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Integrating Traveller Preference Heterogeneity in Transportation Planning From the Perspective of Principal-Agent Theory

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Integrating Traveller Preference Heterogeneity in Transportation Planning From the Perspective of Principal-Agent Theory

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Thesis Certification

I, A.H.M. Mehbub ANWAR, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy (Engineering), in the School of Mechanical, Materials & Mechatronic, Faculty of Engineering and Information Sciences of the University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

A.H.M. Mehbub Anwar

Dedicated to

My family………

Ismat Ara (Runa)

Ramin Tihami (Madhurjo)

Tuhran Tihami (Shanniddho)

List of Publications

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(1) **Anwar, A.H.M.M.,** Tieu, K., Gibson, P., Win, K.T. and Berryman, M. (2013). Analysing the Heterogeneity of Traveller Mode Choice Preference Using A Random Parameter Logit Model from the Perspective of Principal-Agent Theory. *International Journal of Logistics Systems Management*, (in press), (URP:http://www.inderscience.com/info/ingeneral/forthcoming.php?jcode=ijlsm)

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Table of Contents

Title **Page**

List of Tables

List of Figures

Glossary

AIC	**A**kaike **I**nformation **C**riterion
AGFI	**A**djusted **G**oodness-of-**F**it **I**ndex
AMOS	**A**nalysis of **MO**ment **S**tructures
AUV	**A**utomobile **U**ser **V**alue
BDI	**B**eliefs, **D**esires and **I**ntensions
BTS	**B**ureau of **T**ransport **S**tatistics
BWS	**B**est-**W**orst **S**caling
CCP	**C**onditional **C**hoice **P**robability
CFI	**C**omparative **F**it **I**ndex
CFM	**C**onfirmatory **F**actor **M**odel
CO	**C**ar **O**wners
DRACULA	**D**ynamic **R**oute **A**ssignment **C**ombining **U**ser **L**earning and Microsimul**A**tion
DTSMA	**D**iscrete-**T**ime **S**urvival **M**ixture **A**nalysis
EFM	**E**xploratory **F**actor **M**odel
EM	**E**xpectation **M**aximisation
GFI	**G**oodness-of-**F**it **I**ndex
GGEs	**G**reenhouse **G**as **E**missions
HCM	**H**ybrid **C**hoice **M**odel
HRM	**H**uman **R**esource **M**anagement
HRPL	**H**ybrid **R**andom **P**arameter **L**ogit
HTS	**H**ousehold **T**ravel **S**urvey
ICLV	**I**ntegrated **C**hoice and **L**atent **V**ariable
IIA	**I**ndependence of **I**rrelevant **A**lternatives
IID	**I**ndependent and **I**dentically **D**istributed
LCM	**L**atent **C**lass **M**odel
LOS	**L**evel **O**f **S**ervice
LVM	**L**atent **V**ariable **M**odel
LV	**L**atent **V**ariables
MIMIC	**M**ultiple **I**ndicators and **M**ult**I**ple **C**auses
ML	**M**ixed **L**ogit
MLE	**M**aximum **L**ikelihood **E**stimator

MNL	**M**ulti**N**omial **L**ogit
NCO	**N**on-**C**ar **O**wners
NFI	**N**ormed **F**it **I**ndex
NL	**N**ested **L**ogit
NLTTMP	**N**SW **L**ong **T**erm **T**ransport **M**aster **P**lan
NPL	**N**ested **P**seudo-**L**ikelihood
ONS	**O**ffice of **N**ational **S**tatistics
PAT	**P**rincipal-**A**gent **T**heory
PT	**P**ublic **T**ransport
RMSEA	**R**oot-**M**ean-**S**quare **E**rror of **A**pproximation
RP	**R**evealed **P**reference
RPL	**R**andom **P**arameter **L**ogit
RUM	**R**andom **U**tility **M**aximisation
SALCM	**S**cale **A**djusted **L**atent **C**lass **M**odel
SCM	**S**upply **C**hain **M**anagement
SEC	**S**ocio-**E**conomic **C**haracteristics
SEM	**S**tructural **E**quation **M**odelling
SERVQUAL	**SERV**ice **QUAL**ity
SP	**S**tated **P**reference
SRA	**S**tate **R**ail **A**uthority
SSD	**S**ydney **S**tatistical **D**ivision
TC	**T**rip **C**haracteristics
TfNSW	**T**ransport **f**or **N**ew **S**outh **W**ales, the state Government department responsible for transportation
TMA	**T**ransport **M**anagement **A**uthority
TOA	**T**raditional **O**bjective **A**ttributes
TRPL	**T**raditional **R**andom **P**arameter **L**ogit
UK	**U**nited **K**ingdom
US	**U**nited **S**tates

Abstract

This thesis explains the effects of traveller choice attributes in transport mode services to understand an inferred relationship between traveller and Transport for NSW (TfNSW), Australia in the context of Principal-Agent Theory (PAT). As agency problem is found in transport mode services of TfNSW, this thesis also suggests an approach to reduce this problem using traveller mode choice probability analysis.

When travellers entrust their desire for a mode of transport that is customer-focused (i.e. safe, reliable, comfortable and low cost) to TfNSW, this creates a metaphorical contract between travellers and TfNSW, known as an *agency contract*. This contract is often characterised by agency uncertainty (problem) because both the traveller and the TfNSW are most likely to act in their own self-interest. It can be assumed that where there is a high use of public transport, the TfNSW is performing the entrusted tasks as per travellers' expectation, which indicates an improvement in agency uncertainty. On the other hand, where there is a high use of private transport (car), it is likely that the TfNSW is biased in other stakeholders' interest more rather than travellers' interest, and the agency problem remains unresolved.

The thesis focuses on latent variables (LV) and traditional objective attributes (TOA) together during the mode choice process (private and public) within the principal-agent relationship. A method, by which the utility of the principal (traveller) can be maximised and evaluated, is known as discrete choice experiment that has been employed to explore the relationship and an approach to reduce the agency problem in the relationship. A traditional random parameter logit (TRPL) model is compared with a hybrid RPL (HRPL) model in this research. For the later model, a two-step approach (also known as sequential approach) is implemented to incorporate LVs in choice models. Step 1 is the estimation of a MIMIC (multiple indicators and multiple causes) model; a type of regression model with a latent dependent variable(s). Step 2 is the estimation of a choice model with random parameters; information from the first step is incorporated in the second step.

Exploring the agency relationship within transport mode services produces hypotheses and related propositions that are reported and tested in this study. From the results, it is shown that

the probability of car use is significantly higher than public transport, which indicates that an agency problem exists in transport mode services. Similar results are found for car owner and non-car owner samples. The thesis also analyses and compares the results of applying RPL models to a real urban case study using two datasets: 2008/09 and 2010/11 household travel survey (HTS) of Sydney Statistical Division (SSD), and also evaluates the predicted changes of mode choice probabilities based on hypothetical scenarios that have been considered as a mechanism of minimising agency problem in the mode services. The results also show that the HRPL model is superior to TRPL models that ignore the effect of LVs on traveller choice. The minimal changes in the parameter coefficients between the two examined periods for each model suggest that the changes in traveller choice behaviour are gradual. Three hypothetical scenarios were simulated to forecast the changes that would be relevant to transport policy responses and provide a guideline to reduce the agency problem. It is recommended that by analysing traveller preferences according to a hierarchy of importance it would indicate those attributes of the agency in transport mode services that would help to resolve the agency problem and assist in the formulation of a policy response. In this regard, the thesis found *safety* and *reliability* among LVs most important followed by *travel time, travel cost*, *waiting time, car ownership* and *having children* among TOAs.

Thus, the contribution of this research is four-fold: *firstly*, the application of agency theory's utility and implications in traveller choice behaviour, which is rare in transportation management field; *secondly*, the demonstration of scale to which attributes influence traveller mode choice to shape the agency relationship within transport mode services with a comparison between traditional and hybrid discrete choice models; *thirdly*, the inclusion of an extended number of traveller choice attributes (LVs and TOAs) in choice model that assesses a connection between traveller and TfNSW in the context of PAT; and *finally*, the improvement of agency relationship in transport mode services by integrating the traveller choice attributes into the choice models within principal-agent framework.

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I am currently a faculty member of *Urban and Rural Planning discipline* of *Khulna University*, Bangladesh. So I should widen my gratefulness to the personnel of Khulna University because they have allowed me to pursue my PhD study at UOW on study leave.

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Chapter 1

Introduction

This thesis deals with the understanding of principal-agent relationship within transport mode services. To understand the relationship, the effect of traveller choice attributes in transport mode services in the context of Principal-Agent Theory (PAT) is examined. This chapter provides an introduction along with an understanding the research issue followed by a conceptual framework. The later part of this chapter reports the research motivation, research problem and focus, research objectives, and organisation of the thesis.

1.1 Introduction and Understanding of the Research Issue

Traveller preference heterogeneity is well understood by transport management authority (TMA). For example; some travellers value time-saving, some pay more attention to the environmental effects of transport options, some are more sensitive to social status, while others prefer convenience over speed. A percentage prefers more convenient options than faster options, and so on. Most transportation departments around the world set a goal to provide suitable options for travellers, which demands a good understanding of the heterogeneity in traveller preferences, in order to serve the diverse need of each individual. Real life is complex with individual heterogeneity, such as different preferences, for example; *comfort*, *convenience*, *flexibility* etc. This heterogeneity influences largely the mode choice process (Anwar et al., in press).

However, the latent factors (treated as 'black box') people consider in making their travel decisions are more salient than just travel time and cost attributes. Furthermore, people's travel preferences are much more complex than their socio-economic and trip characteristics (Anwar et al., 2011). There is strong evidence in extant research that recent developments, including LVs, latent classes, structural equation modelling (SEM) and integrated frameworks, have advanced ways to examine a wider array of latent variables that might influence travel behaviour. This framework explicitly treats psychological factors, such as attitudes and perceptions, through psychometric indicators instead of traditional objective attributes (TOAs) (Ben-Akiva et al.,

1994; Gopinath, 1995; Walker and Ben-Akiva, 2002; Ashok, 2002; Johansson et al., 2006; Temme et al., 2008). It means, consideration of psychometric (latent) variables, which should be well understood by the transport planners, is becoming very important.

The TMA is established to provide transport services for the public, either directly or indirectly, through managing contracts with private companies. The preference heterogeneity needs to be considered by transport planners when transport services are planned, designed and implemented. Although it seems that transport authorities across the world set goals to accommodate travellers' desires and expectations, and provide acceptable options for travellers, the TMA cannot satisfy fully as per traveller expectations because of budget constraints and its direct obligation to government who is substantially influenced by politics. Therefore, TMA may be aligned with the interests of government. It may or may not be aligned with the interests of the travelling public. Again, the travellers' expectations about services provided by the TMA may vary because people of different socio-economic backgrounds have different expectations. On the other hand, the TMA's work aligned with government agendas that may not fulfil the level of travellers' expectations. Thus the accountability of the TMA is not to travellers directly, and it is not easy for travellers to influence the TMA's performance, and make it act in accord with their interest. Therefore, travellers may not be fully satisfied with the TMA's performance, because it likely behaves in its own best interest. Consequently, it can be assumed that there is a metaphorical connection between traveller and TMA as indicated in 'Principal-Agent Theory' (PAT). Travellers expect transport services that meet their preferences and needs, and the TMA is entrusted with providing those services. As a result, an inferred connection exists between the traveller and the TMA.

What is Principal-Agent (agency) Theory (PAT)? The simplest definition is that PAT, also known as the 'agency' or 'principal agency' theory/model, describes the relationship between two or more parties, in which one party is designated as the 'principal' that assigns another party, called the 'agent', to perform tasks on behalf of the principal (Ross, 1973; Jensen and Meckling, 1976; Moe, 1984). Principal-agent relationships exist in various contexts, involving the entrustment of authority. Some common examples of principal-agent relationships include employer-employee, patient-doctor, landlord-tenant, government-transport operator, and citizen-politician. PAT is concerned to understand those relationships. The theory assumes that, once principals delegate authority to agents, principals often cannot control them, as agents' goal often differ from that of the principal. Thus agents often have better information about their capacity,

skills, and experiences than the principals. PAT focuses on the ways in which principals try to reduce this problem by selecting agents with high ability (Kiser, 1999). The principal-agent problem (described in Chapter 2) in transport mode services may be reduced by examining traveller choice objective attributes (such as *travel cost* and *waiting time*) and traveller latent preferences (such as *safety* and *reliability*) according to the importance of those attributes to the TMA.

The role of the TMA (an agent) should be to maximise the utility of the travellers (the principal) within available resources, by providing satisfactory mode services. To understand the utility function of travellers towards mode choice, the TMA should have information about the nature of traveller's desires and expectations of the mode service. The traveller's utility function considering preference heterogeneity needs to be examined so that the TMA can perform according to traveller expectations. However, the limits of the TMA's budget and cost effectiveness of the projects impact on performance. The sources of the budget are taxes and fares paid by citizen (travellers). Douglas and Brooker (2013) describes that travellers pay a large percentage (about 70%) of cost for transport infrastructure through tax. Therefore, the ultimate source of the TMA's funding is service consumers (e.g. travellers in this research). This means that the TMA procures and executes the delegated task with resources sourced from travellers. However, travellers may not trust the quality of services performed by the TMA, because of its tendency to focus on its internal goals and opportunistic behaviour caused by insufficient funding, poor planning and cost ineffectiveness and it is opposed to more direct measures towards the principal's goals. Consequently, responses to the following two simple interconnected questions shape the principal-agent relationship within transport mode services, and a PAT framework can offer a guideline to address the following questions due to its characteristic mistrust of the agent:

i) Why do travellers evaluate the performance of mode services? and
ii) Why can't travellers rely on the quality of TMA's mode services?

PAT may be able to propose a simple and straightforward answer to the questions presented above like everything needs feedback to monitor performance for improving the situation. As stated by PAT, travellers are reluctant to believe the performance of TMA due to its limitations. Although TMA has the obligation for accountability to the travellers, it can't meet up the expectation level of travellers fully.

Figure 1.1 describes a concept of how an agency relationship can be understood in traveller mode choice behaviour. Travellers entrust their desires (for *reliability* and *comfort*) which is customer-focused mode of transport, and assume that the TMA can be an effective agent to perform the customer-focused mode of transport. After the tasks are delegated, the limited access to monitor the TMA's performance is observed and it causes informational asymmetries/adverse selection/goal conflicts. The TMA provides public transport, such as train and bus, for the traveller and tries to accommodate customer-focused attributes in the service. At the same time, travellers have the opportunity to use their own car (private transport). In this situation, travellers will exercise their choices between private car and public transport based on utility maximisation, determined by TOAs and LVs. Once travellers perceived the maximum utility, she/he will choose that particular mode of transport. Based on the mode choice probability, if the travellers intend to use private car rather than public transport; it means that TMA can't meet the travellers' expectation as their demand. It indicates that travellers' expected tasks are not performed properly by the TMA. It can be treated as goal/choice conflicts or adverse selection in transport mode services. This situation indicates existence of agency problem in the connection between traveller and TMA. On the other hand, if the choice probability of public transport usage is notably higher than private car, that implies low level of agency problem in transport mode services. Accordingly, a principal-agent interaction exists in the connection between traveller and TMA, as indicated in PAT.

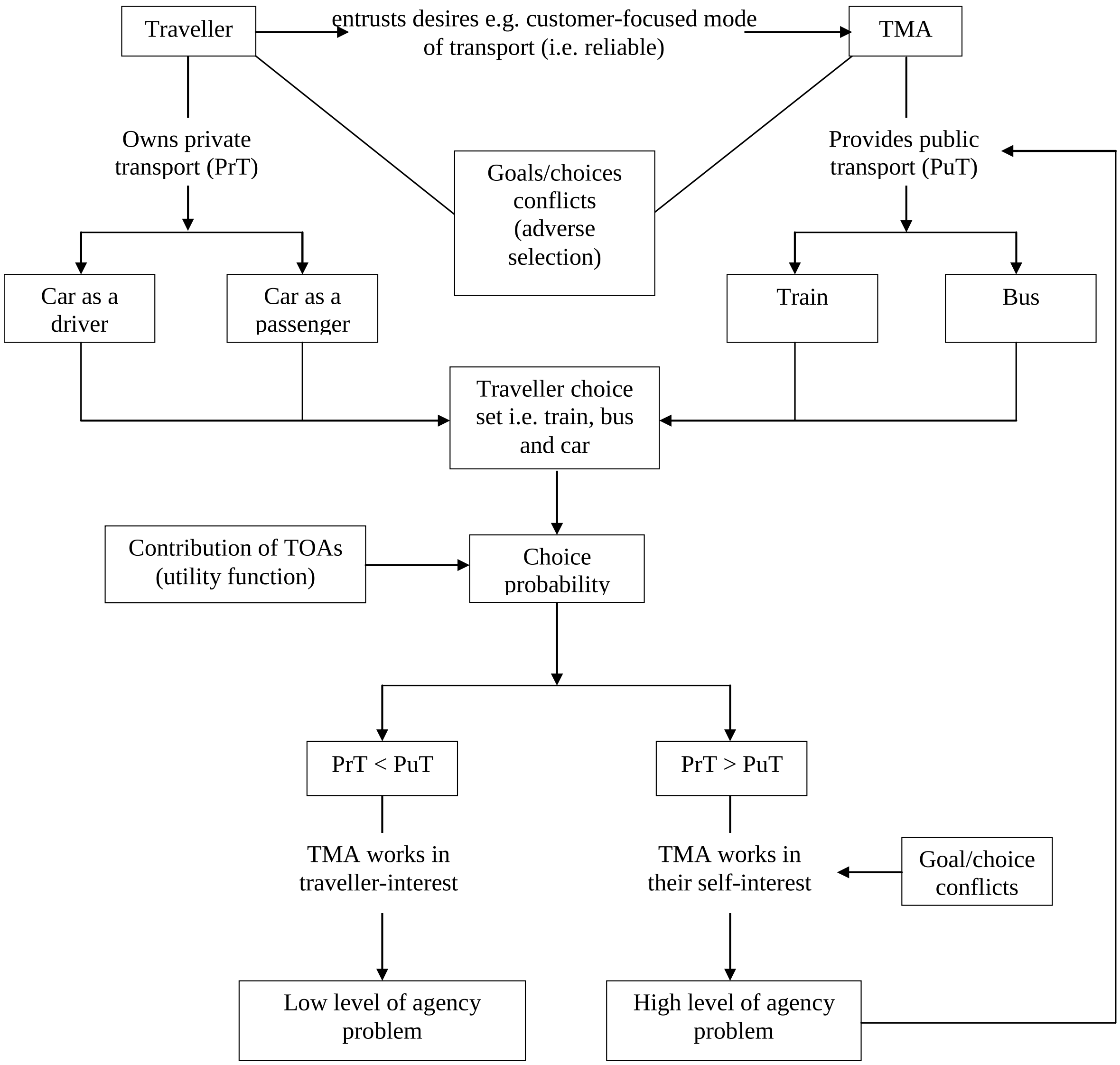


Figure 1.1 Understanding an agency relationship within transport mode services

As said, travellers' behaviour is diverse and complex in real life. Various choice attributes influence them during the decision making process of mode choice (Rahman et al., 2012; Harikrishna and Rajat, 2012; Kim et al., 2012; Can, 2013). The TMA should be aware of those relevant attributes related to traveller choice during the planning and implementing stage of transport projects for improving the principal-agent relationship. Observed heterogeneity can be incorporated easily into choice models by introducing individual *Socio-Economic Characteristics* (SEC), integrating *Level of Service* (LOS) attributes as well as *Trip*

Characteristics (TC). These are called all together as Traditional Objective choice Attributes[1] (TOAs). In addition, there are also *unobserved (latent) heterogeneities* of individuals that are often overlooked by the TMA, as well as traditional transport planners. Though Johansson et al. (2006) argued that latent aspects are sufficiently, or partially, represented by the traditional objective attributes, Anwar et al., (2011, 2013a) disagreed with this statement.

In line of above this discussion, this research uses PAT to understand the principal-agent relationship in transport mode services. To do it, traveller behaviour analysis has been brought into consideration of this research. Commonly, traditional choice attributes influence traveller behaviour. At the same time, latent (psychological) factors such as *safety*, *comfort*, and *reliability* influence traveller behaviour and expectation to a large extent (Anwar et al. 2011 and 2013a). TMA still struggles to acknowledge the importance of these psychological factors in the understanding of travel behaviour, and can rarely integrate them appropriately into the planning practice and policy in a quantitative way, due to their lack of understanding of tools. Thus, this research also reflects the importance of relevant choice attributes to traveller decision and discusses the connection between traveller and TMA in terms of transport mode services using PAT. Besides, this study reviews the innovations in travel behaviour research that may help to improve the principal-agent relationship within transport mode services by incorporating latent variables (LVs), along with objective attributes, as the explanatory variables to extend the interpretive power and enhance the choice modelling structure.

1.2 An Agency Relationship within Transport Mode Services

When travellers entrust their choice for a mode of transport that is customer-focused (i.e. safe, reliable, comfortable and low cost) to TMA (Transport for NSW), this creates a metaphorical contract between the traveller and the TMA, known as a *principal-agent contract*. This contract is often characterised by agency uncertainty (problem) because both the traveller and TMA are most likely biased to act in their self-interest. It can be assumed that where the use of public transport is high and the TMA is performing the entrusted tasks as per travellers' demand. This indicates an improvement in agency uncertainty. On the other hand, where there is a high use of private car, it is likely that the TMA is acting largely in its own self-interest, and the agency problem remains unresolved.

[1] Objective attributes are defined as the attributes those are not swayed by psychological bias (such as safety and reliability).

In this research, the ‘traveller’ of the Sydney Statistical Division (SDD) is considered as the ‘principal’ and the TMA is represented by ‘Transport for NSW’ (TfNSW) as an ‘agent’. In the broadest sense, travellers may represent the choice functions of a whole community of SSD towards a mode of transport service. The TfNSW is a public organization, which takes action to address travellers’ demands/desires that are entrusted to TfNSW, such as comfortable and reliable mode services. The following three components must be contained in the principal-agent relationship within transport mode services:

(i) Tasks (services e.g. modal services with *comfort*, *safety*, *reliability*, *cheaper fare*, *shorter travel time* etc.) that the travellers (principal) desire, are delegated to TfNSW;
(ii) Finance, accumulated from tax and travel fare paid by the public (travellers), is allocated to TfNSW (agent), who may then distribute this to third parties, for accomplishing those tasks; and
(iii) Travellers are interested in influencing the TfNSW’s activities by providing feedback.

The parties to the principal-agent relationship, which are the traveller and TfNSW, also require more detailed specification. The ‘traveller’, as a principal, can be defined differently depending on the chosen context and perspective. In the broadest sense, the traveller may refer to the whole community of a particular region performing the diverse choice of interests. The ‘TfNSW’, as an agent, is a public organisation, which has legal and economical boundaries separating it from the boundaries of other government organisations. The TfNSW is funded and owned by government and its legal status is public.

The traveller is not in a position to be aware, at a reasonable level, of the planning stage to implementation phase of mode service undertaken by TfNSW, and do not have access to monitor it. There is only limited/no public input in major projects[2] that indicates TfNSW may work opportunistically to achieve its own self-interest; therefore, ‘goal/choice conflicts’ occur due to conflicting interests between the traveller and TfNSW.

Due to agency problem, the concept of ‘perfect’ and ‘imperfect’ agent has become apparent. If the agent executes delegated tasks perfectly in line with the principal’s desires, is called a ‘perfect agent’. That is quite impossible in real world and therefore the concept of an ‘imperfect

[2] The argument is based on the NSW long term transport master plan 2012 (Transport for NSW, 2012)

agent' has emerged. To test whether TfNSW is a 'perfect' or 'imperfect' agent, the attributes related to transport mode services should be understood first. Scott and Vick (1999) define a 'perfect' agent as below:

> *one who makes the same decisions that the principal would have made if the principal possessed the same information and expertise as the agent (pp.113).*

According to this definition, TfNSW may not be a perfect agent since travellers of SSD do not possess the same and necessary information and knowledge as TfNSW, and also services (tasks) expected by travellers are not executed perfectly by TfNSW, or agents acting on TfNSW's behalf. Rather, it is more useful to understand the possible sources of imperfect agency with the effects of attributes on the decisions made by travellers. The **first** of these is to what extent TfNSW acts in travellers' best interests. Imperfect agency may arise if the TfNSW has an incorrect perception about travellers' utility function, and also the separate government-operator relationship on top of the public-government relationship.

There are two aspects to this misperception. The first is that travellers have more information than the TfNSW about the attributes of their utility function. The second is only travellers possess information about the importance that they attach to these arguments. Imperfect agency arises where there is a difference between the perception of TfNSW about the travellers' utility function, and the importance attached to its arguments by travellers themselves.

The **second** main source of imperfect agency is informational asymmetries about modal service to the traveller. TfNSW has more information and experience about the process of designing and implementing a transport system and its effects on mobility than travellers.

Hence, two issues are important here, 'information availability' and 'choice'. Information availability explains the flow of information that is related to informational asymmetries. Choice describes traveller preferences that are connected to goal/choice conflicts. Available information about services provided by TfNSW may be helpful to get effective guidance back from the traveller. Knowledge of travellers' choices may be more useful to TfNSW in decision making. Thus, 'information availability' and 'choice' are clearly seen as important in assessing the effectiveness of the principal-agent relationship within transport mode services.

Considering the above discussion, a behavioural agency model is devised to understand the connection between traveller and TfNSW considering transport mode services, as shown in Figure 1.2, which illustrates two types of relationship; one is ‘conflict’ and the other is ‘congruence’. In this understanding, maximisation of benefits is the only congruence for both parties. TfNSW provides transport services for as low a cost as possible due to a limited Government budget, whereas a traveller expects customer-focused service that may require more funding. As a result, goal (choice) conflicts occur. While examining the effect of traveller preference attributes in transport mode choice in the context of PAT, it is useful to draw attention to the classical components of principal-agent theory, such as self-interest, obligation, goal/choice conflicts, and choice context (Figure 1.2).

Travellers sometimes have the option of not travelling altogether, as well as changing their time of travel, in addition to mode. This research is focussing on travel mode via public / private transport where mode is the key variable of interest.

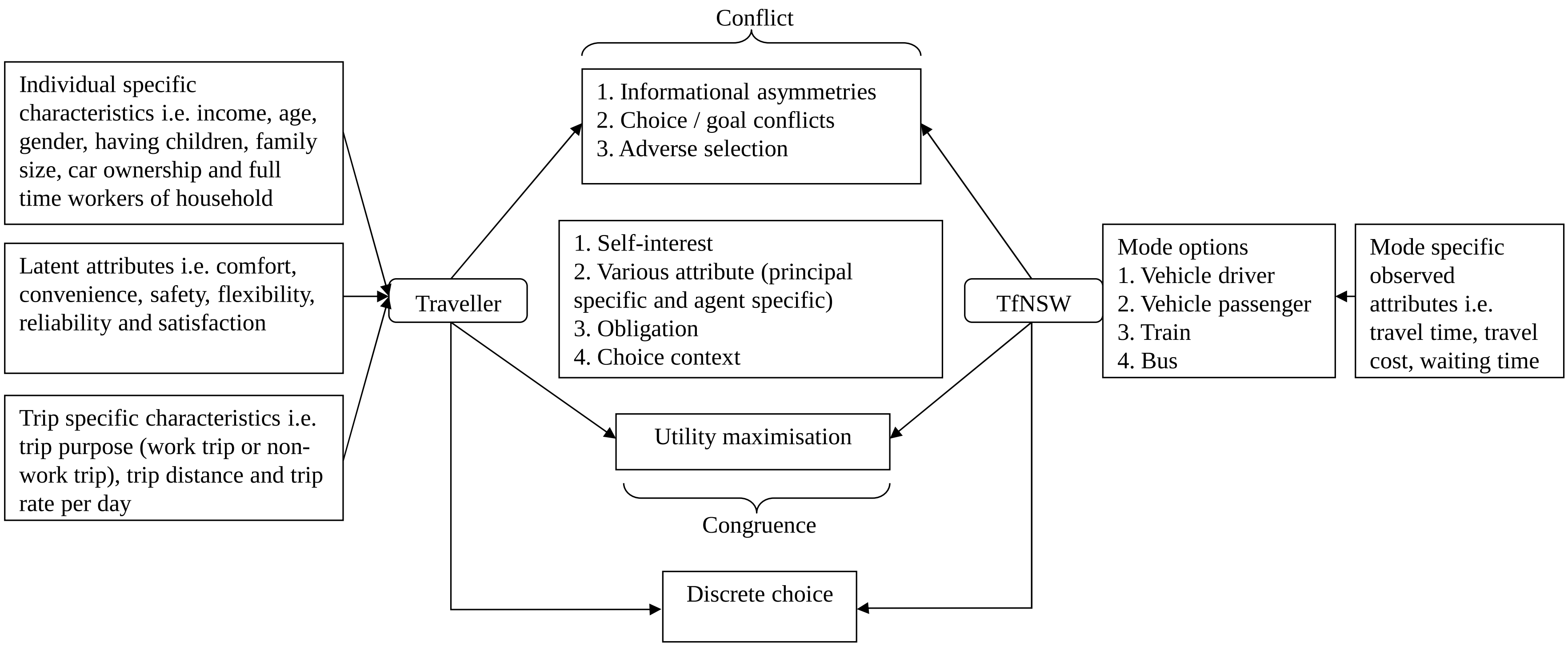


Figure 1.2 A behavioural agency model of traveller mode choice

Travellers prefer a particular mode that maximises the utility. In general, the choice process of travellers is dominated by traditional objective attributes (e.g. *travel time*, *travel cost*, *income*, and *trip distance*), but in real life, the latent attributes contribute remarkably to the determination of utility. The effects of choice attributes and the probability of using a particular mode are crucial aspects of transport mode services. Latent factors (e.g. *comfort*, *convenience*, *safety*, *reliability*), which have been treated as a 'black box', dominate the choice process considerably, in addition to objective variables (Anwar et al., 2011). The TfNSW is not fully aware about the traveller utility function and tends to ignore the latent factors, which causes goal/choice conflicts and adverse selection taken by TfNSW.

1.3 Motivation

The TfNSW provides various types of modal services, and the travellers are supposed to use modal services for their daily trips. At the same time, most of the travellers own private cars and, as a result, they feel comfortable using their cars. From the literature, it is observed that about 68.1% of travellers in Sydney Greater Metropolitan Area make their trips by private car (BTS, 2012). It implies that private car is more popular than public transport to the traveller, although the TfNSW gathers opinions from the traveller before any transport project is finalised. However, it is understood that TfNSW cannot provide the public transport services as per traveller expectation level because it has tended to ignore the 'black box' of traveller behaviour. Some attempts have been made to re-examine the nature of traveller behaviour (Morikawa et al., 2002; Johansson et al., 2006; Anwar et al., 2011, 2013a) to improve the explanatory power of choice models. There is no work on transport mode choice analysis in the context of PAT. Furthermore, economic theory has placed a great weight on consumer decision making process about the goods and services they purchase (Vick and Scott, 1998). However, consumers of transport services may experience disutility from being involved in decision making about the process of transport service implementation.

Although there is a diverse literature using PAT in various management fields, there has been no empirical work on the understanding of the principal-agent relationship in transport mode services. Amongst a variety of attributes that have been shown to be important in transportation planning and management, are the extent to which travellers are involved in decision making that is available for the traveller from TfNSW. Understanding the connection between traveller and

TfNSW is also relevant in the implementation of the transport policy where limitation of budget is concerned.

PAT depicts situations where one actor (the principal) hands over tasks, in a metaphoric contractual relationship (Kivisto, 2007), to other actors (the agents) so as to reach goals that the principal cannot reach alone. The central idea behind PAT is that the principal is not in a position to do a given job and so hires the agent. This inability also means that the principal cannot monitor the agent perfectly. Thus PAT can be used to understand whether the agency problem exists (e.g. goal conflicts/adverse selection) in transport mode services. This understanding provided personal motivation to work on this topic.

As mentioned earlier, traveller mode choice analysis has been used as a method to explore the principal-agent relationship between traveller and TfNSW. The travellers make their choices based on available options and objective attributes; such as travel time, travel cost, waiting time, etc. Besides these, there are other psychological factors (i.e. LVs), which extensively influence the travellers in their decision making process. With and without considering psychological factors in travel mode choice can have different impacts on travel behaviour and recommend changes in traveller preferences over recent decades. These changes act to form an agency problem in traveller mode choice, because it is difficult to realise the human behaviour properly due to the multifaceted human behaviour which is changeable over time. The TfNSW may not able to incorporate these factors into the planning and management process at a reasonable level and past researchers implicitly assume that traveller preferences are to be fixed and explained by TOAs. These reasons have provided motivations for this research to be carried out as well. Thus, the motivations of this research are threefold:

(i) No empirical study on understanding the effect of traveller choice attributes on transport mode services in the context of PAT;

(ii) Relevance of understanding the connection between traveller and TfNSW in transportation planning and this effect to transport policy; and

(iii) Small contribution to black box (i.e. latent factors) in traveller mode choice behaviour.

1.4 Research Issue and Focus

Issue: The principal-agent contract between traveller and TfNSW is metaphorical and both the traveller and the TfNSW are most likely biased to act in their self-interest, though it is assumed that TfNSW should maximise travellers' satisfaction. In the other words, TfNSW may not be able to fulfil travellers' expectation due to its budget constraint for example, and thus agency problem arises in transport mode services. Traveller preference heterogeneity may contribute to shape this agency problem. Furthermore, in general the TfNSW and transport planners often overlook travellers' latent choice preferences (black box) in the choice model that makes the principal-agent relationship between traveller and TfNSW vulnerable. Integrating traveller choice preferences in their mode choice process will help to improve the agency problem. Thus, the research issue are threefold:

(i) Understanding an principal-agent contract as a method of mode choice analysis between traveller and TfNSW from the perspective of PAT;

(ii) Shaping agency problem and relationship in terms of examining the traveller mode choice attributes; and

(iii) Suggesting an approach to reduce the agency problem in transport mode services.

Focus: This research is focused on understanding the principal-agent relationship within transport mode services. Traveller preference heterogeneity in mode choice is extensively and logically discussed from the perspective of PAT. A method of traveller choice attribute analysis is employed to determine the degree of connection between traveller and TfNSW and agency problem. An approach to reduce the agency problem is recommended by examining the mode choice probabilities. Traveller preferences according to a hierarchy of importance are noticed and this would assist in the formulation of a policy response.

1.5 Research Objectives and Questions

As per discussion above, *the broad objective* of this study is to *understand the effect of choice attributes on transport mode services in the context of PAT*. The broad objective can be broken down as below:

i) To analyse the traveller choice attributes to understand the principal-agent relationship within transport mode services;

ii) To suggest an approach to reduce the agency problem as a method of mode choice probability analysis; and
iii) Finally, to present a general discussion on principal-agent relationship within transport mode services and the policy implications.

Within the limits of this research objective, the following three *research questions* are to be answered:

i) What insights can PAT offer when it is used as a tool to explore the principal-agent relationship within transport mode services?
ii) How can choice attributes (observed and unobserved) be related to traveller mode choice shape this relationship?
iii) How can the agency problem to the relationship be reduced and improved?

In examining the first research question, the theoretical insights, with its relevance to the principal-agent relationship within traveller mode choice service as well as highlighting the overall power of PAT, is described.

The answer of the second research question outlines the effect of traveller observed and unobserved choice attributes in shaping the connection between traveller and TfNSW, as indicated in PAT. To understand the connection, traveller mode choice is analysed by considering mode and individual-specific attributes. The LVs are also incorporated in the analysis, to discover the true value of the principal-agent relationship in this context.

Finally, the third research question is addressed by iterating three hypothetical scenarios, as described in chapter 5. The scenarios are related to how the changes in attributes impact on the traveller mode choice behaviour and eventually, the principal-agent relationship between traveller and TfNSW could be improved in terms of modal service. That means the changed and unchanged conditions in choice attributes are applied to evaluate the improvement of the relationship.

1.6 Organisation of the Thesis

The thesis has been organised into seven chapters (Figure 1.3). The introductory chapter is followed by Chapter 2, which provides background material to this study. It reviews PAT, including agency problem and its application in a range of disciplines. Chapter 2 also discusses random utility theory, including enrichments of behavioural models, based on random utility. It then discusses the applications of discrete models in transportation arena. This chapter also includes comparative modelling research in choice analysis. Lastly, a research gap and contribution have been highlighted in this chapter 2.

Required data related to traveller preferences are defined in Chapter 3. Methodological aspects along with model specifications are also described in Chapter 3.

Chapter 4 deals with the empirical analysis that presents the critical analysis of traveller mode choice attributes. There are four sections in this chapter. The first part of this chapter narrates the structure of traveller preference attributes, determination of the objective attributes reflecting LVs in travellers' choice process. The importance of LVs is also discussed as a key aspect of traveller mode choice service. The second and third part are devoted to illustrate the empirical analysis to understand the effect of traveller choice attributes in modal service using random parameter logit (RPL) models. After investigating traveller preferences context, the last part of Chapter 4 demonstrates an inferred relationship between traveller and TfNSW.

Chapter 5 describes the temporal and parametric study. For temporal study, the 2008/09 and 2010/11 HTS data are used. In parametric study, an approach with changing condition has been proposed, and evaluated to determine their effects on the agency problem in transport mode services using an analysis of mode choice probability and this result indicates areas of improvement of the principal-agent relationship within transport mode services.

Chapter 6 presents a general discussion on the transport service provision in the context of PAT. Possible agency relationships within transport mode services are also figured out in this chapter.

Chapter 7 completes the study, presenting the insights and strengths of PAT, and concluding with remarks and policy implications. Furthermore, this chapter demonstrates the limitations of the study, along with some future research directions.

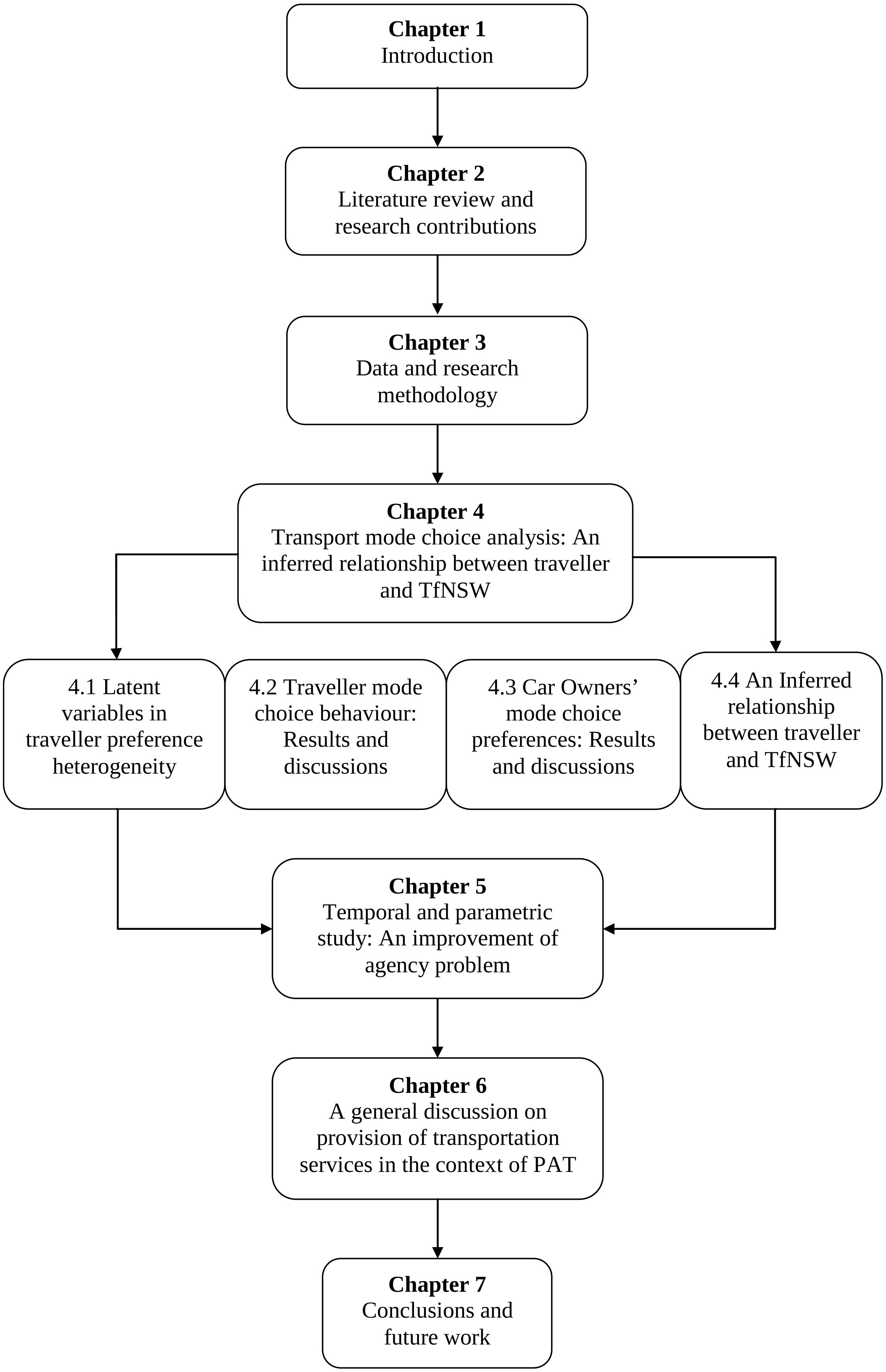


Figure 1.3 Thesis organisation

Chapter 2

Literature Review and Research Contributions

As discussed in Chapter 1, this thesis contributes to the understanding of the principal-agent relationship within traveller mode service. This relationship is interpreted by analysing traveller mode choice preferences. In order to achieve this, the travel demand model is enhanced by incorporating travellers' latent factors, to increase the behavioural richness of models based on Random Utility Maximisation (RUM) theory. To implement this, discrete choice (e.g. Random Parameter Logit) models are exercised and analysed in chapter 4. Chapter 2 therefore contains related background material to PAT and to the theories and models used. The first part of the chapter (section 2.1) reviews PAT and its application in various disciplines. The second part (section 2.2) is a review of travel demand theory and random utility theory. Moreover this section includes assumptions and recent efforts aiming at its enrichment, along with various applications in contemporary researches. The third part (section 2.3) illustrates comparative modelling research in choice analysis. Finally, section 2.4 and 2.5 concludes with research gap and research contributions respectively.

2.1 Principal-Agent Theory (PAT)

Though PAT is strongly influenced by the field of economics, the theory is not, and never has been the exclusive property of one particular discipline or paradigm. Rather, it applies theoretical insights that are used in different disciplines. Nowadays PAT is being used in a wide variety of fields, for example in education sector (Kivisto, 2005, 2007 and 2008; Ahmad et al. 2012; Rasmussen and Gulbrandsen, 2012), labour market segmentation (Cohen and Baruch, 2010), and many other fields. The most significant contribution to this theory was in the field of economics (Coase 1998), as it helped to assess the difficulties associated with the interaction between principal and agent to accomplish specific tasks (Rauchhaus 2009). Thus it investigates the association between principal and agent, and the agency problems of *goal conflicts* and *adverse*

selection and informational asymmetries (Kivisto, 2008; Zu and Kaynak, 2012; Rasmussen and Gulbrandsen, 2012; Ahmad et al., 2012). This is the core idea of PAT, and relevant to the principal-agent relationship within transport mode services.

2.1.1 Origin of the theory

The origin of PAT comes from economics, more specifically information economics (Moe, 1984; Kivisto, 2007). Moe (1984) described that PAT was developed to analyse more general questions of lack of information and risk sharing, among two or more parties. On the other hand, concerning contracts and ability of monitoring between groups/parties were influential motivation to develop PAT (Alchian and Demsetz, 1972; Jensen and Meckling 1976; Fama, 1980).

The mainstream theoretical research into agency is developed along two lines, which are referred to as the "positive theory of agency" ('positive stream') and "principal-agent" (Jensen, 1983; Eisenhardt, 1989). Thus the idea of PAT shares a common unit of analysis: the contract between the principal and the agent, along with some common assumptions of the theory. Jensen (1983) identifies problems in the nature of contract among self-interest maximising parties, and also agency cost minimisation from the both parties is expected. Furthermore, the concept of PAT is generally more abstract and not empirically oriented (Kivisto, 2007). The researchers, who apply PAT, are concerned about the general theory of principal-agent relationships such as lawyer-client, landlord-tenant, and employer-employee, rather than the principal-agent relationship within transport mode services. In other words, Eisenhardt (1989) observes that these two categories describe a similar entity, which is, for example, the contract between the principal and the agent, with common assumptions about people, organisations, and information. The idea of Positivist Agency Theory research is mainly to focus on identifying the situations between principal and agent, and is likely to have conflicting goals/choices among them. Furthermore, the positivist researchers have focused more exclusively on intra-organisational principal-agent relationships, especially shareholder-manager relationship (Kivisto, 2007).

The application of PAT has been increasing in the field of organisational and management studies (Kivisto, 2007; Kury, 2010; Block, 2011; Zona, 2012). In addition, the field of political science has been especially active in applying and developing PAT. Political scientist Barry M. Mitnick was probably the first scholar outside the discipline of economics to distinguish the

value of PAT (Mitnick, 1975). Another researcher Susan Rose-Ackerman (1978) discussed the chain of agency relationships in political-bureaucracy relationships. In the 1980s, the important contribution in analysing the PAT in different public sector settings was made by political scientist Terry M. Moe. The seminal paper "the new economics of organisation" written by Moe (1984) has been widely cited by researchers of different disciplines.

2.1.2 Concept of the theory

Initially, Jensen and Meckling (1976) defined PAT in the following words:

> *A contract under which one or more persons (the principal) engage another person (agent) to perform some service on their behalf, which involves delegating some decision-making authority to the agent (pp.308).*

In other words, Eisenhardt (1989) explains PAT as an agency relationship in which one party (the principal) delegates work(s) or task(s) to another (the agent) to perform the task(s). This relationship is developed between a *principal* and an *agent* with the metaphor of a contract. Based on the contract, it is assumed that the agent holds the skills, information, qualification, experience and abilities to perform the outlined entrusted task, and demonstrates a good outcome for the principal (Bendor et al. 2001; Kivisto, 2008).

Kivisto (2005) has pointed out that this theory has the ability to diversify applications over different disciplines, and it is not, and has never, been the exclusive property of a certain scientific paradigm. Authors Kivisto (2005, 2007 and 2008), Rasmussen and Gulbrandsen (2012), and Ahmad et al., (2012) have applied the knowledge of PAT in the education sector; Cohen and Baruch (2010) in the labour market; Vick and Scott (1998) and Scott and Vick (1999) in the health care sector; Thompson and McKee (2011) in hospital financing; Manatsa and McLaren (2008), and Zu and Kaynak (2012) in supply chain management; Whipple and Roh (2010) in the buyer-supplier relationship; and Zsidisin and Ellram (2003) in risk management. The most significant contribution of this theory was in the field of economics (Coase, 1998) as it helped to assess the difficulties associated with the interaction between principal and agent to accomplish specific tasks (Rauchhaus, 2009). Thus, it investigates the association between principal and agent that leads to *informational asymmetries* and *goal conflicts* called the *agency problem* (Kivisto, 2008; Zu and Kaynak, 2012; Rasmussen and Gulbrandsen, 2012; Ahmad et

al., 2012). However, very few applications can be found in the research on transportation research (Andreassen, 1995; Obeng, 2000).

Andreassen (1995) described that most of the public transportation services offered to the public would be performed by an agent appointed by the principal (i.e. local or central government). It is assumed that the principal designs contracts which reflect principal's interest/goals and also public services perform ideally when they are offered in accordance with the contract. But in reality, the service offers may or may not be in line with the preferences of the users, i.e. the citizens (Andreassen, 1995). In democracy the citizen get chance to reflect their political issue and priorities while election is conducted and citizens elect governments based on their programs.

Obeng (2000) explained the principal-agent relationship as a condition for profit maximising behaviour which is the separation of management from ownership or control. For example, there is a separation between management and control in public transit because the managers (agents) are hired employee; the major stakeholders (principals) are the transit boards, city councils, state government of transportation and the public in some cases.

2.1.2.1 Assumptions of the theory

Based on the literature related to PAT, few behavioural aspects regarding the principal, the agent and the agency relationship are found. The principal and the agent are considered to be self-interested actors. Moreover, some researchers of PAT theorise principals and agents as 'utility maximisers', whereas others do not explicitly make such an assumption. The utility maximisation assumption is especially important for those kinds of research where the consumer chooses the product that maximises the utility. Hendry (2005) argued that PAT has the ability to model and predict the utility maximisation assumption mathematically, in a way that would not be possible otherwise. Whether principals and agents are considered as utility maximisers or not, the assumed self-interest behaviour drives them to act 'opportunistically' towards each other (Barney and Ouchi, 1986).

Opportunism refers to a behaviour that involves a pursuit of self-interest with guile (Yaqub, 2009). Such behaviour may be exhibited, sequentially or simultaneously, by either one or both the parties, in an exchange relationship (Joshi and Stump, 1999). Brown et al. (2000) understood

that the partners might engage in opportunism even during actual formation of a relationship. They could even behave opportunistically after the relationship is launched, which may lead to 'moral hazard'. Moral hazard is an effort to maximise their own wealth and agent may face a dilemma of acting against the interest of principals (Sarens and Abdolmohammadi, 2011).

It may assume that the type (capability) of agents differs according to their experiences and skills, which is another important issue. This type of agent may be described as productive or unproductive, talented or untalented, trustworthy or untrustworthy, and so on (Kivisto, 2007). In the other words, the types explain something about the agent's 'willingness' and 'ability' to perform the entrusted tasks by the principal. It is also sometimes assumed that 'outcomes' of PAT is influenced by 'environmental factors' (Harris and Raviv, 1978; Petersen, 1993). The outcome is usually visible to both the agent and principal in terms of quality and quantity, for example.

Finally, most of the agency theoretical literature adopts two very important assumptions relating the agency relationship. These are (i) informational asymmetries, and (ii) goal conflicts. They exist simultaneously in the relationship (Moe, 1984; Eisenhardt, 1989; Barney and Hesterly, 1996; Waterman and Meier, 1998).

(i) Informational asymmetries

Informational asymmetries arise when "the agent possesses more or better information about the tasks assigned to him, his own skills, actions, abilities, and preferences compared to the principal" (Ahmad et al., 2012). The level of informational asymmetries does not need to be stable and it can vary from one situation to the next. Informational asymmetries deal with the exchange of information and interactions between two parties in performing the specific tasks. These asymmetries create an imbalance of information flow that causes adverse selection and moral hazard problems (Zu and Kaynak, 2012). Thus the principal not only lacks full access to the information, but also the agent may hide certain information.

Saam (2007) describes various situations of informational asymmetries where the principal does not have access to accurate information:

- *Hidden characteristics*. This occurs due to incomplete information about the agent's skills or abilities, unless agent starts contract.
- *Hidden intentions*. This situation occurs when the agent act deliberately unfairly with the principal after contract and the principal cannot resign from the contract, because of the risk of losing the capital that is invested already.
- *Hidden knowledge or hidden information.* This problem arises after a contract between principal and agent. The working environment, what the agent is given, is relevant to agent's outcomes and this knowledge may be used opportunistically by the agent.
- *Hidden action*. This problem also occurs after a contract. The agent can choose a different course of actions that are different from the original agreement with the principal, called 'adverse selection' (Sarens and Abdolmohammadi, 2011).

(ii) Goal/choice conflicts

Goal conflicts happen in "a situation where the principal's and agent's desires and interests on certain tasks are in conflict with each other and that, they would therefore prefer different courses of action" (Ahmad et al., 2012). In other words, goal conflicts may arise where the agent's interests differ from principal. Zu and Kaynak (2012) describe that when no goal conflict exists in an agency relationship, agents will behave as principals expect, whether agent's behaviour is monitored or not. In PAT, goal conflicts arise due to agent's self-interest and the propensity to maximise individual utility/satisfaction. It is important to align agents' goals with those of the principals (Ekanayake, 2004). However, it is assumed that goal conflicts arise in the process of delegating authority from principal to agent (Alvarez and Hall, 2006). With the set terms and conditions in the contract, the agent's actions may be restricted to achieve the fixed goals assigned by principal. But the agent may employ hidden actions that hinder attaining the goals outlined in the metaphoric contract (Eisenhardt, 1989). In this way, goal conflicts are described as a main reason behind agency problems.

2.1.2.2 Principal-agent (Agency) problem/uncertainty

Informational asymmetries and goal conflicts together constitute the agency problem, also known as *moral hazard* and *adverse selection* (Waterman and Meier, 1998; Braun and Guston, 2003; Kivisto, 2008; Reeves et al., 2010; Sarens and Abdolmohammadi, 2011). Whereas moral hazards originate from informational asymmetries while a contract is in effect, adverse selection is the result of informational asymmetries prior to entering into a contract (Rauchhaus, 2009).

The agency problem may arise when an agent pursues self-interested goals at the expense of the principal's goals (Kivisto, 2008). Self-interest may make the agent reluctant to share information about the performance, and can also motivate the agent to send incorrect information to the principal (Bergen et al., 1992).

In the context of the principal-agent relationship, actions and efforts taken by TfNSW may not fulfil the travellers' expectation because of TfNSW's budget constraints, poor planning and management, for example. For this reason, TfNSW may show opportunistic behaviour towards government's interest. Both at the individual and organisational levels, this type of behaviour can take place. According to Kivisto (2007), possible manifestations of opportunistic behaviour could include: (1) *shirking* i.e. where agents either do less than expected or where they do not perform the expected kind of action; (2) *opportunistic pursuit of prestige and revenues*; (3) *opportunistic cross subsidisation*; and (4) *the distortion of monitoring information*.

Adverse selection occurs when the principal is unable to determine whether actions taken by agent are in the best interest of principal (Reeves et al., 2010; Sarens and Abdolmohammadi, 2011). In circumstances of adverse selection, the probability of goal conflicts is increased due to less informative principals. The agent may be induced to act in their self-interests by using the principal's asset (Ahmad et al., 2012). Since it is difficult for the principal to monitor the agent activities and measure outcomes, though both parties enter a contract to achieve some goals, *moral hazard* has occurred. Moreover, Darrough and Stoughton (1986) describes moral hazard as a situation when the action undertaken by the agent is intangible and has a different importance to the agent as compared to the principal.

2.1.3 Applications of PAT in various fields

Various researches using methods of PAT have been conducted, in a range of disciplines. Although a little amount of application of PAT is found in existing research, there is still a space to analyse the depth, origins, different forms and functions of PAT in this new discipline. A substantial number of empirically oriented researches, using quantitative and qualitative methods, of PAT have also been conducted in different disciplines. The following sections describe the content and main findings of those studies.

2.1.3.1 Theory testing studies

Some studies have examined the capacity and insights of the theory to examine the relationship between identified principal and agent and predict the scenario. Commonly, the agency problem has been identified to demonstrate the behaviour or outcome based contracts that can help to solve these problems. Kivisto (2008) examined the agency theory in the context of the government-university relationship, along with the strengths and weakness of the theory. He empirically increased understanding of the applicability of agency theory in the government-university relationship. Ahmad et al. (2012) has also discusses the PAT and its relevance to the study of government-university relationship.

Wiseman et al. (2012) suggested that institutional features should be taken into account as formal variables that retain the key assumptions and structure of agency theory within a deductive research model. Thus the applicability of agency theory to a variety of settings could be enhanced. In this manner, they aimed to respond to critics of agency theory, who note that the theory was not applicable outside a narrow context dominated by egocentric agents, seeking only to maximise wealth at the expense of the principal. In advocating a deductive research approach, they also criticise inductive research, claiming that, through its emphasis on context-specific issues, it is unable to offer generalised propositions that can be applied across institutional settings. Heracleous and Lan (2012) also suggested that inductive studies can not only be more sensitive to institutional features than deductive studies, but can also offer deeper understanding of governance practices in specific contexts. They also have the potential for analytical generalisations. Thus, they recommended that making agency theory institutionally sensitive is reasonable.

2.1.3.2 Studies in supply chain management

More recently, Supply Chain Management (SCM) scholars have shown growing interest in using agency theory to understand how participants within the supply chain (SC) manage risks, align incentives and forge relationships (Halldorsson and Skjott-Larsen, 2006; Ritchie et al., 2008; Norrman, 2008; Shook et al., 2009; Zomorrodi and Fayezi, 2011; Zu and Kaynak, 2012; Fayezi et al., 2012).

Zu and Kaynak (2012) described the buying firm as a principal that delegates the authority of production and/or services to the supplier (the agent) in their supply chain research. Along with

the delegation of production and services, the responsibility of maintaining a satisfactory quality of the supplied products and services is also delegated to suppliers. Thus buying firms need to ensure that suppliers provide products and/or services that conform to the quality requirements stipulated in the supply contracts (Starbird, 2001; Zsidisin and Ellram, 2003; Zomorrodi and Fayezi, 2011; Zu and Kaynak, 2012). This illustrates the enhancement of understanding of the relationship flexibility in supply chain environments. Flexible buyer-supplier relationships would be invaluable in times of crisis and when uninterrupted service to customers deemed essential (Braunscheidel and Suresh, 2009). In this regard, a concept of elasticity in buyer-supplier relationships has been introduced and explained as an important element of relationship flexibility.

2.1.3.3 Studies in education sector

The use of PAT is becoming popular in the education sector, such as the government-university relationship (Kivisto, 2005, 2007, 2008; Rungfamai, 2008; Ahmad et al., 2012). In today's competitive market, and its emphasis on productivity, the government now demands that Higher Education Institutions (HEI's) are economically productive and fulfil the goals outlined in the government's strategic plan (Lane and Kivisto, 2008). Since the government provides HEIs with funding from the taxpayer, it also demands that HEIs agents produce a certain level of output beneficial to the public, and make information available to the public (Leruth et al., 2006). There are various issues from autonomy, accountability, governance, market pressure to lack of funds that have become key in the discussion of the government-HEI relationship (Kivisto, 2005, 2008; Lane and Kivisto, 2008; Global University Network for Innovation, 2009).

2.1.3.4 Studies in transport management

Andreassen (1995) pointed out that most of the public services offered to the public are performed by an agent appointed by the principal, i.e. local or central government. The service offered by the transport operator may or may not be in line with the preferences of the users, i.e. the citizens. Public services are offered to the users based on the double principal-agent relationship, i.e. citizens-government, and government-operator. Finally, the relationships among customer preferences, customer satisfaction, and customer segments have been determined in his study. Because of the low degree of congruence between customer preferences and service category differences, the public transportation industry offers low utility, i.e. low overall satisfaction (Andreassen, 1995).

Huang et al. (2004) conducted another study relating to salesperson salary issues from the agency theory and management perspectives in the Taiwan travel industry context. As a sound salary system could be an effective means to achieve principal's (owner or manager) goals, they found performance-based salary system as more reliable to reduce the agency problem between principal and agent (salesperson). To do that, the principal must measure the effects before deciding on a salary system (Lim and Tang, 1999).

Profit maximising behaviour in transit system is analysed considering a method of the separation of management from the ownership or control, i.e. a principal-agent relationship (Obeng, 2000). There is a separation between management and control in public transit system because the managers (agents) are hired employees. The major stakeholders (principals) are the transit boards, city councils, state departments of transportation in some cases, and the public. Because of high costs, it is only in rare situations that the principals can monitor the activities of the agents to ensure they follow cost minimisation principles. Consequently, the agents may pursue self-interested objectives, different from those established by the principals. Such a principal-agent relationship has been examined by Strausz (1997) who showed that the delegation of monitoring to a third party can be profitable, i.e. reduce agency costs.

2.1.3.5 Risk/uncertainty studies

Outcome and behaviour-based contracts are the two types of management risk (Choi and Liker 1995; Lassar and Kerr 1996; Eisenhardt 1989). In the context of inbound supply, outcome-based management efforts reflect the extent that purchasing organisations emphasise results. Complete reliance on outcome-based efforts signifies an exclusive concern with bottom line results, regardless of how suppliers achieve them (Choi and Liker 1995). As uncertainty becomes insignificant, an agency theory perspective supports outcome-based supply risk management efforts as appropriate (Eisenhardt 1989). Without unnecessary intervention into supplier operations, supply is more efficiently managed on the part of the purchasing organization. Zsidisin and Ellram (2003) indicated that purchasing organizations address various sources of supply risk by implementing management techniques that reduce the likelihood that detrimental events will occur.

2.1.4 Summary of discussion related to PAT

PAT assumes that agent has more information than the principal (Grammenos and Papapostolou, 2012), a condition that is known as *informational asymmetry*. This adversely affects the principal's ability to monitor the agent's activities. Another assumption of PAT is that principal and agent act rationally and try to maximise their interests, which ultimately results in a conflict of interest. This is referred to as "*moral hazard*" (Jensen and Meckling, 1976), which indicates the dilemma of acting against the interest of the principal as the agent tries to maximize their own. Since the principal does not have access to a decision that is made by an agent, they are unable to monitor whether the agent's action(s) are in their best interests. This is called *adverse selection*. To reduce the chance of these problems (moral hazard and adverse selection), principals and agents engage in contracting in order to achieve Pareto-optimality (Sarens and Abdolmohammadi, 2011). This means an optimal outcome by which no-one could be made better off without making someone else worse off.

While authors such, as Ferris (1991), Whynes (1993), Scott and Vick (1999), Zsidisin and Ellram (2003), Bastos and Pindado (2007), Whipple and Roh (2010), Thompson and McKee (2011), Sarens and Abdolmohammadi (2011), Zu and Kaynak (2012), and Rasmussen and Gulbrandsen (2012) etc. have applied the knowledge of PAT to their respective fields in the area of management, little application can be found in transportation research. Where it has been applied in this area, PAT has been used to investigate the relationship between the government and service operator (Hensher et al., 2007; Hensher et al., 1996) but ignored the travellers' desires, which in fact influence government' decision making process. To date, exploring a principal-agent relationship in transport mode services by analysing travellers' mode choice process, is a new challenge and has not yet been analysed. Therefore, this research took the opportunity to work on this issue, which to the best of the author's knowledge has a novel application in transportation research.

2.2 Travel Demand Theory

As mentioned earlier, traveller mode choice analysis is the key approach in this research to investigate the principal-agent relationship in transport mode services. Thus the following section describes the traveller mode choice behaviour and the techniques and methods to analyse those behaviours.

2.2.1 Brief history

Until the 1960s, the dominant tool for travel demand analysis was the gravity model that described aggregate traffic between origin and destination zones in terms of zonal attraction and generalized cost. The model was reasonably successful in describing highway flows but encountered major challenges when modal split was dealt with, particularly dealing with public transportation. This model didn't consider traveller preference heterogeneity at all.

Disaggregate behavioural travel demand analysis, based on Random Utility Maximization (RUM), has been the most commonly used approach since the 1970s (McFadden, 2000). This method forms components of both traditional four-step models and the newer activity based models. It is used in both short-term decisions such as mode choice, route choice, and departure time choice, and long-term decisions such as car ownership and residential location (McFadden, 2000).

More recently, partially as a result of criticism of its lack of behavioural realism (McFadden, 1999), the RUM based transportation models have started to draw on findings from sociology, cognitive psychology, and marketing research (McFadden, 2001). There is a diversity of efforts in the different direction of enriching the travel demand models (Ben Akiva et al., 2002b; Adamowicz et al., 2008).

2.2.2 Random utility models

Extensive discussions of the micro-economic and psychological underpinnings of Random Utility Models can be found in MaFadden (1973), Manski and Lerman (1977) and so on. The model is based on the notation that the individual derives utility by buying or choosing an alternative. The individual is postulated to pick that alternative which maximizes his/her utility. Since the utilities are not known to the analyst, they are treated as random variables. More specifically, the random utility of an alternative can be expressed as a sum of observable and unobservable components as:

$$U_{ij} = V_{ij} + \varepsilon_{ij}, \ \forall j \in C_i \qquad (2\text{-}1)$$

Where, U_{ij} = random utility of alternative j for individual i;

V_{ij} = observable (systematic) component of utility;

C_i = choice set available to individual i with $|C_i|= T_i$; and

ε_{ij} = random component of utility.

The systematic component V_{ij} is written as:

$$V_{ij} = V(X_{ij};\ \beta) \qquad (2\text{-}2)$$

Where, X_{ij} = attributes of alternative j and characteristics of individual i; and β = parameter vector

Further under the maximum utility decision rule, the event that alternative *i* is chosen is linked to the random utilities as:

$$\{i\ chosen\} \Leftrightarrow \{U_{ij} \geq U_{it}\}\ \ \forall t \qquad (2\text{-}3)$$

Consequently, the probability that alternative *i* is chosen by *n* is written as:

$$Pr(j\ chosen) = Pr(U_{ij} \geq U_{it})\ \ \forall t \qquad (2\text{-}4)$$

A class of probabilistic choice models can be constructed by appropriate specifications of the joint probability density of ($\in_{1i}$ ..., $\in_{Ti}i$). For example, if it is assumed that ε_{in} are independently and identically distributed Gumbel across alternatives and individual with scale parameter set to 1 and location parameter set to 0, the choice probability is obtained in a closed form expression referred to as the Multinomial Logit (MNL) model with:

$$\Pr\left(y_{ij} = 1 \middle| X_i ; \beta\right) = \frac{\exp\left(V_{ij}\right)}{\sum_{t \in = C} \exp\left(V_{ij}\right)} \qquad (2\text{-}5)$$

Where

$$Y_{ij} = \begin{cases} 1, \text{ if alternative j is chosen by individual i, or} \\ 0, \text{ otherwise.} \end{cases}$$

$$X_i = \{X_{ij},\ \forall_j \in C_i\}$$

2.2.3 Random utility maximisation (RUM)

Many statistical methods have been developed to model travel mode choice but the standard tool is discrete choice analysis based of Random Utility Maximization (RUM) theory. Discussions regarding economics and the psychological groundwork are available in McFadden (1973), Manski and Lerman (1977).

The model postulates that individuals derive utility by choosing an alternative that maximizes their utility. Since the utilities are unknown to researchers, they are treated as random variables. More specifically, the random utility of an alternative can be expressed as a sum of observable (i.e. measurable or systematic term) and unobservable (treated as random) and error term components. The observable component includes attributes of alternatives and characteristics of individuals. The random component includes four sources of uncertainty, as identified by Manski and Lerman (1977) – (i) unobserved alternative attributes, (ii) unobserved individual characteristics, (iii) measurement error, and (iv) instrumental variables.

The outputs of the models are the probabilities of individual choosing each alternative. These individual probabilities can be aggregated to forecast the population.

2.2.3.1 RUM assumptions

RUM models have their foundation in classic economic consumer theory, which is the source of many important assumptions for the models. The central assumption is the rationality assumption, which has been categorised by McFadden (1999) into three types: (i) perception rationality, (ii) preference rationality and (iii) process rationality. Put simply, economic theory often assumes that people are rational agents with stable preferences, who are able to collect all the necessary information, calculate the utilities from the various options and choose the one with maximum utility. An important feature of the theory is the consumer sovereignty property that preferences are predetermined in any choice situation, and do not depend on what alternatives are available, i.e. desirability precedes availability (McFadden, 2001).

2.2.3.2 Enrichment of RUM

Though RUM has deficiencies such as inadequacy of the behavioural process and violation of perception/preference/process-rationality (Zeid, 2009), a substantial amount of work has been

done over the last few decades to enrich it, by modifying or enhancing certain assumptions or components of the standard model in a way that preserves its basic structure.

Behavioural models based on random utility have recently started to incorporate several of the psychological constructs that affect decision-making. In discrete choice models, a framework that has been proposed for doing that is the Hybrid Choice Model (HCM) (Ben-Akiva et al., 2002a; Walker and Ben-Akiva, 2002). The HCM combines a choice model (based on random utility) with a latent variable model. The latent variable model adds behavioural richness as it can be used to model the formation of latent (unobserved) psychological constructs. These include attitudes, perceptions and through their linkage to the choice model, allow a representation of the effect of these constructs on preferences. The evolution of psychological constructs can also be accommodated within a dynamic version of the HCM that combines a Hidden Markov model with a discrete choice model (Ben-Akiva et al., 2006; Choudhury et al., 2007a, 2007b). A latent class model may be added to this framework to reflect latent segmentation of the population, choice set formation, and decision protocols other than utility maximization (Gopinath, 1995).

2.2.4 Statistical methods in transportation research

2.2.4.1 Latent variable model (LVM)

A general approach to synthesising models with LVs and psychometric-type measurement models has been developed by Bentler (1980). Specifically these models assume that the indicators are continuous and the relationships between the observed and LVs are linear. Such a model consists of two parts: a measurement model and a structural model. The first part specifies how the LVs are related to the indicators and the second specifies the relationship between the LVs. Such models are widely used to define and measure unobserved factors in psychology, sociology and economics. The socio-economic variables can also be introduced into the structural part of the model to produce the Multiple Indicators and Multiple Causes (MIMIC) model.

The MIMIC models belong to the general class of latent variable models (LVMs). A latent variable may be defined as an unobserved variable, conceptual or "true" (without measurement error), and it may be represented by two other variables: an observable proxy, or indicator variable, and a measurement error. The fundamental concepts of LVM were first introduced

almost ninety years ago by the population biologist Wright (1921) at the University of Chicago, and their modern development is based on Zellner's (1970) and Goldberger's (1972) ideas. An early version of the LVM model was introduced and econometrically elaborated by Joreskog and Goldberger (1975). Since then an important convergence in this methodology between psychometrics, socio metrics and econometrics has taken place with econometrics, contributing identification and estimation techniques within the structural errors-in-variables modelling (Lewbel, 1998; Schennach, et al., 2007). Technical overviews on SEM (Structural Equation Modelling) include Bollen (1989), Hoyle (1995), and Marcoulides and Schumacker (1996).

Other recent developments have advanced ways to make use of psychometric indicators and explicitly treat latent constructs such as attitudes and perceptions in discrete choice models. This provides more realistic behavioural descriptions of travel decision making (McFadden 1986; Ben-Akiva et al., 1994; Ben-Akiva et al., 2002a; Morikawa et al., 2002; Ashok et al., 2002; Johansson et al., 2006; Temme et al., 2008).

2.2.4.2 Latent class model (LCM)

Modelling heterogeneity in travel behaviour across individuals has been one of the application of the use discrete choice models. Traveller behaviour heterogeneity includes both observed and unobserved heterogeneity, which constitute very different levels of complexity in the model.

The observed heterogeneity can easily be integrated in mode choice models. Thus, the individual socio-economic and demographic characteristics, level of service and the individual characteristics variables can be included in the systematic portion of the utility function.

Unobserved heterogeneity may result from unobserved decision protocols, unobserved choice sets, unobserved taste variation and unobserved attributes (Gopinath, 1995). Two key techniques have been advanced to account for the unobserved heterogeneity in choice models: a latent class model (finite mixture model) and a random coefficient model, such as the mixed logit model. A recent study by Green and Hensher (2003) compared the latent class choice model with the mixed logit model in an example of drivers' road type choice in New Zealand and argued that each model has its virtues and limitations. In this research, author chooses to apply the latent class model because of the following two advantages over mixed logit model: (i) unlike mixed logit model, the latent class model does not require the analyst to make a specific assumption

about the distribution of parameters across individuals; and (ii) the latent class model explicitly links preference heterogeneity to socioeconomic and demographic characteristics. Latent class models can be used to capture unobservable segmentations in the population regarding tastes, choice sets, and decisions protocols (Gopinath, 1995).

Latent class analysis was introduced to choice models by Swait (1994), Ben-Akiva and Boccara (1995) and Bhat (1997). Gopinath (1995) provided a comprehensive treatment of latent class models in the choice context and applied it to travel demand analysis, including intercity travellers' mode choice, allowing for different decision protocols among classes, and modelling shippers' choices between trains and trucks allowing for different sensitivities to time and cost. Ben-Akiva and Boccara (1995) modelled commuters' mode choice allowing different choice sets among travellers. Also in the marketing research context, the latent classes are typically interpreted as market segments (Dillon et al., 1994). The same principle holds that the overall population is composed of a mixture of heterogeneous subgroups, each of which consists of similar individuals.

Very recently, Islam (2014) and Louviere et al. (2013) introduced a scale adjusted latent class model (SALCM) to capture scale (variance) heterogeneity in addition to preference heterogeneity. Islam (2014) employed bass diffusion model (member of SALCM family) to establish a causal link between the attributes of the technology, attitudinal constructs, socio-demographics and adoption time probabilities. In order to implement this model, the author followed three steps in the methodology: a discrete choice experiment where the respondents state their preferences for the attributes of solar panels; an estimation phase that provides expected preferences for each household; the use of an innovation diffusion model to make time series forecasts. More specifically, this study measured the household level preferences for solar PVs and used these preferences as antecedents to predict innovation diffusion for solar PVs according to household characteristics (i.e. socio- demographics and attitudinal constructs). In the other hand, Louviere et al. (2013) discussed about the best-worst scaling (BWS) approach to illustrate a choice-based experiment method to analysis preferences for weekend getaways and academics' perceptions of quality of marketing journal. They found that adoption of BWS approach was increasing in academic users and thus the paper was involved to describe and discuss ways to implement, analyse and interpret BWS applications and a large number of

objects (e.g. the academic journals), making it accessible to many academic an applied researchers.

2.2.4.3 Applications of SEM in transportation

Most applications of SEM have been in psychology, sociology, the biological sciences, educational research, political science and market research.

Golob (2003) offered a summary of the application of SEM in travel behaviour research including more than 50 studies up to 2003. These studies range from travel demand modelling using cross-sectional data, dynamic travel demand modelling, activity based travel demand modelling, applications to capture attitudes, perceptions and hypothetical choices, organizational behaviour and values, and driver behaviour. Below are 14 examples of the applications to capture attitudes, perceptions and hypothetical choices:

i) Dobson et al. (1978) used structural models to examine the attitude-behaviour relationship and concluded that attitudes are conditioned by choices, while at the same time, attitudes affect choices. A mutual dependence between attitudes and behaviour was demonstrated in the data gathered from Los Angeles central business district workers and behavioural choice situations; behaviour and attitudes concurrently cause each other. In addition it was examined in this paper that two attitudinal components, perceptions of, and affect toward, a mode, function differently with respect to travel behaviour.

ii) Golob and Henser (1998) employed SEM to examine the relationship between an individual's travel behaviour and his/her support for policies that are promoted as benefitting the environment. The authors determined whether attitudes concerning the threat of Greenhouse Gas Emissions (GGEs) and the effectiveness of incentive and disincentive schemes aimed at reducing vehicle emissions could have any influence on travel behaviour. They might provide guidelines to promote environmentally sensitive behaviour, policies to the public by providing information to influence public opinions.

iii) Jakobsson et al. (2000) used a SEM with five LVs in investigating the causality among acceptance of road pricing, behavioural intention concerning reductions in car usage and feelings related to fairness and infringement on personal freedom. These LVs are (i)

expectation of others' car use reduction, (ii) intention of car use reduction, (iii) infringement on freedom, (iv) acceptance of road pricing, and (v) fairness).The results showed that acceptance of road pricing was negatively affected by perceived infringement on freedom and unfairness which in turn increase with intentions to reduce car use.

iv) Golob (2001) developed several joint models of attitude and behaviour to explain how both mode choice and attitudes regarding a combined High Occupancy Vehicle (HOV) and toll lanes differ across the population. These models were estimated based on a dataset from San Diego, California, USA. The study demonstrated that some personal and situational explanations of opinions and perceptions were attributable to mode choices. Furthermore, the perceptions were independent behaviour and dependent only on exogenous personal and household characteristics. With respect to linkages between attitudes and behaviour, none of the models found any significant effects of attitudes on choices; the cause-effect links were from behaviour to attitudes.

v) Kitamura and Susilo (2005) employed structural equation modelling to examine the stability in travel over time. To cover the different time scenarios, they repeated cross-sectional data from Kyoto-Osaka-Kobe metropolitan area of Japan in 1980, 1990 and 2000. The statistical analysis of this research indicate that the structural relationships are unstable, that changes in non-workers' travel patterns are largely due to the instability in the structural relations. While changes in demographic and socio-economic factors play relatively minor roles, urban residents' travel has the tendency to expand over time.

vi) Ory and Mokhtarian (2009) used SEMs to examine the relationships among travel amounts, perceptions, affections, and desires across five short-distance (one-way trips of less than 100 miles) travel categories (overall, commute, work / school-related, entertainment / social / recreation, and personal vehicle). These models were established using data collected in 1998 from more than 1300 working commuters in the San Francisco Bay Area. The robust relationships found across the five travel categories include the amounts of travel influencing perceptions, and both perceptions and affections shaping desires.

vii) Choocharukul and Fujii (2008) investigated the psychological effects of travel behaviour on preference of residential location choice using SEM, based on 176 samples from two cities in Thailand, the preference regarding residential location was significantly affected by a behavioural intention towards the car usage.

viii) Kim and Kim (2009) described a reasonable method of analysing automobile users' empirical cognition on travel mode choice. They also defined the concept of Automobile User Value (AUV). The analysis framework has been developed considering the Customer Value and Service Quality (SERVQUAL) method. AUV has been divided into expected value and perceived value, and evaluated by SERVQUAL method.

ix) Temme *et al.* (2008) presented an Integrated Choice and Latent Variable (ICLV) model to examine the travel mode choice of 907 German commuters. The latent factors were examined to improve the power function and hedonism as well as unobserved factors. Hierarchical relationships between the LVs (specially the value-attitude hierarchy) were estimated simultaneously with the mode choice model.

x) Walker and Li (2007) employed a latent class model to represent lifestyle indicating preferences towards a particular way of living in three heterogeneous lifestyle groups – suburban dwellers, urban dwellers and transit-riders, and examine how lifestyle impacts residential location decisions.

xi) Johansson et al. (2006) hypothesised that differences in people’s attitudes and personality traits lead them to attribute varying importance to environmental considerations, safety, comfort, convenience and flexibility. They modelled these five LVs while considering three alternative travel models and examined the effects of attitudes and personality traits on mode choice. Based on a commuter survey in Sweden, the paper found that both attitudes towards flexibility and comfort, as well as being pro-environmentally inclined, influenced the individual’s choice of mode. Though the paper quotes the integrated choice and latent variable framework (Ben-Akiva et al. 1999), the model is examined in two steps where the LVs are estimated in a MIMIC model first and then the discrete choice model is estimated, instead of being considered simultaneously.

xii) Choo and Mokhtarian (2004) explored the effect consumer's travel attitudes, personality, lifestyle and subjective mobility as factors that affect the vehicle type choice. They developed a disaggregate choice model of vehicle type based on these factors, as well as typical demographic variables using MNL approach. Based on the 1998 San Francisco Bay Area survey, the authors found that these LVs significantly affect an individuals' vehicle type choice.

xiii) Ashok et al. (2002) presented several full information models that can accommodate LVs, such as attitudes and satisfaction, within the context of binary and multinomial choice models. The authors accomplished it by integrating structural equation models within the basic framework of binary and multinomial choice models. The first application was a binary switching model of cable television providers, including latent factors satisfaction (with three indicators) and barriers (with five factors). To control the respondent choice dependency, the correlated response model was used by asking the respondents repeated choices. The second application was in the context of health care providers with two LVs – satisfaction with cost and satisfaction with coverage. A finite mixture model (latent class) is used to test the heterogeneity in the individuals' choice behaviour. Two latent segments are identified with different sensitivities to the satisfaction of cost. Both models are estimated simultaneously by programming maximum likelihood in computer software GAUSS.

xiv) Rossetti et al. (2002) addressed the complex task of modelling drivers' behaviour through the use of agent-based techniques. With assumptions such as exogenous information may exert on drivers' decision making, an extension to an existing microscopic simulation model, called Dynamic Route Assignment Combining User Learning and microsimulAtion (DRACULA), was proposed. In this extension, the traffic domain was modelled as a multi-agent world including drivers' mental attitudes, which might allow rational decisions about route choice and departure time. This work was divided into two main sections. Section one described the original DRACULA framework and the extension proposed to support our agent-based traffic model. The second part was concerned with the reasoning mechanism of drivers modelled by means of a Beliefs, Desires, and Intentions (BDI) architecture.

2.2.4.4 Incorporating LVs in choice models

The constraints on data availability to capture the psychological factors are real and serious. In contrasts to socio-economic information, for which there are well established institutions such as Census Bureau in the US and the Office for National Statistics (ONS) in the UK responsible for collecting data. Data collection on peoples' psychological states such as attitude, perception and personality are limited in range of coverage, inconsistent in methodology, and ad hoc in availability. Transportation agencies rely on the social infrastructure for data collection and are therefore constrained by the data availability on these latent factors. In the 1970s, the data required for disaggregate travel demand analysis was obtained by surveying individuals on their travel behaviour, through home and telephone interviews, and particularly through travel dairies. Later, on-board travel surveys were developed thanks to choice-based sampling techniques (Manski and Lerman, 1977). Some agencies have undertaken customer research that includes elements of psychometric questions to understand travellers' psychological concerns. For example, Transport for London is familiar in this area by engaging in research such as Central London Congestion Charge Social Impact Surveys 2002 and 2003 (Transport for London, 2004).

In Australia, the NSW (New South Wales) transport department (Transport for NSW, or TfNSW for short) are undertaking a Household Travel Survey (HTS) and a customer satisfaction survey, regarding buses and the Cityrail (heavy) rail network, on a regular basis. The first Cityrail survey was in 2004 and the first bus customer satisfaction survey was conducted in 2009. Since their commencement, they both have been conducted annually.

Transport for NSW (formerly known as the Department of Transport NSW) has carried out two separate questionnaire surveys including psychometric questions to learn about the customers' views on bus and rail services in NSW. These are the Survey of City Rail Customers 2010 (Department of Transport NSW, 2010) and Survey of Sydney metropolitan bus users 2010, New South Wales (Department of Transport NSW, 2010). The 2010 survey was undertaken at a time when train users were experiencing good operational performance, with train on-time running consistently above the 92% target. However, this is gradually decreasing over the six months prior to the survey. Patronage levels were essentially the same as in 2009. Compared with the 2009 survey, there were improvements in train users' perceptions of punctuality and frequency of trains, delays and cancellations, removal of litter from stations and personal safety on stations and trains in the evenings. There were however significant decreases in satisfaction related to

knowledge and helpfulness of staff and information about delays and cancellations. Reported customers' experiences of delays and crowding were similar to that reported in the survey 2009 and reflect the similar operational performance and patronage levels in the two survey reference periods. Crowding in peak hours still remained the aspect of service with the highest level of dissatisfactions – 51% of train users' are dissatisfied with crowding in peak hours.

In the context of the Sydney metropolitan bus users report, crowding remains the top issue of concern to Sydney Metropolitan Bus users'. Crowding in buses at peak commute times was the aspect of service with the highest level of customer dissatisfaction and the lowest level of customer satisfaction in both the 2009 and 2010 surveys. Crowding on board the bus was the reason reported by most bus users who experienced difficulty getting onto or off a bus. Compared with the 2009 survey, there was however a significant decrease in the proportion of bus users having access difficulties because of crowding. Having clean seats was the aspect of service with the highest level of customer satisfaction and lowest level of customer dissatisfaction. Compared with 2009 survey findings, there were no significant differences in levels of customer satisfaction and dissatisfaction for any of the aspects of service monitored in the survey.

Most of the developments both in the theory and practice, of discrete choice models have been in the context of revealed preference (RP) data. In recent years, however there have been attempts to shift the focus to a more behaviour oriented choice modelling (McFadden, 1986). The main features of this new paradigm are:

- Explicit treatment of the psychological factors that affect the decision-making process; and
- Data sources other than revealed preference data, such as Stated Preferences (SP) can be effectively utilized in model development.

Behavioural intentions are usually manifested through SP data. For example, a popular method for measuring preferences in market research studies is conjoint analysis (Green and Wind, 1975). In conjoint analysis, respondents are presented with descriptions of several hypothesis alternatives, each of which has different attributes. The respondents would be asked to indicate his/her relative preference towards each of the alternatives. The responses are used to infer the

implicit weights respondents may use on each of the attributes while expressing their preferences. Random utility models have been applied to SP data to model individual choice behaviour (Louviere and Hensher, 1983; Kroes and Sheldon, 1986).

Now the attention was turned to approaches seeking to capture psychological concepts such as attitudes and perceptions. It must be noted that such factors are unobserved (latent), and in principle one can adopt the latent structure models, if adequate attitudinal and perceptual indicators are available. For example, Morikawa et al. (2002) presented an intercity travel mode choice model wherein two perceptual attributes (ride comfort and convenience) are identified, with five point ratings (very poor through to very good) of modal “attributes”. Examples of these are; relaxation during the trip, reliability of the arrival time, flexibility of choosing departure time, ease of travelling with children and/or heavy baggage, safety during the trip, and overall rating of mode, serve as perceptual indicators. Further, the two perceptual factors were used as additional attributes in the choice model with associated coefficients. Jan et al. (2000) addressed personality to understand the variation in path choice.

McFadden (1986) suggested, in a travel mode choice example, an approach to capture individual’s attitudinal factors (such as value of consciousness) by specifying additional variables in the systematic utility function that are interactions between the latent attitudes (e.g. cost consciousness) and relevant attributes (e.g. travel cost). It must be noted that the conceptualizations of McFadden (1986) to incorporate psychometric data are significantly different from earlier paradigms such as Koppelman and Hauser (1978). Earlier works adopted the notion that the perceptual and attitudinal indicators can be directly utilized as predictors in choice models.

Sunitiyoso and Mastsumoto (2009) applied an agent-based approach to model a social dilemma of travel mode choice, considering psychological and sociological aspects. To investigate the mode choice modelling considering social dilemma, a simple bi-modal transport system (car and bus) was assumed in their paper. To model this social dilemma situations, bus users were considered as cooperative travellers, since they behave cooperatively for all people’s benefit. Private car users were considered as non-cooperative travellers, since they only consider their personal interest. Two types of models were illustrated: (i) a transport model and (ii) a traveller model. In case of the transport model, the generalized cost of travel was calculated for car and

bus choice. The detailed equations were borrowed from Kitamura *et al.*'s (1999) paper for this calculation. On the other hand, for traveller model, the decision-making rules of a traveller were represented by the expectations curves that show traveller's belief in the choice. Four types of expectation curves were investigated; these were (i) pessimistic, (ii) normal, (iii) optimistic, and (iv) opportunistic expectation curves.

Golias (2002) concentrated on examining the results of traveller behaviour and mode choice from the introduction of a new Metro system in the city of Athens, Greece. In his study, a questionnaire survey was conducted and it included a large number of inquiries, including questions on mode choice, travel time, travel cost, trip purpose, socioeconomic characteristics, and trip chain behaviour. His paper explored an important finding that the demand for auto, as well as for Metro, usage is fairly inelastic (with respect to both cost and time), and that the users of both modes present a similar behaviour with respect to cost and time changes. Furthermore, the mode choice elasticities revealed that Athens transit users were more sensitive to changes in cost rather than travel time. The results also indicated that increases in travel time and cost for the auto would increase the demand for the Metro, but not as much for the bus.

Vuk (2005) focused on an evaluation of the transport impact of the Copenhagen Metro on traffic growth, induced traffic and choice of destination and mode. When the metro was opened, about 5000 person trips by car in the corridor shifted to the metro from 2002 to 2003, a decrease of 2.9–4.7%. This means that a minimum of 8.2% and a maximum of 13.7% of metro passengers were car users in 2002. Between 25,400 and 26,200 bus trips in the corridor shifted to the metro from 2002 to 2003 (i.e., former bus travellers comprised 69.6% to 71.8% of metro travellers), a decrease of 36.8% to 38.0%. On the other hand, the city centre became significantly better connected to the pre-existing public transport network, following the introduction of the metro. In addition, the Norreport train station, the busiest in the country before the metro, became even more important after the opening of phase 1 of the metro, which terminates at this station. These are the reasons that some car and public transport travellers changed their choice of destination after the introduction of the metro.

2.2.5 Estimating the variations of preferences in modelling

2.2.5.1 Latent variable models in choice models

In the market research arena, latent class models have become a popular tool to capture taste/preference variations. The goal in segmenting the market, especially the market for consumer goods, is to categorise consumers into meaningful groups which have similar needs, tendencies and capabilities, and which react in a similar manner to specific marketing programs. The recognition that consumers differ in one or more respects has led to a stream of research on the theory and practice of segmentation (Wind, 1978). Marketing researchers take the view that there are many possible bases for segmentation including (Lehmann, 1989):

(i) Grouping consumers based on similarities in a multi-dimensional variable space;
(ii) Grouping consumers based on similarities in the choice set considered; and
(iii) Grouping consumers for a particular choice problem based on the similarities in the relationships between consumer characteristics and the product category.

Grover and Srinivasan (1987) performed simultaneous market structuring and segmentation by applying latent class analysis to brand switching data. But their approach does not explicitly account for the impacts of marketing mix variables, such as price, promotions, features, advertisement etc.

Kamakura and Russell (1989) proposed a latent class[3] multinomial logit model with parameterized segment sizes. Each segment is characterized by a vector of mean preferences and a single price sensitivity parameter. Therefore, the central idea is the partitioning of the market into consumer segments, differing in both brand preferences and price sensitivity, and the existence of *prior* probabilities of an individual belonging to different consumer segments. They apply this approach to study the competition between national brands and private labels in one product category.

Zenor and Sirivastava (1993) adopted a similar idea to identify market segments when only macro-level time-series data, such as market shares, are available. Estimates for segment characteristics, such as brand preferences and sensitivity to marketing mix variables, are obtained by applying the latent segment logit model to aggregated panel data.

[3] more popularly referred to as a finite mixture in the statistics literature (Titterinton et al., 1985)

Dillon et al., (1993) agreed with the ideas suggested by Dayton and Macready (1988) for incorporating casual variables, such as individual characteristics in class membership model, to capture individual differences in paired comparisons. They adopted an MNL-type class membership model with the individual characteristics utilized in the systematic functions. Similarly, Swait (1994) went one step further, where a MNL-type class membership model with LVs, such as individual's attitudes, was utilized in the systematic functions.

The estimation of choice models with a simple latent class through the maximum likelihood criterion is difficult as they are plagued with the existence of many maxima. This is also due to a lack of a causal structure for latent class probabilities. To address this issue, researchers start from different initial values to ensure that the estimates are indeed representing the maximum likelihood. In the presence of casual variables, such as the MNL-type class membership model, the casual variables (if relevant and properly specified) are expected to guide the algorithm to the global maximum. Furthermore, the MNL model when used as a choice model, is understandable as it is derived from random utility theory.

The choice model with latent class is a special case of the random coefficients wherein the random coefficients have a non-parametric distribution. Specially, choice models with a non-casual or simple class membership model, are the non-parametric versions of the usual random coefficients models. On the other hand, choice models with a casual class membership model represent a random coefficient model wherein the distribution of the coefficients depends on casual variables. Choice models with class membership models are valuable in gaining insights into the extent of taste variations and the potential characterizations of the latent classes.

2.2.5.2 Choice models with unobserved heterogeneity

In most cases, the discrete choice literature presumes that the individual's choice set is known deterministically to the researcher, i.e. the availability of an alternative is treated as an observable binary variable to the individuals. Misspecification in the choice set leads to choice model misspecification too (Swait and Ben-Akiva, 1987). It is important to note that the probability model that describes the likelihood of each alternative to an individual is derived from a behavioural *theory of random constraints*. The random constraints approach is built on the theme that individuals are expected to have varying perceptions of the degree to which an operative constraint limits their access to certain alternatives. For example, in a travel mode

choice context, the maximum acceptable walking distance to a subway stop is likely to vary across individuals. More recent work by Ben-Akiva and Boccara (1995) incorporates into a single framework of choice set formation modelling the effects of stochastic constraints, or elimination criteria. They also consider the influence of attitudes and perceptions on the choice set of formation process. This estimation approach also jointly incorporates the information on individual's perceived choice set and the revealed preference information corresponding to the observed choice.

Arcidiacono and Miller (2010) adapt the Expectation-Maximization (EM) algorithm to incorporate unobserved heterogeneity into conditional choice probability (CCP) estimators of dynamic discrete choice problems. By developing a class of problems where difference in future value terms depends on few conditional choice probabilities, they extend the class of dynamic optimization problems where CCP estimators provide a computationally cheap alternative to full solution methods.

Unobserved heterogeneity, and therefore dynamic selection, is important to many choice models and economic researches. So this feature is becoming very familiar in dynamic discrete choice models of marketing, transportation, social, economic, etc. research arenas (Miller, 1984; Keane and Wolpin, 1997, 2000 and 2001; Eckstein and Wolpin, 1999; Arcidiacono, 2005; Arcidiacono et al. 2007).

The contributions build on some of the points made in the literature on estimating dynamic games. Bajari et al. (2007) described a two-step algorithm for estimating dynamic games under the assumption that behaviour is consistent with Markov perfect equilibrium. Hotz et al. (1994) analysed a new estimator for the structural parameters of dynamic models of discrete choice in order to forward simulate the future component of the dynamic discrete choice problem. In principle, their method is useful in any distribution of structural errors. Aguirregabiria and Mira (2007) showed the incorporation of permanent unobserved heterogeneity into sequential estimation of dynamic discrete games. On the other hand, Kasahara and Shimotsu (2008) analysed the higher-order properties of the estimators based on the nested pseudo-likelihood (NPL) algorithm and the practical implementation of such estimators for parametric discrete Markov decision models. They derived the rate at which the NPL algorithm converges to the Maximum Likelihood Estimator (MLE) and provided a theoretical explanation for the simulation

results in Aguirregabiria and Mira (2007). Their method requires inverting matrices multiple times, where the number of states is the dimension of the square matrices.

Bishop (2010) described a fully dynamic model of individual migration at the national level that explicitly controls moving costs and forward-looking behaviour. By employing a two-step estimation routine, he avoided the computational burden associated with the full recursive solution, and can then include a richly-specified, realistic state space. In his model, he performs non-market valuation exercises and learns about the spatial determinants of labour market outcomes in a dynamic setting. Joensen and Nielsen (2009) incorporated non-observed heterogeneity, such as ability and preferences as determinants of academic success work decisions. Beresteanu et al. (2010) examined competition between supermarkets as a dynamic discrete game between heterogeneous players, focusing on the impact of Wal-Mart's entry on incumbent supermarket firms and, quantifying the impact on welfare and competition. Finally, Finger (2008), Chung et al. (2010), and Beauchamp (2010) used the non-observed heterogeneity parameters in their researches using dynamic structural models.

Manski (1975) introduced a class of robust estimators of the parameters of a stochastic utility function. The existing maximum likelihood and regression estimation methods require the assumption of a particular distributional family for the random component of utility. Here in contrast, estimators of the 'maximum score' class require only weak distributional assumptions for consistency. This semi-parametric, distribution-free method was followed by other semi-parametric distribution-free methods, developed by Manski (1975), Cosslett (1983), Horowitz (1992), Ichimura (1993), and Klein and Spady (1993), Moon (2004), among others. Geweke and Keane (2000) and Hirano (2002), have applied different techniques that allow nonparametric estimation of the disturbance term in Bayesian models that consider individual unobserved heterogeneity. Similarly, Klein and Sherman (2002) developed an asymptotically normal estimator of the parameters (regression coefficients and threshold points) of a semi parametric ordered response model under the assumption of independence of errors and regressors. These methods are termed semi-parametric because they require a parametric structure for the systematic sub-utility of the observable characteristics.

There are some other empirical works related to the heterogeneity distributions. Briesch et al. (2002) allow consumer heterogeneity in the parametric part of the choice model while restricting

the non-parametric function to be homogeneous. Lancaster (1979) proposes a parametric form for the duration of unemployment distribution that allows one to study the temporal variation in the chances of an unemployed man returning to work, as well as to estimate the regression error variance in Bayesian models. Taber (2000) applied semi-parametric identification techniques and heterogeneity using dynamic discrete choice models and stochastic frontier models in schooling decisions in which students deciding whether to drop out of high school account for the option value of attending college. Dahl (2002) developed an alternative econometric methodology that combines parametric maximum order statistic, approach to reduce the dimensionality of the error terms, with more recent work on semi-parametric estimation of selection models, incorporating unobserved heterogeneity. He applied this approach in the study of mobility and the return to education. Pinkse et al. (2002) allowed for heterogeneity in semi-parametric models of aggregate-level choice in the nature of price competition in firms.

Finally, predictions about adoption of photo-voltaic solar panels by households based on latent variables and relevant attributes preferences have been discussed by Islam and Meade (2013). They modelled attribute preferences using discrete choice model and used discrete-time survival mixture analysis (DTSMA) to model the hazard probability of adoption that allow to compute the cumulative probabilities of adoption over a period up to 10 years for each household. In the model, household level preferences were measured and a causal link between the attributes for the technology and adoption time intentions was also established for making prediction about photo-voltaic (PV) solar panels used by the households.

2.2.6 Choice attributes in mode choice process

Since the 1980s, the integration of latent factors helps the policy makers to understand the individuals' transport decision making process (Stringer, 1981), complementing the standard compensatory approach (Hensher et al., 2005). The explicit consideration of latent factors into the discrete choice modelling was facilitated in the 1990s with the incorporation of LVs (Ben-Akiva et al., 2002a). Traditional and hybrid discrete choice models, along with sophisticated mathematical formulations and computing processes, are increasingly used to analyse the traveller choice behaviour while consider objective (e.g. level of service and cost, socioeconomic) and latent (e.g. comfort) attributes (Svenson, 1998; Johannson et al., 2006; Bolduc et al., 2008; Raveau et al., 2010; Yanez et al., 2010). Most of the researches are the methodological response to the simultaneous consideration objective and latent attributes.

Structural Equation Modelling (SEM) is an alternative method to the hybrid one to include these attributes in the choice analysis (Bollen, 1989; Golob, 2003). Applications of SEM into travel behaviour with choice attributes can also be found in Carrus et al. (2008), Sakano and Benjamin (2008), Ory and Mokhtarian (2009), Farag and Lyons (2010), Habib et al. (2011a), Kattan et al. (2010), Galdames et al. (2011), and Deutsch et al., 2013.

In spite of these advances, little work has been done on measuring these latent factors explicitly and improving of our understanding about the relevance of LVs in mode choice. In this context, aggregated empirical study has been used in measuring of these latent factors, when intending to capture their roles. The impact of these factors and components upon behaviour or intention have been considered in several studies (Verplanken et al., 1997; Bamberg and Schmidt, 2003; Fujii and Garling, 2003; Bogers et al., 2005; Cantillo et al., 2007; Ettema and Verschuren, 2007; Hensher and Pucket, 2007; Domarchi et al., 2008; Galdames et al., 2011; Habib et al., 2011b; Jialing et al., 2013, Hensher et al., 2013). No work is found in the present research on mode choice analysis as a mechanism to explore a connection between traveller and TfNSW in the context of PAT.

Traveller latent preferences are always very difficult to define precisely in quantitative ways. Recent advancements in econometric model estimation techniques make it possible to consider latent (Habib and Zaman, 2012) and random independent variables with RUM (Random Utility Maximisation)-based discrete choice model. The integration of latent attitudinal and/or behavioural variables in RUM-based discrete choice modelling framework is often known as hybrid discrete choice models (Walker and Ben-Akiva 2002).

Johansson et al. (2006) examined traveller modal choice behaviour using latent factors such as attitudinal variables as random variables within RUM-based discrete choice model. The inclusion of unobserved factors in choice model is called hybrid choice models (Walker 2001, Walker and Ben-Akiva 2002; Yanz et al., 2010). Hybrid choice models are able to analyse both RP and SP data to estimate mode choice models. However, the usual practice is to combine revealed mode choice information with stated behavioural information to create model mode choice. Recently, Zeid (2009) investigated the effects of mode choice on happiness and subjective well-being of commuters. It was found that the socio-psychological variables that influence individual mode choice could be captured through the theoretical basis of attitudinal

theory and its link to human behaviour. It is also observed in existing literature that incorporation of latent behavioural and attitudinal variables improves the statistical fit of mode choice models (Domarchi et al., 2008).

2.3 Comparative Modelling Research in Choice Analysis

Habib and Zaman (2012) analysed the effects of incorporating latent attitudinal information in traveller modal choice behaviour. They used a hybrid choice model to capture the effects of LVs in the choice. To have an insight idea of traveller modal choice behaviour, they made a compare between Multinomial Logit Model (MNL) and Hybrid Choice Model (HCM) in their study. It was found that incorporating LVs in the choice model are more effective to understand the actual consumer behaviour. Greene and Hensher (2003) reveal additional dimensions of preference heterogeneity in a latent class mixed multinomial logit model. They have investigated the preferences by comparing between MNL and Mixed Logit (ML) models.

A comparison of transport mode choice data using discrete choice models was conducted by Shen (2009). He provides a detailed comparison between two advanced specifications of discrete choice model, i.e. a Latent Class Model (LCM) and a ML model considering the mode choice behaviour. It was found in his study that LCM is statistically stronger than the ML model, though the author didn't claim LCM strongly as superior to ML model. Cherchi and Cirillo (2008) have also made a comparative analysis between MNL and ML to account for systematic and random variations or responses and preferences in travel behaviour.

Discrete logit model is also applied in determination of bank performance (Barros et al., 2007). They utilised ML model to identify the factors that determine the probability of European banks being either a best or worst performer. In order to evaluate the performance of European banks between 1993 and 2001, a comparison between standard logit and ML model has been conducted.

2.4 Research Gap

As the findings of past studies are described, there are some noticeable research gaps in relation to usage of PAT in transportation planning/management. The research gaps are identified by both the review of the literature and the understanding of the author of this study.

So far as traveller mode choice behaviour is concerned, the connection between traveller and TfNSW using PAT is a new avenue to research. However, till now the defining of agency problem in mode of transport services has not been researched and it has been addressed in this study.

Application of PAT is popular in supply chain management, health care studies, education sector, risk management and labour market (described in section 2.1.3 of Chapter 2). However, there has been very little discussion about PAT in transport related issues. No research has been found related to traveller mode choice behaviour analysis as a mechanism to understand the connection between traveller and TfNSW in the context of PAT.

As described, little is known about PAT in the transport sector and it is not clear what agency variables are responsible for the agency relationship in transport mode services. However, far too little attention has been drawn to the analysis of this relationship. As the propensity of car use, rather than public transport, has been increasing over the last decade, this indicates a need to understand the various perceptions of travellers to their choice process, and thus the agency problem has arisen. The impact of traveller latent preference heterogeneity on mode choice is not yet fully clear and therefore, there is a need to work on it. However, the evidence for understanding the principal-agent relationship in transport mode services is still unseen. From the author's knowledge, much agency uncertainty still exists about the relation between traveller and TfNSW, and it has been evaluated by using a RPL model in this study. So far this method has only been applied to choice analysis, without considering such relationship in mode services. Moreover, still there is not enough research to enable a comparison between traditional and hybrid RPL models. With this model, an attempt has also been taken to reduce the agency problem in transport mode services.

The application of an extended number (six) of LVs in traveller mode choice preferences is also another contribution and to address it as an important research gap. There are some researches that examined the LVs within a small dimension. This current research therefore extends the number of LVs that have been integrated in the choice model to observe the actual behaviour of travellers. Inclusion of extended number (nineteen) of relevant attributes (such as observed variables and LVs) in the choice model gives the robust outcome compared to inclusion of small

number of attributes. Thus, number of attributes including both TOAs and LVs are also strength of this thesis.

In a nutshell, the research gaps are:

(i) Understanding the effects of traveller choice attributes in transport mode services in the context of PAT is not found and examined yet in existing literature;
(ii) Integrating an extended number of relevant attributes including observed and unobserved together in traveller choice process is rare;
(iii) Employing traveller preference heterogeneity analysis as a method has not been considered so far to establish a connection between traveller and TfNSW relationship from the perspective of PAT; and
(iv) Suggesting an approach to reduce the agency problem within transport mode services is also a new contribution in this arena.

2.5 Research Contributions

The study of LVs in traveller choice process is challenging and relatively recent and the use of PAT in the traveller choice process has not been sighted in up to date research. Furthermore, a mode choice probability analysis using RPL models is also exercised for improving the agency problem in transport mode services. Thus, the contributions of this research are four-fold:

(i) the application of PAT's utility and implications in traveller mode choice behaviour, which is rare in transportation management field;
(ii) the demonstration of scale to which attributes influence traveller mode choice to shape the agency relationship within transport mode services with a comparison between traditional and hybrid discrete choice models;
(iii) the inclusion of an extended number of traveller choice attributes (LVs and TOAs) in choice model that assesses a connection between traveller and TfNSW in the context of PAT; and
(iv) the improvement of agency relationship in transport mode services by integrating the traveller choice attributes into the choice models within principal-agent framework.

Furthermore, the contributions of this thesis lie mainly in theoretical and empirical advances. A new concept using PAT is developed to understand a connection between the traveller and

TfNSW by inducing traveller preferences in mode choices. The measures for capturing the traveller LVs at the level of decision making related to the mode of transport offered by TfNSW are also suggested for improving the agency problem to modal services.

Also, a new modelling framework that enriches behavioural models by explicitly including LVs as indicators of utility, is expanded with making a comparison between traditional and hybrid random parameter logit (RPL) models. By adding the LVs in the model (called as hybrid model), a gain in efficiency is achieved. Although the framework is demonstrated in a transportation context, it is general and can be applied to other contexts where random utility models are used to represent behaviour. The LVs in choice models are expected to lead to enhancements in travel behaviour models and project evaluation methods and to the design of policies that enhance traveller preferences.

Chapter 3

Data and Research Methodology

This current research discusses the principal-agent relationship within transport mode services. For understanding this relationship, traveller mode choice behaviour is analysed and alternatives of the transport mode that are offered by TfNSW are specified. Due to modelling the traveller behaviour for understanding the relationship, this chapter describes the necessary data source, with indicators of LVs. From the entire data of Household Travel Survey (HTS), the required data was filtered and structured for this specific research. Then outliers were removed and data were standardised to make the data normal. The modelling issues and econometric methods are also explained here in detail.

3.1 Source of Data

The HTS is the largest and most comprehensive source of personal travel data for the Sydney Greater Metropolitan Area collected by BTS. HTS is a benchmark for best practice in travel surveys in Australia and around the world (BTS, 2013), as well as being the longest running continuous household travel survey in the country. It began in 1997 and has been operating continuously since then.

The 2008/09 HTS data are the key data sources for this study to achieve the research objectives. Later, 2010/11 HTS data has also been used (in Chapter 5) to make a comparison with the results obtained from 2008/09 HTS data, to observe the changes of traveller behaviours over the years. The survey area includes the Sydney and Illawarra Statistical Divisions and the Newcastle Sub-Statistical Division. The investigation in this thesis is confined to travel by residents of the Sydney Statistical Division (SSD) only (Figure 3.1). The survey collects detailed trip information for each day of the year by face-to-face interview. This collection method ensured high data quality and maximized response rates too. Socio-demographic information about the residents of the selected household was also collected. A total of 82,121 trips, after removing outliers, were used in this analysis. Each respondent was requested to maintain a simple travel diary to record the details of all trips undertaken for their nominated 24-hour period. An

interviewer then interviewed each respondent to collect the details of each trip. It should be noted that the tourists are both excluded from this research as well as not captured in the HTS data. However, further details about the HTS, its scope, coverage and methodology can be found in BTS (2012).

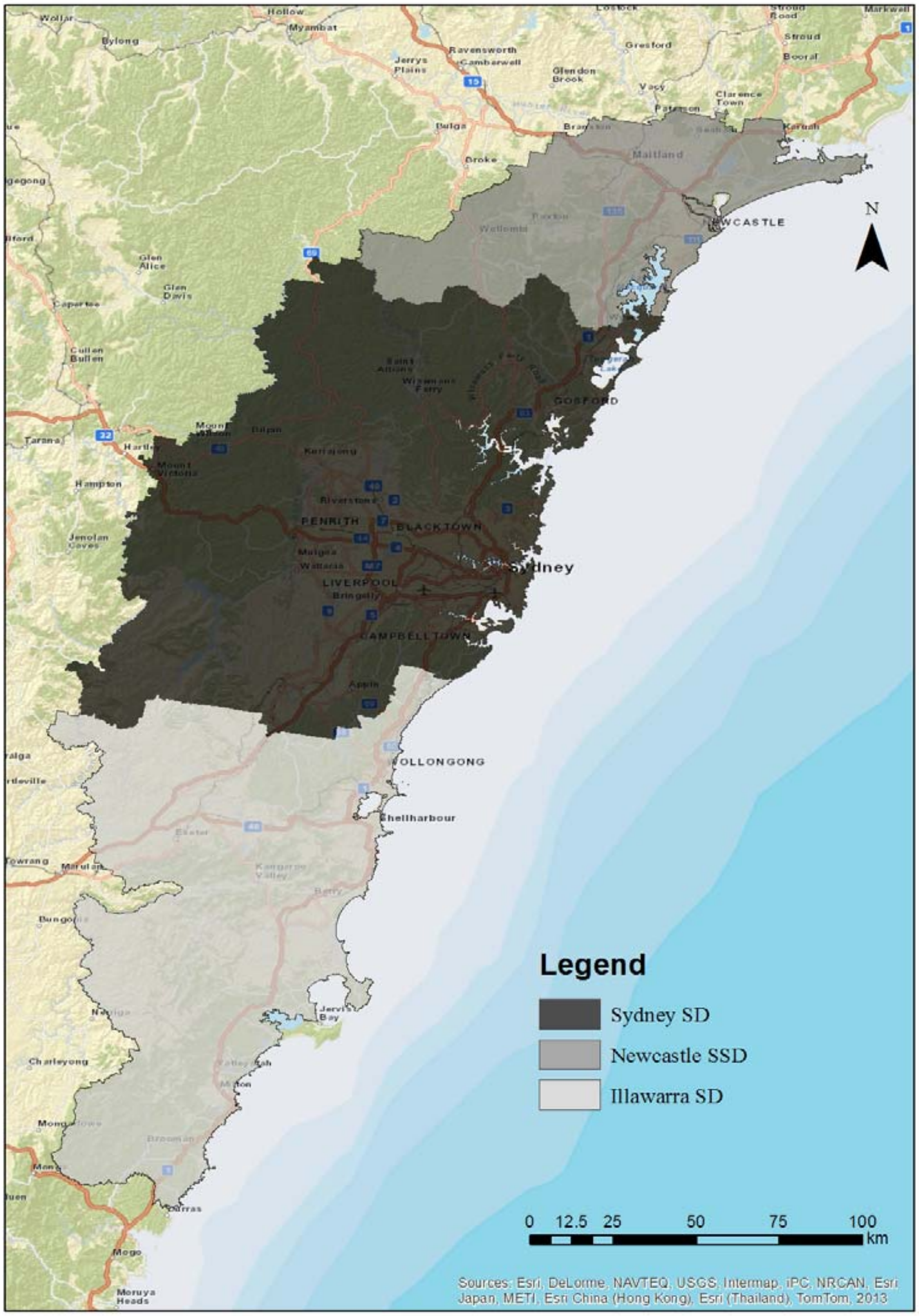


Figure 3.1 Map showing Sydney SD in Sydney Greater Metropolitan Area

Four types of data were available in this survey: household data, personal data, trip data and linked trip data. For this particular study, only personal trip data have been taken into consideration for data analysis. The survey data contained outliers that were removed; otherwise they might have a greater impact on the mean value of the data. This may have produced invalid outcomes for the research questions asked, and normality is an assumption of the methods used. Outliers were removed by applying statistical tools and techniques that are explained in the following section. About 48.7% male and 51.3% female were in the sample size. The average sample age is 36 years and the mode of household annual income is AU$60,000. The proportion of respondents with children under 14 years old is about 60% and the mean family size is 3. In the sample, about 64.4% of respondents use a car for commuting, whereas 4% of respondents and 3.5% respondents use bus and train respectively.

The majority of the commuters (approximately 70%) in Sydney travel more than 10 kilometres for the purposes of work, education, shopping or social/recreation trips. Work trips are the most common, being 44% of all trips. The mean travel time was about 17 minutes and the mean travel cost was about AU$12 in 2008/09, with approximately 8 minutes waiting time for public transport.

Private motor vehicle remains the dominant mode of travel for Sydney residents. About 8 million vehicle driver and 3.6 million vehicle passenger trips are made each weekday. Vehicle travel has remained fairly stable in recent years, while train, bus and walk trips have grown with a faster rate than total trips.

The reasons why people choose a particular mode of travel for a given trip purpose can be complex. The reasons reported by HTS respondents for using public transport as part of the commute to work have remained fairly consistent over time (Figure 3.2), the most important being the availability and cost of parking, as well as trip costs and speed. The cost advantage of public transport was reported by 33% of respondents in 2008/09, up from 27% in the previous year. For some people public transport is faster than driving. The reporting of this reason has remained relatively stable at around 26%.

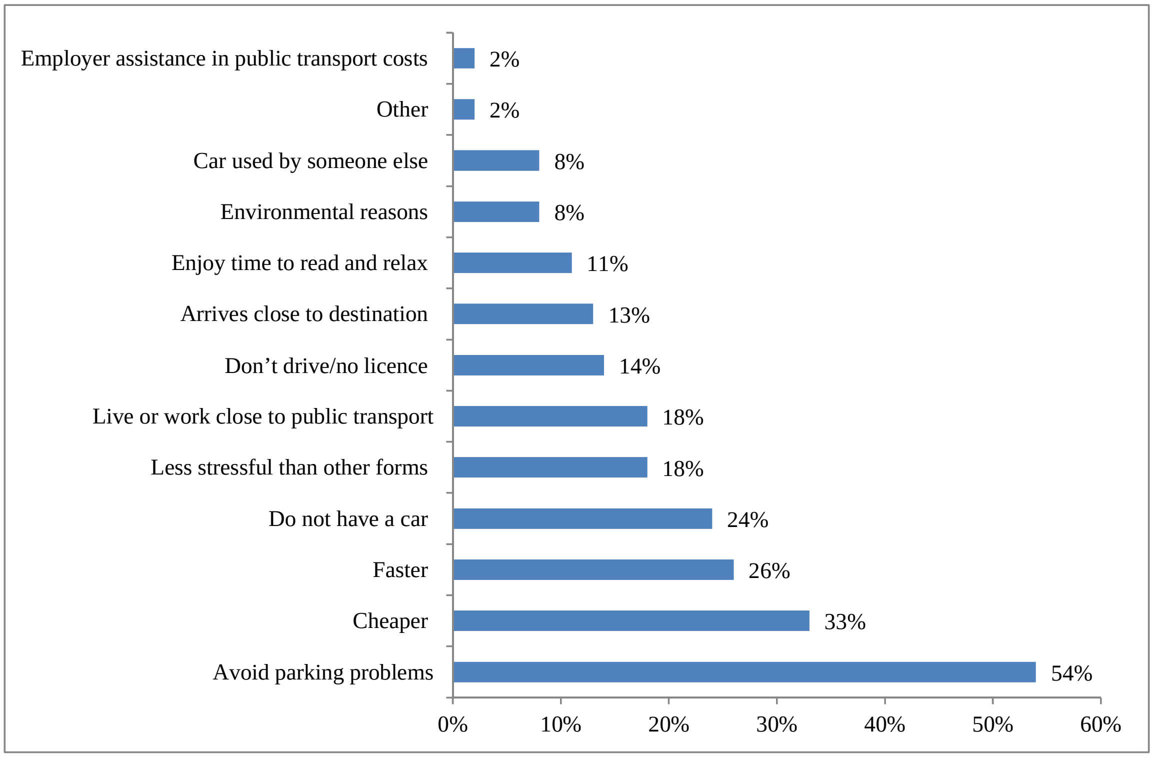


Figure 3.2 Reasons for commuting by public transport

For those who commuted by car only (Figure 3.3), the convenience and independence afforded by private vehicle is still the most important reason given, growing from 44% to 47% over the past year. Obviously those who drive to work require access to parking, and for some, vehicle costs are employer subsidized. The most frequently reported public transport constraints were the indirectness of services (38% up from 26%) and long travel times (24% up from 18%).

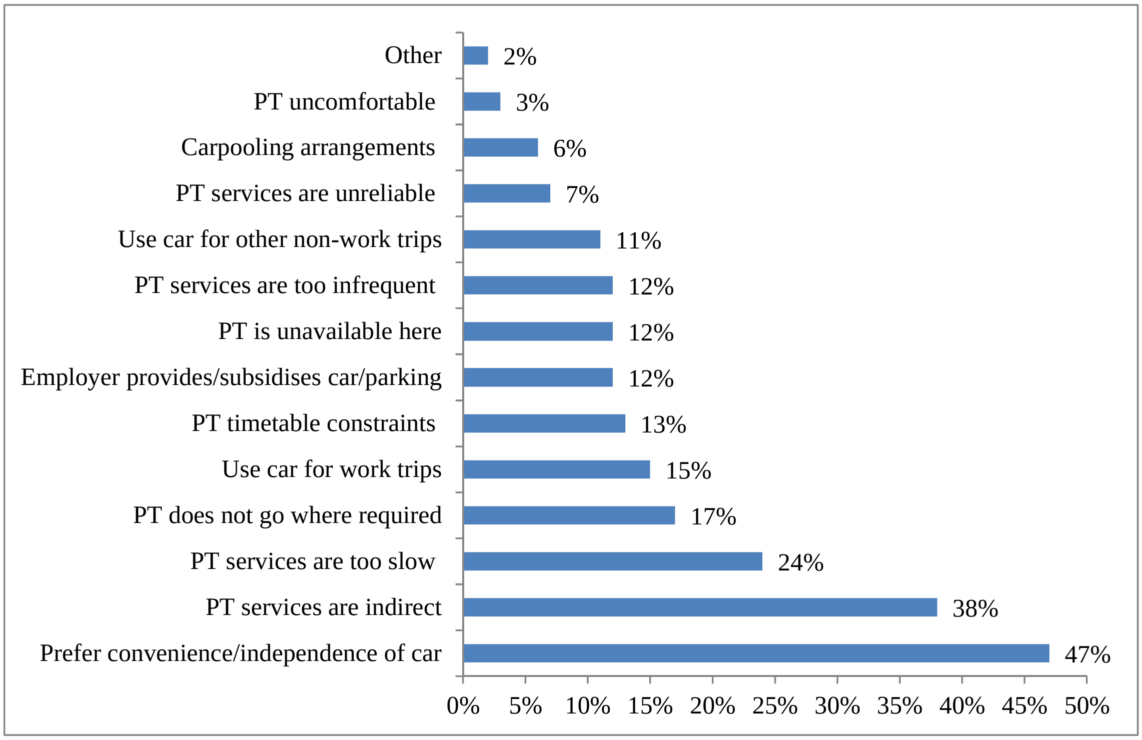


Figure 3.3 Reasons for commuting by car

3.2 Data Screening

Data screening is an important task to make the data normally distributed. This is one of the important data assumptions for getting reasonable results from the MIMIC (multiple indicators and multiple causes) structure model and discrete choice model. Some important assumptions explained by Garson (2011) are required to assess for better results. These assumptions are briefed below.

'Homoscedasticity' refers to the assumption that the dependent variable exhibits a similar amount of variance across the range of values for an independent variable. A violation of the linearity assumption means that estimates of model fit and standard error are biased (not robust). The box plot was employed to detect linearity and or homoscedasticity. The height of 25th percentile to 75th percentile (50% of the cases for the group) is similar across the groups. If the heights of the boxes (25th percentile to 75th percentile) are different, the plot suggests that the variance across groups is not homogeneous.

'Non-zero covariance' is another important assumption that was tested. Random variables whose covariance is zero are called uncorrelated. If the relationship among the variable is uncorrelated, the model will be biased (not robust).

The presence of 'multicollinearity' increases the standard errors of the coefficients. A Complete multicollinearity results in singular covariance matrices, i.e. a matrix inversion cannot be performed because of the possibility of division by zero. Hence a complete multicollinearity prevents a MIMIC structure solution. The correlation matrix was applied to identify its multicollinearity. If a correlation coefficient matrix demonstrates a correlation of 0.75 or higher among variables, there may be multicollinearity.

An 'outlier' is an observation that lies an abnormal distance from other values in a random sample from a population. The presence of outliers can affect the model significantly and bias the results. Therefore, they were removed from the data using box plot techniques.

For purposes of MLE (maximum likelihood estimation), each indicator should be normally distributed for each indicator. A 'normal distribution' is required by MLE, which is the dominant method in the MIMIC model and discrete choice model for estimating coefficients. Due to high sample size, Kolmogorov-Smirnov (K-S) was used to examine the normality of the variables. To test it, there were two hypotheses were assumed:

> H_0: *The data are normally distributed*
> H_1: *The data are not normally distributed.*

The results of K-S test are below:

Table 3.1 Results of K – S test

Variables	**K – S**	**P-value**
Travel time	0.188	0.210
Travel cost	0.210	0.102
Waiting time	0.014	0.201
Income	0.101	0.132
Age	0.152	0.081
Gender	0.036	0.093
No. of full time workers	0.054	0.139
Family size	0.225	0.125
No. of children	0.210	0.262
Car ownership	0.234	0.210
Trip purpose	0.105	0.187
Distance travelled	0.084	0.071
Trip rate	0.111	0.107

The null hypothesis (H_0) is rejected if P-value is below 0.05. The K-S results described in Table 3.1 shows that null hypothesis is not rejected as the P-value is higher than 0.05 and thus, the independent variables are approximately normally distributed. Removing outliers helps to turn the data to normal.

After investigating the assumptions using statistical tools detailed above and removing the outliers, a total 82,121 trips were used as a sample size for this research.

Finally, the scale of data was adjusted to bring all of the variables into proportion with one another. For example, if one variable is 100 times larger than another (on average) then a model may be better behaved if the two variables are adjusted in scale to be approximately equivalent. If adjusted the scale of data, then the coefficients reflect meaningful relative activity between each variable.

The following equation (3-1) is used to implement a unity-based adjustment of the scale of data.

$$X_{i,0to1} = \frac{X_i - X_{Min}}{X_{Max} - X_{Min}} \tag{3-1}$$

where, X_i = each data point,

X_{Min} = The minima among all the data points

X_{Max} = The maxima among all the data points

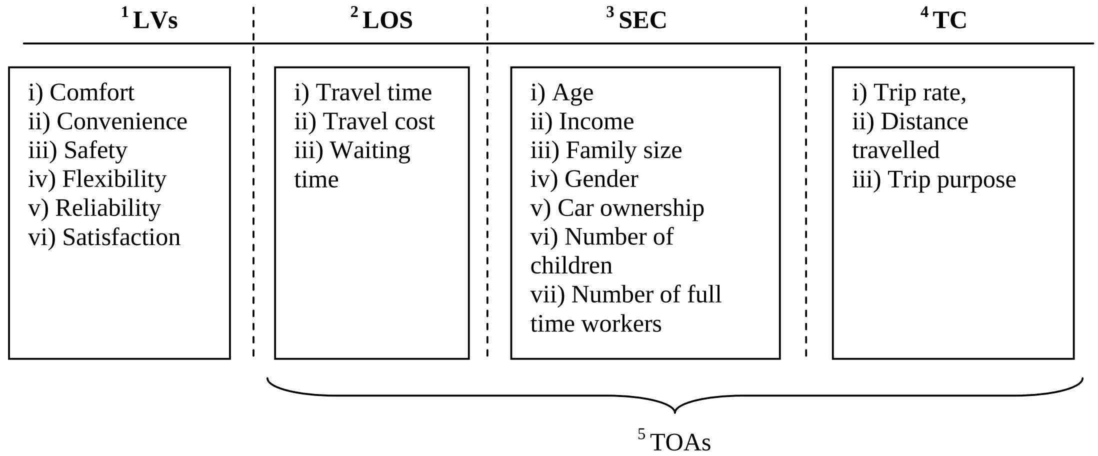
$X_{i, 0 \text{ to } 1}$ = The data point normalised between 0 and 1

3.3 Description of the Variables Used in this Study

This research has been designed to understand about the effect of mode choice attributes on the choice from the PAT perspective. To understand the effect, traveller mode choice preference has been examined. To illustrate the contribution of this study, six LVs and 13 observed variables, including level of service, socio-economic and trip characteristics (Figure 3.4), were selected due to their importance to travellers' decision making processes and evaluated. These factors are not meant to be exhaustive. For example, there might be other possible factor(s) such as friendliness, which was not considered here due to data unavailability. However, observed heterogeneity can be incorporated easily into the models by introducing individual socio-economic characteristics and integrating a level of service attributes, as well as trip characteristics. In addition, there are also unobserved heterogeneities of individuals that are often overlooked by the traditional transportation modellers/planners, because it is assumed by Johansson et al., (2006) that the latent aspects are sufficiently represented by the TOAs. There is a clear need to test whether this is true or not. The commonly used choice attributes are defined here as TOAs, which are defined in this thesis as follows:

1) *Level of Services (LOS)*: travel time (in minutes), travel cost (in Australian dollars) and waiting time (in minutes);
2) *Socio-economic characteristics (SEC)*: age (in years), personal annual income (in Australian dollars), family size, gender (1 if male, 0 otherwise), car ownership, having child (age 0-14 years), and number of full time workers in household; and
3) *Trip characteristics (TC)*: trip rate per day, distance (in kilometre) travelled per trip and trip purpose (1 if work, 0 otherwise).

Figure 3.4 plots all variables together.



[1]Latent variables
[2] Level of service
[3] Socioeconomic characteristics
[4] Trip characteristics
[5] Traditional objective attributes

Figure 3.4 List of LVs and TOAs

Gebeyehu and Takano (2007) argued that in general, traveller modal choice is explained by some basic factors such as characteristics of trip (e.g., length, and purpose) and the socioeconomic characteristics of the traveller. Mode specific attribute such as travel time, travel cost and waiting are also important and significant in travellers' choice process (Anwar et al., 2011 and 2013a). Travellers perceive the car to be more *convenient* and *comfortable* than public transportation. The impact of convenience and comfort on traveller behaviour is well known and well recognised (Steg, 2003; Guzman and Diaz, 2005; Pavlyuk and Gromule, 2010; Pettebone et al., 2011). *Safety* and *flexibility* were also investigated in traveller choice behaviour and were found to be significant (Steg, 2003; Guzman and Diaz, 2005; Johansson et al., 2006). *Reliability* and *satisfaction* have also been chosen for this research to analyse the traveller mode choice behaviour due to their importance and significance in this behaviour (Morikawa et al., 2002; Tam et al., 2011; Konig 2002; Johansson et al., 2006; Gebeyehu and Takano, 2008; Gauthier and Mitchelson, 1981).

Each latent variable is measured by at least three indicators in this research (Table 3.2). The following is the list of psychometric indicators that are available in the 2008/09 HTS data and considered in the modelling approach of this study to achieve the research objectives. The first seventeen indicator variables ($y_1 – y_{17}$) are measured as binary variables either 0 or 1.

Table 3.2 Indicators of latent variables

Latent factors	Label	Explained by (indicators)	Definitions
Comfort	y_1	- Enjoy time to read/relax on vehicle	Importance with 1, otherwise 0
	y_2	- Stressfulness on vehicle	Importance with 1, otherwise 0
	y_3	- Service slower	Importance with 1, otherwise 0
Convenience	y_4	- Alternative mode availability	Importance with 1, otherwise 0
	y_5	- Accessibility (does not go where required)	Importance with 1, otherwise 0
	y_6	- Timetable availability	Importance with 1, otherwise 0
Safety	y_7	- Safety response for mode used in 1st trip	Importance with 1, otherwise 0
	y_8	- Safety response for mode used in 2nd trip	Importance with 1, otherwise 0
	y_9	- Safety response for mode used in 3rd trip	Importance with 1, otherwise 0
Flexibility	y_{10}	- Fixed start and finish times at office – each day can vary	Importance with 1, otherwise 0
	y_{11}	- Rotating shift (work flexibility)	Importance with 1, otherwise 0
	y_{12}	- Roster shift (work flexibility)	Importance with 1, otherwise 0
	y_{13}	- Variable hours (work flexibility)	Importance with 1, otherwise 0
Reliability	y_{14}	- Frequency (travel mode, e.g. bus)	Importance with 1, otherwise 0
	y_{15}	- Punctuality (for public transport)	Importance with 1, otherwise 0
	y_{16}	- Faster (for public transport)	Importance with 1, otherwise 0
Satisfaction	y_{17}	- Cleanliness (cleanliness inside vehicle)	Importance with 1, otherwise 0
	y_{18}	- Travel time	Travel time in minutes
	y_{19}	- Travel cost	Travel cost in Australian dollar
	y_{20}	- Waiting time	Waiting time in minutes

In HTS, the respondents (travellers) were asked about the reason for choosing a particular mode of transport (private or public) and some multiple answers were given. The travellers answered

the appropriate reason according to their preferences. If "enjoy time to read/relax on vehicle" was answered as a reason for choosing a particular mode, it implied that the respondent paid importance on this indicator. Thus, an indicator was marked for 1 if it was answered by the respondent otherwise 0 (zero). In this way, $y_1 – y_6$ and y_{14} - y_{17} were determined by either 1 or 0.

The indicators $y_7 – y_9$ were used to represent safety. The travellers were asked about their experience travelling on the first three modes whether they feel safe. There were five possible answers: (i) always; (ii) mostly; (iii) sometimes; (iv) rarely; and (v) never. If the travellers answered (i) to (iii), it means that they were concerned about the safety while they made travel and it was important to them. Therefore, similarly an indicator was marked for 1 if the respondents put tick in (i) to (iii) otherwise 0 (zero). The indicators ($y_{10} – y_{13}$) for flexibility (work flexibility) were labelled in the same way.

3.4 Modelling Issues

In general, the choice process of travellers is dominated by TOAs, but in real life LVs contribute remarkably to the determination of utility. The effects of choice attributes and probability of using a particular mode are crucial aspects of traveller mode choice analysis. Latent factors (e.g. comfort, convenience, safety, reliability) dominate the choice process considerably in addition to TOAs (Anwar et al., 2011 and 2013a). The TfNSW is not fully aware of the traveller utility function and tends to ignore the LVs that cause goal/choice conflicts and adverse selection.

Considering the concept above, the principal-agent relationship in transport mode services is understood and three hypotheses, and five propositions, are identified from the travel behaviour literature (McFadden, 1986; Ben-Akiva et. al., 1994; Ashok et. al., 2002; Morikawa et. al., 2002; Ben-Akiva et. al. 2002b; Choo and Mokhtarian, 2004; Johansson et al., 2006; Walker and Li, 2007; Temme et. al. 2008; Ory and Mokhtarian, 2009). Three hypotheses (H_1, H_2, and H_3) present the direct understanding about the relationship in transport mode services as below:

Hypothesis 1 (H_1): *Traveller preferences influence TfNSW's decisions on modal services.*
Hypothesis 2 (H_2): *Individual specific attributes affect TfNSW's planning of modal services.*
Hypothesis 3 (H_3): *Mode specific attributes and nature of trips have an effect on TfNSW's decisions on modal service.*

In general, both individual specific attributes such as income, age, gender etc. and mode specific attributes such as travel time, travel cost, etc. are analysed as functions of travel mode choice models. But there has been some evidence in the last decade that this analysis has been criticised, and some researchers recommend integrating LVs into choice models (McFadden 1986; Ashok et al., 2002; Morikawa et al., 2002; Anwar et.al, 2011). Latent factors are the true and adequate representation of traveller behaviour, that helps acquire valuable insight in the decision-making process of the individual (Johansson et al., 2006). Other research indicates that more intangible constructs, such as values, nature of lifestyle, and personality traits, might also have effect on travel mode choice (Choo and Mokhtarian 2004; Nordlund and Garwill 2003; Collins and Chambers 2005). Thus, it is proposed that traveller preferences (e.g. latent factors) affect the mode choice process (P_1):

Proposition 1 (P_1): *Traveller preference heterogeneity structures mode choice*

Socioeconomic characteristics are the dominant features that orient choices, preferences and expectations etc. of the people (Anwar et al. 2013a). By using hybrid choice models, Ben-Akiva et al. (2002b) observed that preferences (e.g. flexibility) of individuals are affected by socioeconomic characteristics. Johansson et al. (2006) also tested that demographic variables impacted preferences of flexibility and comfort. Accordingly, the following proposition (P_2) is proposed:

Proposition 2 (P_2): *Socioeconomic characteristics contribute to the shaping of traveller preferences*

Integration of level of service attributes such as travel time, travel cost etc. is very common (Meixell and Norbis, 2008) in most of the empirical models on travel mode choice in addition to individual socioeconomic characteristics such as income, gender, age etc. (Johansson et al., 2006). The interaction between travel and purpose may also indicate the individual trip nature (Ory and Mokhtarian, 2009). Thus, similar effects are expected in this study and propositions (P_3 – P_5) are proposed:

Proposition 3 (P_3): *Socioeconomic characteristics (e.g., age, income, gender) affect mode choice*
Proposition 4 (P_4): *Mode specific attributes (e.g. waiting time) affect mode choice*
Proposition 5 (P_5): *Trip characteristics (e.g. trip purpose) affect mode choice.*

The analysis specifically investigates the influences of LVs (e.g. safety, comfort and reliability) in concert with TOAs (e.g. income, travel time and travel cost) on traveller mode choice (Figure 3.5). Five propositions were derived from the literature review and are tested in an empirical analysis of traveller mode choice, which is an indicator for the principal-agent relationship in transport mode services. Figure 3.5 also describes the structure of hybrid choice model.

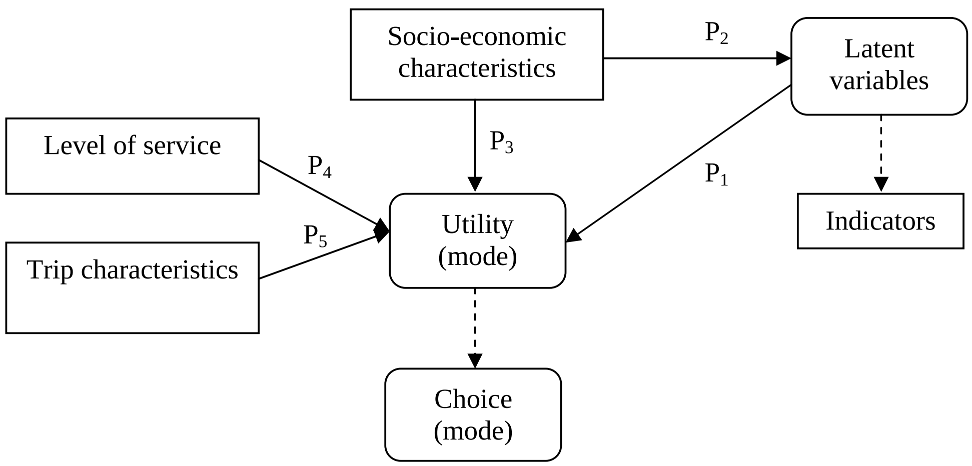


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Figure 3.5 Structure of hybrid discrete choice model with identified propositions

Propositions require testing to assess the hypotheses. Figure 3.6 illustrates how the propositions portray the hypotheses. Hypothesis 1 (H_1) is represented by proposition 1 and 2 (P_1 and P_2). It means, the significant relationship of P_1 and P_2 to the utility of mode choice indicates that traveller preferences have influence on TfNSW's decision to modal services (H_1). Similarly, P_4 and P_5 describe H_3 which means that mode specific attributes and nature of trips have the significant effect on TfNSW's decision towards modal service (H_3), if P_4 and P_5 are found significant and so on. Thus, Figure 3.6 describes the constructs of hypotheses that validate the connection between traveller and TfNSW.

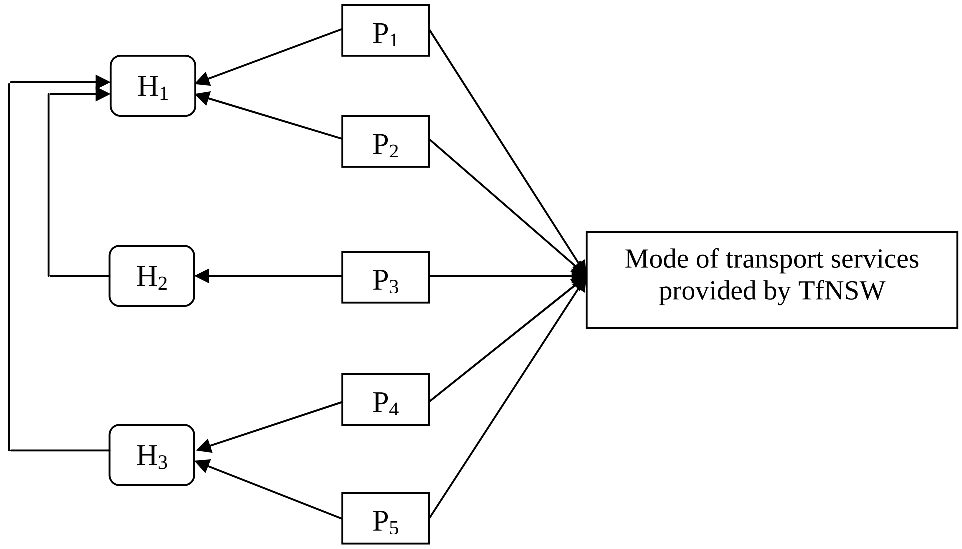


Figure 3.6 Representation of hypotheses explained by propositions

3.5 Econometric Methods

A discrete choice analysis is the most common choice to investigate the nature of modal choice decision-making processes amongst many modes (Train, 2009), because it allows us to understand the behavioural process that leads to an individual's choice. The economic theory of random utility is the fundamental concept of this analysis and it assumes that a traveller chooses the mode with the highest utility under a rational circumstance (Bhat, 1998b; Bolduc, 1999; Train, 2009). Simon (1972) interpreted the rationality of behaviour as an appropriate behaviour to achieve the given goals, within given conditions and constraints. However, though discrete choice analysis was introduced to analyse the transport related problems, it has been applied successfully in various fields for the last two decades (Bolduc, 1999). These studies have focused on analysing the behaviour of the decision-making process, such as modal choice (Train, 1980; Cohen and Harris, 1998; Bolduc, 1999; Bhat, 2000; Ewing et al., 2004; Dissanayake and Morikawa, 2005; Commins and Nolan, 2011; Habib, 2012), choice of car type (McCarthy, 1996; Choo and Mokhtarian, 2004), tourists' mode choice (Fesenmaier, 1988; Train, 1998; Nicolau and Mas, 2006; Can, 2013; Jialing et al., 2013), traveller latent perspective (Daly et al., 2012; Fleischer et al., 2012), survey quality to perceptual and attitudinal questions (Hess and Stathopoulos, 2011), and heterogeneous decision rules (Hess et al., 2011).

While previous transportation related applications have included modal comfort and convenience (Morikawa, et al. 2002), this research expands the list to include six LVs: *comfort, convenience, flexibility, safety, reliability* and *satisfaction*. The latent variable model framework for modelling

and estimation are adapted from Morikawa et al. (2002), Johansson et al. (2006) and Yanez et al. (2010). A general approach to synthesizing models with LVs and psychometric-type measurement models has been developed by Bentler (1980). Specifically, these models assume that the indicators are continuous and the relationships between the observed and LVs are linear. These models consist of two parts: a measurement model and a structural model. The first part specifies how the LVs are related to the indicators and the second specifies the relationship between LVs and observed variables, and LVs themselves. The TOAs can also be introduced into the structural part of the model to produce the MIMIC model. The MIMIC models belong to the general class of Latent Variable Models (LVM).

Because of the complex nature of choice preferences, the discrete choice modelling approach is important (Viau et al., 2009). There are two approaches available now for incorporating LVs into choice models; (i) the *sequential (also known as two-step) approach*, where the LVs need to be constructed before being included into the discrete choice model as regular explanatory variables (Yanez et al., 2010; Johansson et al., 2006). Step 1 is the estimation of a MIMIC (multiple indicators and multiple causes) model; a type of regression model with a latent dependent variable(s). Step 2 is the estimation of a choice model with random parameters. Information from the first step is incorporated in the second step; and (ii) the *simultaneous approach,* where both processes are done simultaneously (Ashok et al., 2002; Bolduc et al., 2008).

Ben-Akiva et al. (2002a) argued that results obtained using the second approach are more consistent and rational than the other approach. However, the second approach is not popular due to its high complexity (Raveau et al., 2010). In this study, the author of this thesis was biased to implement the sequential approach due to the following reasons:

i) the decision underlying a travel pattern is decomposed into a series of interrelated choices and analysed one by one. This is more relevant to the sequential approach rather than the simultaneous approach (Kitamura, 1984);
ii) the estimated results using both sequential and simultaneous approaches were not statistically different (Raveau et al., 2010);
iii) it is less cumbersome to estimate the model sequentially (Johansson et al. 2006);
iv) the sequential approach can be more easily linked to discrete choice analysis than the simultaneous method, to analyse traveller behaviour over a specified period of time; and

v) it is assumed that the travel decision itself is sequential to a certain extent because of uncertainty involvement in the traveller's decision making process.

3.5.1 Modelling with LVs (MIMIC model)

In this study, the endogeneity issue is addressed directly by using the MIMIC model, which is a Structural Equation Model (SEM) approach, rather than a single-equation model. This is used to simultaneously represent each of the six key constructs and their relationships to each other. Thus MIMIC structural modelling is an adequate and appropriate tool for modelling the interactions between traveller behaviour and preferences. Figure 3.7 illustrates the structure of the MIMIC structure model.

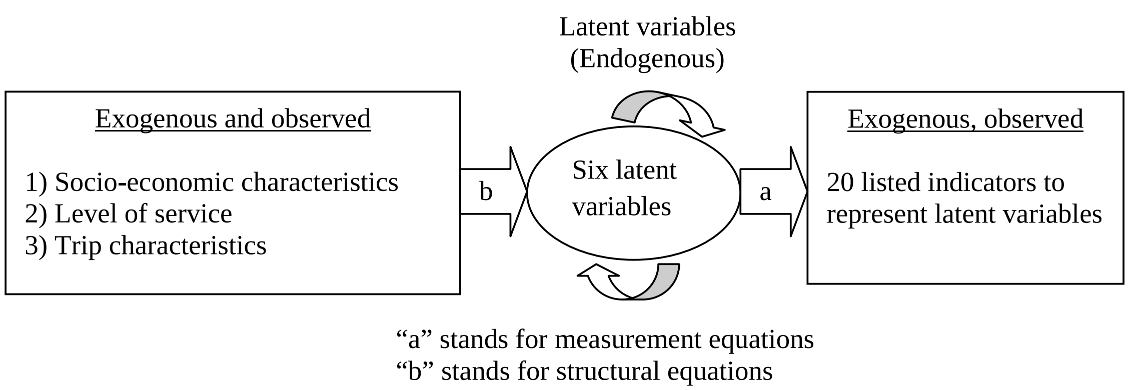


Figure 3.7 Conceptual framework of MIMIC model

While previous transportation related applications have included modal comfort and convenience (Morikawa et. al., 2002), this research extends the list to six LVs such as *comfort, convenience, flexibility, safety, reliability* and *satisfaction*. The MIMIC model is a special case of a longitudinal Structural Equation Model (SEM), in which the influences of formative indicators on unobservable LVs are assessed through their impact on the reflective indicators (Lester, 2009). These models comprise of structural and measurement equations simultaneously.

Exploratory and confirmatory factor analyses assist the specification of the ''multiple indicator part'' (MI) of the MIMIC model performed in the AMOS (Analysis of MOment Structures) software v.19 (Arbuckle, 2010). The resulting latent variable model presented here is relationships between indicators and LVs, as well as several direct tests of postulated relations.

Integration of LVs in choice models has become popular over the last three decades (Koppelman and Hauser, 1978; Koppelman and Pas, 1980) because their inclusions provide a better understanding of individual's decision making processes. Some studies have previously shown its advantages (Spear, 1976; Mokhtarian and Salomon, 1997; Kuppam et al., 1999), due to its significantly improved explanatory power of traditional models, but integrating LVs in choice models from the perspective of PAT is a novel aspect of this research.

A MIMIC model, that defines LVs appropriately, is estimated first, where the LVs (η_{ijl}) are explained by characteristics (s_{ijr}) from the users (individuals), alternatives (mode alternative) and trip nature through structural equation (Eq. 3-2). As the analysts cannot collect data on LVs directly, indicators (y_{ijp}) are assigned to explain them through measurement equation (Eq. 3-3):

$$\eta_{ijl} = \sum_r \alpha_{jlr} * s_{ijr} + \nu_{ijl} \qquad (3\text{-}2)$$

$$y_{ijp} = \sum_l \gamma_{jlp} * \eta_{ijl} + \zeta_{ijp} \qquad (3\text{-}3)$$

where, i denotes an individual, j refers to an alternative mode of transport, l to an LV, r to explanatory variables belonging to LOS, SEC and TC, and p to an indicator; α_{jlr} and γ_{jlp} are parameters to be estimated, while ν_{ijl} and ζ_{ijp} are error terms with mean zero and standard deviation to be estimated.

Eq. (3-2):

$$\begin{pmatrix} \eta_{Comfort} \\ \eta_{Convenience} \\ \eta_{Flexibility} \\ \eta_{Safety} \\ \eta_{Reliability} \\ \eta_{Satisfaction} \end{pmatrix} = \begin{pmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} \\ \alpha_{61} & \alpha_{62} & \alpha_{63} \end{pmatrix} \begin{pmatrix} \text{Socio-economic} \\ \text{Level of service} \\ \text{Trip characteristics} \end{pmatrix} + \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \\ \nu_4 \\ \nu_5 \\ \nu_6 \end{pmatrix}$$

Eq. (3-3):

$$
\begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \\ y_8 \\ y_9 \\ y_{10} \\ y_{11} \\ y_{12} \\ y_{13} \\ y_{14} \\ y_{15} \\ y_{16} \\ y_{17} \\ y_{18} \\ y_{19} \\ y_{20} \end{pmatrix}
=
\begin{pmatrix}
\gamma_{1,1} & \gamma_{1,2} & \gamma_{1,3} & \gamma_{1,4} & \gamma_{1,5} & \gamma_{1,6} \\
\gamma_{2,1} & \gamma_{2,2} & \gamma_{2,3} & \gamma_{2,4} & \gamma_{2,5} & \gamma_{2,6} \\
\gamma_{3,1} & \gamma_{3,2} & \gamma_{3,3} & \gamma_{3,4} & \gamma_{3,5} & \gamma_{3,6} \\
\gamma_{4,1} & \gamma_{4,2} & \gamma_{4,3} & \gamma_{4,4} & \gamma_{4,5} & \gamma_{4,6} \\
\gamma_{5,1} & \gamma_{5,2} & \gamma_{5,3} & \gamma_{5,4} & \gamma_{5,5} & \gamma_{5,6} \\
\gamma_{6,1} & \gamma_{6,2} & \gamma_{6,3} & \gamma_{6,4} & \gamma_{6,5} & \gamma_{6,6} \\
\gamma_{7,1} & \gamma_{7,2} & \gamma_{7,3} & \gamma_{7,4} & \gamma_{7,5} & \gamma_{7,6} \\
\gamma_{8,1} & \gamma_{8,2} & \gamma_{8,3} & \gamma_{8,4} & \gamma_{8,5} & \gamma_{8,6} \\
\gamma_{9,1} & \gamma_{9,2} & \gamma_{9,3} & \gamma_{9,4} & \gamma_{9,5} & \gamma_{9,6} \\
\gamma_{10,1} & \gamma_{10,2} & \gamma_{10,3} & \gamma_{10,4} & \gamma_{10,5} & \gamma_{10,6} \\
\gamma_{11,1} & \gamma_{11,2} & \gamma_{11,3} & \gamma_{11,4} & \gamma_{11,5} & \gamma_{11,6} \\
\gamma_{12,1} & \gamma_{12,2} & \gamma_{12,3} & \gamma_{12,4} & \gamma_{12,5} & \gamma_{12,6} \\
\gamma_{13,1} & \gamma_{13,2} & \gamma_{13,3} & \gamma_{13,4} & \gamma_{13,5} & \gamma_{13,6} \\
\gamma_{14,1} & \gamma_{14,2} & \gamma_{14,3} & \gamma_{14,4} & \gamma_{14,5} & \gamma_{14,6} \\
\gamma_{15,1} & \gamma_{15,2} & \gamma_{15,3} & \gamma_{15,4} & \gamma_{15,5} & \gamma_{15,6} \\
\gamma_{16,1} & \gamma_{16,2} & \gamma_{16,3} & \gamma_{16,4} & \gamma_{16,5} & \gamma_{16,6} \\
\gamma_{17,1} & \gamma_{17,2} & \gamma_{17,3} & \gamma_{17,4} & \gamma_{17,5} & \gamma_{17,6} \\
\gamma_{18,1} & \gamma_{18,2} & \gamma_{18,3} & \gamma_{18,4} & \gamma_{18,5} & \gamma_{18,6} \\
\gamma_{19,1} & \gamma_{19,2} & \gamma_{19,3} & \gamma_{19,4} & \gamma_{19,5} & \gamma_{19,6} \\
\gamma_{20,1} & \gamma_{20,2} & \gamma_{20,3} & \gamma_{20,4} & \gamma_{20,5} & \gamma_{20,6}
\end{pmatrix}
\begin{pmatrix} \eta_{Comfort} \\ \eta_{Convenience} \\ \eta_{Flexibility} \\ \eta_{Safety} \\ \eta_{Reliability} \\ \eta_{Satisfaction} \end{pmatrix}
+
\begin{pmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \\ \zeta_4 \\ \zeta_5 \\ \zeta_6 \\ \zeta_7 \\ \zeta_8 \\ \zeta_9 \\ \zeta_{10} \\ \zeta_{11} \\ \zeta_{12} \\ \zeta_{13} \\ \zeta_{14} \\ \zeta_{15} \\ \zeta_{16} \\ \zeta_{17} \\ \zeta_{18} \\ \zeta_{19} \\ \zeta_{20} \end{pmatrix}
$$

In these equations, y is a vector of observable indicator variables of η, s is a vector of 13 exogenous observable variables that cause η, α and γ are matrices of unknown parameters to be estimated. ν and ζ are measurement errors. Equations (3-2) and (3-3) constitute the MIMIC model (latent variable model).

Table 3.3 shows the definitions of both LVs and TOAs variables used in the model.

Table 3.3 Description of selected variables

Variables	**Definitions**
Travel time	Time in minutes
Travel cost	Cost in Australian dollar (AUD)
Waiting time	Time in minutes
Trip purpose	Dummy variable with 1 for work trip, 0 otherwise
Distance travelled	Trip length in kilometre
Age	The age of respondent in years
Income	The personal income of respondent in AUD per annum
Gender	Dummy variable for the gender of the respondent with 1 for male respondents
No. of full time workers	Full time workers in household
Family size	Number of family member
No. of children	Number children 0-14 years old
Car ownership	No. of car owned
Trip rate	No. of trip per person per day
$\eta_{Comfort}$	Comfort (latent variable)
$\eta_{Convenience}$	Convenience (latent variable)
$\eta_{Flexibility}$	Flexibility (latent variable)
η_{Safety}	Safety (latent variable)
$\eta_{Reliability}$	Reliability (latent variable)
$\eta_{Satisfaction}$	Satisfaction (latent variable)

Whether travellers enjoy the time by reading or relaxing (y_2), or feel stress (y_3) on the vehicle is defined as *comfort*. Slower response (y_3) by the driver is also another determinant of *comfort*. *Convenience* is described by the alternative mode availability (y_4), accessibility that covers most of the required locations (y_5) and timetable availability of public transport (y_6) at the stop. Fixed duration that can be varied each day (y_7), working in an office on a rotating basis (y_8) or roster duty (y_9), or variable hours over the day (y_{10}) constitute the work schedule *flexibility* in modelling. The travellers consider *safety* a concern while they make trip. To determine *safety,* three consecutive trips were considered, where travelers thought about safety before decision making for trips (y_{11}-y_{13}) *safety* issues. Frequency of public transport (y_{14}), on-time arrival and departure were called *punctuality* (y_{15}) and necessary speed of the vehicles defined *faster* (y_{16})

are described as *reliability* of public transport. The travellers' *satisfaction* is explained by cleanliness inside the vehicle and stoppages (y_{17}), travel time (y_{18}), travel cost (y_{19}), and waiting time for public transport (y_{20}).

3.5.1.1 Specification of latent variable model

The structural relationship in MIMIC model guides the specification for computation of LVs (Figure 3.8 illustrates the results of this process), which results in the following set of equations:

$$\textbf{Comfort}_{\textbf{ij}} = \alpha_{inc\text{-}com,j}*Income_i + \alpha_{age\text{-}com,j}*Age_i + \alpha_{gen\text{-}com,j}*Gender_i + \alpha_{car\text{-}com,j}*Car\ ownership_i + \alpha_{ftw\text{-}com,j}*Full\ time\ workers_i + \alpha_{dt\text{-}com,j}*Distance\ travelled + \alpha_{chi\text{-}com,j}*Having\ children + v_{com,ij}$$

$$\textbf{Convenience}_{\textbf{ij}} = \alpha_{age\text{-}conv,j}*Age_i + \alpha_{gen\text{-}conv,j}*Gender_i + \alpha_{car\text{-}conv,j}*Car\ ownership_i + v_{conv,ij}$$

$$\textbf{Safety}_{\textbf{ij}} = \alpha_{inc\text{-}saf,j}*Income_i + \alpha_{age\text{-}saf,j}*Age_i + \alpha_{gen\text{-}saf,j}*Gender_i + \alpha_{fs\text{-}saf,j}*Family\ size_i + \alpha_{tr\text{-}saf,j}*Trip\ rate_i + v_{saf,ij}$$

$$\textbf{Flexibility}_{\textbf{ij}} = \alpha_{gen\text{-}fle,j}*Gender_i + \alpha_{chi\text{-}fle,j}*Having\ children_i + \alpha_{car\text{-}fle,j}*Car\ ownership_i + \alpha_{tr\text{-}fle,j}*Trip\ rate_i + v_{fle,ij}$$

$$\textbf{Reliability}_{\textbf{ij}} = \alpha_{tti\text{-}rel,j}*Travel\ time_i + \alpha_{wti\text{-}rel,j}*Waiting\ time_i + \alpha_{ft\text{-}rel,j}*Full\ time\ workers_i + \alpha_{tp\text{-}rel,j}*Trip\ purpopse_i + v_{rel,ij}$$

$$\textbf{Satisfaction}_{\textbf{ij}} \quad \alpha_{tti\text{-}sat,j}*Travel\ time_i + \alpha_{tco\text{-}sat,j}*Travel\ cost_i + \alpha_{wti\text{-}sat,j}*Waiting\ time_i + \alpha_{dt\text{-}sat,j}*Distance\ travelled_i + v_{sat,ij}$$

$$y_{y1,ij} = \gamma_{y1,j} * Comfort_{ij} + \zeta_{y1,ij}$$

$$y_{y2,ij} = \gamma_{y2,j} * Comfort_{ij} + \zeta_{y2,ij}$$

$$y_{y3,ij} = \gamma_{y3,j} * Comfort_{ij} + \zeta_{y3,iq}$$

$$y_{y4,ij} = \gamma_{y4,j} * Convenience_{ij} + \zeta_{y4,ij}$$

$$y_{y5,ij} = \gamma_{y5,j} * Convenience_{ij} + \zeta_{y5,ij}$$

$$y_{y6,ij} = \gamma_{y6,j} * Convenience_{ij} + \zeta_{y6,ij}$$

$y_{y7ij} = \gamma_{y7,j} * Safety_{ij} + \zeta_{y7,ij}$

$y_{y8,iq} = \gamma_{y8,j} * Safety_{ij} + \zeta_{y8,ij}$

$y_{y9,ij} = \gamma_{y9,j} * Safety_{ij} + \zeta_{y9,ij}$

$y_{y10,ij} = \gamma_{y10,j} * Flexibility_{ij} + \zeta_{y10,ij}$

$y_{y11,ij} = \gamma_{y11,j} * Flexibility_{ij} + \zeta_{y11,ij}$

$y_{y12,ij} = \gamma_{y12,j} * Flexibility_{ij} + \zeta_{y12,ij}$

$y_{y13,ij} = \gamma_{y13,j} * Flexibility_{ij} + \zeta_{y13,ij}$

$y_{y14,ij} = \gamma_{y14,j} * Reliability_{ij} + \zeta_{y14,ij}$

$y_{y15,ij} = \gamma_{y15,j} * Reliability_{ij} + \zeta_{y15,ij}$

$y_{y16,ij} = \gamma_{y16,j} * Reliability_{ij} + \zeta_{y16,ij}$

$y_{y17,ij} = \gamma_{y17,j} * Satisfaction_{ij} + \zeta_{y17,ij}$

$y_{y18,ij} = \gamma_{y18,j} * Satisfaction_{ij} + \zeta_{y18,ij}$

$y_{y19,ij} = \gamma_{y19,j} * Satisfaction_{ij} + \zeta_{y19,ij}$

$y_{y20,ij} = \gamma_{y20,j} * Satisfaction_{ij} + \zeta_{y20,ij}$

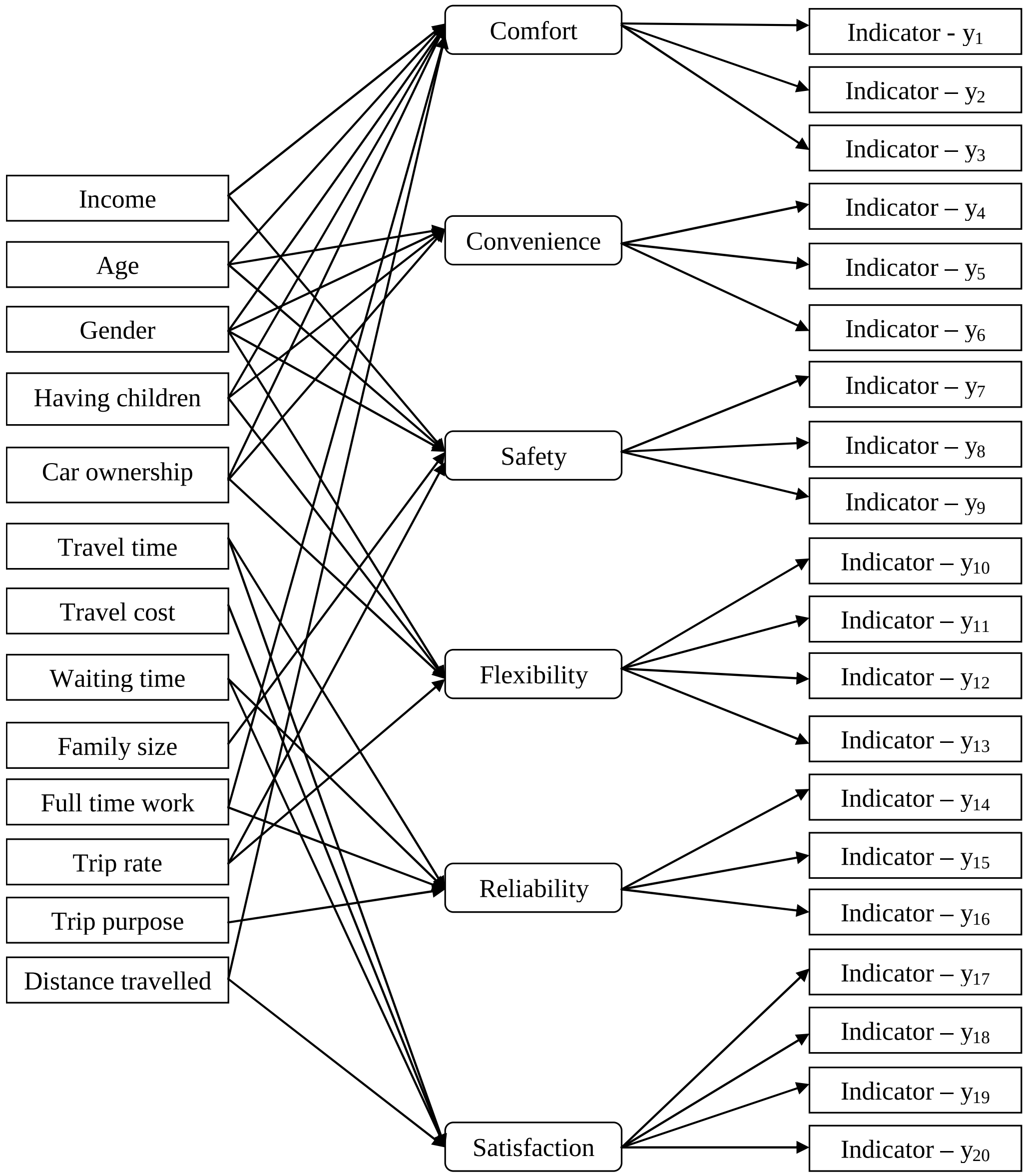


Figure 3.8 Process of structural and measurement relationship

3.5.2 Hybrid discrete choice modelling

It is assumed that individuals make a decision by maximising the utility (U_{ij}), based on the assumption of random utility theory. It is also assumed that an analyst can only determine a representative portion (systematic component) of utility (V_{ij}) function, therefore, an error term (ε_{ij}) to each alternative (Ortuzar and Willumsen, 2001) is required to be included in the function as a stochastic component. Mathematically the utility function becomes:

$$U_{ij} = V_{ij} + \varepsilon_{ij}, \quad (3\text{-}4)$$

where V_{ij} is a function of objective attributes X_{ijk}, i.e. travel time and cost, socio-economic and trip characteristics of the individual, etc. and k stands for all objective variables taken together.

Eq. (3-5) is derived by including LVs in the utility function, where θ_{jk} and β_{jl} are parameters to be estimated:

$$V_{ij} = \Sigma_k \theta_{jk} * X_{ijk} + \Sigma_l \beta_{jl} * \eta_{ijl} \quad (3\text{-}5)$$

Only the alternative j is chosen, if the utility of alternative, U_{ij} is greater than or equal to the utility of all alternatives t (including j), in the choice set, C. This can be expressed mathematically with binary variables d_{ij}:

$$d_{ij} = \begin{cases} 1 \text{ if } U_{ij} >= U_{it}, \ \forall_t \in C \\ 0, \text{ other case} \end{cases} \quad (3\text{-}6)$$

Since a sequential approach is used in this study, a discrete choice model is estimated with MIMIC model's structure (Eq. 3-2) and measurement (Eq. 3-3) equations (Ben-Akiva et al., 2002a).

3.5.2.1 Specification of random parameter logit[4] (RPL) model

RPL model has been chosen to analyse the data due to the following advantages. It is capable of measuring random taste variation, and allows unrestricted substitution patterns and correlations among unobserved factors, that help to address the limitations of initially innovated logit models, e.g. Multi-Nomial Logit (MNL) and Nested Logit (NL) models. An analyst collects data from the sample population and it is not possible to observe the intangible factors related to respondents. Therefore, it is common to have the existence of intangible heterogeneity in the sample population and this unobserved heterogeneity is accommodated by the random parameters in the RPL model. The standard deviations of random parameters depict the degree of unobserved heterogeneity. Heterogeneity around the mean describes the interaction between random parameters and specified attributes.

[4] Random parameters logit is also known as "mixed logit (ML)," "mixed multinomial logit (MMNL)," "Kernel logit", "hybrid logit", "random coefficients logit," and "error components logit".

The utility maximization rule states that an individual selects the alternative from his/her set of available alternatives, in such a way that maximizes his or her utility (Koppelman and Bhat, 2006). Thus, an individual selects an alternative once he/she perceives highest utility from that alternative. Further, the value of utility is determined as a function of alternative-specific and individual-specific attributes. According to Eq. (3-4), the utility U_{ij} that individual i receives from alternative j is the linear sum of systematic component V_{ij} and a stochastic component ε_{ij}. Within a logit context the condition is imposed that ε_{ij} is independent and identically distributed (IID) extreme value type 1 (Gumbel Distribution), independence of irrelevant alternatives (IIA) property also exists in initially innovated logit models such as MNL and NL models. These limitations (IID and IIA) should be taken into account in some way. One way to do that is by dividing the stochastic component into two additive parts that are uncorrelated. One part is correlated and heteroskedastic among alternatives and, and another part is IID over alternatives and individuals.

The systematic component of utility V_{ij} can be rewritten as $x_{ij}\beta_j$, where x_{ij} is a vector of explanatory variables that are observed by the analyst from any source related to individuals and alternatives. β_j is a vector of parameters to be estimated. The stochastic component of utility ε_{ij} can also be rewritten as $z_{ij}\eta_i + e_{ij}$, where z_{ij} is a vector of characteristics that can vary over individuals, alternatives, or both (there may have some or all common elements in both z_{ij} and x_{ij}), and e_{ij} is a random term with zero mean that is IID over individuals and alternatives, and is normalised to set the scale of utility. The random variable η_i is a vector of random terms with a zero mean that varies over individuals according to the distribution $f(\eta \mid \Omega)$, where Ω are the fixed parameters of the distribution f. Accordingly, the utility U_{ij} that individual i gets from alternative j can be written as $[x_{ij}\beta_j + (z_{ij}\eta_i + e_{ij})]$. In matrix form, it can be written as:

$$U = X\beta + (Z\eta + e) \qquad (3\text{-}7)$$

If IIA exists, then $\eta = 0$ for all i, and so utility U depends only on the systematic and IID stochastic portion of utility. Initially innovated logit models (e.g. MNL) assume that IIA does not estimate $Z\eta$; thus η is assumed as zero. Because of that, unobserved taste variations have not been addressed in initially innovated logit models. Hence, by incorporating the effect of $Z\eta$ in utility function, discrete choice models can be able to accommodate those impacts and thus avoid

the IIA assumption. These models estimate Ω (the parameters of the distribution of η) as well as β.

To derive a RPL model from Eq. (3-7), e is assumed as IID extreme value, while η follows a general distribution, $f(\eta \mid \Omega)$. If η = 0, it is MNL which has the IIA property. An estimation of the RPL generally involves estimating β and Ω. The choice probabilities depend on β and η and the probability to select alternative j for individual i with conditional on η is similar as MNL below:

$$P(j|\eta)=Lj(\eta)=\frac{e^{X_j\beta_j+Z_j\eta}}{\sum_{k\in J}e^{X_k\beta_k+Z_k\eta}} \qquad (3\text{-}8)$$

As η is not given, by integrating over all values of η weighted by the density of η, the unconditional choice probability for each individual can be obtained as below.

$$P(j)=\int_\eta\left[\frac{e^{X_j\beta_j+Z_j\eta}}{\sum_{k\in J}e^{X_k\beta_k+Z_k\eta}}\right]f(\eta|\Omega)\partial\eta \qquad (3\text{-}9)$$

$$i.e.\ \ P(j)=\int_\eta Lj(\eta)f(\eta|\Omega)\partial\eta \qquad (3\text{-}10)$$

Models of this form are called *Random Parameter Logit (RPL)* models. The probabilities do not exhibit the IIA property, and the specification of f describes different substitution patterns. The RPL model handles it in two ways. One way is known as random parameter specification, which specifies each β_i with both a mean and a standard deviation. The error component is another way of dealing with the unobserved taste variation, as a separate error component in the random parameter, by estimating with standard deviation as an additional error component.

3.6 Conclusions

The BTS provides current and high quality data of household travel survey in a cost effective manner for the transportation plans and policy making process. The author used this high quality data in this research to extract worthwhile conclusions. The MIMIC and RPL models have been developed successfully by using this HTS data, and LVs are incorporated, to improve the

explanatory power of the models. It can provide the insights of traveller behavioural process towards mode choice, from the perspective of PAT.

MIMIC models are intensively used to analyse the LVs. In contrast, the RPL model is not intensively used to analyse discrete choice models. Nowadays RPL model is becoming popular, due to its comparative advantages. MIMIC (multiple indicators and multiple causes) models are used to test the reliability of LVs indicators, due to their capability of simultaneous estimation of measurement equations relating each factor to its indicators. The structural equations specify the relationships among latent factors, and between them and TOAs. Furthermore, the study is analysed using the RPL (random parameter logit) model, because of its power to overcome the problem of independence of irrelevant alternatives (IIA) and independent and identically distributed (IID) assumption.

After describing the data and explaining the methods of data analysis, the next chapter deals with the empirical analysis of understanding the principal-agent relationship in traveller mode services. The empirical analysis in the next chapter is divided into four major sections: (a) the importance of LVs in choice model and also the merit of LVs over TOAs for traveller mode choice; (b) exploring the traveller mode choice behaviour; (c) exploring the car owner mod echoic preferences; (d) understanding an inferred relationship between traveller and TfNSW based on mode choice analysis. Moreover, traveller mode choice probability, which is also interpreted in next chapter, indicates the existence of principal-agent problem.

Chapter 4

Transport Mode Choice Analysis: An Inferred Relationship between Traveller and TfNSW

This chapter examines the traveller mode choice behaviour to understand the principal-agent relationship in transport mode service. Six LVs and thirteen TOAs have been evaluated to determine the mode choice probabilities that indicate whether the agency problem within transport mode services exists. Coefficients of the nineteen variables are estimated using TRPL (traditional random parameter logit) and HRPL (hybrid random parameter logit) models to see the differences of the effects of relevant variables on the traveller mode choice. Prior to analysing mode choice behaviour, the influence/importance of LVs to traveller choice behaviour is considered. The analysis then proceeds to explore the relationship, subject to analysis, of traveller mode choice behaviour.

4.1 LVs in Traveller Preference Heterogeneity

Traditional Objectives Attributes (TOAs) such as level of service (e.g. travel time, cost, etc.), socio-economic (e.g. income, gender etc.) and trip characteristics (e.g. trip rate, trip purpose, etc.) can be incorporated easily into choice models. However, there are also latent heterogeneities (comfort, reliability etc.) that are often overlooked by the traditional transportation modellers. Section 4.1 deals with this issue and tests the (in) adequacy of TOAs representing latent factors. It also deals with the structure of the influence of latent and objective factors. MIMIC (Multiple Indicators and Multiple Causes) structural modelling was employed to analyse the relationships among the LVs, and between latent factors and TOAs.

4.1.1 Validity of indicators representing LVs

There can be several possible combinations in a measurement model in SEM. The exploratory and confirmatory factor models (CFM & EFM) are used to guide the significant indicators in the

MIMIC measurement model. The factor analytic models (EFM and CFM) focus solely on how, and the extent to which, the observed variables are linked to their underlying latent factors (Byrne, 2010).

In this research, twenty indicators are involved explaining six LVs. Several groups of exploratory and confirmatory factor models are examined to identify the weights of indicators to represent the LVs. The factor analytic models are estimated using AMOS v.19 software (Arbuckle, 2010). There are three exploratory models described in table 4.1.

The first exploratory factor model (model 1 in Table 4.1) is performed to check the behaviour indicators related to *comfort* and *convenience* variables. There were six indicators in model 1 to represent the travellers' comfort and convenience factors. After assessing the statistical results and inferences, the six indicators and two factor models fit the data well, as the values of model fit criteria show the acceptable level. The model fit criteria includes Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), Normed Fit Index (NFI), Comparative Fit Index (CFI) and Root-Mean-Square Error of Approximation (RMSEA). The correlation between comfort and convenience is estimated at 0.39 (not high), which shows that these two variables as defined are dissimilar for the data used in this research (Table 4.2).

The standardized regression coefficients represent the average amount of change of standard deviation in the dependent variable with correspondence to a standard deviation change in the predictor variable. Standardized regression coefficients allow comparison of the intensity of effects of the different predictor variables on the dependent variable. That is, the regression weights for two factors (e.g. *comf* and *conv*) explain how much difference it makes to be in the category for which the dummy variable is 1. Therefore, the estimates calculate how much more important the indicators are to represent comfort and convenience. The negative sign of slower service of public transport indicates a lesser influence on comfort and convenience.

Table 4.1 The γ vector matrix of standardized regression weights of indicators using 2008/09 data (t-statistics in parenthesis)

Indicators	**Regression weights**					
	Model 1		Model 2		Model 3	
	comf	*conv*	*flex*	*safety*	*reliab*	*satis*
Enjoy time to read/relax on the vehicle	0.138 (6.56)	0.003 (0.05)				
Stressfulness on the vehicle	1.253 (7.99)	0.134 (2.01)				
Slower service	-0.044 (-5.75)	-0.04 (-0.05)				
Availability of alternative mode	0.206 (1.89)	0.235 (6.59)				
Accessibility (go where required)	0.81 (0.04)	1.080 (4.52)				
Timetable availability	0.079 (1.77)	0.191 (6.15)				
Fixed start and finish times – each day can vary			-0.911 (-9.42)	-0.451 (-1.56)		
Rotating shift			1.070 (6.23)	-0.845 (-0.02)		
Roster shift			0.343 (7.52)	-0.152 (-0.05)		
Variable hours			0.896 (6.33)	-0.154 (-0.04)		
Safety response for mode used in 1st trip			0.010 (0.01)	0.960 (8.30)		
Safety response for mode used in 2nd trip			0.007 (0.52)	1.048 (4.56)		
Safety response for mode used in 3rd trip			0.067 (1.21)	0.912 (6.32)		
Frequency					1.536 (6.54)	0.315 (1.23)
Punctuality					1.477 (3.85)	0.405 (0.04)
Faster					1.247 (6.53)	0.308 (1.11)
Cleanliness					0.580 (0.05)	0.699 (5.21)
Travel time					-1.052 (-0.15)	-1.136 (-7.85)
Travel cost					-0.015 (-1.22)	-0.033 (-6.42)
Waiting time					-1.752 (-1.09)	-1.829 (-4.65)
Goodness-of-fit						
GFI	0.993		0.991		0.993	
AGFI	0.966		0.958		0.975	
NFI	0.872		0.978		0.840	

Indicators	**Regression weights**					
	Model 1		Model 2		Model 3	
	comf	*conv*	*flex*	*safety*	*reliab*	*satis*
CFI	0.924		0.990		0.980	
RMSEA	0.047		0.048		0.016	
lower bound	0.000 (90% CI of RMSEA)		0.000 (90% CI of RMSEA)		0.000 (90% CI of RMSEA)	
upper bound	0.103 (90% CI of RMSEA)		0.094 (90% CI of RMSEA)		0.067 (90% CI of RMSEA)	

Legend:
Significant at 90% level of confidence if 1.960 > t ≥ 1.645;
Significant at 95% level of confidence if 2.576 > t ≥ 1.960;
Significant at 99% level of confidence if 2.810 > t ≥ 2.576;
Significant at 99.5% level of confidence if 3.290 > t ≥ 2.810;
Significant at 99.9% level of confidence if t ≥ 3.290.

Table 4.2 Correlation among LVs using 2008/09 HTS data

Latent factors	**Coefficient of correlation (*r*)**
Comfort ↔ Convenience	0.39
Flexibility ↔ Safety	0.45
Reliability ↔ Satisfaction	0.09

Another finding is that comfort is highly dependent on *stressfulness* while people travel. In the case of convenience, *accessibility* is more sensitive for travelers in their choice process. The regression weights of *comf* for first three indicators (model 1) are higher than *conv*, which specify that these three indicators are more sensitive in representing *comfort* over *convenience*. For the last three indicators in same model, regression weights of *conv* are greater than *comf*, which is interpreted in the same way.

The second exploratory factor model (model 2 in Table 4.1) depicts two latent factors; i.e. *safety* and *flexibility*. These two latent factors are known as *safety* and *flex*. Model 2 shows seven indicators for both factors. The correlation between these two factors is 0.45 (not high) suggesting that these two factors reflect distinct attitudinal behaviour (Table 4.2).

In terms of safety and flexibility factors of travellers' behaviour, *safety* concerns are more prominent than *flexibility* since the average value of safety is greater than flexibility (model 2). People who work on rotating shift basis are most concerned with the flexibility. The indicators *fixed start*, *rotating shift*, *roster shift* and *variable hours* achieved negative signs. Hence, they do not play an important role in defining safety. The overall model acceptability was satisfactory, as

the sufficient evidence of acceptable level was achieved through various model fit criteria, described in model 2.

The third exploratory factor model was performed for the assessment of *reliability* and *satisfaction*. Model 3 in Table 4.1 illustrates the regression coefficients for each indicator. Seven indicators are employed, explaining *reliability* and *satisfaction*. The positive correlation between reliability and satisfaction is achieved. The latent factors are not strongly correlated (0.09) showing these factors are distinct in representing preferences (Table 4.2).

The indicators *travel time*, *travel cost* and *waiting time* show negative sign what indicate disutility of reliability and satisfaction of the transport service. *Punctuality* of the mode is the most influential indicator for the travelers. The overall goodness of fit measures of a third exploratory factor model also indicates this is at an acceptable level and highly significant.

After investigating the regression weights using exploratory factor models, confirmatory factor model is performed, called path analysis, to estimate the factor definitions simultaneously. The path coefficients for all six latent factors are described in Table 4.3 The coefficient of first indicator of each factor were set as constant 1, as required for identification. All indicators are highly significant at between 95% and 99.9% level of confidence based on t-values.

Table 4.3 Standardized path coefficients using 2008/09 HTS data (t-values in parenthesis)

Latent factors	Observed indicators	Path coefficients
Comfort (*pcomf*)	Enjoy time to read/relax on the vehicle	0.069 (5.19)
	Stressfulness on the vehicle	0.482(7.87)
	Slower service	-0.215 (-3.99)
Convenience (*pconv*)	Availability of alternative mode	0.150 (3.89)
	Accessibility (go where required)	0.319 (6.77)
	Timetable availability	0.208 (2.85)
Flexibility (*pflex*)	Fixed start and finish times-each day can vary	-0.021(-4.34)
	Rotating shift	0.407 (6.01)
	Roster shift	0.088 (5.33)
	Variable hours	0.313 (2.99)
Safety (*psafety*)	Safety response for mode used in 1st trip	1.214 (3.01)
	Safety response for mode used in 2nd trip	0.331(5.96)
	Safety response for mode used in 3rd trip	0.206 (1.99)
Reliability (*preliab*)	Frequency	0.382 (2.00)
	Punctuality	0.653 (3.85)
	Faster	0.182 (8.45)
Satisfaction (*psatis*)	Cleanliness	0.049 (5.96)
	Travel time	-0.217 (-3.02)
	Travel cost	-0.069 (-4.55)
	Waiting time	-0.211 (-9.12)
Goodness-of-fit criteria		
Goodness-of-Fit Index (GFI)		0.926
Adjusted Goodness-of-Fit Index (AGFI)		0.900
Normed Fit Index (NFI)		0.887
Comparative Ft Index (CFI)		0.926
Root-Mean-Square Error of Approximation (RMSEA)		0.044
lower bound		0.037 (90% CI of RMSEA)
upper bound		0.056 (90% CI of RMSEA)

Legend:
Significant at 90% level of confidence if $1.960 > t \geq 1.645$;
Significant at 95% level of confidence if $2.576 > t \geq 1.960$;
Significant at 99% level of confidence if $2.810 > t \geq 2.576$;
Significant at 99.5% level of confidence if $3.290 > t \geq 2.810$;
Significant at 99.9% level of confidence if $t \geq 3.290$.

Though NFI is slightly lower it is still within the acceptance level. In addition, the overall goodness-of-fit for confirmatory factor model is very good, as indicated by GFI, AGFI, CFI and

RMSEA (Table 4.3). The statistics of all the model fit criteria achieve the acceptable level, giving a good indication that the model fits data reasonably well.

4.1.2 Associations between TOAs and LVs

Although Ben-Akiva et al. (1999) note that it sometimes can be difficult to find good causal variables for the LVs, this does not seem to be the case here. This is because the causal variables (as well as the indicator variables) are predictors of LVs and retain the statistical significant (at the individual 1% - 5% level). Table 4.4 shows the overall model fitness evaluation of MIMIC model. The calculated GFI, AGFI, CFI, NFI and RMSEA indices show that the model accuracy is very good and thus the overall data fit is acceptable, i.e. the model cannot reject the hypothesis of the relationship between LVs and TOAs.

Table 4.4 Overall model fit criteria of MIMIC model

Goodness-of-fit criteria	**Acceptable range***	**Magnitudes**
GFI	0.75 - 0.99	0.927
AGFI	0.63 - 0.97	0.902
NFI	0.72 - 0.99	0.964
CFI	0.88 - 1.00	0.911
RMSEA	0.01 - 0.14	0.043
lower bound		0.030 (90% CI of RMSEA)
upper bound		0.051 (90% CI of RMSEA)

* Shah and Goldstein (2006)

The relationship between TOAs and latent factors are summarized as regression weights (coefficients) depicted in Table 4.5. The associations indicate the contributions of TOAs to LVs in a quantitative way.

Table 4.5 The α vector matrix showing impacts of LOS, SEC and TC on LVs

Observed variables	Comfort (t-value)	Convenience (t-value)	Flexibility (t-value)	Safety (t-value)	Reliability (t-value)	Satisfaction (t-value)
Level of service (LOS)						
Travel time	-0.055 (-2.10)	-0.127 (-9.51)	-0.171 (-7.52)	-0.166 (-6.23)	-0.444 (-5.24)	-0.129 (-1.98)
Travel cost	-0.202 (-5.77)	-0.058 (-2.00)	-0.004 (-1.99)	-0.100 (-3.04)	-0.022 (-1.87)	-0.155 (-6.66)
Waiting time	-0.175 (-2.00)	-0.222 (-4.35)	-0.067 (-2.99)	-0.089 (-1.97)	-0.107 (-3.33)	-0.077 (-2.80)
Socio-economic characteristics (SEC)						
Age	-0.014 (-11.1)	-0.132 (-2.45)	-0.184 (-4.12)	-0.258 (-3.45)	-0.142 (-4.44)	-0.143 (-11.11)
Income	0.145 (2.72)	0.189 (2.33)	-0.082 (-3.50)	-0.136 (-4.49)	0.026 (2.17)	0.028 (4.52)
Family size	-0.008 (-3.15)	-0.006 (-3.45)	0.021 (5.10)	0.011 (6.0)	-0.009 (-2.10)	-0.086 (-4.44)
Gender	0.054 (3.35)	0.189 (2.85)	-0.106 (-3.13)	-0.08 (-6.85)	0.074 (3.85)	-0.086 (-3.45)
Car ownership	0.221 (5.00)	0.132 (5.63)	-0.011 (-2.50)	-0.087 (-6.78)	0.122 (3.21)	0.102 (6.19)
No. of children	0.221 (4.21)	0.136 (2.89)	-0.121 (-6.37)	-0.121 (-6.37)	0.013 (4.25)	0.109 (15.25)
Full times workers	0.008 (2.03)	0.071 (3.44)	-0.037 (-3.63)	-0.037 (-3.44)	0.025 (3.13)	0.045 (5.63)
Trip characteristics (TC)						
Trip rate	0.058 (4.68)	0.137 (3.43)	0.012 (2.00)	0.012 (2.00)	0.019 (3.17)	0.107 (17.83)
Distance travelled	0.111 (4.84)	0.115 (2.05)	0.160 (8.00)	0.168 (6.41)	0.212 (3.45)	0.022 (7.33)
Trip purpose	0.063 (1.75*)	0.171 (2.00)	0.126 (10.5)	0.126 (5.73)	0.031 (2.58)	0.025 (2.08)

Legend:
Significant at 90% level of confidence if $1.960 > t \geq 1.645$;
Significant at 95% level of confidence if $2.576 > t \geq 1.960$;
Significant at 99% level of confidence if $2.810 > t \geq 2.576$;
Significant at 99.5% level of confidence if $3.290 > t \geq 2.810$;
Significant at 99.9% level of confidence if $t \geq 3.290$.

Going over the parameters of the model (Table 4.5), the estimated coefficients on the LOS variables has the expected negative signs since the comfort and convenience decrease as travel time, travel cost and waiting time are increased, and this decrease is considered as a disutility. They satisfactorily passed the acceptable significance level.

Owning car(s) increases the positive perceptions of the car's comfort and convenience compared to public transport. The car is perceived as more comfortable and convenient relative to public transport, for those who have a child, or are female. Age and family size have negative impacts on comfort and convenience factors. Age is one of the strongest negative predictor of flexibility and safety attitude, besides level of service. On the other hand, having a car has found predictor of flexibility though it is negative.

4.1.3 Overall explanation of LVs by TOAs

Despite the complex relationships between TOAs individually and LVs, the overall capacity of TOAs is considered to represent the LVs (Table 4.6). The capacity has been determined by *R-square* values (coefficient of determination) of regression and does not exceed 11%, 15% and 14% of SEC, LOS and TC respectively. That is, latent factors are explained at on average 7.68%, 11.96% and 7.91% by SEC, LOS and TC correspondingly which is very minimal. It is an indication of inadequacy of TOAs to reflect LVs.

Table 4.6 The contribution of TOAs to LVs by R-square values

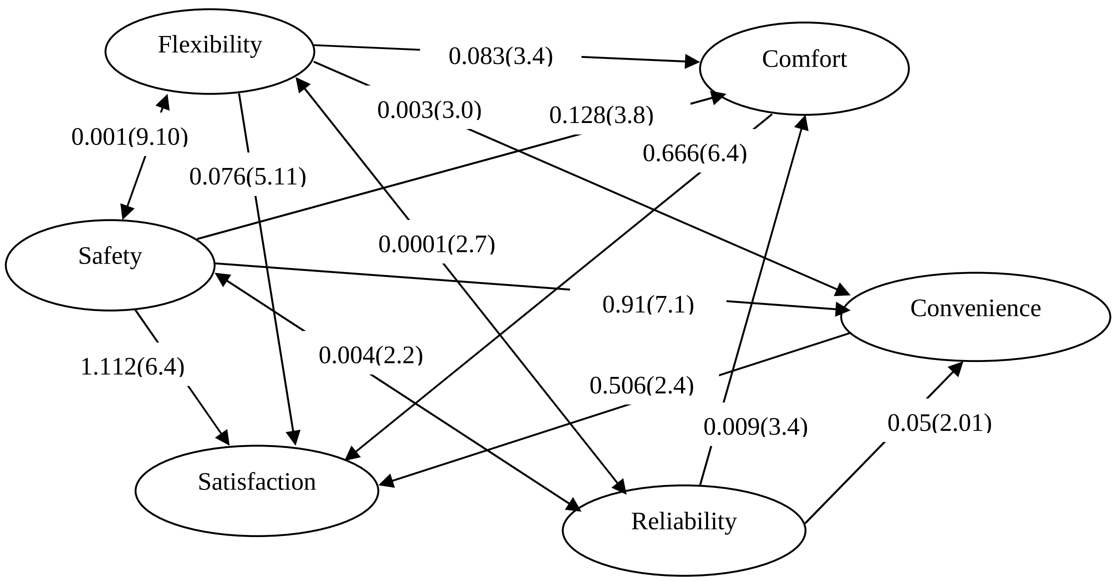
LVs	**SEC**	**LOS**	**TC**
	Beta (t- statistic)	Beta (t- statistic)	Beta (t- statistic)
Comfort	0.096 (12.44)	0.144 (2.45)	0.077 (4.45)
Convenience	0.122 (2.99)	0.135 (4.10)	0.141 (3.17)
Flexibility	0.080 (1.98)	0.080 (1.65)	0.099 (4.24)
Safety	0.104 (11.5)	0.118 (4.15)	0.102 (7.25)
Reliability	0.058 (1.99)	0.117 (2.44)	0.087 (6.08)
Satisfaction	0.085 (10.00)	0.120 (4.01)	0.051 (4.17)

Legend:
Significant at 90% level of confidence if $1.960 > t \geq 1.645$;
Significant at 95% level of confidence if $2.576 > t \geq 1.960$;
Significant at 99% level of confidence if $2.810 > t \geq 2.576$;
Significant at 99.5% level of confidence if $3.290 > t \geq 2.810$;
Significant at 99.9% level of confidence if $t \geq 3.290$.

Around 11% of the variation of convenience is explained by unit changes of SEC, about 15% of the variation of reliability is explained by LOS and about 14% of the variation of convenience is described by unit changes of TC. The influence by the SEC on other latent factors is minimal, compared with LOS and TC. LOS and TC are also not affecting the variation of latent factors substantially. However, on average, the TOAs account for only 10.1% variation of latent factors.

4.1.4 Interrelationships among the LVs

The significant interrelationships among the latent factors are summarized in Figure 4.1 that shows the standardised coefficients (t-values in parenthesis) among LVs. The t-values were highly significant at a 95% to 99.9% level of confidence.



Legend:
Significant at 90% level of confidence if $1.960 > t \geq 1.645$;
Significant at 95% level of confidence if $2.576 > t \geq 1.960$;
Significant at 99% level of confidence if $2.810 > t \geq 2.576$;
Significant at 99.5% level of confidence if $3.290 > t \geq 2.810$;
Significant at 99.9% level of confidence if $t \geq 3.290$.

Figure 4.1 Standardised path coefficients among LVs using 2008/09 HTS data

The established model structure properly captures the relationships that exist in the data with rational signs. In Figure 4.1, safety, comfort and convenience are highly dependent variables that lead to satisfaction. On the other hand, safety has greater effect on convenience. The covariance is almost zero between safety and flexibility, and between flexibility and reliability. This means that they are uncorrelated between themselves. The hypotheses of relationship (shown in Figure 4.1) among the LVs that were assumed by the authors based on the literature

review, cannot be rejected. This model presents the evidence to accept the hypotheses related to relationships among the factors in Figure 4.1.

4.1.5 Discussions on LVs in traveller preference heterogeneity

This Section (4.1) evaluates the influence of LVs on the travellers' preference heterogeneity of SSD. In extant research, choice process is dominated by the TOAs, but in real life the scenario is different. Psychological factors, which have previously been treated as a *black box*, dominate the choice process considerably, in addition to TOAs. This section quantified these effects on latent factors using a factor analytic model and MIMIC structure models. The important relationships among latent factors, and between TOAs and latent factors, were measured and it was found that the overall model fits the data reasonably well. That is, the influence of latent factors is stronger than the TOAs. This is because the overall connection of TOAs minimally explains latent aspects in traveller preference heterogeneity. In reality, latent factors are, therefore, responsible for structuring the traveller's choice preference at 89.9% of all potential attribute concerns.

This study observes that LOS, SEC and TC have a limited contribution to latent factors. The important relationships among LVs, and between latent factors and TOAs, are measured. It is also found that the overall capacity of TOAs (10.1%) is not sufficient to explain the LVs. Therefore, other factors indicate the distinctness of LVs in traveller preferences, and require measurement separately from LOS, SEC and TC.

It is concluded that the behavioural findings and the modelling techniques have direct policy and planning implications in SSD future transportation planning. These include:

i) Many latent factors can be as important as the TOAs, such as SEC, TC and LOS in explaining travel behaviour. Ignoring them in the planning process could result in significant errors in model estimation and application. A systematic review of latent factors is required in transportation planning to achieve the set objectives fixed by the transport agencies and planners.
ii) Incorporating these latent factors not only improves the explanatory power of the transportation models but also provides more realistic descriptions of travellers' decision making. In other words, the models and descriptions of HTS data can be used in the policy and planning implication. It may help to get the worthwhile outcome related to traveller mode choice behaviour from the perspective of PAT.

The results of this section support the contention that LVs are important in travellers' choice processes, in ways that are relevant to transportation planners and policy-makers. Although possibly not directly susceptible to policy intervention, a better understanding of these relationships is useful for decision makers and transportation planners, when designing and developing sustainable transportation policies for the dwellers of SSD.

As it was found that LVs are important in travellers' mode choice decision making process with compared to TOAs, they should be considered along with TOAs to explore the relationship between travellers and TfNSW. In this section, the importance of latent attributes to TOAs is explained and structured and then the traveller mode choice behaviour analysis, using RPL models, is described in the following two sections.

4.2 Traveller Mode Choice Behaviour: Results and Discussions

This section (4.2) provides empirical results of the traveller mode choice behaviour by incorporating LVs and TOAs into the RPL models. In section 4.3, travellers are categorised into car owner and non-car owner and mode choice behaviour is analysed based on car owner preferences. RPL models are also used in the analysis of car owner preferences. However, there is little understanding about traveller latent preferences towards various modes for their daily trips (Recker and Stevens 1976; Williams 1978; Cervero 1996; Bhat 1998). Not much research has been done to investigate travellers' perceptions of the various modes. Therefore, this research also attempts to fill the gap by investigating the preferences of travellers towards modes choice analysis.

To understand the effect of traveller choice attributes on mode choice, this section discusses the results of two types of RPL models: traditional RPL (TRPL) and hybrid RPL (HRPL). These illustrate the effects of choice attributes on mode choice and examine the probability of mode choice. TRPL model deals with only TOAs and in HRPL, LVs are included with TOAs. The results obtained from MIMIC model (described in earlier Section 4.1) have been used to quantify LVs, which are incorporated in RPL models as explanatory variables. The coefficients of attributes to mode choice are interpreted by using traditional (in which LVs are not integrated) and hybrid (in which LVs are integrated) RPL models (Table 4.7). The models were estimated in LIMDEP (Nlogit 4), computer software, using maximum likelihood estimation procedures.

Table 4.7 presents the results obtained from RPL models. A series of four RPL models were estimated considering TOAs and LVs. Only LOS attributes are included in TRPL1. Then LOS and SEC are considered in TRPL2 model. In TRPL3 model, all TOAs have been incorporated simultaneously and finally, HRPL explains the impact of TOAs and LVs together.

HRPL model has the similar specification of model TRPL3, but the effect of LVs is allowed to vary among individuals. This also models the introduction of an interaction between the mean estimate of the random parameter and a covariate. This is equivalent to revealing the presence (or absence) of heterogeneity around the mean parameter estimate. In the traditional RPL (TRPL1, TRPL2 and TRPL3) models, all variables except *age*, *income*, *family size*, *full time workers of household*, *trip rate per day per person* and *distance travelled* are significantly associated with the choice of travel mode. The HRPL model provides a better representation of the nature of preferences, as it accounts for variation in travellers' preference heterogeneity across socioeconomic and other characteristics.

Table 4.7 Results of random parameter logit models

Attributes	TRPL1	TRPL2	TRPL3	HRPL
Random parameter in utility functions				
Travel cost (mean) Travel cost (st.dev.)	-3.14 (-2.11) 1.07 (1.99)	-3.19 (-2.56) 1.02 (2.45)	-3.20 (-5.55) 1.05 (3.45)	-2.11 (-2.62) 1.06 (4.21)
Waiting time (mean) Waiting time (st.dev.)	-1.72 (-2.12) 0.08 (3.11)	-1.85 (-3.11) 0.03 (3.41)	-1.93 (-3.15) 0.004 (2.48)	-1.75 (-3.14) 0.004 (2.99)
Age (mean) Age (st.dev.)		-0.22 (-1.89) 0.48 (1.66)	-0.11 (-1.11) 0.22 (2.01)	-0.09 (-2.84) 0.58 (2.63)
Car ownership (mean) Car ownership (st.dev.)		1.84 (3.52) 0.03 (3.51)	1.91 (5.21) 0.02 (4.21)	1.89 (4.00) 0.04 (4.44)
Having children (mean) Having child (st.dev.)		-1.78 (-6.44) 0.11 (3.65)	-1.80 (-5.41) 0.26 (3.11)	-1.77 (-5.02) 0.12 (2.87)
Trip purpose (mean) Trip purpose (st.dev.)			0.07(3.44) 0.003 (2.33)	0.06 (2.15) 0.001 (3.63)
Comfort (mean) Comfort (st.dev.)				3.32 (7.89) 0.12 (5.66)
Convenience (mean) Convenience (st.dev.)				3.18 (4.66) 0.22 (5.66)
Safety (mean) Safety (st.dev.)				5.18 (11.11) 0.45 (9.84)
Flexibility (mean) Flexibility (st.dev.)				0.73 (1.00) 0.30 (2.16)
Reliability (mean) Reliability (st.dev.)				5.17 (11.10) 0.01 (9.15)
Satisfaction (mean) Satisfaction (st.dev.)				1.23 (2.66) 0.09 (2.99)
Nonrandom parameter in utility functions				
Age	-0.08 (-0.99)			
Having children under 5 yrs	-0.97 (-3.62)			
Car ownership	1.27 (3.91)			
Trip purpose	0.97 (2.89)	0.97 (2.91)		
Travel time	-1.17 (-7.85)	-1.17 (-8.77)	-1.19 (-6.42)	-1.11 (-3.63)
Gender	0.29 (1.89)	0.32 (2.13)	0.39 (2.15)	0.21 (2.69)
Income	1.32 (1.85)	1.69 (1.11)	1.98 (1.91)	1.50 (0.89)
Family size	-0.94 (-0.45)	0.94 (1.01)	0.93 (0.99)	0.94 (1.00)
Full time workers of HH	0.97 (0.32)	0.97 (1.45)	0.97 (0.85)	0.97 (1.01)
Trip rate	0.91 (1.11)	0.91 (1.00)	0.91 (1.74)	0.91 (1.86)
Distance travelled	-0.19 (-1.89)	-0.17 (-1.11)	-0.78 (-1.01)	-0.24 (-1.12)
Mode constant				
Car as a passenger (base)	0	0	0	0
Car as a driver	-2.22 (-2.45)	-2.23 (-2.54)	-2.22 (-3.10)	-2.41 (-9.00)
Train	-1.00 (-1.99)	-1.17 (-1.98)	-2.18 (-3.41)	-2.39 (-7.15)
Bus	-0.11 (-0.52)	-0.12 (-1.23)	-0.14 (-1.22)	-0.10 (-1.53)
Heterogeneity around the mean				
Travel cost :Income	-0.11 (-4.21)	-0.10 (-2.98)	-0.12 (-3.62)	-0.01 (-3.99)
Waiting time :Income	-0.54 (-3.56)	-0.54 (-2.56)	-0.54 (-2.96)	-0.03 (-3.85)
Age: Income		-0.11 (-1.89)	-0.08 (-1.98)	-0.12 (-2.14)
Car ownership: Income		0.02 (3.12)	0.01 (3.01)	0.65 (5.14)
Having child: income		-0.02 (-1.99)	-0.09 (-2.66)	-0.17 (-3.01)
Purpose: Income			0.01 (4.01)	0.05 (3.01)
Comfort: Income				0.09 (3.10)
Convenience: Income				0.10 (2.89)

Attributes	**TRPL1**	**TRPL2**	**TRPL3**	**HRPL**
Safety: Income				0.45 (11.52)
Flexibility: Income				0.05 (2.45)
Reliability: Income				0.31 (10.20)
Satisfaction: Income				0.08 (5.10)
Model statistics				
Log likelihood function	-812.41	-768.31	-715.28	-613.37
McFadden Pseudo R-squared	0.21	0.25	0.27	0.36
Akaike Information Criterion (AIC)	0.019	0.018	0.017	0.014
Modal choice probability				
Car as a driver	0.713	0.721	0.731	0.785
Car as a passenger	0.080	0.075	0.055	0.010
Train	0.159	0.160	0.181	0.190
Bus	0.048	0.044	0.033	0.015

Legend:
t-values within the parenthesis.
TRPL1 = Effect of LOS;
TRPL2 = Effect of LOS and SEC;
TRPL3 = Effect of LOS, SEC and TC;
HRPL = Effect of LVs along with LOS, SEC and TC.
Significant at 90% level of confidence if 1.960 > t ≥ 1.645;
Significant at 95% level of confidence if 2.576 > t ≥ 1.960;
Significant at 99% level of confidence if 2.810 > t ≥ 2.576;
Significant at 99.5% level of confidence if 3.290 > t ≥ 2.810;
Significant at 99.9% level of confidence if t ≥ 3.290.

The signs of the parameters estimated from RPL models are coherent and there are no directional differences in the results of TRPL and HRPL models. Log likelihood has decreased significantly from a TRPL to HRPL model. This indicates that HRPL model has a greater explanatory power than TRPL model, as expected. The models presented in Table 4.7 seem to fit the data reasonably well in terms of their predictive power and the model log likelihood function. The low pseudo R^2 is to be expected. A lower AIC means that the predicted values using this model is closer to reality. Thus among four RPL models, the best model is the HRPL model as the AIC shows the lowest value and TRPL3 is the better model among TRPL models for the same indication.

The parameters of LVs are statistically significant in hybrid RPL model. Moreover, the high significance of the LVs standard deviation parameters in hybrid RPL model implies that the effects of the LVs over the choice process effectively and importantly vary across individuals. Interestingly it is observed in the estimated parameters that the significance level of TRPL2 is stronger than TRPL1, and TRPL3 is stronger than TRPL2. It indicates good explanatory power of the models, while socioeconomic and trip characteristics variables are included with the level of service variables. On the other words, it seems that inclusion of more relevant variables in the model increases the explanatory power. With respect to mode-related and individual-specific

attributes, the *car ownership* per adult in household exhibits strong effects on travel mode choice (Bresson et al., 2004). As expected, owning a car per adult in a household increases the propensity to use a car for daily trips. An interesting finding in this study is that the impact of *income variable* on mode choice is lower and insignificant in the results of HRPL model. It implies that people are more concerned about the latent attributes than TOAs in mode choice. However, this may be explained by the fact that owning a car might capture much of the income effect and therefore, car ownership was found as a strong explanatory variable with a strong significance level of 0.001.

According to the TRPL model, the highest preference goes on *travel cost* with a high confidence level in relation to mode choice. Mode choice is also highly influenced by *waiting time*, *car ownership, travel time* and *having child* while LVs are not included in the model. As per the hybrid RPL models, very high preferences are given to *safety*, *reliability*, *comfort*, and *convenience*. Also the impact of *travel cost, car ownership,* and *waiting time* on choice cannot be ignored and is still adequately observed. *Having child* also influences preferences for *comfort, safety* and *reliability* of mode as the coefficients have been increased in a hybrid RPL model. Its negative sign indicates the sensitivity over the choice.

Safety and *reliability* among LVs and *travel cost, waiting time, car ownership* among TOAs are dominant attributes in mode choice case. The coefficient of *travel time*, *waiting time* and *travel cost* sharply decreases when LVs are integrated in the model. This indicates the dominant characteristics of LVs over the traveller mode choice. The estimated coefficients of the *waiting time, travel time* and *travel cost* variables have the expected negative signs since the utility of a mode decreases as *waiting time* increases and/or *travel time* increases and/or the mode becomes more expensive. The negative signs of these three variables, in turn, imply that this reduces the choice probability of the corresponding mode.

The *trip purpose* (1 if work, 0 otherwise) and gender (1 if male, 0 otherwise) variables are assigned as dummy variables in this analysis. Signs are positive for both of them. A positive sign of the estimated parameter for trip purpose indicates that travellers prefer to drive a car or take train to commute to work. And a positive sign of the gender variable can be interpreted as females have a higher preference for cars as a mode of transport than males. *Having child* also influences preferences for *comfortable*, *safe* and *reliable* mode of transport. Because parents want to make sure comfortable journey for their children either it is compulsory or optional trip

in order to ensure safe driving. While LVs are incorporated in the model, significance level of objective variables has been decreased and it implies that travellers are more motivated by their latent preferences during the mode choice process. Thus, TfNSW is obliged to promote the modal services as per travellers' expectations.

Due to incorporating the LVs in the HRPL model, the results are more realistic than TRPL, and *safety* and *reliability* are the most influential attributes in mode choice. The importance of a *convenient* and *comfortable* mode of transport is also adequately observed which is as expected, confirming the theoretical validity. However, the introduction of HRPL allows us not only to improve model fit, but also to achieve better estimates of the parameters.

The HRPL model is more powerful than the TRPL model for predicting mode choice among travellers, as LVs are integrated into the model that provide valuable insights into the travellers' motivational processes. The variables *travel time*, *waiting time*, *travel cost*, *car ownership* and *having child* among TOAs are significant predictors of mode choice. On the other hand, results from the HRPL model show how latent factors impact on mode choice. Interestingly, incorporating LVs into the model leads not only to the reduction of the effects of TOAs, but also to a decrease in its significance level on mode choice. This indicates the dominant influence of LVs in the decision making process, and in that sense delivers true additional insight. Thus, LVs are observed as being more influential than TOAs on mode choice of the people of SSD.

Safety and *reliability* have been shown to be important determinants of travellers' mode choice in SSD. Second to these are *comfort* and *convenience*. Considering LVs, it is observed that the likelihood of train use has increased, though car use is still dominant. Thus RailCorp, in conjunction with TfNSW, might consider how they could provide better services. In contrast, as the probability of bus usage is declining, bus companies need to improve services to attract passengers.

The *first proposition* that travellers prioritise LVs when making a decision about mode choice in relation to their utility function is supported (Table 4.7). Importantly, the integration of travellers' expectations in the design and implementation process of mode related projects undertaken by TfNSW is valued highly by the travellers, and this is something important that TfNSW should focus on.

The *second proposition* that LVs are constituted by the socioeconomic characteristics of people is also supported by the estimated results (Table 4.5). For example, due to high *income* and *having child*, people may be more motivated by a comfortable journey, while professional people might value *reliability* more. Older and female travellers may pay more attention to a *safe* journey rather than travel time or cost. The *third proposition* is that socioeconomic characteristics have a direct effect on mode choice. For example, mode choice matters whether a traveller is *male or female*. *Owning a car* and/or *having a child* are found to be factors why travellers might preference the use of a car. Elderly people prefer public transport (e.g. bus or train) rather than a private car due to their declining health (Table 4.7).

The *fourth proposition* explains the role of LOS on mode choice. LOS has a notable influence on traveller mode choice. Even though this influence decreases slightly once LVs are included, it remains strongly significant (Table 4.7). The *fifth proposition* elucidates the relevance of TC to mode choice. Although the influence of TC variables is considerable, the level of significance is not high. This implies that the influence of TC variables should be considered.

The TfNSW should be aware of the consequences relating to the environmental effects of private transport, due to the absence of suitable public transport provision, and therefore, more efforts are needed to attract travellers by satisfying their demands. Providing suitable public transport involves understanding traveller desires and evaluating utilities related to individual and mode specific attributes subject to financial constraints, resources, expertise etc.

In the following section, the travellers have been divided into two samples, (i) car owner, and (ii) non-car owner to observe the car owners’ preferences for modal choices.

4.3 Car Owners’ Mode Choice Preferences: Results and Discussions

This section attempts to analyse car owners and non-car owners’ perceptions of the different types of transport modes (i.e., car as a driver, car as a passenger, bus and train). This section finds that each transport mode may have its own unique set of attributes. In addition, CO and NCO should portray different preferences towards various public and private transports. This should justify different strategies for these two groups of travellers in encouraging them to use public transport modes and limit the use of the car.

The decision of being a household/personal car owner is largely a collective household decision (Zhao, 2009). This decision causes urban transportation problems such as congestion and the associated consequences on climate change and sustainability, etc. There may be some feedback of consideration of global warming, congestion, and other factors, on car ownership decisions. LVs have been incorporated in the car ownership model to evaluate car owners' choice behaviour.

Section 4.2 described the traveller preference heterogeneity in transport mode services without any categorising of travellers (all samples). This section (4.3) deals with the car owners' and non-car owners' preferences separately using the same methodology. How the two samples of travellers (car owner and non-car owner) work in mode services and help to understand traveller behaviour dynamics. To analyse effects of choice attributes on the mode choice, RPL models have also been employed in this section to analyse car owners' preferences.

The key data source of this section is also the cross-sectional 2008/09 household travel survey (HTS) data, released in 2010. The following Table 4.8 shows the ratio of CO (who own one or more cars) and NCO (who does not own car) samples in the entire dataset.

Table 4.8 Ratio of car owner and non-car owner samples

Category of samples	**Per cent**
Car owner	86.8%
No-car owner	13.2%
Total	100%

This section presents a quantitative analysis of traveller mode choice preferences from CO and NCO perspectives, to understand the comparison between them. The results of the structural equation of MIMIC (multiple indicators and multiple causes) model (Table 4.9 and 4.10) are presented here. Directional changes in the structural MIMIC model are similar between the CO and NCO sample but coefficients vary. The estimated coefficients were valid according to model fit criteria, such as GFI, AGI, NFI, CFA and RMSEA, with lower and upper bound. The results obtained from the MIMIC model (structural equations) were used to calculate the expected values of LVs, which were incorporated in RPL models as explanatory variables. The mean scores of the attributes towards mode choice are analysed followed by the traditional (in which

LVs are not included) and hybrid (in which LVs are included) RPL models to understand the agency relationship within the transport mode services.

According to RPL models shown in Table 4.11, the signs of the estimated parameters are coherent and there are no directional differences in the results, based on the two samples. Traditional RPL and hybrid RPL models are evaluated for each sample. In each sample, log likelihood values have decreased in going from TRPL to HRPL, but in TRPL and HRPL models between CO and NCO samples, these values are not largely different. This indicates that the level of preferences between the two samples is stable. On the other hand, the hybrid RPL model has an increased explanatory power when compared with the traditional RPL model. HRPL models are the best model, which is indicated by the lowest values of AIC.

Table 4.9 MIMIC model results of car owner sample: structural equations using 2008/09 data (t-values in the parenthesis)

	Travel time	**Travel cost**	**Waiting time**	**Age**	**Income**	**Family size**	**Gender**	**Car ownership**	**No. child**	**Full time**	**Trip rate**	**Distance travelled**	**Trip purpose**
Comfort	-0.159 (-3.10)	-0.199 (-4.75)	-0.210 (-2.10)	-0.011 (-4.85)	-0.146 (3.00)	0.005 (2.85)	-0.061 (-2.98)	0.289 (5.89)	0.210 (5.41)	0.003 (2.11)	0.066 (3.41)	0.099 (3.84)	0.005 (1.86)
Convenience	-0.121 (-7.51)	-0.029 (-1.95)	-0.201 (-5.24)	-0.132 (-2.31)	0.089 (3.12)	-0.006 (-2.51)	0.077 (3.51)	0.187 (6.48)	0.200 (4.51)	0.071 (2.61)	0.018 (2.96)	0.015 (1.95)	0.002 (2.01)
Flexibility	-0.111 (-5.55)	-0.002 (-1.69)	-0.077 (3.08)	0.085 (3.08)	0.055 (2.81)	0.001 (1.89)	0.106 (2.01)	-0.013 (-1.96)	-0.111 (-3.52)	-0.038 (-2.01)	0.011 (1.99)	0.166 (3.84)	0.089 (6.10)
Safety	-0.101 (-1.98)	-0.076 (-2.11)	-0.075 (-3.41)	-0.199 (-4.10)	-0.086 (-2.52)	0.005 (3.10)	0.09 (4.51)	-0.099 (-7.41)	-0.151 (-6.61)	-0.008 (-2.01)	0.019 (1.96)	0.121 (4.63)	0.111 (2.33)
Reliability	-0.207 (-7.84)	-0.019 (-2.00)	-0.375 (-6.99)	-0.124 (-2.94)	0.021 (2.41)	-0.003 (-2.04)	0.044 (2.85)	0.122 (4.41)	0.084 (3.96)	0.026 (2.12)	0.011 (2.10)	0.021 (1.99)	-0.045 (-2.41)
Satisfaction	-0.128 (-2.46)	-0.166 (-5.11)	-0.101 (-2.53)	0.089 (4.51)	0.025 (3.41)	0.012 (2.63)	-0.061 (-2.10)	0.021 (5.96)	0.101 (8.23)	0.015 (2.96)	0.017 (4.84)	0.042 (6.74)	0.013 (2.84)
Model fit criteria													
GFI	0.952												
AGFI	0.941												
NFI	0.956												
CFI	0.931												
RMSEA Lower bound upper bound	0.028 0.000 (90% CI of RMSEA) 0.045 (90% CI of RMSEA)												

Legend:
Significant at 90% level of confidence if 1.960 > t ≥ 1.645;
Significant at 95% level of confidence if 2.576 > t ≥ 1.960;
Significant at 99% level of confidence if 2.810 > t ≥ 2.576;
Significant at 99.5% level of confidence if 3.290 > t ≥ 2.810;
Significant at 99.9% level of confidence if t ≥ 3.290.

Table 4.10 MIMIC model results of non-car owner sample: structural equations using 2008/09 data (t-values in the parenthesis)

	Travel time	**Travel cost**	**Waiting time**	**Age**	**Income**	**Family size**	**Gender**	**Car ownership**	**No. child**	**Full time**	**Trip rate**	**Distance travelled**	**Trip purpose**
Comfort	-0.154 (-5.10)	-0.198 (-3.75)	-0.199 (-2.22)	-0.013 (-3.41)	-0.176 (-2.99)	0.004 (1.99)	-0.071 (-1.86)	n/a	0.200 (4.41)	0.002 (2.10)	0.055 (2.41)	0.077 (3.01)	0.011 (1.96)
Convenience	-0.115 (-4.51)	-0.022 (-2.01)	-0.119 (-5.95)	-0.122 (-2.66)	0.091 (3.41)	-0.005 (-2.50)	0.072 (2.89)	n/a	0.211 (3.96)	0.051 (2.10)	0.011 (3.01)	0.012 (2.01)	0.006 (1.96)
Flexibility	-0.011 (-4.41)	-0.003 (-1.84)	-0.062 (-3.10)	0.077 (3.12)	0.035 (2.01)	0.004 (1.99)	0.101 (1.89)	n/a	-0.011 (-2.22)	-0.036 (-2.00)	0.010 (1.84)	0.106 (2.84)	0.077 (3.41)
Safety	-0.100 (-1.90)	-0.071 (-2.00)	-0.073 (-4.10)	-0.191 (-3.89)	-0.087 (-2.10)	0.005 (2.89)	0.089 (5.12)	n/a	-0.149 (-5.96)	-0.007 (-2.10)	0.018 (2.11)	0.091 (3.89)	0.081 (2.13)
Reliability	-0.201 (-6.89)	-0.022 (-2.10)	-0.269 (-6.74)	-0.116 (-2.51)	0.019 (2.31)	-0.003 (-2.01)	0.033 (2.63)	n/a	0.088 (3.31)	0.021 (2.10)	0.012 (1.96)	0.015 (1.97)	-0.040 (-2.19)
Satisfaction	-0.118 (-2.44)	-0.116 (-4.12)	-0.109 (-2.10)	0.081 (3.30)	0.015 (3.35)	0.011 (2.06)	-0.055 (-2.01)	n/a	0.112 (6.79)	0.016 (2.74)	0.012 (4.12)	0.039 (5.79)	0.018 (2.97)
Model fit criteria													
GFI	0.922												
AGFI	0.912												
NFI	0.936												
CFI	0.919												
RMSEA Lower bound upper bound	0.033 0.013 (90% CI of RMSEA) 0.048 (90% CI of RMSEA)												

Legend:
Significant at 90% level of confidence if 1.960 > t ≥ 1.645;
Significant at 95% level of confidence if 2.576 > t ≥ 1.960;
Significant at 99% level of confidence if 2.810 > t ≥ 2.576;
Significant at 99.5% level of confidence if 3.290 > t ≥ 2.810;
Significant at 99.9% level of confidence if t ≥ 3.290.

Table 4.11 Results of RPL models: A comparison between car owner and non-car owner sample

Attributes	Car owner		Non-car owner	
	TRPL	*HRPL*	*TRPL*	*HRPL*
Random parameter in utility functions				
Travel cost (mean)	-4.01(-4.32)	-3.45(-2.85)	-3.99(-3.89)	-3.89(-2.96)
Travel cost (st.dev.)	0.08(2.11)	0.82(3.51)	0.09(2.55)	0.11(2.31)
Waiting time (mean)	-2.13(-3.01)	-2.01(-2.89)	-1.96(-3.00)	-1.95(-3.16)
Waiting time (st.dev.)	0.07(2.73)	0.09 (2.66)	0.003 (2.41)	0.006(3.85)
Age (mean)	-0.11(-0.56)	-0.13(-1.00)	-0.12(-1.01)	-0.10(-1.95)
Age (st.dev.)	1.11(1.05)	0.39 (2.11)	0.21(1.15)	0.62(1.63)
Car ownership (mean)	1.99 (3.10)	2.03 (4.52)	N/A	N/A
Car ownership (st.dev.)	0.11(2.52)	0.03 (3.29)		
Having child (mean)	1.00 (3.45)	-1.02(-5.44)	-0.98 (-5.41)	-1.00 (-5.74)
Having child (st.dev.)	0.12 (2.93)	0.11 (2.65)	0.26 (3.11)	0.12 (2.87)
Trip purpose (mean)	0.003 (0.42)	0.005 (0.89)	0.007 (1.44)	0.09 (1.00)
Trip purpose (st.dev.)	0.001 (1.11)	0.003 (1.00)	0.003 (0.33)	0.002 (1.63)
Comfort (mean)		3.86 (5.15)		2.67 (4.31)
Comfort (st.dev.)		0.002(2.96)		0.08 (3.33)
Convenience (mean)		2.14 (3.86)		2.96 (3.62)
Convenience (st.dev.)		0.012(2.64)		0.02 (3.55)
Safety (mean)		5.62(5.62)		5.42 (4.31)
Safety (st.dev.)		0.003(3.64)		0.04 (4.84)
Flexibility (mean)		0.89 (1.62)		0.39 (0.85)
Flexibility (st.dev.)		0.031 (1.34)		0.03 (1.16)
Reliability (mean)		5.19 (7.14)		4.96 (8.12)
Reliability (st.dev.)		0.06 (4.66)		0.06 (4.63)
Satisfaction (mean)		0.69 (2.96)		0.68 (2.59)
Satisfaction (st.dev.)		0.03 (1.98)		0.03 (2.71)
Nonrandom parameter in utility functions				
Travel time	-1.01(-5.41)	-0.98(-4.98)	-0.94 (-4.41)	-0.90 (-3.61)
Gender	0.56(2.81)	0.72(2.86)	0.49 (2.00)	0.65 (3.61)
Income	0.62(1.70)	0.71(1.69)	1.75 (2.81)	1.63 (2.61)
Family size	-0.02(-1.45)	-0.04(-1.41)	0.09 (1.09)	0.07 (1.52)
Full time workers of HH	0.01(0.96)	0.02 (0.91)	0.02 (0.45)	0.04 (0.94)
Trip rate	0.91(2.41)	0.94 (3.00)	0.74 (2.52)	0.72 (2.97)
Distance travelled	-0.81(-0.89)	-0.75(-1.00)	-0.79 (-0.99)	-0.72 (-1.42)
Mode constant				

Attributes	Car owner		Non-car owner	
	TRPL	*HRPL*	*TRPL*	*HRPL*
Car as a passenger (base)	0	0	0	0
Car as a driver	-1.12(-3.41)	-1.23(-4.54)	N/A	N/A
Train	-0.97(-2.11)	-0.88(-2.98)	-1.01(-1.98)	-1.10(-2.79)
Bus	-0.56(-1.52)	-0.44(-0.79)	-0.35(-1.65)	-0.38(-2.53)
Heterogeneity around the mean				
Travel cost :Income	-0.09(-1.21)	-0.10(-2.68)	-0.12(-3.62)	-0.11 (-2.99)
Waiting time :Income	-0.15(-4.10)	-0.63(-5.12)	-0.09(-2.96)	-0.12 (-3.90)
Age: Income	-0.06(-0.69)	-0.10(-2.89)	-0.04(-1.85)	-0.03 (-2.14)
Car ownership: Income	0.52(2.96)	0.86(3.74)	N/A	N/A
Having child: income	-0.04(-1.97)	-0.08(-1.99)	-0.02(-1.66)	-0.0.4 (-2.01)
Purpose: Income	0.01(0.49)	0.05 (0.89)	0.01(1.11)	0.02 (1.89)
Comfort: Income		0.21 (4.21)		0.20 (4.10)
Convenience: Income		0.18 (3.41)		0.12 (2.41)
Safety: Income		0.32 (5.41)		0.40 (8.42)
Flexibility: Income		0.02 (0.45)		0.03 (1.89)
Reliability: Income		0.34 (5.44)		0.31(7.41)
Satisfaction: Income		0.15 (3.46)		0.11(3.74)
Modal choice probability				
Car as a driver	0.773	0.781	N/A	N/A
Car as a passenger	0.03	0.034	0.050	0.040
Train	0.169	0.170	0.580	0.600
Bus	0.036	0.041	0.410	0.390
Model statistics				
Log likelihood function	-649.12	-562.87	-676.21	-590.64
McFadden Pseudo R-squared	0.24	0.28	0.23	0.26
Akaike Information Criterion (AIC)	0.015	0.013	0.016	0.014

Legend:
0 in "Coef." column indicates that the constant term set to zero; t-values within the parenthesis.
Significant at 90% level of confidence if $1.960 > t \geq 1.645$;
Significant at 95% level of confidence if $2.576 > t \geq 1.960$;
Significant at 99% level of confidence if $2.810 > t \geq 2.576$;
Significant at 99.5% level of confidence if $3.290 > t \geq 2.810$;
Significant at 99.9% level of confidence if $t \geq 3.290$.

According to the traditional RPL model, both CO and NCO place a high preference on *travel cost* in relation to mode choice. Besides *travel cost*, mode choice is highly influenced by *waiting time*, *car ownership*, *travel time and having children*. As per the hybrid RPL models, very high preferences are given to *safety*, *reliability*, *comfort*, and *convenience* among LVs, however the

impact of *travel cost, car ownership,* and *waiting time* on choice cannot be ignored. Respondents, who own a car recorded higher mean scores for most of the mode-specific and individual-specific attributes than those who do not own a car.

The most dominant attributes are *safety, reliability* among LVs followed by *travel cost*, *waiting time, car ownership* among TOAs, for both CO and NCO. The coefficient of *waiting time* sharply decreases from CO to NCO. This means that the people who place importance on *waiting time* are more motivated to own a car. Or it could mean that car owners get used to short waiting times, or it could mean that they state preferences in order to justify their ownership of a car. It does not mean that *waiting time* is not important to NCO and the results support this. The estimated coefficients of *waiting time*, *travel cost*, and *travel time* variables have expected negative signs since the utility of a mode decreases as waiting time increases, travel time increases, and/or the mode becomes more expensive. The expected negative signs of these three variables, in turn, imply that this reduces the choice probability of the corresponding mode.

People who have children are more inclined to own a car and the results support this. Thus, the mean score of the attribute *having child* is higher to a CO than a NCO, and this indicates the influence of having a child on owning a car. Its negative sign indicates the sensitivity over the choice. *Having child* also influences preferences for *comfort*, *safety* and *reliability* of mode as the coefficients have been increased in a hybrid RPL model.

An interesting finding is also that the *income* variable in CO sample was not as significant a variable for mode choice as has been found in previous studies (McFadden, 1974; Train, 1980; Kitamura, 1989). This may be explained by the fact that owning a car might capture much of the income effect, and car ownership was found as a strong explanatory variable with a strong confidence level of 99.9%.

Results found from hybrid RPL models are more rational according to the model fit statistics compared with traditional RPL models as per model statistics in Table 4.11. Effects of LVs depict that both CO and NCO prefer *safer* and more *reliable* modes of transport. The coefficients of these two variables are high, which indicates its dominant influence over the mode choice process. The influences of these two attributes on NCO are slightly lower than CO and it infers that CO travellers are more concerned about *safety* and *reliability* than NCOs. The importance of a *convenient* and *comfortable* mode of transport is also adequately observed for both samples

according to the coefficient (Table 4.11). These are all as expected, confirming the theoretical validity. However, the introduction of hybrid RPL model allows us not only to improve model fit, but also to achieve better estimates of the parameters. While LVs are incorporated in the model, the significance level of objective variables decreased marginally. This implies that both CO and NCO are more influenced by the latent preferences during the mode choice process. Thus, TfNSW should consider the aspects of latent preferences in mode services.

The effect of LVs is allowed to vary among individuals; and also models the introduction of an interaction between the mean estimate of the random parameter and a covariate. This is equivalent to revealing the presence or absence of heterogeneity around the mean parameter estimate. The hybrid RPL model provides a better representation of the nature of preferences, as it accounts for variation in travellers' preference heterogeneity across socioeconomic and other characteristics. The high significance of the LVs standard deviation parameters in hybrid RPL model implies that the effects of the LVs over the choice process vary effectively and importantly across individuals.

All models presented in this section seem to fit the data reasonably well in terms of their predictive power and the model log likelihood function. The low pseudo R^2 is to be expected however, since most discrete choice models in the literature have a poor fit because of the inherent randomness in individual decision making (Cramer, 1991). AIC values also show that CO models are better than NCO models. As per the results, the best model is the HRPL model of the CO sample as the AIC is the lowest, indicating it is the best model. However, the estimated results illustrate an analogous kind of observation towards mode choice made by both CO and NCO.

Similar to the findings in Section 4.2, the hybrid RPL model is more powerful and explanatory than the traditional RPL model as LVs are integrated into the model that provides valuable insights into the travellers' motivational processes. Results confirm similarities of previous findings of traveller preference heterogeneity analysis that *travel time*, *waiting time*, *travel cost*, and *car ownership* of objective variables are significant predictors of mode choice. Additionally results from hybrid RPL models also show the influences of latent factors on mode choice decision. It is noted that due to the inclusion of LVs into the model, effects of the TOAs are reduced which indicates the dominant influence of LVs on the mode choice decision making process. They provide behavioural insights into traveller behaviour. LVs are shown to be more

preferred than individual and mode specific attributes in mode choice by the people of SSD. However, it could be argued that socioeconomic variables affect attitudes and perception and thereby also preference and choice. Although personality traits such as attitude, perception, and preference cannot be easily forecasted, the relation of these constructs to socioeconomic variables may aid in forecasting such variables (Johansson et al. 2006), e.g. in an ageing society the salience of the safety value is increased and thereby also the relevance of security for mode choice becomes important.

The *first proposition* that both CO and NCO prefer to evaluate the mode choice based on LVs about the contents of their utility function is supported (Table 4.9 and 4.10). Incorporating travellers' desires in designing and implementing process of mode related project undertaken by TfNSW is highly valued by travellers and it is an important factor in choosing a mode.

The *second proposition* is also supported by the estimated results. LVs are affected by the SECs (Table 4.9 and 4.10). For example, due to high income and concern about children, people may prefer a more comfortable journey, while professional people may prefer a reliable journey. Older and female travellers may pay more attention to a safe journey rather than travel time or cost. The *third proposition* is that SEC affects mode choice too. For example, whether the traveller is male or female may affect their choice. Travellers owning a car and having children may push themselves to use a car. In contrast, elderly people prefer to use public transport (bus or train) rather than private car in order to avoid driving at old age (Table 4.11).

The *fourth proposition* explains the relevance of LOS to mode choice. LOS are found as significant variables influencing travellers' decisions. It is also observed that LOS variables are mostly influential in traditional RPL models but, once LVs are included in the RPL model, the influences of LOS variables decrease slightly though still remaining strongly significant (Table 4.11). This means that the *fourth proposition* is adequately supported by the model estimations. The *fifth proposition* is that travellers consider the nature of trip in their mode choice decision making process. Although TC variables except trip rate are not significant, the level of influence is not low. It implies that the influence of TC variables on mode choice cannot be ignored (Table 4.11).

4.4 An Inferred Relationship between Traveller and TfNSW as Indicated in PAT

Based on the discussions about the results of mode choice models, an inferred relationship between the traveller and TfNSW as indicated in PAT is outlined in this section.

4.4.1 Traveller preference, utility and agency relationship

In this research, traveller preference and utility are regarded as key indicators to understand a connection between the traveller and TfNSW. Traveller preference is one of the major choice functions, which has a multitude of influences on TfNSW (Anwar et al., in press). Incorporating the traveller's preference in project design and implementation phase may reduce project failure. There are also a large number of actors, both internal and external, who affect the success and/or failure of a transport project. This means that TfNSW may need to compromise with multiple sets of interests while it performs on behalf of the traveller and as such, adverse selection and goal conflicts may arise. The ability of TfNSW to resolve these conflicts of interest will significantly affect its success or failure to overcome agency problem (Anwar et al., 2013b; Anwar et al., in press).

Utility is considered as a key indicator of traveller satisfaction. The idea of an individual's utility function is an expression of desire or satisfaction, which may be financial, social, and/or psychic, in mathematical form (Anwar et al. in press). Obtained satisfaction is called "*utility*" from an economics point of view and is assumed to be maximized by the individual. The idea of utility is that the individual tries to maximize utility (i.e., gains) over the set of possible choice sets that are obtainable.

PAT argues that the agency problem (uncertainty) arises from the *informational asymmetries, adverse selection and conflict of interest* that also find in the transport services provided by TfNSW. PAT regards this relationship as a contractual phenomenon (Jenson and Meckling, 1976), where a principal (traveller) contracts with an agent (TfNSW) to perform entrusted services on behalf of the traveller. Based on these assumptions, both principal and agent are rational economic entities, both of whom are self-interested maximisers of personal utility. The idea of a 'contract' in PAT is introduced to recognise the necessary metaphorical agreement between the principal and the agent that specifies the obligations of each party. This implies that TfNSW is obliged to provide mode of transport services as travellers expect. Accordingly,

traveller preference is an element that influences utility, and as such needs to be analysed from the supply side to achieve a balanced principal-agent relationship (Anwar et al. in press).

4.4.2 The inferred relationship: Perspective of transport mode services

Exploring the nature of the relationship produces hypotheses and associated propositions that are tested in earlier section of this chapter. From the results, it is shown that the probability of car use is significantly higher than public transport, which indicates that an agency problem exists in transport mode services.

PAT provides an intellectual framework, offers a conceptual hypothesis, and suggests a testable proposition that may enhance the understanding of the impact of choice attributes on mode choice, by integrating traveller preferences into the analysis of transport planning problems. Understanding traveller preferences is vital to organisational survival and competitiveness. TfNSW should evaluate those preferences critically to reduce the agency problem within transport mode services.

In general, travellers take either public transport (e.g. train, bus) or private transport (e.g. car) that maximises their level of satisfaction or 'utility'. In this case, the TfNSW provides public transport and travellers own their own cars. Travellers expect *reliable*, *safe* and *comfortable* public transport, and entrust this task to TfNSW to perform. TfNSW applies its experiences and skills to execute this task as per travellers' expectations. A higher probability of public transport usage would indicate better performance by TfNSW. It would imply that the travellers are getting their desirable mode of transport, similar to what they get from their own car, which is an indication of low agency problem in transport mode services. In contrast, a high probability of car usage would indicate the presence of high level of agency problem.

In terms of the adverse selection of PAT, travellers are not in a position to be aware, at a reasonable level, about the implementing phase of mode service undertaken by TfNSW, and do not have the access to monitor it. Thus, TfNSW may be influenced by other related stakeholders such as political, civil servants, transport companies (Figure 6.2) and traveller's access is limited to TfNSW's project finalising stage. Therefore, *goal/choice conflicts/adverse selection* may occur.

Generally, choice processes of travellers are dominated by TOAs, such as travel time, travel cost, income. But in real life, LVs contribute significantly to the determination of utility. The effects of choice attributes and the probability of using a particular mode are crucial aspects of understanding the principal-agent relationship in mode of transport service. Latent factors (e.g. comfort, convenience, safety, reliability) dominate the choice process considerably in addition to objective variables (Anwar et al., 2011 and 2013a). The TfNSW is not fully aware about the traveller utility function and tends to ignore the LVs, which cause goal/choice conflicts and adverse selection.

In terms of mode choice probability, the decreasing rate of probability for the mode "car as a passenger" (Table 4.7) indicates that the travellers are not comfortable with being a passenger on a car once the travellers consider the latent and other relevant attributes. The probability of car usage as a driver is notably high which means that travellers (principal) are not provided with the services they desire and have entrusted to TfNSW for execution. Basically, TfNSW struggles to reduce the transport problems of cities such as 'unreliable' 'no direct route' and 'congestion' that travellers expect. However, since TfNSW does not perform according to travellers' expectations, travellers continue to use the private car. It indicates an agency problem in transport mode services.

The results identify the prominent critical aspects of traveller preferences (i.e. expectations) that should be met by TfNSW to solve this agency problem. The results are also useful to policy makers in shaping worthwhile policies and programs to encourage the use of public transport (PT), as well as reducing the use of the car to improve the urban environment. Therefore, TfNSW and associated organisations should value the expectations (e.g. safety and reliability) of the travellers and work together to increase the probability of PT usage and reduce the agency problem.

Car ownership has a meaningful impact on the mode choice. Therefore, exploring car owners' and non-car owners' (principal) preferences separately for mode choices describes a unit understanding of the choice behaviour. This understanding also enriches the knowledge of agency relationship in transport mode services. The results identify the important critical aspects of car owners' (CO) and non-car owners' (NCO) preferences that should be performed by the TMA to solve agency problem within transport mode services. Also, it helps policy makers in

shaping their broad policy and programmes in encouraging the use of the public transport modes, as well as reducing the use of the car to improve the urban environment.

Entrusting the desire of CO and NCO to TfNSW develops a metaphor contract between travellers and TfNSW. Travellers desire customer-focused (i.e. safe, reliable, comfortable, gender sensitive, acceptable fare and travel time, etc.) modes, which are supposed to be provided by TfNSW in conjunction with transport service operators, an *agency contract* between travellers and TfNSW. Travellers measure the performance of TfNSW by analysing the attributes related to the mode and then select either public transport (e.g. bus, train) or a private mode (e.g. car). The higher probability of mode usage to public transport indicates the improvement of agency uncertainty. Thus it assumes that TfNSW performs the entrusted tasks as per travellers' demands. In contrast, the increasing probability of car usage signifies that TfNSW cannot fulfil travellers' expectations, and therefore, the agency problem remains unresolved. From the results, the probability of car use is significantly higher than public transport use. This reveals that the agency problem remains in transport mode services. The general theoretical conclusion of this section is that future mode projects undertaken by TfNSW can be more successful by including travellers' latent preferences, and ultimately this is proposed as the way to reduce the agency problem. In addition, reduction of car ownership or usage could be another option to reduce the agency problem too.

The CO and NCO preferences have significant effects on mode choice and it is imperative to understand these preferences to ensure worthwhile policies to implement successful projects by TfNSW. The CO and NCO portrayed the effects of different preferences to the modes and inclusion of these preferences in mode service is delegated to TfNSW to perform on behalf of travellers.

Based on the findings, TfNSW and associated organisations should work together to execute the desire of travellers, in order to improve the various limitations of the public transport system in Sydney, so that the probability of public transport use is increased. This would reduce the uncertainty in the principal–agent relationship. For example, TfNSW should pay more attention to making the bus and trains more attractive, appropriate and accessible for all groups of society and the probability of public transport use might be increased. Further improvements in the bus system can be in the form of providing more congestion-free travel ways for the buses. This

enhances the speed of travelling on the bus and reduces the travel time and agency problem would be reduced in the end.

The TfNSW should also realise consequences relating to the environmental effects of private transport due to failure of suitable public transport provision. Therefore more efforts are needed to attract travellers, by satisfying their demand and improving their awareness. This can also be in the form of understanding traveller desires and evaluating utilities related to individual and mode specific attributes, which should help to provide acceptable public transport. CO makes a significant difference to preferences about what travellers expect from public transport. Hence different strategies should be adopted in the design of the mode service for the CO and NCO so that TfNSW can fulfil the demand of travellers in order to reduce the agency problem.

In order to reduce the agency problem caused by a lack of TfNSW's consideration about CO and NCO's utility functions in modal services, it is necessary for the expectations and demands of CO and NCO to be integrated in design to implementation of transport projects. From the modelling findings, it is observed that current policy is not meeting travellers' preferences, since the probability of using a private car is dominantly high. Therefore, TfNSW should take necessary steps to reduce private car use by incorporating traveller preferences. From the RPL results, it is noticed that integrating LVs in transport projects motivates the travellers to switch from private car to public transport significantly. In this case, TfNSW should measure traveller latent preferences in mode services as being important to provide safe, reliable, cheaper, faster and least waiting time public transport for the traveller. This section has clarified the nature of traveller both CO and NCO preferences by showing hierarchy of importance according to the magnitude of coefficients and t-values. The hierarchy would assist TfNSW to formulate policy response according to travellers' demand by indicating those attributes of the mode choice services.

This chapter describes the empirical results of understanding the effects of traveller choice attributes on modal choice and an inferred relationship between traveller and TfNSW and as per the outcome of this analysis, agency problem within the transport mode services has been noticed. The next chapter (Chapter 5) deals with the minimisation of this agency problem. In addition, Chapter 5 also discusses a temporal study on the traveller mode choice behaviour using 2008/09 and 2010/11 HTS data.

Chapter 5

Temporal and Parametric Study: An Improvement of Agency Problem

It was found in Chapter 4 that the use of private transport was dominantly high rather than public transport use. According to the definition of agency problem within transport mode services, high probability of private transport use indicates the existence of agency problem. It then concludes that the agency problem exists in the transport mode services of TfNSW. In this line, this chapter analyses and compares the results of RPL models using two-year dataset: 2008/09 and 2010/11 HTS of SSD. It also evaluates the predicted changes of mode choice probabilities based on hypothetical scenarios using RPL models. Three hypothetical scenarios were simulated to forecast the changes that would be relevant to transport policy responses as well as improvement of agency problem. Thus, the main contribution of this chapter is two-fold: comparing the hybrid choice models between the different examined years; forecasting the results of different scenarios as an approach of agency problem improvement.

5.1 Two Datasets

Two datasets regarding transport mode choice collected by BTS in 2008/09 and 2010/11 are used in this chapter for temporal analysis. The scope of the HTS involves people who are usual residents of private dwellings in SSD. Visitors to the selected dwellings are not included in the survey. All usual residents of the selected households, regardless of age, are included in the survey.

Since the agency problem within transport mode services of TfNSW is investigated based on traveller choice probabilities, the raw mode choice data of 2008/09 and 2010/11 are showed below in Table 5.1 for further comparison with the output of models. Travel demand can be expressed in terms of the proportion of trips for travelling. The statistics of mode of transport mode can provide a more inclusive picture of modal shift across the travellers. Table 5.1 shows a

comparison about the proportion of trips by mode between 2008/09 and 2010/11 which is adopted from BTS (2012). It is noticed that the use of private transport (car) is decreased and conversely, public transport use has been increased over the year from 2008/09 to 2010/11 though the rates of increase and decrease are minimal. However, this information indicates the decreasing trend in private car use and increasing trend in public transport use. It can be helpful to validate the output of modal probability estimated using RPL models in the later part of this chapter.

Table 5.1 Proportion of trips by mode

Mode	**2008/09**	**2010/11**
Car as a driver	59.26%	59.10%
Car as a passenger	26.88%	26.78%
Train	6.58%	6.74%
Bus	7.28%	7.38%

Source: BTS, (2012)

5.2 Validity of Indicators Representing LVs Using 2010/11 Data

The indicators using 2008/09 HTS data have already been described in Chapter 5. In order to compare the two datasets, the indicators using another 2010/11 HTS data are validated in this chapter through the factor analytic model (EFM and CFM).

In model 1 in Table 5.2, the indicators representing *comfort* and *convenience* have been evaluated to check their validity. Six indicators are assumed to have a significant impact on the variables *comfort* and *convenience*. After estimated the regressions weights, it was found that indicators have a significant effect in representing *comfort* and *convenience* variables. According to model fit criteria, which are Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), Normed Fit Index (NFI), Comparative Fit Index (CFI) and Root- M-Square Error of Approximation (RMSEA), the factors are well fitted to the data. The value of coefficient of correlation between comfort and convenience is 0.41, which indicates a lower strength relationship between them (Table 5.3). Hence these two LVs can be used separately in the analysis of traveller mode choice behaviour.

With standardised regression weights, the effects of indicators on latent factors can be understood and the negative sign indicates how much lesser influence to explain comfort and convenience.

Table 5.2 The γ vector matrix of standardized regression weights of indicators using 2010/11 HTS data (t-statistics in parenthesis)

Indicators	**Regression weights**					
	Model 1		Model 2		Model 3	
	comf	*conv*	*flex*	*safety*	*reliab*	*satis*
Enjoy time to read/relax on the vehicle	0.136 (5.59)	0.007 (0.141)				
Stressfulness on the vehicle	1.178 (4.89)	0.141 (1.11)				
Slower service	-0.056 (-3.84)	-0.002 (-0.04)				
Availability of alternative mode	0.201 (0.152)	0.239 (5.61)				
Accessibility (go where required)	0.834 (1.21)	1.060 (7.12)				
Timetable availability	0.090 (0.89)	0.195 (4.44)				
Fixed start and finish times – each day can vary			-0.201 (-7.10)	-0.021 (-0.98)		
Rotating shift			0.992 (4.51)	-0.717 (-0.06)		
Roster shift			0.331 (5.36)	-0.215 (-1.01)		
Variable hours			0.916 (6.12)	-0.202 (-1.20)		
Safety response for mode used in 1st trip			0.071 (0.21)	1.250 (10.41)		
Safety response for mode used in 2nd trip			0.010 (0.11)	0.970 (7.84)		
Safety response for mode used in 3rd trip			0.069 (0.09)	0.870 (7.11)		
Frequency					1.415 (7.11)	0.213 (0.12)
Punctuality					1.517 (6.10)	0.201 (0.10)
Faster					1.211 (4.14)	0.415 (0.09)
Cleanliness					0.450 (0.05)	0.568 (3.84)
Travel time					-1.015 (-0.10)	-1.212 (-6.74)
Travel cost					-0.008	-0.024

Indicators	**Regression weights**					
	Model 1		Model 2		Model 3	
	comf	*conv*	*flex*	*safety*	*reliab*	*satis*
					(-0.84)	(-4.15)
Waiting time					-1.111 (-0.76)	-1.512 (-6.14)
Goodness-of-fit						
	Model 1		Model 2		Model 3	
GFI	0.985		0.989		0.984	
AGFI	0.978		0.981		0.971	
NFI	0.911		0.975		0.901	
CFI	0.931		0.981		0.990	
RMSEA lower bound upper bound	0.036 0.000 (90% CI of RMSEA) 0.076 (90% CI of RMSEA)		0.017 0.000 (90% CI of RMSEA) 0.067 (90% CI of RMSEA)		0.039 0.017 (90% CI of RMSEA) 0.057 (90% CI of RMSEA)	

Legend:
Significant at 90% level of confidence if $1.960 > t \geq 1.645$;
Significant at 95% level of confidence if $2.576 > t \geq 1.960$;
Significant at 99% level of confidence if $2.810 > t \geq 2.576$;
Significant at 99.5% level of confidence if $3.290 > t \geq 2.810$;
Significant at 99.9% level of confidence if $t \geq 3.290$.

Table 5.3 Correlation among LVs using 2010/11 HTS data

Latent factors	**Coefficient of correlation (*r*)**
Comfort ↔ Convenience	0.41
Flexibility ↔ Safety	0.36
Reliability ↔ Satisfaction	0.10

The influence of *stressfulness* is higher on comfort while people travel, whereas convenience is highly dependent on *accessibility* of mode in their choice process. According to model 1 described in Table 5.2, the regression weights of first three indicators are higher and more significant than *conv*. This indicates that these three indicators are mostly relevant to represent the comfort over convenience. For the rest indicators in model 1 in the same table, the regression weights are more relevant to *conv* as they are statistically significant and have a higher value of regression weights than *comf*.

Models 2 and 3 can also be explained in the same way. The overall model acceptability was satisfactory as sufficient evidence of acceptable level was achieved through various model fit criteria such as GFI, AGFI, NFI, CFI and RMSEA, as described for models 2 and 3 in Table 5.2.

Table 5.4 shows the standardised path coefficients that have been estimated using confirmatory factor models, known as path analysis. With the path analysis, the factor definitions are estimated simultaneously. In order to estimate the path coefficients, the regression weight was set at 1 for the first indicator of each factor, which is required for model identification. The t-values of each indicator show that indicators are statistically significant at 95% to 99.9% level of confidence.

Table 5.4 Standardized path coefficients using 2010/11 HTS data (t-values in the parenthesis)

Latent factors	Observed indicators	Path coefficients
Comfort (*comf*)	Enjoy time to read/relax on the vehicle	0.062 (6.12)
	Stressfulness on the vehicle	0.611 (8.62)
	Slower service	-0.205 (-4.00)
Convenience (*conv*)	Availability of alternative mode	0.113 (4.25)
	Accessibility (go where required)	0.330 (5.11)
	Timetable availability	0.311(6.11)
Flexibility (*flex*)	Fixed start and finish times-each day can vary	0.011 (3.01)
	Rotating shift	0.018 (5.51)
	Roster shift	0.051 (4.44)
	Variable hours	0.021 (3.99)
Safety (*safety*)	Safety response for mode used in 1st trip	0.912 (6.01)
	Safety response for mode used in 2nd trip	0.251 (5.01)
	Safety response for mode used in 3rd trip	0.211 (4.44)
Reliability (*reliab*)	Frequency	0.511 (3.52)
	Punctuality	0.431 (4.13)
	Faster	0.081 (2.89)
Satisfaction (*satis*)	Cleanliness	0.059 (4.23)
	Travel time	-0.300 (-2.81)
	Travel cost	-0.159 (-5.66)
	Waiting time	-0.221 (-8.11)
Goodness-of-fit criteria		
GFI		0.945
AGFI		0.941
NFI		0.891
CFI		0.911
RMSEA lower bound upper bound		0.016 0.000 (90% CI of RMSEA) 0.067 (90% CI of RMSEA)

Legend:
Significant at 90% level of confidence if 1.960 > t ≥ 1.645;
Significant at 95% level of confidence if 2.576 > t ≥ 1.960;
Significant at 99% level of confidence if 2.810 > t ≥ 2.576;
Significant at 99.5% level of confidence if 3.290 > t ≥ 2.810;
Significant at 99.9% level of confidence if t ≥ 3.290.

The estimated values of GFI, AGFI, NFI, CFI and RMSEA show that the path model is very good statistically and the model fits the data reasonably well, as the statistics of all the model fit criteria achieve the acceptable level.

5.3 Temporal Analysis between 2008/09 and 2010/11 HTS Data

5.3.1 Effects of choice attributes on traveller mode choice

This section discusses the impact of TOAs and LVs on traveller mode choice, with comparisons between 2008/09 and 2010/11 using TRPL3 and HRPL models. The TRPL3 model deals with TOAs only and in HRPL, LVs are included with TOAs. The results of the α vector matrix in the structural equation of MIMIC model using 2010/11 HTS data are described in Table 5.5. The results of the α vector matrix using 2008/09 have been explained in chapter 4 (Table 4.5). The estimated coefficients were valid according to model fit criteria, such as GFI, AGFI, NFI, CFI and RMSEA, with lower and upper bound that were calculated by computer software AMOS v.19. The estimated parameters in MIMIC model are used to quantify LVs that are incorporated in RPL models as explanatory variables. The models were estimated with Nlogit v.4, using maximum likelihood estimation procedures.

Table 5.5 MIMIC model results using 2008/09 and 2010/11 HTS data: α vector matrix of structural equations (t-values in the parenthesis)

LVs	Travel time		Travel cost		Waiting time		Age		Income		Family size	
	2008/09	2010/11	2008/09	2010/11	2008/09	2010/11	2008/09	2010/11	2008/09	2010/11	2008/09	2010/11
Comfort	-0.055	-0.045	-0.202	-0.212	-0.175	-0.165	-0.014	-0.011	0.145	0.121	-0.008	-0.002
	(-2.10)	(-3.16)	(-5.77)	(-3.86)	(-2.00)	(-5.71)	(-11.1)	(-2.91)	(-2.72)	(-2.87)	(-3.15)	(-3.01)
Convenience	-0.127	-0.211	-0.058	-0.102	-0.222	-0.216	-0.132	-0.125	0.189	0.156	-0.006	-0.002
	(-9.51)	(-7.27)	(-2.00)	(-1.71)	(-4.35)	(-5.13)	(-2.45)	(-2.21)	(-2.33)	(-2.53)	(-3.45)	(-2.76)
Flexibility	-0.171	-0.092	-0.004	-0.003	-0.067	-0.066	-0.184	-0.088	0.082	0.031	0.021	0.022
	(-7.52)	(-3.47)	(-1.99)	(-1.99)	-2.99	(-1.89)	(-4.12)	(-3.41)	(-3.50)	(-1.90)	(-5.10)	(-3.01)
Safety	-0.166	-0.091	-0.1	-0.012	-0.089	-0.132	-0.258	-0.21	-0.136	-0.088	0.011	0.005
	(-6.23)	(-4.22)	(-3.04)	(-3.04)	(-1.97)	(-3.91)	(-3.45)	(-4.67)	(-4.49)	(-2.89)	(-6.00)	(-3.64)
Reliability	-0.444	-0.514	-0.022	-0.011	-0.107	-0.107	-0.142	-0.042	0.026	0.031	-0.009	-0.005
	(-5.24)	(-6.21)	-1.87	(-2.01)	(-3.33)	(-6.11)	(-4.44)	(-1.89)	(-2.17)	(-2.12)	(-2.10)	(-2.11)
Satisfaction	-0.129	-0.192	-0.155	-0.166	-0.077	-0.121	-0.143	-0.142	0.028	0.032	-0.086	-0.008
	(-1.98)	(-3.91)	(-6.66)	(-6.21)	(-2.80)	(-3.71)	(-11.11)	(-5.11)	(-4.52)	(-3.90)	(-4.44)	(-2.12)

Table 5.5 MIMIC model results using 2008/09 and 2010/11 HTS data: α vector matrix of structural equations (t-values in the parenthesis) (cont'd)

LVs	**Gender**		**Car ownership**		**No. child**		**Full time**		**Trip rate**		**Distance travelled**		**Trip purpose**	
	2008/09	2010/11	2008/09	2010/11	2008/09	2010/11	2008/09	2010/11	2008/09	2010/11	2008/09	2010/11	2008/09	2010/11
Comfort	0.054 (-3.35)	0.061 (-4.10)	0.221 (-5.00)	0.301 (-6.12)	0.221 (-4.21)	0.202 (-3.89)	0.008 (-2.03)	0.006 (2.01)	0.058 (-4.68)	0.038 (2.21)	0.111 (-4.84)	0.123 (3.81)	0.063 (1.75)	0.021 (1.90)
Convenience	0.189 (-2.85)	0.126 (-2.63)	0.132 (-5.63)	0.275 (-5.48)	0.136 (-2.89)	0.189 (-4.51)	0.071 (-3.44)	0.002 (1.67)	0.137 (-3.43)	0.117 (2.51)	0.115 (-2.05)	0.11 (2.63)	0.171 (-2.00)	0.131 (2.01)
Flexibility	-0.106 (-3.13)	-0.102 (-2.13)	-0.011 (-2.50)	-0.117 (-5.15)	-0.121 (-6.37)	-0.131 (-5.31)	-0.037 (-3.63)	-0.007 (-2.85)	0.012 (-2.00)	0.001 (2.13)	0.16 (-8.00)	0.013 (4.11)	0.126 (-10.50)	0.126 (4.20)
Safety	-0.08 (-6.85)	-0.098 (-4.12)	-0.087 (-6.78)	-0.219 (-7.72)	-0.121 (-6.37)	-0.166 (-6.61)	-0.037 (-3.44)	-0.008 (-2.44)	0.012 (-2.00)	0.112 (3.01)	0.168 (-6.41)	0.171 (3.69)	0.126 (-5.73)	0.041 (2.58)
Reliability	0.074 -3.85	0.012 (-3.07)	0.122 (-3.21)	0.414 (-4.56)	0.013 (-4.25)	0.003 (-4.11)	0.025 (-3.13)	0.007 (2.12)	0.019 (-3.17)	0.016 (3.19)	0.212 (-3.45)	0.112 (3.12)	0.031 (-2.58)	0.009 (2.51)
Satisfaction	-0.086 (-3.45)	-0.087 (-3.21)	0.102 (-6.19)	0.139 (-5.11)	0.109 (-15.25)	0.092 (-6.15)	0.045 (-5.63)	0.007 (5.16)	0.107 -17.83	0.097 (6.91)	0.022 (-7.33)	0.062 (5.33)	0.025 (-2.08)	0.068 (3.01)

Table 5.5 MIMIC model results using 2008/09 and 2010/11 HTS data: α vector matrix of structural equations (t-values in the parenthesis) (cont'd)

Model fit criteria	2008/09	2010/11
GFI	0.927	0.963
AGFI	0.902	0.945
NFI	0.964	0.901
CFI	0.911	0.950
RMSEA	0.043	0.033
Lower bound	0.030 (90% CI of RMSEA)	0.013 (90% CI of RMSEA)
upper bound	0.051 (90% CI of RMSEA)	0.048 (90% CI of RMSEA)

Legend:
Significant at 90% level of confidence if 1.960 > t ≥ 1.645;
Significant at 95% level of confidence if 2.576 > t ≥ 1.960;
Significant at 99% level of confidence if 2.810 > t ≥ 2.576;
Significant at 99.5% level of confidence if 3.290 > t ≥ 2.810;
Significant at 99.9% level of confidence if t ≥ 3.290.

Table 5.6 summarises the estimated results of the two datasets with the specifications of RPL model. A specified number of TOAs and LVs have been integrated in the models to observe the overall impacts on traveller mode choice from 2008/09 to 2010/11.

The analysis suggests that both models produce similar results when considering TOAs, but when LVs are included, the importance of LVs exceeds those of TOAs for both dataset. For example, findings from both the TRPL and HRPL models suggest that in 2010/11, *travel time* had a greater impact on traveller mode choice than *travel cost*. Also, the effect of *trip purpose* on mode choice was shown to increase between 2008/09 and 2010/11, while the effects of *family size*, *full time workers*, and *trip rate* declined. An interesting outcome was the identified decrease in the effect of *waiting time* on mode choice in both models. This finding is consistent with those of the BTS Report (BTS, 2012), which suggests a growing uptake of public transport by travellers who appear to place less importance on waiting time. Unlike the TRPL model, however, the HRPL model identified age as a significant factor in mode choice, particularly in the case of elderly people, who generally seek a comfortable or convenient mode of transport. Similarly, the effect of *car ownership* is higher in the HRPL model, which indicates that owning a car maximises the desired utility that may come from LVs rather than TOAs.

The importance of LVs to travellers is clearly observed in the HRPL models. All of them are also statistically significant except the variable *flexibility*. The variables with the highest impact in both years were *safety* and *reliability*, followed by *comfort* and *convenience*. Overall, the impact of LVs on mode choice was shown to increase between 2008/09 and 2010/11.

Table 5.6 Results of temporal study between 2008/09 and 2010/11 HTS data

Attributes	**TRPL3** (t-values)		**HRPL** (t-values)		**Differences in coefficient** (limit of both directions)	
	(2008/09)	*(2010/11)*	*(2008/09)*	*(2010/11)*	*TRPL3*	*HRPL*
Random parameter in utility functions						
Travel cost (mean) Travel cost (st.dev.)	-3.20 (-5.55) 1.05 (3.45)	-3.14 (-4.15) 0.41 (3.11)	-2.11 (-2.62) 1.06 (4.21)	-2.09 (-3.00) 0.70 (2.22)	↓ 1.8% (±0.02%)	↓0.9% (±0.01%)
Waiting time (mean) Waiting time (st.dev.)	-1.93 (-3.15) 0.004 (2.48)	-1.76 (-3.19) 0.03 (5.00)	-1.75 (-3.14) 0.004 (2.99)	-1.70 (-4.00) 0.09 (3.94)	↓ 8.8% (±0.55%)	↓2.8% (±0.06%)
Age (mean) Age (st.dev.)	-0.11 (-1.11) 0.22 (2.01)	-0.11 (-0.05) 0.25 (1.891)	-0.09 (-2.01) 0.58 (2.63)	-0.091(-1.60) 0.49 (1.70)	↓0.9% (±0.01%)	↑1.1% (±0.01%)
Car ownership (mean) Car ownership (st.dev.)	1.91 (5.21) 0.02 (4.21)	1.86 (5.11) 0.01 (4.51)	1.89 (4.00) 0.04 (4.44)	1.94 (5.55) 0.05 (3.55)	↓2.6% (±0.05%)	↑2.6% (±0.05%)
Having child (mean) Having child (st.dev.)	-1.80 (-5.41) 0.26 (3.11)	-1.77 (-4.11) 0.06 (4.00)	-1.77 (-5.02) 0.12 (2.87)	-1.81 (-5.01) 0.09 (5.19)	↓1.6% (±0.02%)	↑2.2% (±0.04%)
Trip purpose (mean) Trip purpose (st.dev.)	0.07 (3.44) 0.003 (2.33)	0.071 (3.01) 0.04 (3.12)	0.06 (2.15) 0.001 (3.63)	0.062 (3.00) 0.02 2.72)	↑1.4% (±0.01%)	↑3.3% (±0.08%)
Comfort (mean) Comfort (st.dev.)			3.32 (7.89) 0.12 (5.66)	3.51 (8.79) 0.11 (6.66)		↑5.7% (±0.23%)
Convenience (mean) Convenience (st.dev.)			3.18 (4.66) 0.22 (5.66)	3.25 (5.46) 0.02 (4.36)		↑2.2% (±0.03%)
Safety (mean) Safety (st.dev.)			5.18 (11.11) 0.45 (9.84)	5.51 (10.22) 0.09 (7.01)		↑6.3% (±0.29%)
Flexibility (mean) Flexibility (st.dev.)			0.73 (1.00) 0.30 (2.16)	0.72 (0.80) 0.03 (1.21)		↓1.3% (±0.01%)
Reliability (mean) Reliability (st.dev.)			5.17 (11.10) 0.01 (9.15)	5.71 (9.01) 0.01 (5.15)		↑10.4% (±0.78%)
Satisfaction (mean) Satisfaction (st.dev.)			1.23 (2.66) 0.09 (2.99)	1.25 (3.00) 0.10 (3.25)		↑1.6% (±0.02%)
Nonrandom parameter in utility functions						
Travel time	-1.19 (-6.42)	-1.20 (-4.10)	-1.11 (-3.63)	-1.13 (-4.64)	↑0.8% (±0.02)	↑1.7% (±0.02%)
Gender	0.39 (2.15)	0.40 (1.89)	0.21 (2.11)	-0.214 (2.01)	↑2.5% (±0.05%)	↓1.9% (±0.03%)
Income	1.98 (1.91)	1.99 (2.11)	1.50 (0.89)	1.46 (1.99)	↑0.5% (±0.01%)	↓2.7% (±0.05%)
Family size	0.93 (0.99)	0.90 (1.12)	0.94 (1.00)	0.89 (1.00)	↓3.2% (±0.07%)	↓5.3% (±0.2%)
Full time workers of HH	0.97 (0.85)	0.94 (0.56)	0.97 (1.01)	0.93 (0.07)	↓3.0% (±0.07%)	↓4.1% (±0.12%)
Trip rate	0.91 (1.74)	0.89 (2.55)	0.91 (1.86)	0.85 (2.70)	↓2.1% (±0.03%)	↓6.5% (±0.13%)
Distance travelled	-0.78 (-1.01)	-0.81 (-2.22)	-0.24 (-1.12)	-0.26 (-1.90)	↑3.8% (±0.1%)	↑8.3% (±0.49%)
Mode constant						
Car as a passenger (base)	0	0	0	0	0	0
Car as a driver	-2.22 (-3.10)	-2.09 (-3.00)	-2.41 (-9.00)	-2.56 (-10.0)	↓5.8% (±0.24%)	↑6.2% (±0.27%)

Attributes	**TRPL3** (t-values)		**HRPL** (t-values)		**Differences in coefficient** (limit of both directions)	
	(2008/09)	*(2010/11)*	*(2008/09)*	*(2010/11)*	*TRPL3*	*HRPL*
Train	-2.18 (-3.41)	-2.21 (-4.41	-2.39 (-7.15)	-2.41 (-4.15)	↑1.3% (±0.01%)	↑0.8% (±0.0%)
Bus	-0.14 (-1.22)	-0.15 (-4.89)	-0.10 (-1.53)	-0.103 (-3.11)	↑7.1% (±0.36%)	↑3.0% (±0.06%)
Heterogeneity around the mean						
Travel cost :Income	-0.12 (-3.62)	-0.129 (-3.51)	-0.01 (-3.99)	-0.011 (-4.11)	↑7.5% (±0.4%)	↑9.0% (±0.71%)
Waiting time :Income	-0.54 (-2.96)	-0.48 (-5.01)	-0.03 (-3.85)	-0.033 (-4.15)	↓11.1% (±0.88%)	↑10.0% (±0.71%)
Age: Income	-0.08 (-1.98)	-0.07 (-0.98)	-0.12 (-2.14)	-0.11 (-1.96)	↓12.5% (±1.11%)	↓8.3% (±0.49%)
Car ownership: Income	0.01 (3.01)	0.011 (2.91)	0.65 (5.14)	0.61 (4.15)	↑10.0% (±0.71%)	↓6.1% (± 0.27%)
Having child: income	-0.09 (-2.66)	-0.1 (-3.16)	-0.17 (-3.01)	-0.19 (-4.07)	↑11.1% (±0.88%)	↑11.7% (±0.99%)
Purpose: Income	0.01 (4.01)	0.001 (3.01)	0.05 (3.01)	0.052 (3.11)	↓9.0% (±2.01%)	↑4.0% (±0.11%)
Comfort: Income			0.09 (3.10)	0.101 (4.21)		↑12.2% (±1.06%)
Convenience: Income			0.10 (2.89)	0.112 (3.80)		↑12.0% (±1.03%)
Safety: Income			0.45 (11.52)	0.51 (10.51)		↑13.3% (±1.27%)
Flexibility: Income			0.05 (2.45)	0.052 (1.80)		↑4.0% (±0.11%)
Reliability: Income			0.31 (10.20)	0.35 (9.10)		↑12.8% (±1.19%)
Satisfaction: Income			0.08 (5.10)	0.089 (4.11)		↑11.2% (±0.90%)
Model statistics						
Log likelihood function	-715.28	-696.80	-613.37	-576.53	↓2.58% (±0.05%)	↓6.00% (±0.26%)
McFadden Pseudo R-squared	0.27	0.28	0.36	0.38	↑3.7% (±0.1%)	↑5.56% (±0.22%)
Akaike Information Criterion (AIC)	0.0170	0.0165	0.0145	0.0136	↓2.94% (±0.06%)	↓6.21% (±0.27%)
Modal choice probability						
Car as a driver	0.731	0.720	0.785	0.770	↓1.1% (±0.02%)	↓1.5% (±0.03%)
Car as a passenger	0.055	0.049	0.010	0.020	↓0.6% (±0.85%)	↑1.0% (±02.01%)
Train	0.181	0.204	0.190	0.211	↑2.3% (±1.15%)	↑2.1% (±0.87%)
Bus	0.033	0.053	0.015	0.033	↑2.0% (±2.02)	↑1.8% (±2.12%)

Legend:
↑ means increase; ↓ means decrease;
Significant at 90% level of confidence if $1.960 > t \geq 1.645$;
Significant at 95% level of confidence if $2.576 > t \geq 1.960$;
Significant at 99% level of confidence if $2.810 > t \geq 2.576$;
Significant at 99.5% level of confidence if $3.290 > t \geq 2.810$;
Significant at 99.9% level of confidence if $t \geq 3.290$.

The probability of train usage was shown to increase by 2.3% and 2.1% from 2008/09 to 2010/11 according to TRPL and HRPL models respectively. On the other hand, the probability

of car usage decreased by 1.1% and 1.5% in TRPL and HRPL model respectively. Bus usage increased by 2% and 1.8% accordingly. The estimated modal choice probabilities in Table 5.6 are supported by the raw data of modal choice described in Table 5.1. According to raw data of 2008/09 and 2010/11 about modal shift, the private mode of transport (i.e. car) use has been decreased and conversely, the use of public transport (i.e. bus and train) is increased marginally which are similar to the output of models regarding the mode choice probability. In this sense the models are valid. However, the overall difference in results between 2008/09 and 2010/11 are minimal, which suggest that changes in traveller behaviour are gradual. However, it is noticed that the use of public transport is increased and private transport usage is decreased at a certain percent. Perhaps, the infrastructural development, which was initiated by TfNSW, has influenced to promote the public transport use. Some examples of infrastructural development have been described in the later part of this chapter.

As per model statistics, the values of McFadden pseudo R-squared are inflated from 2008/09, which indicates that the models using 2010/11 HTS data are better than 2008/09. The lower AIC means that the predicted values using this model are closer to reality compare with the other model. Thus, the lowest AIC values signify the best model and thus HRPL models are better than TRPL models in this case.

The average changes in modal choice probability are 1.5% and 1.6% as per TRPL3 and HRPL models (Table 5.7). As there are no significant differences of modal choice probability between two years it indicates that changes in traveller behaviour are not so fast. In addition, the increment level of bus and train trips is similar to the 2010/11 HTS summary report.

Table 5.7 Overall (average) changes of coefficients from 2008/09 to 2010/11 HTS data

Estimated items	Overall changes (direction is ignored)	
	TRPL3	HRPL
Random parameter in utility functions	2.8%	3.3%
Non-random parameter in utility functions	2.1%	4.3%
Mode constant	4.7%	1.6%
Heterogeneity around the mean	10.2%	9.5%
Modal choice probability	1.5%	1.6%

According to random parameters, the average changes of coefficients in TRPL3 model is 2.8% compared with 3.3% in HRPL model from the HTS data of 2008/09 to 2010/11 (Table 5.7). In the context of non-random parameters, the changes in TRPL3 and HRPL are 2.1% and 4.3% respectively (Table 5.7). The changes in heterogeneity around the mean are also at a minimum level. As the changes of the coefficient (mean) are very nominal, the models validate the accuracy of the impact of traveller choice preferences with the HTS data too. The model is statistically significant as the magnitudes of log likelihood and McFadden pseudo R-squared are also at an acceptable level.

In terms of mode choice probability, it is clearly found that travellers have started to switch to public transport. There are also some tangible public transport (e.g. bus, train) improvement projects that may have led to such a result. Relevant projects that may increase public transport usage are discussed in Section 5.4.

5.3.2 Car owners' preferences in mode choice

This section also details RPL models using other HTS data of 2010/11 to make a comparison with the results obtained from 2008/09 HTS data, in the context of car owners' preferences. This section discusses the impact of TOAs and LVs on traveller mode choice with comparisons between 2008/09 and 2010/11 using TRPL3 and HRPL models towards CO-TfNSW and NCO-TfNSW relationship. The results of the α vector matrix in the structural equation of MIMIC model using 2010/11 HTS data are described in Table 5.8 for CO traveller and 5.9 for NCO traveller samples respectively. The results of the α vector matrix using 2008/09 have been explained in chapter 4 (Table 4.9 and 4.10). The estimated parameters in MIMIC model are used to quantify LVs that are incorporated in RPL models as explanatory variables. The models were estimated with Nlogit v.4 using maximum likelihood estimation procedures. The Table 5.10 describes the differences of car owners' preferences in 2010/11.

Table 5.8 MIMIC model results of car owner sample using 2010/11 HTS data: structural equations (t-values in the parenthesis)

LVs	Travel time	Trave l cost	Waiting time	Age	Income	Family size	Gender	Car ownership	No. child	Full time	Trip rate	Distance travelled	Trip purpose
Comfort	-0.121 (-2.89)	-0.109 (-3.18)	-0.198 (-2.79)	-0.111 (-3.74)	-0.147 (-2.99)	0.006 (2.14)	-0.077 (-1.97)	0.149 (5.74)	0.110 (6.14)	0.004 (2.14)	0.023 (3.01)	0.071 (3.11)	0.009 (1.98)
Convenience	-0.122 (-5.41)	-0.019 (-2.10)	-0.199 (-3.84)	-0.133 (-1.99)	0.088 (3.84)	-0.004 (-2.78)	0.081 (2.97)	0.199 (5.74)	0.189 (3.78)	0.061 (1.99)	0.021 (2.45)	0.011 (1.86)	0.003 (2.13)
Flexibility	-0.097 (-3.84)	-0.007 (-1.51)	-0.087 (-4.15)	0.066 (2.97)	0.011 (3.41)	0.014 (2.14)	1.97 (2.41)	-0.022 (-2.87)	-0.191 (-3.45)	-0.028 (-3.01)	0.022 (1.97)	0.112 (3.11)	0.091 (4.10)
Safety	-0.089 (-2.71)	-0.066 (-1.99)	-0.091 (-4.10)	-0.200 (-3.98)	-0.011 (-2.15)	0.021 (3.22)	0.121 (5.10)	-0.103 (-6.21)	-0.115 (-4.71)	-0.081 (-1.97)	0.017 (2.63)	0.113 (3.96)	0.132 (1.96)
Reliability	-0.203 (-6.41)	-0.011 (-1.87)	-0.301 (-7.61)	-0.111 (-2.89)	0.023 (2.01)	-0.001 (-1.99)	0.033 (1.96)	0.134 (5.41)	0.074 (3.10)	0.024 (2.01)	0.010 (3.14)	0.019 (2.00)	-0.031 (-1.89)
Satisfaction	-0.118 (-3.41)	-0.197 (-4.51)	-0.012 (-3.41)	0.081 (2.84)	0.031 (2.89)	0.011 (2.01)	-0.055 (-3.10)	0.022 (5.10)	0.121 (6.52)	0.011 (2.74)	0.018 (3.96)	0.045 (6.10)	0.014 (2.96)
Model fit criteria													
GFI	0.954												
AGFI	0.938												
NFI	0.912												
CFI	0.900												
RMSEA Lower bound upper bound	0.027 0.000 (90% CI of RMSEA) 0.045 (90% CI of RMSEA)												

Legend:
Significant at 90% level of confidence if 1.960 > t ≥ 1.645;
Significant at 95% level of confidence if 2.576 > t ≥ 1.960;
Significant at 99% level of confidence if 2.810 > t ≥ 2.576;
Significant at 99.5% level of confidence if 3.290 > t ≥ 2.810;
Significant at 99.9% level of confidence if t ≥ 3.290.

Table 5.9 MIMIC model results of non-car owner sample using 2010/11 HTS data: structural equations (t-values in the parenthesis)

LVs	Travel time	Travel cost	Waiting time	Age	Income	Family size	Gender	Car ownership	No. child	Full time	Trip rate	Distance travelled	Trip purpose
Comfort	-0.144 (-6.13)	-0.145 (-3.41)	-0.201 (-3.74)	-0.014 (-2.62)	-0.166 (-2.01)	0.007 (1.96)	-0.077 (-2.41)	n/a	0.179 (5.12)	0.001 (1.98)	0.044 (2.74)	0.033 (3.52)	0.022 (2.00)
Convenience	-0.175 (-3.41)	-0.011 (-1.99)	-0.108 (-4.85)	-0.144 (-2.01)	0.093 (3.96)	-0.003 (-1.96)	0.063 (3.01)	n/a	0.201 (4.01)	0.041 (2.08)	0.010 (2.01)	0.017 (3.01)	0.003 (2.00)
Flexibility	-0.010 (-3.85)	-0.002 (-1.08)	-0.052 (-3.41)	0.066 (2.63)	-0.029 (-3.14)	0.006 (1.90)	0.111 (2.11)	n/a	-0.012 (-2.01)	-0.031 (-1.97)	0.090 (2.11)	0.101 (2.81)	0.066 (2.85)
Safety	-0.151 (-2.51)	-0.051 (-2.69)	-0.074 (-3.20)	-0.181 (-3.63)	-0.077 (-2.74)	0.006 (2.44)	0.087 (4.85)	n/a	-0.144 (-4.63)	-0.006 (-1.98)	0.019 (3.11)	0.093 (4.12)	0.071 (2.03)
Reliability	-0.222 (-7.41)	-0.021 (-1.96)	-0.203 (-5.75)	-0.109 (-2.08)	0.021 (3.14)	-0.001 (-2.96)	0.013 (2.96)	n/a	0.087 (4.51)	0.031 (3.10)	0.013 (2.01)	0.016 (2.16)	0.031 (3.14)
Satisfaction	-0.121 (-4.15)	-0.118 (-3.85)	-0.108 (-3.51)	0.063 (2.97)	0.017 (4.15)	0.022 (1.89)	-0.034 (-1.98)	n/a	0.131 (5.69)	0.014 (2.10)	0.011 (3.74)	0.041 (4.71)	0.012 (2.41)
Model fit criteria													
GFI	0.971												
AGFI	0.947												
NFI	0.921												
CFI	0.912												
RMSEA Lower bound upper bound	0.034 0.010 (90% CI of RMSEA) 0.052 (90% CI of RMSEA)												

Legend:
Significant at 90% level of confidence if 1.960 > t ≥ 1.645;
Significant at 95% level of confidence if 2.576 > t ≥ 1.960;
Significant at 99% level of confidence if 2.810 > t ≥ 2.576;
Significant at 99.5% level of confidence if 3.290 > t ≥ 2.810;

The signs of estimated parameters using 2010/11 HTS data are also coherent, as indicated in results of 2008/09 HTS data. According to TRPL3 model using 2010/11 HTS data, travel time, travel cost, waiting time, car ownership and having children have high influences on traveller mode choice process the SSD. Both samples have similar results. Among LVs in the HRPL model, safety and reliability are the most dominant in the mode choice process and comfort and convenience also significantly influence the choice process. The impact of travel cost is increased for non-car owner travellers but decreased for car owner travellers. The effect of having children on mode choice has been increased for each model except TRPL3 of non-car owner travellers. It indicates that the effects of LVs become important for travellers. The car owner travellers pay more attention on waiting time and that's why they own a car. According to HRPL models, the influences of LVs have been increased with significant confidence levels to exhibit true explanatory power of the models.

The detailed changes, as per all the attributes used in the models, are shown in Table 5.10. According to choice probability, the inclination of train and bus use is being increased, as indicated in 2010/11 HTS survey summary report. The extent of increment is similar between the outcomes of this current study and 2010/11 HTS survey summary report.

Table 5.10 Comparison the results of RPL models between two datasets

Attributes	**Car owner**						**Non-car owner**					
	TRPL3			HRPL			TRPL3			HRPL		
	2008/09 (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*
Random parameter in utility functions												
Travel cost (mean)	-4.01 (-4.32)	-3.89 (-5.41)	↓2.9% (±0.06%)	-3.45 (-2.85)	-3.11 (-3.10)	↓9.8% (±0.69%)	-3.99 (-3.89)	-4.00 (-4.11)	↑0.25% (±0.02%)	-3.89 (-2.96)	-3.92 (-3.26)	↑0.77% (±0.01%)
Travel cost (st.dev.)	0.08 (2.11)	0.11 (1.97)		0.82 (3.51)	0.21 (2.51)		0.09 (2.55)	0.08 (2.89)		0.11 (2.31)	0.02 (3.01)	
Waiting time (mean)	-2.13 (-3.01)	-2.35 (-4.01)	↑10.3% (±0.76%)	-2.01 (-2.89)	-1.91 (-3.01)	↓4.9% (±0.18%)	-1.96 (-3.00)	-1.89 (-3.11)	↓3.5% (±0.09%)	-1.95 (-3.16)	-2.07 (-3.51)	↑6.1% (±0.27%)
Waiting time (st.dev.)	0.07 (2.73)	0.02 (3.11)		0.09 (2.66)	0.07 (3.11)		0.003 (2.41)	0.01 (1.89)		0.006 (3.85)	0.003 (3.85)	
Age (mean)	-0.11 (-0.56)	-0.10 (-1.01)	↓9.0% (±0.59%)	-0.13 (-1.00)	-0.14 (-0.51)	↑7.6% (±0.42%)	-0.12 (-1.01)	-0.13 (-0.81)	↑8.3% (±0.49%)	-0.10 (-1.95)	-0.09 (-1.77)	↓10.0% (±0.71%)
Age (st.dev.)	1.11 (1.05)	0.11 (0.89)		0.39 (2.11)	0.22 (2.71)		0.21 (1.15)	0.10 (1.11)		0.62 (1.63)	0.22 (1.70)	
Car ownership (mean)	1.99 (3.10)	2.01 (4.31)	↑1.0% (±0.01%)	2.03 (4.52)	2.09 (5.12)	↑2.9% (0.06%)	N/A	N/A	N/A	N/A	N/A	N/A
Car ownership (st.dev.)	0.11 (2.52)	0.08 (3.11)		0.03 (3.29)	0.01 (2.39)							
Having children (mean)	1.00 (3.45)	1.11 (4.31)	↑11.0% (±0.86%)	-1.02 (-5.44)	-1.13 (-6.17)	↑10.7% (0.83%)	-0.98 (-5.41)	-0.95 (-5.66)	↓3.0% (±0.07%)	-1.00 (5.74)	-1.02 (5.79)	↑2.0% (0.03%)
Having child (st.dev.)	0.12 (2.93)	0.14 (2.11)		0.11 (2.65)	0.17 (2.71)		0.26 (3.11)	0.19 (3.51)		0.12 (2.87)	0.16 (3.27)	
Trip purpose (mean)	0.003 (0.42)	0.0031 (1.51)	↑3.3% (±0.08%)	0.005 (0.89)	0.0051 (0.89)	↑2% (±0.03%)	0.007 (1.44)	0.0071 (1.44)	↑1.4% (±0.01%)	0.09 (1.00)	0.092 (1.00)	↑2.2% (±0.03%)
Trip purpose (st.dev.)	0.001 (1.11)	0.01 (0.89)		0.003 (1.00)	0.04 (1.64)		0.003 (0.33)	0.01 (1.00)		0.002 (1.63)	0.02 (1.12)	
Comfort (mean)				3.86 (5.15)	3.97 (6.91)	↑2.8% (0.06%)				2.67 (4.31)	2.75 (4.21)	↑2.9% (±0.06%)
Comfort (st.dev.)				0.002 (2.96)	0.02 (3.96)					0.08 (3.33)	0.07 (3.41)	
Convenience (mean)				2.14 (3.86)	2.34 (4.11)	↑9.3% (±0.62%)				2.96 (3.62)	3.01 (3.91)	↑1.7% (±0.02%)

Attributes	**Car owner**						**Non-car owner**					
	TRPL3			HRPL			TRPL3			HRPL		
	2008/09 (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*
Convenience (st.dev.)				0.012 (2.64)	0.07 (2.11)					0.02 (3.55)	0.09 (3.56)	
Safety (mean) Safety (st.dev.)				5.62 (5.62) (0.003 (3.64)	6.01 (7.61) 0.013 (3.70)	↑6.9% (±0.34%)				5.42 (4.31) 0.04 (4.84)	5.71 (6.20) 0.05 (4.71)	↑5.3% (±0.02%)
Flexibility (mean) Flexibility (st.dev.)				0.89 (1.62) 0.031 (1.34)	0.82 (1.81) 0.042 (1.51)	↓7.8% (0.44%)				0.39 (0.85) 0.03 (1.16)	0.36 (1.11) 0.09 (0.51)	↓7.6% (±0.42)
Reliability (mean) Reliability (st.dev.)				5.19 (7.14) 0.06 (4.66)	5.91 (7.19) 0.01 (5.11)	↑13.8% (±1.37%)				4.96 (8.12) 0.06 (4.63)	5.21 (6.51) 0.02 (5.11)	↑5.0% (±0.18%)
Satisfaction (mean) Satisfaction (st.dev.)				0.69 (2.96) 0.03 (1.98)	0.76 (3.91) 0.04 (2.11)	↑10.1% (±0.73%)				0.68 (2.59) 0.03 (2.71)	0.73 (2.89) 0.05 (3.51)	↑7.3% (±0.38%)
Nonrandom parameter in utility functions												
Travel time	-1.01 (-5.41)	-1.10 (-4.40)	↑8.9% (±0.56%)	-0.98 (-4.98)	-1.02 (-5.11)	↑4.0% (±0.12%)	-0.94 (-4.41)	-1.04 (-3.41)	↑10.6% (±0.80%)	-0.90 (-3.61)	-0.98 (-4.63)	↑8.8% (±0.56%)
Gender	0.56 (2.81)	0.49 (3.11)	↓12.5% (±1.11%)	0.72 (2.86)	0.63 (2.51)	↓12.5% (±1.11%)	0.49 (2.00)	0.44 (3.00)	↓10.2% (±0.74%)	0.65 (3.61)	0.57 (3.14)	↓12.3% (±1.08%)
Income	0.62 (1.70)	0.70 (1.00)	↑12.9% (±1.19%)	0.71 (1.69)	0.77 (0.89)	↑8.4% (±0.51%)	1.75 (2.81)	1.80 (2.01)	↑2.8% (±0.06%)	1.63 (2.61)	1.70 (2.17)	↑4.2% (±0.13%)
Family size	-0.02 (-1.45)	-0.021 (-2.11)	↑5.0% (±0.18%)	-0.04 (-1.41)	-0.042 (-2.01)	↑5.0% (±0.18%)	0.09 (1.09)	0.087 (0.21)	↓3.3% (±0.08%)	0.07 (1.52)	0.069 (1.21)	↓1.4% (±0.01%)
Full time workers of HH	0.01 (0.96)	0.011 (0.71)	↑10.0% (±0.71%)	0.02 (0.91)	0.019 (0.21)	↓5.0% (±0.18%)	0.02 (0.45)	0.021 (0.51)	↑5.0% (±0.18%)	0.04 (0.94)	0.038 (0.91)	↓5.0% (±0.18%)
Trip rate	0.91 (2.41)	0.83 (2.79)	↓8.7% (±0.55%)	0.94 (3.00)	0.89 (3.17)	↓5.9% (±0.20)	0.74 (2.52)	0.67 (2.15)	↓9.4% (±0.64%)	0.72 (2.97)	0.66 (3.61)	↓8.3% (±0.49%)
Distance travelled	-0.81 (-0.89)	-0.72 (-0.01)	↓11.1% (±0.88%)	-0.75 (-1.00)	-0.77 (-0.72)	↑2.6% (±0.05%)	-0.79 (-0.99)	-0.72 (-0.07)	↓8.8% (±0.56%)	-0.72 (-1.42)	-0.69 (-1.01)	↓4.1% (±0.12%)

Attributes	Car owner						Non-car owner					
	TRPL3			HRPL			TRPL3			HRPL		
	2008/09 (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*
Mode constant												
Car as a passenger (base)	0	0		0	0		0	0		0	0	
Car as a driver	-1.12 (-3.41)	-1.21 (-4.11)	↑8.0% (±0.46%)	-1.23 (-4.54)	-1.24 (-5.22)	↑0.8% (0.03%)	N/A	N/A	N/A	N/A	N/A	N/A
Train	-0.97 (-2.11)	-0.86 (-3.21)	↓11.3% (±0.92%)	-0.88 (-2.98)	-0.77 (-4.11)	↓12.5% (±1.11%)	-1.01 (-1.98)	-1.09 (-2.22)	↑7.9% (±0.45%)	-1.1 (-2.79)	-1.13 (-4.11)	↑2.7% (±0.05%)
Bus	-0.56 (-1.52)	-0.53 (-2.12)	↓5.3% (±0.20%)	-0.44 (-0.79)	-0.4 (-0.05)	↓9.0% (±0.59%)	-0.35 (-1.65)	-0.39 (-1.71)	↑11.4% (±0.93%)	-0.38 (-2.53)	-0.42 (-2.91)	↑10.5% (±0.79%)
Heterogeneity around the mean												
Travel cost :Income	-0.09 (-1.21)	-0.08 (-3.12)	↓11.1% (±0.88%)	-0.10 (-2.68)	-0.09 (-2.41)	↓10.0% (±0.71%)	-0.12 (-3.62)	-0.11 (-3.21)	↓8.3% (±0.49%)	-0.11 (-2.99)	-0.10 (-3.00)	↓9.0% (±0.59%)
Waiting time :Income	-0.15 (-4.10)	-0.14 (-3.41)	↓6.6% (±0.31%)	-0.63 (-5.12)	-0.67 (-4.51)	↑6.3% (±0.29%)	-0.09 (-2.96)	-0.093 (-3.93)	↓3.3% (±0.08%)	-0.12 (-3.90)	-0.13 (-3.71)	↑8.3% (±0.49%)
Age: Income	-0.06 (-0.69)	-0.062 (-0.12)	↑3.3% (±0.08%)	-0.10 (-2.89)	-0.102 (-1.81)	↑2.0% (±0.03%)	-0.04 (-1.85)	-0.042 (-1.66)	↓5.0% (±0.18%)	-0.03 (-2.14)	-0.032 (-1.86)	↓6.6% (±0.31%)
Car ownership: Income	0.52 (2.96)	0.58 (3.11)	↑11.5% (±0.95%)	0.86 (3.74)	0.75 (5.22)	↓12.7% (±1.17%)	N/A	N/A	N/A	N/A	N/A	N/A
Having child: income	-0.04 (-1.97)	-0.044 (-2.11)	↑10.0% (±0.71%)	-0.08 (-1.99)	-0.083 (-1.89)	↑3.7% (±0.10%)	-0.02 (-1.66)	-0.021 (-1.91)	↑5.0% (±0.18%)	-0.04 (-2.01)	-0.045 (-3.11)	↑12.5% (±1.11%)
Purpose: Income	0.01 (0.49)	0.03 (0.01)	↑10.0% (±0.21%)	0.05 (0.89)	0.055 (0.05)	↑10.0% (±0.71%)	0.01 (1.11)	0.011 (0.71)	↑10.0% (±0.71%)	0.02 (1.89)	0.021 (0.81)	↑5.0% (±0.18%)
Comfort: Income				0.21 (4.21)	0.23 (3.99)	↑9.5% (±0.64%)				0.20 (4.10)	0.21 (3.15)	↑5.0% (±0.18%)
Convenience: Income				0.18 (3.41)	0.20 (4.10)	↑11.1% (±0.88%)				0.12 (2.41)	0.13 (3.41)	↑8.3% (±0.49%)
Safety: Income				0.32 (5.41)	0.35 (6.52)	↑9.3% (±0.62%)				0.40 (8.42)	0.41 (7.16)	↑2.5% (±0.04%)
Flexibility: Income				0.02 (0.45)	0.022 (1.21)	↑10.0% (±0.71%)				0.03 (1.89)	0.032 (1.70)	↑6.6% (±0.31%)
Reliability: Income				0.34 (5.44)	0.39 (5.11)	↑14.5% (±1.55%)				0.31 (7.41)	0.35 (4.55)	↑12.9% (±1.19%)
Satisfaction: Income				0.15 (3.46)	0.17 (4.34)	↑13.3% (±1.27%)				0.11 (3.74)	0.16 (3.12)	↑4.5% (±1.01%)

Attributes	**Car owner**						**Non-car owner**					
	TRPL3			HRPL			TRPL3			HRPL		
	2008/09 (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*	*2008/09* (t-values)	*2010/11* (t-values)	*Changes of means (limit of both directions)*
Modal choice probability												
Car as a driver	0.773	0.741	↓3.2% (±0.12%)	0.781	0.761	↓2.0% (±0.05%)	N/A	N/A	N/A	N/A	N/A	N/A
Car as a passenger	0.03	0.014	↓1.6% (±0.012)	0.034	0.022	↓1.2% (±1.35%)	0.050	0.056	↑0.6% (±1.03%)	0.040	0.021	↓1.9% (±1.24%)
Train	0.169	0.191	↑2.2% (±1.21%)	0.170	0.183	↑1.3% (±0.41%)	0.580	0.611	↑3.1% (±0.20%)	0.600	0.633	↑3.3% (±0.21%)
Bus	0.036	0.056	↑2.0% (±0.03)	0.041	0.050	↑0.9% (±0.49%)	0.410	0.430	↑2.0% (±0.17%)	0.390	0.401	↑1.1% (±0.06%)
Model statistics												
Log likelihood function	-676.21	-655.14	↓3.1% (±0.07%)	-599.87	-544.52	↓9.2% (±0.60%)	-669.12	-601.85	↓10.0% (±0.72%)	-590.64	-501.14	↓15.1% (±1.64%)
McFadden Pseudo R-squared	0.24	0.26	↑8.3% (±0.49%)	0.26	0.29	↑11.5% (±0.95%)	0.23	0.25	↑8.7% (±0.54%)	0.28	0.29	↑3.6% (±0.09%)
Akaike Information Criterion (AIC)	0.016	0.015	↓6.25% (±0.28%)	0.014	0.012	↓14.2% (±1.46%)	0.015	0.014	↓6.66% (±0.31%)	0.013	0.011	↓15.3% (±1.69%)

Legend:
↑ means increase
↓ means decrease
Significant at 90% level of confidence if $1.960 > t \geq 1.645$;
Significant at 95% level of confidence if $2.576 > t \geq 1.960$;
Significant at 99% level of confidence if $2.810 > t \geq 2.576$;
Significant at 99.5% level of confidence if $3.290 > t \geq 2.810$;
Significant at 99.9% level of confidence if $t \geq 3.290$.

As per the results shown in Table 5.10, the changes are very minimal between the results obtained from 2008/09 and 2010/11 HTS survey data, and these findings are the indication of low changes in traveller behaviour. On other words, the changes of mean coefficients are small. This concludes that the traveller behaviour and expectations are not changed dramatically and the results represent the data validity. In other words, changes in operation of TfNSW are not effective.

5.4 Indications of Reasons for Increasing Public Transport Use

It is likely the uptake of public transport increased from 2008/09 to 2010/11 due to some infrastructural developments implemented by the NSW government. Some of them are described below. The listed items below are not only the reasons that contribute to increase the public transport usage but also there are other facts such as fare structure, increasing population that are not considered in this description.

5.4.1 Improvement of bus service

Overall bus patronage was strongest in areas serviced by private bus operators, with an average of 5.6% growth across these Sydney regions (Transport for NSW, 2009). Extended bus lanes on Elizabeth and George streets and standardised bus lane hours during the peaks have improved the efficiency of bus operation. Bus priority measures continued to be rolled out in 2009-10 as part of the overall Bus Reform strategy to improve services for travellers.

5.4.2 Improvement of Rail service

The TfNSW worked with RailCorp to enhance rail service, by implementing the new timetable from October 2009, acquiring 626 new rail cars. Due to the greatest demand in the morning and afternoon peaks, extra 8,000 train seats were made available to the travelling public. The new Cronulla Line Duplication project was officially opened in April 2010, which delivered faster, more regular and more comfortable services for train passengers travelling between Cronulla, Sutherland and beyond each day.

5.4.3 Improving infrastructure

In December 2008, a major new transport interchange at Bankstown—a joint project between the Department of Transport and Bankstown Council—was completed. It provides improved passenger facilities including a taxi rank, ‘kiss and ride’ (easy drop-off for car passengers to

public services) and service information on digital screen. During 2008-09, the Government extended its previous commitment to build 4,000 extra car park spaces for commuters, by an additional 3,000 new parking spaces. In May 2009, a 160-space commuter car park at Wentworthville was opened by the government. Transport NSW continued the delivery of 7,000 extra car spaces at rail stations across Sydney, the Blue Mountains, the Central Coast and Illawarra. More than 1,600 new spaces have already been delivered under this program, with 4,400 more under construction.

5.4.4 Safety initiative

The TfNSW continued to monitor, as a priority, the safety of bus and taxi services, focusing on critical areas including driver capability, driver and passenger security, and operator systems.

Some of safety initiatives are below.

- expansion of Secure Taxi Ranks to a total of 41 locations jointly identified with the taxi industry, NSW Police and local communities;
- fitting of security cameras in every taxi across NSW; and
- development of a new bus incident management database to enable electronic reporting of bus incidents to relevant bodies.

Mandatory security cameras were introduced in all Sydney, Newcastle, Wollongong and Central Coast taxis. The Secure Taxi Rank Program, whereby ranks are attended by either security guards or feature CCTV, provided more secure environments at more taxi ranks across NSW.

The improvement services described above have contribution on public transport usage increase as indicated in the mode choice probabilities analysis (Table 5.5).

5.5 Mode Choice Probability Analysis and Improvement of Agency Problem

Forecasting and policy evaluation have not been discussed in the last decade to the same extent as the estimation of hybrid discrete choice models. Although the concept of LVM has been used to explore the effect of latent factors on the decision making process either through factor analysis or logistic regression, this has been done without reference to policy intervention (Mokhtarian, 1998; Fujii and Garling, 2003; Cao et al., 2009).

According to the specifications of the MIMIC model, change in the explanatory variables should cause changes in the LVs and then, these changes may have an impact on the MIMIC model as well as on the utility functions in the choice model. Due to the changes in utility function, traveller mode choice probabilities are affected accordingly. The changes in the choice forecasting probabilities may be caused by the variations in explanatory variables related to TOAs. The changes in the explanatory variables s_{ijr} and the tangible attributes X_{ijk} may affect the choices implicitly through the LVs or the alternative utilities respectively, by which the changes in choice probabilities may be observed.

The changes in traveller choices, which are associated with the overall transport system in a city, are allied with changes in TOAs. Again the changes in TOAs contribute to construct the psychological mindset (i.e. LVs) of travellers, and eventually, the LVs impact on mode choice to influence overall trips structure. Thus, the transport forecasting context is an interrelationship among various observed and unobserved factors related the transport management system, and it is understood that traditional mode choice models (without LVs) are not generally sensitive to policies that affect the transport management system. Policies are associated with the changes over the management system, which, in turn, may have an impact on the observed mobility structure of the travellers. Thus, the LVs would be able to capture transport system changes because the explanatory variables are related to demographics as well as the alternatives included in the MIMIC model to evaluate the traveller motivational process. This is an important measure to be considered for forecasting the changes using the estimated models.

On the basis of the empirical case presented in this study, three hypothetical scenarios of (S1) income increased for all respondents by 10%; (S2) travel cost and waiting time for public transport reduced by 10%; and (S3) implementing both (S1) and (S2) concurrently are tested to compare the forecasting performance of the estimated models. The variation of income affects directly: (i) the LV, as income is an explanatory variable in the MIMIC model and (ii) the utility functions, due to inclusion of it in the utility functions.

Table 5.11 Forecasting changes in traveller mode choice

Mode	Base year market share in %		Predicted changes[5]					
			Scenario 1 (S1)		Scenario 2 (S2)		Scenario 3 (S3)	
	TRPL3	HRPL	TRPL3	HRPL	TRPL3	HRPL	TRPL3	HRPL
Car as a driver	72.0	77.0	-0.07	0.21	-1.00	-0.85	-0.54	-0.32
Car as a passenger	4.9	2.0	-0.04	0.08	-0.08	-0.01	-0.06	0.04
Train	20.4	21.1	0.33	0.17	0.95	0.52	0.64	0.35
Bus	5.3	3.3	-0.08	-0.04	0.51	0.48	0.22	0.22

Legend:
S1: Income increased for all respondents by 10%
S2: Travel cost and waiting time for public transport reduced by 10%
S3: S1 and S2 implemented concurrently

Table 5.11 presents the base year market shares that are estimated by each model under the condition of no-change in data of any variable. The market share changes are predicted by the estimated models with three hypothetical scenarios. Due to the complexity of the probability function (Eq. 3-10 in Chapter 3), it is difficult to get exact resolution of the choice probabilities but a reasonable idea can be obtained about the forecasting from these iterations.

The forecast changes do not have the same direction for all modes. Three scenarios have been considered here to understand the predicted policies. For S1, the variations in HRPL model have the same direction for all modes except the bus. According to the TRPL model under the same scenario, only train usage probability is increased. This indicates that increasing individual income may promote the travellers to travel by train, which is an interesting finding to help policy makers. Some cases, the cost of travel by train is higher than that of car in Sydney Greater Metropolitan Area. For instance, the travel to Sydney Airport by train is significantly expensive than travel by car. As per AirportLink website (http://www.airportlink.com.au/ accessed at 3:45pm on November 26, 2013), the price of a day return ticket between Central Rail Station and Sydney Airport (about 8 km) is AU$31.80 per adult which is costly. In this situation, people may prefer car to train. Thus, the result described in table 5.11 is that increasing income may motivate travellers to use train rather than car in some situations. On the other hand, it is well recognised that congestion is responsible to increase the travel time by car. In this regard, train journey is quicker. This phenomenon may also influence the traveller to train.

[5] Changes, that were calculated using 2010/11 HTS data only, are the differences of the probabilities between changed and unchanged condition

As per S2, the probabilities of train and bus use are increased for both TRPL and HRPL models. This implies that a reduction of travel cost and waiting time are helpful to reduce the travel by car (with a corresponding increase in public transportation use). In S3, TRPL model shows that probabilities of car use as a driver and a passenger are reduced while the condition of S1 and S2 are implemented concurrently. On the other hand, probability of train usage is higher than HRPL model as increasing individual income and reduced travel cost and waiting time are included together.

Additionally, as expected, the HRPL model for S1 predicts an increase in private modes due to increasing income as a changed condition, while the other HRPL models in S2 and S3 forecast a decrease in private modes because of inclusion of reduced travel cost and waiting time as a changed condition. This may indicate that the hybrid RPL models are effectively more sensitive, as we expected, but this higher sensitivity does not imply just a simple amplification of the effects involved. Consequently, it is even more clear the importance of including LV in the choice models.

Finally, it is established that increasing income, reducing travel cost and waiting time can attract travellers towards public transport rather than private mode of transport and it results to reduce the agency problem. After implementing these hypothetical scenarios, it is found that the probability of private transport use has been reduced at a significant level and the probabilities of public transport (train and bus) use have also been increased to some extent (Table 5.11). Therefore, it may confirm that integrating traveller choice preferences in transport mode services helps to improve the customer-focused mode of transport and thus, agency problem can be reduced.

5.6 Discussions and Conclusions

This chapter illustrates the comparison of impact on mode choice between 2008/09 to 2010/11 HTS data and it demonstrates predicted changes of traveller mode choice for hypothetical scenarios, which offers a mechanism to reduce the agency problem within transport mode services.

Based on the analysis of HRPL models, we can conclude that the hybrid model is clearly superior in terms of goodness of fit over TRPL models that do not incorporate LV, and it shows insight into the travellers' motivational behaviour.

Both TRPL3 and HRPL models, estimated with real data collected from SSD, reveals that LVs have significant effects over the choice process. Moreover, the influences of LVs on utility functions vary significantly among individuals. The introduction of LVs in RPL models allows us not only to improve model fit, but also to achieve better estimates of parameters.

The inclusion of LVs in RPL model has improved the ability of the RPL model to explain the travellers' behaviours. On the other hand, the exclusion of LVs from the choice models is not policy sensitive, as there is a big gap between the behaviours, with and without human psychological factors (i.e. LVs). Thus, certain policies may influence a particular individual's behaviour and therefore, it is strongly recommended to pay appropriate attention to LVs.

The results of the HRPL model show how LVs impact mode choice as compared with the TRPL3 model. Interestingly, the inclusion of LVs changed the magnitude of coefficients of the TOAs substantially and in that sense delivered true additional insight about choice process. For example, the significance level of the income variable sharply declined once LVs were included in the hybrid RPL model. This can be interpreted as LVs being considered a preferred attribute than personal income for people in the SSD. However, it could be explained by socioeconomic variables affecting preferences and thereby also choice. Moreover, the results support the contention that travellers' preference heterogeneity is an important determinant in the process of mode choice. The general theoretical conclusion of this study is that future projects can be successful by including LVs of travellers.

It seems that TfNSW is working towards a customer-focused transport system (Table 5.6). Due to its performance for last few years, the travellers have started to switch from car to public transport. But still there is a big gap between the probabilities of car and public transport use, which indicate that the agency problem within transport mode service of TfNSW still continues.

To reduce the agency problem, three hypothetical scenarios were implemented and it was found that the probability of car usage was decreased. It indicates that TfNSW can reduce the agency problem by performing as per travellers' interests.

In Chapter 4 and 5, effects of traveller choice attributes on mode choice and comparisons the effects between 2008/09 and 2010/11 HTS data in the context of PAT were discussed and interpreted. The mode choice probability analysis was examined in this Chapter to propose an approach for improving the agency problem. Thus, the next chapter (Chapter 6) presents a general discussion about agency relationship within mode of transport services.

Chapter 6

A General Discussion on Provision of Transportation Services in the Context of PAT

This chapter discusses the broader relevance of PAT to the problem of traveller mode choice. It is divided into six sections. Section 6.1 discusses about the relationships in transport mode services. A discussion of travellers and TfNSW as a principal-agent relationship within the process of NSW Long Term Transport Master Plan 2012 (NLTTMP2012) is given in Section 6.2. This is an example of agency relationship in a real transport project. Section 6.3 presents a discussion about the agency problem in the connection between traveller expectations and TfNSW performance. Some discussions on governing the agency problem are described in Section 6.4. To discuss this connection, transport mode service is considered. Section 6.5 describes the understanding of agency relationship in transport mode service and finally conclusions are presented in Section 6.6.

6.1 Possible Relationships within Transport Mode Services

Due to the unavailability of data, only the informational asymmetry in the agency relationship in transport mode services between travellers and TfNSW is presented in detail in this thesis. Besides this connection, there are other connections that may be existed in transport mode services. Figure 6.1 reveals some other principal-agent relationships within the mode services of TfNSW. According to Figure 6.1, five relationships may be understood. These are described below.

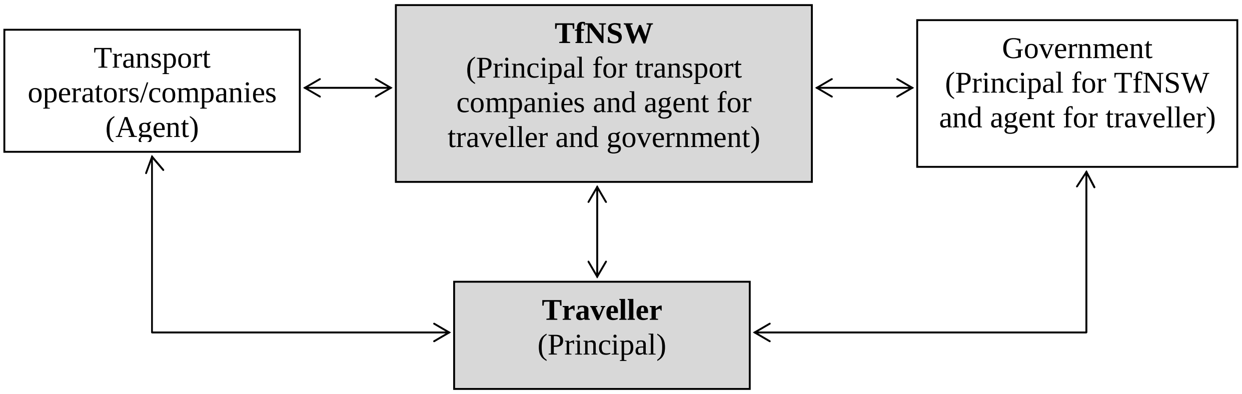


Figure 6.1 Relevant and potential principal-agent relationships in transport services

TfNSW – Transport operators/companies relationship: TfNSW provides mode services for travellers through managing contract with transport operators/companies. This is an employer-employee relationship. A contract exists between TfNSW and transport companies to perform the delegated tasks on behalf of TfNSW. Thus, TfNSW works as a principal and transport companies work as agents.

Traveller – Transport operators/companies relationship: This may be another principal-agent relationship in transport mode services. Transport companies operate the transport services as per the contract with TfNSW for traveller well-being. The transport companies have a direct contact with the traveller at the field level as they are assigned to operate and manage the services for the citizen. Travellers have their say to get the desirable services and feedback for the transport companies. Accordingly, there is a connection between traveller (principal) and transport companies (agents) as indicated in PAT.

Traveller (Citizen) – Government: The relationship between traveller (citizen) and government is more complex because the direct political issues are involved here. Government is formed by the politicians and is obliged to perform the programs and priorities according to citizens' welfare. Thus, in this relationship Government works as an agent on behalf of the citizens.

Government – TfNSW: This is also employer and employee relationship. Government employed and established TfNSW for providing transport services for travellers. Thus TfNSW works as an agent to perform the delegated tasks on behalf of the government.

Traveller – TfNSW: This is the most important relationship within transport mode services and this relationship has been described and interpreted throughout this thesis. The Government basically assigns TfNSW to provide necessary services for the public, i.e. travellers and TfNSW is assigned to perform for the travellers. At the same time, travellers have their expectations and desires for comfortable and convenient services and TfNSW, as an agent, is obliged to fulfil them. Between travellers and TfNSW, there is no direct contractual, but rather a loose and indirect (via transport agencies) contractual relationship by virtue of payments made for services rendered, as well as TfNSW's obligations to travellers by law.

6.2 Agency Relationship in the Process of Transport Master Plan: An example

Delivering a transport system that meets the needs and preferences of customers is a cornerstone objective of NLTTMP2012. As a part of the NLTTMP process, public consultation activities (face-to-face regional forums) were undertaken to gauge travellers' transport priorities. On the other hand, the citizen (travellers) expresses and entrusts the tasks (demands/desires) to TfNSW to be performed.

Figure 6.2 shows how TfNSW addresses the delegated tasks assigned by citizens (travellers). TfNSW collects and gathers the information about the desires of travellers (principal) by organising transport forums, which indicates a relationship between travellers and TfNSW with a metaphoric contract[6]. This is the first step in the process of transport plan preparation. Travellers communicate their desires/tasks to TfNSW (agent) through these forums (organised by TfNSW) to address transport challenges and desired long-term transport outcomes for the region. In other words, the principal (travellers) delegates tasks to the agent (TfNSW) to perform. This is a key

[6] The metaphoric contract is partly metaphoric (particularly in terms of feedback from passengers to TfNSW) but also actual in part: between TfNSW and the various transport service providers (written contract) and between the transport service providers and passengers (since they're paying for a service and implicitly agreeing to terms and conditions as printed on tickets / other sources). There is also some, incomplete feedback (on passenger numbers) back along that path.

idea of PAT. Once the task is delegated to TfNSW, travellers are not aware of the role of TfNSW towards the execution of the task at reasonable level, thus give rise to 'informational asymmetries'. At the same time, after evaluating the opinions/feedbacks, TfNSW proceeds with its own skills and experiences and under the hidden influence from different actors (Figure 6.2) to develop the first outcome of NLTTMP. During the plan preparation process, TfNSW is influenced directly by various external and internal actors, such as political members, lobbying groups, transport companies, civil and private sectors, bureaucrats etc. rather than citizens (travellers) although TfNSW collects all the feedback. However, citizens (travellers) cannot participate in the process of finalising and implementing transport master plan. Political influence is higher than the influence from civil and private sectors due to concerns about election and cost savings, for example. Therefore, political influence can be quite strong in the process. Bureaucrats are civil servants who serve the Government, thus bureaucrats influence the planning process. Transport companies are much aware about the outcome of the plan because ultimately they bring the services to the travellers, according to the plan. For example, new fare structure or modified route direction may be recommended in the master plan and the transport companies participate in the execution of those plans. Transport companies ensure their benefits that can be gained by providing services and they exert some influence over TfNSW to ensure the balance between their profit and travellers expectation.

As a result, alignment of interest between traveller and TfNSW may be in partial conflict. Due to low level of influence of travellers, TfNSW performs the tasks with the interest of other actors and misalignment of interest occurs in the principal-agent relationship between travellers and TfNSW. Therefore, the best interest of travellers may not be reflected in the outcome, which can be interpreted as 'goal/choice conflicts'. Thus, an agency problem exists due to hidden influence in the process of transport master plan preparation.

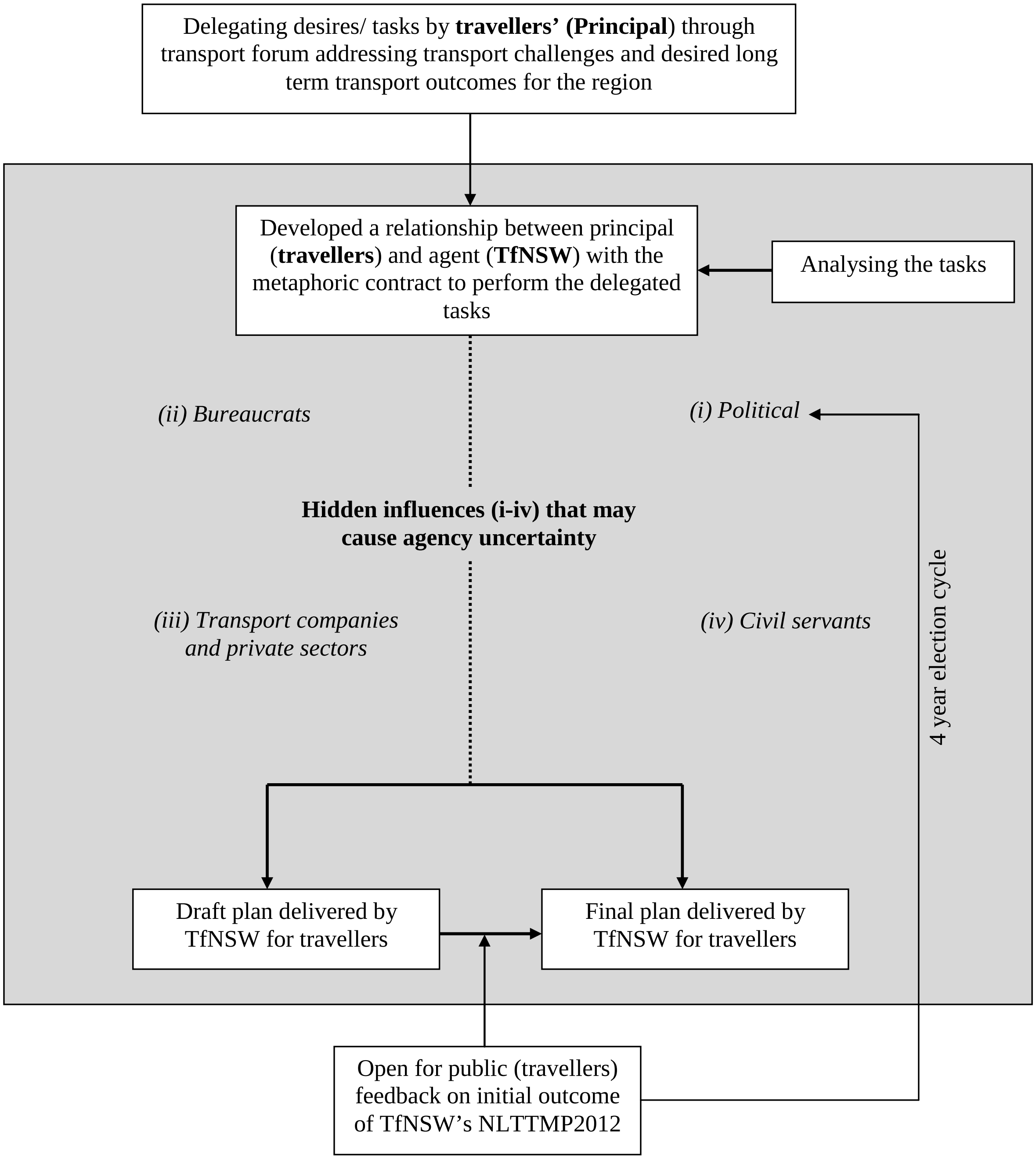


Figure 6.2 Understanding of agency relationship in the process of NLTTMP2012

6.3 Agency Problem in Transport Mode Service

Travellers have various choices to explain their preferences and TfNSW, as an agent, has the ability to realise and address them. Due to experiences and skills of TfNSW, travellers feel that TfNSW is a reasonably effective agent to fulfil the goals entrusted by them. Since the tax and travel fare paid by citizens (travellers) are the source of TfNSW's resource, the traveller expects

a certain level of beneficial outcome from the TfNSW. In 2010/11, $4.7 billion was spent operating, maintaining and investing in the NSW road network. Travellers paid around 70% of the costs through a combination of road user charges, motor vehicle taxation and tolls on State-owned motorways (Douglas and Brooker, 2013).

TfNSW makes the services of transport mode available for the travellers. TfNSW is responsible for the public transportation services and the public transportation service should align with travellers' expectations in order to compete with the private mode of transport. However, it varies from service to service and across regions. For example: ferries are run as a franchise, RailCorp is currently government owned but run at arm's length, and buses are a mix of public and private services. At the same time, travellers are comfortable to use their own car as a private mode of transport. Thus to increase public transportation use is a complex and it may be difficult to understand the traveller behaviour properly that influences TfNSW's performance. There is a conflict in choice and the probability of mode usage, which was estimated in Chapter 4 to quantify the actual intention of travellers as per the service available. This indicates the existence of agency problem in traveller mode choice behaviour as public transport use is remarkably higher than private car use.

Danielis et al. (2005) said that an agency problem might arise if the transport manager has different information and goals than the company (operator) owners. Likewise, travellers are not aware enough about the project design, planning and implementing phase of TfNSW. TfNSW uses its management skills, technology, expertise, experiences, abilities, etc. to provide transport services according to the public/travellers' demand, as best as possible. However, Liefner (2003) and Kivisto and Holtta (2008) have argued that in reality it is hard for the principal to monitor the quality of outcomes performed by the agent. Similarly, travellers only can share their expectations in the planning process of TfNSW but cannot monitor the performance. Therefore, limited understanding about the travellers' utility/expectations leads choice conflicts between traveller and TfNSW and eventually adverse selection may arise.

A transport management system deals with a wide array of interdependent activities and department and thus a highl and complex infrastructural development is required (Bagloee and Tavana, 2012). Likewise, TfNSW composes of various departments that are interrelated to each other in order to perform their activities efficiently (TfNSW, 2011). The roles in different departments may vary over the time due to financial constraints as well as changes in people

expectation and behaviour. Again TfNSW also has a variety of types of rules and policies that sometimes hinder the information being made available to the public and also because of commercial-in-confidence between TfNSW and business, some information are not allowed to be accessible to the traveller (public). Thus travellers are prevented from the accessing necessary information, though the information is relevant to them. Hence informational asymmetries as well as choice/goal conflicts occur. Understanding of traveller choice attributes may help TfNSW to provide appropriate services and it may contribute to reduce agency problem in the connection between traveller and TfNSW.

Currently, TfNSW is an appropriate agent for traveller mode services and has a good ability to align traveller-oriented transport mode services and thus, the project planning, designing and implementing procedure may be modified accordingly. In some cases, TfNSW alters its plans and goals due to heterogeneous preferences of travellers. However traveller behaviour is changeable and variable over the time and situation and TfNSW may not address or notice them to satisfy properly. The lack of this understanding may expedite the agency problem in transport mode services. As discussed in Figure 6.2, TfNSW is also influenced by different stakeholders and this influence may not align with traveller interest. Slyke (2007) describes that it is not often possible to incorporate all the issues in an initial metaphoric contract because of various natures of customers in the real world. TfNSW also cannot incorporate all travellers' desired utility because of budget constraint and political influences. It can also be argued that a consistent and effective transport strategy is an important tool to ensure a sustainable transport system, although it is difficult to achieve in practice due to traditional bureaucratic and political constraints. In the last decade, consultations between the community and stakeholder within transport decision-making frameworks have become more important (Tsolakis et al., 2008). This mechanism of perceiving travellers' desires, and incorporating them in the planning at a reasonable level with an effective use of funds/resources, might be an efficient means to improve the agency relationship in transportation services.

6.3.1 Informational asymmetries in transport mode service

Liefner (2003) and Kivisto and Holtta (2008) have argued that in reality it is hard for the principal to monitor the quality of outcomes performed by the agent. Therefore, limited understanding/access about/to the operations of TfNSW leads to informational asymmetries, as travellers find TfNSW's competencies and actions difficult to monitor. Informational asymmetries in the transport mode service can be caused by four factors:

(i) Different service quality between public and private transport,

(ii) Diverse types of travellers' expectation over modes of transport,

(iii) TfNSW's strict and confidential policies and strategies, and

(iv) A lack of understanding of travellers' mode choice preferences and integrating them at reasonable manner in TfNSW's decision making process.

The service provision by TfNSW, which does not fulfil traveller expectation, can lead informational asymmetries or adverse selection. The **first** reason behind this is that travellers' choice attributes and affordability are not taken into account properly in transport mode service when TfNSW designs and implements it. The **second** cause of information asymmetries arise when it becomes difficult to produce standardised information to satisfy different types of travellers (consumers), due to a variety of choice preferences. Available information about transport mode can help travellers to maximise the utility for making a choice, and utility varies over the travellers because different socio-economic backgrounds have different expectations. Therefore, the choice is also very diverse among travellers. **Thirdly**, TfNSW has various types of rules and policies and some of them are confidential that restrict the information available to the public (travellers). Thus the travellers are not able to access the required relevant information, which lead to an informational asymmetry. **Finally**, an understanding of the impact of traveller choice attributes on transport mode service is important for resolving informational asymmetries (adverse selection).

6.3.2 Goal/choice conflicts in transport mode service

Ahmad et al. (2012) identified two types of goals in a contract from an agent point of view: (i) official; and (ii) operative. An official goal describes the general aims of an organisation as expressed in the annual report, public statements and mission statement. The purpose is to give the organisation a favourable public image, provide legitimacy, and justify its activities. On the other hand, operative goals report day-to-day activities of an organisation. They describe the specific steps to be taken to achieve the organisation's purpose. The official goals may act as an initial goal that may not cause goal/choice conflicts because goals taken at initial stage of the contract may aligns to the public's (travellers) interest. The operative goals are carried out subject to budget constraints, quality of management and political influence which can lead to adverse selection (goal conflicts). The State Government may intervene in operative goals and thus the State Government influences TfNSW. Therefore TfNSW may not perform full

customer-oriented transport services. Occasionally, the operative goals of TfNSW may also be shaped by the traveller participation to satisfy the needs of its main customer i.e. the traveller. The operative goals of TfNSW may be revised due to Government's involvement or other influences (e.g. political influence in transport master) that contribute to goal/choice conflicts.

6.4 Governing the Agency Problem in Transport Mode Service

Nowadays, travellers' participation in transportation planning is becoming important for effective and successful projects. Thus, the development of mechanisms to recognise travellers' desires and effective use of budgets might be the most effective means of doing so. A system of performance based on mechanisms promotes a better alignment of agent's actions and principal's objectives (Kivisto 2008). Recently, TfNSW arranged a public forum (consultation process) in their recent projects, the NLTTMP2012. The consultation process was broad, inviting and encouraging a diverse and a large number of voices to inform TfNSW what the transport system should be like. Anyone interested in improving transport in NSW was encouraged to participate, whether a commuter or truck driver, an industry representative, a business person or local government representative. In the 12 month consultation process for NLTTMP2012, about 1000 people from those sectors were asked to identify their key transport objectives and priorities, which were then brought into consideration in the NLTTMP2012.

After TfNSW's consultation process with travellers, travellers are then supposed to be more fulfilled by their expectations about the modal services. But in reality, the propensity of private car usage is still high. It indicates that in one aspect the involvement of customers in the projects/services could be improved and public transport service should satisfy better the travellers' expectations.

However, the financial constraints on TfNSW are an important reason why choice conflicts occur between traveller and the TfNSW. Over time, traveller behaviour is changing and the decision making process of TfNSW for any project is also becoming complex due to influences from the different stakeholders. Therefore, understanding the traveller mode choice behaviour may improve the agency relationship in transportation services.

In order to reduce agency problem, the principal may exercise two different mechanisms: (i) behaviour-based management; and (ii) outcome-based management (Zu and Kaynak, 2012). A better understanding of behaviour-based and outcome-based approaches helps the agent to

evaluate which approach is best suited to managing the agency problem. With the outcome-based mechanism, both parties can observe outcomes, and the principals reward agents according to measured performance of outcomes (Ekanayake, 2004). In transport mode service, the traveller may agree to pay extra money according to measured performance, called "willingness to pay" for better transport services. The behaviour-based management mechanism emphasises the tasks and activities that are performed during the processes executed by agents and these actions lead to the outcomes of the agents (Eisenhardt, 1989; Ekanayake, 2004). For instance, traveller opinions regarding their expectation may have an influence on the designing and planning of any project to make it successful and worthwhile. For any new project (service), TfNSW should organise public consultation, which can reduce informational asymmetries and goal/choice conflicts.

TfNSW can offer travellers' need-oriented services and it is the best way to overcome goal/choice conflicts. Billy and To (2011) described that controls (e.g. behaviour, output etc.) are generally associated work performance differently in a principal-agent relationship. Thus, TfNSW should try to understand better travellers' utility for transport services. It should reasonably incorporate the traveller preference heterogeneity in the outcome to reduce goal/choice conflicts. Travellers with various attributes including LVs and TOAs can provide guidance to TfNSW to implement satisfactory services to travellers.

The incentive system is an efficient method that can be implemented by principal as a mechanism to control the agent's activities. In terms of an agency relationship in transport mode service, incentives can be assumed as travellers' 'willingness-to-pay' for additional or improved transport mode services. Travellers may agree to increase the expenditure on travel once TfNSW provides comfortable, efficient and reliable services (Brownstone et al., 2003; Li et al., 2010; Hensher, 2010); and this increased expenditure is received by the TfNSW from the Government. The amount of 'willingness-to-pay' depends on the quality of services. Travellers pay more and it will be reflected in services provided by TfNSW, which reduces the goal/choice conflicts. Eboli and Mazzulla (2008) describe service quality by asking the users about their perceptions and expectations, and by considering the importance and satisfaction levels stated by users. Thus service quality attributes can be identified. There is much evidence that willingness-to-pay is a factor in better transport services (Li et al., 2010; Brownstone et al., 2003; Hensher, 2010).

6.5 Transport Mode Services and Principal-Agent Relationship

In general, a principal and an agent design contracts that reflect agent's interests or goals. In this PAT context, it can be inferred that TfNSW's public transportation services perform perfectly if the service offer is performed in accordance with the contract. The public transportation service may or may not be in line with the preferences of the travellers. In a democracy, citizens elect governments based on their programs and performance, which to a large extent reflect citizens' political issues and priorities. Public transportation services are offered to the users (travellers) based on the double principal-agent relationship, i.e. citizens-government, and government-operator. Although in the same field of transport, these two relationships (i) policy and public transport (PT) company; and (ii) traveller–TfNSW are quite different. This research has encapsulated the first kind in thinking about a combined TfNSW–PTs entity. Surprisingly, no work has been found in the field of transport mode service under a contract offered by a principal.

6.5.1 Efficiency and customer-focused

The goal of TfNSW for public transportation services must be to maximise citizens' (travellers') utility. When travellers have other alternative services, it is critical for TfNSW to increase users based on satisfaction with the performance of public transport service.

In general, TfNSW loses relative market share of the public transport compared to the personal mode of transport (privately owned car) because of travellers' dissatisfaction with public transport service. Perceived service quality compared to personal mode of transport is an explanation of this development. TfNSW can improve its performance if it manages to:

(i) Switch travellers to the public transportation service by improving the performance;
(ii) Attract travellers to the agent (i.e. TfNSW and travel service providers are combined into a single agent, called TfNSW in this research);
(iii) Reduce travellers' exit from public transportation service; and
(iv) Influence the affordability and the trip rate. This management may make the public transportation system efficient and customer–focused that relates to TfNSW's performance.

The efficient and customer–focused performance will occur if TfNSW offers a higher expected utility for public transportation service relative to car use. Travellers may stop using public

transport if TfNSW is less responsive to customers' dissatisfaction. In spite of the private alternatives, several factors may hinder the customers from making use of private car due to inability to purchase a car, maintenance cost of a car, travel time etc. Because of these reasons, the traveller may be forced to use public transport.

In these situations the traveller can be characterised as loyal but not satisfied (Fornell, 1992). Confronted with real competition, TfNSW may use incentives in order to attract new travellers or reduce loss of market share. It is assumed that TfNSW does not worsen the conditions for private transport users, the switching of travellers to public transport can occur only by increasing the expected utility of using public transportation services without reducing expected utility for private car. In other words, TfNSW keeps continuing the improvement of public transport service offer without reducing the good conditions for the private car. Such a policy is in agreement with Sarens and Abdolmohammadi (2011), who state that a policy should be regarded as adding to social welfare if it has the potential for making someone better off without making anyone else worse off.

One of the goals of TfNSW is to develop an efficient and easily available public transport service that may help improve the road network and reduce urban environmental problems. Due to heterogeneous traveller preferences, public and private transport services are perceived differently by the travellers. Incorporating traveller preference heterogeneity into transport services may promote efficient public transportation service. Thus, traveller preference heterogeneity influences the decision making process of TfNSW and a lower level of traveller satisfaction may occur because of the mismatch between preference heterogeneity and TfNSW's services. On the other hand, a high degree of traveller satisfaction can be obtained if there is a good match between preference heterogeneity and TfNSW's services through a provision of traveller preference heterogeneous oriented services. Based on this, it may be assumed that congruence between the services implies a good match that can be described as an improvement in the agency relationship. Accordingly, traveller-oriented services will have a higher degree of traveller satisfaction than less traveller-oriented services.

6.5.2 Traveller preferences and choice

Traveller satisfaction is the accumulated experience of a traveller's mode usage and experiences about the mode services. It is assumed that the traveller is capable of evaluating the performance of transport mode service and it results in the right selection of mode of transport for trips. It is

anticipated that if the traveller preference exists, they should be reflected in the choices. In this research, the highest and lowest choice probability (described in Chapter 4) are found in private car and public transport respectively. Therefore, a mismatch between traveller expectation and TfNSW's services is noticed and it indicates a low level of satisfaction with public transportation service. Thus this finding supports the notion that the congruence between traveller preferences and services provided by TfNSW is not satisfactory. Based on this discussion, the public transportation service should reflect traveller preferences that can be offered by the TfNSW to reduce the choice conflicts between traveller and TfNSW.

The share of public transportation use is lower than the use of private car due to relative improvement in private car related conditions and flexibility to use private car over public transport. It can also claim that public transportation service is not fully traveller-focused and TfNSW may not understand the travellers' utilities properly. Therefore, TfNSW may have pursued the wrong strategy to support the heterogeneous market of public transportation in the real world. TfNSW provides public transportation services based on the principle of equality so that different group of different income level of the society can afford it. As a result, the service quality of public transportation cannot satisfy all categories of travellers. A good marketing practice recognises different customer preferences and develops products and services accordingly. Fulfilling customer needs is the foundation for customer satisfaction and then, customer uses the same service (Andreassen, 1995).

6.5.3 Necessity of high frequency users with public transportation

It is assumed that TfNSW's goal is to improve traveller's welfare and thus high frequency usage of public transportation should be targeted. By looking at the results describe in Table 4.7, priorities for managerial actions are highlighted below. Base of the estimated coefficients of relevant parameters, the followings quality areas are the critical ones for the agent (TfNSW) to make improvements of the situation:

Among LVs

- Safety;
- Reliability;
- Comfort; and
- Convenience.

Among TOAs

- Travel cost;
- Travel time;
- Waiting time; and
- Car ownership.

The analysis described in earlier chapters indicates that these traveller choice attributes are found important and TfNSW has not satisfactorily succeeded in meeting these needs since the percentage of public transport use is remarkably low. TfNSW should attempt to increase its ability to meet these needs that helps to improve the agency problem in transport mode services.

All quality areas should be emphasised equally to satisfy the travellers. For example reducing only traveller cost does not consequently resolve the problem of low satisfaction. TfNSW should offer a "balanced" improvement of these quality areas and thus the traveller satisfaction level to public transport can be increased. In Chapter 5 (Table 5.10), it was discussed that reducing travel cost and waiting time have impacted on the travellers' mode choice and use of public transport was predicted to increase. Improving these areas requires cooperation between the agent (TfNSW) and his principal (traveller).

6.6 Conclusions

A low degree of congruence between traveller preferences and TfNSW's transport mode services is found and therefore, the public transportation offers low utility. TfNSW is a government organisation and it therefore has limitations due to political influences over the transport services. Privatisation and deregulation may be *two* solutions that have proved successful with regard to increasing expected utility (Andreassen, 1995). A *third* solution is a systematic measurement of traveller preferences and utility for the transport mode services to satisfy them through TfNSW's services. Increased satisfaction or reduced dissatisfaction with the public transportation service may contribute to switching travellers from private transport to public transport and increase existing travellers' retention rate, or reduce travellers' exit from the market i.e. public transport. Traveller-focused public transport can reflect high frequency travellers' satisfaction, may reduce the problem of market exit and the loss of relative market share to private car.

This theory offers an understanding of the agency relationship in transport mode service by which a range of parties can be benefitted: travel behaviour researchers, transport stakeholders, and transportation policy makers, etc. PAT offers a theoretical framework to conceptualise the quality assurance mechanisms from TfNSW, demanded by travellers. For travel behaviour research, the theory possesses enough theoretical framework wisdom in its concepts but, at the same time, these concepts are broad enough to allow for a wide variety of operational scenarios to be considered.

Chapter 7

Conclusions and Future Works

This chapter discusses summary of the findings that were found from the modelling approach described in previous chapters. Based on the outcomes of models, some policy implications and future work are illustrated here.

7.1 Insights and Strengths of PAT

Traveller mode choice behaviour has been analysed in the context of PAT to understand an inferred relationship between traveller and TfNSW. Within the limits of this objective, three research questions have guided analysis conducted in this study. The first research question focuses on exploring the insights that PAT can offer to understand the connection between traveller and TfNSW through traveller mode choice analysis. Prior to the empirical analysis, theoretical concept of PAT is understood and a conceptual framework is developed to analyse the traveller mode choice behaviour. The second research question directed the study towards an evaluation of empirical analysis that shapes this understanding of principal-agent relationship in transport mode services. To understand this relationship, mode choice probability analysis is employed using RPL models. Finally, the third question deals with the approach by which the agency problem within transport mode services of TfNSW can be reduced and improved. With the regard to these research questions, the following conclusions can be drawn.

The framework of PAT is not particularly cumbersome. This simplicity, along with the universal nature of agency relationships, has made PAT generic enough to allow the application of the theory outside of economics, the discipline in which it was originally developed. Attempts to apply PAT as a heuristic or illustrative framework for theoretical and empirical studies in disciplines outsides economics have been growing in number. The determination of the theory's potential to understand the effects of traveller choice attributes on mode choice, as conceptualising in terms of an agency relationship is relatively new and has not been sighted in extant research yet.

In general, the agency relationship in modal services seems to contain both of the essential conditions of PAT such as goal/choice conflict and adverse selection. Both of these conditions can be operative in the theoretical and empirical contexts of the connection between the traveller and TfNSW. On the basis of this context, the probability of public transport use is remarkably low which indicates an agency problem within the transport mode services of TfNSW.

The analysis of the empirical case study appears to provide support for the theoretical insights. The analysis showed that travellers preferred to use their private mode of transport than public transport and most of the travellers did not like to take public transport due to its lack of customer-focused services. Therefore, TfNSW is performing an *adverse selection,* which is one of the assumptions of PAT. TfNSW has not been able to satisfy travellers' interests, which is also known as *opportunistic behaviour*. Empirical findings concerning adverse selection were highly evident as the usage of private car is significantly higher than that of public transport. Adverse selection problem underlies the possibility for opportunistic behaviour by TfNSW. PAT can help to understand this problem. Analysing traveller mode choice attributes and incorporating traveller preference heterogeneity in choice process may support to overcome the goal conflicts/adverse selection problem. It can be assumed that this method, known as integration of traveller preferences in transport project, is able to decrease goal conflicts/adverse selection too. From the empirical perspective, the existence and importance of the adverse selection problem was identified and verified with the mode choice probability of travellers. On the other hand, the traveller preferences related to LVs has more influence in the implementation process of transport projects, and when it is not integrated properly in the project, the adverse selection may occur. In this research, three hypothetical scenarios of increasing annual income, reducing travel cost and waiting time for public transport were trialled and, as a result, it was found that public transport use could be increased, indicating a way forward to reduce the agency problem within mode services of TfNSW.

As an important part of discerning the governance of agency problem, PAT introduces the agency cost (e.g. fare, tax paid by travellers) and agency variables (e.g. choice attributes). Agency variables of the inferred relationship between traveller and TfNSW can offer insights for analysing traveller choice behaviour, providing a tool to understand a connection between traveller and TfNSW as indicated in PAT. The theoretical and empirical analysis conducted for this study showed that the agency variables can offer either general or case specific ex-ante as

well as ex-post insights concerning the effectiveness of principal-agent relationship in transport mode services.

Theoretical analysis also allows for some general conclusions to be drawn regarding the mode choice analysis within PAT framework to understand a connection between traveller and TfNSW. Firstly, utilisation of agency variables (e.g. choice attributes) to analyse the principal-agent relationship in transport mode services of TfNSW shows how difficult it is for the travellers to monitor the tasks accomplished by TfNSW. It implies that the traveller inevitably suffers relatively high agency costs. This is because travellers pay high travel costs and they are not getting their expected services. As per Figure 6.2, there are some relevant stakeholders who influence TfNSW's plans and programs but traveller cannot influence TfNSW at that much. Secondly, determining agency cost can include the travel fare and obtained utility of the services.

As a whole, all the strengths offered by PAT to understand the effects of choice attributes on traveller mode choice as an agency connection between traveller and TfNSW. PAT is a unique theory that help to understand a relationship between two parties such as traveller and TfNSW and other theories do not contribute to that extent. Basically the insights of PAT can guide to understand the questions of TfNSW's compliance with the travellers' expectations in exchange for the resources they receive from the travellers. Analysing different forms of TfNSW opportunism, and issues related to governing the opportunism, are clearly the strongest and most unique insights that the theory can offer. PAT can provide alternative insights by examining the socioeconomic characteristics and LVs of travellers with behavioural implications for TfNSW that may help the resource allocation mechanism of TfNSW. According to the choice attributes analysis, *safety*, *reliability*, *comfort* and *convenience* among LVs and *travel cost*, *travel time*, *waiting time* and *car ownership* among TOAs are found prominent to understand the impact on the mode choice process. These variables help to reduce the agency problem by allocating the resources for the customer-oriented transport services. As such, it seems to able to offer a broad but logically consistent framework about the influence of travellers on TfNSW's decision making, in which traveller latent preferences along with TOAs can be integrated in a meaningful way to reduce the agency problem within transport mode services of TfNSW.

7.2 Concluding Remarks

TfNSW has to work within constraints of a gridlock network of transport and an exploding population. The network built in the old days cannot cope with population increase. There are competing demands on government funding, and TfNSW cannot get all the money they need to fix the problems according to travellers' expectations, particularly with continually rising costs (labour costs, construction costs, materials costs, etc.). It is found that LVs can help to make it better, and TfNSW cannot do much about them due to lack of resources. Perhaps, LVs cannot alone solve the agency problem but can improve the situation.

However, this study analyses the merits of LVs over TOAs for traveller mode choice first and it is documented that travellers make the decision differently in LVs, which affect the utility of alternatives in a systematic way. Integrating LVs in choice model leads to a deeper understanding of the choice process that helps TfNSW to provide suitable transport mode services for the travellers. In this study, LVs were also found as prominent attributes of traveller mode choice behaviour which is the key method of this research to understand the principal-agent relationship in transport mode services. Traveller (principal) entrusts their expectations and desires to TfNSW (agent) to perform modal services as per their demand. In extant research, it was found that TOAs dominate traveller choice process but in real life, the attributes that influence individual choice may be complex. Anwar et al. (2011) argued that LVs (known as black box) in choice process are most influential than TOAs. Previously, Johansson et al. (2006) assumed that TOAs explain traveller preference sufficiently. However, this current study observes that TOAs make a very limited contribution (only 10.1%) to explain LVs. It indicates that LVs and TOAs should be described separately to clarify the influence of traveller preference heterogeneity to mode choice process.

There are several other strengths of this research. *Firstly*, it demonstrates an inferred relationship between traveller and TfNSW as indicated in PAT, which is a novel approach for addressing agency problem in transport mode services. *Secondly*, it reveals the extent to which LVs influence traveller mode choice as a tool to understand the principal-agent relationship. *Thirdly*, it illustrates the superiority of the hybrid RPL model over the traditional RPL model. *Finally*, it proposes an approach of demonstrating hypothetical scenarios with changes the condition of relevant variables to reduce the agency problem in transport mode services of TfNSW.

From the findings of this research, it was found that the probability of traveller transport mode choice is dominantly higher for private car use than public transport, which suggests that an agency problem exists in traveller mode services. To reduce the agency problem, TfNSW should integrate traveller preferences, which are identified in this research as prominent critical aspects, in planning and implementing stages of transport mode related projects. The results are also very useful for policy makers in shaping effective policies and it may help to encourage travellers to use public transport rather than private cars. Understanding traveller desires and expectations with utility function of traveller choice could help to promote suitable public transport and reduce agency problem ultimately.

As it was found that LVs are mostly dominant in traveller mode choice process, it should be adequately reflected in the current policy responses. Since the probability of using a private car is dominantly high, it indicates that public transport is not efficiently successful to attract travellers. It means, in other words, that TfNSW does not consider appropriately the dominant features of traveller expectation regarding mode choice in a reasonable manner in the planning and implementing phase. Furthermore, the high usage of private cars may be also due to congested roads, constrained public transport network, long travel time, etc. The TfNSW cannot do much with gridlock network although this thesis does not discuss about the spatial-related transport problem. However, as per the analysis, LVs is very influential aspects to measure the TfNSW performance. In this case TfNSW should incorporate the traveller latent choice preferences in mode service and public transport use may be increased, which is found by iterating changed (hypothetical scenarios) conditions described in chapter 5 (Section 5.5). Importantly, the strength of this study is the clarification of the nature of traveller preference heterogeneity, both observed and unobserved, in the process of mode choice as a principal-agent relationship in transport mode services. It can assist the transport planners or departments such as TfNSW to formulate effective and worthwhile policies to improve the transport system and to rectify the agency problem in the services finally.

From a theoretical perspective, TfNSW comprises of a number of interdependent sections and requires a high level of infrastructure management for a good transportation system. The *goal/choice conflict* generates insights for analysing the goal structure of TfNSW from the perspective of traveller expectations. The assumption of goal/choice conflicts also assists in discerning the principal-agent relationship in modal services in a more logical and structured

manner. Furthermore, the *adverse selection* problem outlines the possibility for opportunistic behaviour by TfNSW. It can be assumed that integrating traveller choice preference heterogeneity (i.e. observed and unobserved) into the modal choice project can reduce the *adverse selection* problem.

It is desirable that TfNSW should work in the interest of travellers in order to resolve the various limitations of the public transport system in the SSD so that the people can be attracted to use public transport and thus agency problem might be reduced. TfNSW should pay more attention to the choice attributes that are dominantly identified such as LVs accordingly and make sure suitable, appropriate and accessible mode of transport is available to all groups of society. It may help to increase public transport use. Moreover, the mechanism of reducing travel cost and waiting time in the public transport system may improve the performance of TfNSW and people may be motivated to use public transport rather than cars. Hence, a percentage of travellers may switch to public transport and the probability of private car usage should decline, which in turn reduces agency problem in mode services.

Categorising the full sample into two groups of CO and NCO provides greater insight to understand the effects of choice attributes on traveller mode choice. Analysing CO and NCO samples separately give unique guidelines related to mode choice attributes. These modelling outcomes can contribute to useful policies on sustainable transport management. Failure to provide suitable public transport for all groups in the society may cause urban environmental degradation, due to too much usage of private cars by travellers. Therefore, TfNSW must realise the expectations of CO and NCO so that modal services can perform accordingly. Analysis of CO and NCO samples identified different set of attributes related to CO and NCO and these attributes should be addressed in a reasonable manner in order to reduce the agency problem.

Finally, a temporal analysis was done using 2008/09 and 2010/11 HTS data. The changes in results between two set of data were critically analysed to observe the differences and it concludes that the representation of HTS data used is reasonably suitable. Furthermore, the 2010/11 HTS data has been used to analyse the predicted changes regarding traveller mode choice behaviour as an approach for minimising agency problem in the relationship. Three hypothetical scenarios were made with considering the changes of traveller behaviour, which have been described in chapter 5. Forecasting results supported the proposed mechanism to

reduce the agency problem which was, not only reduce travel time and waiting time but also increase income impacts. This could increase public transport use and decrease private car use.

Last but not the least, the modelling approach of this study is mainly based on the HTS data that has been collected by BTS of TfNSW. The main focus of this study was to analyse traveller behaviour considering LVs and TOAs. This analysis was performed in the line of principal-agent relationship and finally to reduce the agency problem by using mode choice probability analysis. The conclusions were based on the results obtained from 2008/09 HTS data. The 2010/11 HTS data was also used to examine the traveller choice behaviours from the same perspective, as indicated in the results acquired from the 2008/09 HTS data. Between 2008/09 and 2010/11, the probabilities of traveller mode choices were varied. For example, the choice to public transport has been increased on an average 1.8% to 2.3% (Table 5.6). In contrast, the choice to private car decreased on an average 1.1% to 1.5% (Table 5.6). Some improvement projects related to transport management were noticed such as rail services, bus services, timetable and infrastructure (described in Chapter 5) undertaken by TfNSW between 2008 and 2010 and these improvement project may case these differences. Therefore, it could be assumed that these improvement projects might cause these changes related to mode choices. It is not possible, in a straightforward manner, to interpret that these improvement projects caused the changes because the data regarding the connection between improvement projects and traveller choice behaviour was not available in the HTS data. Additionally there was no question in the HTS questionnaire related to potential changes of traveller behaviour if some improvement projects are implemented. Not only that, environmental factors were also absent in this questionnaire. Therefore, this current study was unable to relate infrastructural development implemented by TfNSW to changes of traveller behaviour directly, and also unable to draw any conclusion about environmental issue of traveller behaviour.

On the other hand, this study focuses only on the outcome using real HTS data and analyses the traveller choice behaviour to the mode of transport. The real HTS data was used in the models and the outcomes of the models are only confined for that specific dataset and spatial location (SSD in this case). The validity of models was assessed by statistical accuracy that also tells the model fit criteria reasonable well. Thus, the statistical tools such as GFI, AGFI, CFI, NFI and RMSEA were used to infer the validity of MIMIC models and log likelihood function, McFadden Pseudo and ACI were interpreted to determine the validity of RPL models.

7.3 Policy Implications

Understanding traveller mode choice analysis in the context of PAT is relevant for transport policy formulation. Budget is a big issue regarding the management/enhancement of a transport system (e.g. new infrastructure, new service such as bus, rail etc.) for the travellers. Fixed budgets have been given to TfNSW to perform the tasks and an additional resource is the revenue from the tax/fare payers who are citizens (travellers). As travellers pay for the services, they expect their desirable services from TfNSW. Therefore, the nature of demand/behaviour of travellers should be included in the transport policy to make it worthwhile.

As the people of SSD (Sydney Statistical Division) were inclined to use their private car rather than public transport, it indicates that TfNSW has a dearth of awareness about travellers' utility functions. For improving the agency problem within transport mode service, the policy responses suggest to pay more attention to the traveller utility functions. It is well validated as important by this research that transport policy makers should recognise them at the policy formulation level. On the other hand, this study has clarified the nature of traveller preference attributes, which form the traveller utility function, in the modal services to realise a connection between traveller and TfNSW. It indicates which attributes of the principal-agent relationship in mode services are most important to travellers and they should impact the policy finalisation.

From the comprehensive modelling approach in this research, the specific impact (coefficient) of various attributes, both observed and unobserved, has been determined. According to hierarchy of the impact, the attributes could help to design effective and relevant transport policies for modal services.

Furthermore, the behavioural findings and modelling techniques have direct policy and planning interventions in future transport management. *Firstly*, as LVs are found as significantly important in travel behaviour, ignoring them in the planning process could result serious errors in public transport management. Therefore, a systematic effort of LVs is required in transportation planning and policies to achieve the set objectives fixed by TfNSW and transport planners. *Secondly*, integrating the LVs in the relationship improves the agency problem with understanding more realistic descriptions of travellers' decision making.

The results found from this research demonstrate that LVs are important in travellers' choice processes and they are relevant for the transportation policy. Perhaps, it is not directly applicable to the policy making stage, but this importance to traveller choice process is useful when transport decision makers and planners will be designing and developing sustainable transportation policies for the city dwellers.

Finally, TfNSW should provide customer-focused public transport so that private car use may be reduced. Failure to do so could result in negative consequences on the urban environment. From this research, the relevant and important attributes related CO and NCO are identified and verified, which can provide direction in policy making. In other words, CO and NCO exhibit a different unique set of attitudes to the car and public transport choice and hence, different policies should be adopted in the design of the mode service for CO and NCO. Thus TfNSW can fulfil the demands of both CO and NCO travellers in order to reduce the agency problem.

According to forecasting analysis, improvement of travel cost and waiting time has a significant effect on switching usage from private transport to public transport. Such kind of TOAs represents the LVs and eventually LVs impact on traveller behaviour changes. It is also observed that increasing income and reducing travel cost and waiting time impacts to reduce private car usage. This research evaluated three hypothetical scenarios, which could be key issues, which might be helpful to reduce the agency problem in the relationship in modal services.

7.4 Limitations and Future Works

This study has few limitations. *Firstly*, the geographical area of the study is limited to the SSD. It would be better if the results were reinforced by applications on other geographical areas in order to be able to generalise the conclusions. *Secondly*, all the possible choice attributes (e.g. habit, differences between psychological understandings among individuals) that could be used to evaluate the relationship within transport mode services were not included in this study. *Thirdly*, the agent (i.e. TfNSW) might be influenced by the political influences that are beyond the scope of this study. *Fourthly*, the environmental considerations (e.g. CO_2 emission) of TfNSW are not included in this study as the survey data focused on the traveller's perspective. *Finally*, the concept of multiple principals/agents was not considered in this study.

The possibility of merging agency theoretical perspectives with other approaches could help to understand the relationship more specifically. For example, there is a hierarchy of transport system provision and management and *social exchange theory* may also be merged with the agency perspective to improve the analysis. PAT's ability to adjust to the interaction of multiple principals/agents in the agency framework presents a great challenge for future theoretical and empirical research on this topic. Multiple principal-agent relationship can also be considered in future work. Additionally, incorporating the political influences on TfNSW's performance and environmental issues in the choice behaviour within the PAT framework could be another interesting angle of research and very complex though. Future research may also include a joint estimation of the models, which requires the use of a simulation based approach and agent-based modelling to explore PAT can also be a good research topic in future. It would be interesting to extend the current framework to incorporate other known behavioural processes such as habit formation, cognitive learning (of causal knowledge), spatial search, variety seeking, choice-set formation and dynamic updating/adaptation of mental representations. Furthermore, the interdependencies among the traveller choice sets, which could capture the correlation among the multiple travel modes, are ignored in this research. For example, people who travel by train are more likely to travel by bus. These types of correlations can be captured using copulas method (Meade and Islam, 2010) that has been left for future research. Although substantive work already exists in all or most of these areas separately, the extended model that has been presented in this study may offer a starting point for an integrated approach, as it combines latent and non-latent components of choice behaviour.

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