: Travel whilst at work

Car	Motorbike	Bus	Metro	Train
High speed train	Bike	Walk	Taxi	Not applicable

PART 4: Socio-demographic characteristics

Q68: Which gender do you most identify with?

○ Male ○ Female ○ Decline to respond

Q69: What is your age?

○ Under 18 ○ 18-24 ○ 25-34 ○ 35-44 ○ 45-54 ○ 55-64
○ 65 and over

Q70: What is your occupation?

(1)Agriculture, forestry, fishing and hunting, and mining
(2)Construction
(3)Manufacturing
(4)Wholesale trade
(5)Retail trade
(6)Transportation and warehousing, and utilities
(7)Information
(8)Finance and insurance, and real estate and rental and leasing
(9) Professional, scientific, and management, and administrative and waste management services (10) Educational services, and health care and social assistance
(11) Arts, entertainment, and recreation and accommodation and food services (12) Other services, except public administration
(13) Public administration
(14)Other (please specify)

Other, please specify:

Q71: What is your highest education?

Secondary or less	High school	Bachelor’s degree
Master’s degree	Doctoral or professional degree	Decline to answer

Q72: Do you have car driver's license?

○ No ○ Yes

Q73: Do you have motorbike driver's license?

○ No ○ Yes

Q74: What is your approximate monthly income before taxs?

Under NT$10,000	NT$10,000-NT$19,999	NT$20,000-NT$39,999	NT$40,000-NT$59,999
NT$60,000-NT$79,999	NT$80,000-NT$99,999	NT$100,000 and over	Decline to respond

Q75: How many persons live in your household (include you)?

Q76: How many are 18 years or younger in your household?

Q77: How many are work in your household?

Q78: How many cars in your household?

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Q79: How many motorbikes in your household?

Q80: How many bikes in your household?

Where is your home located?(Please give the home address details to village in order for this study to do the geographic analysis)

Q81: 1. Which city/county is your home located in Taiwan?

Q82: 2. Which district is your home located in the city/ county?

Q83: 3. Which village is your home located in the district?

Q84: Your email address is:(Fill in your email address, in order for me to contact to you, if you win the awards.)

All questions have finished. I am very grateful for your participation in this survey.

Would you please forward this survey link to your friends and relatives.

APPENDIX F: MATHEMATICAL FORMULAS USED IN THIS STUDY

1. Person Correlation Coefficient

If we have one dataset $\{x_1,...,x_n\}$ containing n values and another dataset $\{y_1,...,y_n\}$ containing n values then that formula for r is:

$$\mathrm{r} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

2. McFadden R^2

Let L_0 be the value of the likelihood function for a model with no predictors, and let L_M be the likelihood for the model being estimated. McFadden's R^2 is defined as

$$R^2_{McF} = 1 - \ln(L_M)/\ln(L_0)$$

where ln(.) is the natural logarithm.

3. Likelihood Ratio Test

Each of the two competing models, the null model and the alternative model, is separately fitted to the data and the log-likelihood recorded. The test statistic (often denoted by D) is twice the log of the likelihoods ratio or it is twice the difference in the log-likelihoods:

$$\begin{aligned} \mathrm{D} &= -2\ln\left(\frac{L_0}{L_M}\right) \\ &= 2 \times [\ln(L_M) - \ln(L_0)] \end{aligned}$$

4. Intra-class Correlation Coefficient (ICC)

Assuming a random effects model:

$$Y_{ij} = \mu + \alpha_j + \epsilon_{ij}$$

where Y_{ij} is the ith observation in the jth group, μ is an unobserved overall mean, αj is an unobserved random effect shared by all values in group j, and ϵ_{ij} is an unobserved noise term. For the model to be identified, the αj and ϵ_{ij} are assumed to have expected value zero and to be uncorrelated with each other. Also, the αj are assumed to be identically distributed, and the ϵ_{ij} are assumed to be identically distributed. The variance of αj is denoted σ_α^2 and the variance of ϵ_{ij} is denoted σ_ϵ^2.

The ICC in this framework is

$$\mathrm{ICC} = \frac{\sigma_\alpha^2}{\sigma_\alpha^2 + \sigma_\epsilon^2}$$

5. Cronbach's Alpha

Cronbach's alpha is computed by correlating the score for each scale item with the total score for each observation (usually individual survey respondents or test takers), and then comparing that to the variance for all individual item scores:

$$\alpha = \left(\frac{k}{k-1}\right)\left(\frac{\sum_{i=1}^{k}\sigma_{y_i}^2}{\sigma_x^2}\right)$$

where: k refers to the number of scale items, $\sigma_{y_i}^2$ refers to the variance associated with item I, and σ_x^2 refers to the variance associated with the observed total scores.

6. Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA)

The formula for the KMO test is:

$$KMO_j = \frac{\sum_{i\neq j} r_{ij}^2}{\sum_{i\neq j} r_{ij}^2 + \sum_{i\neq j} u_{ij}^2}$$

7. Bartlett's Test of Sphericity

Bartlett's test for homogeneity of variances is used to test that variances are equal for all samples. It checks that the assumption of equal variances is true before running certain statistical tests like the One-Way ANOVA.

$$\chi^2 = \frac{(N-k)\ln(S_p^2) - \sum_{i=1}^{k}(n_i-1)\ln(S_i^2)}{1 + \frac{1}{3(k-1)}\left(\sum_{i=1}^{k}\left(\frac{1}{n_i-1}\right) - \frac{1}{N-k}\right)}$$