TRAVEL ADAPTIVE CAPACITY ASSESSMENT SIMULATION (TACA SIM)

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by
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

More than 95% of fuel used for personal transportation is petroleum-based (Environment and Development Division (EDD), 2005). The peak and decline of world oil production is producing price and uncertainty pressures that may cause significant travel behaviour change in the future. Current travel behaviour has developed during conditions of low cost fuel and government investment in private vehicle mobility. Current urban forms and land use have also been developed during a period of growth in vehicle travel demand. Research that explores the long term (permanent oil supply reduction period) implications of reduced fuel demand on private travel behaviour is needed. Local and national government investments in transport infrastructure and urban development will be used and require maintenance for decades. Research is needed to assess long-term mode choice and car travel demand as a function of urban form and demographic indicators. This type of travel behaviour adaptive potential should be relevant to transport planning decision making.

Literature review shows that there are a few available long-term planning methods, models, or tools in transportation engineering for future oil depletion. Transportation engineers need information of how current travel demand patterns may change over the lifetime of infrastructure investments in response to oil supply depletion. Behaviour change data for long term future situations would be difficult to obtain using traditional survey methods because most people have never experienced oil depletion situations. This research proposes that immersing people into the situation of oil depletion through sharp price

rise would be necessary to generate relevant behaviour change decisions. The thesis is that the long term behaviour change can be assessed by characterising current *adaptive capacity*. Adaptive capacity is defined in this thesis as the travel demand pattern with maximum fuel reduction without reducing participation in activities. The reasons why people might change travel demand to reduce fuel use is not part of the definition.

This research also proposed that an immersive sim game environment could be used to prompt behaviour change decisions relating to fuel price shocks. Research into sim game surveys and travel behaviour surveys was used to inform the design of a Transport Adaptive Capacity Assessment (TACA) Sim survey tool. The TACA Sim survey was designed to assess capacity to adapt travel behaviour to reduce fuel use, and to characterise the potential for mode change. Participants experience the TACA Sim survey as a self assessment or transport energy audit. The survey provides a personal feel, focuses on the usual weekly activities, and provides feedback to participants about their fuel use and car dependence. Participants supply their normal travel activities over a week, and three weeks of sim play includes a steep fuel price rise while people are allowed to change their travel behaviour in response. The TACA Sim survey was evaluated through a case study of surveys of staff and students at the University of Canterbury.

A second version of the TACA survey was developed that surveyed the one week of normal travel, but then probed adaptive capacity by asking a simple question after each travel activity was entered "Could you get to the activity another way?” The sim game travel adaptive capacity is compared with the available alternative adaptive behaviour for participants in a case study at the University of Canterbury.

The results of the case study show that the participants responded well with the simulated situation. This reflects that the TACA Sim is successful in helping participants to perceive the situation of fuel price rise and think about their alternatives to car travel. Asking people “Could you get to the activity another way?” was found to effectively probe their adaptive capacity which agreed well with the virtual reality survey. The virtual reality survey yields more details of what people can do such as moving house, chaining trips, combining trips and buying a more efficient vehicle. The web-based TACA survey has been developed and deployed in two further research projects.

GLOSSARY

Travel Adaptive Capacity total percentage of trips, kilometres or fuel that is currently associated with single occupant vehicle mode that could be changed to a lower fuel alternative.

Travel Adaptive Potential the fuel use reduction potential related to mode changes, activity changes and lifestyle changes in responses to the given fuel price pressures.

Household means either one person or more who usually live together and share facilities (such as living room, kitchen, bathroom and toilet), in a private residence.

Transport supply is particularly involved with a service, which must be consumed when and where it is produced.

Transport system is a combination of infrastructure, vehicles, and a set of rules for their operation.

Transportation systems planning is a process that aims to design, create, modify, and upgrade infrastructure and services to meet societal needs for accessibility and mobility in an efficient, safe and reliable manner.

Travel demand modelling is the development of mathematical formulations that represent observed travel patterns by travel mode, as well as the volume, travel speeds, and congestion level on the links of the transportation network.

Trip leg is a non-stop travel by a single mode for a single purpose. For example, if a person walks to work and returns, it is two trip legs.

Virtual reality is a technology that uses the combination of hardware and software, which allows a user to see, move around in and manipulate computer graphics.

CHAPTER 1

INTRODUCTION

What can you change during fuel price shocks?

Could you get to the activity another way?

This chapter describes the motivation for research, objectives of the study and research approach. The motivation section explains why the TACA Sim survey is needed for understanding long term trends in vehicle travel demand. The motivating issue of global peak oil production is briefly discussed with focus on how it presents planning problems for organizations, local authorities, and transportation engineers. The research approach section explains why a virtual reality survey approach was used. Detailed review of literature for the various subjects is presented in later chapters.

1.1 Motivation for the research

This research project began in 2005, when the crude oil price was rising sharply from below $50 per barrel to over $130 per barrel by the middle of the year 2008 (EIA, 2010). It appeared that the end of cheap oil was in sight. The research group that included Transportation Engineering, Mechanical Engineering, Energy Engineering and Computer Science agreed that the future conditions for transportation planning were likely to be different from the past. Transport planning analysis depends on travel demand data and projections of growth due to future development. This research project was motivated by the need for projections of future travel demand as populations adapt to high fuel price and as world production of conventional oil declines. This study does not seek to determine the price elasticity of fuel demand. The research contributes to an emerging area of transport energy engineering, which will require data about *how* travel behaviour will change in response to energy constraints. Methods currently exist to assess travel demand behaviour and to model the travel demand on urban transport networks. This thesis proposes a survey approach to assess the adaptive capacity for fuel demand reduction for a current travel activity system and urban form. The survey also captures the adaptive potential for change of current vehicle travel to alternative modes.

1.2 The motivating issue of Peak Oil

Oil supply has been a concern of governments and the public for decades. A major issue is that the largest oil producers are politically unstable Middle Eastern countries. Peak oil – the inflection between increasing and decreasing world oil production – has been discussed since the 1970's when the USA production peaked. The year of world peak oil production has been a subject of more recent publications. The peak oil date cited by eleven different, and highly cited analysts range from 2006 to after 2025 (Bakhtiari, 2004; Campbell and Laherrere, 1998; Deffeyes, 2003; Hirsch et al., 2005; Skrebowski, 2004; WEC, 2003; Davis, 2003). These analysts agree that the production rate of conventional oil will permanently decline in the near future. At the time of writing, in New Zealand a new report forecasted that world oil production will not increase in the next five years while demand will continue to rise (C. Smith, 2010).

The world's transportation systems are highly dependent on oil. Peak oil, and future oil depletion will cause adaptation in transport activity systems. In the transportation sector, various reports have shown that the current situation of oil dependence and demand for oil growth is likely to continue for years. (BTRE, 2005; Hirsch, Bezdek, & Wendling, 2005). This is due to a combination of factors such as continual population increase and economic growth in developing countries, and the lack of immediately foreseeable and economically alternative fuel sources to replace petroleum (BTRE, 2005; Hirsch, Bezdek, & Wendling, 2005; Jefferson, 2006; Lynch, 1999; Rawlins, 2007). Peak oil is seen by some as a national security issue that, if not managed wisely, may result in total chaos. Recently on 10 November 2010, a New Zealand Green Party Co-leader, Dr Russel Norman said: "*Our Government is flying blind. They have no plan for how high oil prices will affect our transport sector and economy. They continue to look backwards*" (Press Releases, 2010).

Developing urban form and transportation systems that facilitate normal activities while demand for fuel reduces, is a key solution for local authorities and governments in coping with future permanent oil depletion. In decision-making about future urban form and transport system developments, it is necessary to know how people can adapt in response to future permanent oil depletion. This information can be used to not only assess vulnerability of current urban form and transport systems, but also direct local authorities and governments in long-term planning for future asset management. However, after searching for literature reporting previous studies on peak oil vulnerability assessment and long term planning, there were two knowledge gaps identified:

1) No long-term planning methods, models or tools for future oil depletion are available in transportation.
2) No data are available for modelling personal travel behaviour adaptation in response to future pressure from oil price or disruption.

This research, therefore, is a response to this opportunity for adding an engineering approach to retrieve data of what people can do in response to fuel price pressures. The thesis further adds several new concepts for characterising personal travel behaviour adaptation to fuel supply pressure; adaptive capacity and adaptive potential.

1.3 New method needed to collect data on adaptive capacity

The most straightforward survey approach would be to simply ask people what they would do if the fuel price increased dramatically. The research programme began in 2005 when the fuel price in New Zealand was under $1.00 NZD per litre. An undergraduate Honours project student attempted a survey that asked what people would change if the price of petrol doubled. The project was not successful as none of the participants completed the questionnaire. The reasons given for non-participation were "that could not be possible" or "that would be so far in the future that my income would have doubled as well". Of course, by 2008, the price has surpassed the $2.00 level that was unbelievable to the participants just three years earlier. Now that there has been a recent price spike, it might be possible to gain participation in a survey that asks how people changed their behaviour when the price went up. However, with an overall fuel demand reduction of 2-3%, it is not likely that the recent travel demand changes are indicative of long term future adaptation to deal with much more severe fuel reduction.

The fundamental hypothesis for this thesis is that, in order to assess the capacity to adapt to reduced fuel demand, a survey must create the condition where participants accept the premise of the situation. The main research objective of this thesis was to develop a virtual reality (VR) survey that could put participants into the frame of mind to seriously consider how they would reduce fuel use. The VR survey would have to capture the current transport activity system of the participant in order to reliably assess the adaptation potential for alternatives. Another method which was also developed is to simply ask for alternatives to vehicle trips, without proposing or postulating any reason why the participant might want to use an alternative. The idea in asking “Could you get to the activity another way?” is that participants will mentally substitute a conceivable situation where they might not be able to use their car, such as a flat battery or malfunction.

This research began by reviewing literature on how to probe an individual’s decision making and their intended behaviour. There have been many studies on individual’s decisions and intended behaviour that have been done using gaming virtual reality. All studies have pointed to the need to immerse the participant in the situation. VR has been studied as a means for training for pilots and military personnel. It has also been used for surveys in several fields. Using a VR game platform for transportation surveys and for assessing the adaptive capacity is a new contribution to the field.

In the transport field, there have been several game-based methods used for investigating responses to hypothetical questions. Each method has had a different design customized to fit the requirements of the study. This is because an approach used in one circumstance may not be the best for another, as each study has unique features that need to be considered and included (P. M. Jones & Bradley, 2006). This research, therefore, proposed a particular method to explore an individual’s ability to adjust their travel behaviour in response to extreme fuel price pressures.

1.4 Research objectives

The main objectives of this research are related to characterization of travel behaviour adaptive capacity within a particular cohort or for an urban form.

1) To design and develop a survey tool to retrieve data about what people may do in response to shocks in fuel prices or other fuel supply constraint pressure.
2) To improve the survey tool design by conducting a statistically valid survey set of people.

1.5 Research contribution

The research approach has four main components: background and literature review, design and development, testing and improvement, and evaluation of the survey tool for collection of adaptive capacity data. The background research focused on understanding transport engineering, urban development and the peak oil issue. The literature review focused on two areas, simulation gaming platforms for behaviour surveys, and travel behaviour surveys used in transportation engineering. The survey tool design focused on a "sim game" platform and included learning how to develop this type of interactive software and how to manage travel behaviour data. The testing was done through a survey conducted at the University of Canterbury involving students, staff and academics. The feedback of the participants about how they experienced the survey helped to improve the design. Evaluation of the data collected showed that the TACA Sim survey does prompt participants to consider how they would change their behaviour in response to a fuel price shock. Further development of the survey concept then led to a web-based version of the first level of the TACA Sim survey which does not simulate a price rise, but simply asks, "Could you get to the activity another way?". This question is used to probe *Travel Adaptive Capacity,* which is defined as fuel reduction via currently known alternatives to car use.

The main contribution of this research is understanding of travel behaviour adaptive capacity through development of the TACA Sim. The prototype transport activity constraint assessment VR survey (TACA Sim) was developed using DarkBASIC Professional software. This approach is used to exert fuel price pressures in order to get an upper limit of travel behaviour change or so-called *Travel Adaptive Potential*. *Travel Adaptive Potential* is defined as the fuel use reduction potential related to mode changes, activity changes and lifestyle changes in responses to the given fuel price pressures.

The TACA Sim survey design contains three main levels, i.e. personal and vehicle information survey level, travel adaptive capacity survey level and travel adaptive potential survey level. The first two levels are constructed to obtain the information of normal transport energy use pattern and available alternatives for reducing energy. The current transport energy use pattern is used as a fact base that is probed for travel adaptive potential in the last level of the survey.

It is important to underline here that the TACA Sim survey is not aimed at behaviour change forecasting as such. The main purpose of TACA Sim is to help understanding of what people have the *capacity* to do. In the same way that the capacity to withstand other potential risks such as earthquakes is assessed for future planning, assessing the travel adaptive capacity of a current urban form and transport system can help with decisions and peak oil vulnerability planning. In this research, the individual was surveyed because the fuel prices affected directly on personal financial situations and fuel purchasing decisions. An individual, therefore, has certain priorities for decisions regarding his or her own travel demand pattern. The TACA Sim in this thesis was not designed as a self-administered survey. The participants were taken through the survey by a survey facilitator. The survey facilitator provided help to participants by entering in data, operating Google Maps™, clarifying the meaning of questions and prompting the participants to recall their travel activities in order to reduce respondent burdens and errors from data input.

According to literatures of Ajzen (1991) and Bamberg *et al*. (2003), a way to explore people's behavioural intention change is to introduce information to perturb their cognitive process. The given information will affect and stimulate the cognitive foundation of their intentions. The travel adaptive potential survey level of TACA Sim is supported by the Theory of Planned Behaviour proposed by Icek Ajzen (Ajzen 1991). The theory, in brief, suggests that human's intention to perform behaviour is directed by three elements (Bamberg, et al., 2003):

1) Beliefs about the possible consequence of the behaviour (behavioural beliefs);
2) Beliefs about the other person's normative expectation (normative beliefs);
3) Beliefs about self-ability that may be either obstructed or supported by the presence factors (control beliefs).

For characterizing travel adaptive potentials, the TACA Sim was designed to provide fuel price-pressure in the form of visual contact, and allow the respondents to experience refueling at the given price if they travel by car so that the respondent's consideration structure (three elements) was perturbed. During the sim part of the survey, the price pressure was quite dramatic:

***Pressure 1*:** the fuel price increased from \$1.64 per litre to \$5.65 per litre.

***Pressure 2*:** the fuel price increased from \$5.65 per litre to \$9.64 per litre.

It may be argued that the fuel prices simulated in the TACA Sim are too far beyond the respondent's experience to make decisions about realistic behaviour change. However, the fuel prices simulated in this research: \$5.65 per litre and \$9.64 per litre are used only as pressures on the respondent to induce their decision making process. As the TACA Sim did not provide new information or attributes of choices, the decision making was within the participant's range of experience and perception on the options. The travel patterns at the given fuel price-pressures in this research were not a conclusive prediction on how the travel behaviour will be at these particular prices. It simply shows travel adaptive potentials that are used for assessing current urban form and transportation systems of a particular cohort in a given area.

The purpose of the implementation for a case study in this thesis is to evaluate the extent to which goals of characterizing private travel adaptive capacity and travel adaptive potential have been met. The feedback and verification of the case study were used to assess the effectiveness of the TACA Sim tool and to improve the tool in the future work.

1.6 Outline of Thesis

This thesis contains nine chapters including this introduction chapter. The thesis is structured as follows:

Chapter 1 describes the motivation for research, objectives of the study and research approach. The motivation section explains why TACA Sim is needed. The research approach contains a description of how TACA Sim idea is developed.

Chapter 2 provides the background of oil supplies and prices. The current and future global oil supply and demand situations were described.

Chapter 3 presents the background on conventional survey methods. The reviews of methods for travel and behaviour studies are also contained in this chapter.

Chapter 4 describes the design and structure of TACA Sim, including how the datasets are stored electronically.

Chapter 5 describes the survey method and data collection on a particular activity centre: University of Canterbury (UC).

Chapter 6 focuses on verification of the TACA Sim design. The results of feedback from participants are analysed. The data from the TACA Sim survey at the UC are compared to the previous studies, i.e. an online UC travel survey and New Zealand price elasticity studies.

Chapter 7 illustrates the basic analysis using the dataset collected through TACA Sim. The analysis shows differences in travel demand pattern, travel adaptive capacity and travel adaptive potential between occupational groups. The travel demand dataset is investigated specifically in terms of number of trips, travel distance, travel mode, trip purpose, essentiality, and alternatives. Further, the travel adaptive potential is analysed for travel mode shifts, reduction in car trips, and reduction in car travel distance.

Chapter 8 describes a feature of the web-based TACA Sim for travel adaptive capacity survey and how it improves the survey time and operational speed.

Chapter 9 concludes the achievement of the research objectives. The conclusions of TACA Sim design in terms of structures, graphics, information, and functions are described. Finally, the chapter discusses the limitations of TACA Sim use and its future work.

CHAPTER 2

OIL SUPPLIES AND PRICES

2.1 Introduction

This chapter provides basic knowledge of oil supply and oil prices. The background helps to understand the current oil supply and demand situation. The chapter also contains the concept of supply and demand for oil price, oil history, example of fuel disruption in the UK and the future fuel price trends prediction. This information firms the background of oil depletion and high fuel prices occurrences possibility.

2.2 Oil Supply

2.2.1 Global Oil Supplies

At the end of 2008, global oil production was 8.1 million barrels per day. The oil production outside OPEC, however, decreased by 1.4%, which was the largest decline since 1992 (BP, 2009). Based on the BP (2009) oil production database, the OECD[1] production fell 4.0% mainly from a decline in the oil production in the European Union and North America. Figure 2.1 presents the trends in annual world oil production by region from 1980 to 2008. The trends in the oil production rate in all regions have exhibited a plateau from 2005 to 2008 except in Middle East, Africa and Asia and Oceania. Table 2.1 shows the percentage change in world oil production and consumption during 2004-2008.

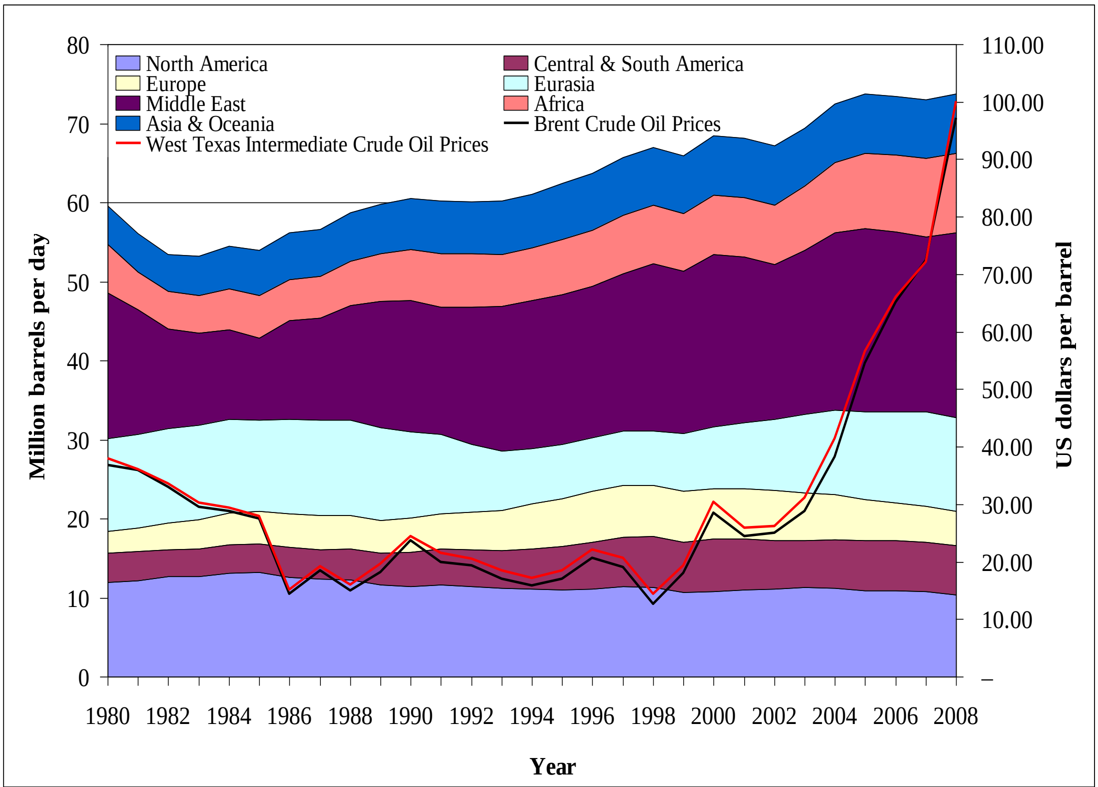


Figure 2.1: World Oil Production (BP, 2009; EIA, 2010b)

[1] The Organisation for Economic Co-operation and Development (OECD) consists of thirty countries and its members cooperate as market democracies in order to address the economic, social and governance challenges of globalisation. Most OECD members are regarded as developed countries (OECD 2008).

Table 2.1: The percentage change in world oil production and consumption from 2004 to 2008 (BP 2009)

	% change		Spot crude prices ($/bbl)		
Year	Production	Consumption	Dubai	Brent	West Texas Intermediate
2004	4.24	3.45	33.64	38.27	41.49
2005	1.04	1.55	49.35	54.52	56.59
2006	0.5	0.88	61.5	65.14	66.02
2007	-0.07	1.29	68.19	72.39	72.2
2008	0.46	-0.5	94.34	97.26	100.06

Growing uncertainty in the fuel supply is a concern for governments and other stakeholders. An uncertain oil supply brings about high fuel prices. For example, the Arab embargo on oil shipments to the United States (US) during the Yom Kippur War in 1973 and incapacity to increase oil production in the US result in the fuel price rose from $3.65 to $10 per barrel (Ariweriokuma, 2009; EIA, 2009). Considering the limited amount of cheap fossil fuels (Deffeyes, 2003; GAO, 2007), renewable sources have become of high interest as an alternative. However, renewable energy sources (such as solar, wind, biofuel) may not currently produce enough energy to substitute economically and environmentally for traditional fossil fuels (BTRE, 2005; Huesemann, 2003).

2.2.2 Peak Oil Predictions

Few major oil fields have been discovered in recent years. The discovered world oil fields have already reached their peak and the rate of new discoveries has decreased continually over forty years (US House of Representatives, 2005). Figure 2.2 shows the annual discovery of global oil fields and a growing gap between projected world new oil discoveries and production.

Historically, the total world oil production reached its peak at over 1,030 billion barrels in 2006 (Berge, 2008). The oil demand was predicted to increase while the projected oil discoveries in the foreseeable future decline (Berge 2008). The increasing demand and the decline in the oil supply have been public concerns for decades. The oil industries, however, claim that they have sufficient oil resources to meet global demand for decades as projected by the International Energy Agency (IEA) in 2007 (IEA, 2007).

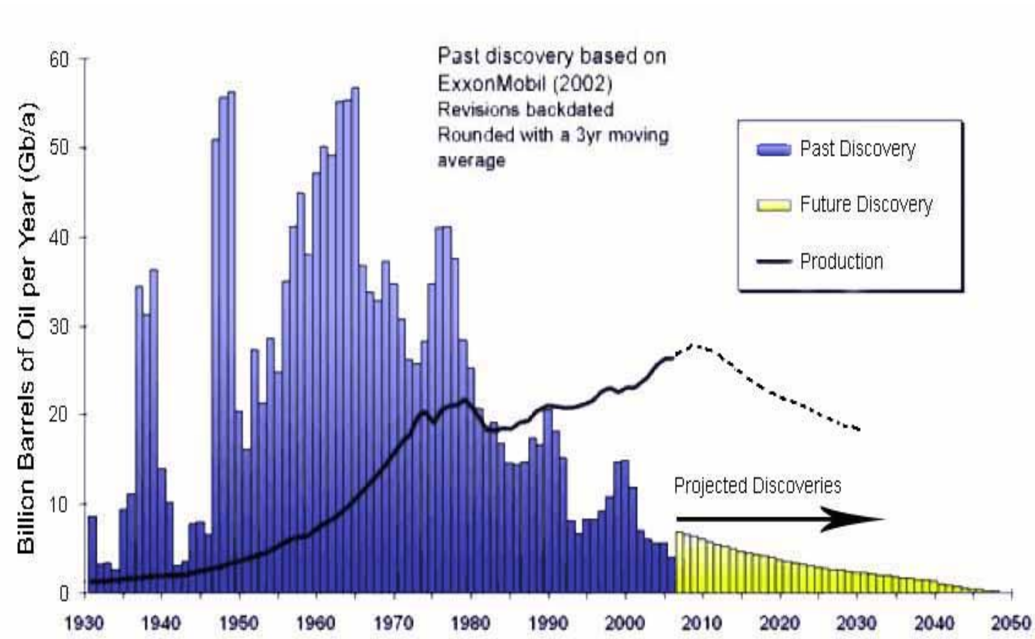


Figure 2.2: Past discoveries and a growing gap in future oil discoveries and production (US House of Representatives, 2005)

Recently, anxiety concerning global peak oil has increased in all industrial sectors as the peak oil will be followed by a rapid fall in oil production. The peak oil is generally presented as a bell curve representing an increase in oil production and its decline as shown in Figure 2.3 (Campbell & Laherrere, 1998).

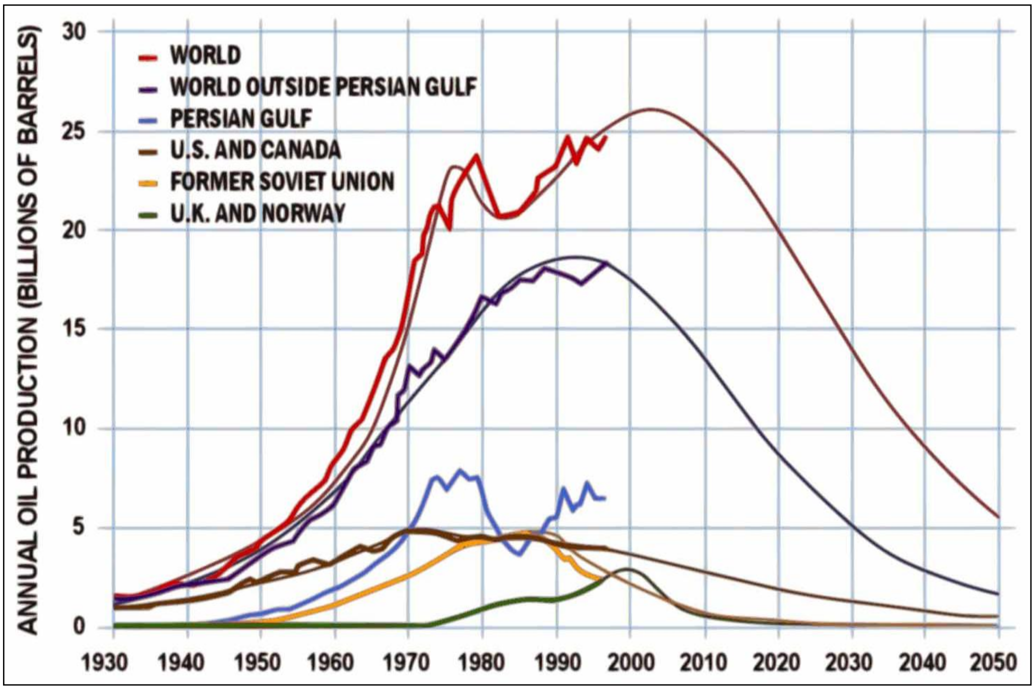


Figure 2.3: Estimations of world oil production (Campbell and Laherrere 1998)

The question of when oil will be depleted has been explored in international publications. A number of organisations and experts such as the Oil Depletion Analysis Centre (ODAC, 2009), the Association for the study of Peak Oil and Gas (ASPO, 2009) and the Energy Watch Group (Schnidler & Zittel, 2008) agree that conventional oil may have already peaked or will do soon owing to limited resources.

A wide range of dates for the decline in oil supplies has been predicted in a number of published reports. Hirsch *et al.* (2005) in a publication have reviewed the years of the peaking of the world oil production as predicted by 12 analysts. The predicted years range between 2006 and 2025 as shown in Table 2.2.

Table 2.2: Predictions of the years of the Peaking of the World Oil Production (adapted from Hirsch *et al.* (2005))

Predicted Year	Predictor	References
2006-2007	Bakhitari, A.M.S.	(Bakhtiari, 2004)
2007-2009	Simmons, M.R.	(Hirsch, et al., 2005)
After 2007	Skrebowski, C.	(Skrebowski, 2004)
Before 2009	Deffeyes, K.S.	(Deffeyes, 2003)
Before 2010	Goodstein, D.	(Hirsch, et al., 2005)
Around 2010	Campbell, C.J.	(Campbell & Laherrere, 1998)
After 2010	World Energy Council	(World Energy Council (WEC), 2003)
2010-2020	Laherrere, J.	(Hirsch, et al., 2005)
2016	EIA nominal case	(Hirsch, et al., 2005)
After 2020	CERA	(Hirsch, et al., 2005)
2025 or later	Shell	(Davis, 2003)
No visible peak	Lynch, M.C.	(Lynch, 2003)

2.3 Oil Prices and Oil Crisis

2.3.1 Concept of Supply and Demand for High Oil Price

The high oil price, as a consequence of “Peak Oil”, occurs when the demand for oil is higher than the production rate. The high oil price can be explained by using the concept of supply and demand (Boyes & Melvin, 2008). On the supply side, the capacity for oil extraction is stable in the short term cost (e.g. pumping cost) because the capacity for oil extraction cannot be changed quickly (Mankiw, 2008). The demand for oil does not respond rapidly to changes in price because it is not easy to substitute for oil for heating and propulsion purposes (Mankiw, 2008). The supply and demand curves are plotted as a function of price as shown in Figure 2.4. The supply curve (S) represents the amount of oil supply and the demand curve (*D*) represents the amount of demand for oil at a certain price (*P*).

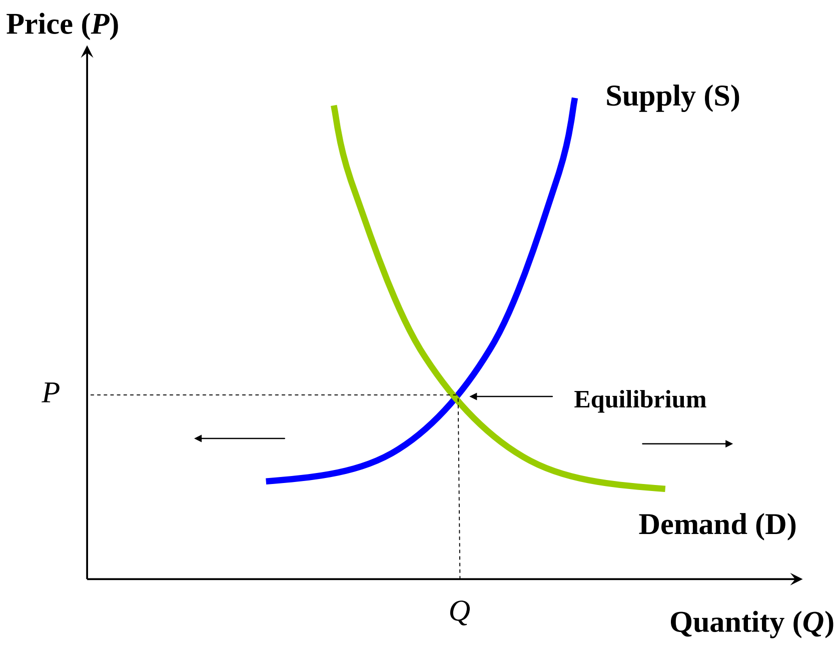


Figure 2.4: Demand and supply equilibrium (adapted from (Boyes & Melvin, 2008)).

Future population and demand growths will cause higher oil consumption and shift the demand curve to the right. This will result in increase of the fuel price if the oil production does not increase in the same time frame. After the Peak Oil period, the oil production will decrease. This will shift the supply curve to the left. Therefore, the fuel price will be increased as shown in Figure 2.5. The high fuel price will bring down the consumption, causing the demand curve to move to the left. Consequently, the fuel price decreases. The fuel price, however, will increase again as the oil production decreases continuously. This cycle will continue for years. The same concept of supply and demand appeared in the oil shocks of the 1970’s (Stevens, 2000).

Before the first oil shock, the demand curve was moving to the right as the demand for oil increased owing to the post-war economic boom. World oil demand grew approximately 7.7% per year between 1965 and 1973. During the Yom Kippur war (Brown, 2002), the OPEC stopped supplying oil to the US and restricted their oil production. The US could not increase production in 1974 because its domestic oil fields had already peaked and were in decline (EIA 2009). This resulted in less oil supply that moved the supply curve to the left, while the demand curve was trying to move to the right as the demand increased for stocks against the shortage. However, the demand increase was limited by oil availability constraints. This fuel shortage situation resulted in rocketing oil prices (Stevens, 2000).

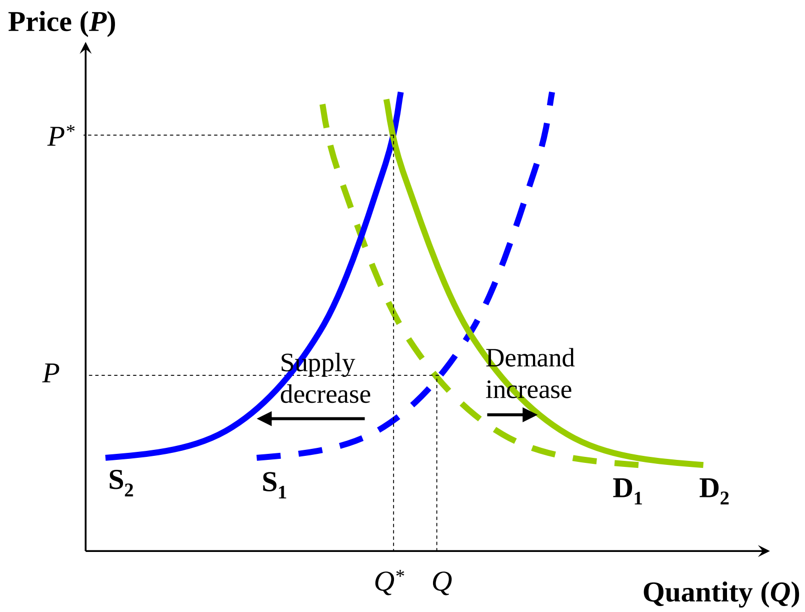


Figure 2.5: Growing oil demand and constrained oil supply results in high oil prices. (adapted from (Boyes & Melvin, 2008)).

2.3.2 Oil Price History

The first oil crisis started in 1973. The members of the Organization of Arab Petroleum Exporting Countries (OAPEC) (the Arab members of OPEC plus Egypt and Syria) declared an oil embargo to stop exports to the US and other western nations in order to punish them for supporting Israel in the Yom Kippur War. The Arab oil embargo then caused a temporary fuel shortage. From this situation, the US suddenly realised their dependence on oil and became aware of the limitations to the petroleum supply (Hakes, 1998). Figure 2.6 shows crude oil price history from 1970 to 2007 viewed in 2008 dollars.

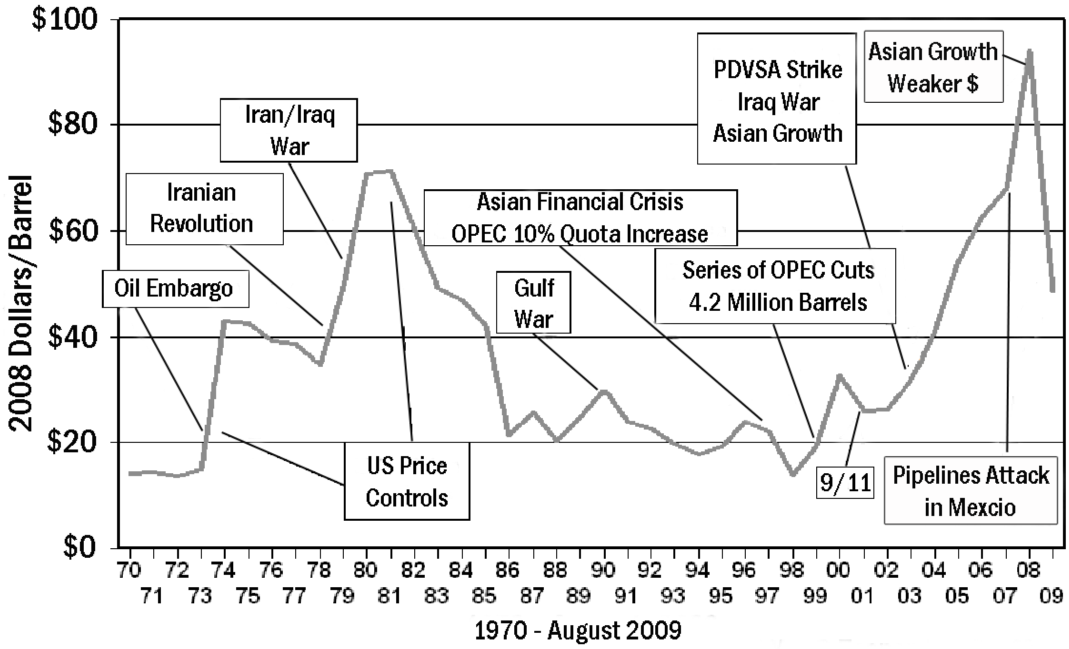


Figure 2.6: World Oil Price in 2008 dollars during 1970-2009 (WTRG Economics, 2009).

The second oil crisis occurred in the US in 1979 as a result of the Iranian Revolution. The shattering of the Iranian oil sector by massive protests caused an inconsistent decrease in the volume of oil production. This resulted in higher oil prices than would be expected under normal circumstances (Feld, 1995). However, during the second oil shock in 1979-80, Canada, Mexico, Alaska and the North Sea had made rapid progress in raising the oil production (Kemp, 2004). Americans reduced their dependence on oil imports from OPEC and improved their end-use efficiency of oil (Hakes, 1998).

Independently, the OPEC members attempted to use their leverage over the world price-setting mechanism by setting low production quotas for oil to stabilize their real incomes. Nevertheless, the attempts failed as various members of OPEC produced beyond their quotas. The peak world oil price in 1980 collapsed and the price of oil had fallen to below $10 by mid-1986 (Williams, 2009). The prices retreated to more moderate levels, American oil production decreased, and the share of imports rose again through the 1990's (Hakes, 1998).

In 1990, the price of crude oil spiked with the lowering production and uncertainty during the Gulf War (Looney, 2003). The crude oil price entered a period of steady decline again after the war and remained low till 1994 when it rose in response to the world oil consumption increase (EIA, 2010b). The world oil consumption increased by 0.7 million barrels per day from 1990 to 1997 owing to the prosperity of the economies of the US and Asia (EIA, 2010b). Together with declining Russian production, the price recovered until the end of 1997 (Williams, 2009).

By the beginning of 1998, the Asian economies had collapsed. Consequently, the oil consumption in the Asian Pacific region declined and the combination of decreasing Asian consumption and increasing OPEC production caused the oil price reduction (Mabro, 1998). However, oil prices began to recover in early 1999 and the OPEC cut-off in production was sufficient to move prices above $25 per barrel. The price continued to rise throughout 2000 and dropped due to a weakened US economy and an increase in non-OPEC production. The

September 11, 2001 terrorist attack also kept the price down until the trend of the price reversed in 2002 (Williams, 2009). Table 2.3 shows important incidents that influenced the world oil prices.

Table 2.3: Important incidents influencing the world oil prices.

Year	Incidents
1973	Yom Kippur War; Oil Embargo
1979	Iranian revolution
1980	OPEC members produced beyond their quotas
1986	The peak of world oil collapsed
1990	Lower oil production and uncertainty during the Gulf War
1990-1997	Economic boom in the US and Asia
1998	Asian economies collapsed
2000	Y2K problems, growing US and world economies
2001	Terrorist attack in the US
2003	Strike at PDVSA in Venezuela; Iraq war; Asian growth
2004/05	Increase in oil demand; Not enough spare capacity to cover an interruption of supply from OPEC producers
2005	Hurricanes; US finery problem associated with the conversion from MTBE to ethanol (Williams, 2009)
2006	OPEC cut back oil production by 1.2 million barrels a day
2007	OPEC announced an output increase lower than expected; Six pipelines were attacked by a leftist group in Mexico
2008	Asian growth, US dollars weak

After 2002, the oil price kept rising as a strike at a Venezuelan state-owned petroleum company, Petróleos de Venezuela, S.A. (PDVSA), caused Venezuelan production to plummet (Shore & Hackworth, 2007). Following the PDVSA incidents, military action commenced in Iraq and the demand in US and Asia was growing. A combination of demand increase and interruption of supply from most OPEC producers contributed to the crude oil price exceeding $40-50 per barrel in 2004/05.

The price trend had been higher in late 2007 when OPEC announced an output increase (OPEC, 2007), which was lower than its cutting back on oil production in November 2006 (Mufson, 2006). Pipelines were attacked by a leftist group in Mexico also contributing to the high price in 2007 (Johnson, 2007). The strength of the US dollar was an another major factor contributing to the level of price increases (Jackson, 2008).

Oil price for Brent Crude went over $90 in January 2008, and rose to a new record of over $140 on 1 July 2008, then declined by more than $20 in August 2008, and continued downward until the end of 2008 (EIA, 2010a). Meanwhile, the world oil consumption reduced as a result of the global economic downturn (EIA, 2009b). The oil prices, however, rebounded in 2009 (EIA, 2010a).

2.3.3 Example of Fuel Disruption owing to High Fuel Price in the UK

Several countries have also faced the disruption caused by the oil crisis. In 2000, widespread protests against high petrol and diesel prices had taken place in several European countries including the UK. Fuel taxes in the UK had increased to 81.5% of the total cost of unleaded petrol (BBC, 2000; Hammar, 2004). This caused the fuel prices in the UK which were amongst the cheapest in Europe, to become the most expensive in the same period (Hammar, 2004).

The protests against high fuel taxes caused serial blockades of many oil refineries and roads. Consequently, extensive panic buying at fuel stations and short-term fuel shortages occurred (Lyons & Chatterjee, 2002). The temporary fuel shortage forced car users to reconsider their travel behaviour. This resulted in a significant reduction in car traffic by average 39% on motorways, 25% on major roads and 16% on minor roads (measured on 14 September 2000 at 135 sites throughout the UK) (J. W. Polak, Noland, Bell, Thorpe, & Wofinden, 2001).

2.3.4 Fuel Price Trends

In 2008, real fuel prices surpassed the peak levels that occurred during the second OPEC oil shocks (Read, 2008). Many countries faced high fuel prices in 2008, which led undoubtedly to some reduction in demand because of low economic growth (OPEC, 2009). Plans and policies have been introduced in many countries such as the USA, UK, Australia, and New Zealand to improve efficiencies in the transportation sector, and use alternative fuels such as bio-fuels owing to high prices and greenhouse gas emission concerns (European Federation for Transport and Environment, 2009; FIA, 2009; Harnden, 2009; Todd Litman, 2008; MOT, 2009a). Influenced by the implementation of policies to improve transport efficiencies, OPEC predicted that the long-term world oil demand will be decreased from 113 million barrels per day (bbl/d) to fewer than 106 million bbl/d over the period 2008-2030 (OPEC, 2009).

A number of professional analysts and modellers have projected a trend for world oil prices to increase. Table 2.4 illustrates the forecasts of world oil prices in constant dollar during 2010-2030 from seven organisations. The range of prices for the short term and long term are predicted based on the market volatility and different assumptions about the future of the world economy.

Table 2.4: Projection of world oil prices between 2010 and 2030 in 2007 US Dollars per barrel. (Energy Information Administration, 2009a).

Projection	2010	2015	2020	2025	2030
AEO2008 (reference case) [2]	75.97	61.41	61.26	66.17	72.29
AEO2008 (high price case)	81.08	92.77	104.74	112.10	121.75
AEO2009 (reference case) [3]	80.16	110.49	115.45	121.94	130.43
Deutsche Bank AG (DB)	47.43	72.20	66.09	68.27	70.31
IHS Global Insight (IHSGI)	101.99	97.60	75.18	71.33	68.14
International Energy Agency (IEA) (reference)	100.00	100.00	110.00	116.00	122.00
Institute of Energy Economics and the Rational Use of Energy at the University of Stuttgart (IER)	65.24	67.03	70.21	72.37	74.61
Energy Ventures Analysis, Inc. (EVA)	57.09	74.61	95.33	105.25	116.21
Strategic Energy and Economic Research, Inc. (SEER)	54.82	98.40	89.88	82.10	75.00

The Energy Information Administration (EIA) of the US forecasts an average spot price of West Texas Intermediate (WTI) crude oil to be nearly $70 per barrel through the second half of 2009. However, the actual average WTI spot oil price during the second half of 2009 was approximately $72 per barrel (EIA, 2010). The EIA also predicts that the WTI spot prices will rise slowly owing to improvements in economic conditions. Global consumption is

[2] AEO2008 refers to the US Energy Information Administration's forecasts, as published in the Annual Energy Outlook 2008.
[3] AEO2009 refers to the Annual Energy Outlook 2009.

projected to grow by 0.9 million bbl/d and the average price will be about $72 per barrel in 2010 for the short term (EIA, 2009b).

2.4 Reviews of Effects of Rising Fuel Prices

Current travel demand patterns have already shown a response to recent increases of petrol prices in 2008 (WSDOT, 2009). Travel behaviour patterns have changed due to temporarily increasing petrol prices such as driving more slowly, making fewer trips, and increasing public transport use (CBO, 2008). Several studies investigated how travel demand response to the prices through elasticities measurement. This is because the elasticity and cross-elasticity estimations are important for transport policy options in short-term planning. The policy makers require elasticity estimations to assess the effects of their policies on travel demand in a particular region (Acutt & Dodgson, 1995).

2.4.1 Elasticity of Demand with Respect to Prices

Price elasticity is used for measuring an aggregate effect of prices on the consumption decisions (P. B. Goodwin, 1992). For example, a 1% increase in car prices causes a 0.1% reduction in car demand. Therefore, price elasticity equals to -0.1 (a negative sign shows the opposite direction from the price change). The price elasticity is simply defined as the percentage change in consumption of a commodity (ΔX) responding to the percent change in its price (ΔY) (Gans, King, & Mankiw, 2003).

$$\text{Elasticity} = (\text{\% of } \Delta X)/(\text{\% of } \Delta Y) \qquad \textbf{(2.1)}$$

If the percentage change of demand is greater than the percentage change in price, the demand for a good is elastic (elasticity is greater than 1). The demand for a good is inelastic when the percentage change of demand is less than the percentage change in price (elasticity is less than 1).

Cross-elasticities is defined as the percentage change in demand for a particular good caused by a percentage change in the price of another good (such as fuel price, parking fee) (Todd Litman, 2007). For example, car use is complementary to fuel price and parking fee. If these costs of driving are increased, the demand for car travels will be reduced.

Several methods have been proposed to calculate elasticities because price elasticities vary at different points and the percentage changes are not symmetrical. The frequently found methods for calculating elasticity of travel demand are (S. Kennedy & Hossain, 2006; Koushki, 1991; Todd Litman, 2009):

Arc elasticity (shrinkage ratio):

$$E_{arc} = \frac{(Q_2 - Q_1)/Q_1}{(P_2 - P_1)P_1} \qquad \textbf{(2.2)}$$

Mid-point arc elasticity:

$$E_{mid} = \frac{(Q_2 - Q_1)/((Q_1 + Q_2)/2)}{(P_2 - P_1)/((P_1 + P_2)/2)} \tag{2.3}$$

Log-arc elasticity:

$$E_{\log-arc} = \frac{(\log Q_2 - \log Q_1)}{(\log P_2 - \log P_1)} \tag{2.4}$$

where Q_1 and Q_2 are the demand before and after, and P_1 and P_2 are the price before and after.

Kennedy and Hossain (2006) studied the respondent's perceived behavioural changes to the fuel price increase by using the shrinkage ratio to obtain elasticities for fuel expenditure, kilometres travelled, and car trips. Their study shows a reasonable amount of elasticity for car trips (-0.1) and kilometres travelled (-0.21) compared to the EU study. However, the price elasticity for fuel expenditure in their study was overestimated (greater than 1) owing to an exaggerated perception of the participants' increase in expenditure when the price was increased 18.5%. Koushki (1991) also quantified the effect of fuel cost increase on the change in daily car trips of different income households in Riyadh, the developing capital of Saudi Arabia. The data on the number of daily trips were collected before and after the fuel price increase during 1987/88. The effect was quantified by measuring shrinkage ratio, mid-point arc and log-arc elasticities. Their study showed that an increase in fuel costs has an effect on car travel (empirical elasticities are between -0.30 and -0.37). Households with a large family size and low income level were more responsive to the increase in the price of fuel than a small family size with a high income level (Koushki, 1991).

Acutt and Dodgson (1995) derived a set of cross-elasticities of demand at the national level for travel in Great Britain. The elasticities between car travel and fares on six different public transport modes, and between public transport modes and the price of petrol were calculated and compared. Their study aims to forecast the effects of various policy options on the emission levels of greenhouse gases from all land transport modes in Great Britain.

Litman (2004) examined previous research on transit elasticities. Based on available evidence, Litman (2004) reported that the elasticity of transit ridership with respect to fares is usually between -0.2 to -0.5 in the short run (within a year). The transit elasticity then increases to the range of -0.6 to -0.9 over the long run (five to ten years) as consumers may have more options (e.g. choosing where to live or work, and new telecommunication technologies that can replace physical travel) (T. Litman, 2004). Similarly to the study of Litman (2004), Goodwin (1992) noted in his study that, from empirical observation, behavioural theory, and common sense, long-term elasticities are higher than short term ones.

2.4.2 Studies on Effects of Rising Fuel Prices

Other studies have also supported the effect of fuel price on fuel consumption and travel behaviour. VTPI (2007) presented data, which shows relationships between fuel prices rises and transport energy consumption per capita and annual vehicle travel for various countries such as Germany, France, the UK, the US, and New Zealand. According to the data, per capita transportation energy consumption seems to decline when fuel prices increase as motorists drive reduced annual miles (Todd Litman, 2009).

Glaister and Graham (2000) investigated international studies on price elasticity effects on petrol consumption and private travel demand. Taking differences in the magnitude of price elasticities into account, they found short run price elasticities ranged from -0.2 in the OECD to –0.5 in Germany. Long run price elasticities ranged from -0.24 in the US to -1.35 in the OECD. The price elasticities within the US itself ranged from -0.24 to -0.8, and from -0.75 to -1.35 within the OECD. From the reviews, they also concluded that variation in fuel price elasticities could be influenced by functional form, time span, estimation technique, geographical area of study, and inclusion of other factors (e.g. vehicle ownership). The overwhelming evidence from their survey suggests that long-run price elasticities tend to fall in the range of -0.6 to -0.8 Graham and Glaister (2002). Their reviews of fuel price elasticities are consistent with the surveying studies of Sterner (2006) in which he summarized fuel price elasticities as approximately -0.3 in the short term, and from -0.65 to -0.8 in the long term. However, Sterner and Lipow mentioned that the elasticity values from previous studies are a summary of past behaviour. The current demand elasticities may differ from these previous studies as the behavioural and structural factors over the past several decades have been changed (Lipow, 2007; Sterner, 2006).

Impacts of fuel price changes on petrol consumption for short runs and medium runs, traffic volume, vehicle kilometres travelled (VKT) by peak/off-peak, and public transport patronage in New Zealand have been studied by Kennedy and Wallis (2007). Their study aimed to improve the information on the responses of motorists to petrol price changes, and to add to the body of knowledge for a model forecasting and policy analysis. Their evaluation showed a short run elasticity of -0.15 and -0.20 for the medium run (after two years). This means that if the price of petrol increases 10%, petrol consumption will decrease by 1.5% within a year and decrease more by 2% after two years. Further, Kennedy and Wallis found a 2.7% fall in urban highway (less than 5.5 m in length) traffic volumes for cars at off-peak times within a year (short run elasticity = -0.27), and a 3.6% decrease after two years (medium run elasticity = -0.36). The urban traffic volume at peak times was found to have only a 0.9% reduction in the short term (short run elasticity = -0.09) and a 2.4% drop in the medium term (medium run elasticity = -0.24). Their study also included the rural traffic volume, which decreased by 1.6% within a year (short run elasticity = -0.16) and by 1.9% after two years (medium run elasticity = -0.19). For the most appropriate New Zealand elasticity values, they suggested -0.15 and -0.30 fuel consumption elasticities in the short run and in the long run respectively. The VKT elasticities were suggested to be -0.12 for the short run and -0.24 for the long run. As for the study, the New Zealand petrol consumption elasticities were investigated based on long-term 1974-2006 data, while the VKT elasticities evaluation was based on recent 2002-2006 data. The elasticity values presented in their report may not characterize current travel and petrol consumption behaviour as populations, structure of the transport system, behavioural and other factors have changed over time.

2.5 Reviews of Travel Behaviour Change during Fuel Supply Issues

The history of travel behaviour shows that people will adapt themselves according to their needs and the availability of resources. Travel adaptation occurs when a person's mobility freedom is restricted or threatened with elimination (Wakeley, 1980). Similarly to the studies on what happened during the 1970s' oil shocks, Polak *et al.* (2001) and Chatterjee *et al.* (2002) investigated the nature of behavioural responses during the 2000 fuel crisis in the UK. Their study was carried out soon after the end of the UK fuel crisis. From group discussions with the survey participants, the most frequently mentioned adaptations and coping strategies included:

(1) Using public transport for commuting journeys;

(2) Using public transport and other modes for local journeys;

(3) Conserving and rationing fuel use;

(4) Using (older) vehicles that could use diesel or leaded fuel;

(5) Transferring fuel between vehicles (siphoning fuel from one car, and transferring it to a smaller car);

(6) Cutting out non-obligatory journeys and using the car only for essential journeys;

(7) More car-sharing;

(8) Shopping locally;

(9) Re-planning travel to maximise the productivity of a trip;

(10) Changing work patterns (e.g. working from home, and use of video conferencing and computer imaging as a substitute for meetings);

(11) Travelling less.

However, these issues appeared to be short-term responses to the fuel crisis. There was little evidence that the fuel crisis had a longer-term impact on their behaviour as it occurred for a short period only (J. W. Polak, et al., 2001). The changes in travel behaviour in the long term such as changing residence location were not presented. Sagner (1974) hypothesized that it is impracticable to move the worker’s residence to be closer to the employment place or change jobs so that the work trip length is shortened, in the very short-term of the shortage. Therefore, the worker was assumed to have only four options in times of energy shortages, i.e. car pool, mode shifts, reducing non-work trips, and acquiring a more efficient automobile. The solution of carpooling and mode shifting to work however depends on the density of employment and urban form in a specific city (Sagner, 1974).

Many travellers have been seeking more efficient transport technologies as well as adjusting travel habits owing to the energy and environmental policies, and incentives. For example, better public transport services, permission to drive in high occupancy vehicle lanes with one person in the car, and tax-free purchase of cleaner vehicles (Ewing, 1998; Potoglou & Kanaroglou, 2007). The policies encourage people to take action by changing their lifestyle, for example, reducing unnecessary kilometres and needs to travel, in order to reduce their automobile dependency. BusVic (2005), Cao and Mokhtarian (2005), Vincent (2006), and Litman (2008) focused on inducing mode switching to reduce congestion or air pollution, and understanding the reasons people do not abandon their automobile. They described supply and demand side approaches such as improving public transport provision, improving integration of public transport services, reducing road capacity for private cars, applying parking levies, with the assessments to cope with the transport congestion.

Commuters modify their travel behaviour by travel mode shifting, destination change, and curtailing trips to mitigate the impacts of the threat. These travel behaviour changes depend on the "*essentiality*" of the trips, which is classified by the impact on people's wellbeing. "Essentiality" is a new term to measure the importance of the trip to a household's wellbeing as proposed by Dantas *et* *al.* (2006) who classified trips into three levels of essentiality; optional, necessary, and essential. Changing behaviour and losing accessibility were tied to different scales of costs and other negative effects. The impacts were divided into three levels:

- *Low impact* occurs if an optional trip is curtailed.
- *Medium impact* is generated if a necessary trip cannot be made.
- *High impact* happens if an essential trip cannot be made so that an impact on the individual's wellbeing may occur.

Currently, travel behaviour patterns have already shown a number of changes owing to recent increases in petrol prices such as driving more slowly, making fewer trips, and increasing public transport use (CBO, 2008; Koushki, 1991; Maley & Weinberger, 2009; PSRC, 2007; Rubin & Tal, 2008). Bailey (2007) reported that the US public transportation ridership has gone up by 25 percent during price increases since 1995. In the first quarter of 2006, the US public transportation use increased by 4 percent over 2005. The study found that current public transportation usage reduces the US gasoline consumption by 1.4 billion gallons each year (Bailey, 2007).

Schipper *et al.* (1993) demonstrated the relationship between fuel price and fuel intensity (litre/100km) developed in the US, Japan and certain European countries. The fuel use or intensity was compared to fuel prices in the years 1973 and 1988. They concluded that fleet fuel intensity is a function of the inverse of the fuel price. Nevertheless, the Department for Transport UK forecasts that the increasing income in Great Britain between 1996 and 2010 will make people richer and they will not really care much about the cost of travel, as the prediction showed car ownership and car use have increased along with income. The increase in car ownership results in increasing traffic growth as reported in Goodwin (2002) , DFT (2005), DFT (2006a), and DFT (2006b). In a fuel economy survey, Turrentine and Kurani (2007) have confirmed that people are not concerned with fuel price. According to their survey, no US household was found to analyse the fuel costs in a systematic way in their automobile or gasoline purchases. The largest number of 57 interviewed households either said they had no idea of their gasoline expenditures over any period of time or knew only what they spent per tank of gasoline.

CHAPTER 3

METHODS FOR TRAVEL AND BEHAVIOUR STUDIES

3.1 Introduction

This chapter provides background on type of travel demand data that are used in conventional transportation systems planning. It also illustrates advantages and disadvantages of different survey methods. The literatures reviewed in this chapter shows conventional and specialist methods that have been implemented to investigate travel and behaviour. Conventional travel surveys do not include an adaptive capacity measurement, as the objective is to capture current travel behaviour only. The reviews on applications of virtual reality have directed that people will have a clear perception about the topic and response to the given questions when they are immersed into the situation.

3.2 Transportation Systems Planning and Travel Demand Data

Transportation systems planning is a process that aims to design, evaluate, create, modify, and upgrade infrastructure and services to meet societal needs for accessibility and mobility in an efficient, safe and reliable manner (Goulias, 2003). The conventional transportation planning deals with traffic congestion, parking difficulties, air and noise pollutions, and public transport inadequacy (Ortúzar & Willumsen, 2001). It has focused on expanding road networks and getting people to take public transport or other non-private vehicle transport in order to reduce congestion and air pollution (O' Flaherty, 1997). The transportation systems planning does not yet include the future permanent oil depletion as a problem (Ortúzar & Willumsen, 2001).

Evidence from the past shows adverse impacts of fuel constraints (Lyons & Chatterjee, 2002; Transportation Research Board, 1980). The future oil depletion will limit the accessibility of individuals to activities and services. This will cause commuters to change their travel pattern; therefore, the data of how people would travel in times of high fuel prices is needed for transportation systems planning.

The normal travel demand data focuses on travel mode, route, the number of generated trips, trip frequency, and the travel distance (P. R. Stopher & Meyburg, 1977). The travel demand data conducted from household travel surveys can be categorised into four types: household, personal, vehicle, and activity (P. R. Stopher, Wilmot, Stecher, & Alsmih, 2006). Table 3.1 shows the data types that are generally obtained from the house travel survey.

Table 3.1: Types of data in a household travel survey (adapted from Stopher *et al.* (2006)).

Category	**Data type**	**Description**
Household	Location Type of Building Household size Relationships Number of vehicles Housing tenure	Home address or home position in geographic terms Detached, semi-detached, terraced, flat, etc. Number of household members Relation between all members in the household Summary of number of vehicles from vehicle data Own or rent status
Personal	Gender Year of birth Paid jobs Job classification Driving licence Non-mobility Education level Disability Race	- (Preferable to requesting age) Number of paid positions and hours worked at each in the past week Employee, self-employed, student, unemployed, retired, unemployed, etc. Whether of not a current driver's licence is held Indication of why no out-of-home activity was performed on a survey day including work-at-home days Highest level of education achieved Types of mobility disability, both temporary and permanent -
Vehicle	Body type Year of production Ownership of vehicle Use of vehicle	E.g., car, van, RV, SUV, etc. - Household/person, lease, institution Main user of vehicle
Activity	Start time Activity or purpose Location Means of travel Group size Group membership Costs Parking	- - Where the activity was performed If activity is travel, what mode(s) was used (including specifying if a car passenger or driver) Number of persons travelling with respondent as a group Number of persons in the group who live in respondent's household Total amount spent on tolls, fares and respondent's share Amount spent to park

The normal travel demand data can be collected by surveying a large number of people, but this can be very time consuming and costly (P. R. Stopher & Meyburg, 1977). Historical data sets are mostly used for travel demand modelling for transportation systems planning where possible. However, the travel demand will change over time owing to changing lifestyles, demographics (e.g. age and gender structure change, population), economics (e.g. employment, income), technologies and so on (Goulias, 2003). The existing data must be evaluated to determine if it is still valid, or if it needs to be wholly or selectively updated.

There are a number of survey methods such as paper surveys, telephone surveys, and face-to-face interviews that have been used to collect normal travel demand data. The travel survey methods and examples of travel surveys will be described in the following section.

3.3 Travel Survey Methods

3.3.1 Survey Methods

A paper-and-pencil approach has been used for many years as a traditional survey method (Fowler, 2009). In particular survey, telephone interviewing has a limit in conveying the information as all information has to be conveyed orally and clearly if material is not given to the respondent prior to the interview. The pen and paper method has less restriction on this case as the interviewer can add an explanation to the nature of the option or present material such as pictures to help respondent perceiving the option's attributes (P. M. Jones & Bradley, 2006).

Some specialist surveys are conducted on computer using virtual reality (VR) because it can present pictorial forms and sounds to convey the nature of each option (Tan, de Vries, & Timmermans, 2006). The computer also facilitates data collection as the information technology has been developed. A great advantage of computer-assisted data collection is that it can automatically read and rearrange the data in a desired form. Additionally, the computer helps in data analysis (Fowler, 2009).

The conventional methods of survey can be divided into two types (Fink, 2006):

- A self-administered survey where respondents complete a survey without the surveyor i.e. mail back, on-site survey; and online survey.
- Interview i.e. an interview by the telephone or face-to-face.

Each survey technique has different pros and cons. Fink (2006) stated that there is no single survey with better reliability and validity than another. The survey method must be selected based on the researcher's specific purpose. A proper and reliable survey yields consistent and accurate information (Fink, 2006). For example, if a researcher is concerned about the participants who cannot read or write well, an interview method is a good approach to receive a better quality of data than the paper and pencil one (Fink, 2006). Table 3.2 and Table 3.3 present three types of self-administered approach with characteristics, advantages and disadvantages, and requirements. Table 3.4 shows the characteristics, advantages and disadvantages, and requirements of telephone, face-to-face and virtual reality (VR) interviews.

Table 3.2: Comparing self-administered survey types (adapted from Fink (2006) and Fowler (2009)).

	Self-administered		
	Mailed	**On-site**	**Online**
Characteristics	Paper and pencil	Paper and pencil	Internet based
Advantage	1. The mail can be distributed to large areas 2. People are familiar with paper-and -pencil surveys 3. The respondents can take the survey and complete it anywhere 4. Visual aids for the difficult questions are possible 5. Collection of sensitive data is more valid as the respondent does not have to share answers with the interviewer 6. Provide time for thoughtful answers, checking records, or consulting with others	1. Can obtain information immediately 2. Respondents can ask questions about the survey if they do not understand it 3. In some cases, survey can be done with groups of people	1. Can be accessed globally 2. Order of questions can be pre-programmed 3. Can filter the answers 4. Can provide respondents with the links that explain unfamiliar words and help with difficult questions 5. Data are automatically entered and can be automatically analysed 6. The unit cost of data collection is low 7. Potential for high speed of answer returns 8. Provides time for thoughtful answers, checking records, or consulting with others

Table 3.3: Comparing self-administered survey types (continued) (adapted from Fink (2006) and Fowler (2009)).

	Self-administered		
	Mailed	**On-site**	**Online**
Disadvantages	1. Participants need a motivation to complete and return survey 2. Respondents must be able to read, see, and write 3. Must be very careful in designing questionnaire 4. Open questions usually are not useful 5. It is difficult to ensure integrity of survey response	1. Limited to responses from just those who are on site 2. Respondents must be able to read, see, and write	1. Need reliable access to Internet 2. Respondent must be familiar with computer and able to use browser 3. Browser must support survey graphics 4. System can go down or be unreliable 5. Samples are limited to Internet users
Special needs	1. Up-to-date address list 2. Follow-up mailings 3. Incentives	1. Space and privacy for respondent to complete the survey	1. Technical expertise 2. Convincing method of ensuring privacy and confidentiality
Costs	1. Printing, paper, envelopes, stamps, incentives	1. Printing, paper, incentives, survey supervisor, and possibly space for respondent to work on survey	1. Mainly technical (e.g. someone who is experienced in designing online surveys)

Table 3.4: Comparing interview types (adapted from Fink (2006), Fowler (2009) and Tan et al. (2006)).

	Interviews		
	Telephone	**Face-to-face**	**VR**
Characteristics	Can be done with written script or computer assisted	Same as telephone	Computer assisted
Advantage	1. Telephone provides better access to certain populations, especially compared to face-to-face interviews 2. Interviewer can explore answers with respondents 3. The interviewer can assist respondents with unfamiliar words	1. Interviewer can explore answers with respondents 2. The interviewer can assist respondents with unfamiliar words	1. Interviewer can explore answers with respondents 2. Information can be deliver with less description 3. Facilitate complex tasks in data gathering 4. Help simulate situation that participants have never had experience 5. Help improving perception or recalling memory
Disadvantages	1. Interviewer needs to be well-trained 2. Needs to make sure respondents have enough time for interview 3. Technical expertise is required if using computer-assisted interviews 4. Difficult to access those who do not have telephone or use call filter	1. Interviewer needs to be well-trained 2. Must find a suitable place to conduct the interview	1. Interviewee needs to be familiar with computer 2. Must find a suitable place to conduct the interview 3. Technical expertise is required 4. High costs for VR development 5. Long-time consumed in the survey
Special needs	1. Up-to-date phone numbers 2. Schedule for reaching respondents 3. May need a sampling expert for random digit dialling 4. Incentives	1. If on-site, space and privacy is required 2. May be difficult or dangerous to go to person's home	1. Computer with high specifications is needed
Costs	1. Training, incentives, telephones and telephone charges, computers and technical expertise, sampling expert, incentives	1. Training, space, travel, incentives	1. Training, space, travel, incentives 2. computers and technical expertise 3. VR development costs

Telephone recruitment with random-digit dialling (RDD) has been a conventional method used in Household Travel Surveys for some time. In the United States (US), the method was followed by a mail-out, mail-back survey. However, the mail-back often did not achieve good response rate, so a telephone retrieval of the diary data using Computer-Assisted Telephone Interviews (CATI) was introduced to replace it and has been used until now (Stopher 2009). As suggested by Stopher and Metcalf (1996), the method of using the telephone for surveying is becoming more problematic because of the increase in resistance to the use of the telephone in both recruitment and retrieval data. Owing to the potential biases of not including households that do not have a telephone or use telephone answering machine, face-to-face interviews seem to be a good way to reduce this bias. Stopher and Metcalf (1996) therefore supported a new technology using Computer-Aided Personal Interviews (CAPI) to facilitate a face-to-face survey method in which the respondents enter data directly into a notebook computer, or use touch screens for data entry. The operational cost of the survey for this method can be minimized by using the notebook as the interviewers could even provide their own notebook with wireless attached.

Combining the advantages of graphically rich Computer-Assisted Self Interviewing (CASI), internet administration, and respondent interactive geocoding, Resource Systems Group (1999) introduced a prototype of a computer-based intelligent travel survey system that allows respondents to interact with a geocoding module. Additionally, the software combines a graphical user interface, photographic images, and other related multimedia with the internet travel diary in order to increase accessibility and response rate, and hold respondent interest.

In addition to the conventional survey method, a mobility technology and computerized techniques such as Global Positioning Systems (GPS) devices, computer-based surveys and internet surveys have been increasingly applied as survey tools because of evolving requirements of transportation modelling. The GPS technology has been introduced for travel surveys to improve accuracy of trip reporting and increase the depth of spatial and temporal details (Bricka & Chandra, 2006; P. Stopher, FitzGerald, & Xu, 2007a). This enables efficient investigation and recording of complex travel activities, locations and decision-making. GPS has been used for travel surveys in many countries such as France, the US, the UK, Japan, Canada, and Australia to record travel of individuals (Bricka, 2008). A GPS device has a promising aptitude for complex data collection than the diary survey. It also allows the researchers to collect data over many days (Greaves, Fifer, Ellison, & Germanos, 2009; P. R. Stopher & Greaves, 2007b). The first fully GPS-based household travel survey was conducted in Cincinnati, Ohio (Giaimo, Anderson, & Stopher, 2010).

In travel survey by governments, various methods have been used such as telephone recruitment, mail-out and mail-back survey, a face-to-face interview and the Global Positioning System (GPS). In US, the standard method used in household travel survey is telephone recruitment followed by mail-out of the survey with telephone retrieval of the diary data. Only a few regions have continued to use the telephone recruitment with mail-out and mail-back survey (P. R. Stopher, 2009). One of the methods used for household travel surveys in Australia is face-to-face recruitment interviewing followed by leaving and picking up the paper-based survey in person by the interviewer (P. R. Stopher, 2009). New Zealand travel surveys use a method of face-to-recruitment interviewing, which is similar to Australia, but on the household will receive memory jogger to record their travel and the interviewer will return for an interview as described in the next section.

3.3.2 Examples of Travel Survey in UK and NZ

Travel surveys have been conducted through face-to-face contact followed by travel diary and/or conventional questionnaires. For example, the Department of Transport UK (DFT, 2008) conducted the National Travel Survey with a random sample of 15,048 private households, drawn from the Postcode Address File. The interviewer sent out advance letters outlining the purpose of the survey, and mentioning that the interviewer will contact the sampled addressees. Interviewers then followed up the letter by making face-to-face contact with the household and arranging an interview with all household members. The information about the household, individual members, household vehicles, and long distance journeys that the household recently made were gathered. At the end of the interview, all household members received a week’s travel diary for recording their 7-day travel activities. After the Travel Week was completed, the interviewer returned to collect the diary and conducted a pick up interview in order to check whether any key factors (such as new car purchase) had changed.

Similarly, the current New Zealand (NZ) Household Travel Survey (2008/09) with over 4,000 households is conducted for the Ministry of Transport by Opus International Consultants (MOT, 2009b). The travel survey aims to improve the understanding of where and how New Zealand people travel. The survey was started by sending an introductory letter to the households in randomly selected meshblocks. Before the travel days, a well-trained interviewer visits each household to explain the survey and the chosen participating households are invited to complete a memory jogger (MOT, 2009c) by recording their travel over a two-day period. Every single trip, including, for instance, a walk across the road to buy a newspaper, is required to be recorded in the memory jogger. The interviewer returns after the travel days to conduct a personal interview with household members for their travel details, and other personal data. Figure 3.1 shows a memory jogger used for the household travel survey.

First travel day:

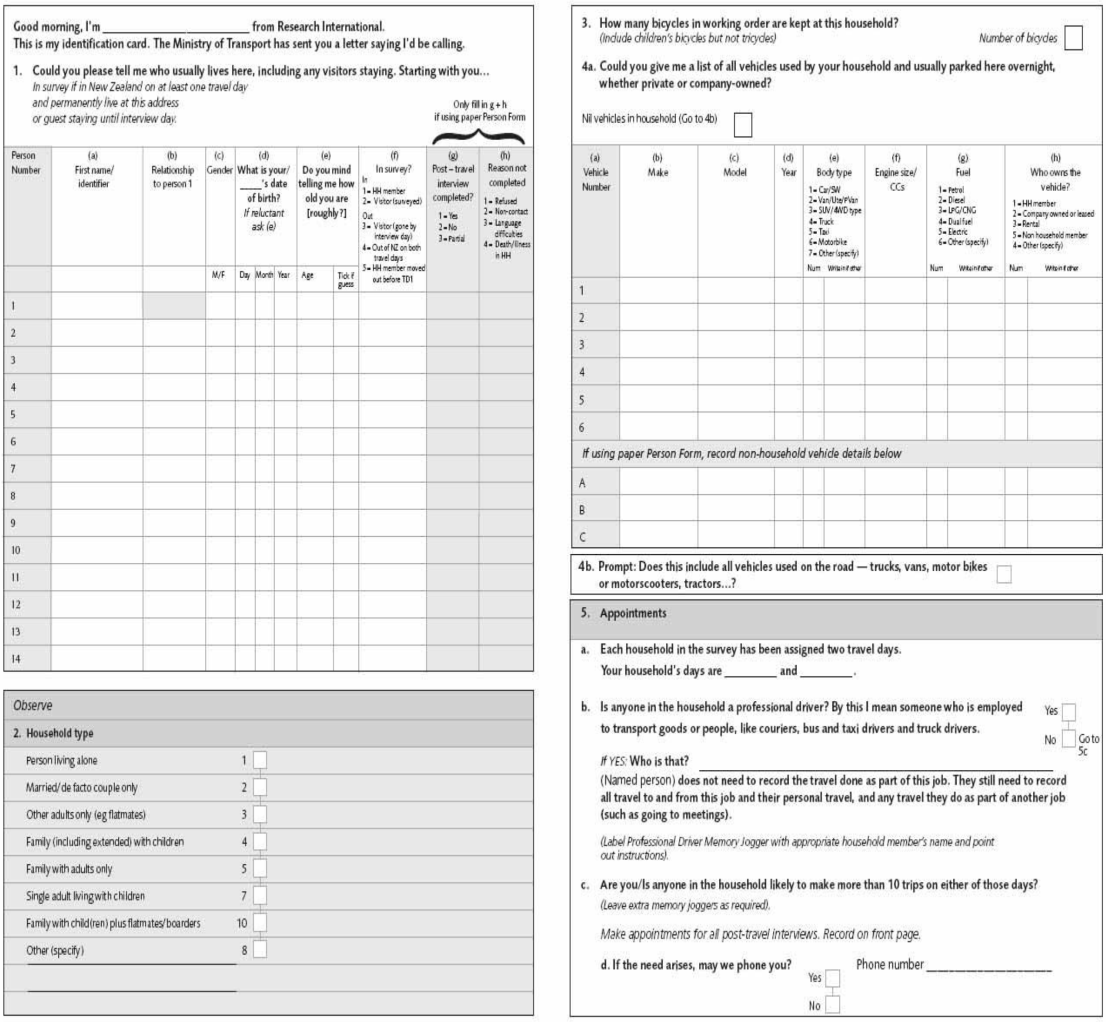
Where	When	
I began the day at…		I left at…
I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…

Second travel day:

Where	When	
I began the day at…		I left at…
I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…
Then I went to…	I arrived at…	I left at…

Figure 3.1: A Travel Survey Memory Jogger used to help the household members memorise their two-day travel activities. (Source: www.transport.govt.nz).

In the personal interview, two questionnaires: a household questionnaire and a personal interview questionnaire are used for data gathering. The household questionnaire collects the data about household information (e.g. gender and age of each household member, household type) and vehicle used (e.g. make, model, year, engine size) in the household (MOT, 2009d). Figure 3.2 illustrates the second page of the household survey form, where the information on household members and vehicles used in the household are collected. The personal survey form contains the questions about employment/school information, travel activities information (e.g. origin and destination addresses, travel purposes, transport modes), and other information (e.g. alcohol consumption, cycling behaviour, public transport use) (MOT, 2009e). Figure 3.3 shows a travel demand survey page in the personal survey form.



Good morning, I'm ______________________ from Research International.
This is my identification card. The Ministry of Transport has sent you a letter saying I'd be calling.

1. Could you please tell me who usually lives here, including any visitors staying. Starting with you...
In survey if in New Zealand on at least one travel day and permanently live at this address or guest staying until interview day.

Only fill in g + h if using paper Person Form

Person Number	(a) First name/ identifier	(b) Relationship to person 1	(c) Gender	(d) What is your/ ____'s date of birth? *If reluctant ask (e)*			(e) Do you mind telling me how old you are [roughly?]		(f) In survey? In 1= HH member 2= Visitor (surveyed) Out 3= Visitor (gone by interview day) 4= Out of NZ on both travel days 5= HH member moved out before TD1	(g) Post – travel interview completed? 1 = Yes 2 = No 3 = Partial	(h) Reason not completed 1 = Refused 2 = Non-contact 3 = Language difficulties 4 = Death/Illness in HH
			M/F	Day	Month	Year	Age	Tick if guess			
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											

Observe

2. Household type

Person living alone	1	☐
Married/ de facto couple only	2	☐
Other adults only (eg flatmates)	3	☐
Family (including extended) with children	4	☐
Family with adults only	5	☐
Single adult living with children	7	☐
Family with child(ren) plus flatmates/boarders	10	☐
Other (specify)	8	☐

3. How many bicycles in working order are kept at this household?
(Include children's bicycles but not tricycles) *Number of bicycles* ☐

4a. Could you give me a list of all vehicles used by your household and usually parked here overnight, whether private or company-owned?

Nil vehicles in household (Go to 4b) ☐

(a) Vehicle Number	(b) Make	(c) Model	(d) Year	(e) Body type 1= Car/SW 2= Van/Ute/PVan 3= SUV/4WD type 4= Truck 5= Taxi 6= Motorbike 7= Other (specify)		(f) Engine size/ CCs	(g) Fuel 1= Petrol 2= Diesel 3= LPG/CNG 4= Dual fuel 5= Electric 6= Other (specify)		(h) Who owns the vehicle? 1 = HH member 2 = Company owned or leased 3 = Rental 5 = Non household member 4 = Other (specify)	
				Num	Write in if other		Num	Write in if other	Num	Write in if other
1										
2										
3										
4										
5										
6										
If using paper Person Form, record non-household vehicle details below										
A										
B										
C										

4b. Prompt: Does this include all vehicles used on the road — trucks, vans, motor bikes or motorscooters, tractors...? ☐

5. Appointments

a. Each household in the survey has been assigned two travel days.
Your household's days are ________ and ________.

b. Is anyone in the household a professional driver? By this I mean someone who is employed to transport goods or people, like couriers, bus and taxi drivers and truck drivers. Yes ☐ No ☐ Go to 5c

If YES: Who is that? ______________________
(Named person) does not need to record the travel done as part of this job. They still need to record all travel to and from this job and their personal travel, and any travel they do as part of another job (such as going to meetings).

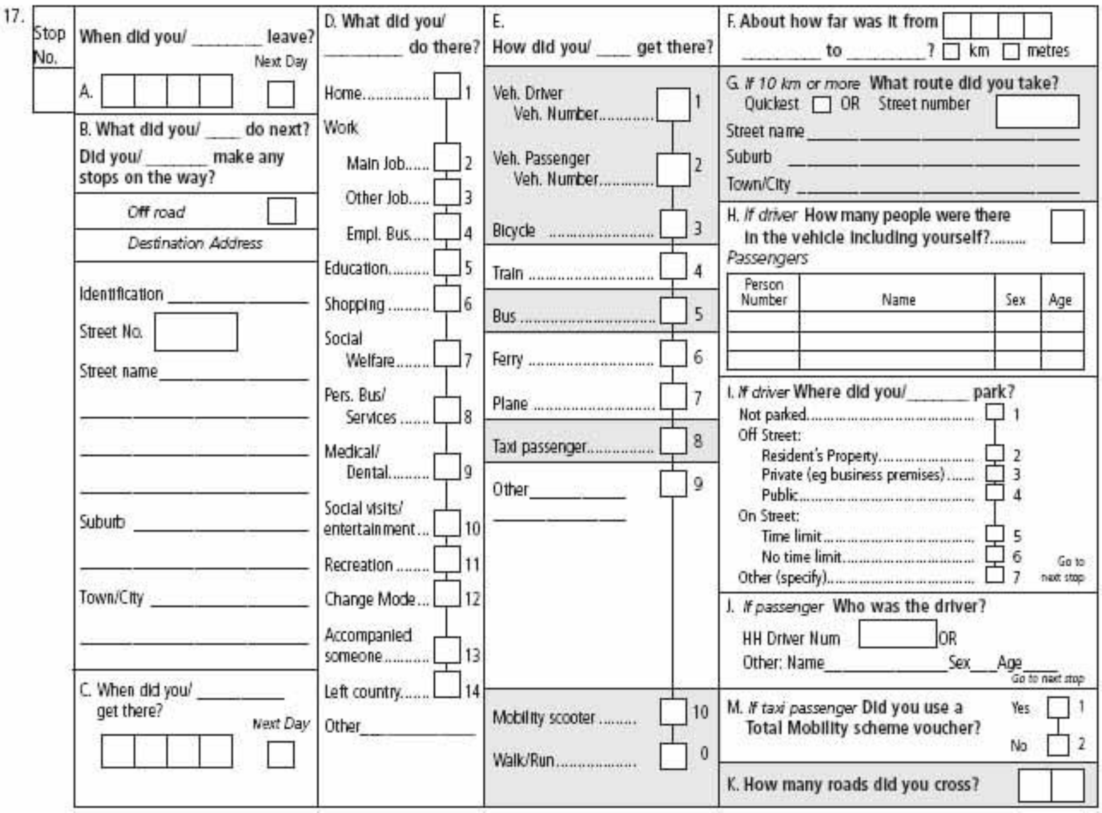
(Label Professional Driver Memory Jogger with appropriate household member's name and point out instructions).

c. Are you/Is anyone in the household likely to make more than 10 trips on either of those days?
(Leave extra memory joggers as required).

Make appointments for all post-travel interviews. Record on front page.

d. If the need arises, may we phone you? Yes ☐ No ☐ Phone number ______________

Figure 3.2: The second page of the household survey form used to collect the information on household members and vehicles used in the household. (Source: www.transport.govt.nz).


17.

Stop No.

When did you/ ________ leave?
Next Day
A.

B. What did you/ ____ do next?
Did you/ _______ make any stops on the way?
Off road
Destination Address
Identification ______________
Street No.
Street name______________
Suburb ______________
Town/City ______________

C. When did you/ __________ get there?
Next Day

D. What did you/ _________ do there?
Home............... 1
Work
Main Job...... 2
Other Job..... 3
Empl. Bus..... 4
Education.......... 5
Shopping 6
Social Welfare....... 7
Pers. Bus/ Services 8
Medical/ Dental......... 9
Social visits/ entertainment... 10
Recreation 11
Change Mode... 12
Accompanied someone.......... 13
Left country....... 14
Other____________

E. How did you/ ____ get there?
Veh. Driver
Veh. Number............ 1
Veh. Passenger
Veh. Number............ 2
Bicycle 3
Train 4
Bus 5
Ferry 6
Plane 7
Taxi passenger............... 8
Other__________ 9
Mobility scooter 10
Walk/Run.................. 0

F. About how far was it from
_________ to _________? ☐ km ☐ metres

G. If 10 km or more What route did you take?
Quickest ☐ OR Street number
Street name______________
Suburb ______________
Town/City ______________

H. If driver How many people were there in the vehicle including yourself?.........
Passengers

Person Number	Name	Sex	Age

I. If driver Where did you/_______ park?
Not parked.. 1
Off Street:
Resident's Property........................ 2
Private (eg business premises)....... 3
Public.. 4
On Street:
Time limit.. 5
No time limit.................................. 6
Other (specify)................................ 7
Go to next stop

J. If passenger Who was the driver?
HH Driver Num OR
Other: Name____________Sex___Age____
Go to next stop

M. If taxi passenger Did you use a Total Mobility scheme voucher?
Yes 1
No 2

K. How many roads did you cross?

Figure 3.3: Travel demand survey page in the Personal Survey Form conducted for the Ministry of Transport New Zealand: 28 pages long and takes hours to complete. (Source: www.transport.govt.nz).

The travel distances of each trip leg are estimated from the provided origin and destination addresses based on the shortest route. In the case of a street number not being valid, the closest valid address is used for approximation. Two earlier surveys were carried out in 1989/90 and 1997/98. The latest results from the NZ travel survey have been published and used for further analysis, for example, travel behaviour trends, travel mode share, travel distances, and trip purposes (MOT, 2009f).

3.4 Reviews of Methods for Investigation of Responses to Hypothetical Choices and Situations

Stated Preference (SP) is a well-known technique to probe people's attitudes and preferences on hypothetical alternatives. It is used to evaluate products, services or situations that are qualitatively different from those commonly experience (Bradley, 1988). Stated Choice (SC) experiment is a type of SP technique used in transportation studies. Puckett et al. (2007) developed a stated choice experiment for interdependent urban freight stakeholders. Their research focused on the effect of the implementation of a variable user charging system on levels of service and costs of transporting freight. A computer-assisted personal survey instrument containing the written context describing situations and choices was used in their study to capture the preferences of freight stakeholders on the range of levels of services and costs that may occur under a hypothetical distance-based road user charging system.

Earth and Axhausen (2009) analyzed how residence location choice is influenced by substantial changes in transport costs in Switzerland. The SC experiment of residence location was designed to evaluate the respondents' tendency to move to more central locations due to travel cost increases. Their results showed that people react on housing costs while car and public transport costs were less negatively perceived. The perception of these costs is income dependent, i.e. the higher the household's income, the lower the perception of costs. The unwillingness to leave the current residence location was substantial.

Kitamura et al. (1991) used an SP mail survey of vehicle and fuel type choice. They began by sending out postcard questionnaires to elicit initial information of household size, home ownership status, number of drivers, number of vehicles owned or leased, and three characteristics of the respondent's anticipated next vehicle purchase: new/used, vehicle type, vehicle price range, and fuel economy range. This information was used to design subsequent choice questions about three hypothetical vehicles. They were asked which one of the three hypothetical vehicles they prefer and whether or not they would replace their existing vehicle if their first choice were available. In the fuel-choice SP task, the respondents were asked which fuel (i.e. gasoline and alternative) they would most likely choose on a regular basis in four hypothetical situations. The preliminary results could prove valuable in forecasting demand for clean fuels and clean-fuel vehicles.

Transportation research to capture attitudes and preferences require careful instrument, user interface and experimental design (Timmermans & Hato, 2009). Collins et al. (2007) used an innovative SP design to study air travel choice behaviour. The instrument imitated decision-making process of the air traveller on an online booking engine. The booking screen displayed number of ticket options with attributes for a given day. The attributes included ticket cost, travel time to the airport, flight time, departure and or arrival time, number of connections, and on-time performance of the carrier.

Klabbers and Timmermans (1999) designed a multimedia interview engine: ESCAPE (Engine for Stated Choice and Preference Experiments) for measuring tourism consumer behaviour. A visual presentation format, i.e. combination of textual, pictorial, auditory forms, was used in their stated choice and preference experiment. The experiment was constructed to vary characteristics of the tourism product systematically. The implementation of this new interactive technique helped to improve the quality of collected data.

Stated Adaptation (SA) is another technique that can be use in encouraging the respondent to react to hypothetical situations (Bonsall, 2009). The hypothetical situation can be presented in written, verbal or pictorial forms that encourage the respondents to consider and reflect on the potential future patterns of behaviour. Gaming and simulation have been developed for the SA studies for decades to assist respondent’s imagination. The best-known example of a game for stated-adaptation study is HATS (Household Activity Travel Simulator) proposed by Jones (1979). The HATS technique involves in-depth group interviews to elicit behaviour under constraints and commitments. The technique uses a display board game that consists of a map and three schedule slots showing one person’s daily activity pattern as shown in Figure 3.4. The board game allowed respondents to simulate reactions to a wide range of applications, particularly policy testing, by building and manipulating a representation of their daily behaviour according to a given constraint.

An example of extended application of HATS was conducted by Phifer et al. (1980) to study family reactions to energy constraints using REACT. The REACT (Response to Energy and Activity Constraints on Travel) was applied to study 12 households in Albany, New York, concerning reaction to the 1979 gasoline shortage. The constraint policies, i.e. 20 percent reduction in vehicle miles of travel (VMT) and no-drive day, were conducted to investigate how the household dealt with these constraints. The objective of the REACT study was to examine the possible impacts of the proposed policies on households before implementing it. The result of REACT study revealed that households with two cars would circumvent a no-drive day policy by shifting travel to the other available car.

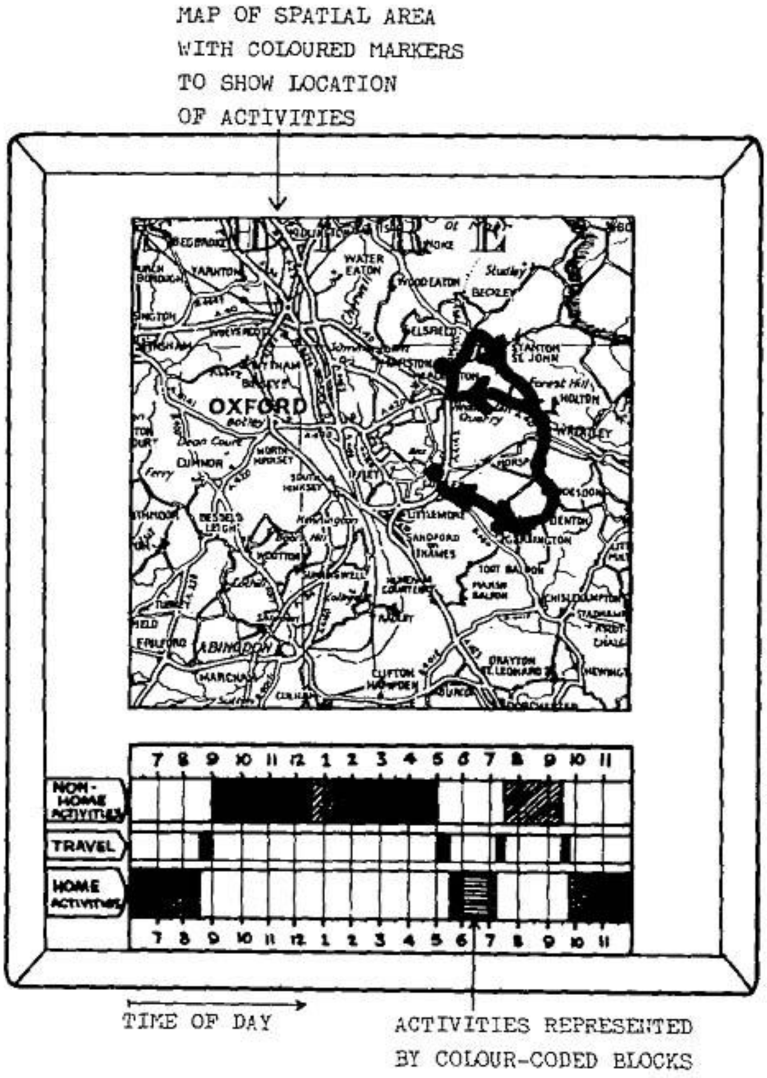


Figure 3.4: HATS display board (P. Jones, 1980)**.**

(Source: Jones, P. Experience with Household Activity-Travel Simulator (HATS). In *Transportation Research Record 765*, Figure 2, p. 7. Copyright, National Academy of Sciences, Washington, D.C., 1980. Reproduced with permission of the Transportation Research Board.)

In 1989, Jones et al. proposed ATAQ (Adelaide Travel and Activity Questioner) as a fully computerised technique designed to identify household responses to travel demand management policies, focusing on the impacts on all household members. It incorporates an attitudinal section to the questionnaire and a representation of activity/travel patterns of other household members. The ATAQ combined the SA stage and SP technique in the package. The study assesses reactions of peak period drivers travelling to work in Central Adelaide to pricing policies designed to reduce congestion. The policies aimed to either encourage a re-timing of car trip or switching to an alternative mode such as bus, rail and car sharing. The ATAQ approach was used to survey the alternative work journey in terms of mode change and the patterns associated with the earlier and later journey to work. The respondents then were asked to rank the options in order of their preference on time and costs. Finally, Jones et al. (1989) concluded that the results from ATAQ survey were useful for activity-based modelling.

Turrentine and Kurani (1998) used interactive SA and SP methods and reflexive technique to explore the household's response to the introduction of electric vehicles in order to measure its market in California. The interactive SA and SP methods were used with the designed gaming simulations to observe household responses to home recharging and limited range of electrical vehicles (Kurani, Turrentine, & Sperling, 1994). The reflexive technique was a method that encourages individuals to respond to information about themselves. In Turrentine and Kurani's interactive gaming interview, they used activity timelines to draw participants' attention to their driving patterns and help the participants to understand how electrical vehicles might suit or not suit their travel pattern and lifestyle goals in the future. Little evidence was found in their study that most consumers are willing to pay significantly more for battery electric vehicles (BEVs).

Doherty and Miller (2000) introduced an advanced software program called Computerized Household Activity Scheduling Elicitor (CHASE) for travel surveys. The CHASE program was installed on laptop computers to capture household activity scheduling for a week-long period during which all adult household members log in daily to record their scheduling decisions as they occur. Later, Lee *et al.* (1999) developed an Internet Computerized Household Activity Scheduling Elicitor (iCHASE) which aims to reduce data collection costs, and improve data quality and quantity as iCHASE allows a continuous data collection through the internet. Doherty *et al.* (2002) used CHASE to explore household rescheduling and the range of adaptations to vehicle reduction scenarios: fuel price increase and long-term change from two-vehicle to one vehicle use. In total 10 households were interviewed and engaged in an open discussion of the strategies they could use to reduce their automobile travel in response to verbally induced situations of fuel price increase and one vehicle removal. The household members were requested to do the following:

"*Please look at your schedule for the whole week and tell us what is the easiest way you could have done something to reduce your use of your cars in light of the increased fuel costs*."
(for fuel price increase study)

"*If you had one of your vehicles stolen (you can choose which one), and for reasons of your own, decided not to replace it, what is the first thing that you would most likely change looking back upon your week*?"
(for vehicle removal study)

The household members then reschedule their current activity-travel pattern on CHASE. The decisions to add, modify and delete rescheduling were recorded for analysis.

Extending from the structure of CHASE, Lee and McNally (2001) designed a web-based travel/activity survey, REACT!, as a computer aided, self-administered interview (CASI). REACT! was used to obtain and evaluate information on household travel and activity pattern as well as to examine the process of planning, scheduling, and executing activities and travel over a typical week. REACT! contains a series of screen interfaces for recording information of household and vehicle, activities and travel. The initial interviews are completed on the day before the diary period begins to gather information of activities and travel planned for the survey period. Every 24 hours the plan is updated to record the actual travel.

Lee-Gosselin (1989) devised “Car Use Pattern Interview Game” or CUPIG to study potential for change in car use due to a fuel shortage. The CUPIG procedure included recording a trip diary for each vehicle in the household for one week, drawing time-trace chart that displays seven days of vehicle use, and a 12 columns x3 rows matrix board that represents activity categories with the total fuel used by each vehicle and savings achieved in the game. In the in-depth interview of CUPIG, the household member engaged in a fuel budget reallocation game using the vehicle use time-trace chart and the game accounting board. The household members played four rounds of the game that simulated worsening fuel supply conditions. The household discussed and agreed on strategies to save fuel.

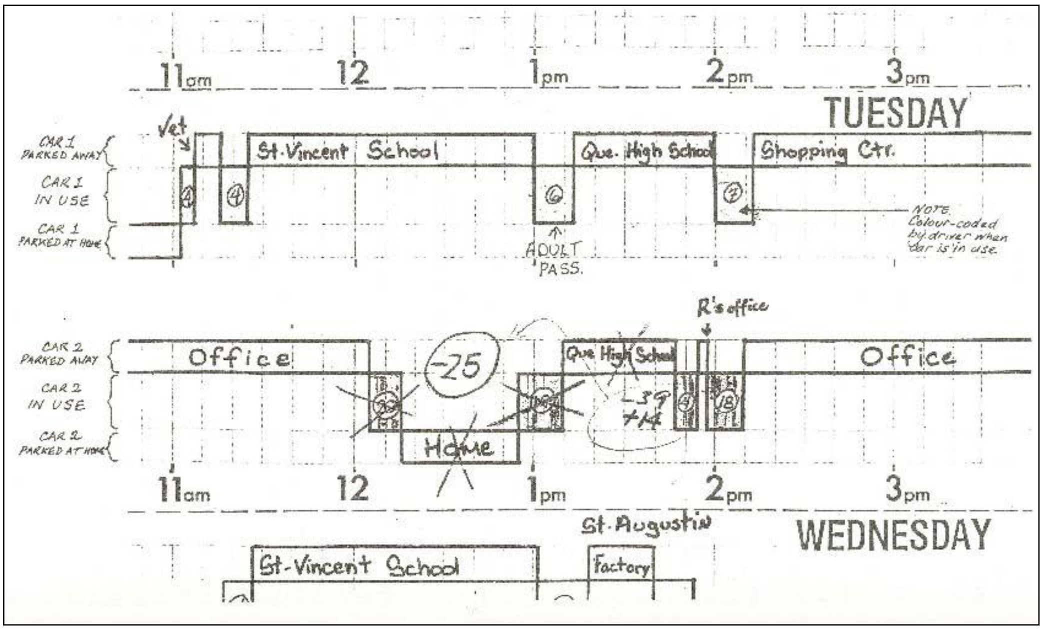


Figure 3.5: Part of vehicle use time-trace chart (Lee-Gosselin, 1989).

(Source: Lee-Gosseling, M. In-depth research on lifestyle and household car use under future conditions in Canada. In *The Fifth International Conference on Travel Behaviour (1987: Aix-en-Provence, France)*, Figure 2, p. 106. Reproduced with permission of Ashgate, Gower & Lund Humphries Publishing.)

3.5 Reviews of Specialist Computerised Travel Activity Survey Methods

Computer-assisted diary instruments have been developed to facilitate data collection of travel behaviour. MAGIC was the first of computer-assisted diary written in MS-DOS proposed by Ettema, Borgers and Timmermans (1994). It was built to log respondents' activities scheduling and rescheduling processes. The MAGIC was text-based graphic and limited in size and differentiation of fonts, colour schemes and other visualization. Janssens *et al.* (2004) developed a computer-assisted software tool called VIRGIL for collecting activity data using activity diary. The software collected the data of personal and household characteristics (e.g. year of birth, gender, household size, household income and possession of a driver's license) and activity and travel-related information (i.e. which activities were conducted where, when, for how long, with whom and the transport mode involved). The VIRGIL opened with a login-screen that the respondents with an existing username could enter the system. This system ensured that the survey will be filled out once for each respondent in the household. In term of data collection, in-home and out-home activities with the travel-related information were collected through the diary grid interface and geo-coded map. From the empirical results of putting VIRGIL into practice, the tool showed positive potential in data collection. However, the VIRGIL was only used in internal small-scale projects (Timmermans & Hato, 2009).

Bellemans *et al.* (2008) built PARROTS (Personal Digital Assistant (PDA) system for Activity Registration and Recording of Travel Scheduling) to improve in data quality. The PARROTS was a tool to collect data of activities and travels developed on a PDA with an integrated GPS logger. The activity and travel diaries on the PDA require input by respondents, and a GPS receiver automatically logged the location information. Bellemans *et al.* incorporated previous experiences with computer-assisted data collection tools (i.e. MAGIC and VIRGIL) and knowledge-based semiautomated correction software, such as SYLVIA (System for Logical Verification and Inference of Activity) (Arentze, Hofman, Kalfs, & Timmermans, 1999) in the PARROTS design. The results for using PARROTS showed that the response rate was slightly lower than for traditional paper- and-pencil survey during the recruitment process. However, the reported number of executed trips was more stable, and more trips per person on average were reported for PARROTS survey. The limitations of the PDA were only in terms of memory, speed, and battery life (Timmermans & Hato, 2009).

Similarly, Rindsfüser et al. (2003) developed EX-ACT, a computerized hand-held survey instrument. The EX-ACT was built upon the CHASE's scheduling and rescheduling concept (Sean T. Doherty & Eric J. Miller, 2000) to trace the activity scheduling decision processes. It executed on the PDA so that the flexibility of the users and a situational data entry were improved. The user recorded their scheduling decisions by adding, modifying and deleting activities to the on-screen schedules as they occurred. The program automatically tracked the sequence of decisions made, and prompted the user for additional information on certain decisions, such as the reasons for the modification, or the exact timing of decisions. Additionally, it efficiently tracked how distinct attributes of activities, such as timing, location, involved person, mode, etc., were differentially planned.

In addition to these computer-assisted activity diaries, virtual reality has been introduced in travel behaviour study as a progress in the field of data collection to increase realism in recalling data. Tan *et al.*(2006) developed SPIN (a stereoscopic panoramic system) that displayed a panorama picture. The picture can be viewed 60 degrees vertically and 80 degrees horizontally. The SPIN consists of travel functions such as changing mode choice, conducting activity, changing time and checking information about performed travel behaviour. This system provides experiences of congestion, time, weather and travel to the respondents while collecting data of their actions. Their findings indicated that the stereo panoramic interactive navigation system performed better than a traditional paper-and-pencil instrument in collecting data on activity agendas and trip sequences. However, reporting durations of the activities was a problematic for this method (Tan, et al., 2006).

3.6 Reviews of Applications of Virtual Reality and a Computer Game to a Human Behaviour Study

International applications of Virtual Reality (VR technology) are evidences that have directed to an agreement that people will have a clear perception and response to a given question or situation when they are immersed into the scenario in built environment. Over the past few decades, the computer has become a prominent research tool for monitoring, modelling and simulation. In terms of simulation, VR technology has been extensively applied in many human behaviour studies. It immerses the respondent in a controlled environment, which is evocative of the actual world. The technology allows the user to interact with a computer-simulated environment displayed either on a computer screen or through special stereoscopic displays as primarily visual experiences (Brooks, 1999). The VR technology has been widely adopted in training such as flight simulation, merchant ship simulation, and in facilitating engineering activities such as automobile designing (Brooks, 1999). The virtual environment can also be simulated significantly differently from reality as seen generally in VR game products, particularly for the commercialising of movies or other popular themes. Therefore, the VR technology can be used to simulate the situations or conditions that people have not had experienced before. Achieving lifelike and role-playing interactive characters in a real-life virtual world significantly improves the players' motivation and retention in the game (Sims, 2007).

Computer graphics and communications have advanced rapidly. Computer games are used not only for entertainment, but also for scientific and medical training, and human decision and behaviour studies. Ruley (2002) described an air-combat simulation training game, which allows a user to choose the plane and to choose the position: pilot, gunner or bombardier. Childs and Lubaczewski (1987) evaluated a computerized battle simulation (COMBAT-SIM) to train Brigade and Battalion commanders and staff for procedures and decision-making skills. They concluded COMBAT-SIM was a truly remarkable achievement in the area of command distribution and control training simulations at that time. Similarly, Zeller (2005) analysed a simulation and video game used in the US Army for identifying potential recruits. Zeller concluded that the game cost $4 million to develop, and has the potential to mitigate the perennial problem of high-cost, high quality training being spent on unsuitable recruits.

Besides the advantages in battle training, computerized games have been applied in several studies on human behaviour and cognition. Ducheneaut and Moore (2004) used the Star Wars Galaxies (SWG) game to analyze social interactions of players in two SWG locations. Their data shows a relatively low level of interactivity between the players. They believed this is mainly from a lack of incentives for players to actively engage in interactions in two locations.

Hoobler *et al.* (2004) proposed a popular team-based, first-person perspective game "Return to Castle Wolfenstein: Enemy Territory" in order to enhance observation of user interactions in virtual environments. Peterson (1972) developed the Ecology Decision Game as a prototype for experimental use within IBM. The game allows participants to treat decision-making in the environmental area of solid-waste management, regarding a particular written scenario. In city planning, the growth, accretion, and decay of cities have been studied through a popular computer game, SimCity 2000 (Peschon, 1996). Peschon postulated five city structures with greatly differing population densities and transportation solutions ranging from traditional pedestrianfriendly to auto-dependent sprawl. The evolution of a city was analyzed by using decision analysis. Warren *et al.* (2005) proposed a computer-based game project, modified from a popular medieval fantasy role-playing game Neverwinter Nights, to simulate scenarios on the culture and cognition of foreign and American teams. The game events and participants' typical actions, strategies and behaviours were captured and logged in a database. Although computer games can reveal personality and behaviour features induced through the simulated scenarios, behavioural computer game-based studies need to be well designed and controlled in order to avoid unforeseen effects gained from free-play and unintentional game error (Lofgren & Fefferman, 2007; Warren, et al., 2005)

CHAPTER 4

TACA SIM DESIGN

4.1 An Overview of the TACA Sim

TACA Sim is designed as a survey tool that captures participants' adaptive capacity and adaptive potential in the situation of fuel price shocks. Figure 4.1 illustrates the conceptual framework for designing TACA Sim. The idea is motivated by future permanent oil depletion leading to the question of whether and what people can do to continue their normal activities. The concept of designing TACA Sim is based on the proposal that virtual reality participation can represent intended behaviour, and could support the collection of data about what people can do in response to fuel price pressures. The virtual reality survey method combines an interface with multiple related choices. Participants are immersed in a spatially referenced environment that makes the player (survey participant) interactively participate and react to changing conditions. These properties have been previously identified in studies of human cognition and its experiments (Warren, et al., 2005).

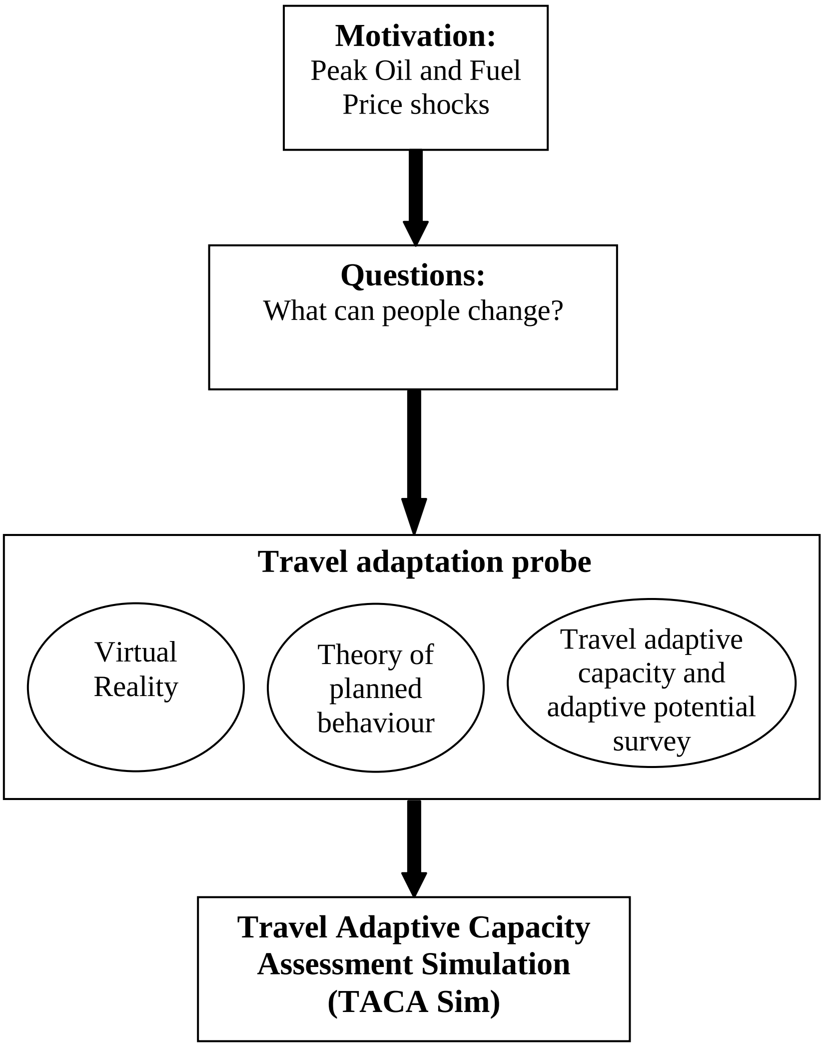


Figure 4.1: Conceptual framework for designing TACA Sim.

According to the Theory of Planned Behaviour, behavioural beliefs and normative beliefs, which partially affect the individual intention, adhere to the participants. The participants will change their behavioural beliefs and normative beliefs when they receive new external information – for example, if the government promotes new environmental policies. During the survey, TACA Sim provides fuel price pressures to the participants in the form of visual contact, which is defined as a “signal” in this research. The fuel price signal works as a constraint that has an effect on the participant’s intention in addition to behavioural beliefs and normative beliefs. Therefore, the participants analyse their ability (control beliefs) to perform the same travel pattern when they receive the fuel price pressure signal.

The TACA Sim is designed to stimulate participants to think about their transport alternatives in response to fuel price pressures. The stimulation in TACA Sim only triggers the participants to imagine the alternatives available for them. TACA Sim does not provide any information about the existing transport system the participants are facing. The decisions on choices then totally depend on the participants’ experience and perception. The TACA Sim design includes pop-up questions to explain the scenario and prompt the participants to make decisions from the provided options. The TACA Sim does not include the objective of maximizing scores in the game to avoid distraction from decisions about transport choices. TACA Sim also integrates Google map™ technology and pop-up questions related to travel behaviour into the scenario. The Google map allows the TACA Sim platform to acquire the origin and destination of each trip conducted by the participants. Travel distance is generated via the map.

The TACA Sim platform was constructed using the *DarkBASIC Professional* game engine, which is a commercial game creation program, built on the

BASIC language. The TACA Sim is a combination of 2D and 3D graphics scenes. The character and interactive objects are rendered as 3D low-polygons. *DarkBASIC Professional* was chosen for TACA Sim because it facilitates rapid game-development and provides the same range of capability as C++/Win32/DirectX (Lloyd, 2003), but can produce both 2D and 3D environments with low development costs.

4.2 TACA Sim's structure

TACA Sim is designed using a role-playing game concept with three levels: personal information survey, travel adaptive capacity survey and travel adaptive potential survey. These are represented schematically in Figure 4.2. Initially, individuals were asked to choose their personal role-playing character and provided their personal details and information about their vehicle. Subsequently, the participants' travel activities were filled in a travel diary that is structured like a personal daytime planner or desk diary. Participants are also asked to rate the essentiality of each trip, to select the travel mode and specify possible alternative modes. Participants also locate the origin, destination and routes for each trip on a Google map. The participants were then returned to the travel activity schedule to either add more trips or continue to the schedule for next day. Finally, fuel price pressures are simulated and participants decide whether to maintain their current activities. Their adaptive changes due to the fuel price pressures are recorded and analysed. At the end of each survey level, the stored data can be retrieved for analysis. The following sub-sections describe in detail each of the three survey levels. All questions asked in TACA Sim are included in Appendix A.

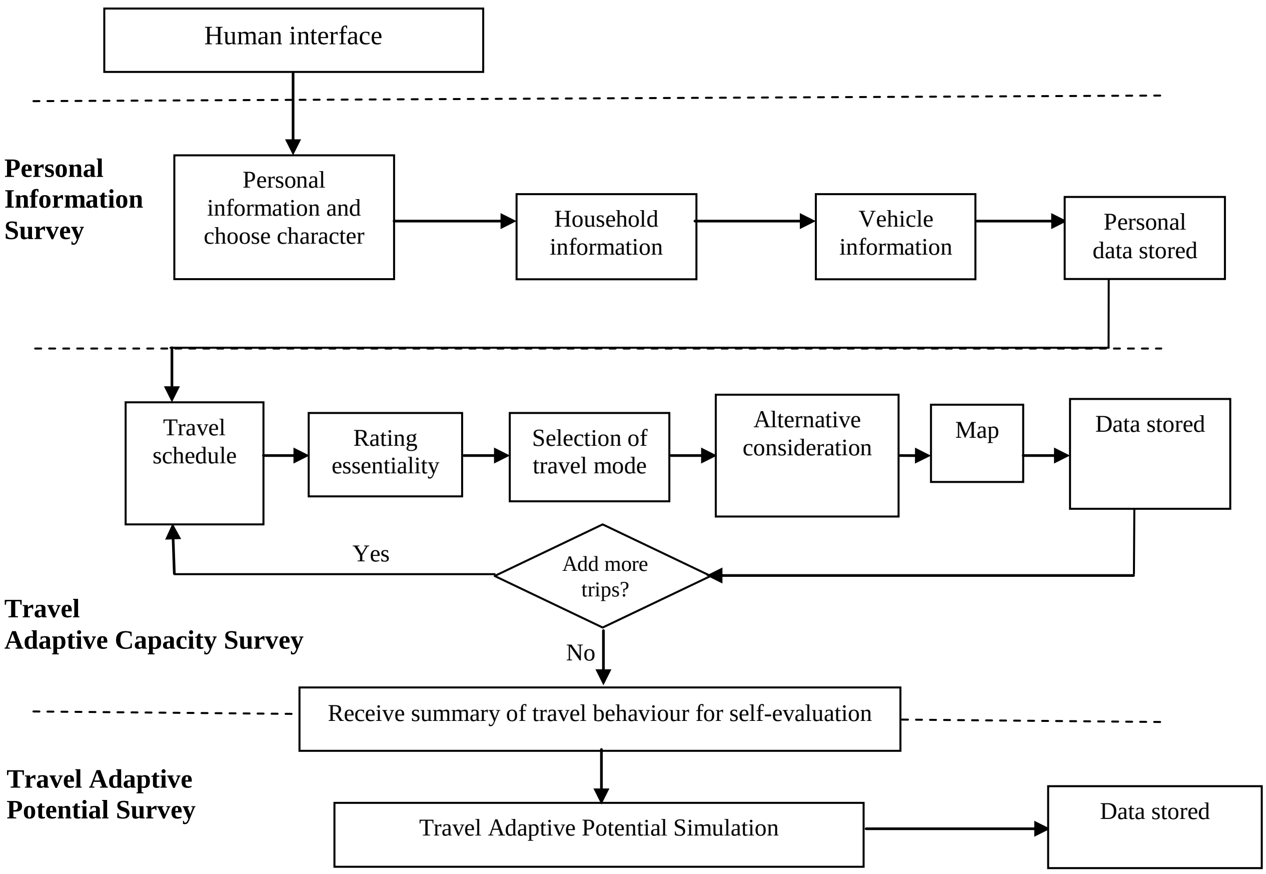


Figure 4.2: The three major levels of the TACA Sim framework implementation: an immersive survey.

4.2.1 Personal and Vehicle Information Survey Level

The personal information survey includes questions regarding the participant's sex, occupation, and occupational status (see Figure 4.3 for screenshot). Income and household information followed by vehicle information are entered in the scenes in Figure 4.4 and Figure 4.5.

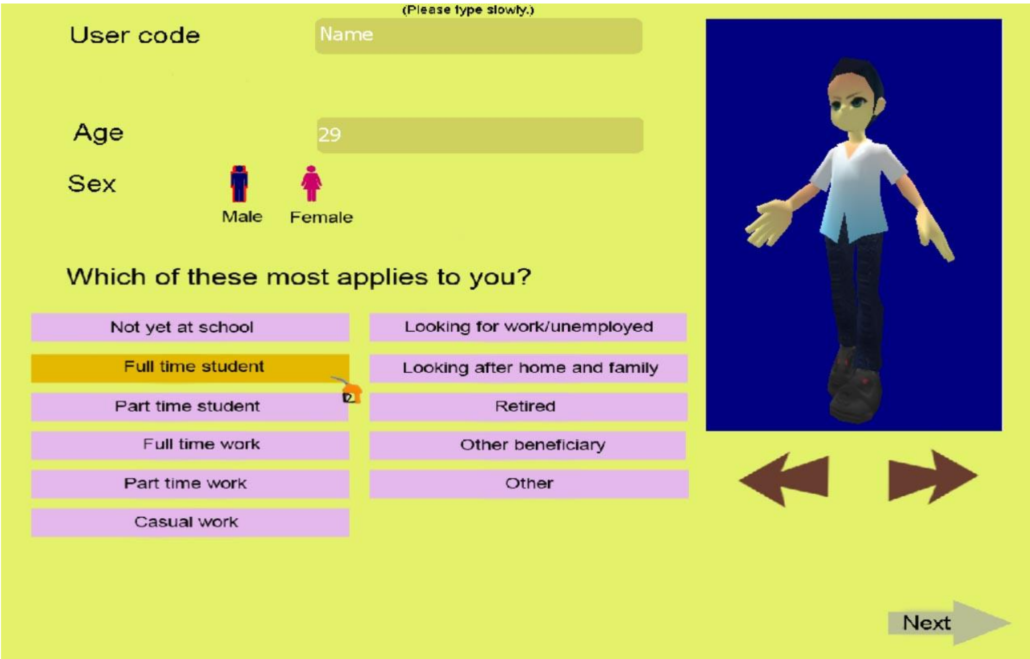


Figure 4.3: A screenshot of the personal information interface in the Personal Information Survey level.

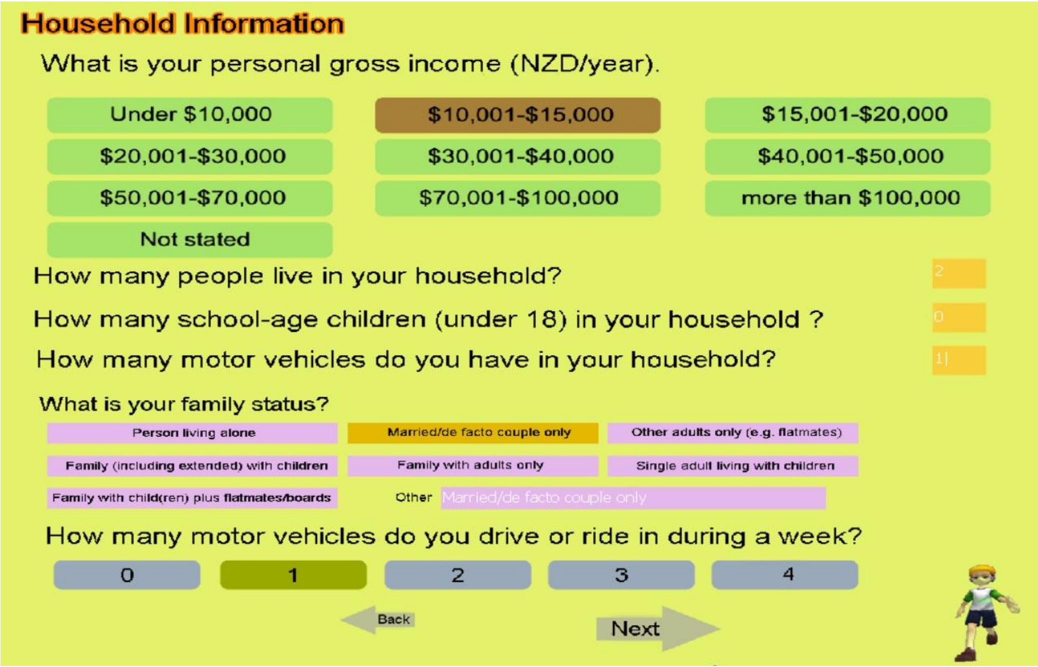


Figure 4.4: A screenshot of the personal information interface in the Personal Information Survey level.

The TACA Sim platform allows the participants to fill in the information about the vehicle that they use (Figure 4.5). If the participant does not use a motor vehicle, the vehicle information scene can be skipped. Information on the motor vehicle (such as engine size) will be used in calculations for an approximation of fuel consumption.

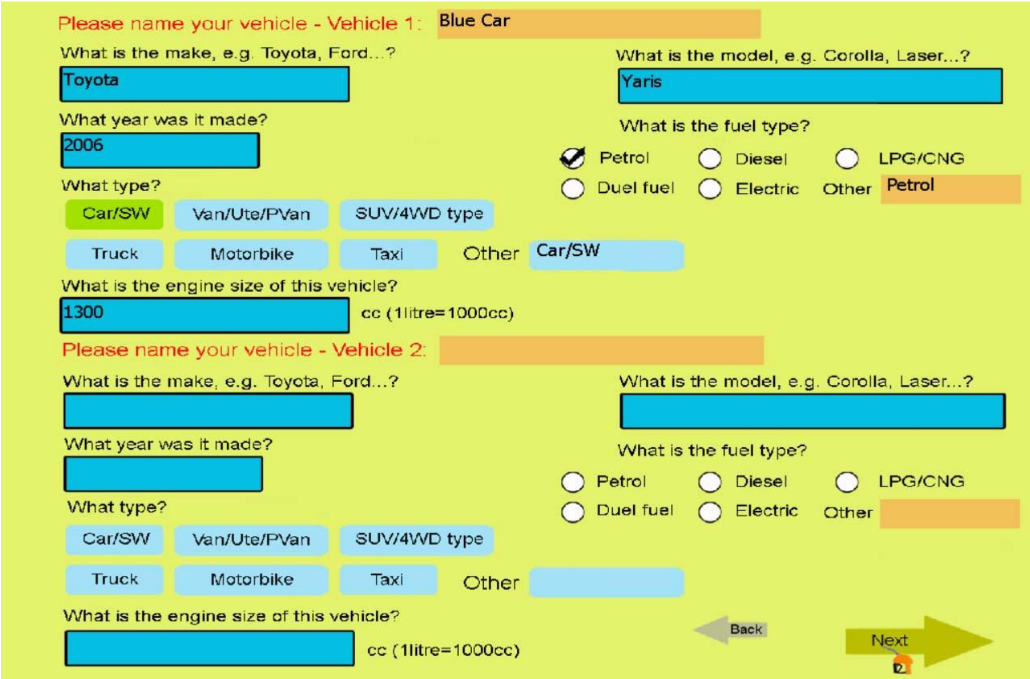


Figure 4.5: A screenshot of the vehicle information interface in the Personal Information Survey level.

4.2.2 Travel Adaptive Capacity Survey Level

This level captures trips that the participants make to participate in the activities in a week. The questions includes when, where, with whom, what for, and for how long people travel for. The participants are asked to provide their travel activities for a week on a day-planner as shown in Figure 4.6. The day-planner allows up to 8 trips a day to be recorded. This design is supported by Bricka and Chandra (2006) who state that people mostly declare 5 trips in a day on average. The participant provides in their activities, origin, departure and arrival time for each day, then clicks on the mode button to continue with essentiality and modal questions as shown in Figure 4.7.

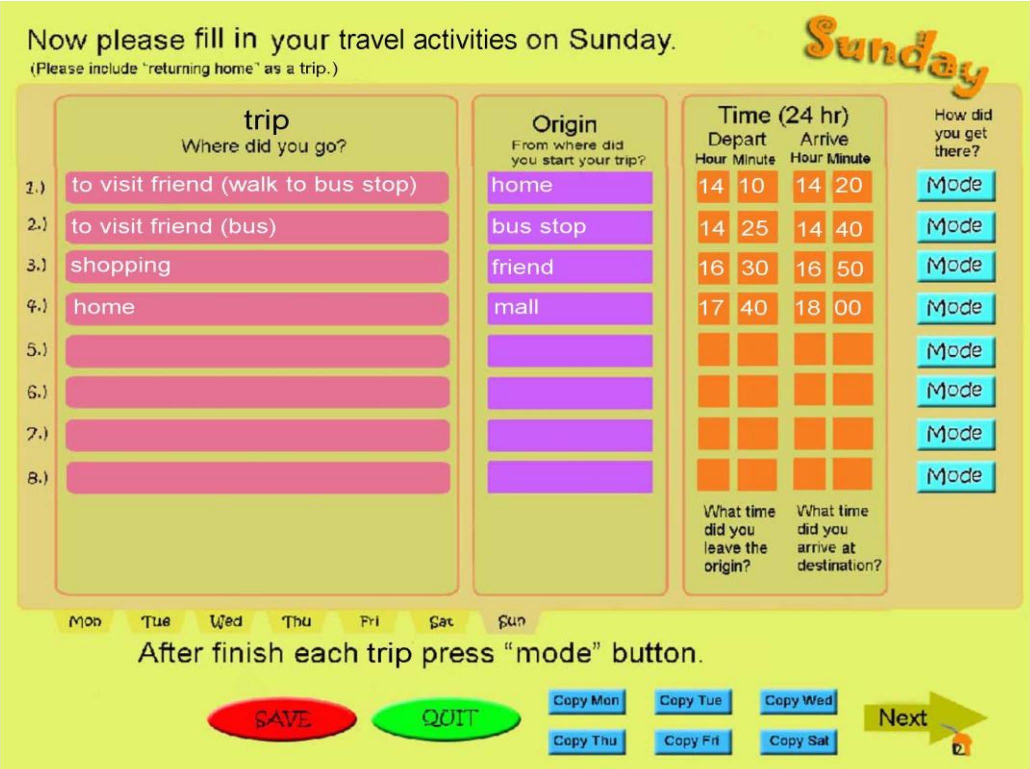


Figure 4.6: A travel schedule interface for Sunday.

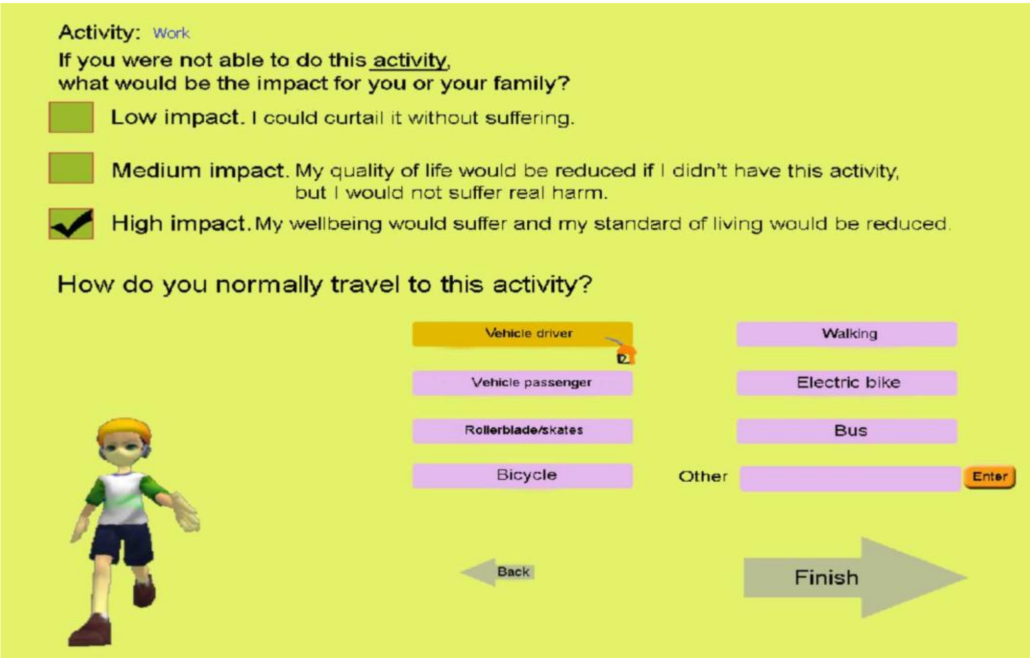


Figure 4.7: A screenshot of the modal scene in the travel energy adaptive capacity survey level.

For measuring essentiality, the surveyor asked the participants to rank the impact of each of their activities if they were not able to participate in that activity. In Figure 4.7, the following question is asked for the given activity:

> *If you were not able to do this activity, what would be the impact for you or your family?*
>
> - ***Low*** *I could curtail it without suffering.*
> - ***Medium*** *My quality of life would be reduced if I didn't have this activity, but I would not suffer real harm.*
> - ***High*** *My wellbeing would suffer and my standard of living would be reduced.*

The travel mode is selected, and if "car (vehicle driver or vehicle passenger)" is selected, the participant is asked which vehicle the participant would use to get to the activity. Figure 4.8 presents a screen with a list of vehicles previously added. If the vehicle has not been added, the participant can select "Add new" to enter the details of the vehicle (e.g. engine size, make of vehicle, and type of vehicle) used for the activity.

The purpose of each travel activity is collected by tick box selection as illustrated in Figure 4.9. The participants are asked about the trip purpose in order to generate standard travel data, as they have been required to provide the name of their activity in the diary. The participants categorise their trip purpose using the list of trip categories provided for them.

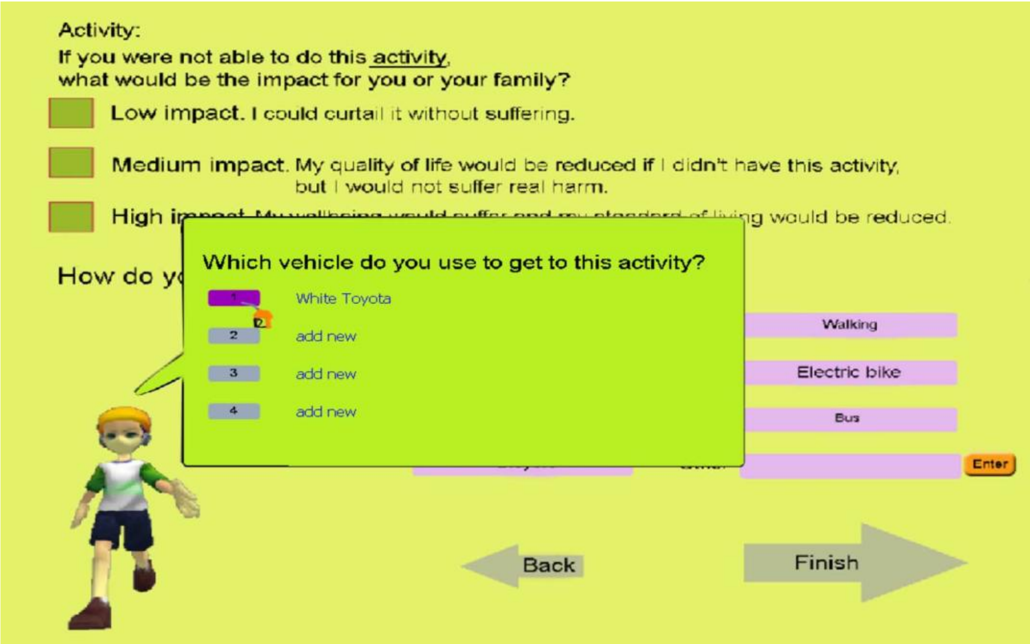


Figure 4.8: A participant selects a vehicle used for a trip.

TACA Sim uses the trip purposes categorised by Lee and McNally (2001), and Doherty and Miller (2000). The categories are home, work, education, personal business/services, change mode (such as park and ride), hospital/medical, accompanying someone, shopping, recreation, social visit/entertainment, left country/city, social, and other. Lists of trip purposes are shown in Appendix B. For example, a person may indicate "go to university" as their activity, but they may be a student with the purpose of "study", or a lecturer with the purpose of "work". Participants also are asked the number of passengers in the vehicle and, subsequently, whether there are any other possible modes for each trip.

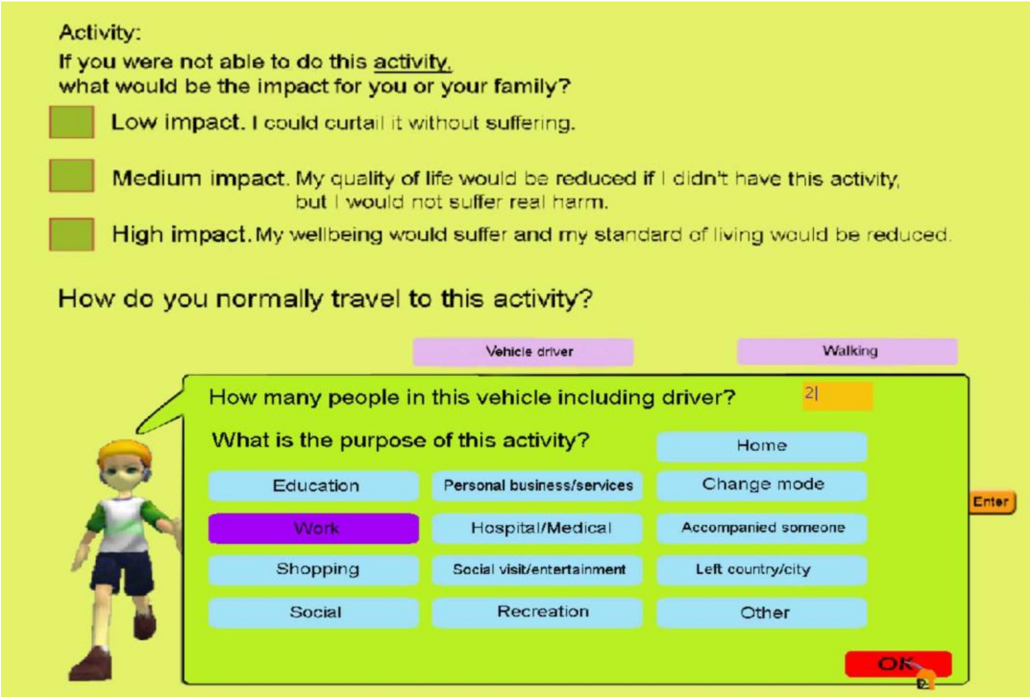


Figure 4.9: A participant identifies the purpose of an activity.

Figure 4.10 shows a screenshot asking for the alternative modes of transport that the participant can use to access the activity. The participant may select more than one alternative. The question "Could you get to this activity another way?" is used for analysis of travel adaptive capacity. Such a question has been widely used in previous studies for seeking the way to get people out of their car in order to reduce congestion, pollutions and environmental and travel costs from driving car (Gärling, Gärling, & Johansson, 2000; Kingham, Dickinson, & Copsey, 2001; Van Exel & Rietveld, 2009) The previous studies show that asking for individual alternative is an effective way to probe people's adaptive capacity.

Figure 4.11 shows the next scene that records origin address, destination address and travel distance data. Participants indicated the trip origin and destination of each activity and their route for each trip on a built-in Google map. The navigation tools on the left of the map provided a function to search for the origin and destination. Alternatively, right clicking on the mouse to select “Find directions from here” will mark the exact trip origin on the map.

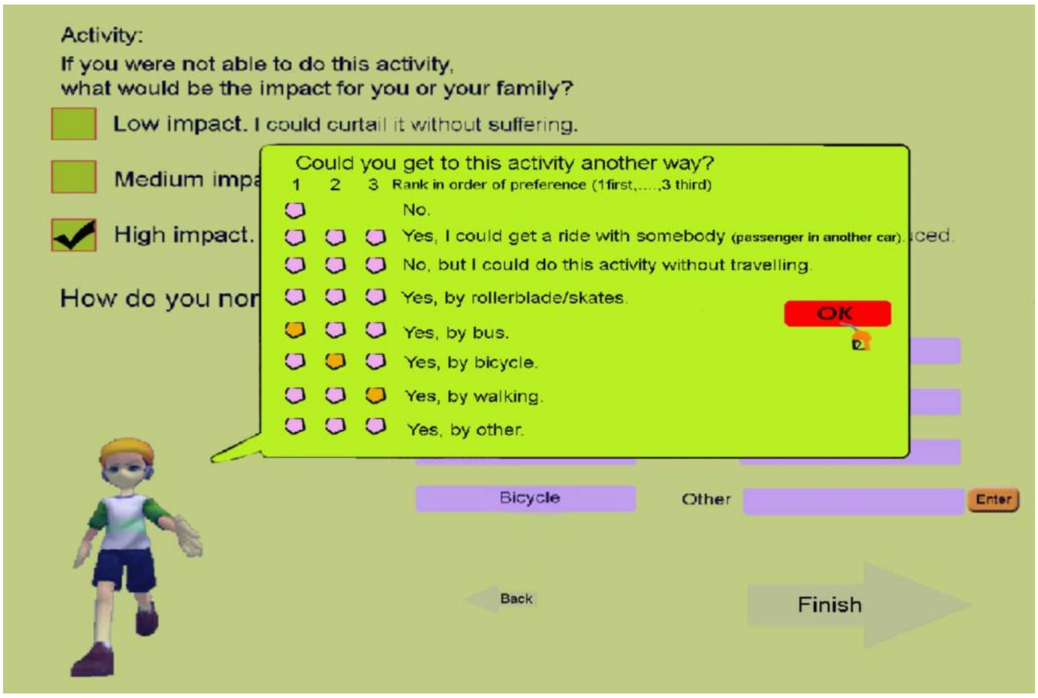


Figure 4.10: Travel alternatives.

Then, the map is moved to find the destination. Right clicking the mouse again on the map to select “Find directions to here” will mark the destination. The map will generate the suggested route of origin and destination. The route may be changed to represent the taken route by using the left mouse button to drag the line connecting the trip origin to the destination. After the travel distance is obtained, the surveyor typed the origin address, destination address, coordinates (if any), and kilometre travel distance into the boxes in the grey zone at the bottom of the screen. The distance data is used to calculate fuel consumption according to the given vehicle information (fuel consumption rate) by using equations 4.4, 4.5, and 7.1. This information is displayed at the end of the survey.

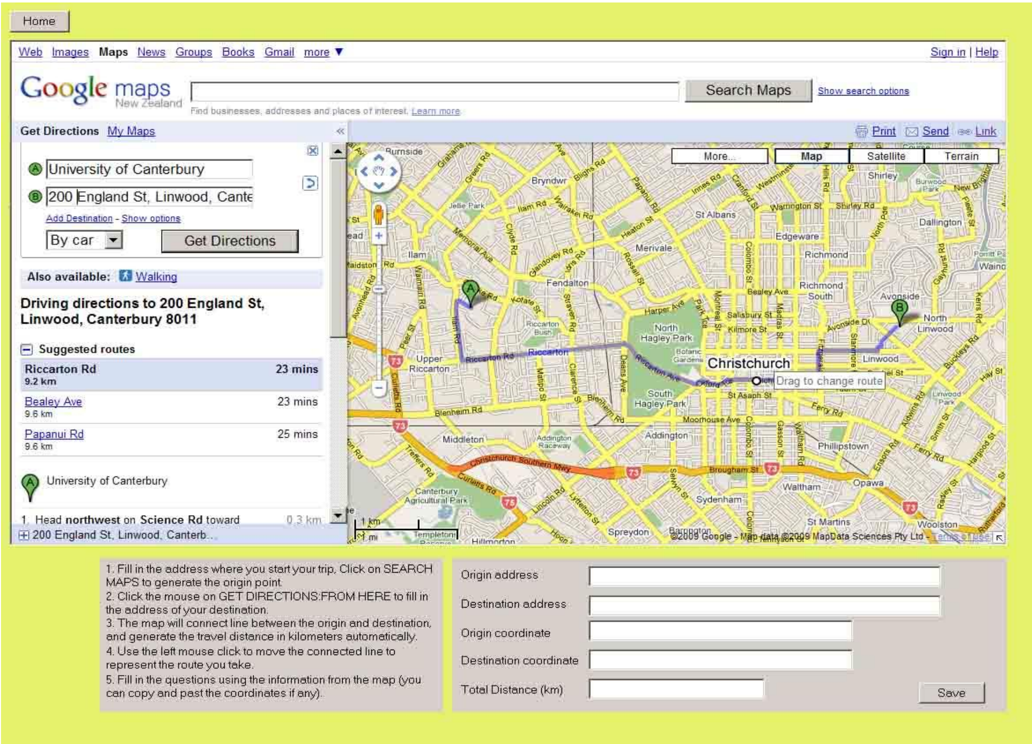


Figure 4.11: A screenshot of the map screen interface in TACA Sim.

After trips for each day of the week have been surveyed, a travel behaviour summary page is generated for the conclusion of this level. Participants can see the number of trips they make, total distance and fuel used in a week.

The travel behaviour summaries are presented in terms of distance travelled by car and the number of optional, necessary and essential trips in a week. The term *Car* includes all fossil fuel-using vehicles except public transport modes (e.g. bus, ferry, plane and taxi). Travel behaviour scores are reported in terms of *Car Dependence*, *Fossil Fuel Intensity* and *Fuel Price Exposure (Risk)*.

Car Dependence is the proportion of the total number of trips made using a fuel-consuming vehicle.

$$Car_{dep} = \frac{n_{car}}{N} \cdot 100 \qquad \textbf{(4.1)}$$

where,

Car_{dep} = percentage of fuel-using vehicle trips per person

N_{car} = number of fuel-using vehicle trips

N = total number of trips

Fossil Fuel Intensity is the proportion of total distance travelled by car.

$$FI = \frac{d_{car}}{D} \cdot 100 \qquad \textbf{(4.2)}$$

where,

FI = Fossil Fuel Intensity per person (percentage)

d_{car} = Distance travelled by fuel-using vehicle (Rindsfüser, et al.)

D = Total distance travelled (Rindsfüser, et al.)

For example, a person travels by bicycle 2 km to school and back each day for 5 days (total 20 km in a week) as presented in Table 4.1. On Saturday, he drives 6 km each way to the mall and back (a total of 12 km). He also drives 15 km on Sunday to the beach (a round trip of 30 km). The total number of trips is 14 (10 trips by bicycle and 4 trips by car) and the total distance travelled is 62 km (20 + 12 + 30).

Table 4.1: Example of weekly travel behaviour.

Day	No. of trip	Trip	Distance (Rindsfüser, et al.)	Mode
Monday	1	School	2	Bicycle
	2	Home	2	Bicycle
Tuesday	3	School	2	Bicycle
	4	Home	2	Bicycle
Wednesday	5	School	2	Bicycle
	6	Home	2	Bicycle
Thursday	7	School	2	Bicycle
	8	Home	2	Bicycle
Friday	9	School	2	Bicycle
	10	Home	2	Bicycle
Saturday	11	Mall	6	Car
	12	Home	6	Car
Sunday	13	Beach	15	Car
	14	Home	15	Car
Total	**14**		**62**	

Therefore, *car dependence* for activities would be:

$$Car_{dep} = \frac{4}{14} \cdot 100 = 28.6\%$$

and *fuel intensity* is:

$$FI = \frac{42}{62} \cdot 100 = 67.7\%$$

Fuel Price Exposure (Risk) is a measure of exposure to fuel price rise, tied to the number of options other than to travel by car for participation in activities. The Fuel Price Exposure (FPE) was developed in this research work as a way to indicate to participants how hard they might find it to change if fuel prices were to rise. In TACA Sim, participants are asked if they have an alternative mode to get to the activity. The value of the FPE ranges from 0 to 1. Zero indicates that the person has high adaptive capacity and low exposure to the high fuel price. A score of 1 means the person has no alternative to car use for all trips. Equation 4.3 presents the FPE calculated as a score. The number of available alternatives deducted from car trips is weighted by an essentiality/impact score. These essentiality scores were assumed in this research based on the intense of the impact i.e. 1 for low impact; 3 for medium impact; 5 for high impact.

$$FPE = \frac{(n_1^{opt} - n_2^{opt})IW^{opt} + (n_1^{nec} - n_2^{nec})IW^{nec} + (n_1^{ess} - n_2^{ess})IW^{ess}}{N^{opt}IW^{opt} + N^{nec}IW^{nec} + N^{ess}IW^{ess}} \quad \textbf{(4.3)}$$

where,

n_1 = number of trips travelled by car

n_2 = number of available alternatives

IW = impact weight of trip at the essentiality (1, 3, 5)

N = total number of trips

^{opt}, ^{nec}, ^{ess} = superscripts for optional, necessary, and essential trips, respectively

The FPE value is presented as a weighted percentage in order to allow comparison of results. A passenger in a personal car has the same score of FPE as the driver. The amount of fuel used in a trip and the efficiency of the vehicle are not used as mitigating factors.

For example, a person conducts 14 trips in total (including return trips) in a week as shown in Table 4.2. Two trips are optional (giving a weighted point score of 2), ten trips are necessary (total 30 points), and the final two trips are essential (total 10 points). Out of these 14 trips, 4 trips are travelled by car. Two of the car trips are optional (total 2) and two car trips are essential (total 10).

Table 4.2: Example of essentiality and alternative modes for weekly trips.

Day	No. of trip	Distance (Rindsfüser, et al.)	Mode	Essentiality	Alternative
Monday	1	2	Bicycle	Necessary	Walk
	2	2	Bicycle	Necessary	Walk
Tuesday	3	2	Bicycle	Necessary	Walk
	4	2	Bicycle	Necessary	Walk
Wednesday	5	2	Bicycle	Necessary	Walk
	6	2	Bicycle	Necessary	Walk
Thursday	7	2	Bicycle	Necessary	Walk
	8	2	Bicycle	Necessary	Walk
Friday	9	2	Bicycle	Necessary	Walk
	10	2	Bicycle	Necessary	Walk
Saturday	11	6	Car	Essential	Bus
	12	6	Car	Essential	Bus
Sunday	13	15	Car	Optional	No alternative
	14	15	Car	Optional	No alternative
Total		**62**			

$N^{opt}W^{opt}$	$N^{nec}W^{nec}$	$N^{ess}W^{ess}$	$(n_1^{opt}-n_2^{opt})lW^{opt}$	$(n_1^{nec}-n_2^{nec})lW^{nec}$	$(n_1^{ess}-n_2^{ess})lW^{ess}$
(2·1)=2	(10·3)=30	(2·5)=10	(2-0)·1=2	0	(2-2)·5=0

Using equation 4.3, the fuel price exposure of this person is:

$$FPE = \frac{2+0+0}{2+30+10} = 0.05 \text{ or } 5\%.$$

Figure 4.12 shows the feedback scene of the travel demand data collection for a participant. The participant can compare their perceptions of their travel behaviour with reality.

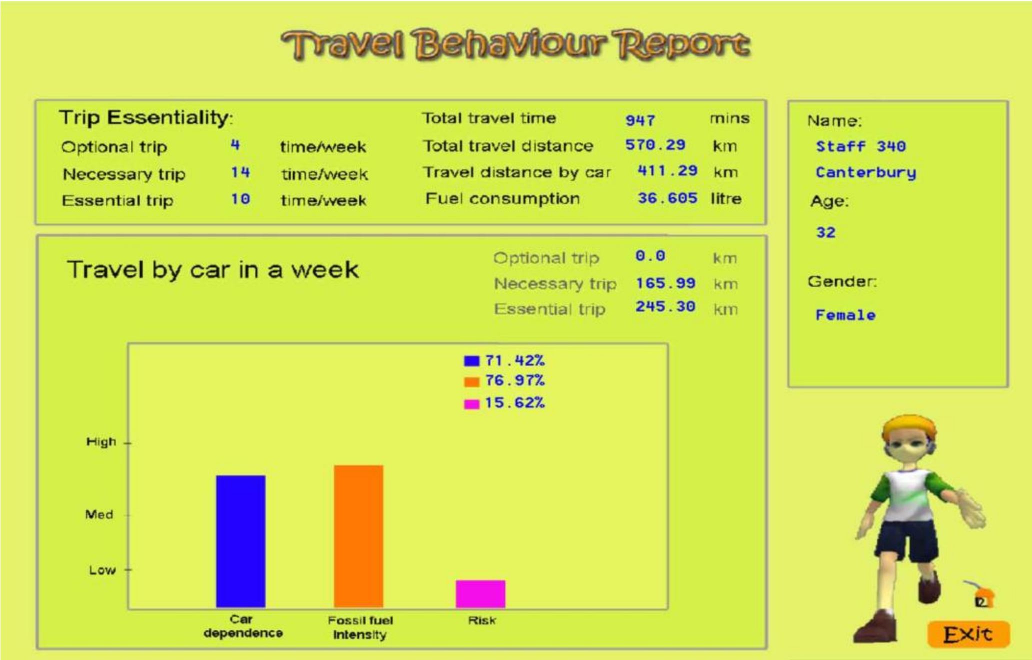
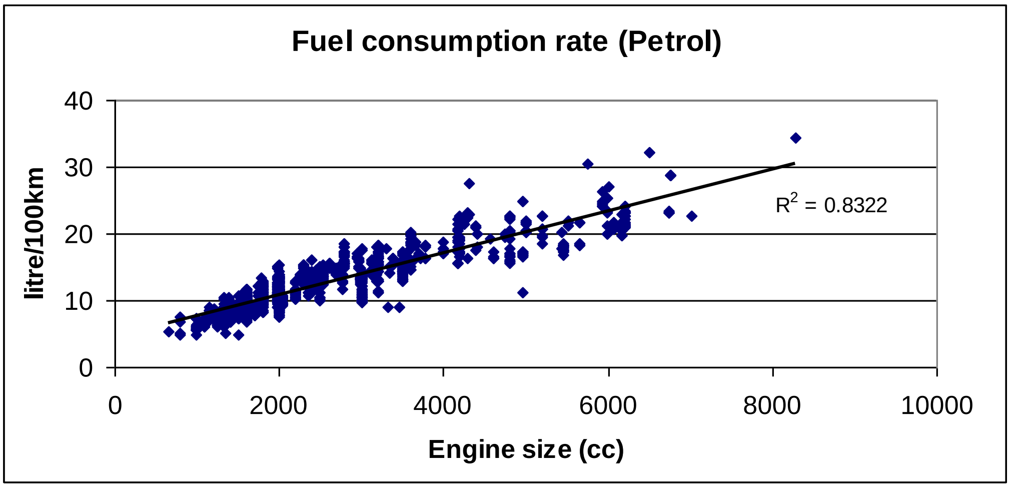


Figure 4.12: Score feedback after the travel demand survey level is completed.

Car trips, in which the person was a passenger, are counted as though the person was a driver in these feedback score calculations. The passenger has the same number of car trips and kilometres travelled by car as the driver, however, fuel consumption will be different for shared journeys.

The fuel consumption for each trip is shared among people in the car. The fuel consumption of a trip is determined by vehicle occupancy, engine size and distance travelled. The fuel consumption calculation does not include other factors, such as driving behaviour, vehicle or conditions. The relationship between engine size and fuel consumption rate is taken from the Vehicle Certification Agency (VCA) data (VCA, 2009). Figure 4.13 shows the petrol and diesel consumption rate varied by engine sizes.



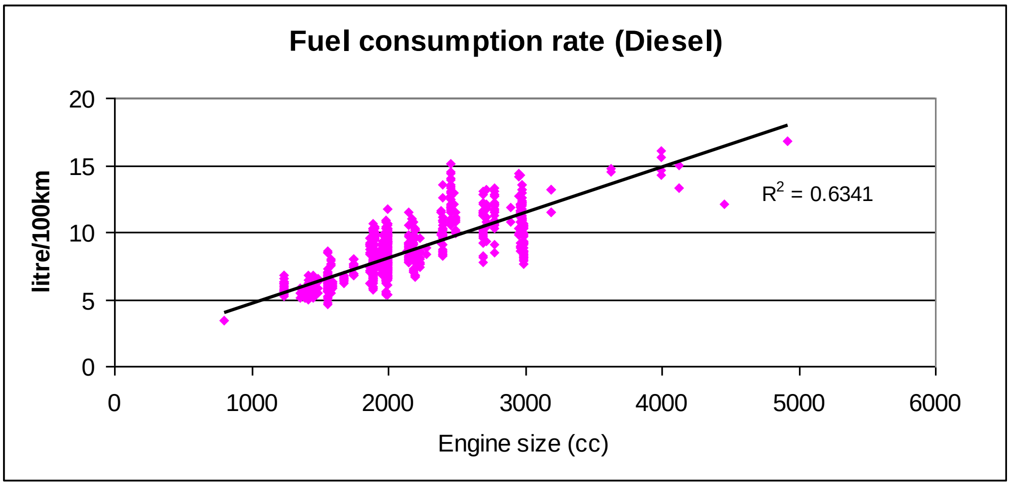


Figure 4.13: The relationships of the engine size, and petrol and diesel consumption rates.

From these relationships, fuel consumption rate can be estimated by using the equations below.

For petrol: $Y_{petrol} = 0.0031X_{petrol} + 4.645$ **(4.4)**

For diesel: $Y_{diesel} = 0.0034X_{diesel} + 1.2961$ **(4.5)**

where,

Y_{fuel} is fuel consumption rate (litres per 100 kilometres)

X_{fuel} is vehicle engine size (cc)

4.2.3 Travel Adaptive Potential Survey Level

The participant who completed transport adaptive capacity survey level may choose to continue to this level. In this level, the participants are immersed in a role-playing environment in order to induce decisions in response to fuel price pressures. The fuel price pressures used in the simulation represents the price of octane 91 petrol. The collected data from the personal information and travel adaptive capacity survey levels are imported into this stage. The participants then work through their travel activity schedule in different simulated fuel price pressure. Figure 4.14 presents the structure of the scenario design for the travel adaptive potential survey.

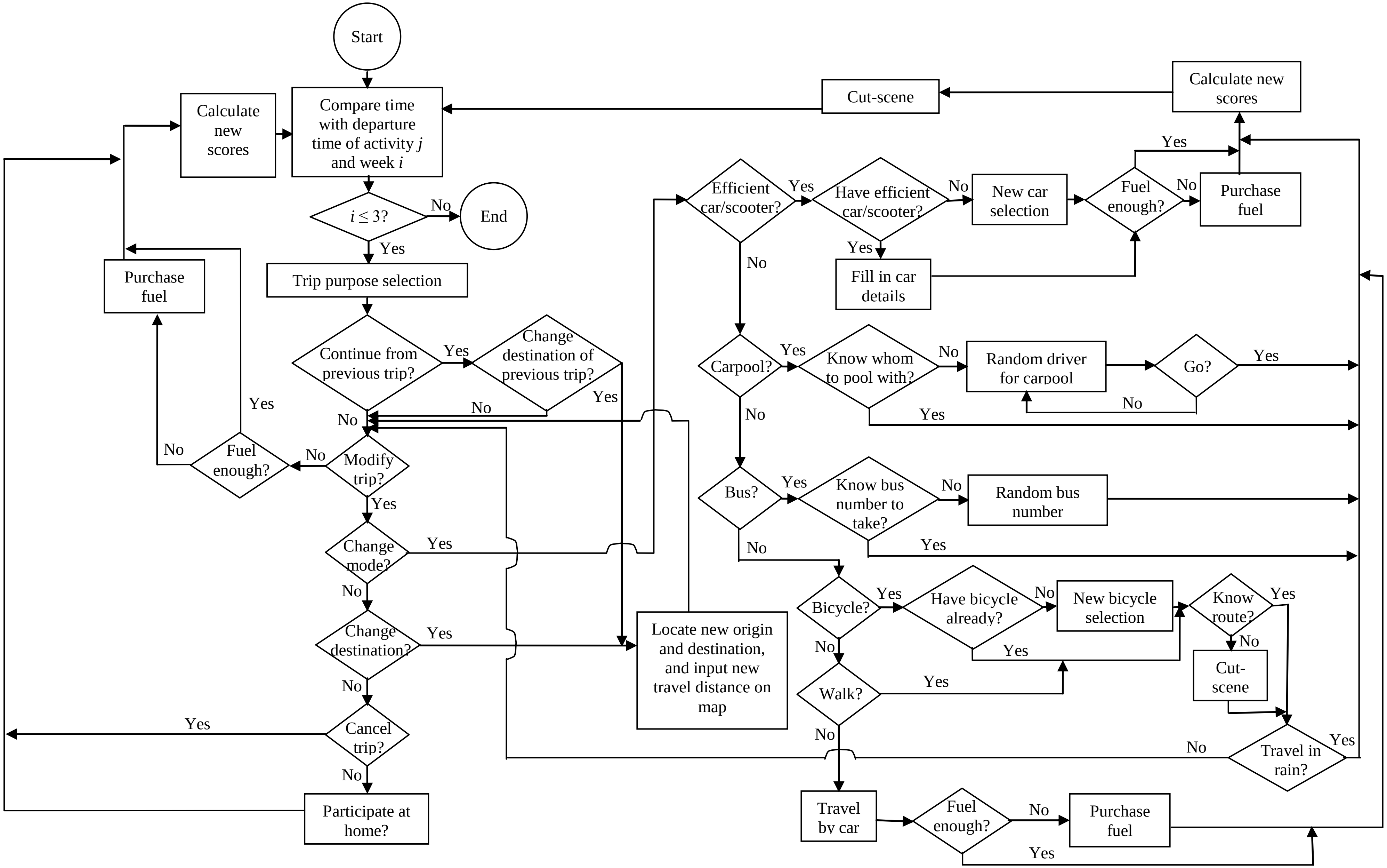


Figure 4.14: Designed structure of the travel adaptive potential survey level.

The game starts with a bedroom scene with a "Time" representing the passage of time as shown in Figure 4.15. The screen dims briefly as the hours of the night go by. A series of pop-up questions appear at the departure time of each activity stated in travel diary. The participant is given the opportunity to continue with or modify their trips in response to the given fuel price pressure. During the simulated situations, the information panel interface (the blue bar at the bottom of the screen in Figure 4.15) is provided to help participants make decisions. The game panel contains information on fuel price, travel and fuel consumption pattern scores (i.e. car dependence score, fuel intensity score, and fuel price exposure (risk)), activity scores (a green bar at the top-right of the panel), fuel level in their car, fuel consumption and cost in a week, date and time, and travel expenses per week.

Faivre D' Arcier *et al.* (1998) suggested two conditions that must be enforced in designing to ensure the efficiency of the game:

1) Make the participants enter into the "game" by means of scene setting i.e. introduce the topic to allow a gradual progression in order for the participants to willingly express a view about a topic.
2) Introduce pressure on life-styles that elicit reactions from the subject.

Therefore, the fuel price starts with non-pressure at a level similar to the actual level at the time of the survey (at $1.64/litre) in order to introduce the fuel price pressure scenario to the participants and familiarize them to the game. This non-pressure stage was also used as a filter to identify the respondents who may be affected by information about their current energy consumption and car dependence provided at the end of the first two levels. Two escalations of fuel-price pressure are then simulated over the course of three weeks' game-play in order to capture the change of characteristics of the trips. The fuel price pressure is increased three-fold at the beginning of the second week, and goes up a further 70% in the final week. In the second week, the magnitude of fuel price pressure increases to $5.65/litre on Monday, and increases again to $9.64/litre on Monday in the third week. The participant may select the "Accept price" button (green button in Figure 4.15) on the information panel to continue the same travel pattern for the week and skip to the next week. The fuel in the tank (fuel bar on the control panel) will be emptied at the beginning of each week. This is to force the participants to make a decision on whether they want to travel by car and how much fuel they will purchase at the price in that week. TACA Sim displays travel and activity cut-scenes after the participants make a choice in order to provide the participants with a perception of their choices.

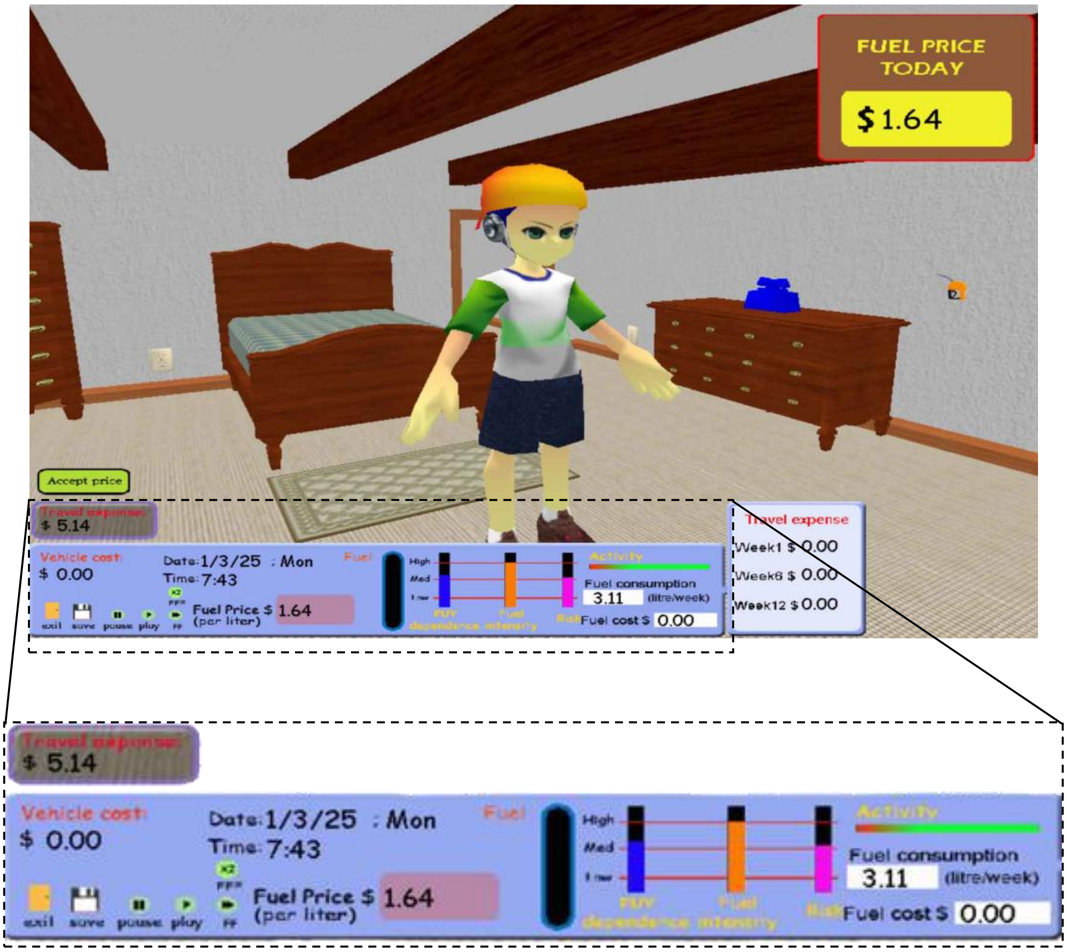


Figure 4.15: A room screen with the information panel interface.

The activity participation score (on the right side of the information panel in Figure 4.15) drops if the participants choose not to carry out an activity. The travel pattern scores are logically associated with a decision on activities. For example, choosing to travel by bicycle rather than by car noticeably reduces the levels of car dependency, fuel intensity, and fuel price exposure.

During the game, the participant categorises their trip purpose according to the choices as shown in Figure 4.16. These choices are used to activate the scene for each activity. For example if the participant categorised their "Go to school" activity under the purpose "Education" the screen background will change to a classroom scene after the participant has finished all travel questions. This is to immerse the participants in the virtual environment for their imagination on participating activity. However, it is not aimed to improve data accuracy. Figure 4.17 presents a classroom scene with the information panel.

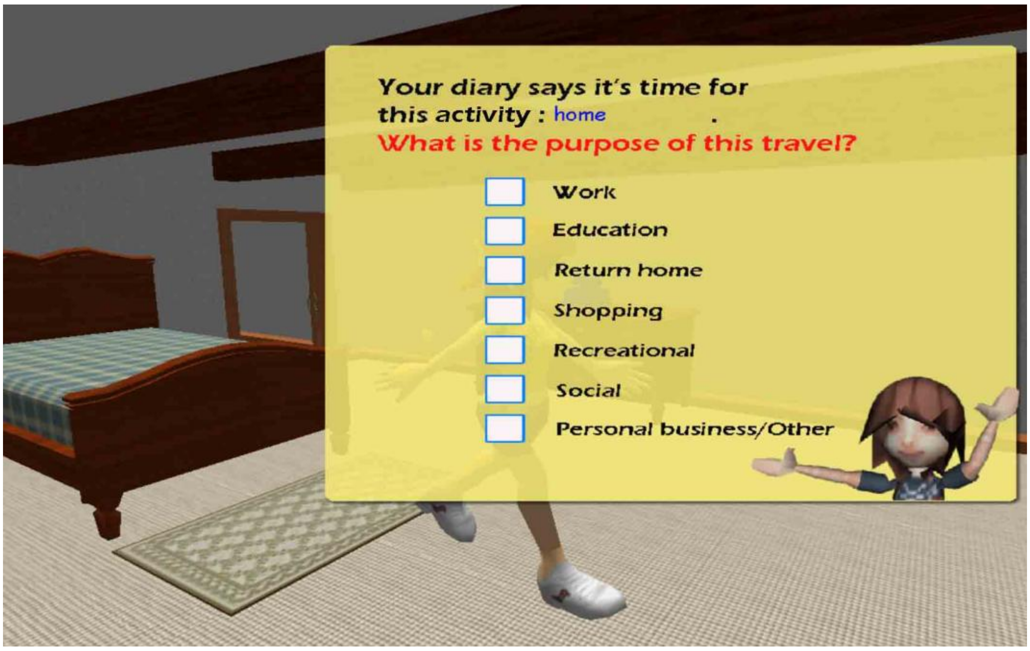


Figure 4.16: A screenshot of activity purpose categories in the travel adaptive potential survey level.

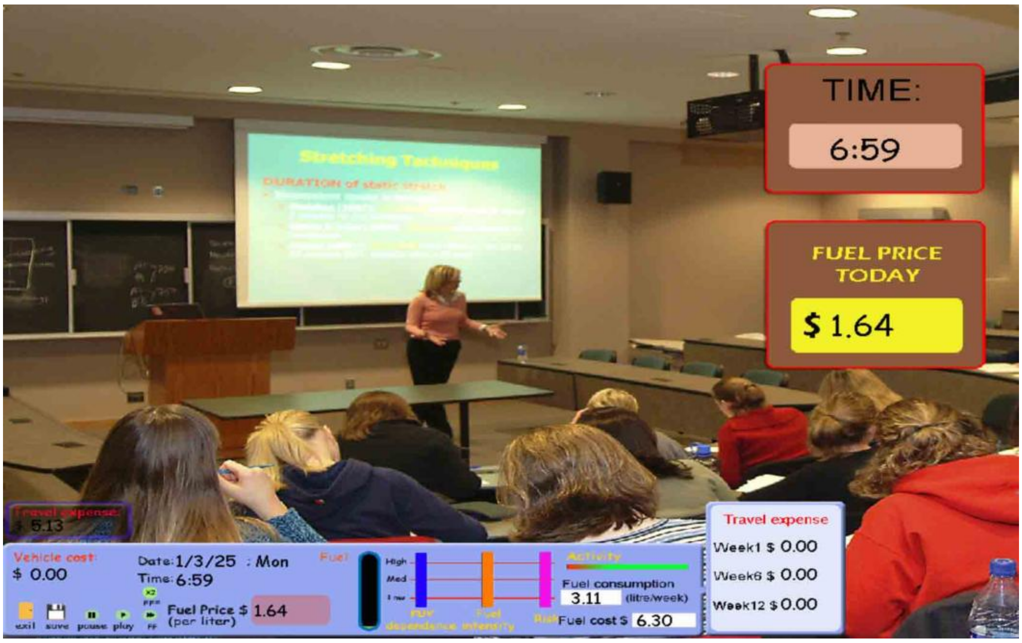


Figure 4.17: A classroom scene with information panel displays when the education purpose is selected.

After selecting the trip purpose, the participant is asked about their willingness to retain or change their travel activities. The question offers the options for changing modes, changing destinations, curtailing activities; or not travelling, but participating in the activity at home. Figure 4.18 illustrates a pop-up question with the options. The question of each travel activity is displayed in the example below:

Your diary says it's time for this activity: ***work.*** *You normally travel by this mode:* ***vehicle driver****. Would you like to go now?*

The activity and travel mode in bold have been supplied by the participants in the travel diary.

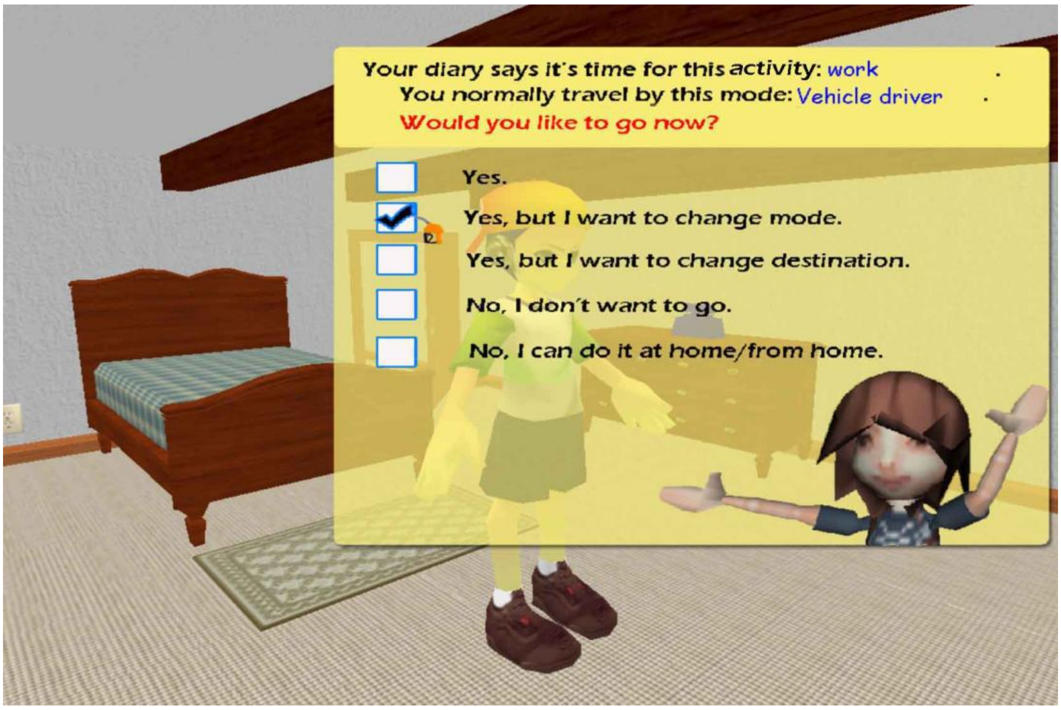


Figure 4.18: A screenshot of the question on willingness to participate in the activity.

If the participants travel by car, fuel availability is checked by comparing the expected fuel consumed for the trip (fuel consumption rate of the car times travel distance) to the amount of fuel remaining in their fuel tank. If their car is too low on fuel to carry out the trip, the fuel-purchasing scene pops up automatically. Figure 4.19 shows a screen of purchasing fuel (yellow box) with a workplace background (for work purpose).

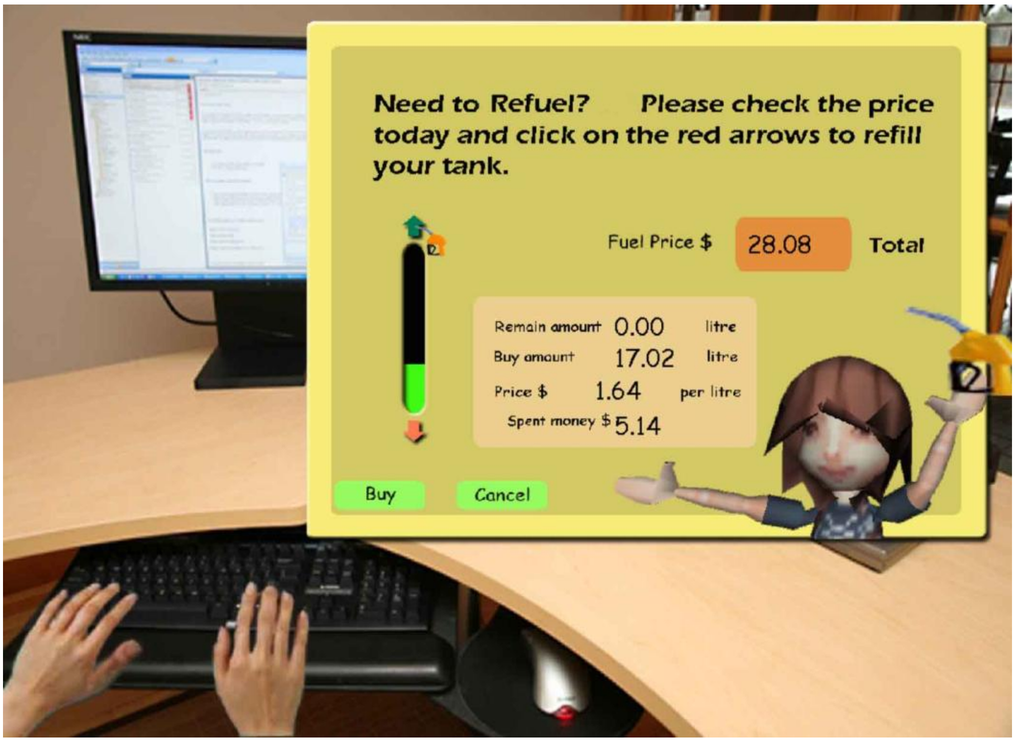


Figure 4.19: A screenshot of refuelling with the fuel price reported.

Figure 4.20 presents a screenshot of mode change options presented when the "*Yes, but I want to change mode"* button is chosen in Figure 4.18. The mode change screen provides options of: a more efficient vehicle (car/scooter), walk, bus, bicycle, or carpool. The participant can choose "back to drive" when they want to shift back from: walk, bus, bicycle, or other non–vehicular modes, to the car. TACA Sim then takes the engine size of the car that they use in a week to calculate their fuel consumption and check for fuel availability for the trip.

Figure 4.20: A screenshot of travel mode choices.

Choosing walking brings up scenes that ask if the route is known, as illustrated in Figure 4.21. If the participant does not know the route, they can click to use the map service. The map image will be presented as shown in Figure 4.22. This map image is used to help give the participant a perception of using the map to search for the route. After the image of the map, a message which says, "Now, you know how to go. Let's check the weather before taking off" is displayed. Following this route question is a weather forecast screen, which always reports rain, as shown in Figure 4.23. Participants are asked if they still want to walk in the rain. The data collected through this question will be evaluated in future work for improving the tool.

Figure 4.21: A question asks whether the walking route is known.

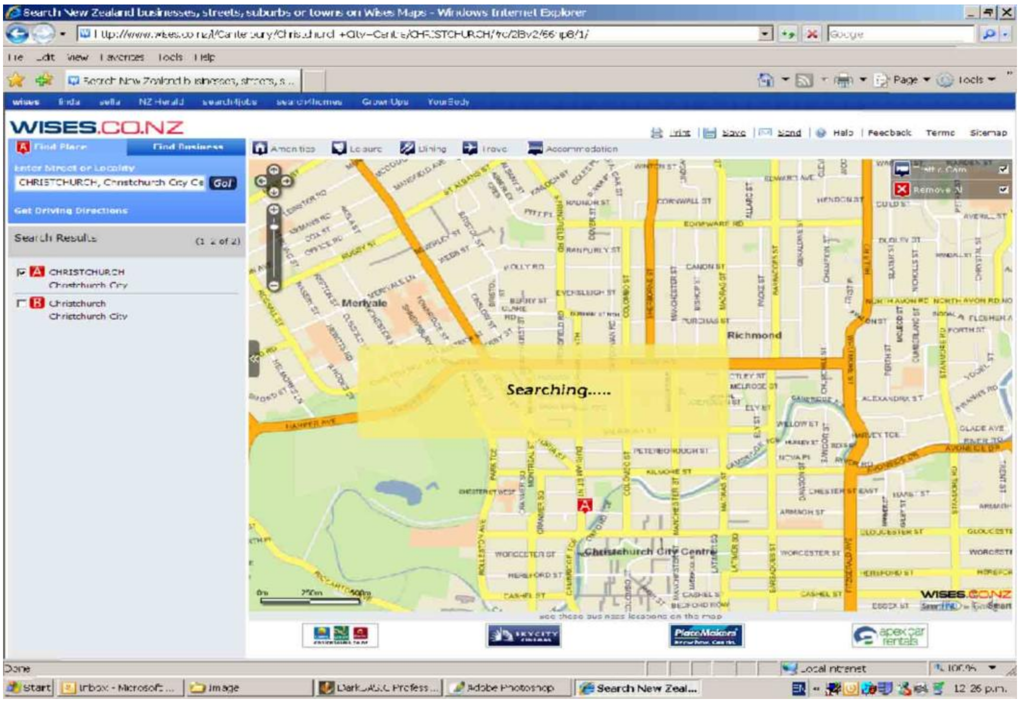


Figure 4.22: An image of a map searching for the route.

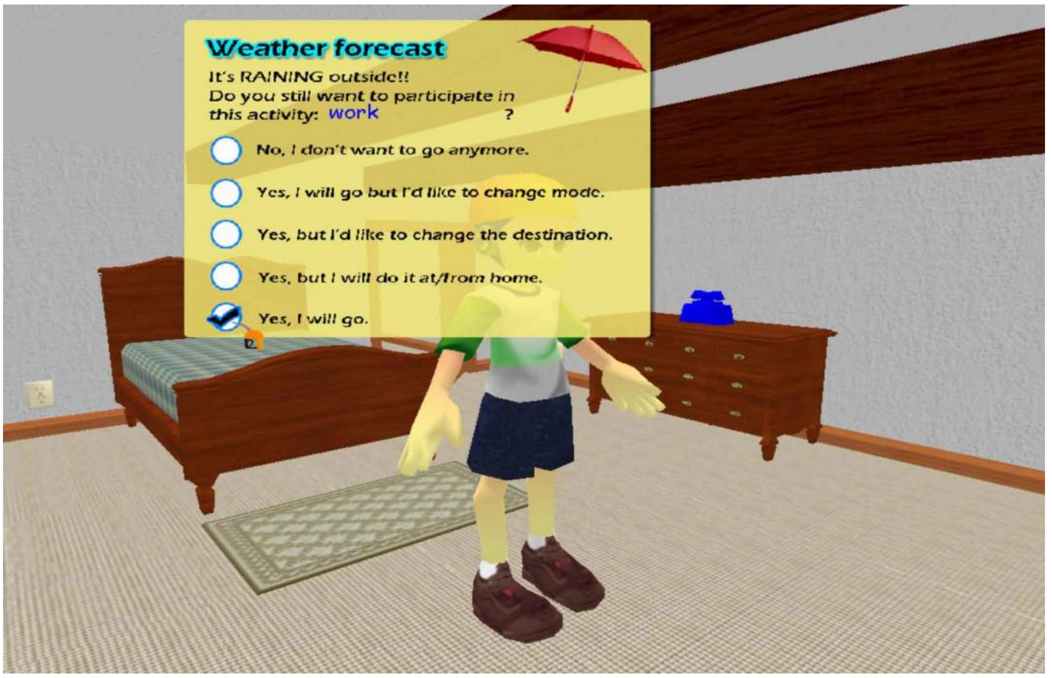


Figure 4.23: A screenshot of the weather forecast for rain.

Figure 4.24: A question asks if the participant already has a bicycle.

The participant, who chooses to travel by bicycle, will be asked whether they already have a bicycle (see Figure 4.24). If the participant decides to buy a bicycle, then TACA Sim displays a bicycle selection scene as illustrated in Figure 4.25. Figure 4.26 shows images of bicycles used in the bicycle selection scene.

Figure 4.25: A bicycle selection scene.

Figure 4.26: Images of bicycles used in the bicycle selection scene.

Similarly to the walking choices, after purchasing a bicycle the participant is asked whether they know the route, as shown in Figure 4.27. The map image in Figure 4.22 is used when the participant chooses to find a route to cycle. The weather forecast (Figure 4.23) is provided to find out whether the participant still wants to cycle in the rain. The data showing whether participants know suitable routes and their decision on whether to change travel mode or destination when it rains, is stored.

Figure 4.27: A question asks whether the cycle route is known.

For the carpool selection in Figure 4.20, the participant will be asked whether they know whom to call for a ride as shown in Figure 4.28. If the participant knows whom to call, TACA Sim presents an image of a hypothetical friend talking on the phone to allow the participant to come with him as presented in Figure 4.29. If the participant does not know of anyone, an image of a carpooling website is displayed to imitate a search for carpool availability. Figure 4.30 presents an image of carpool search website.

Figure 4.28: A screenshot illustrates the question being asked whether the participant knows of anyone with whom to carpool.

Figure 4.29: An image of a hypothetical carpool friend.

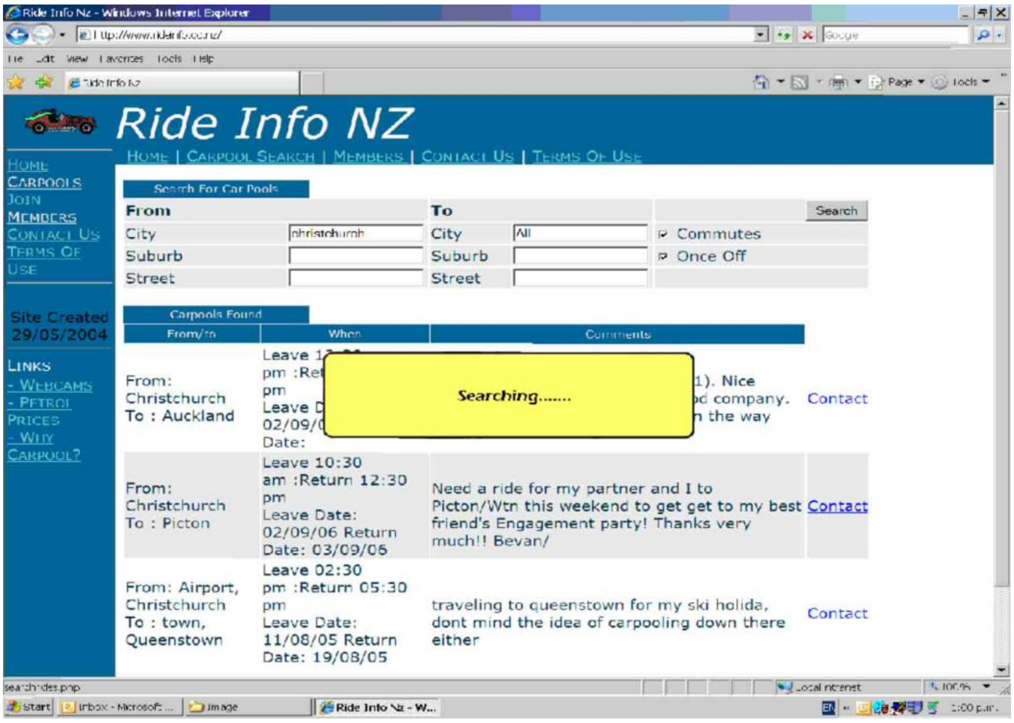


Figure 4.30: An image of carpool search website displays a search for an available carpool (Source: www.rideinfo.co.nz).

Subsequently, an image is randomly provided of a person who is available to share a ride as shown in Figure 4.31. The TACA Sim contains six car-poolers: Susan, Andre, Richard, Shannon, Muavi, and Sohel (see Figure 4.32).

Figure 4.31: A screenshot shows a ride share available.

Figure 4.32: Images of persons available for random carpooling.

If the participant chooses to take a bus, they are asked if they already know which bus to take as shown in Figure 4.33. A negative answer brings up a representative image of a web-search bus schedule scene as shown in Figure 4.34. After that a pop-up message says “Bus number (*bus number*) is coming. Let’s go to wait at bus stop.” When the participant clicks “ok”, the hypothetical images representing the bus travel will be displayed and the data of participants’ knowledge of a suitable bus route is recorded.

Figure 4.33: A question enquires whether bus information is known.

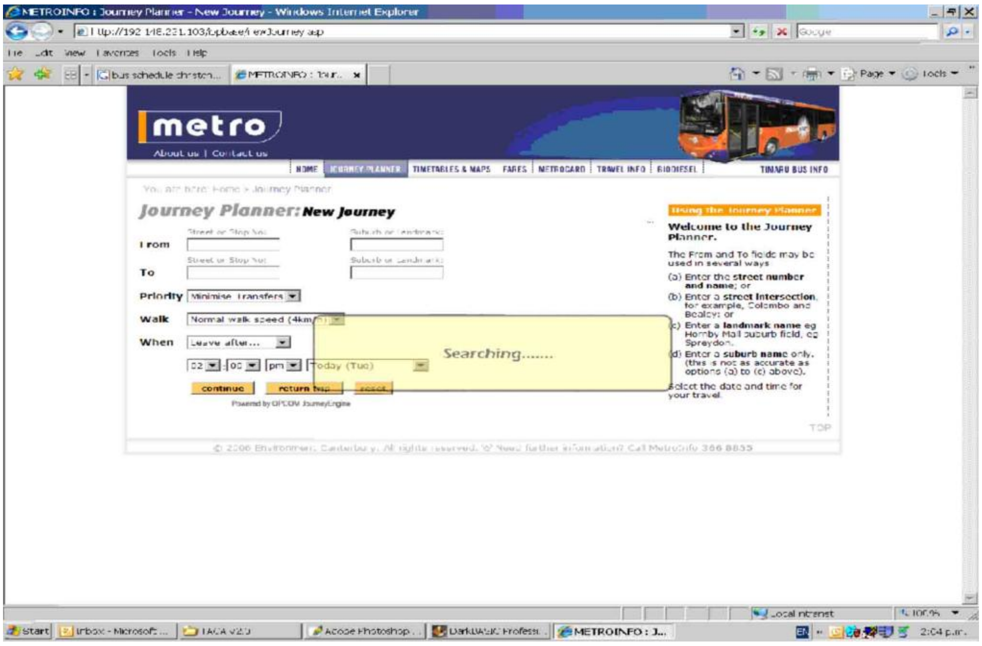


Figure 4.34: A representative image of a web-search bus schedule (Source: www.metroinfo.org.nz).

A new motor vehicle mode choice in Figure 4.20 brings up a question asking whether the participant already owns an efficient motor vehicle as illustrated in Figure 4.35. The vehicle selection scene will be provided if the participant does not have another vehicle. The participant can then buy a more efficient car or scooter, examples of which are shown in Figure 4.36 and Figure 4.37.

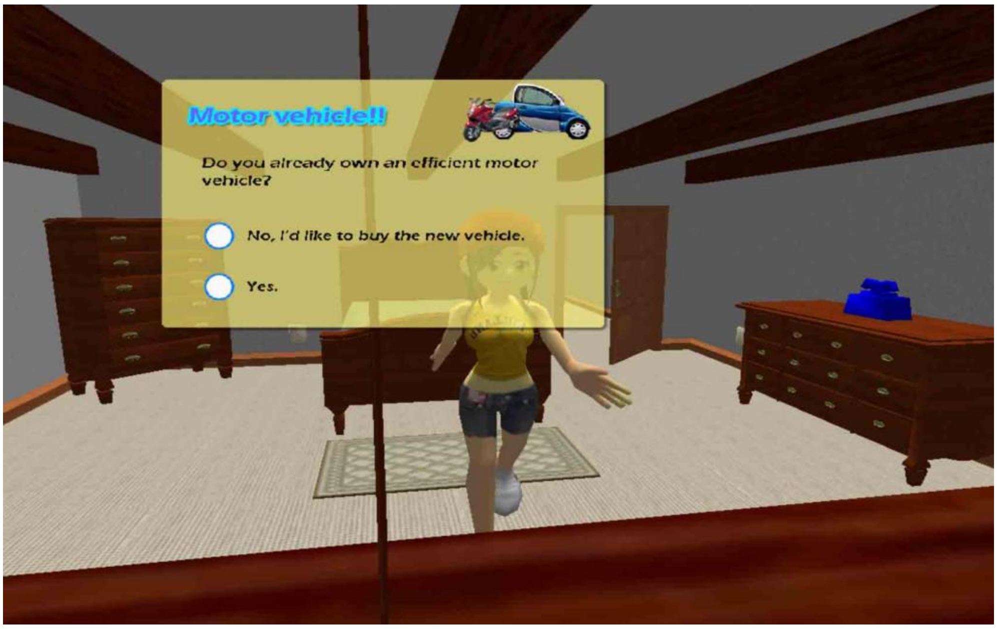


Figure 4.35: A screenshot shows the question about efficient motor vehicle ownership.

Figure 4.36: A vehicle selection scene for car buying.

Figure 4.37: A vehicle selection scene for scooter buying.

Cars used in the vehicle selection scene are:

- Toyota Prius generation II Hybrid, 1500 cc, fuel consumption rate 5 litre/100km, price $13,995.
- Toyota Prius generation II Hybrid, 1500 cc, fuel consumption rate 5 litre/100km, price $16,995.
- Toyota Prius generation III Hybrid, 1500 cc, fuel consumption rate 5 litre/100km, price $33,995.
- Honda Legend, 3471 cc, fuel consumption rate 8.8 litre/100km, price $80,000.
- Mercedes-Benz, 2034 cc, fuel consumption rate 7.7 litre/100km, price $50,000.

- Daihatsu Charade 1.0P hatch 5 5M, 989 cc, fuel consumption rate 4.8 litre/100km, price $25,000.

Scooters used in the vehicle selection scene are:

- Ludix Trend, 50 cc, fuel consumption rate 2.9 litre/100km, price $2,999.
- Jetforce, 125 cc ABS, fuel consumption rate 3.3 litre/100km, price $6,490.
- Sachs MadAss 125, 120 cc, fuel consumption rate 3.3 litre/100km, price $3,499.
- Sachs MadAss 50, 50 cc, fuel consumption rate 2.9 litre/100km, price $2,499.
- CPI Hussar 50 cc, fuel consumption rate 2.9 litre/100km, price $1,999.
- CPI GTR 150, 152 cc, fuel consumption rate 4.5 litre/100km, price $3,999.
- Suzuki B-King GSX 1300 BK, 1340 cc, fuel consumption rate 5.4 litre/100km, price $22,995.
- Honda CBR 125 R, 124.7 cc, fuel consumption rate 3.3 litre/100km, price $5,195.
- Yamaha Viro 125, 125 cc, fuel consumption rate 3.3 litre/100km, price $2,995.

If the participants already own an efficient motor vehicle, they will be required to provide the details of the new vehicle. Figure 4.38 presents a screenshot requiring the details of the vehicle that the participant intends to use. The participants are asked to provide an approximate fuel consumption rate and cost of the new vehicle in this scene. The estimated cost is used to calculate the total vehicle cost which is shown on the control panel (Figure 4.15). The fuel consumption rate is used to calculate the fuel consumption of the trip in the new vehicle, rather than estimating from the engine size. This fuel consumption rate is used because the participants' old vehicle may have the same engine size as the new efficient vehicle, hence, the fuel consumption would not reduce for their adaptation if calculated by engine size alone. The participants who already have an efficient vehicle are expected to know the approximate fuel consumption rate of their vehicle. Otherwise, the surveyor may help them to search for a similar model online.

Figure 4.38: A screenshot requiring the motor vehicle details.

Besides changing the mode of transport, the participant can also change the origin/destination. When the *Yes, but I want to change destination* button is selected in Figure 4.18, the participant calls the Google map by clicking on the "Call Map" button. The surveyor then helps them to rearrange their origin and destination addresses, and travel distance for the activity as illustrated in Figure 4.39. At the end of this audit level, TACA Sim again presents a feedback scene that compares the scores of the three rounds as shown in Figure 4.40.

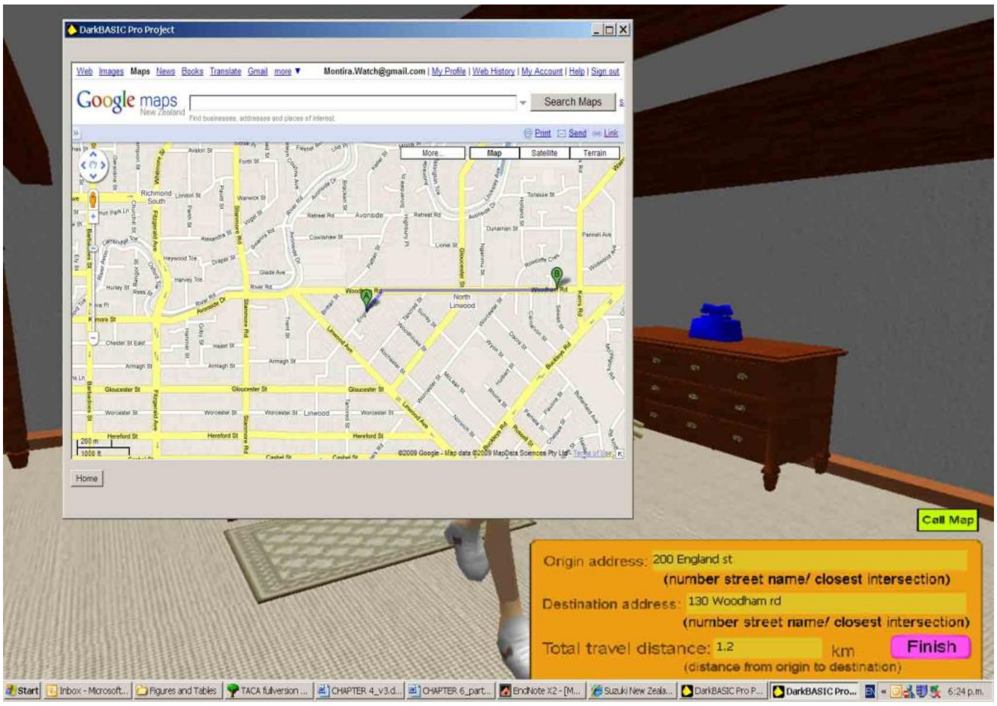


Figure 4.39: A Google map appears if the participant chooses to change destination.

TACA Sim is designed in such a way as to increase the completion rate by using the game environment. The feedback scores (car dependence, fuel intensity, inadaptability indicator) of travel behaviour at the end attract participants to complete the survey.

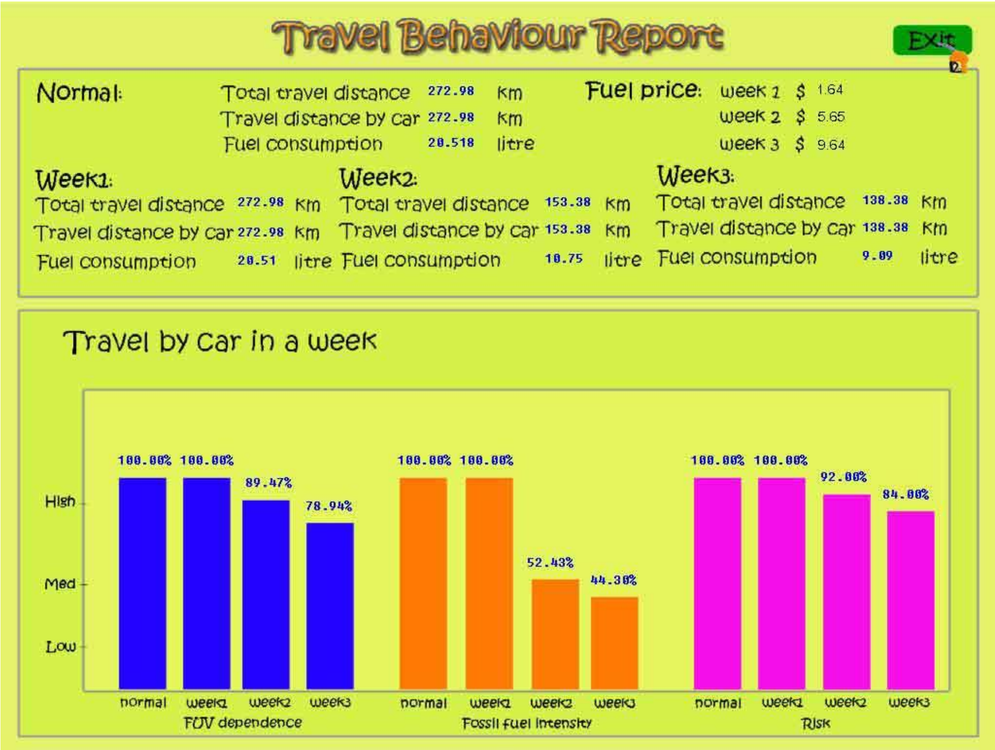


Figure 4.40: Feedback scene at the end of the travel adaptive potential survey.

The questions and provided information including the scores are designed in a way that avoids the decision bias from trying to maximising the scores. The purpose and motivations in TACA Sim are different from the commercial Sim game. The Sim game objective is to make money and buy things. Conversely, the TACA Sim game is not designed to encourage participants to maximise any scores. TACA Sim operates for a pre-determined period, while the Sim game is normally set in a full 3D environment and is open-ended. Instead of pursuing the needs of the human-controlled agent or developing its skills, TACA Sim aims at participants implementing strategies to reduce fuel use under the fuel price pressures. The colourful scenes and game-like structures are aimed to make the travel survey enjoyable, while the game is operated in a manner that encourages participants making decisions in a serious and responsible way.

4.3 Data Logging

The TACA Sim platform has three integrated levels (as shown in Figure 4.2), each collecting a different type of data and storing it into output files for the next level and for further analysis. The first level generates a data file of personal information. The second level collects travel activity and location data that can be processed for investigating travel adaptive capacity. The third level collects data on responses to fuel price pressures, to provide information about travel adaptive potential. TACA Sim consists of many programs (executable files). The data recorded in saved files from previous programs are accessed by subsequent programs. All data files of an individual participant are created into two formats: Save file (.sav) and text file (.txt). The text file is written in a comprehensible format for the analyst to easily observe and convert into another form for further analysis, while the save file is readable by the next program. During game operation, the decision-making on provided choices is collected and data logged in individual folders, named according to the user code. Figure 4.41 shows the data logging structure in an individual folder.

- **Individual folder** (name: user code)
  - **Refill tank at $1.64/litre**
  - **Refill tank at $5.65/litre**
  - **Refill tank at $9.64/litre**
  - **Change data *i* (*i*=week1, week2, week3)**
  - **Datasave folder**
    - Personal data file (sex, age, income, occupation, family status)
    - Vehicle data file (make, model. year, engine size, fuel type)
    - Trips data file (activities, departure and arrival time, distance, mode)
  - **Day *k* folder for recording normal travel pattern (*k*=Monday,**
    - Day *k* information file (name of activities, departure times, arrival times)
    - Mode information file of activity *j* (*j*= 1, 2, 3,…) (mode, alternative, purpose, vehicle details (if travel by car))
    - Travel information file of activity *j* (*j*= 1, 2, 3,…) (distance, origin, destination)
  - **Day *k* folder for activities at fuel price $1.64/litre (*k*=Monday, Tuesday,…, Sunday)**
    - Mode data file (name, travel mode of all activities)
    - Distance data file (distances, origins, destinations of all activities)
    - Weather mode data file (travel mode of all activities when it rains, knowing route or person to carpool)
    - Weather distance file (distance, origins, destinations of all activities when it rains)
  - **Day *k* folder for activities at fuel price at $5.65/litre (*k*=Monday, Tuesday,…, Sunday)**
    - Same format as above
  - **Day *k* folder for activities at fuel price at $9.64/litre (*k*=Monday, Tuesday,…, Sunday)**
    - Same format as above

Figure 4.41: Structure of data logging in an individual folder.

An individual folder contains three files and five subfolders, which are described in detail below.

- **Refill tank at $1.64/litre file**. This file holds the data on how much fuel the participant purchases when the fuel price is at $1.64 per litre.
- **Refill tank at $5.65/litre file**. This file holds the data on how much fuel the participant purchases when the fuel price is at $5.65 per litre.
- **Refill tank at $9.64/litre file**. This file holds the data on how much fuel the participant purchases when the fuel price is at $9.64 per litre.
- **Change data *i file* (*i*=week1, week2, week3)**. This file includes the summary of travel behaviour for a week. The participant's ownership of a bicycle and the information of efficient motor vehicles used in the trips are also presented in this file.
- **Datasave folder**. This folder contains three files: personal data, vehicle data, and trips data. ***Personal data file*** includes information of sex, age, income, occupation, occupation status, family status, household size, and number of school age children in the household. ***Vehicle data file*** includes information of make, model, year, engine size, fuel type, and vehicle type. ***Trips data file*** includes information of departure time, arrival time, activities, origin and destination addresses, travel distance, trip purposes, essentialities, travel mode, vehicle occupancy, and alternatives.
- **Day *k* folder for recording normal travel pattern folder (*k*= Monday, Tuesday,…, Sunday)**. A day *k* folder contains three types of files for each normal travel activity: day *k* information, mode information of activity *j*,

travel information of activity *j*. The ***day i information file*** includes name of all travel activities, departure and arrival times of each trip. ***Mode information file of activity j*** includes essentiality, travel mode, alternative, trip purpose, and vehicle details (if travelling by car). ***Travel information file of activity j*** includes travel distance, origin address, and destination address.

- **Day *k* folder for activities at fuel price $1.64/litre**. A day *k* folder holds the information on travel pattern and the travel pattern when it rains at fuel price $1.64 per litre. The folder consists of four different files: mode information, distance information, mode information when it rains, distance information when it rains. ***Mode data file*** includes the name and travel mode of all activities. ***Distance data file*** includes travel distance, origin addresses, and destination addresses of all activities. ***Weather mode data file*** includes travel modes for the activities that the participant intends to use when it rains. The information of the participant knowing the route and with whom to carpool are recorded in this file. ***Weather distance file*** includes travel distance, origin and destination addresses of the activities when it rains. If the participant decides to continue the same travel pattern when they find out it is raining, the weather mode data file and the weather distance data file contain the same information as the mode data file and the distance data file, respectively.
- **Day *k* folder for activities at fuel price $5.65/litre**. This folder holds the information of the travel pattern and the travel pattern when it rains at fuel

price \$5.65 per litre. It has the same file structure as in “Day *k* folder for activities at fuel price \$1.64/litre”.

- **Day *k* folder for activities at fuel price \$9.64/litre**. This folder holds the information of travel pattern and the travel pattern when it rains at fuel price \$9.64 per litre. The folder has the same file structure as in “Day *k* folder for activities at fuel price \$1.64/litre”.

All data logged in TACA Sim can be extracted to format as excel spreadsheets. As an example, the spreadsheets are divided into 4 types. The first type contains the personal information of the participants as shown in Table 4.3. The second type holds the information of the participants’ vehicles as illustrated in Table 4.4. The third type includes the data of trips’ characteristics for a week at the current fuel price (see Table 4.5). The fourth type contains travel demand data at different fuel prices (\$1.64/litre, \$5.65/litre and \$9.64/litre) (see Table 4.6a and Table 4.6b). The tables of trip characteristics at each fuel price pressure have a similar format to the table of travel demand data. Table 4.6b also contains the additional information i.e. whether the participants know the route, whether they already have a bicycle, whether they know whom to call for carpooling, whether they want to walk or bike in the rain, and what travel mode they would take if it rains.

Table 4.3: An example of personal information dataset.

ID	Gender	Age	Income	Occupation	Occupation status	Family status	Household size	No. of School age	No. of car in household	No. of car drive
stu104	Male	21	Under 10000	Student	FullTime	Family (including extended) with children	7	3	5	2
stu001	Male	33	40001 to 50000	Student	FullTime	Other adults only (e.g. flatmates)	6	0	5	1
STU101	Female	20	40001 to 50000	Student	FullTime	Family (including extended) with children	4	1	2	2
Stu102	Female	23	Under 10000	Student	Full time student with PT	Other adults only (e.g. flatmates)	4	0	3	1
Stu103	Male	29	15001 to 20000	Student	FullTime	Person living alone	1	0	0	0
stu106	Female	26	20001 to 30000	Student	FullTime	Other adults only (e.g. flatmates)	3	0	1	0
Stu109	Female	29	10001 to 15000	Student	FullTime	Other adults only (e.g. flatmates)	2	0	0	1
stu110	Male	27	10001 to 15000	Student	FullTime	flatting single	4	0	1	0
Stu116	Female	26	10001 to 15000	Student	FullTime	Other adults only (e.g. flatmates)	6	0	4	1
ktb16	Female	20	Under 10000	Student	FullTime	Hall of Residence	11	0	0	0
stu113	Female	19	Under 10000	Student	FullTime	Other adults only (e.g. flatmates)	13	0	3	1
stu115	Male	26	Under 10000	Student	FullTime	Married/de facto couple only	3	0	2	1

Table 4.4: An example of vehicle information dataset.

ID	Car number	Name	Make	Model	Year	Engine Size	Fuel consumption rate (l/100km)	Fuel type	Vehicle Type
stu104	1	Mini	Morris	Clubman	1977	1100	-	Petrol	Car/SW
	2	Bernie	Honda	Accord	1988	1800	-	Petrol	Car/SW
	3	Efficient car	-		2008	1500	5.5	Petrol	Car/SW
stu001	1	Bluebird	Nissan	Bluebird	1992	1800	-	Petrol	Car/SW
STU101	1	CRV	Honda	CRV	1996	2000	-	Petrol	SUV/4WD type
	2	Nissan	Nissan	Maxima	1999	3000	-	Petrol	Car/SW
Stu102	1	My Car	Toyota	Corolla	2000	2000	-	Petrol	Car/SW
Stu103	None	-	-	-	-	-	-	-	-
stu106	1	James' car	Subaru	Unknown	Unknown	1500	-	Petrol	SUV/4WD type
	2	Simon's car	Unknown	Unknown	Unknown	1500	-	Petrol	Car/SW
Stu109	1	Scooter	Kymco	Espresso	2007	150	-	Petrol	Motorbike
	2	Dean's car	Subaru	Legacy	Unknown	1500	-	Petrol	Car/SW
stu110	1	Car 1	Toyota	Unknown	1992	1500	-	Petrol	Car/SW
Stu116	1	Tor's car	Mitsubishi	Eterna	unknown	2000	-	Petrol	Car/SW
ktb16	1	Gertrude	Unknown	Unknown	Unknown	1500	-	Petrol	Car/SW
	2	Gerty	Unknown	Unknown	Unknown	1500	-	Petrol	Car/SW
stu113	1	White	Toyota	Corolla	1980	1800	-	Petrol	Car/SW
stu115	1	Car1	Nissan	Sunny	1986	1300	-	Petrol	Car/SW

Table 4.5: An example of travel pattern dataset at current fuel price.

ID	Trip	Day	Time		Travel	Origin	Destination	Distance
			Depart	Arrive	time	text	text	(Rindsfüser, et al.)
stu104	1	Monday	8:10	8:40	0:30	XXX Marshland Road	University of Canterbury	10
	2	Monday	19:00	19:06	0:06	University of Canterbury	XX Elizabeth St	2
	3	Monday	20:30	20:36	0:06	XX Elizabeth St	University of Canterbury	2
	4	Monday	23:00	23:06	0:06	University of Canterbury	XX Elizabeth St	2
	5	Tuesday	9:10	9:16	0:06	XX Elizabeth St	University of Canterbury	2
	6	Tuesday	19:00	19:06	0:06	University of Canterbury	XX Elizabeth St	2
	7	Tuesday	20:30	20:36	0:06	XX Elizabeth St	University of Canterbury	2
	8	Tuesday	23:00	23:06	0:06	University of Canterbury	XX Elizabeth St	2
	9	Wednesday	9:10	9:40	0:30	XX Elizabeth St	University of Canterbury	2
	10	Wednesday	19:00	19:30	0:30	University of Canterbury	XXX marshland Rd	10
	11	Thursday	9:10	9:40	0:30	XXX marshland Road	University of Canterbury	10
	12	Thursday	19:00	19:06	0:06	University of Canterbury	XX Elizabeth St	2
	13	Thursday	20:30	20:36	0:06	XX Elizabeth St	University of Canterbury	2
	14	Thursday	23:00	23:06	0:06	University of Canterbury	XX Elizabeth St	2
	15	Friday	9:10	9:40	0:30	XX Elizabeth St	University of Canterbury	2
	16	Friday	19:00	19:06	0:06	University of Canterbury	XX Elizabeth St	2
	17	Saturday	10:10	10:40	0:30	XX Elizabeth St	University of Canterbury	2
	18	Saturday	15:00	15:30	0:30	University of Canterbury	XXX Marshland Rd	10
	19	Saturday	20:00	20:20	0:20	XXX Marshland Rd	CHC town	5
	20	Sunday	1:00	1:20	0:20	CHC town	XXX Marshland Rd	5
	21	Sunday	9:40	10:00	0:20	XXX marshland Rd	X Gayhurst Rd, Dallington	7.4
	22	Sunday	11:40	12:00	0:20	X Gayhurst Rd, Dallington	XXX Marshland Rd	7.4

Note: X is number.

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Table 4.5: An example of travel pattern dataset at current fuel price (continued).

Purpose		Essentiality	Mode	Occu-pancy	Alternative mode			Car number
by user	**by sort**				**1**	**2**	**3**	
uni	Education	Necessary trip	Bicycle	1	Bicycle	Walk	-	-
flat	Home	Necessary trip	Bicycle	1	Walk	Ride with somebody	-	-
uni	Education	Optional trip	Bicycle	1	Bicycle	Walk	Ride with somebody	-
flat	Home	Necessary trip	Bicycle	1	Bicycle	Walk	-	-
uni	Education	Necessary trip	Bicycle	1	Bicycle	Walk	-	-
flat	Home	Necessary trip	Bicycle	1	Walk	Ride with somebody	-	-
uni	Education	Optional trip	Bicycle	1	Bicycle	Walk	Ride with somebody	-
flat	Home	Necessary trip	Bicycle	1	Bicycle	Walk	-	-
uni	Education	Necessary trip	Bicycle	1	Bicycle	-	-	-
home	Home	Necessary trip	Bicycle	1	Walk	-	-	-
uni	Education	Necessary trip	Vehicle driver	1	Bicycle	Walk	-	-
flat	Home	Necessary trip	Vehicle driver	1	Walk	Ride with somebody	-	-
uni	Education	Optional trip	Vehicle driver	1	Bicycle	Walk	Ride with somebody	-
flat	Home	Necessary trip	Vehicle driver	1	Bicycle	Walk	-	-
uni	Education	Necessary trip	Vehicle driver	1	Bicycle	Walk	-	-
flat	Home	Necessary trip	Vehicle driver	1	Walk	Ride with somebody	-	-
uni	Education	Necessary trip	Vehicle driver	1	Bicycle	Walk	-	-
home	Home	Necessary trip	Vehicle driver	1	Bicycle	Walk	-	-
out	Social visit/ Entertainment	Optional trip	Vehicle driver	1	Ride with somebody	Bicycle	Walk	1
home	Home	Necessary trip	Vehicle driver	1	Bicycle	Walk	-	1
church	Social	Necessary trip	Vehicle passenger	4	Bicycle	Walk	-	2
home	Home	Necessary trip	Vehicle passenger	4	Bicycle	Walk	-	2

Table 4.6a: An example of travel pattern dataset at fuel price $5.65/litre.

Fuel price at $5.65/L								
ID	Trip	Day	Time		Travel	Origin	Destination	Distance
			Depart	Arrive	time	text	text	km
Stu104	1	Monday	8:10	8:40	0:30	XXX Marshland Road	University of Canterbury	10
	2	Monday	19:00	19:06	0:06	University of Canterbury	XX Elizabeth St	2
	3	Monday	20:30	20:36	0:06	XX Elizabeth St	University of Canterbury	2
	4	Monday	23:00	23:06	0:06	University of Canterbury	XX Elizabeth St	2
	5	Tuesday	9:10	9:16	0:06	XX Elizabeth St	University of Canterbury	2
	6	Tuesday	19:00	19:06	0:06	University of Canterbury	XX Elizabeth St	2
	7	Tuesday	20:30	20:36	0:06	XX Elizabeth St	University of Canterbury	2
	8	Tuesday	23:00	23:06	0:06	University of Canterbury	XX Elizabeth St	2
	9	Wednesday	9:10	9:40	0:30	XX Elizabeth St	University of Canterbury	2
	10	Wednesday	19:00	19:30	0:30	University of Canterbury	XXX marshland Rd	10
	11	Thursday	9:10	9:40	0:30	XXX marshland Road	University of Canterbury	10
	12	Thursday	19:00	19:06	0:06	University of Canterbury	XX Elizabeth St	2
	13	Thursday	20:30	20:36	0:06	XX Elizabeth St	University of Canterbury	2
	14	Thursday	23:00	23:06	0:06	University of Canterbury	XX Elizabeth St	2
	15	Friday	9:10	9:40	0:30	XX Elizabeth St	University of Canterbury	2
	16	Friday	19:00	19:06	0:06	University of Canterbury	XX Elizabeth St	2
	17	Saturday	10:10	10:40	0:30	XX Elizabeth St	University of Canterbury	2
	18	Saturday	15:00	15:30	0:30	University of Canterbury	XXX Marshland Rd	10
	19	Saturday	20:00	20:20	0:20	XXX Marshland Rd	CHC town	5
	20	Sunday	1:00	1:20	0:20	CHC town	XXX Marshland Rd	5
	21	Sunday	9:40	10:00	0:20	XXX Marshland Rd	X Gayhurst Rd, Dallington	7.4
	22	Sunday	11:40	12:00	0:20	X Gayhurst Rd, Dallington	XXX Marshland Rd	7.4

Continue on next page

Table 4.6b: An example of travel pattern dataset at fuel price $5.65/litre. (continue)

Fuel price at $5.65/L								
Purpose		Essentiality	Mode	Have	Know	When	Occu-	Car
by user	by sort			vehicle	Route/Carpool	it rains	pancy	number
uni	Education	Necessary trip	Bicycle	-	-	-	1	-
flat	Home	Necessary trip	Bicycle	-	-	-	1	-
uni	Education	Optional trip	Bicycle	-	-	-	1	-
flat	Home	Necessary trip	Bicycle	-	-	-	1	-
uni	Education	Necessary trip	Bicycle	-	-	-	1	-
flat	Home	Necessary trip	Bicycle	-	-	-	1	-
uni	Education	Optional trip	Bicycle	-	-	-	1	-
flat	Home	Necessary trip	Bicycle	-	-	-	1	-
uni	Education	Necessary trip	Bicycle	-	-	-	1	-
home	Home	Necessary trip	Bicycle	-	-	-	1	-
uni	Education	Necessary trip	Efficient car	Have	-	-	1	3
flat	Home	Necessary trip	Efficient car	Have	-	-	1	3
uni	Education	Optional trip	Carpool	-	Unknown	-	2	-
flat	Home	Necessary trip	Carpool	-	Unknown	-	2	-
uni	Education	Necessary trip	Bus	-	Known	-	1	-
flat	Home	Necessary trip	Bus	-	Known	-	1	-
uni	Education	Necessary trip	Bicycle	Have	Known	Bicycle	1	-
home	Home	Necessary trip	Bicycle	Have	Known	Bicycle	1	-
out	Social visit/ Entertainment	Optional trip	Walk	-	Known	Bus	1	1
home	Home	Necessary trip	Walk	-	Known	Bus	1	1
church	Social	Necessary trip	Vehicle passenger	-	-	-	4	2
home	Home	Necessary trip	Vehicle passenger	-	-	-	4	2

CHAPTER 5

A CASE STUDY OF AN ACTIVITY CENTRE

5.1 An Overview of the Case Study

Survey planning is the first step in the survey method and is necessary in order to obtain high quality data. For a case study, the first step was started by selecting a study area. The participants in the study area were expected to use the same transport infrastructure. The travel activity and income level of participants were then considered in the study area selection. The high income is assumed to have bigger size of disposable income than the low income. Participants were categorised into three groups to represent different roles and income levels in order to account for different impacts on decisions when the fuel price pressure is introduced. After an area was selected, methods for conducting the survey and collecting data were subsequently designed. The regional information and transport system of the study area are described in the following sections.

5.2 University of Canterbury

The University of Canterbury (UC) in Christchurch was selected for this study as its profile contains students and staff with different travel activities and a wide range of income levels. Students and staff from many residential locations travel to the same destination, i.e. UC, with different purposes (education and work) using the same transport system with different travel choices. The University of Canterbury reported that the UC was the destination for over 22,000 people in 2009 (UC, 2009). The university has 22,403 students and 1,672 full time staff (UC, 2008, 2009). The latest version of the UC Data Handbook reports that 52.2% of the students are female and 47.8% are male, while staff are 48.2% male and 51.8% female (UC, 2008).

Figure 5.1 shows the UC is located in Ilam suburb, about 5 kilometres from the Christchurch city centre. The university's ground area covers 87 hectares (UC, 2009). It is bound by four main roads: Ilam Road, Creyke Road, Clyde Road and Waimairi Road. Six bus routes serve the UC campus (UCSustainability, 2009).

5.3 Christchurch

Christchurch is situated in the Canterbury region, near the centre of the east coast of the South Island as shown in Figure 5.2. It is the largest city in New

Zealand’s South Island, and the country's second-largest urban area. Christchurch city has a land area of 141,260 hectares (CCC, 2007). It comprises the central city, 24 inner suburbs, 42 outer suburbs, and 8 satellite towns (StatisticsNZ, 2006). The population of Christchurch is 348,435 (CCC, 2007).

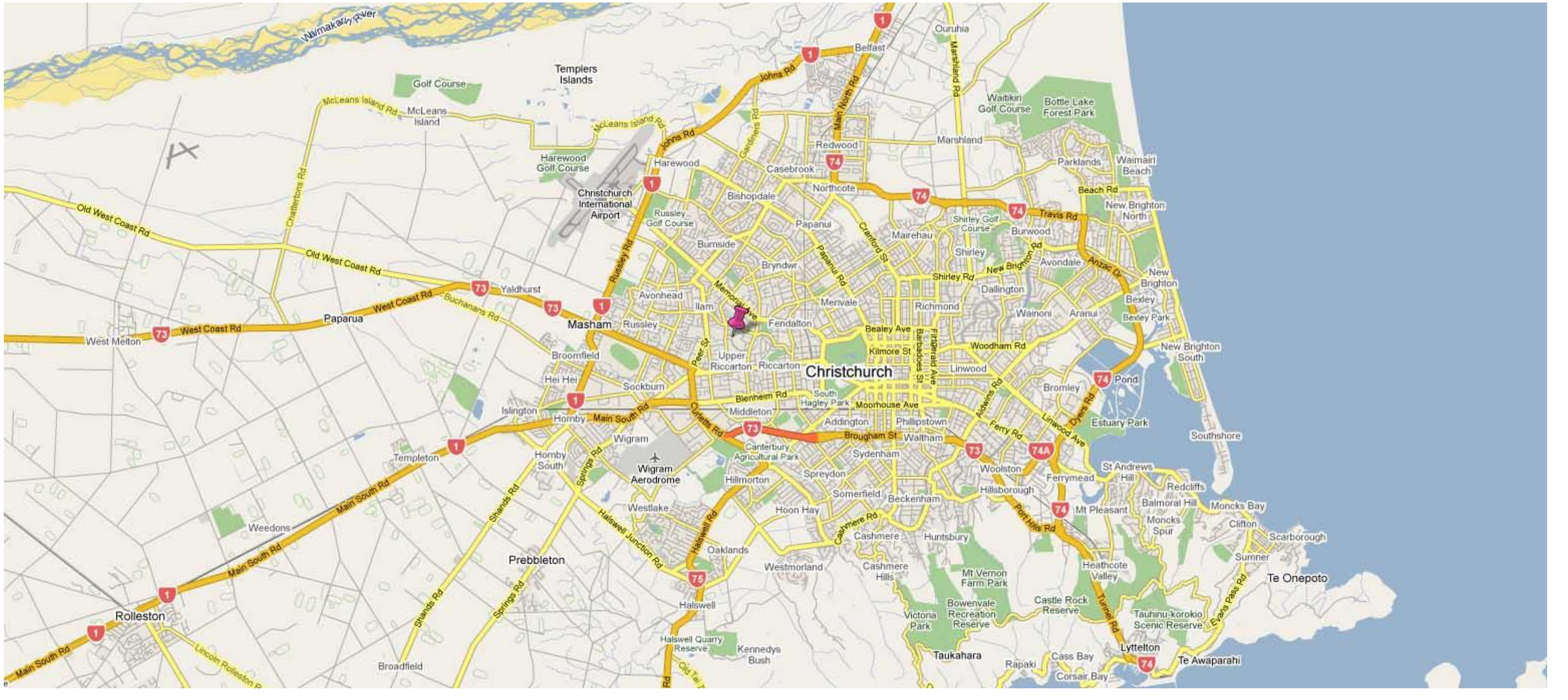


Figure 5.1: University of Canterbury in Christchurch (Source: Google map, accessed on 22/11/2009).

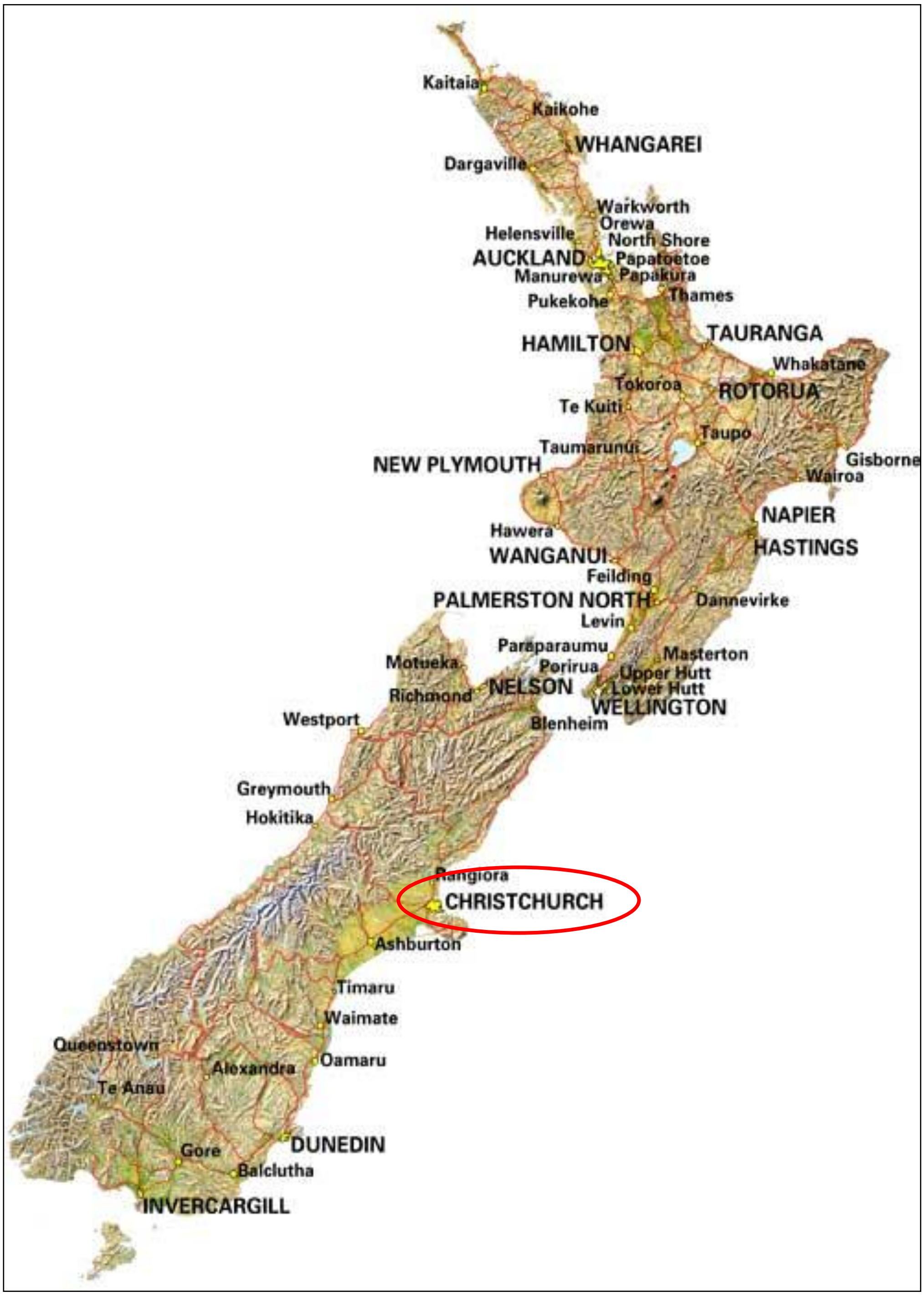


Figure 5.2: New Zealand map locating Christchurch city
(Source: www.newzealand.govt.nz).

5.3.1 Transport in Christchurch

Christchurch is easily accessible via an international airport, roads and rail services. Local and long-distance buses and long-distance trains serve as land transport in Christchurch. Currently, the local bus service is provided by Environment Canterbury (ECan), Christchurch City Council, and other bus operators such as Red Bus Ltd and Christchurch Bus Services Ltd (METRO, 2010). Figure 5.3 shows an example of a Metro bus in Christchurch. The Bus Exchange is the main point in the city centre for transit between routes. Figure 5.4 presents bus routes from the city centre. Bus fare is shown in Table 5.1. The frequency of bus in Christchurch are varied from 10-30 minutes during peak time on weekday, and from 1-2 times an hour during off-peak and on weekend. There are 5 bus routes that come by UC. The frequency of these 5 bus routes are shown in Appendix H. A specific bus route that enables public transport to filter quickly during peak hours is in Papanui area.

Table 5.1: Bus fare in Christchurch.

Method	Fare type	Adult	Child*	Notes
Cash fare	Single Trip	$3.20	$1.60	Includes one free transfer within 2 hours
Metrocard	Single Trip	$2.30	$1.15	Includes unlimited free transfers for the first 2 hours
	All-Day	$4.60	$2.30	Maximum pay per day for as many trips as you like
	Weekly	$23.00	$11.50	Use your Metrocard Monday to Friday - All-Day Travel - and your weekend travel is free

*__Note:__

- Under the age of 5 travel free when accompanied by a fare-paying passenger.
- Under the age of 18 pay approximately half-price.

In addition to the bus services, the Christchurch City Council has established a network for cycling on roads. There is a tram loop restricted to a track in the central city as a tourist attraction. The Ministry of Transport New Zealand (MOT, 2007) has reported that car use remains the dominant form for Christchurch transport (72%) as illustrated in Table 5.2.

Figure 5.3: A Metro bus in Christchurch.

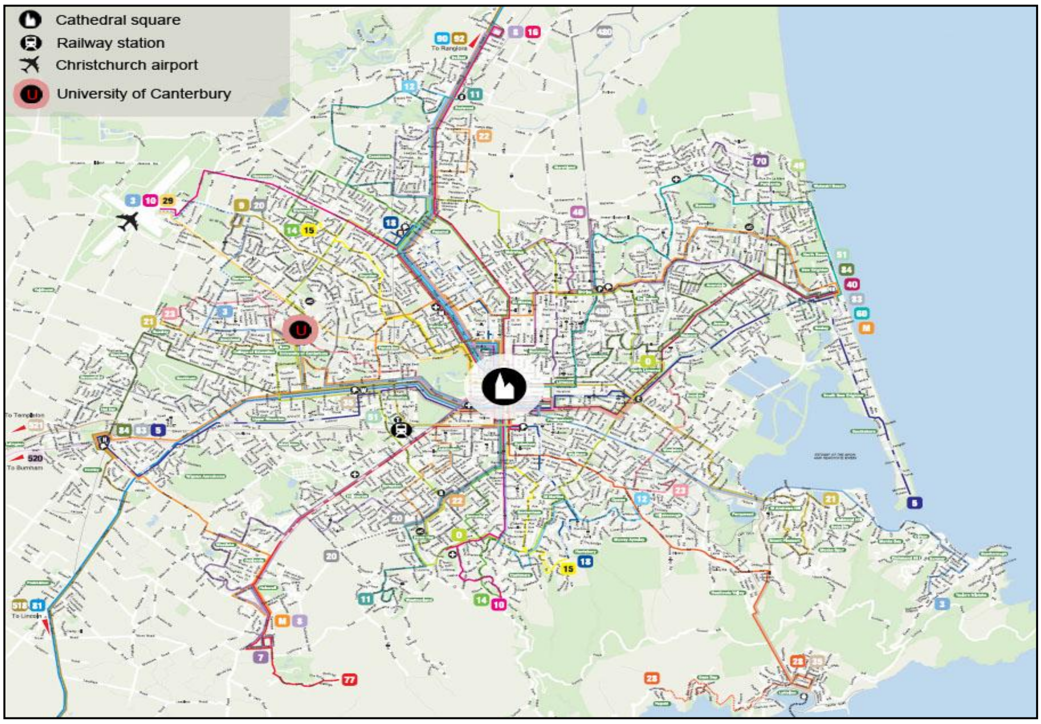


Figure 5.4: Christchurch map with bus routes and location of UC (Source: www.metroinfo.org.nz).

Table 5.2: Mode share of trip legs for the five main metropolitan areas (MOT, 2007).

	Mode share of trip legs				
2003-07	**Auckland**	**Wellington**	**Christchurch**	**Hamilton**	**Dunedin**
Trip legs in sample	*16289*	*14784*	***10882***	*3533*	*4078*
%household travel trip legs					
1.Car/ van driver	51%	47%	**48%**	55%	49%
2.Car/van passenger	26%	24%	**24%**	27%	27%
3.Pedestrian	17%	22%	**21%**	12%	19%
4.Cyclist	0%	1%	**2%**	2%	1%
5.PT (bus/train/ferry)	3%	4%	**3%**	2%	2%
6.Motorcyclist	0%	0%	**0%**	0%	1%
7.Other	2%	1%	**2%**	3%	1%
Total	100%	100%	**100%**	100%	100%

PT= Public Transport

5.4 Survey Preparation

This section describes the preparation before conducting the survey. The section includes the trial plays, design of the sample size, and assumptions used in the survey.

5.4.1 Trials

The TACA Sim tool was trialled with more than 10 volunteers to ensure that the questions asked in the survey game were understandable, and the TACA Sim software worked without problems. The participants were asked to provide their travel activities in a week. The average time for completion of the first two survey levels was 30 minutes with a maximum of 45 minutes and a minimum of 20 minutes. The transport energy use reduction potential audit level took 20 to 40 minutes. The principal participants included postgraduate students (low and medium income), and academic staff (high income) at the University of Canterbury as well as several other people. All participants were given a basic instruction (approximately 5 minutes) about the purpose of the TACA Sim survey and the style of questions included before starting the game. The volunteers were monitored during the trial. Problems that the volunteers encountered during the trial were recorded and recurring problems included:

- A participant did not have a certain travel pattern and cannot perceive what they normally do in a week. Instead, any one-off travel activities they engaged in over the previous week were used for the survey to represent normal travel demand pattern for travelling to errands, social engagements or entertainment activities. However, the participants declared a difficulty in perceiving their change potential for the trips that occurred in their last week's activities, but would only occur occasionally in their normal life.
- A participant had a perception that their income would increase along with the fuel price. They then perceived themselves to be able to afford the high fuel prices. The high fuel price therefore did not have an effect on their travel decision.
- The travel adaptive potential survey level was too long because the participants must wait for the counting time to end each playing week. Thus, an "Accept price" button was created to cut the playing week when the fuel price is acceptable (see Figure 4.14).
- The term "Risk" on the feedback scene was difficult to understand without explanation from the surveyor.
- The programme would only allow the keystroke function to be operated slowly. Consequently, the survey took longer than should have been necessary.

Additionally, minor technical errors also occurred. Once the pros and cons of each question had been discussed and agreed on, the questions used in the game were modified and the software was debugged and tested again before launching the survey.

5.4.2 Sample Size and Clusters

This study use convenience sampling method. The convenience sampling method is a type of sampling which involves the sample being drawn from a part of the population that is close to hand. The samples may be drawn through meeting the person or finding them through technological means such as the internet or through phone. The person will participate the survey when he or she is available (Fink, 2006).

In this study, the UC population was categorized into three clusters: students, general staff, and academic staff, as these were anticipated to represent low, medium, and high income levels, respectively. Roscoe (1975) proposed “rules of thumb” that are used in most behavioural research for determining sample sizes which state these are recommended to be between 30 and 500. A sample size of at least 30 for each category is suggested if the samples are broken into subsamples (e.g. low income/medium income/high income, males/females, etc.) (Sekaran, 2002). Following the “rules of thumb”, more than 30 participants of each cluster (155 participants in total) were defined as a sample size in the survey. The student cluster has 54 participants, the general staff cluster has 56 participants, and the academic staff cluster has 45 participants.

The travel adaptive potential survey aimed to investigate changes of persons who conduct car trips, as they might be affected by fuel price pressures. In the sampling for this survey level, a criterion was defined with an expectation that the simulation of fuel price pressures in TACA Sim would have an impact on the participant’s travel decisions. At least a 30% share of car trips or 30% of travel kilometres was taken as a baseline. This criterion is crucial as non drivers or the participants who consider themselves consume less fuel would not have a clear idea about what they may do to reduce fuel use. Survey invitations were continued until a valid sample of 30 participants in each cohort were surveyed who met the baseline criteria.

5.5 Invitation Method

Email, and paper advertisements were selected as the means to contact the respondents in this survey for the UC case study. The survey was begun by sending out the invitation email to the samples i.e. general staff and academic staff. The invitation method used for sampling students was slightly different from that for general staff and academics. The inclusion of incentives in the emails and advertisements was expected to increase the response rate. This was also anticipated to increase the distribution of the samples. The incentives used in this research were not related to any particular mode of transport and any particular environmental attitude (suggested by Bonsall (2009)). The detailed information on the survey methods in each sample group is presented in the following subsections.

5.5.1 Student Survey

The student samples in this study were in two groups: undergraduate students and postgraduate students. These two groups were subjected to different sampling methods. It is impossible to access the university undergraduate students' database without permission, so the undergraduate students' email was not reachable. Therefore, "win an iPod" leaflets as shown in Figure 5.5 were implemented for undergraduate students to persuade them to participate in the survey. The 50 leaflets were posted all over the university and the information on the leaflets included an offer of an iPod draw with a 1 in 30 chance. The objective of the study and approximate survey time were presented briefly in the advertisement.

Figure 5.5: An invitation leaflet used to encourage undergraduate students to participate in the survey.

Additionally, the postgraduate students were invited to participate in the survey via email. All student surveys were conducted on a personal computer at the Advanced Energy and Material Systems (AEMS) Lab.

5.5.2 General and Academic Staff Survey

Seven hundred invitation emails were sent to general and academic staff. The email stated the goal and purposes of the survey and the approximate survey time. It also gave the reasons for, and information on, the benefits that the respondents could get from the survey. The content in the email assured the anonymity of the respondents. Additionally, the email included the incentive of a gift for the respondent's participation. Figure 5.6 illustrates the email sent to postgraduate students and staff.

Dear ...<name>...,

We would like to invite you to participate in a survey, which uses a novel computer-based approach. You may have seen this research featured in the staff newsletter. We are undertaking research to understand how people adjust their travel behaviour during this time of uncertainty in oil prices.

The survey is being carried out as a part of the Doctor of Philosophy degree in Mechanical Engineering and has been approved by the University Ethics Committee. The results will be anonymous but will be published through the New Zealand Transport Authority, which has funded the research project. We also anticipate that the survey findings will be of interest to the media.

The survey is fun and interactive, and is carried out on computers in the engineering building. The survey normally takes around 30-50 minutes to complete. You will learn something about your own travel behaviour (e.g. fuel consumption, car dependence, your transport score compared to others…), and you will receive a little thank you gift.

The survey is completely anonymous and the information you provide will be used for academic research and statistical purposes only.

Either you can choose to come or I can visit your office for the survey. Please contact me at the email below. We will arrange survey times to suit your schedule.

Yours sincerely,

Figure 5.6: An invitation email sent to postgraduate students and staff.

The email specified the receiver individually in order to encourage the receiver to reply so that the response rate could be improved. The respondent could either choose to come to the AEMS Lab, or the researcher would visit their office for the survey to facilitate the survey participation for the respondent who may have very limited time. A follow-up email as shown below in Figure 5.7 was sent again after three weeks to remind any respondents who did not reply to the first email about the on-going survey.

> *Dear ..<name>..,*
>
> *I would like to remind you of our travel adaptation survey. You might have forgotten or been busy, but the survey is still on-going and we would be happy if you could participate.*
>
> *The research aims to understand how people adjust their travel behaviour during this time of uncertainty in oil prices. It is fun and interactive, and is carried out on computers in the engineering building. The survey would take around 30-50 minutes. As a thank you for participating in the survey, you will receive a $5 cafe voucher.*
>
> *I will arrange survey times to suit your schedule. Please suggest to me the date and time when you will be available. Either you can choose to come to my office or I take my laptop to your office. Please let me know what you would prefer.*
>
> *Kind regards,*

Figure 5.7: A follow-up email sent to staff.

5.6 Conducting the Survey

The TACA Sim survey was conducted at the University of Canterbury, New Zealand. The survey was achieved with response rate 22.1% under time and budget constraints. The travel adaptive capacity survey level was carried out during September 2008 to May 2009 (spring to autumn). The fuel prices for petrol 91 during the survey varied between \$1.96 and \$1.49 per litre. The average fuel price over the travel adaptive capacity survey period was \$1.67 per litre. The travel adaptive potential survey level was conducted from February to May 2009. During the adaptation survey, prices for petrol 91 varied between 1.72 New Zealand dollars per litre (\$/litre) and \$1.54/litre. The average fuel price at the time of the survey then was \$1.62/litre.

Before the survey started, the participant signed a consent form as shown in Figure 5.8.

CONSENT FORM

Travel Activity Constraint Adaptation Simulation (TACA Sim)

I have read and understood the description of the above-named project. On this basis, I agree to participate as a subject in the project, and I consent to publication of the results of the project with the understanding that anonymity will be preserved.

I understand also that I may at any time withdraw from the project, including withdrawal of any information I have provided.

I note that the project has been reviewed ***and approved*** by the University of Canterbury Human Ethics Committee.

NAME (please print):
…………………………………………………………….

Signature:

Date:

Figure 5.8: A consent form used in the TACA Sim survey.

A five-minute instruction was given to the respondent to explain the research objective and survey structure. The participant then was provided help by entering in data, operating Google Maps, clarifying the meaning of questions and prompting the participants to recall their travel activities. This was to ensure that the data was input correctly, to minimize data input mistakes owing to the participant's misunderstanding of the questions and reduce respondent burdens. Besides the personal information and the car/motor vehicle information, the participants were asked to provide the trips that they normally make to participate in the activities in a week (see Figure 4.6). On travel diary, multimodal trips are recorded separately as trip legs connected to the departure and arrival time, origin, destination, mode, and route that the participants take. This information is used in shaping a core travel pattern. This core pattern is expected consistence in long term under normal situation, thus a clear perception for respondents to perceive their adaptive potential. A feedback form was given to the participant at the end of the survey for their assessment of the design.

In travel adaptive potential survey level, the simulation of fuel price pressures was introduced as a signal to the participants. The participants received this fuel price pressure signal via the interface on the screen and decided whether and what trips to modify. At beginning of the survey, the participants were told to assume that only the fuel price had risen, while the transport systems, individual's income, and other factors remain the same. This is to confine the respondents' perception to focusing on their current situation and existing transport systems so that unchanged travel behaviour from an overly optimistic perception can be avoided. An example of overly optimistic perception is that a person perceives his income to be raised along the fuel price increase. The person then assumes that he can afford to purchase fuel and ignore the price pressure.

Some participants did not continue the travel adaptive potential survey level on the same day as the travel adaptive capacity survey level. Those participants were asked to confirm their existing travel pattern when they returned for the survey. This is to ensure that the participants did not change their travel pattern. The participants who changed their travel pattern were asked to modify their travel activities in the travel diary before continuing the survey. This increased the expected survey time. However, this case applied to only two participants who changed residence after they participated in the first two survey levels. The participant is shown information about their travel behaviour and car dependence at each stage of price pressure for self-evaluation once the game is over. A feedback form for the travel adaptive potential survey was provided to the participants when they completed the survey. Additionally, the participants' comments on the TACA Sim design and their opinions about the changes due to the fuel price pressures were noted for analysis. An informal conversation is also opened so that the participants can explain to the surveyor the perceived consequences of the scenario, the difficulties in coping with the situation and the reasons for not being able to adapt if they require (as suggested by Faivre d' Arcier, Andan & Raux (1998)).

CHAPTER 6

FEEDBACK AND VERIFICATION

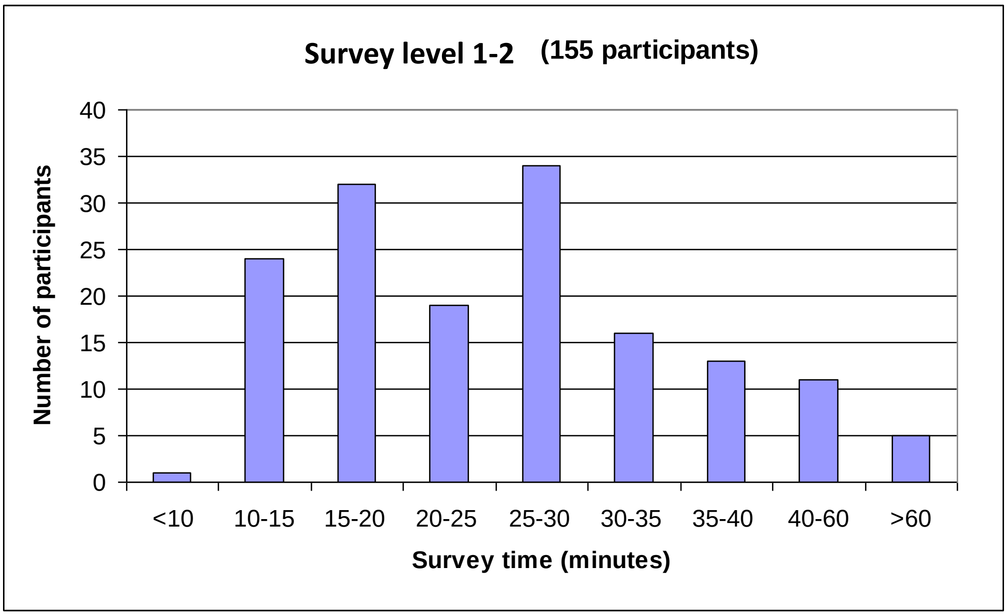
6.1 Introduction

This chapter describes the participants' feedback on the TACA Sim design and the verification. The participants' comments from the surveyor's notes are also used to highlight the feedback results. For verification, the data of the University trips collected by TACA Sim was compared to the data from the university online-survey taken in 2008. The participants' intention changes after participating the survey shows that the immersive environment survey was effective in helping the participants to perceive the situation of fuel price pressures.

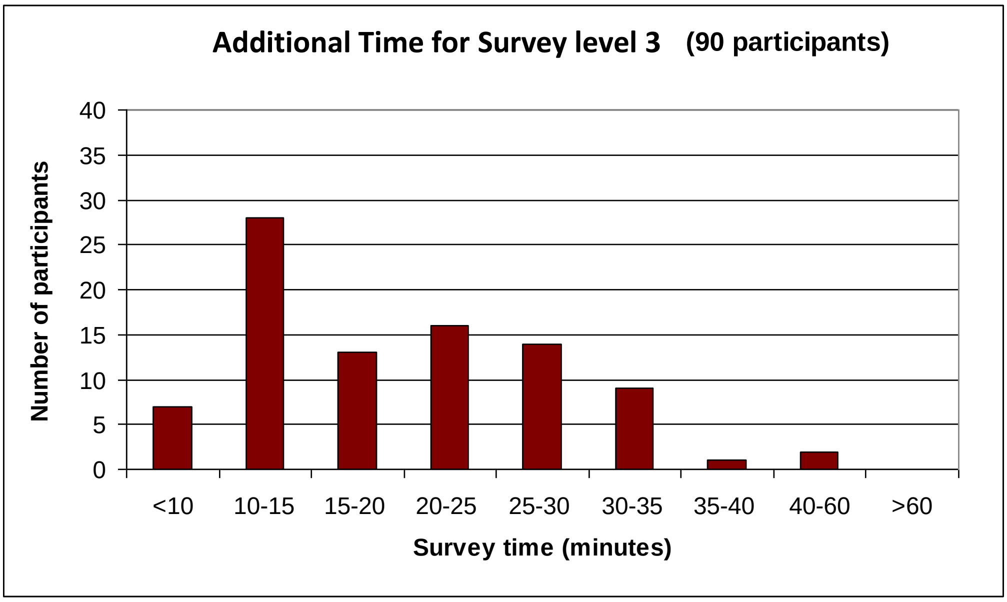
6.2 Survey Time

Survey time has not been widely reported in travel surveys. It is also difficult to generalise about how long people can be studied (Fowler, 2009). The quality and completeness of the data are the main concerns of the survey. However, long survey times can reduce the participants' willingness to provide information on their trips. From the surveyor's notes, a person stated that she reduced the number of her trips to hasten the process after she spent 34 minutes on level 1-2 of the TACA Sim survey. *"The survey is too long and complicated. I declared a reduced number of trips to get it over."* (Staff, female, age 42) The person, therefore, was excluded from the results analysis of case study.

In the TACA Sim survey, a hundred and fifty-five participants completed the travel adaptive capacity survey level (level 1-2 of the TACA Sim) with an average time of 28 minutes. Out of 155 participants, 90 participants continued on to the travel adaptive potential survey level (level 3). They spent another 21 minutes on average in level 3. Figure 6.1 shows the distribution of time that participants spent in each level. From the participant feedback, 3 participants out of 76 participants declared that the survey was too long. These 3 participants spent more than 60 minutes on level 1-2 of the survey. Out of 76, 9 participants stated that the survey was relatively long. They took 30-60 minutes to complete level 1-2 of the survey. The datasets in TACA Sim provided by the participants are assumed to be completed as they contain mainly the normal weekday trips to university and weekend trips. The survey time, however, is a major issue that can be improved in the future design by developing the software on another platform that allows fast operation and adding copy function to enable copying single trip.



(a)



(b)

Figure 6.1: Distribution of survey time spent in (a) the Travel Adaptive Capacity Survey level and (b) the Travel Adaptive Potential Survey level.

For TACA Sim used in this study, the "copy (day)" function was developed to minimise the survey time, yet the survey time depends on the number of days repeated and the number of total trips in a week. Figure 6.2 shows the correlation of time spent on the survey at level 1-2 and the ratio of repeated days per number of total trips. The participants who have more trips varying each day tended to spend more time on the survey than those who have the same travel pattern every day. Also, the participants who conduct more trips tended to take more time on the survey than those who have fewer trips.

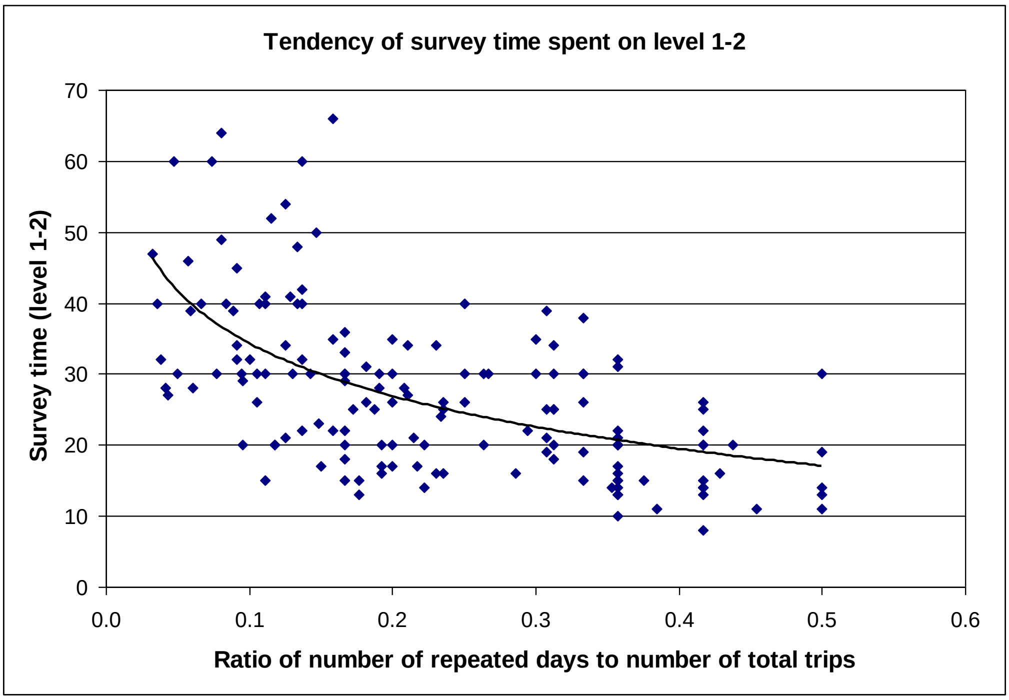


Figure 6.2: Correlation of time spent on the survey at level 1-2 and ratio of number of repeated days to number of total trips.

6.3 Participant Feedback on the TACA Sim Design

The participants were asked to rate their satisfaction with the function and design of each survey level. Less than 5% of all participants declared that they did not have a routine travel activity. They were required to provide the last week's travel activities in order to represent their travel pattern. However, these participants were not included in the survey level 3.

Feedback on the design of the survey level 1-2 was provided by 76 out of 155 participants. Figure 6.3 and Figure 6.4 show the feedback results of the survey level 1-2. It is important to note here that this feedback is based on responses from individuals in a university who may not represent the general public. Most participants (72%) did not choose the TACA Sim survey because they were interested in a computer-based survey (Question 1). This shows that the participants who took the survey were motivated by other factors such as interest in the topic, an incentive (gift voucher) and contributing to the PhD research of the author.

FEEDBACK ON THE SURVEY DESIGN (Total 76 participants)

1) Did you choose to participate in the TACA Sim survey because it's a computer-based survey? [**17%**] Yes [**72%**] No [**11%**]N/A
2) How do you feel about the time to do the survey in this project?
   [**84%**] Acceptable [**12%**] Relatively long [**4%**] Too long
3) Are language, designed buttons and interface functions easy to understand? [**82%**] Yes [**3%**] Middle [**4%**] No [**12%**] N/A
   Comments (if any) ___________**see Table 6.1**
4) Did the questions and map in TACA Sim help you to perceive the travel alternatives (e.g. mode, route) you may have in order to reduce your travel time and fuel consumption?
   [**32%**] Yes [**54%**] No [**14%**] N/A
5) Does the feedback scene at the end help you realise your personal travel behaviour?
   [**13%**] Strongly agree [**54%**] Agree
   [**18%**] Partly agree and partly disagree [**4%**] Disagree
   [**0%**] Strongly disagree [**11%**] N/A
   Comments (if any) _________**see Table 6.2**
6) Did you enjoy the TACA Sim survey (compared to a paper survey)?
   [**12%**] Strongly agree [**60%**] Agree
   [**12%**] Partly agree and partly disagree [**12%**] N/A
   [**4%**] Disagree why? ____**see Table 6.1**
   [**0%**] Strongly disagree why? ____**see Table 6.1**
7) Were you surprised about your travel behaviour as reported in the feedback scene (the last scene)?
   [**13%**] Yes [**74%**] No [**13%**] N/A

Note: N/A=no answer

Figure 6.3: Feedback results on the travel adaptive capacity survey level.

FEEDBACK ON THE SURVEY DESIGN (continued)

8) Do you feel that the information provided in the TACA Sim survey was useful for your travel pattern management in the future?

   [**4%**] Strongly agree [**20%**] Agree

   [**34%**] Partly agree and partly disagree

   [**25%**] Disagree [**4%**] Strongly disagree [**13%**] N/A

9) How do you feel about the feedback scene (the last scene)?

   see Table 6.2

10) Which scene of the TACA Sim survey did you like the most?

   see Table 6.2

11) Would you like to participate in the next TACA Sim adaptation part (approx. 30 minutes)? *Invitation email will be sent later*.

   [**78%**] Yes [**11%**] No [**12%**] N/A

12) Comments (if any):

Note: N/A=no answer

Figure 6.4: Feedback results on the travel adaptive capacity survey level (continued).

The results of the feedback also show 82% agreed that the language, designed buttons, and functions in TACA Sim are easy to understand. However, some participants suggested improvement in the "Tab" key function, colour design and the terms used in TACA Sim. Their comments on Question 3 are shown in Table 6.1.

Table 6.1: Comments on Question 3: Are language, designed buttons and interface functions easy to understand?

Comments on Question 3	**Number of participant**
Participants who ticked "Yes"	
Tab key does not work	2
Simple but need explanation	1
Cute animation	1
Could be easier	1
Fun and exciting	1
Boxes/buttons not always in expected order	1
Mostly easy	1
If some order in the question is necessary, it is not always clear	1
Some categories overlap	1
Nice design	1
Needed guidance on map	1
Participants who ticked "No"	
Colour is hard to see	1
Some problems I needed help with	1
Participants who ticked "Middle"	
I did need someone to help	1
Slow for typing	1
Participant who did not tick any choice	
Usability and stability should be improved	1

Question 4 (Figure 6.3) shows 32% were interested in the survey questions that encouraged them to ponder their alternatives. For instance, take the case of one staff member who was affected by questions about alternatives. *"It made me realise I can still make changes."* (Staff, male, age 36) Upon completion of the survey, several participants requested repeat playing on the scores and map scene to discover the transport mode and shortest route that may reduce their travel time and fuel consumption. One participant wanted to re-input the vehicle details of his second car, which is more efficient than the car he usually

uses. *"I would like to compare the fuel consumption of driving all week between two cars."* (Staff, male, age 41)

Question 5 (Figure 6.3) presents 67% agreeing that the feedback scene in TACA Sim helps them realise their personal travel behaviour. An example comes from the following participant after receiving the scores from the feedback scene:

A student (age 30) was a car passenger for all fuel-using vehicle trips. She did not change modes, and did not express concern about rising fuel price. She did not consider that her friend might decide not to drive the car. However, she realized her fuel price exposure at the end of the survey from the feedback scenes.

The result from Question 5 also shows 22% disagree that the feedback scene enlightens the participants about their travel behaviour. This is because some of the participants are already aware of their travel behaviour and fuel consumption as their comments showed in Table 6.2.

Table 6.2: Comments on Question 5: Does the feedback scene at the end help you realise your personal travel behaviour?

Comments to question 5
Participants who "Strongly agree"
Confirming what I already know. Lots of kilometres/ lots of fuel but temporary situation.
Participants who "Agree"
It was cool to see the amount of time spent travelling. It helps me realise how much I rely on my car. Good idea.
Participants who "Partly agree and partly disagree"
Already largely aware. The car is used by another so the picture is biased. Fuel consumption 26 litres was reported but I use 50+ litres. I was already aware of it.
Participant who "Disagree"
I am aware of it already.

Eight participants provided comments on Question 6 (Figure 6.3) regarding the TACA Sim design compared to a conventional paper survey in terms of enjoyment. The comments are shown in Table 6.3. The table shows four negative satisfactions on the interface functions, i.e. slow operation between keystroke and monitor, and a non-functional tab button. These functions slow down the operational speed of TACA Sim. Consequently, the enjoyment on TACA Sim survey was reduced.

Table 6.3: Comments on Question 6: Did you enjoy the TACA Sim survey (compared to a paper survey)?

Comments on Question 6	Answer to Question 6	Number of participants
Time is too long but useful to have mapping and data capture	partly agree and partly disagree	1
Less tedious and more novel	agree	1
The speed was controlled by the interface	disagree	1
The interface had issues i.e. Tab button does not work	disagree	1
Have not done a paper survey	disagree	2
Quick, simple, graphics	agree	1
Using the mouse then switching to enter data is a pain	partly agree and partly disagree	1
Did not participate in paper survey	disagree	1

The results in Question 7 (Figure 6.3) present 13% of participants as viewing their current travel behaviour information such as fuel consumption, car dependence, fuel intensity and fuel price exposure in the feedback scene with surprise because they had never thought about it before. From the surveyor's notes, as examples, three participants expressed their surprise:

> *"The feedback after the survey is interesting. I was surprised about my fuel intensity."* (Staff, male, age 61)

> *"Surprisingly, my fuel intensity is very high because I share the car, even though I do not own any car."* (Student, female, age 26)
>
> *"It was very informative and something to think about."* (Staff, female, age 61)

An additional example of a participant's response to the information in the feedback scene is as follows:

A professor (age 45) made all work trips by bicycle. Although the number of trips by car and bicycle was the same, the total kilometres travelled by car in a week were much more. The professor then expressed "surprise" at the amount of car travel for recreational activities. In the fuel price pressures simulation level, the professor changed mode to bicycle for one of the car trips and investigated taking the bus for another car trip in order to reduce fuel consumption before the fuel price pressure was introduced.

The information in the TACA Sim survey was useful to 24% of participants. Nevertheless, 29% did not find it useful for their future travel management (Question 8, Figure 6.4). From the surveyor's notes, most of these participants insisted that they are well managing their current travel behaviour. For example:

> "*I am already largely aware of my travel behaviour*." (Academic staff, male, age 47)

> "*It was interesting to see the summary of my behaviour but it confirmed what I knew, that I was a low fuel consumer*." (Staff, female, age 33)

The feedback from participants shows that the feedback scores and the map scenes were the most popular. Table 6.4 illustrates the participants' attitudes to the design of the feedback scene and preferences for the overall components of the survey level 1-2 (Question 9 and Question 10, Figure 6.4). The results indicate 11% had negative attitudes on the feedback scores at the end of the survey. The reasons for the negative attitudes stemmed mainly from the difficulty in some technical terms used and the objections to the visual design. These issues have been improved in the web-based TACA Sim design, which will be discussed in Chapter 8.

Table 6.4: Attitudes toward the design of the survey level 1-2.

N = 76 participants	**Percent responding**
How do you feel about the feedback scene? (Question 9)	
Positive (62%)	
Easy to understand	1%
Confirms what I thought	7%
Surprising and Informative	18%
Interesting	18%
Good	17%
Neutral (28%)	
Not surprising	7%
Neutral	9%
N/A	12%
Negative (11%)	
Hard to understand	5%
Visual design not advanced	3%
Not accurate	3%
Which scene of the TACA Sim survey do you like the most? (Question 10)	
All	3%
Avatars	3%
Cut-scene	1%
Personal Information (choosing character)	8%
Travel diary	3%
Feedback scores	22%
Map	17%
N/A	43%

Note: N/A=no answer

FEEDBACK ON THE SURVEY LEVEL 3
(Total 90 participants)

1) How do you feel about the time to do the survey in this part?
   [**88%**] Acceptable [**9%**] Relatively long [**1%**] Too long
2) "The 2nd level in TACA Sim stimulated you to think about your transport alternatives or changes (including refilling fuel behaviour change) in response to fuel price more than the first level." Do you agree with this statement?
   [**87%**] Agree [**6%**] Disagree [**7%**] N/A

Note: N/A=no answer

Figure 6.5: Feedback results on survey time and fuel price pressures simulation in the survey level 3.

In the survey level 3, 87% agreed that TACA Sim stimulated them to think about their transport alternatives and changes in response to the fuel price pressures (see Figure 6.5). The following example of a participant's responses illustrates the engagement achieved with the design.

A student (male, age 36) reported car trips for delivering his children to/from school. The student thought about the alternatives to reduce car trips after he was exposed to the high fuel prices. He decided to change from car to bus when the fuel price was $5.65 per litre. Additionally, the student decided to take his children to a local drama school within a walkable zone. The student considered moving house to be near the University when the fuel price pressure rose to $9.64 per litre.

From observations, the most frequently found potential behaviour changes were in the form of: mode shifting from a car to a non-fuel using mode, changing destination to maintain the activity (e.g. shopping at the local supermarket), working from home, and reducing the frequency of the trips. These responses show that the fuel price signal in TACA Sim can expose the participants to the fuel price pressures. The influence of the fuel price signal will be further discussed in section 6.5.3.

6.4 Verification of data collection

Verification of data collection is to ensure that the data collected through TACA Sim reflects a mode choice pattern of UC students and staff for journey to work/ education. In this verification, mode choice and travel time for journey to University of 155 respondents was compared to the results from UC Travel Survey 2009 (UC Survey, 2009).

The UC survey was developed by engineering consultants GHD Ltd as an online survey in order to collect information about staff and student travel to the University of Canterbury. The UC survey aims to understand the existing travel pattern of UC staff and students and provide information for future travel demand analysis. The questions in the UC survey were mainly about the transport modes that the participants usually take to the university, travel purposes, and their travel times. For example:

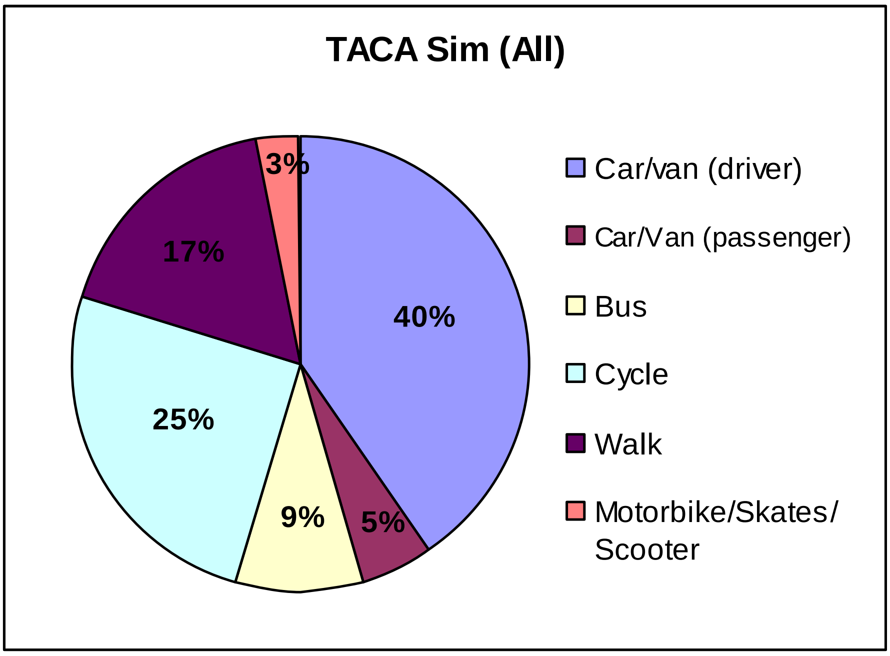
- What is your usual (i.e. most frequent) form of transport to the University? (If you usually use more than one form of transport, such as bus or car, then walk, select the one that you use for the longest time).
- How long does it normally take you to travel from where you live to the University by your usual form of transport? (in minutes)
- What are your main reasons for using your usual form of transport to University?

The UC survey was conducted in July 2008 (winter) by sending out an email that contained the survey link to all 1,874 UC staff and 14,860 students. By using this method, the UC survey obtained 4,772 responses (1,027 staff and 3,745 students), thus a 28% response rate.

6.4.1 Trips to University

The TACA Sim survey has 155 participants in total (14% response rate for staff). The participants are 54 students, 56 general staff, and 45 academic staff. The frequent transport mode to the University and the travel time was filtered from the TACA Sim dataset to compare with the result from the UC survey. The results of TACA Sim and the UC survey show that the car is the major transport mode taken to the university. Figure 6.6 and Figure 6.7 present similar patterns of travel time and modes taken to university in TACA Sim and UC survey respectively. From the results of the travel mode share in both surveys (Figure 6.6), the portions of car/van (driver and passenger) and motorbike/skates/scooter were similar. Except for travel mode shares for cycling and walking, the TACA Sim results were within 1-3% of the UC survey results. The reason for the large difference in the mode share of cycling and walking between both surveys might be due to the survey having been conducted in different periods. That is, the TACA Sim survey level 1-2 had been conducted in spring to autumn and the UC survey had been conducted in winter.

Considering travel time, the average travel time of a car trip as the driver and a car trip as a passenger in TACA Sim were very close to the average travel time of a car trip as the driver and as a passenger in the UC survey (Figure 6.7). The average travel time for bus, cycling, walking in TACA Sim survey was slightly different from in the UC survey. The difference in the average travel time of the TACA Sim and the UC survey for those travel modes was between 3 and 6 minutes (see Figure 6.7).



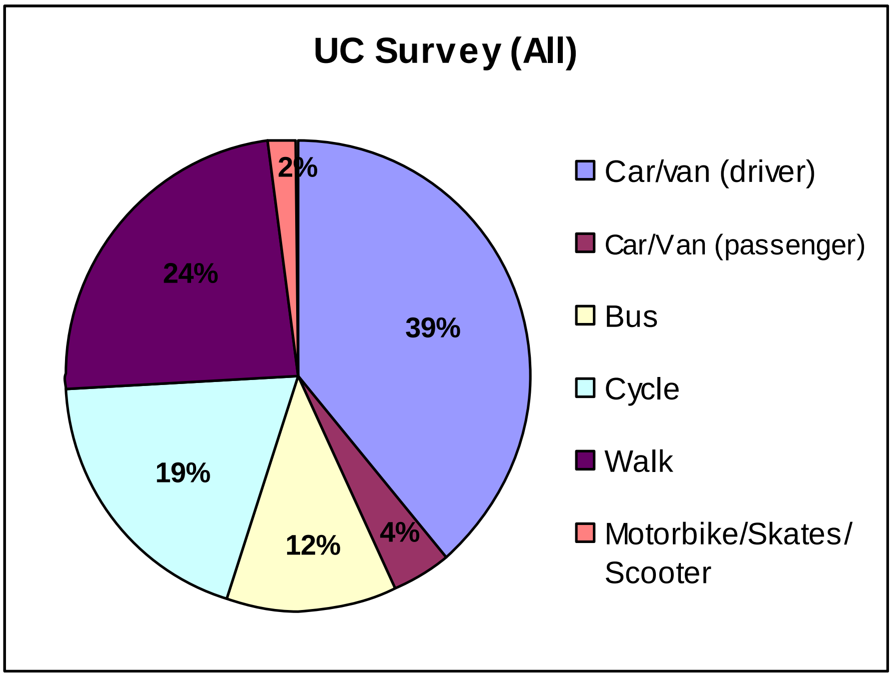


Figure 6.6: A comparison of mode shares to university between the TACA Sim survey and the UC survey (UC Survey, 2009).

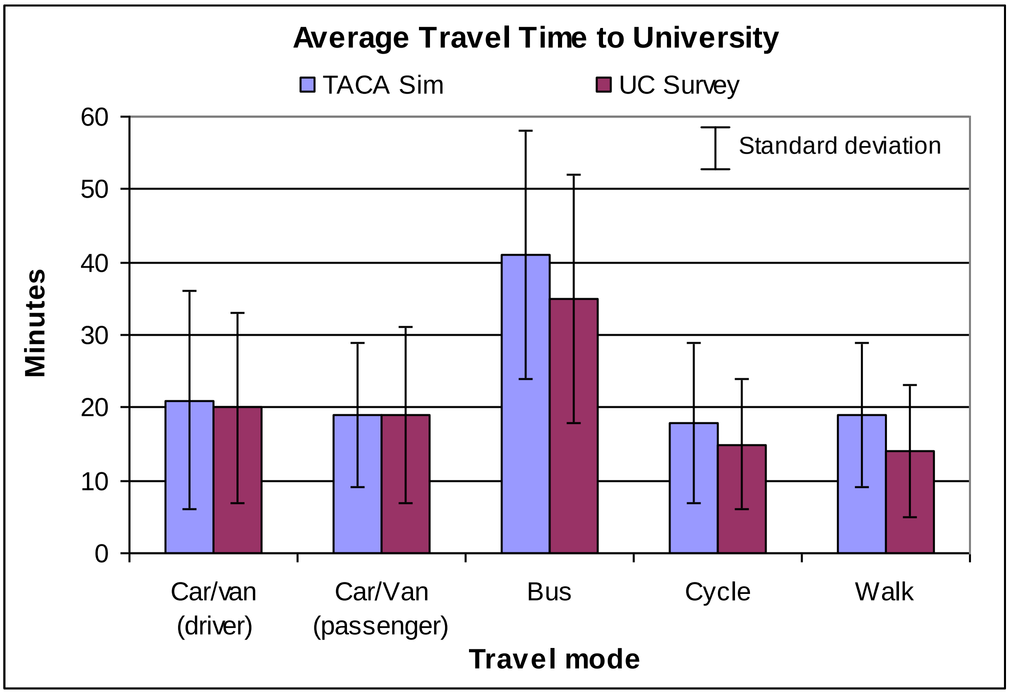


Figure 6.7: A comparison of travel time to university between the TACA Sim and UC Survey 2009 (UC Survey, 2009).

6.5 Discussion of Design Attributes

6.5.1 Game-like Simulation

Using TACA Sim as a survey tool has other points that should be considered. The choices made during the survey to change mode to cycle, walk or bus may not be 100% carried through in the actual world, as physical exertion, weather conditions, and extra travel time may cause the participant to carry on using a car for some trips. However, this research did not try to forecast the future travel behaviour in relation to specific fuel prices. It is focused on what people can do to reduce fuel use under the fuel price pressure. This kind of information is useful for assessing the existing transport systems and urban form, which will lead to an idea for developing transport policies, transport systems and urban form.

Another issue of using game-like simulation is that the game-like simulation may elicit playful rather than thoughtful responses. Although, TACA Sim provides an analysis of travel behaviour as feedback to the participant and displays it as a score, it does not encourage actions to maximize the scores as in a game for entertainment, in order to elicit choices based on the participant's own actual world situation.

6.5.2 Changes of Intention induced by Fuel Price Simulation

Figure 6.8 shows the questions on the feedback form for the survey level 3 about the fuel price pressure simulation. The participants were asked about their estimation of a fuel price of petrol 91 that would cause them to try to stop using fuel before and after the adaptation survey level (Question 1 and Question 2). These questions reflect the participants' change of intentions after they took the survey. Most participants queried what was meant by "stop" using fuel. The surveyor clarified to all participants that they could interpret the "stop" as a significant reduction in fuel use.

Note: Numbers in brackets are the number of participants responding to the options.

1) Before you played, at what fuel price would you try to stop using fuel?

<u>**see Figure 6.9**</u>

2) After you played, at what fuel price would you try to stop using fuel?

<u>**see Figure 6.9**</u>

<u>Week 1</u> ($1.64/L)

3) Did you change your travel behaviour in the first week?

   [**8**] Yes [**82**] No *skip to question 5*

4) Why did you change your travel behaviour in the first week? (can choose more than 1 answer) *Please also circle to rank the factor.*

   [**8**] Scores (e.g. car dependence, fuel intensity, risk) *high med low*

   [**1**] Fuel price/costs (e.g. fuel price, travel expenses) *high med low*

   [**2**] Other <u>**Health, Weather**</u>

<u>6 week later</u> ($5.65/L)

5) Did you change your travel behaviour?

   [**76**] Yes [**14**] No *skip to question 7*

6) What factors did you use in the decision on your behaviour change? (can choose more than 1 answer) *Please also circle to rank the factor.*

   [**14**] Scores (e.g. car dependence, fuel intensity, risk) *high med low*

   [**76**] Fuel price/costs (e.g. fuel price, travel expenses) *high med low*

   [**13**] Other <u>**Health, Time, Family, Weather, Accessibility, Convenience, Environment, Location**</u>

<u>12 week later</u> ($9.64/L)

7) Did you change your travel behaviour?

   [**85**] Yes [**5**] No *skip to question 9*

8) What factors did you use in the decision on your behaviour change? (can choose more than 1 answer) *Please also circle to rank the factor.*

   [**15**] Scores (e.g. car dependence, fuel intensity, risk) *high med low*

   [**85**] Fuel price/costs(e.g. fuel price, travel expenses) *high med low*

   [**4**] Other <u>**Time, Family, Convenience, Accessibility**</u>

Figure 6.8: Feedback on scores and fuel price in the travel adaptive potential survey level.

According to the theory of planned behaviour, the behavioural beliefs and normative beliefs of the participants were consistent, as the participants did not receive any external information. Therefore, the fuel price pressure in the TACA Sim is what caused the participants to change their responses to questions after the survey was conducted. For example, a person said he would reduce fuel use at $7 per litre. During the survey, the person came to realize the effect of fuel price pressure from the survey game. He then decided to reduce fuel use when the fuel price was at $5 per litre in the game. Afterward, he indicated that he would reduce fuel use if the fuel were $5 per litre when the same question was repeated.

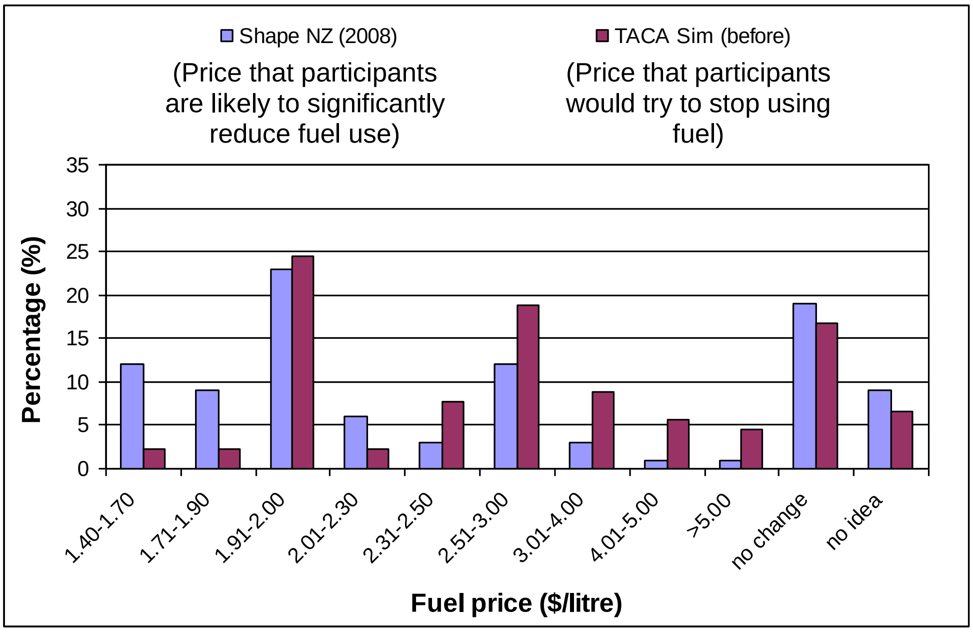
The result of what fuel price will trigger significant reductions in fuel use from ShapeNZ (2008) was compared to the result from TACA Sim in order to show the participants' intention changes after they participated in the immersive environment survey. The question asked in ShapeNZ (2008) was:

"Thinking about the price of 91 octane petrol or its diesel equivalent at which of the following prices would you be most likely to significantly reduce your fuel use?"

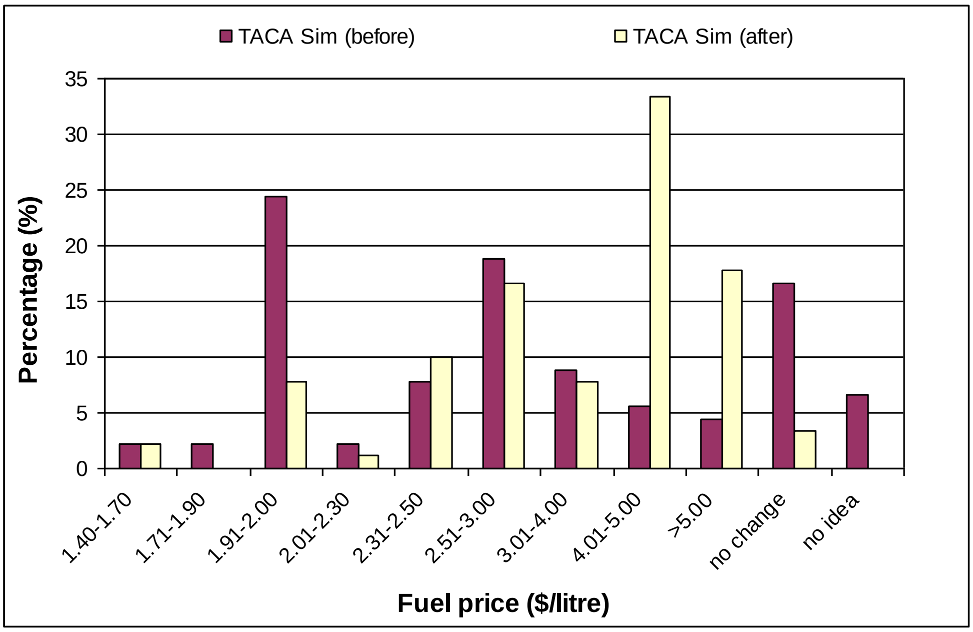
Figure 6.9a presents the results of the fuel price at which the participants would try to reduce using fuel from TACA Sim and ShapeNZ (2008). The results from TACA Sim in Figure 6.8a were the intentions of the participants before they went through the travel adaptive potential survey level in TACA Sim. The comparison shows a similar pattern in the distribution between both surveys.

Similarly to the results from ShapeNZ (2008), nearly a quarter of all participants in TACA Sim (24%) declared their intention of trying to reduce using fuel at a price of \$1.91-\$2 per litre before they took the survey. Nevertheless, their intention changed after they finished the survey. Figure 6.9b shows the results of participants' intention change after the participants took the travel adaptive potential survey level.

The results show 71% of the participants changed their intention after they were exposed to the fuel price pressures in the survey. The major intention to reduce their fuel consumption significantly shifted from \$1.91-\$2 to \$4.01-\$5.00. The result shows more participants tolerated the fuel price escalating beyond \$5 per litre than before immersion in the survey in TACA Sim. Additionally, the TACA Sim encouraged the participants who had no idea about the fuel price to estimate what fuel price they would try to reduce using fuel. This can be seen from the result in Figure 6.9b. For participants who had no perception of what fuel price would cause them to reduce fuel consumption, the TACA Sim survey was helpful in providing an idea. However, the result in this section aims to show the participants' experiences changed their perceptions through TACA Sim. The result of the perceived fuel price is not conclusive as the TACA Sim did not have a smooth fuel price change. The fuel price pressure in TACA Sim jumps from \$1.64 per litre to \$5.65 per litre. The participants who declared their fuel reduction at fuel price \$5 per litre may be affected by this price pressure design.



(a)



(b)

Figure 6.9: Participants' intention changes after they participated in the immersive environment survey (a) Distribution of the participants' intention at different fuel prices (b) Intention change after the participants took the immersive environment survey in TACA Sim.

Considering the designed components in the survey, the purchasing fuel scene (Figure 4.19) worked very well as a signal of fuel price pressures to the participants, while the scores on the control panel did not play a major role in the participants' decisions. This purchasing fuel scene stimulates the participants to feel the situation of fuel price pressures with the cost of purchasing fuel. The participants then took the fuel price as a factor in their decision-making. Examples of participants' statements from the surveyor's notes are:

> *"The price of filling up the fuel tank makes me realize the cost and surprises me. Normally I do not think about the price per litre."* (Academic staff, male, age 46)
>
> *"I do not think about the fuel price per litre but the fuel cost of a tank. The simulation of refilling the tank helps me to focus more on alternatives."* (Academic staff, male, age 55)
>
> *"I think the game has stimulation e.g. when refilling fuel, I can see the cost I have to pay. I was so surprised and aware of the fuel price."* (Student, female, age 26)

6.5.3 Effects of Fuel Price Pressure and Feedback Score on Travel Behaviour Change

The travel adaptive potential survey level in TACA Sim simulated three different fuel prices: \$1.64/litre, \$5.65/litre, \$9.64/litre in the first, second, and third week of playing, respectively. The fuel price pressure and feedback score effects are different in each playing week. The effect of fuel price pressures on participants' travel behaviour change is dependent on the internal economic decision-making of individuals.

The fuel Price Pressure and the feedback Score Effect points (Kingham, et al.) were developed to quantify the effectiveness of the fuel price pressure and feedback score on the participant's decision. It is derived from questions in the feedback form given to participants after the transport energy use reduction potential audit level (see Figure 6.8, Question 3-8). The respondents were asked to rate the effectiveness of price pressures and feedback scores (i.e. low, medium, high) if they changed behaviour in each playing week. The rates of the effectiveness were assumed 1, 2, and 3 for low, medium, and high effects respectively in this research based on the effects on the participants' decisions in behaviour change. If the effect of the fuel price pressures or the feedback scores are *f* and the number of respondents to the signal is *R*, then the Effect Points (*Eff*) for a signal are

$$Eff_m^k = R_m^k f^k \tag{6.1}$$

where,

m = subscript for signal type i.e. fuel price pressure and feedback score

R = number of respondents who rate the signal

k = superscripts for rate of effects (k = low, medium, high)

f = weighting factor (low = 1, medium = 2, high = 3)

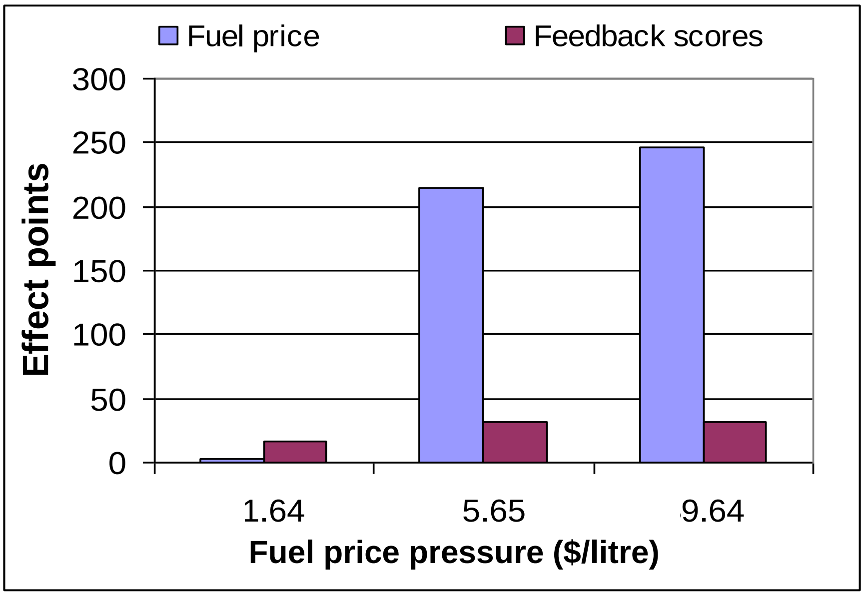
Therefore, the Total Effect Points (*EFF*) of each playing week for a signal are measured by:

$$EFF_m = Eff_m^{low} + Eff_m^{med} + Eff_m^{high} \qquad \textbf{(6.2)}$$

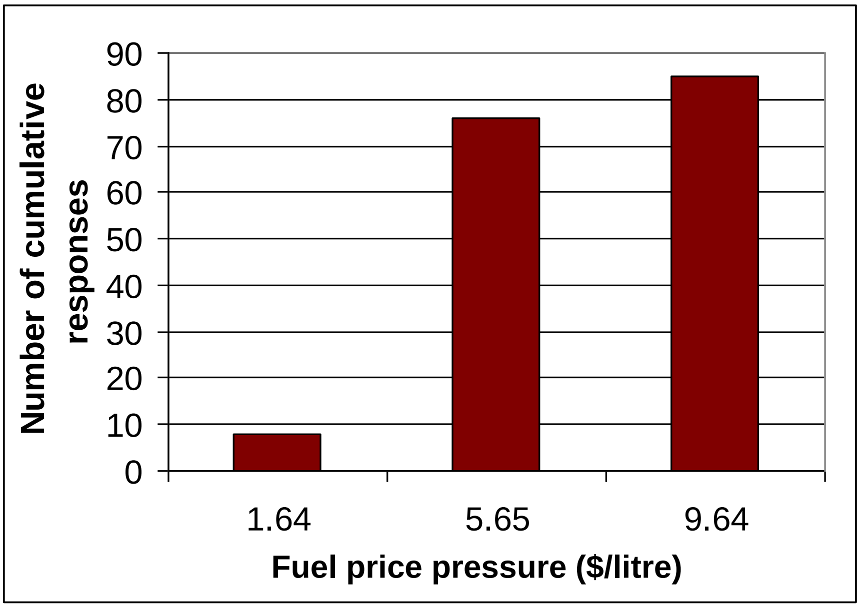
where,

$^{low,\ med,\ high}$ = superscripts for low, medium, and high effects

Figure 6.10 illustrates the fuel price pressures and feedback score effects on the participants' responses. The results of rating effects show that the fuel price at \$1.64/litre does not have much effect on the participants' decisions (see Figure 6.10a). At this price pressure, the feedback score has more effect than the fuel price. The fuel price affected participants' travel behaviour more after the fuel price pressure increased to \$5.65/litre. This can be seen from the increase in effect points, which corresponded to the increase in the response number in Figure 6.10b. The feedback score, however, does not have much effect as the fuel price increases.



(a)



(b)

Figure 6.10: The fuel price pressure and feedback score effects on participants' responses (a) Effect points of fuel price and feedback scores (b) Number of cumulative responses.

Additionally, the results from the feedback in Figure 6.8 show that the participants included other factors such as time and role in their consideration on travel choices. For example, a participant drove a car because he had to take his daughter to preschool before he came to work. From the surveyor's notes, *"It totally depends on my daughter. I do not consider the bus is a safe mode for my daughter. If safety is improved for the bus, I would consider using it."* (Academic staff, male, age 42) However, the academic staff decided to ride a bicycle and stop taking his daughter to preschool when the fuel price pressure was at $5.65/litre.

In TACA Sim, a fuel price pressure at $1.64/litre was close to the fuel price in the period of the survey. Therefore, the result shows 91% of participants did not change their travel pattern at this price. The nine percent who changed their travel behaviour were assumed to have responded to the feedback information (e.g. fuel consumption, car dependence, fuel intensity) provided at the end of the survey level 1-2.

6.5.4 Feedback Scores for Self-evaluation

The TACA Sim has potential as a useful tool for travel adaptive capacity survey and self-evaluation. The feedback scores are designed mainly to encourage the participants to complete the survey in order to receive the evaluation of the input travel pattern. The participants' feedback shows most participants are interested in seeing the scores at the end of the survey.

However, the fuel intensity score does not seem to be a comprehensible indicator as the fuel intensity is calculated only based on the distance travelled by a fuel-using vehicle. The participants who travel by a more efficient vehicle (consuming less fuel) may obtain the same fuel intensity score when compared to another participant who travels by a less efficient vehicle for the same distance. Therefore, “fuel economy” is suggested as a new indicator in TACA Sim’s future design.

Comparing the scores to others has benefits for the participants. The participants may be encouraged by the scores to improve their travel pattern via reducing travel time and/or fuel consumption in the actual world after being exposed to the survey. Nevertheless, in terms of data collection, the evaluation scores at the end of the survey may lead to response bias and a bias of the data because of the phenomenon of “social desirability” (Rocci, 2009) if the survey is self-operated. Social desirability is the concept in that people need to be recognised and accepted by society. The social desirability bias is used as a term to explain the tendency of respondents to deceive themselves and others to comply with the favourable social norm (King & Bruner, 1999; W. W. Smith, 2007). Some participants are biased by what they think the researcher expects (response bias) given societal pressures regarding existing environmental and energy saving campaigns, such as sustainability and low carbon footprints. Thus, they might go back to the travel diary and alter their answers in order to minimize the practices harmful for the environment and emphasize the favourable trips after their travel patterns are evaluated.

As an example of this case, an academic staff (male, age 55) showed a desire to add his bus trips to work after he realised his high scores for car dependence and the fuel intensity of his travel pattern in a typical week at the end of the survey. *"I occasionally take the bus to university. Would you like to add it into your data?"* (from the surveyor's notes). This social desirability and response biases will reduce the quality of data in future applications as a self-administration survey tool because the participants may self-modify their travel pattern toward their perceptions of what is publicly acceptable. The future design may help to mitigate this problem by requesting the participants to submit their data before receiving the evaluation of their travel behaviour.

6.6 Summary

TACA Sim has a positive potential to be employed as a tool for travel adaptive capacity survey. The fuel price pressure and feedback scores have effects on the participants' travel behaviour change. The verification of the TACA Sim design shows that it can immerse the participants to the fuel price pressures and perceive their travel adaptive potential. However, the graphical and functional designs of TACA Sim still need to be improved in order to reduce the survey time and increase immersive perception. This will help ensure data obtained will be more accurate and the enjoyment of the survey will be increased. The results from the case study will be described in the next chapter as an example of using the TACA Sim dataset.

CHAPTER 7

BASIC ANALYSIS OF ADAPTIVE CAPACITY AND ADAPTIVE POTENTIAL

7.1 Introduction

This chapter presents a case study showing how a TACA Sim dataset was used for travel adaptive capacity and energy adaptive potential of the UC participants. The participants are divided into three groups: students, general staff, and academic staff because the role was hypothesised to be a factor that influences current travel patterns. These groups were also expected to represent income levels: low, medium, and high as the income level was investigated as having an effect on decisions for changes potential to reduce fuel use under fuel price pressures. The participants’ travel demand pattern was measured in terms of: travel distance in kilometres, the mode used for each trip, the number of trips in a week, essentiality and fuel consumption. These variables were expected to change when the participants were exposed to fuel price pressures. The adaptive capacity for journey to University of each group was investigated through alternative to car trips.

7.2 Income Distribution of Participants

Figure 7.1 shows the income distribution of the sample. Most students (87%) had an income lower than 30,000 New Zealand Dollars per year (NZD/year). Over 65% of general staff had an income between 30,000 NZD/year and 70,000 NZD/year. Of academic staff, 80% had an income more than 70,000 NZD/year. Therefore, students, general staff, and academic staff are representative of low income, medium income, and high income respectively in this case study.

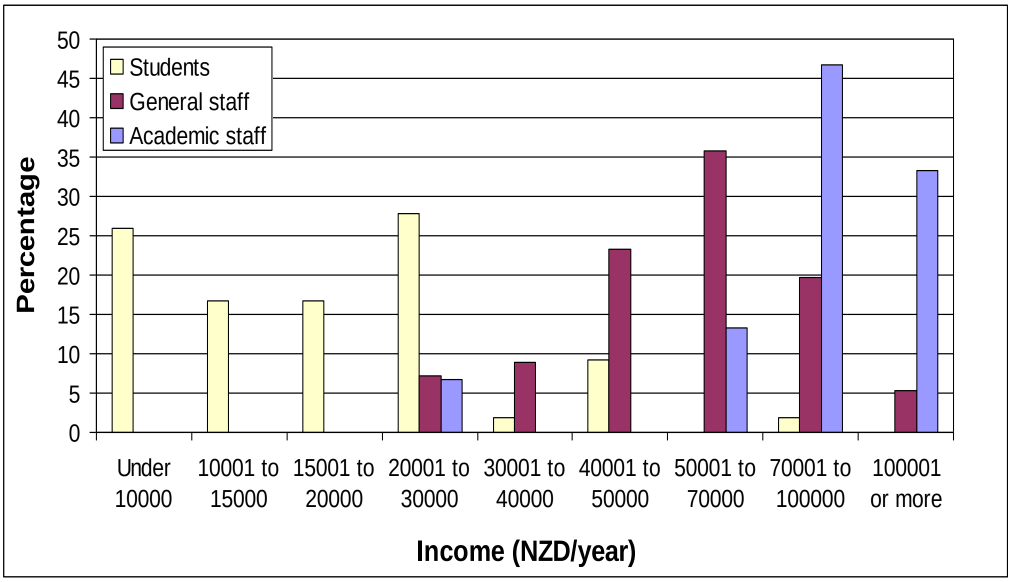


Figure 7.1: Income distribution of the sample at the University of Canterbury.

7.3 Travel Demand Pattern

7.3.1 Comparisons of Trips and Travel Distances between Occupational Groups

Table 7.1 presents the average total trips and car trips per person generated by students, general staff and academic staff. The term “Car” presented in the results includes all private fuel-using vehicles such as cars, scooters and motorbikes. “Public Transport” includes the bus, ferry, and taxis. The transport mode of rollerblades/skates, skateboards, walking, and running were grouped in “Walk”. These terms are applied to all results in this case study.

Table 7.1: Comparisons of average total trips and car trips generated per week between groups.

N=155	Students (n=54)	General staff (n=56)	Academic staff (n=45)
Trips/pp			
Mean	19.93	18.41	17.71
Max	53	39	45
Min	12	10	6
SD	7.64	5.59	7.24
Car trips/pp			
Mean	12.37	12.56	11.44
Max	53	39	35
Min	0	0	0
SD	10.61	7.82	6.84
Distance/pp			
Mean	99.80	193.80	164.26
Max	430.00	690.00	602.39
Min	14.78	24.00	24.00
SD	81.09	153.18	128.72
Car distance/pp			
Mean	76.93	156.17	117.87
Max	400.00	684.00	602.39
Min	0.00	0.00	0.00
SD	77.57	164.72	111.29
Average car occupancy (people/km)	2.14	1.50	2.01

Comparisons of the results in Table 7.1 can be written in simple orders as below:

Trips per person: *Students > General staff >Academic staff*

Travel distance per person: *General staff > Academic staff > Students*

Car trips per person: *General staff ≈ Students > Academic staff*

Car distance per person: *General staff > Academic staff > Students*

Overall, the 155 UC respondents normally travelled on average of 152.62 kilometres in a week. This was counted as 67% of average kilometres travelled by people in New Zealand or 68% of average kilometres travelled of people in Canterbury region. An average of kilometres travelled per person for New Zealand was 226.61 (NZ household travel survey 2005-2009) (MOT, 2010). The results from Table 7.1 show that the student group had a slightly higher average number of trips conducted in a week than the general staff and academic staff. The travel distance per person of the students however was shorter than that of the general staff and academic staff. This characteristic is similar to their car travel pattern.

From the comparisons of total trips, the general staff tended to travel longer distances than the other groups. The student group had a greater number of trips in a week than the staff groups, while their travel distance was shorter. Similarly, the student group travelled by car more frequently than the academic group despite the fact that the car distance travelled by the student group was shorter than for the academic staff group.

An assumption was made to find a link between the groups and car travel distance. According to the literature review, urban form is a factor that affects travel distance. Thus, the residential location in terms of distance from the residence to the university was assumed to influence the total car travel distance, as the work/education trip is a major trip for all participants in a week. This assumption is analysed and discussed in the next section.

7.3.2 Investigation of Residential Distance from the University

A further investigation of the relationship between the groups and residential distance was examined by exploring the distance from the individual residences to the University of Canterbury. The residential distance was generated by using a combination of the TACA Sim dataset and Google maps. The individual residential addresses from the travel pattern dataset were plotted on a GIS map. Then, the residential distance was measured by drawing straight lines from a defined centre point (at the end of Science Road in UC) to the residences. Subsequently, the data was grouped by distance to less than 5 kilometres, 5-10 kilometres, and more than 10 kilometres.

Figure 7.2 and Figure 7.3 show residential locations and residential distance from UC of students and staff respectively. The distribution of the residential location shows that students who live within 5 km of the university were predominant. The residential locations of general and academic staff were more scattered. Therefore, statistical analysis was applied to compare mean residential distance from UC between the occupational groups.

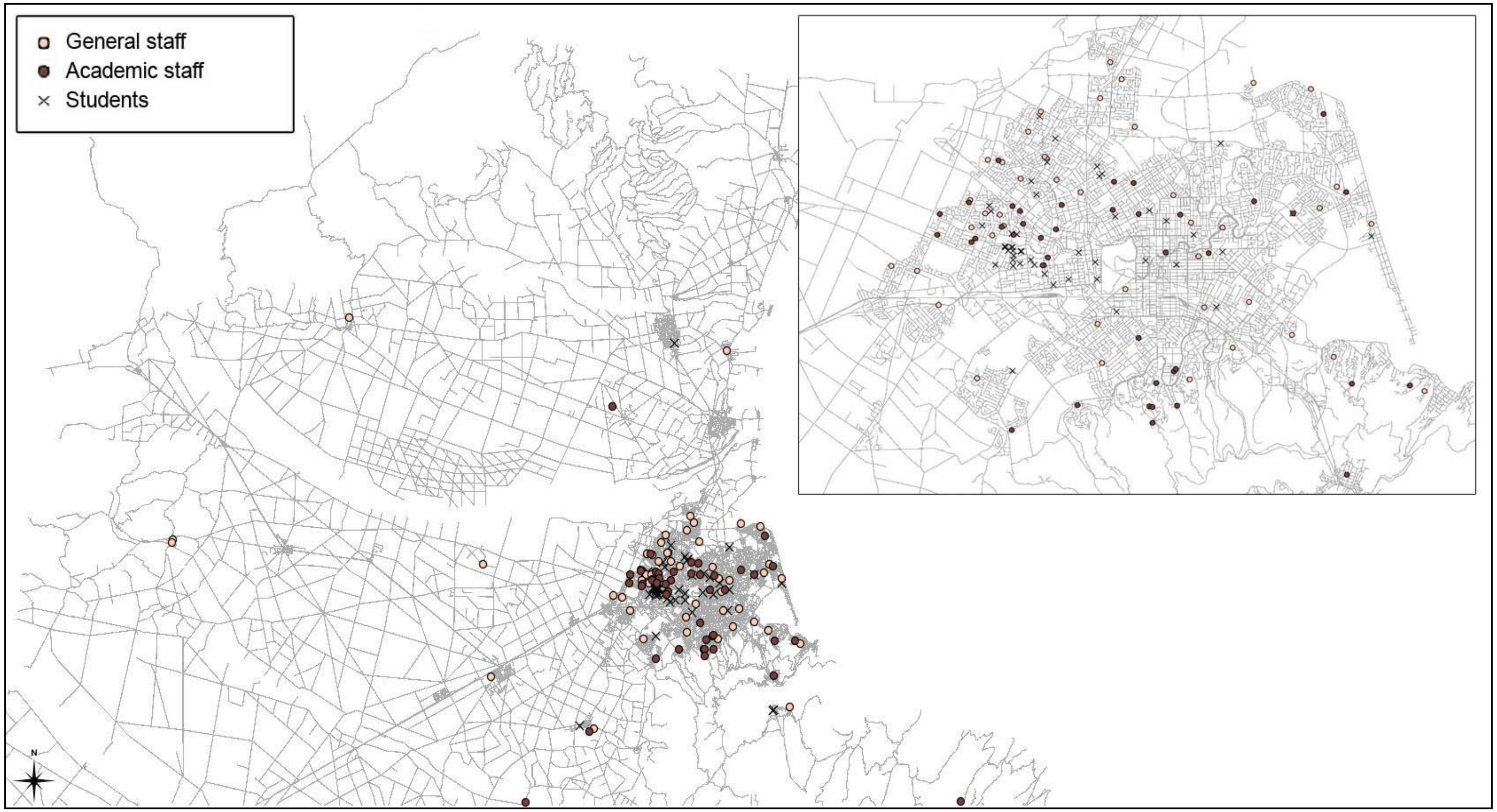


Figure 7.2: Geocoded residential locations of UC students and staff in Christchurch.

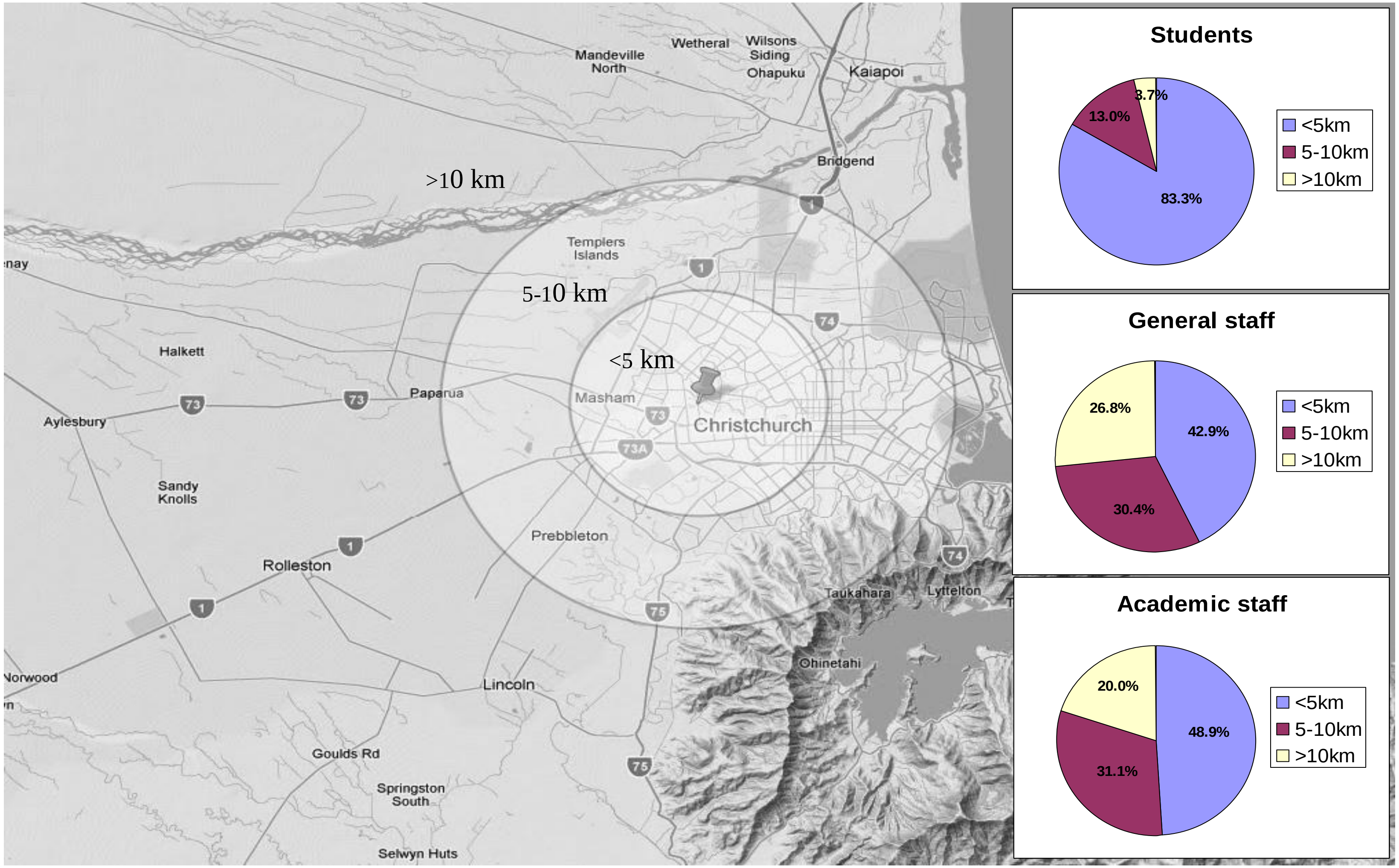
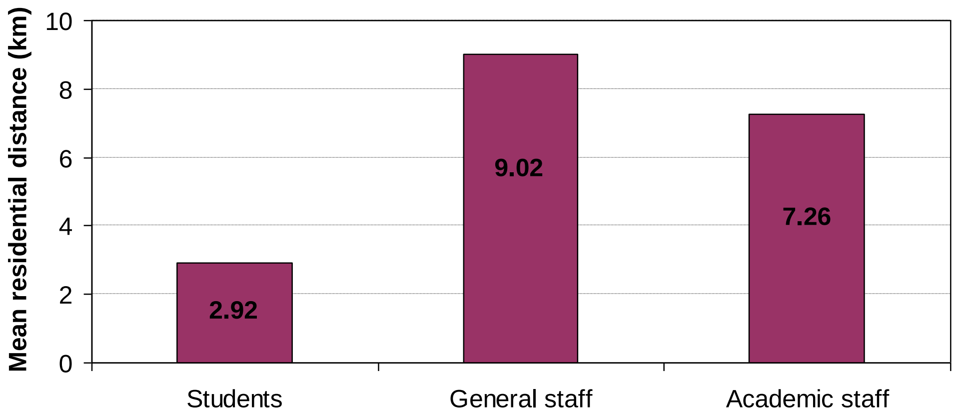


Figure 7.3: Residential distance from UC of students and staff.

For statistical analysis, Statistical Package for the Social Sciences (SPSS) 16.0 software (Norušis, 2009) was employed using Analysis of Variance (ANOVA) method (Norušis, 2009). The One-Way ANOVA method is used to compare mean distance from UC to the residences between students and staff. The dependent variable is residential distance from university and the independent variable is occupational group. Variances on the dependent variable were assumed to be equal across the occupational groups. However, the homogeneity of variances was tested (Levene test) and it was found that the assumption that they were equal was violated. Therefore, the Games-Howell post hoc test was applied to compare the means (Morgan, Leech, Gloeckner, & Barrett, 2007). Figure 7.4 presents the result of ANOVA analysis of mean residential distance for occupational groups.



Occupational group	Mean distance -km-	Std. Deviation	Test of Significance (1-tailed)
Students	2.92	3.031	Sig.
General staff	9.02	10.970	General staff>>Students
Academic staff	7.26	8.492	Academic staff>>Students

Note: "Sig." shows statistical significance at 95% confidence level.

Figure 7.4: Comparison of mean residential distances for the three occupational groups surveyed.

The residential distance means of general staff and academic staff groups are significantly higher than that of the student group. The magnitude of differences between the academic staff group and the general staff group are not strong. These results show that the staff groups have difference travel patterns from the student group.

Further analysis was then applied to investigate the mode choices between the occupational groups. The next section will describe the different relationships of mode choice and travel distances between occupational groups.

7.3.3 Relationships of Mode Choice and Travel Distances for Occupational Groups

In this descriptive analysis, a travel distance less than 5 kilometres was defined as a short distance. The distance between 5 to 10 kilometres was a medium distance, while more than 10 kilometres was a long distance. The ANOVA method was applied again to compare the mode choices between the occupational groups at different travel distances. The occupational group is the independent variable and the numbers of trips of each travel mode for different travel distances are dependent variables. The assumption of homogeneity of variances was tested. The results of the test show that the assumption of homogeneity of variances between occupational groups for short distances (public transport and bicycle) and for medium distances (car, public transport, and bicycle) was valid. Thus, Tukey's HSD test was applied for comparing the mean of these variables. Additionally, the Games-Howell test was applied to compare the mean number of trips of other modes. This is because the assumption of homogeneity of variances between occupational groups of those travel modes was violated (Morgan, et al., 2007). Figure 7.5 and Table 7.2 illustrate ANOVA results for comparison of the number of trips of each mode choice for different travel distances. From the results of ANOVA, a medium distance (5-10 km) does not show significant differences of mode choices between occupational groups.

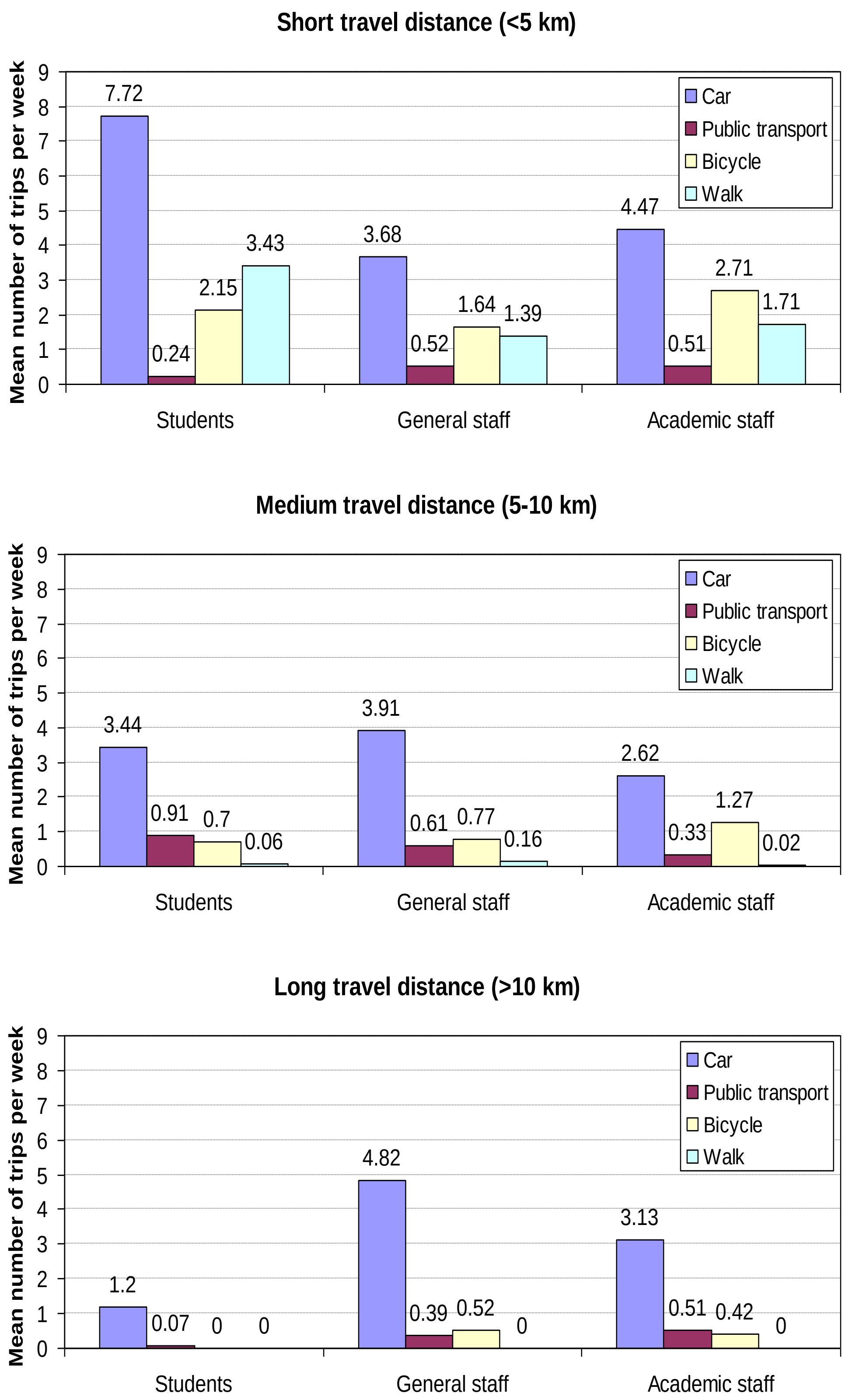


Figure 7.5: Mean number of trips for different mode choices in different travel distances.

Table 7.2: Comparison of mode choices for different travel distances between occupational groups.

	Compare means between occupational groups	Test of Significance
Short travel distance (<5km)		
Car	Students >>General staff	Sig.
Public transport	-	Not Sig.
Bicycle	-	Not Sig.
Walk	Students>>General staff	Sig.
Medium travel distance (5-10km)		
Car	-	Not Sig.
Public transport	-	Not Sig.
Bicycle	-	Not Sig.
Walk	-	Not Sig.
Long travel distance (>10km)		
Car	General staff>>Students	Sig.
	Academic staff>>Students	Sig.
Public transport	-	Not Sig.
Bicycle	-	Not Sig.
Walk	-	N/A

Note: "Sig." shows statistical significance at 95% confidence level. N/A = not applicable

The mean number of car trips for long travel distances (>10 km) of the staff groups are significantly higher than of the student group. This shows that the general staff group and academic staff group who live further from university than the student group used more car travel for long distances. However, the results show that the student group travelled by car and walked for short distances (<5 km) significantly more than the general staff.

7.3.4 Essentiality

Besides analysis of travel distances and mode choices, the TACA Sim dataset can be used to explore essentiality of travel. “Essentiality” was proposed by Krumdieck and Dantas as a potentially important factor in adaptive behaviour to fuel supply disruption (Dantas, et al., 2006). Essentiality helps us to understand the necessity of a travel activity and an intensity of impact when the activity cannot be achieved. Figure 7.6 presents the essentialities of trip purposes of occupational groups. The results show that work activity was the most important to the academic staff and general staff groups, while the educational activity was the most important to the student group. This essentiality pattern also validates the question regarding the essentiality of travel activities in TACA Sim.

The patterns of essentiality of activities were similar for the general staff group and the academic staff group except for the educational activity. The student group’s essentiality pattern was different. This could be the case that the different essentiality pattern of the student group was induced by differences in the roles of students and staff.

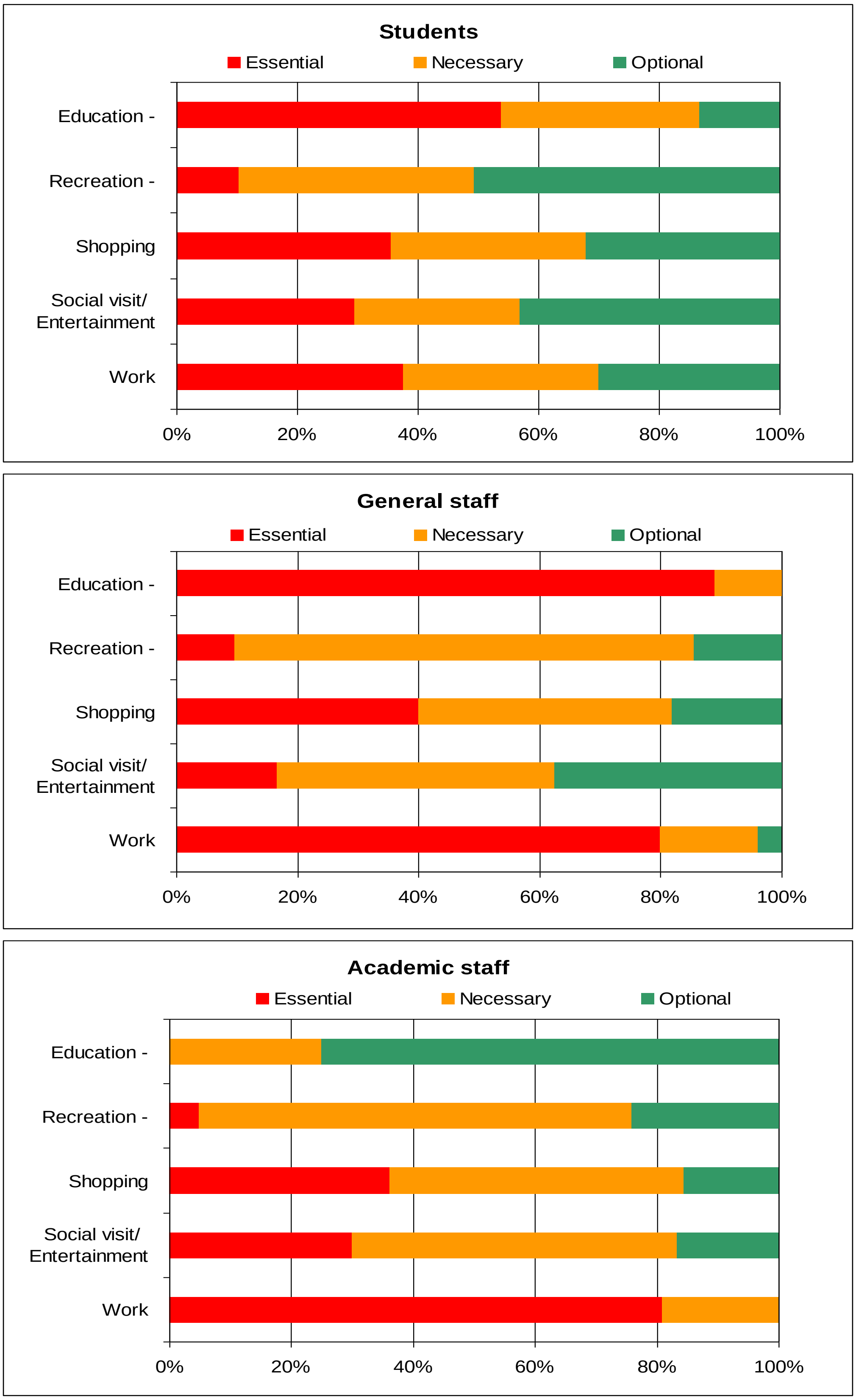


Figure 7.6: Comparison of essentialities of trip purposes between groups.

The TACA Sim dataset also can be used to explore trip purposes in more details. From observing self-defined travel activities in the dataset, most grocery shopping activities were defined as essential activities, while the general shopping trips were defined as necessary or optional activities. The social visit/entertainment was rated as essential mostly when the participants travelled to visit relatives or friends. The essential education trips for general staff were identified as taking their children to school.

Eight trips of the student group were essential recreation trips, involved with health i.e. swimming, going to the gym, and skiing. All the essential recreational trips (12 trips) of the staff group were for their health and lifestyle such as camping, sailing, walking in a nature park, sightseeing out of the city, having dinner at a restaurant. Sixty-six percent of these trips were for more than 25 kilometres by car.

7.3.5 Alternatives to Car Trips for Work/Education Purposes

The travel pattern dataset can be used to analyse the availability of alternatives for many trip purposes such as work, shopping, recreation, and social visit/entertainment purposes. However, the case study focuses on the availability of alternatives to car trips for work/educational activities, as they are a major travel activity in a week. The availability of travel alternatives for work/educational purposes was compared between the occupational groups.

Figure 7.7 presents the percentage availability of alternatives to car trips for work/education.

The percentage of available alternatives for work/educational trips of the student group (91%) was more than for the general staff group (73%) and the academic staff group (64%). The numbers of available alternatives to car trips were implied to travel adaptive capacity of the groups. The essentiality was applied to help define an impact level of not having transport alternatives for the trips. Thus, fuel price exposure was calculated using equation 4.3. Table 7.3 illustrates the fuel price exposure of the three different groups.

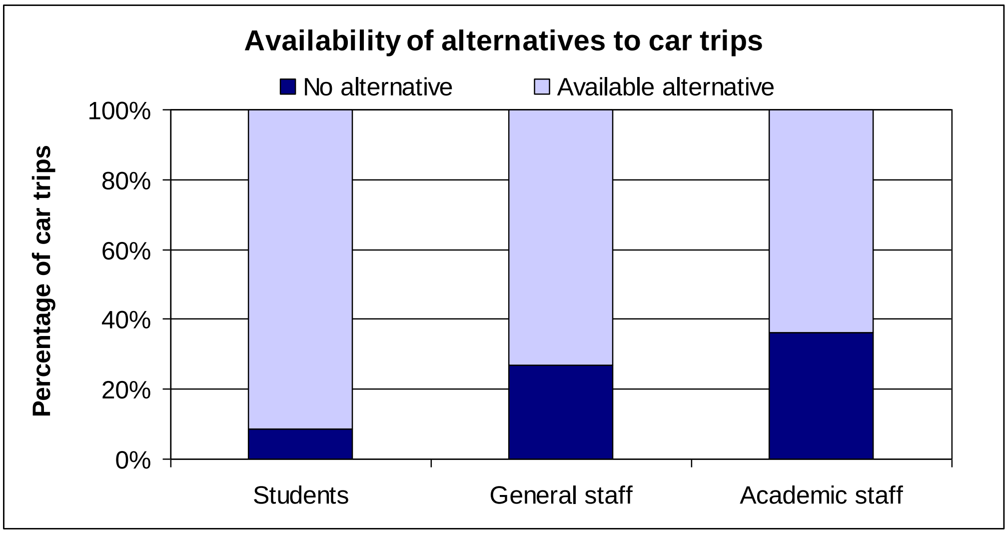


Figure 7.7: Availability of alternatives to car trips for work/educational purposes.

Table 7.3: Fuel price exposure of occupational groups.

	Student	General staff	Academic staff
Fuel price exposure	0.06	0.23	0.20

From the results, the indicators for general staff and academic staff groups were similar. This similarity was caused by the similarities of both groups in percentages of essentiality (see Figure 7.6) and alternatives available (see Figure 7.7) for work trips, which are the major trips in their normal week. Comparing students and staff, the travel adaptive capacity of the staff groups is less than the student group. This is because their essential work trips are more than the essential educational trips of the student group (see Figure 7.6), and the availability of alternatives to the car for their work trips is less than for the student group (see Figure 7.7).

7.4 Travel Adaptive Potential

This section reports the results obtained from the investigation of a subset of 90 participants from the 155 participants in the travel demand survey level. These participants have either more than 30% of car trips or 30% of kilometres travelled by car, which are expected to be affected by fuel price pressures. The results show a similar travel pattern to the results of the 155 participants as shown in Table 7.4.

Table 7.4: Comparisons of average total trips and car trips generation per week between occupational groups for the subset of total participants who carried out the travel adaptive potential survey.

N=90	**Students** (n=30)	**General staff** (n=30)	**Academic staff** (n=30)
Trips/pp			
Mean	21.03	19.43	18.07
Max	53	39	31
Min	12	12	6
SD	8.68	6.19	7.09
Car trips/pp			
Mean	15.67	14.83	12.1
Max	53	39	30
Min	2	4	2
SD	10.73	8.17	7.55
Distance/pp			
Mean	99.1	229.5	177.7
Max	364.0	690.0	602.4
Min	14.8	49.0	24.0
SD	75.8	182.5	129.8
Car distance/pp			
Mean	86.3	197.4	151.1
Max	312.1	674.0	602.4
Min	13.0	11.6	12.0
SD	66.8	188.3	131.0
Average car occupancy (people/km)	1.92	1.49	1.82

The average numbers of total trips and car trips of the student group were more than the other groups. Nonetheless, the general staff group had higher average travel distances and distances travelled by car than the academic staff and student groups. This result of the subset was comparable to the group of 155 participants in the survey level 1-2.

Table 7.5 shows the comparison of mean residential distance between occupational groups of 90 participants. The result for these 90 participants repeats the results from the 155 participants that general staff tend to live significantly farther from the university than the students do.

Table 7.5: Comparison of mean residential distance between occupational groups of 90 participants.

Occupational group	**Mean distance –km-**	**Std. Deviation**	**Test of Significance (1-tailed)**
Students	3.09	3.199	Sig.
General staff	9.55	12.705	General staff>>Students
Academic staff	7.61	9.769	

Note: "Sig." shows statistical significance at 95% confidence level.

7.5 Comparisons of Travel Adaptive Potential for Occupational Groups

A further investigation of travel demand changes potential was examined by using the travel adaptive potential survey. In the case study, travel demand changes potential in terms of travel mode, activities, car trips and fuel consumption under good weather condition were observed. The results from investigation were described in the following subsections.

7.5.1 Mode-related and Activity-related Adaptive Potential

Fig. 7.8 shows the results from both Level 2 and Level 3. The left-hand bar shows the answer to the question, “Could you get to the activity another way?”, as a percentage of all car trips. Surprisingly over 60% of car trips for all groups were reported as currently having an alternative. The mode shift adaptive potential from the fuel price pressure simulation stages is shown in the right-hand bars. By the end of the $5.65 per litre week, more than 50% of normal car trips had been changed, and 80% of trips had been adapted after the week at $9.64 per litre for all groups. The total percentage of car trip adaptive capacity between the high fuel price simulation and the survey question of potential alternatives was similar at the $9.64 per litre week except for general staff. The total percentage of car trip adaptive capacity of the survey question for general staff was similar to of the high fuel price simulation at the $5.65 per litre week.

Demand for bus, cycling, walking and car-pooling grew under fuel price pressures, while numbers of car trips were reduced as shown in Figure 7.8. Nearly 33% of vehicle trips were changed to bicycle, 21% to walking and 22% to bus. Students chose the bus for an alternative less than academics and general staff. Students re-scheduled 15% of car trips to bus, compared to 22% for general staff and 30% for academics respectively. This may be because students do not find the bus to be low cost. Students and academics adapted to walking more than general staff.

Only 11% of vehicle trips for general staff were shifted to walking compared to 23% for students and 30% for academics. House prices near the university are some of the highest in the city. Bicycle trips were increased to 30% of trips for general staff, 21% for academics and 20% for students at the highest price pressure ($9.64/L). General staff includes office workers and secretaries whose dress code is often perceived as an impediment to active mode travel.

Car-pooling was not a favoured response to high fuel costs. General staff and academics changed 6% of their vehicle trips to carpooling, while only 2% of vehicle trips were shifted for students. The level of carpooling as an alternative is supported by Kingham and Copsey's study. Their study reports that people seem to be attracted by the thought of staying in a car, while willing to reduce car use in order to mitigate congestion (Kingham, et al., 2001). Only 5% of all participants chose to replace their existing vehicle with a more efficient vehicle during the TACA Sim game.

Changing destination, rearranging trips, combining activities and changing trips were the main alternatives that the participants rescheduled under fuel price pressure simulation. Figure 7.8 shows activity-related change during fuel price pressures. At the end of the game 6% of respondents had chosen to move residence to a new location closer to the university. This type of behaviour could have a significant impact on property values in locations that require long distance car travel to access activities.

Very few people, 1% of respondents, shortened their travel distance by selecting a closer destination and then switching from car to cycling or walking. Most of these destination changes were for shopping and recreational purposes. The majority of trips in this survey were to the university, thus there is no alternative location. The urban form of Christchurch has supermarkets with strip malls located in every suburb at 2-3 km intervals, so people could already be shopping at the closest market. Out of the 90 participants, only one academic rescheduled trips into a trip chain to reduce fuel use during the game.

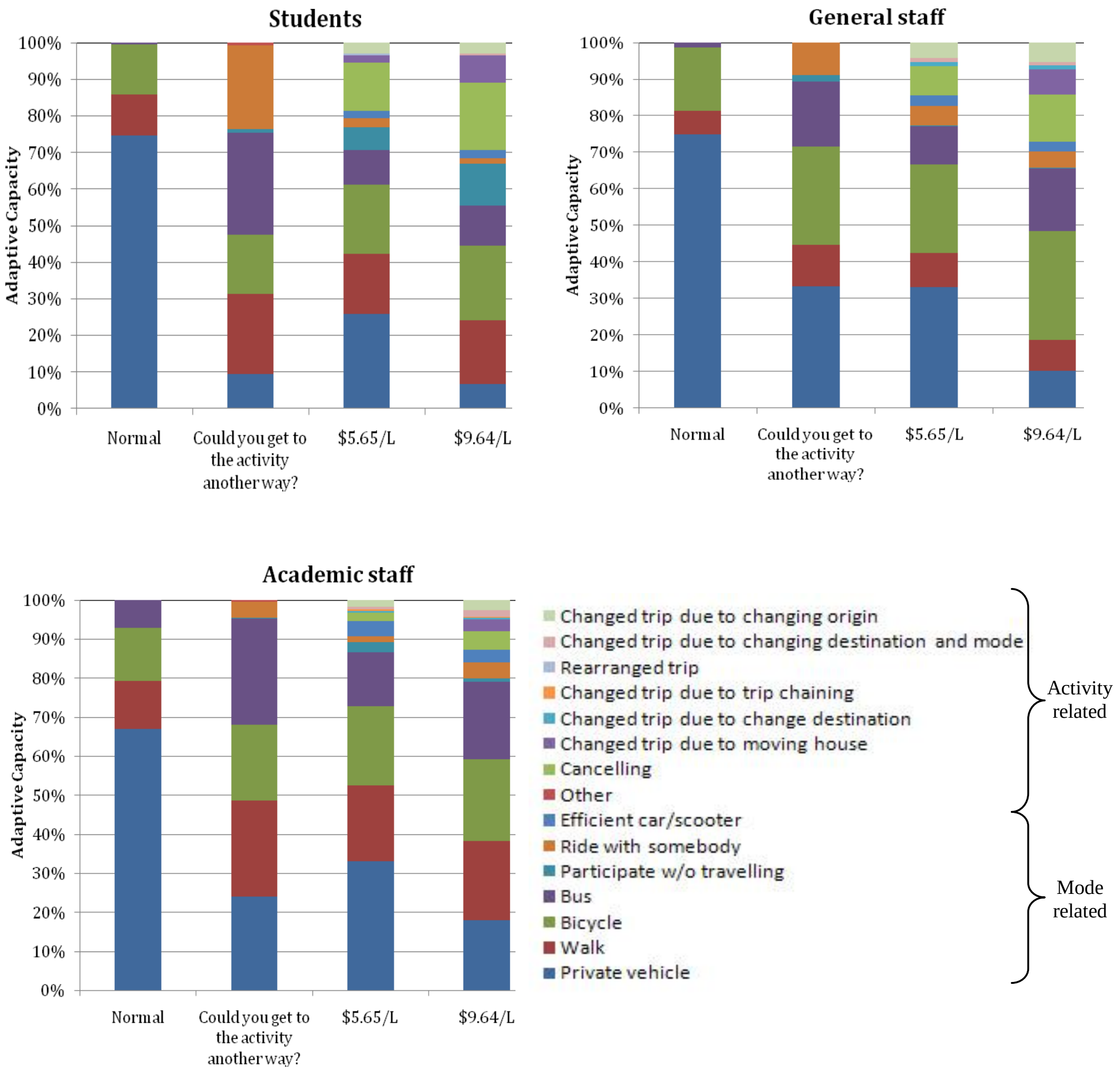


Figure 7.8: Initial mode share of all travel and adaptive potential of activity and mode-related strategies reported as alternatives in Level 2, and used to reschedule trips during the TACA Sim game in Level 3. Results are displayed separately for students, general staff and academics.

7.5.2 Investigation of Mode Shifts of Occupational Groups

For investigation of mode shifts, transport modes were observed to compare between different fuel price pressures. Figure 7.9 shows the percentage of car trips shifted to other modes when the fuel price pressure was increased to \$5.65 per litre and \$9.64 per litre.

The percentage of car trips from the academic staff group was reduced 45% at fuel price \$5.65 per litre, which is less than the percent reduction from the general staff (55%) and student (63%) groups. The car trips were further reduced when the fuel price rose to \$9.64 per litre. At this fuel price, the academic group also reduced their car trips less than either the general staff or the student groups. This result shows that the academic staff group is less likely to reduce their car trip than the other two groups when the fuel price increased. Considering the residential location, many staff live on the outskirts of the city (>5 km from the university). Thus, it is likely that they have less available alternatives to the car mode compared to the student group who live closer to the university. The residential location tends to be a factor in their lower ability to reduce car use than the student group. Additionally, the academic staff group reduced car trips less than the general staff group despite their residential distance from the university not being significantly different. This shows that the income level is likely to be another factor that affects the car trip reductions.

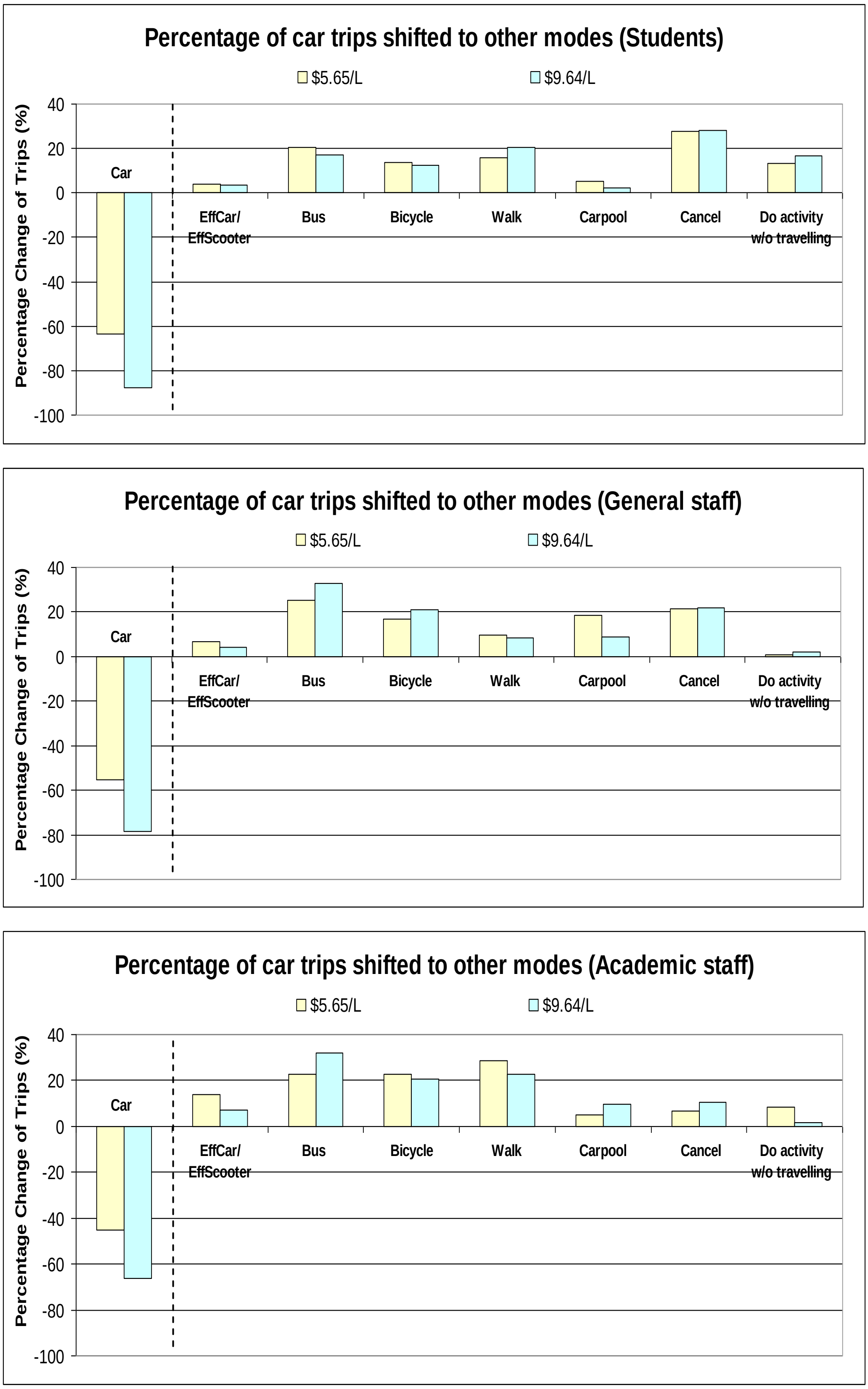


Figure 7.9: Comparisons of travel mode shifts due to fuel price rise.

From the results of mode shift, a student replaced their old car with a new efficient car when the fuel price was $5.65 per litre. Another student changed to a new efficient car when the fuel price increased to $9.64 per litre. A general staff bought an efficient car at fuel price $5.65 per litre, while another general staff shifted from his car to a scooter. He moved two scooter trips to walking and carpooling when the fuel price increased to $9.64 per litre. At the fuel price of $5.65 per litre, two academic staff bought new efficient cars to replace their cars. However, one of them abandoned the new car and shifted to the bus when the fuel price rose to $9.64 per litre. Travelling by bus, cycling and walking were the popular modes that the participants shifted to when they were affected by the increased fuel price. At the fuel price of $9.64 per litre, a student relocated house to be near the University within a walkable zone, and an academic staff moved house from out of Christchurch city to the Christchurch city centre and used a bicycle to travel.

7.5.3 Mode Choice by Travel Distance

The changes in transport mode and travel distance in the travel adaptation dataset were analysed and compared between occupational groups. Figure 7.10-7.12 shows mode choice by travel distance of three occupational groups. Travel distance of less than 5 kilometres is categorised as short travel distance in this research. Travel distance between 5 to 10 kilometres is medium and more than 10 kilometres is long distance travel.

From investigation of mode choice by travel distance, the student group conducted more short trips than the other two groups. The students eliminated their car trips and used more bus, bicycle and walking modes for short travel distances when the fuel price increased to $5.65 per litre. The students used only cars to travel long distances. However, the students increased their bus use for long distance trips when the fuel price was $5.65 per litre. The students further eliminated their car trips for long distance travel when the fuel price increased from $5.65 per litre to $9.64 per litre.

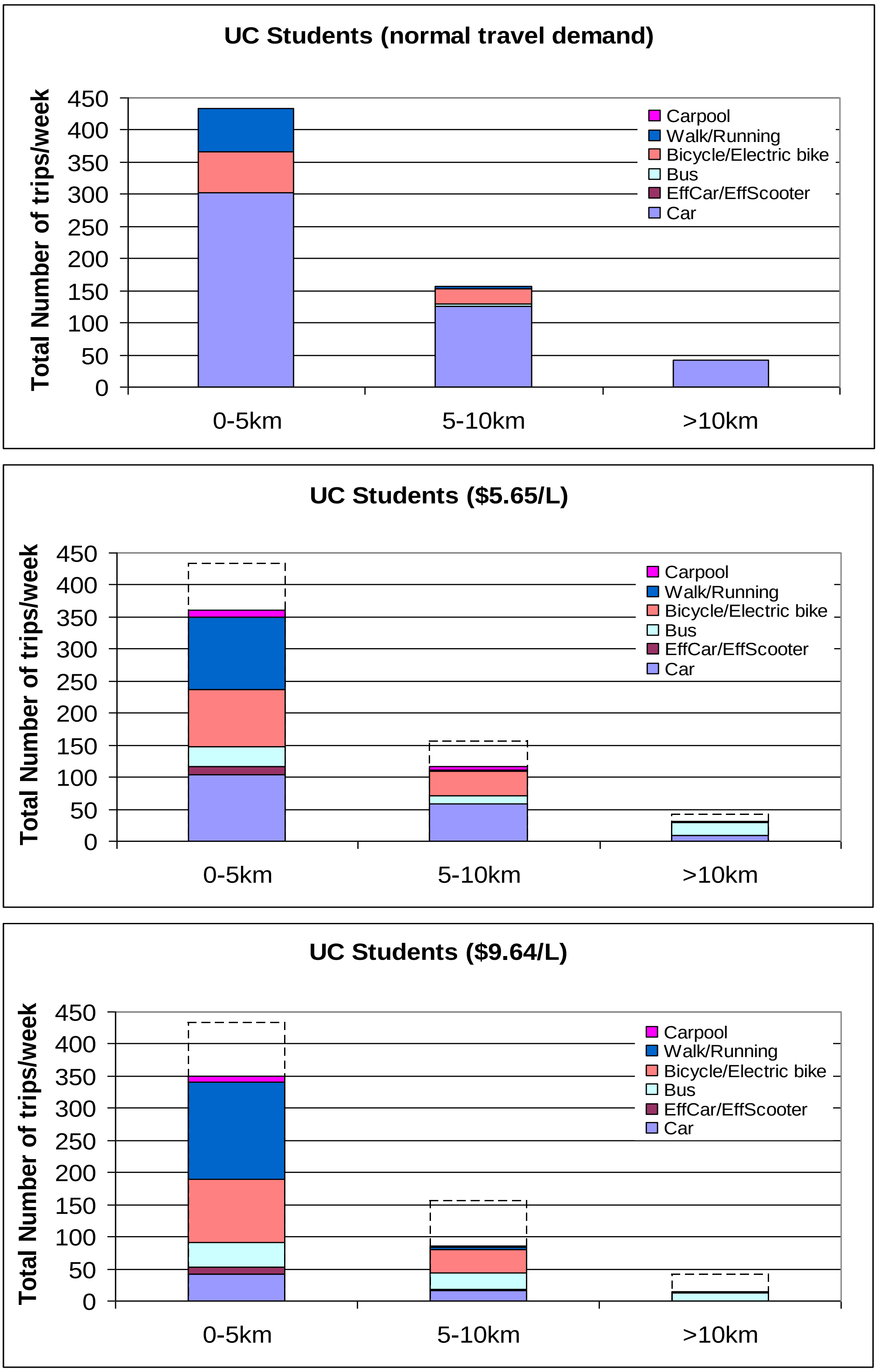


Figure 7.10: Mode choice by travel distance of UC students at fuel prices $5.65 per litre and $9.64 per litre (Total 30 participants).

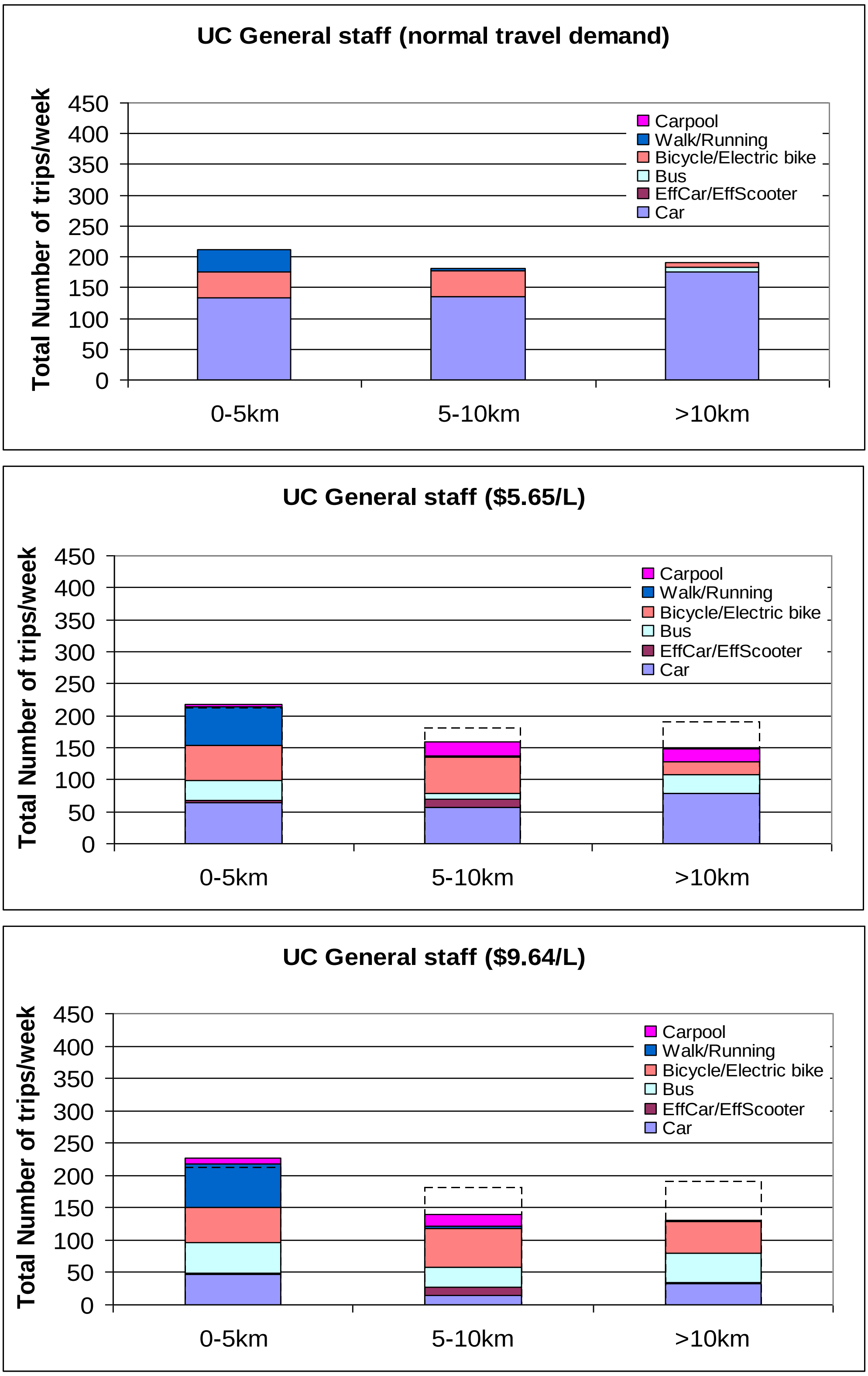


Figure 7.11: Mode choice by travel distance of UC general staff at fuel prices $5.65 per litre and $9.64 per litre (Total 30 participants).

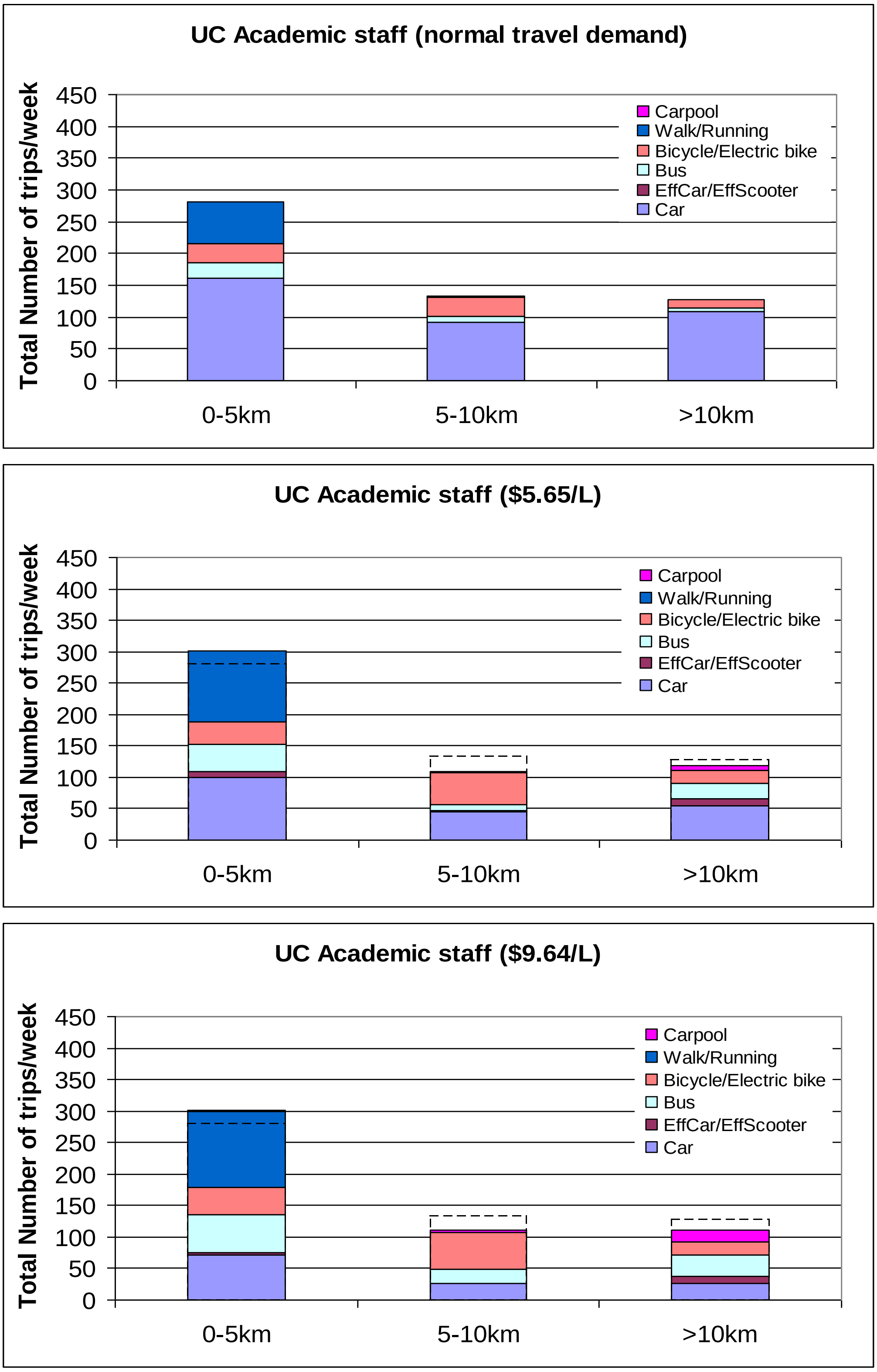


Figure 7.12: Mode choice by travel distance of UC academic staff at fuel prices $5.65 per litre and $9.64 per litre (Total 30 participants).

The general and academic staff reduced their car trips for medium and long distances when the fuel price increased to $5.65 per litre. However, the number of trips for short distance travel was increased at this fuel price. The increase in the number of trips for short distances was because the participants changed destination. For example, the participants changed to carry out recreational activities in their local area so they could abandon their car and use non-fuel using modes such as a bicycle or walking. Changing the destination to a short travelling distance also was observed when the fuel price pressure further increased to $9.64 per litre. The general staff group used more carpooling than the academic group and student group when the fuel price was at $5.65 per litre. It is likely that the general staff who live far from the university have more similar working hour patterns than the academic staff. Therefore, it is more feasible for them to carpool.

7.5.4 Reduction Potential in Car Travel and Fuel Consumption

The simulation of fuel price pressures in TACA Sim captured the tendencies for car use reduction by the participants. The carpool mode was not included in "car" category in this analysis as it was assumed that the participants were the passengers in the other cars. Table 7.6 shows the distribution of the reduction in the number of car trips in a week. The first category (0%) shows the number of participants who did not reduce their car trips when the fuel price was at $5.65 per litre and $9.64 per litre. The academic staff group had a lower number of participants who reduced their car trips compared to the general staff and students groups. Most participants reduced their car trips by 50-70% when the fuel price rose to $5.65 per litre. After the fuel price increased to $9.64 per litre, more participants in all groups reduced the number of car trips.

Table 7.6: Car trip reductions in a week at fuel prices $5.65 per litre and $9.64 per litre.

Number of participants who reduced the number of car trips							
Number of car trip reductions per week	**Fuel price at $5.65/litre**			**Cumulative number of car trip reductions per week**	**Fuel price at $9.64/litre**		
	Students	**General staff**	**Academic staff**		**Students**	**General staff**	**Academic staff**
0%	2	3	9	**0%**	0	0	6
<10%	0	1	1	**<10%**	0	0	0
10-20%	1	0	1	**10-20%**	0	0	0
20-40%	3	4	1	**20-40%**	1	3	4
40-50%	2	1	1	**40-50%**	0	0	0
50-70%	8	9	8	**50-70%**	4	3	2
70-90%	8	5	2	**70-90%**	6	9	7
90-100%	0	1	0	**90-100%**	3	2	1
100%	6	6	7	**100%**	16	13	10
Sum	30	30	30	**Sum**	30	30	30

Similarly to the reduction in car trips, the academic staff group had a lower number of participants who decreased their kilometres travelled by car than the general staff and student groups. Table 7.7 illustrates the distribution of car travel distances reduction in a week at fuel prices $5.65 per litre and $9.64 per litre. Most participants reduced more than 50% of their car travel distances when the fuel price increased to $5.65 per litre. After the fuel price rose to $9.64 per litre, the student group showed the highest number of participants eliminating all of their car travel. The results of the reduction in car travel distances are also relevant to the students' and staff's capacity in reducing fuel use as shown in Table 7.8.

Table 7.7: Reduction in kilometres travelled by car in a week at fuel prices $5.65 per litre and $9.64 per litre.

Number of participants who reduced kilometres travelled by car							
Car kilometres reduction per week	**Fuel price at $5.65/litre**			**Cumulative car kilometres reduction per week**	**Fuel price at $9.64/litre (week 3)**		
	Students	**General staff**	**Academic staff**		**Students**	**General staff**	**Academic staff**
0%	2	3	8	**0%**	0	0	5
<10%	0	1	2	**<10%**	0	1	0
10-20%	1	2	1	**10-20%**	0	0	0
20-40%	4	4	1	**20-40%**	1	2	1
40-50%	5	3	4	**40-50%**	0	0	1
50-70%	6	3	5	**50-70%**	3	3	4
70-90%	4	6	2	**70-90%**	7	7	9
90-100%	2	2	0	**90-100%**	3	4	0
100%	6	6	7	**100%**	16	13	10
Sum	30	30	30	**Sum**	30	30	30

Table 7.8: Reduction in fuel consumption in a week at $5.65 per litre and $9.64 per litre.

Number of participants who reduced fuel consumption							
Fuel consumption reduction per week	**Fuel price at $5.65/litre**			**Cumulative Fuel consumption reduction per week**	**Fuel price at $9.64/litre**		
	Students	**General staff**	**Academic staff**		**Students**	**General staff**	**Academic staff**
0%	2	3	8	**0%**	0	0	5
<10%	0	1	2	**<10%**	0	1	0
10-20%	1	2	0	**10-20%**	0	0	0
20-40%	4	3	3	**20-40%**	1	1	1
40-50%	2	3	1	**40-50%**	0	2	2
50-70%	5	4	6	**50-70%**	1	3	2
70-90%	6	4	3	**70-90%**	7	6	10
90-100%	4	4	0	**90-100%**	5	4	0
100%	6	6	7	**100%**	16	13	10
Sum	30	30	30	**Sum**	30	30	30

The reduction in distance travelled by car was converted to the reduction in fuel consumption in a week using equation 7.1 as shown below.

***Total Fuel consumption (V) calculation*:**

$$V = \sum_{i=1}^{n} \left(\frac{Y_i \cdot d_i}{O_i} \right) \qquad \textbf{(7.1)}$$

where,

Y_i = fuel consumption rate (litres per 100 kilometres)

d_i = Distance travelled by fuel-using vehicle (Rindsfüser, et al.)

O_i = number of people in vehicle

n = number of trips

At the fuel price $5.65 per litre, most participants reduced fuel consumption more than 50%. More participants reduced their fuel consumption when the fuel price increased to $9.64 per litre. Over 30% of the participants of each group reduced all of their fuel consumption at this fuel price.

From observation of trip purposes, the student group contributed the greatest reduction in car trips for their educational activity compared to work activity of the staff groups. Figure 7.13 presents the percentage of car trip reductions potential for work/educational purposes of students and staff. The participants in all groups reduced car trips more when the fuel price pressure increased to $9.64 per litre. However, the student group is still predominant for the car trip reduction.

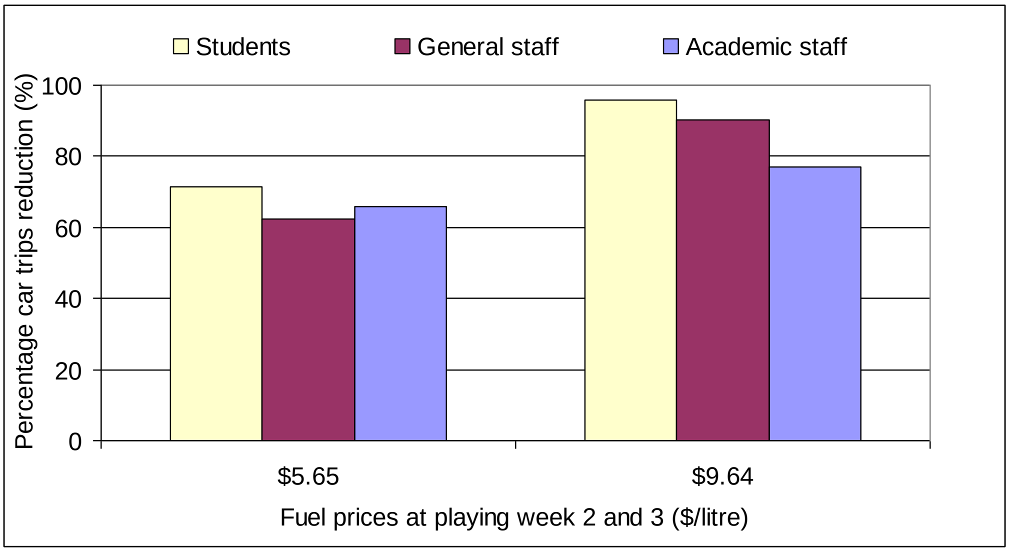


Figure 7.13: Percentage reduction potential in car trips for work/education purposes under fuel price pressures at $5.65 per litre and $9.64 per litre.

7.5.5 Petrol Consumption Elasticity

Two large intervals in the price increases were simulated to observe travel pattern changes in the travel adaptive potential survey level. The changes in travel distance when the fuel price rises from $1.64/litre to $5.65/litre and to $9.64/litre were used to calculate changes of petrol consumption. The radical changes in the fuel price in the TACA Sim result in no continuous function of time. Therefore, shrinkage ratio (equation 2.2) was applied to estimate fuel consumption elasticities in the case study.

Table 7.9 shows the total petrol consumption at different fuel price pressures. The total petrol consumption was calculated by using equation 7.1. The petrol consumption at week 1 was not included in the elasticity calculation because the fuel price assigned in week 1 is the same as the average current price. The participants reduced fuel consumption in this week as they responded to the feedback scores. This was proven by the participants' feedback on scores as shown in Figure 6.10. From the surveyor's observation, only one participant responded to the fuel price in week 1. This person was a passenger in a vehicle. Therefore, she responded to the price when she was asked to purchase the fuel herself.

Table 7.9: Total petrol consumption at different fuel prices.

	Normal (*i*=1)	**week 1 (*i*=2)**	**week 2 (*i*=3)**	**week 3 (*i*=4)**
Fuel price ($/litre) P_i	1.64	1.64	5.65	9.64
Total petrol consumption (litre) V_i	927.27	914.16	411.09	232.30

Petrol consumption elasticity of petrol price pressure increase from $1.64 per litre to $5.65 per litre:

Percentage change in petrol consumption (ΔV_{13}):

$$\Delta V_{13} = \frac{(V_3 - V_1)}{V_1} = \frac{(411.09 - 927.27)}{927.27} = -0.55$$

Percentage change in petrol price pressure from $1.64/litre to $5.65/litre:

$$\Delta P_{13} = \frac{(P_3 - P_1)}{P_1} = \frac{(5.65 - 1.64)}{1.64} = 2.44$$

According to shrinkage ratio, petrol consumption elasticity (E_P) is defined as:

$$E_{P13} = \frac{\Delta V_{13}}{\Delta P_{13}} = \frac{-0.55}{2.44} = -0.22$$

Therefore, petrol consumption elasticity is equal to -0.22.

Additional petrol consumption elasticity of petrol price pressure increase from \$5.65 per litre to \$9.64 per litre:

Change in petrol consumption (ΔV_{34}):

$$\Delta V_{34} = \frac{(V_4 - V_3)}{V_3} = \frac{(232.30 - 411.09)}{411.09} = -0.43$$

Percentage change in petrol price pressure from \$1.64/litre to \$9.64/litre:

$$\Delta P_{34} = \frac{(P_4 - P_3)}{P_3} = \frac{(9.64 - 5.65)}{5.65} = 0.71$$

According to shrinkage ratio, petrol consumption elasticity (E_P) is defined as:

$$E_{P34} = \frac{\Delta V_{34}}{\Delta P_{34}} = \frac{-0.43}{0.71} = -0.61$$

Therefore, petrol consumption elasticity is equal to -0.61.

Petrol consumption elasticity obtained from the travel behaviour change in TACA Sim was compared to the petrol consumption elasticities in previous New Zealand studies as shown in Table 7.10.

Table 7.10: A comparison of fuel consumption elasticities between TACA Sim and previous New Zealand studies (adapted from Kennedy and Wallis (2007)).

	SR	MR	LR	Estimation Method
TACA Sim ($1.64/litre-$5.65/litre)	**-0.22**			Shrinkage ratio
TACA Sim ($5.65/litre-$9.64/litre)	**-0.61**			Shrinkage ratio
Kennedy and Wallis (2007)	-0.15	-0.20		Econometric model
Barns (2002)	-0.20		-0.07	Cointegration model
MED (2000)	-0.07		-0.19	Partial adjustment model

SR = short run (over a year)
MR = medium run (2-4 years)
LR = long run (5-10 years)

The elasticity obtained from TACA Sim survey was assumed short-run (SR) elasticity (the impact of prices over the first year) because the participants were asked to perceive the possible changes of their normal travel pattern based on their situation at the time of the survey. Therefore, the petrol consumption elasticity in this case is consistent throughout a certain period.

Most price elasticities of New Zealand studies show short-run values between -0.03 to -0.15 and long-run values from -0.07 to -0.19 (D. Kennedy & Wallis, 2007). Price elasticity of petrol consumption at $1.64/litre-$5.65/litre of TACA Sim survey is above this range (-0.22). However, the value is similar to the elasticity of Barns (2002). The petrol consumption elasticity estimated from the TACA Sim dataset becomes -0.61 when the fuel price increased again from $5.65/litre to $9.64/litre. This elasticity value presents an additional reduction in petrol consumption when the fuel price increased the second time in week 3 ($5.65/litre-$9.64/litre). The elasticity value of the price increase in this week is bigger than the value of the price increase in week 2. This is because the price increase in week 2 was 244% and the price increase in week 3 was 71%, while the percentage of the petrol consumption reduction in week 3 (43%) was not much different from the percentage of the reduction in week 2 (54%). Therefore, the petrol consumption of the second increase is more elastic than the first increase ($1.64/litre-$5.65/litre).

7.6 Policy Implications of the Results

Future growth

Participants first indicated that they currently had alternatives to over 60% of their car trips. Then they voluntarily re-scheduled to virtually eliminate car use when fuel price pressure was simulated. The results from case study show that future growth in demand for alternative modes is likely. The participants reduced their fuel consumption through changing destination (e.g. shopping at local shops), changing transport mode, chaining trips, etc. There was a noticeable growth in demand for bus, cycling, walking and car pooling, while numbers of car trips were reduced. This research indicates that building more roads for future growth is not the best alternative solution to the transport demand management. These changes in demand trend could be supported by policy that targets the following:

- Providing a safe walking environment and bicycle lanes.
- Improving availability of public transport.

- Considering providing electric buses so that people have an option for their travels.
- Subsidizing bus fare for low-income people to encourage changing mode.
- Encouraging institutions to acquire buses that can transport their workers.
- Local authorities can put measures in place that would encourage carpooling.

Land Use and Developments

Integration of residential, commercial and industrial sectors to improve access to housing, jobs and services by walking, cycling and public transport may help people to reduce travel distance by car. Over 90% of participants lived within the urban area of the city, and within 20 km of the university. Christchurch already has a high degree of integration, particularly with regard to food shopping and basic services such as mail, banking, medical and schools. The integration of the urban form may have contributed to the participants' high adaptive potential for reducing car trips while maintaining participation in activities. Policy to maintain the city's high adaptive potential would focus on controlling development of large discount retail centres on the fringe of the city and managing residential construction to ensure affordable units are available in all areas.

Housing and Using Technologies

Cancellation of jobs and studies was another potential that the participants did in the travel adaptive potential survey. This indicates a possibility that the University as an organization may lose their employees and students if future oil depletion or fuel price pressures occur. In the light of policy implications for an organization, providing accommodation near workplace for low income staff and students (for university) and technologies to facilitate working from home are solutions that could be done.

Real Estate Values

During the survey, there was a potential that people will buy a house close to where they work. Real estate developer may see the future trend of land and housing value from this information.

7.7 Summary

Data collected by TACA Sim can be used to analyse many aspects of individual transport adaptive capacity. The case study shows that residential distance to and from the university is a main factor that influences distance travelled by car. This is because working/studying trips account for the majority of trips in a normal week. The students who live within 5 kilometres of the university were likely to reduce more car trips than the staff who live more than 5 kilometres away when the fuel price pressure was high. Income level is another factor that affects the car trips and car kilometre reduction potential under the fuel price pressures. The results from TACA Sim survey are useful not only for assessing urban form and transportation systems, but also for policy implications as shown in section 7.6.

CHAPTER 8

WEB-BASED TACA SIM DESIGN

8.1 Introduction

This chapter focuses on the embodiment of the TACA Sim platform in a commercial game engine. In response to this prospect, a web version of the TACA Sim has been developed for the travel adaptive capacity survey level in order to increase accessibility to the survey and improve operational speed and survey time. A research project has been initiated to use the web version to develop datasets for urban and rural settlements in New Zealand. Currently, the web version of TACA Sim has been launched for travel adaptive capacity assessing services. The application of web-based TACA Sim for adaptive capacity assessment was demonstrated in "*TACA Sim: a survey for adaptability assessment.* (Krumdieck, Watcharasukarn, & Page, 2010)"

8.2 Web Design of Travel Adaptive Capacity Survey

The TACA Sim web version has been developed from the computer-based TACA Sim's structure (see section 4.2). In this web-based version, TACA Sim was improved by:

- Operating it on the faster platform,
- Adding copy a single trip function and edit trip,
- Adding "Swap" button for creating a return trip to flip the address from origin to destination and vice versa.
- Allowing database data storage on a web server,
- Automatically recording coordination of origin and destination.

However, the data type, structure of questions and information were not changed in the web version. The web-based TACA Sim maintains the three levels of the survey, namely the personal information level, vehicle information level, and travel adaptive capacity survey level.

8.2.1 Personal Information Level

Maintaining the same structure, the participants can register with the TACA Sim system by filling in their personal information on the "Personal Info" webpage. The participants define user name and password for future login to the system before creating a personal profile. The profile includes the questions of age, gender, occupational status, family status, annual personal income, number of people in the household, number of school age children, and number of cars and motorcycles in household. The participants are also asked to choose a cartoon character avatar for enjoyment. Figure 9.1 shows a webpage of the personal information survey.

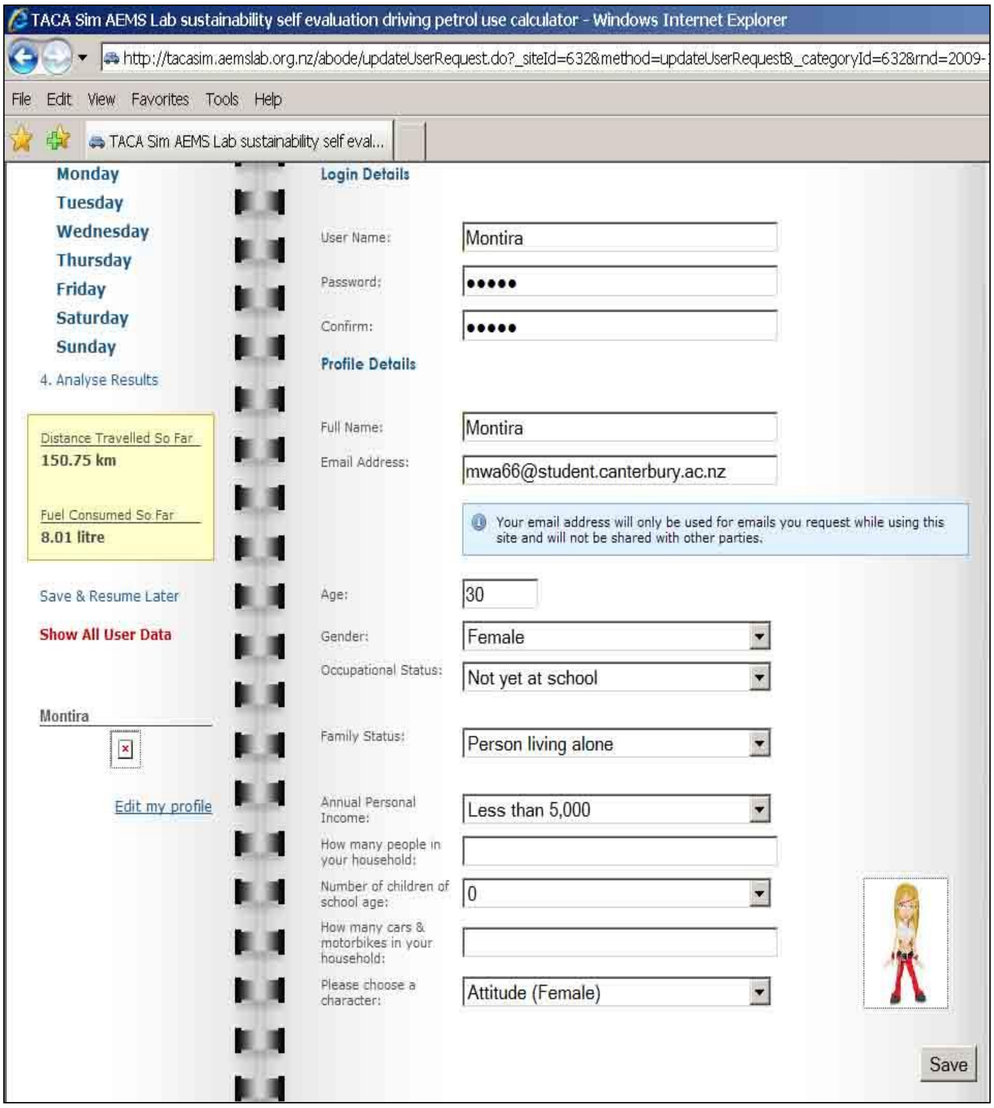


Figure 8.1: A personal information survey page on the TACA Sim website

8.2.2 Vehicle Information Level

The vehicle information or "My Vehicles" page allows the participants to fill in the details of their vehicles. The TACA Sim website provides drop-down lists for vehicle type and fuel type used in the vehicle. Figure 9.2 presents a vehicle information webpage on the TACA Sim website. The participants can click on the "My Vehicles" page to add or modify the vehicle that they use for a trip at anytime. The participants who do not use any motor vehicle in a typical week can skip this page and continue on to the travel diary.

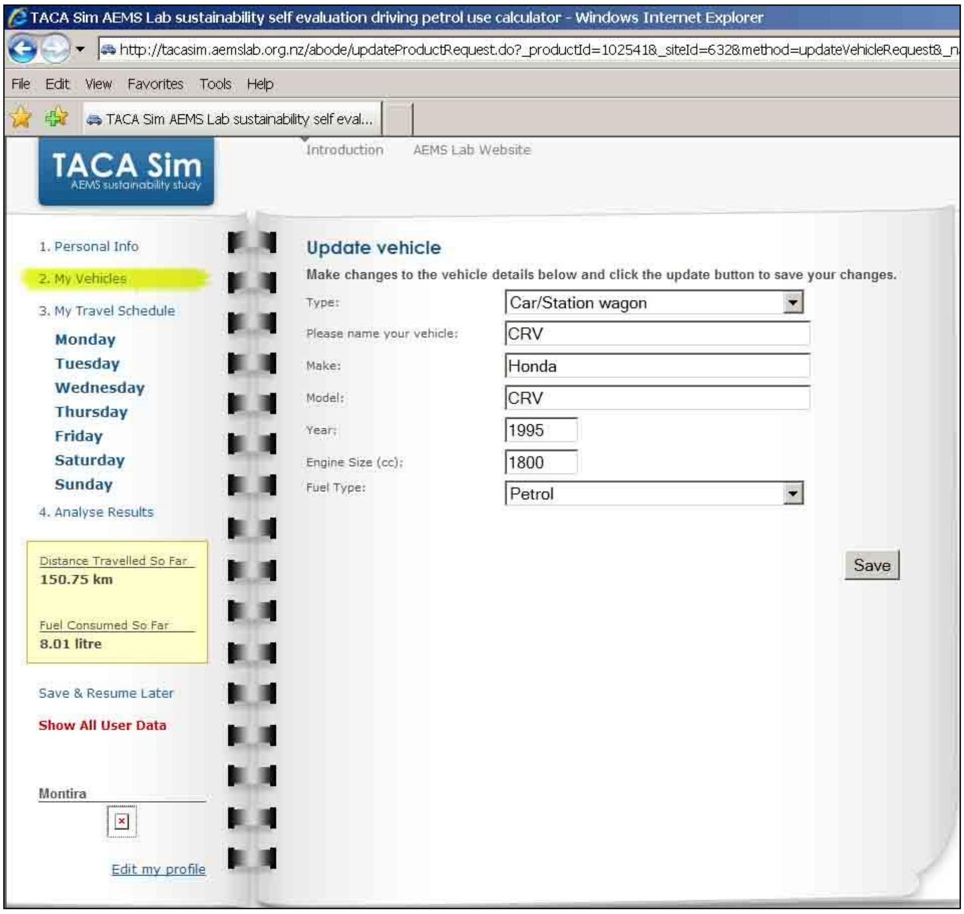


Figure 8.2: A vehicle information survey page on the TACA Sim website

8.2.3 Travel Adaptive Capacity Survey Level

The travel diary feature was improved in the TACA Sim website as shown in Figure 9.3. The participants can record their travel activities in a week and there is no limit to the number of trips recorded in the TACA Sim web version. The questions on the TACA Sim computer-based version are shortened in this version and the questions include the activity description, activity purpose, and the importance of the activity. The term "Importance of the activity" is developed from the question "If you were not able to do this activity, what would be the impact for you or your family?" term used in the computer-based version for easy understanding. The choices of this question are low, medium, and high (see the definitions in section 4.2.2). These choices reflect the essentiality of the activity.

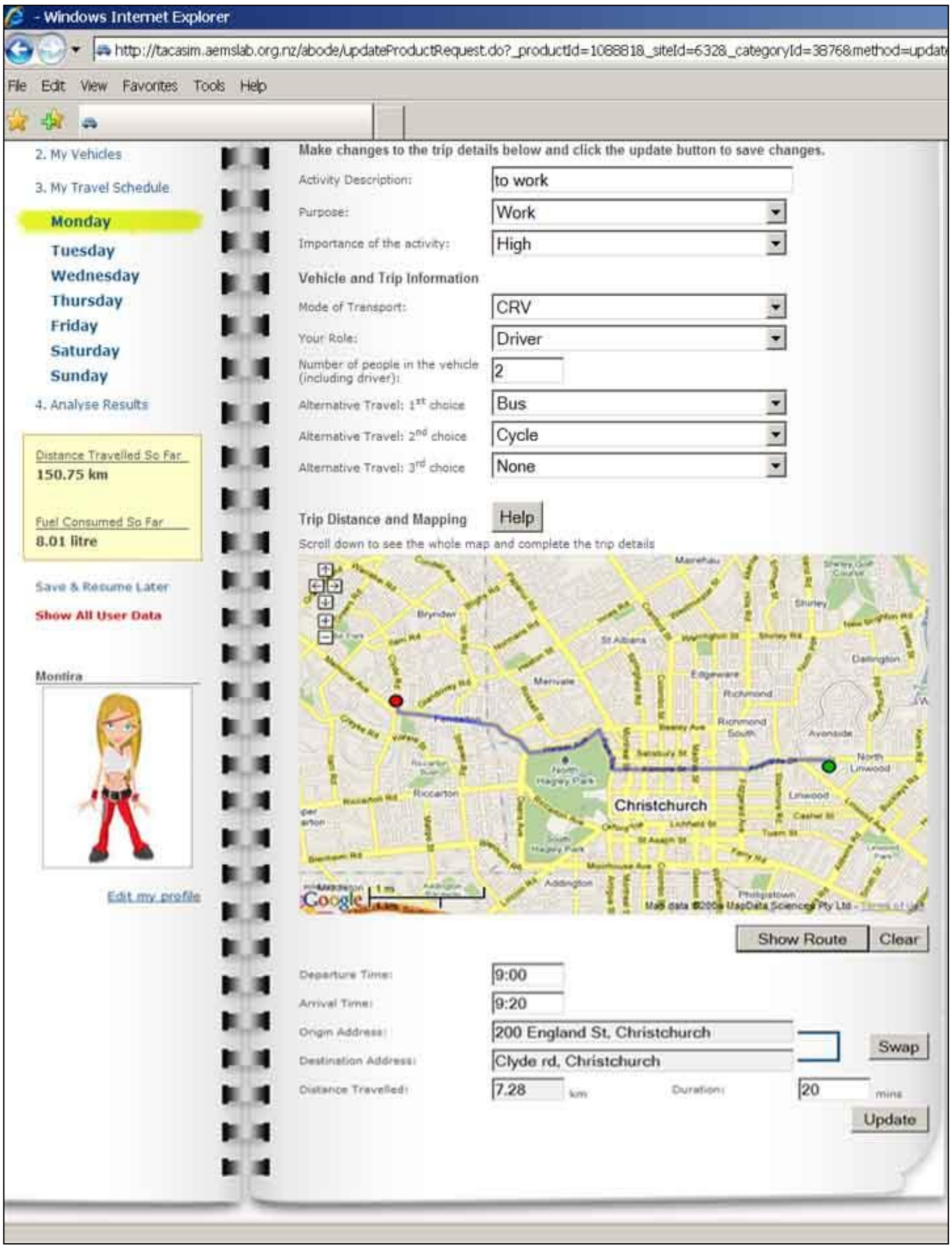


Figure 8.3: A travel diary page on the TACA Sim website

Further, the questions on vehicle and trip information are asked for mode of transport, role as a driver/passenger and number of people in the vehicle. The question "Could you get to the activity another way?" is used to probe alternatives. On the travel diary page, a Google map is embedded in the diary so the participant can generate their travel distance either by filling in their full addresses of origin and destination or by indicating the origin and destination on the map. The Google map will automatically generate a recommended route and travel distance for them. If the participants do not travel on the given route, they can use the mouse to drag the route following the route they normally take. The map also produces coordinates of the origin, destination, and route, which will be recorded in the dataset. On the mapping section, departure and arrival time are required for generating travel duration.

For creating a return trip, the participants can copy trip and use the "Swap" button on the mapping section in the travel diary to flip the address from origin to destination. The TACA Sim web version allows copying a single trip and editing the trip functions. Figure 9.4 illustrates the copy, edit and delete buttons of each trip on the Monday diary page. These functions help in reducing the time spent to create the new trips as the participants can copy the trip to the same day or another day on the diary. After the participants finish their travel diary, they can click on "Analyse Results" to get scores for the self-evaluation of their travel activities in a week.

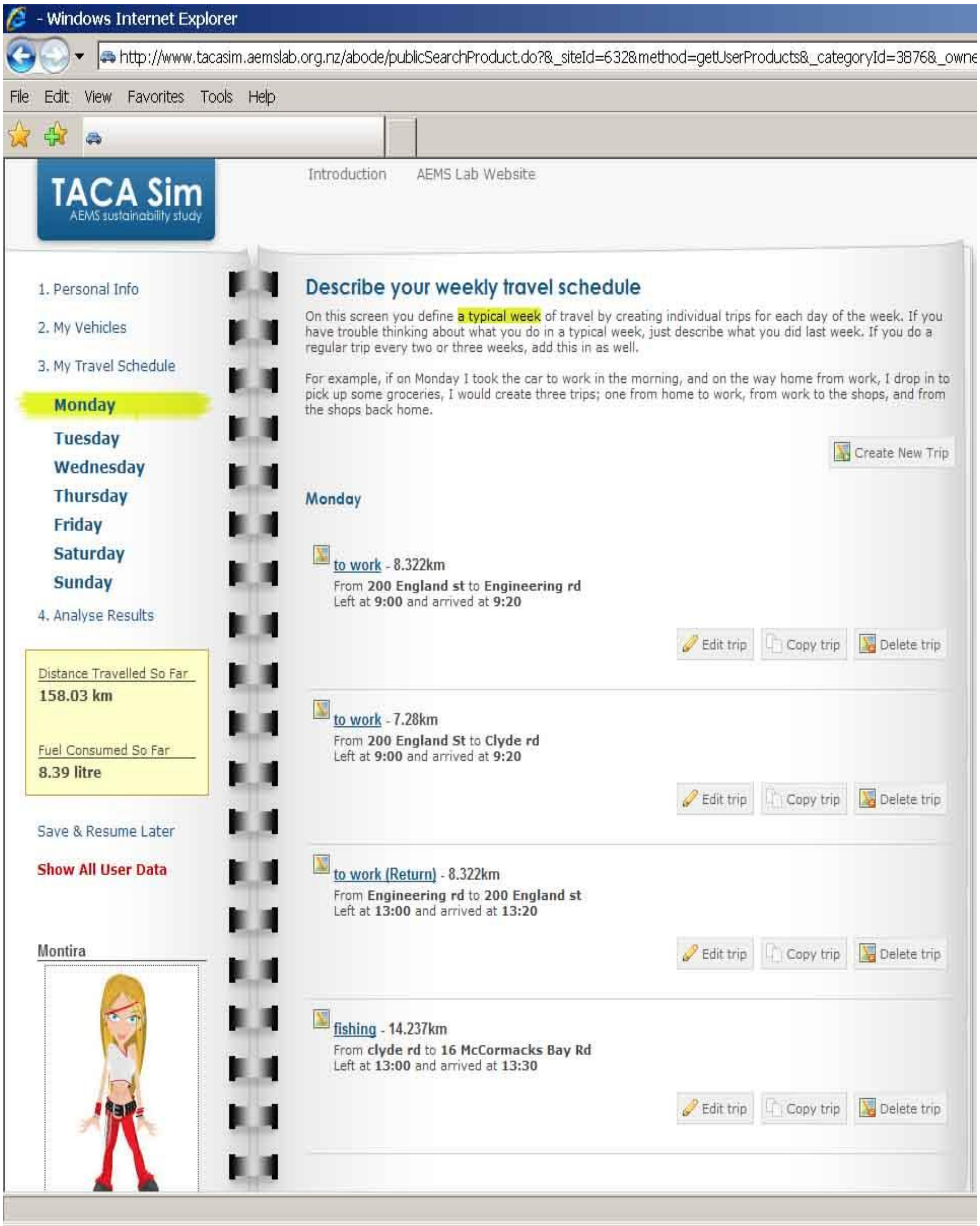


Figure 8.4: Travel diary on Monday with copy, edit and delete buttons of each trip

8.2.4 Scores for Self-evaluation

The feedback page is modified in the TACA Sim web version as shown in Figure 9.5. The participants receive a summary of their weekly total travel distance (kilometres), travel distance by car (kilometres), fuel consumption (litre/person) and travel time (minutes).

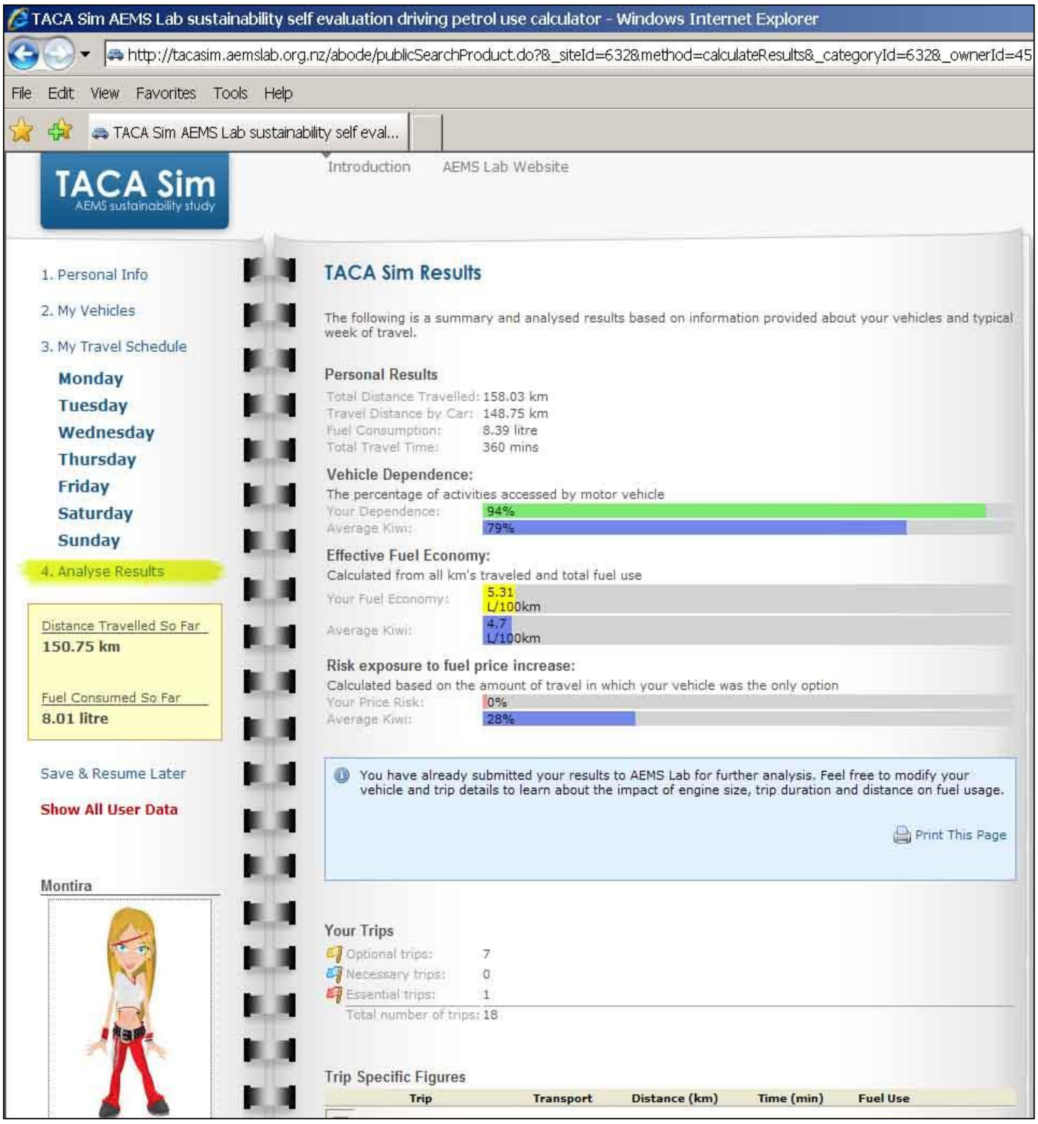


Figure 8.5: Scores page on the TACA Sim web version

The three indicators, i.e. vehicle dependence, effective fuel economy, risk exposure to fuel price increase, with short descriptions are presented as the feedback scores. Moreover, the feedback page of the TACA Sim web version has added the New Zealand (Kiwi) average values of three indicators. Then, the participants evaluate their travel behaviour comparing the Kiwi averages.

Vehicle Dependence: Similarly to the TACA Sim computer-based version, vehicle dependence is the percentage of private car trips out of the total trips that a person made in a week (see equation 4.1). The Kiwi average of vehicle dependence is calculated by using the dataset of the Ministry of Transport New Zealand (MOT, 2008a):

Number of trips (million trip legs per year)		
Car Driver	Car Passenger	Total trips
3467	1633	6409

According to equation 4.1, Kiwi vehicle dependence, therefore, equals to (3467+1633)·100/6409 = 79%.

Effective Fuel Economy: The total fuel consumption per 100 kilometres travelled in a week (litre/100km). Use equation 7.1 to obtain total fuel consumption. The fuel economy can be calculated by:

$$Fuel = \frac{V}{D} \cdot 100 \qquad \textbf{(8.1)}$$

where,

V = Total fuel consumption (litre).

Fuel = Fuel economy (litre/100km).

D = Total distance travelled in a week. (kilometres)

For example, a person drives a car 42 km from the total travel of 62 km in a week. His total fuel consumption is 3 litres. The effective fuel economy would be (3/62)*100 = 4.8 litre/100km.

Car distance -km-	Total distance -km-	Total fuel consumption (litre)	Effective fuel economy (litre/100km)	Kiwi average of petrol economy (litre/100km)
42	62	3	4.8	9.9

The Kiwi average of petrol economy in 2008 is 9.9 litre/100km (MOT, 2008b). Therefore, the fuel economy of this person is better than the Kiwi average.

Risk exposure to fuel price increase is measured from using equation 4.3. The Kiwi average of the risk exposure score is estimated from the TACA Sim dataset, which was generated from UC and Oamaru TACA Sim surveys during November 2008 to August 2009. The dataset of UC was assumed to represent the travel demand data of 149 participants in the urban area, while the Oamaru travel pattern dataset (79 participants) was assumed to represent travel pattern characteristics in a rural area. The UC average risk exposure score was 0.17. The average risk exposure score of Oamaru participants was 0.49. Therefore, the average risk exposure score equals 0.28 when all participants in both areas are combined.

8.3 Summary

The web-based TACA Sim design for adaptive capacity study was developed to meet a rapid requirement for assessing given urban form and transportation systems. "Copy", "Edit" and "Swap" buttons were added to the web-base version in order to reduce survey time. These additional functions however did not affect quality of data. The quality of data collected through the web-based version was the same as collected through the computer-based version. Asking "Could you get to the activity another way?" is a key approach to probe individual's alternatives. This question works effectively to retrieve data about alternatives to car trip. The alternatives to car trips are used for investigating travel adaptive capacity.

CHAPTER 9

CONCLUSIONS

9.1 Achievements of research

1) TACA Sim provides data about travel adaptive capacity and adaptive potential:
    a. by asking “Could you get to the activity another way?”
    b. by prompting people to perceive price-pressured situation.
2) TACA Survey provides data about:
    a. Travel Adaptive Capacity.
    b. Travel Adaptive Potential.

9.2 Contributions of research to the field

1.) A way to retrieve data of individual travel adaptive capacity of particular cohort in a given urban form.

2.) A way to retrieve data of individual travel adaptive potential in response to shocks in fuel prices as a proxy of future oil depletion (after peak oil).

3.) Data available for supporting decision making for long-term plan to cope with future oil depletion.

9.3 TACA Sim design

Using virtual reality in TACA Sim improved participants' perception on the simulated situation. This conclusion is supported by the results of observation on participants' intention change in Figure 6.9 (see Section 6.5.2). The results from feedback on the TACA design also show that the given questions encouraged the participants to consider their current travel pattern and the transport alternatives.

The game-like in TACA Sim may induce playful responses. However, the controlled scenario in TACA Sim reduced the negative impacts from the participants' distraction from the survey objectives e.g. participants trying to get high scores rather than reflecting the real intention. Although TACA Sim is constructed using the role-playing game concept, the surveyor operated it in a manner that encourages participants to make decisions in a serious and responsible way.

Generally, development costs for a commercial Sim game with high polygon 3D models and motion capture techniques are very high, as the game requires an advanced level of virtual technologies to imitate human life. Considering the research objectives, TACA Sim suffices to have simple graphics and performances to prompt the participants to perceive their travel options through the provided questions and information. Therefore, development costs of the TACA Sim were minimised.

The version of TACA Sim used in this study was a prototype. It does not have a professional visual look that people would expect from a commercial product even though the TACA Sim can collect the data at a certain level. The graphics and operations for gaming part need to be improved in future work for better operation. Most participants agreed that the designed buttons and interface functions are easy to understand. Nevertheless, some technical terms used in TACA Sim, i.e. fuel intensity and risk, need to be modified. Improving operational speed in TACA Sim will reduce the time consumed in the survey.

TACA Sim provides feedback information on participants’ travel pattern. The feedback information provided in TACA Sim is not expected to force the participants to change their behaviour. It is useful as a self-evaluation tool for the participants to be prepared to consider their current travel behaviour so that they may reduce fuel consumption. However, further in-depth study is needed to evaluate using feedback information to encourage reduction of fuel consumption.

9.4 Results from Case Study

The results from the case study at UC show that residential location tends to be a factor that affects the driving distance. The students tend to live closer to the university than the staff, thus driving fewer kilometres and being able to walk to the university. The income level is another factor that affects car travel during fuel price pressures. The student group that represents a low income is more sensitive to the high fuel price than the staff groups in term of car trips and car distance reductions. Bus, bicycle, and walking were popular alternative transport modes that the participants chose during the period of fuel price pressures. This information is useful for transport planners and policy makers to provide transport services and facilities that enhance individual adaptive capacity.

9.5 Limitations and Recommendations

The limitation of TACA Sim is that the tool is not suitable for long-term assessments because the transport system may be changed over the years due to developments in new transport technologies (e.g. tram lines, sky train), environmental policies, land use, transport infrastructures and networks.

In this study, it is assumed that high income people have bigger size of disposable income than low income people. In fact, it is not always the case that having higher income will have bigger disposal income. Therefore, putting a cap on disposable income for individual may reflect more on behaviour.

The travel diary in computer-based TACA Sim limits recordings to eight activities a day so this design works well for normal travellers who do not have more than eight trips a day. However, it is possible that the heavy traveller (a person who has >8 trips a day) will declare only up to eight trips as he/she is limited by visual space on the diary. This issue has been solved in the TACA Sim web-based version.

The TACA Sim requires a high-speed internet in the operation of the Google map. Dial up or slow-speed internet is not recommended as it may expand the time of the survey. Additionally, the participants in the TACA Sim need assistance at all time of the survey to complete data in order to reduce respondent burdens and errors. However, the future design may focus on developing TACA Sim for a self-administered survey to reduce travel time and costs in conducting the survey.

The data analysis of the UC case study includes the data of the participants who provided their last week's activities. Although these participants were accounted as less than 5%, the results of the normal travel pattern analysis are likely to be biased. For future work, the data analysis of the normal travel behaviour can be improved by identifying and separating the participants who do not perform routine travel activities.

Although the TACA Sim survey did not show a significant number of the respondents who stated that their travel pattern change were depended jointly on another household member's decision, it may be a bias on the result from assuming that the respondents made decision to change on their own. As studied by Jones (1979), a change in travel pattern of a person may create an impact on another person in the same household. The results of TACA sim survey also did not include a delayed response from the effects of fuel price increase (e.g. increase in food prices). However, the TACA Sim is not aimed to predict future travel behaviour. The information about their decisions to show that the choices are available and good enough is therefore still useful for assessing current urban form and transportation systems.

9.6 Future Work

Future development will focus on improvement of the design and embodiment of the TACA Sim platform in a commercial game engine in order to allow faster and smoother operation, but maintain quality of data. TACA Sim future survey may be also customised in order to compare the abilities of different cohorts (groups) to change and to understand the influences behind these differences (e.g. latent pressures, difference in cultural traditions and taboos, or difference in duties). Additionally, TACA Sim may be extended for educational purpose using feedback scores for self-evaluation.

Design development for self-administration may be considered for the future work. However, it is important to underline that the survey method where the analyst relies on self-reporting may reveal further issues associated with respondent error and bias. Although the use of self-administration survey to isolate the respondent from social charge may help reducing social disability bias, it must be emphasize that the self- administrating may allow response bias from the respondents providing answers to overly support the questions (Nederhof, 1985). This is because they realised that the questions in TACA Sim were related to the sustainability of their travel behaviour, which is currently a susceptible issue. The practitioner therefore should be aware and consider whether to allow self-completion on the TACA Sim survey. Additionally, the author would like to underline the interviewer effects that could be occurred from interactive survey. This may lead to a response bias. However, this kind of bias can be partially avoided by an appropriate training of the surveyor. The surveyor can be trained to identify the bias that is from obtaining over representation of either people who consider themselves ‘green’ or people who totally depend on car. Furthermore, questions and questions ordering of TACA Sim need a redesign to minimize “respondent burden” (P. Stopher, 1998) in applying self-administrated approach as the respondent burden may leads to negative impacts and biases on the results in a case that the respondent is tired and does not include certain trips that they make.

Moreover, future work may be focused on combination use of TACA Sim with more in-depth interview, which will enhance understanding individual decision making. This will provide a deeper insight into an individual's motivations and attitudes on the choices that were selected and not selected and on personal constraints that obstruct the changes in travel pattern. This may be useful for the researcher who is interested in constructing choice models. However, Bonsall (2009) suggested that the in-depth interviewing could be subject to interviewer effects in term if the nature of the answer given is exaggerated, especially on individual's preparedness to sacrifice money, time or convenience for greener environment and energy (social desirability bias). This has been proven significant in interviewer-administered surveys e.g. Richman *et al.* (1999) and Rocci (2009). Skilled researcher is required to investigate, analyse and isolate this potential effect.

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Appendix A: List of questions in TACA Sim survey

Personal Information

1. User name and choose character
2. Age
3. Sex
   - Male/Female
4. Which of these most applies to you?
   - Not yet at school
   - Full time student
   - Part time student
   - Full time work
   - Part time work
   - Casual work
   - Looking for work/unemployed
   - Looking after home and family
   - Retired
   - Other beneficiary
   - Other

Household Information

5. What is your personal gross income (NZD/year)
   - Under $10,000
   - $10,001-$15,000
   - $15,001-$20,000
   - $20,001-$30,000
   - $30,001-$40,000
   - $40,001-$50,000
   - $50,001-$70,000
   - $70,001-$100,000
   - More than $100,000
   - Not stated
6. How many people live in your household?
7. How many school-age children (under 18) in your household?
8. How many motor vehicles do you have in your household?
9. What is your family status?
   - Personal living alone
   - Married/de facto couple only
   - Other adults only (e.g. flatmates)
   - Family (including extended) with children
   - Family with adults only
   - Single adult living with children

- Family with child(ren) plus flatmates/boards
- Other ……………

10. How many motor vehicles do you drive or ride in during a week?
    - 0/1/2/3/4

Vehicle Information

11. Please name your vehicle………………..
12. What is the make, e.g. Toyota, Ford? …………………………
13. What is the model, e.g. Corolla, Laser? …………………………
14. What year was it made? …………………………………….
15. What type?
    - Car/SW
    - Van/Ute/PVan
    - SUV/4WD type
    - Truck
    - Motorbike
    - Taxi
    - Other ………………..

16. What is the engine size of this vehicle? …………………….(cc)
17. What is the fuel type?
    - Petrol
    - Diesel
    - LPG/CNG
    - Duel fuel
    - Electric
    - Other ………………..

Travel demand Information (diary)

18. Where did you go? (Activity) ………………
19. From where did you start your trip? (Origin) ………………………..
20. Departure time ……………………..
21. Arrival time ………………………..
22. If you were not able to do this activity, what would be the impact for you and your family?
    - Low impact. I could curtail it without suffering.
    - Medium impact. My quality of life would be reduced if I didn't have this activity, but I would not suffer real harm.
    - High impact. My wellbeing would suffer and my standard of living would be reduced.

23. How do you normally travel to this activity?
    12) Vehicle driver
    13) Vehicle passenger
    14) Rollerblade/skates
    15) Bicycle
    16) Walking
    17) Electric bike
    18) Bus
    19) Other ………………….

If choose Vehicle driver:
24. Which vehicle do you use to get to this activity?

If click add new:
25. Please name your vehicle ………………..
26. What make of motor vehicle do you drive/ride?.......................
27. What model?
28. What year was it made? …………….
29. What is the engine size of this vehicle?.............................. cc.
30. What kind
    - Car/SW
    - Van/Ute/PVan
    - SUV/4WD type
    - Truck
    - Taxi
    - Motorbike
    - Other ……………………..
31. What is the fuel type?
    - Petrol
    - Diesel
    - LPG/CNG
    - Duel fuel
    - Electric
    - Other ………………..

    After choose mode:
32. How many people in this vehicle including driver? ……..
33. What is the purpose of this activity?
    - Education
    - Work
    - Shopping
    - Social
    - Personal business/services
    - Hospital/Medical

- Social visit/Entertainment
- Recreation
- Home
- Change mode
- Accompanied someone
- Left country
- Other

If choose Vehicle passenger:

34. What vehicle do you travel in to get to this activity?
35. Could you get to this activity another way (without taking the car/fuel-using vehicle)? (please rank in order of preference 1 first,…., 3 third)
    - No
    - Yes, I could get a ride with somebody (passenger in another car)
    - No, but I could do this activity without travelling
    - Yes, by rollerblade/skates
    - Yes, by bus
    - Yes, by bicycle
    - Yes, by walking
    - Yes, by other

Map (Origin, Destination, Travel distance, Coordinates) Information

36. Origin address
37. Destination address
38. Origin coordinate
39. Destination coordinate
40. Total Distance (Rindsfüser, et al.)

Feedback scores

41. Number of Optional trip
42. Number of Necessary trip
43. Number of Essential trip
44. Total travel time (min)
45. Total travel distance (Rindsfüser, et al.)
46. Travel distance by car (Rindsfüser, et al.)
47. Fuel consumption (litre)
48. Car dependence (%)
49. Fuel intensity (%)
50. Fuel price exposure (Risk) (%)

Appendix B: Trip purposes

Home
Return home
Stay at home

Education
School
University
Special training

Personal business/Services
Personal services (Salon, barber, laundry, auto repair,…)
Banking
Video store
Library
Other service
Other errands
Delivered/picked-up something
Gas station

Change mode
Travel to bus stop/bus exchange
Travel to take Taxi or other different mode

Work
Work
Business meeting
Volunteer work
Other works

Hospital/Medical
Doctor
Dentist
Drug store
Other medical professional

Accompanied someone
Drop off/Pick up someone
Chauffeuring
Attending to children

Shopping
Minor groceries (<10 items)
Major groceries (10+ items)
Housewares
Clothing/personal items
Mostly browsing/ Window-shopping
Convenience store
Pick-up meal
Other shopping

Social visit/Entertainment
Visiting
Hosting visitors
Bars, special clubs
Coffee/snack shops
Restaurant
Overnight at someone's house

Social
Cultural events
Religious events
Planned social events
Helping others
Other social

Left country/city
Leaving country/city

Recreation
Exercise or active sports
Golf
Spectator sports
Movies/theatre
Other spectator events
Playing with kids
Parks, recreation areas
Regular TV programs
Unspecific TV
Movie video
Browsing Web sites/Using internet
Relaxation/Rest
Relaxing/pleasure reading/napping
Hobbies (crafts, gardening, etc.)
Other recreation/entertainment

Other
Pleasure driving

(Sean T. Doherty & Eric J. Miller, 2000; Ming S. Lee & McNally, 2001)

Appendix C: Results of individual travel demand

Student participants ([yellow box] = participants who continue to adaptation survey)

ID	Total Trips/person	Total Distance	Car trips per person	Car dependence (%)	Car km per person	Car km (%)	Total fuel per person(L/week)
S-001	22	92.8	4	18.2	24.8	26.7	1.18
S-002	24	42	6	25	30.4	72.4	1.65
S-003	12	77	0	0	0	0	0
S-004	20	364	6	30	262	72	12.18
S-005	16	81.58	6	37.5	51.99	63.7	1.98
S-006	13	231.5	2	15.4	172	74.3	4
S-007	15	45	4	26.7	25	55.6	2.06
S-008	22	40.2	4	18.2	14.2	35.3	0.5
S-009	14	38.19	2	14.3	13.2	34.6	0.45
S-010	12	40	12	100	40	100	1.59
S-011	17	71	3	17.6	23	32.4	0.53
S-012	14	430	4	28.6	400	93	10.23
S-013	20	138	14	70	114	82.6	6.56
S-014	12	18	2	16.7	8	44.4	0.43
S-015	15	26.2	15	100	26.2	100	1.96
S-016	21	123.1	8	38.1	29.8	24.2	2.61
S-017	12	77.18	12	100	77.18	100	3.95
S-018	12	44	12	100	44	100	2.11
S-019	34	137.18	34	100	137.18	100	7.76
S-020	26	145	6	23.1	100.8	69.5	8.74
S-021	18	49.2	10	55.6	31.6	64.2	2.21
S-022	26	145.79	16	61.5	127.8	87.7	9.31
S-023	16	30.2	2	12.5	2.2	7.3	0.1
S-024	18	155.29	16	88.9	151.89	97.8	0.23
S-025	14	127	14	100	127	100	10.13
S-026	18	100.4	4	22.2	51.2	51	1.87
S-027	30	102	30	100	102	100	9.8
S-028	16	97.2	16	100	97.2	100	4.75
S-029	22	107.07	22	100	107.07	100	5.2
S-030	13	44.99	11	84.6	31.19	69.3	1.57
S-031	20	50.4	20	100	50.4	100	2.37
S-032	14	116.6	4	28.6	63.6	54.5	64.1
S-033	21	114.18	15	71.4	87.19	76.4	3.8
S-034	23	47.08	13	56.5	40.09	85.2	3.42
S-035	27	120.49	27	100	120.49	100	10.68
S-036	14	22.2	0	0	0	0	0
S-037	14	86.8	0	0	0	0	0
S-038	18	40.6	6	33.3	28.6	70.4	1.33
S-039	12	14.78	12	100	14.78	100	1.37
S-040	28	101.09	28	100	101.09	100	6.67
S-041	13	144.2	13	100	144.2	100	15.64
S-042	22	101.59	10	45.5	87.59	86.2	5.33
S-043	18	83.39	16	88.9	76.69	92	4.72
S-044	17	312.09	17	100	312.09	100	27.66
S-045	14	28.59	2	14.3	13	45.5	1.25
S-046	30	40.46	2	6.7	16	39.5	1.64
S-047	22	58.88	17	77.3	55.38	94.1	3.13
S-048	27	164.78	3	11.1	18.5	11.2	1.57
S-049	15	34.6	15	100	34.6	100	2.34
S-050	33	56.57	31	93.9	54.57	96.5	2.03
S-051	53	158.46	53	100	158.46	100	7.91
S-052	24	101.08	24	100	101.08	100	3.96
S-053	19	63.58	11	57.9	48.39	76.1	2.42
S-054	34	105.59	32	94.1	104.39	98.9	11.32

General staff participants ([yellow box] = participants who continue to adaptation survey)

ID	Total Trips/person	Total Distance	Car trips per person	Car dependence (%)	Car km per person	Car km (%)	Total fuel per person(L/week)
G-001	14	117	14	100	117	100	10.88
G-002	24	99.78	14	58.3	70.78	70.9	3.6
G-003	16	146	16	100	146	100	14.75
G-004	14	163.8	2	14.3	71.8	43.8	4.45
G-005	16	24	2	12.5	4	16.7	0.2
G-006	20	280	20	100	280	100	23.42
G-007	12	88.18	12	100	88.18	100	3.84
G-008	15	168.29	15	100	168.29	100	9.14
G-009	16	180.39	6	37.5	82.39	45.7	10.03
G-010	21	183.8	18	85.7	171.7	93.4	8.81
G-011	19	228.1	12	63.2	134.6	59	9.62
G-012	19	188	8	42.1	52	27.7	1.72
G-013	19	272.98	19	100	272.98	100	20.29
G-014	26	175.09	6	23.1	123.79	70.7	10.45
G-015	15	432	15	100	432	100	18.64
G-016	39	189.98	39	100	189.98	100	7.68
G-017	14	80.8	4	28.6	16.8	20.8	0.86
G-018	22	206	22	100	206	100	16.49
G-019	21	177	21	100	177	100	15.09
G-020	13	615.38	13	100	615.38	100	59.11
G-021	14	65	14	100	65	100	4.03
G-022	16	76.69	12	75	62.69	81.7	4.81
G-023	14	125	4	28.6	100	80	4.8
G-024	19	215	12	63.2	187	87	20.03
G-025	19	139.1	15	78.9	89.1	64.1	7.69
G-026	25	289.19	25	100	289.19	100	25.31
G-027	35	205.5	2	5.7	16.5	8	0.86
G-028	16	137.2	15	93.8	129.2	94.2	7.93
G-029	18	72.39	14	77.8	53.59	74	4.68
G-030	23	117.09	12	52.2	35.29	30.1	2.08
G-031	16	99.6	6	37.5	11.6	11.6	0.67
G-032	15	67.99	0	0	0	0	0
G-033	25	147.49	25	100	147.49	100	15.08
G-034	17	173.96	15	88.2	156.5	90	8
G-035	18	93.03	10	55.6	43.14	46.4	3.1
G-036	17	148.76	17	100	148.76	100	8.04
G-037	17	29.71	14	82.4	25.36	85.4	0.94
G-038	20	77.82	0	0	0	0	0
G-039	18	325	18	100	325	100	30.79
G-040	14	49	4	28.6	24	49	2.45
G-041	22	104.38	5	22.7	35.2	33.7	3.05
G-042	14	73	4	28.6	23	31.5	0.4
G-043	28	578.9	20	71.4	419.9	72.5	36.43
G-044	10	90	10	100	90	100	6.02
G-045	14	56	2	14.3	13	23.2	0.66
G-046	19	178.6	6	31.6	140.8	78.8	7.39
G-047	12	139.6	0	0	0	0	0
G-048	16	77.2	16	100	77.2	100	6.86
G-049	29	329	27	93.1	325	98.8	39.04
G-050	14	412.4	14	100	412.4	100	50.79
G-051	11	140	0	0	0	0	0
G-052	12	684	12	100	684	100	60.14
G-053	24	690	20	83.3	674	97.7	76.1
G-054	17	149.97	17	100	149.97	100	11.9
G-055	20	230.39	12	60	104.79	45.5	10.03
G-056	18	248.5	18	100	248.5	100	20.78

Academic staff participants (▭ = participants who continue to adaptation survey)

ID	Total Trips/person	Total Distance	Car trips per person	Car dependence (%)	Car km per person	Car km (%)	Total fuel per person(L/week)
A-001	21	85.2	1	4.8	6	7	0.58
A-002	6	84	6	100	84	100	3.77
A-003	9	24	9	100	24	100	2.02
A-004	15	59.4	5	33.3	39.4	66.3	8.16
A-005	45	163.89	35	77.8	153.89	93.9	11.55
A-006	16	602.39	16	100	602.39	100	51.06
A-007	18	80.79	8	44.4	67.8	83.9	3.46
A-008	8	78.4	6	75	58.8	75	6.01
A-009	17	41.66	0	0	0	0	0
A-010	15	292	11	73.3	212	72.6	8.1
A-011	14	232	2	14.3	200	86.2	5.42
A-012	9	55	9	100	55	100	3.87
A-013	12	58	12	100	58	100	4.01
A-014	26	260	16	61.5	230	88.5	9.03
A-015	13	200.18	0	0	0	0	0
A-016	14	92	4	28.6	12	13	0.41
A-017	12	136	5	41.7	55	40.4	3.49
A-018	23	164.58	14	60.9	110.59	67.2	6.74
A-019	20	47.98	6	30	25.19	52.5	2.89
A-020	16	120	6	37.5	60	50	1.45
A-021	16	88	4	25	40	45.5	1.45
A-022	24	167.6	16	66.7	162	96.7	8.43
A-023	16	35.39	12	75	28.2	79.7	2.22
A-024	14	76	0	0	0	0	0
A-025	31	88.88	19	61.3	72.49	81.6	3.03
A-026	13	275	3	23.1	170	61.8	3.87
A-027	10	24	4	40	12	50	1.12
A-028	19	149	15	78.9	111	74.5	8.36
A-029	30	253.08	30	100	253.08	100	17.82
A-030	13	70	6	46.2	31	44.3	1.2
A-031	22	207	9	40.9	192	92.8	9.87
A-032	22	180	21	95.5	170	94.4	11.85
A-033	22	444	22	100	444	100	25.93
A-034	12	145.2	12	100	145.2	100	8.61
A-035	26	314.11	4	15.4	218	69.4	12.36
A-036	17	147	17	100	147	100	15.81
A-037	14	87.19	4	28.6	44.19	50.7	1.07
A-038	24	348.8	8	33.3	76.8	22	4.08
A-039	17	92.49	17	100	92.49	100	6
A-040	19	72.7	7	36.8	27.7	38.1	1
A-041	12	243.79	8	66.7	168.99	69.3	6.53
A-042	10	524.39	10	100	524.39	100	71.64
A-043	25	150.3	25	100	150.3	100	9.94
A-044	26	236.57	2	7.7	167	70.6	7.24
A-045	14	93.8	14	100	93.8	100	6.66

Appendix D: Oil Supplies in New Zealand

New Zealand is heavily dependent on oil for transportation. The domestic and international transport sectors shared 86% of oil consumption in 2004 (MED, 2006a). Approximately 70% of petrol and diesel demand in New Zealand is supplied by Marsden Point, which is a major New Zealand oil refinery operated by the New Zealand Refining Company (NZRC). As local oil production does not cover all transport fuel demand, the demand is also supplemented by the importing of refined petroleum products (MED, 2009). Figure A illustrates the oil flow distribution summary for the year ending December 2007.

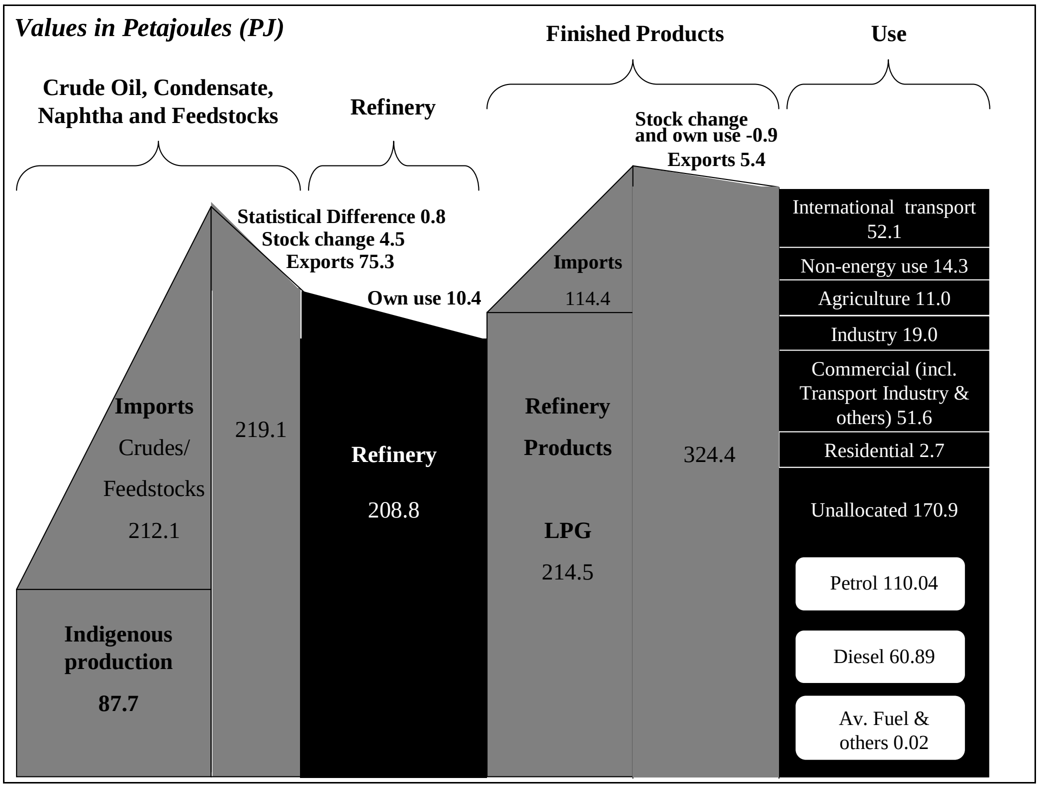

Figure A: Oil flow distribution summary for year ending December 2007 (Dang, 2008).

Around 50-60% of the crude oil and feedstock processed by NZRC is imported from the Middle East to combine with 30-40% from the Far East/Northern Australia and the indigenous production (Colegrave, Denne, Hale, Small, & Twomey, 2004). In the year 2004, 217 Petajoules (PJ) of crude oil and feedstock were imported into New Zealand (MED, 2004). The imports decreased by 0.54% in 2006 (MED, 2006b). Meanwhile, the indigenous oil production in 2006 declined 9.6% from 2004, which is 45% lower than the indigenous oil produced in 2000 (MED, 2000, 2004, 2006b). The demand for domestic transport has been continually growing since 2000 and New Zealand's self-sufficiency (domestic oil production divided by total domestic consumption) reduced to 18% in 2004 and remained 18% in the year ending September 2005 (Dang, 2006). New Zealand's self-sufficiency has increased again to 32% in 2007 owing to a domestic production increase (Dang, 2008).

Appendix E: Theory of Planned Behaviour

Travel demand, choices, and behaviour changes are planned behaviour influenced by human intentions. This section provides a psychological background about the "Theory of Planned Behaviour (TPB)" in order to understand how TACA Sim is structured and how its functions affect individual decision-making.

The theory of planned behaviour was proposed by Icek Ajzen in 1985 to help understand why people change their behaviour. Human behaviour will be performed according to personal intention (Ajzen, 1991) and the theory of planned behaviour is a theory that explains the links between human attitude, intention, and deliberated behaviour (Ajzen, 1988). The TPB proved that the behaviour is not 100% voluntary or 100% under control (Ajzen, 1991). Figure B presents the links between three kinds of elements that affect the intention and behaviour.

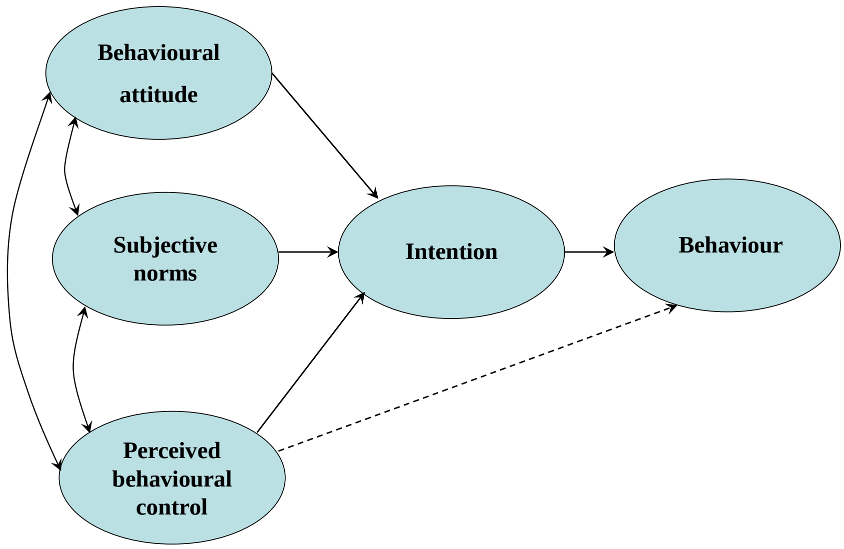

Figure B: Theory of Planned Behaviour diagram (Ajzen, 1991).

The theory of planned behaviour was developed from the Theory of Reasoned Action (TRA). The TRA suggests that the person's attitude about behaviour and norms has an influence on a person's behavioural intention (Armitage & Christian, 2004). The intention is an instant precursor of the behaviour that represents a person's willingness to perform behaviour (see Figure 2.11). When people evaluate an action as positive, and they conceive that their peers (e.g. family, friends, co-workers, supervisors) want them to do it, they have more intention of and the possibility of performing that behaviour (Ajzen, 1988).

Expanded from the theory of reasoned action, a person's intentions in the theory of planned behaviour are predicted by three things: Behavioural Attitude, Subjective Norm, and Perceived Behavioural Control (Mathiesen, 1991).

Behavioural Attitude

Attitude is affected by the summation of personal beliefs. People believe that a behaviour they intended to perform would produce an expected outcome (Schultz & Oskamp, 2005). Then, the behavioural belief determines the attitude, which will have an influence on the intention and behaviour. Before the intention will be generated, a performance of the behaviour will be evaluated for negative and positive values (Crisp & Turner, 2007). This results in a subjective probability of conducting the behaviour.

Subjective Norm

Subjective norm refers to people's beliefs and expectations of how the others they care about will see their planned behaviour (Bordens & Horowitz, 2002). The attitudes and subjective norms have a high correlation with a person's planned behaviour (Sheppard, Hartwick, & Warshaw, 1988). The perceived social pressure will affect people's decisions on either to engage or not to engage in the behaviour (Ajzen, 1988). For example, a person thinks that driving a car seems to be good as it is popular among his friends. Another person may feel ashamed of driving car while his colleagues are riding bicycles to reduce air pollution.

Perceived Behavioural Control

Perceived behavioural control is determined by a set of control beliefs, which involve a perception of presented factors that may ease or impede performance of the planned behaviour (Crisp & Turner, 2007). It is related to the ability of a person to perform the behaviour. The perceived behavioural control measures the confidence, possibility, and feasibility of a person to execute the given behaviour (Armitage & Christian, 2004). This behavioural control, therefore, leads to the intention and behaviour. For example, in the application of transport mode choice, a person intends to drive a car to work as he thinks it is convenient to travel by car. However, he decides to ride a bicycle when he considers the fuel price and finds the price is unaffordable.

The theory of planned behaviour is very useful in predicting and assessing behavioral intention in various fields, for example, in traffic and transportation (e.g. (de Groot & Steg, 2007; Diaz, 2002)), health (e.g. (Kakoko, Astrøm, Lugoe, & Lie, 2006)), tourism (e.g. (Lam & Hsu, 2004), exercise (e.g. (Rhodes, Courneya, & Jones, 2004)), and diet (e.g. (Conner, Kirk, Cade, & Barrett, 2003; Nejad, Wertheim, & Greenwood, 2005)). The theory, however, has limitations as it ignores human emotional variables such as threats, fear, mood, and negative or positive feelings.

Appendix F: Impacts of Urban Form on Travel Behaviour

Urban form refers to the physical form of a city including the layout of buildings, transport system (e.g. roads and rail), open spaces and other adjacent physical infrastructures (The Department of Internal Affairs New Zealand, 2009). The urban form is an important factor that has effects on travel behaviour and adaptation. This section presents the historical evidence for the impacts of urban form on travel pattern. Sharpe (1978), Boarnet and Crane (2001), and Clifton and Dill (2004) stated that urban design is a key element of many initiative plans aimed at reducing car travel and transport energy consumption. Gilbert and Dajani (1974), Sharpe (1978), Handy (1996), and Boarnet and Crane (2001) attempted to develop the methods for modelling and exploring the linkage between urban form and travel activity in order to comprehend the relationship of urban form and travel behaviour. Based on results of the studies of Sharpe (1978) and Buchanan *et al.* (2006), urban sprawl with a low density suburban area generates high percentages of car trips and increases suburban travel distance and time.

In the earlier period, the priority for urban infrastructure development was to serve the growth of mass car use. For example, the US congress authorized a highway construction program covering 16 years (1957-72). The program gave a system 41,000 miles (36,300 miles of inter-city routes and 6,700 miles within urban areas) to connect urban or rural freeways on a national scale. However, this enormous road network undoubtedly brought problems caused by an increase in private car use (Richards, 1969). Besides the road construction, planners and traffic engineers have been committed to search for alternative solutions for car use in a journey to work such as limiting car parking in the city centres, high parking charges and providing good public transport. However, the problem has grown further by the growth of work places outside the city centre, to which the journey is easier to make by car (Richards, 1969).

Lau and Chiu (2004) provided a case study of the accessibility of workers in a compact city like Hong Kong (short distances between residential and employment locations, high population density and the diverse provision of public transport modes). The results show that the public transport services for work trips have been efficiently operated in the compact land-use. The urban form is not the only factor that has an influence on the accessibility. Compact cities with efficient integration and performance of public transport systems can also contribute in minimizing the travel time difference between rich and poor, and between the workers who live near the railway lines and those who live in inaccessible districts. Nevertheless, Gwilliam (2001) has stated that in many cities in developing countries like Bangkok, and in some parts of Central Asia, the transfer cost of public transportation is calculated per leg trips. This is a problem of the integration of public transport modes in transport networks that the governments should consider in their transportation planning (Gwilliam, 2001).

Appendix G: Effects of Travel Information and Weather on Travel Behaviour

Decisions to perform a behaviour are based on considerations of consequences (good or bad) of the behaviour (Ajzen, 1991). The decision makers use information to evaluate their choices. Several studies have analysed the effects of travel information (such as travel time, route, alternative mode, and weather conditions) on travel choices and the requirement for travel information. For example, John and Rampellini (2004) reported that providing bus information (such as pocket bus timetable, route, and map showing the position of the bus stop) in the TravelSmart Household Program in Perth, Australia helps increase bus patronage between 9% and 20%. TravelSmart is a program conducted by governments that asks people to make voluntary changes in their travel choices. The program provides information and encourages people to use other ways rather than driving alone in a car. It does not involve any form of regulations, fees or taxes directed to compel change in travel behaviour (TravelSmart, 2010). Polak and Jones (1993) investigated travellers' requirements for travel information and methods of enquiry. They used a computer-based survey with the simulation of an in-home pre-trip information system that offers information about travel times for bus and car travel from home to the city centre at different times of the day. The survey was conducted in Birmingham and Athens. Their results show a significant use of all the enquiry facilities available, i.e. alternative mode and timing enquiries. Respondents in Athens are more interested in making enquiries concerning public transport options than respondents in Birmingham. Furthermore, their results indicate that the probability of bus option enquiries decreases along with increasing travel distance. This probably reflects a perception of the drivers that the bus becomes less competitive than the car over longer distances (J. Polak & Jones, 1993).

Aarts *et al.* (1997) conducted an experiment with 82 students who owned a bicycle at the University of Nijmegen. The students received a description of a travel situation and used it to indicate their preference for using the bicycle in that situation (scale ranges from 1 (unfavourable) to 10 (favourable). Each situation was described with four attributes, i.e., weather conditions (rain, no rain), weight of luggage (4 kilograms, 20 kilograms), departure time (9:00 a.m., 2:00 p.m.) and distance to the destination (2.5 kilometres, 5 kilometres). The results show that 92% of the students used information about the weather conditions, 68% about the weight of the luggage, and 38% about the distance. Only 2% considered the information about departure time.

The results from Aarts *et al.* (1997)'s study supports the effect of weather on travel demand and choice. Chung *et al.* (2005) studied the effect of rain on travel demand on the Tokyo Metropolitan Expressway (MEX). Their study shows that on average 2.9% daily trips decrease during rain on weekdays (the total depth of rainwater threshold >13 millimetres per day). The daily trips during rain decreased more on weekends (7.9% for Saturday and 5.2% for Sunday) than on weekdays. Khattak and de Palma (1997) studied on the impact of adverse weather conditions on travel pattern (i.e. departure time, route, and mode). They conducted a survey with 1218 participants in Brussels. Regular automobile users who responded to the adverse weather question totalled 57 %. Their results showed that 54% of the automobile users change their travel pattern in adverse weather. Among respondents, 27% found that the influence of weather on travel mode change to be either very important or important. Khattak and de Palma (1997) also reported that almost 70% of the respondents who change travel patterns owing to the weather kept themselves informed about weather conditions through radio, television and newspaper.

Additionally, Khattak and de Palma (1997) asked the respondents about their choice of travel routes. The results show that approximately 57% of the participants, i.e. regular automobile users, have a choice of route. The majority of automobile users (66%) select their route at home before travelling. The other (34%) choose the route during their trip. About half of automobile users who select the route at home occasionally changed their route and 25% remain strictly using their route. Of the automobile users, 83% had one or more alternative routes in mind.

Appendix H.1: Timetable for Orbiter

Orbiter CLOCKWISE Timetable

MONDAY to FRIDAY

	1 Eastgate Mall	2 St Martins	3 Princess Margaret Hospital	4 Barrington	5 Westfield Riccarton	6 University of Canterbury	7 Northlands Mall	8 The Palms	1 Eastgate Mall
AM	6.00	6.12	6.18	6.24	6.35	6.44	6.59	7.15	7.30
Every 10 minutes between 6am and 7pm									
Every 15 minutes between 7pm and 9pm									
From 9pm onwards									
PM	9.00	9.08	9.14	9.20	9.30	9.37	9.49	10.03	10.15
	9.30	9.38	9.44	9.50	10.00	10.07	10.19	10.33	10.45
	10.00	10.08	10.14	10.20	10.30	10.37	10.49	11.03	11.15
	10.30	10.38	10.44	10.50	11.00	11.07	11.19	11.33	11.45
	11.00	11.08	11.14	11.20	11.30	11.37	11.49	12.03	12.15
	11.30	11.38	11.44	11.50	12.00	12.07	12.19	12.33	12.45

SATURDAY

	1 Eastgate Mall	2 St Martins	3 Princess Margaret Hospital	4 Barrington	5 Westfield Riccarton	6 University of Canterbury	7 Northlands Mall	8 The Palms	1 Eastgate Mall
AM	6.00	6.08	6.14	6.19	6.26	6.32	6.47	6.59	7.15
	6.30	6.38	6.44	6.49	6.56	7.02	7.17	6.29	7.45
	7.00	7.08	7.14	7.19	7.26	7.32	7.47	7.59	8.15
Every 15 minutes between 7am and 10am									
Every 10 minutes between 10am and 6pm									
Every 15 minutes between 6pm and 9pm									
From 9pm onwards									
PM	9.00	9.08	9.14	9.19	9.26	9.32	9.47	9.59	10.15
	9.30	9.38	9.44	9.49	9.56	10.02	10.17	10.29	10.45
	10.00	10.08	10.14	10.19	10.26	10.32	10.47	10.59	11.15
	10.30	10.38	10.44	10.49	10.56	11.02	11.17	11.29	11.45
	11.00	11.08	11.14	11.19	11.26	11.32	11.47	11.59	12.15
	11.30	11.38	11.44	11.49	11.56	12.02	12.17	12.29	12.45

SUNDAY

	1 Eastgate Mall	2 St Martins	3 Princess Margaret Hospital	4 Barrington	5 Westfield Riccarton	6 University of Canterbury	7 Northlands Mall	8 The Palms	1 Eastgate Mall
AM	7.00	7.08	7.14	7.19	7.26	7.32	7.47	7.59	8.15
	7.30	7.38	7.44	7.49	7.56	8.02	8.17	8.29	8.45
	8.00	8.08	8.14	8.19	8.26	8.32	8.47	8.59	9.15
	8.30	8.38	8.44	8.49	8.56	9.02	9.17	9.29	9.45
	9.00	9.08	9.14	9.19	9.26	9.32	9.45	9.59	10.15
Every 15 minutes between 9am and 6pm									
From 6pm onwards									
PM	6.00	6.08	6.14	6.19	6.26	6.32	6.47	6.59	7.15
	6.30	6.38	6.44	6.49	6.56	7.02	7.17	7.29	7.45
	7.00	7.08	7.14	7.19	7.26	7.32	7.47	7.59	8.15
	7.30	7.38	7.44	7.49	7.56	8.02	8.17	8.29	8.45
	8.00	8.08	8.14	8.19	8.26	8.32	8.47	8.59	9.15
	8.30	8.38	8.44	8.49	8.56	9.02	9.17	9.29	9.45
	9.00	9.08	9.14	9.19	9.26	9.32	9.47	9.59	10.15
	9.30	9.38	9.44	9.49	9.56	10.02	10.17	10.29	10.45
	10.00	10.08	10.14	10.19	10.26	10.32	10.47	10.59	11.15
	10.30	10.38	10.44	10.49	10.56	11.02	11.17	11.29	11.45

Orbiter ANTI-CLOCKWISE Timetable

MONDAY to FRIDAY

	1 Eastgate Mall	8 The Palms	7 Northlands Mall	6 University of Canterbury	5 Westfield Riccarton	4 Barrington	3 Princess Margaret Hospital	2 St Martins	1 Eastgate Mall
AM	5.40	5.50	6.05	6.22	6.33	6.45	6.52	7.00	7.10
	6.00	6.10	6.25	6.42	6.53	7.05	7.12	7.20	7.30
Every 10 minutes between 6am and 7pm									
Every 15 minutes between 7pm and 10pm									
From 10pm onwards									
PM	10.00	10.10	10.23	10.36	10.43	10.51	10.58	11.06	11.15
	10.30	10.40	10.53	11.06	11.13	11.21	11.28	11.36	11.45
	11.00	11.10	11.23	11.36	11.43	11.51	11.58	12.06	12.15
	11.30	11.40	11.53	12.06	12.13	12.21	12.28	12.36	12.45

SATURDAY

	1 Eastgate Mall	8 The Palms	7 Northlands Mall	6 University of Canterbury	5 Westfield Riccarton	4 Barrington	3 Princess Margaret Hospital	2 St Martins	1 Eastgate Mall
AM	6.00	6.09	6.21	6.32	6.39	6.48	6.54	7.01	7.15
	6.30	6.39	6.51	6.02	7.09	7.18	7.24	7.31	7.45
	7.00	7.09	7.21	7.32	7.39	7.48	7.54	8.01	8.15
Every 15 minutes between 7am and 10am									
Every 10 minutes between 10am and 6pm									
Every 15 minutes between 6pm and 9pm									
From 9pm onwards									
PM	9.00	9.09	9.21	9.32	9.39	9.48	9.54	10.01	10.15
	9.30	9.39	9.51	10.02	10.09	10.18	10.24	10.31	10.45
	10.00	10.09	10.21	10.32	10.39	10.48	10.54	11.01	11.15
	10.30	10.39	10.51	11.02	11.09	11.18	11.24	11.31	11.45
	11.00	11.09	11.21	11.32	11.39	11.48	11.54	12.01	12.15
	11.30	11.39	11.51	12.02	12.09	12.18	12.24	12.31	12.45

SUNDAY

	1 Eastgate Mall	8 The Palms	7 Northlands Mall	6 University of Canterbury	5 Westfield Riccarton	4 Barrington	3 Princess Margaret Hospital	2 St Martins	1 Eastgate Mall
AM	7.00	7.09	7.21	7.32	7.39	7.48	7.54	8.01	8.15
	7.30	7.39	7.51	8.02	8.09	8.18	8.24	8.31	8.45
	8.00	8.09	8.21	8.32	8.39	8.48	8.54	9.01	9.15
	8.30	8.39	8.51	9.02	9.09	9.18	9.24	9.31	9.45
	9.00	9.09	9.21	9.32	9.39	9.48	9.54	10.01	10.15
Every 15 minutes between 9am and 6pm									
From 6pm onwards									
PM	6.00	6.09	6.21	6.32	6.39	6.48	6.54	7.01	7.15
	6.30	6.39	6.51	7.02	7.09	7.18	7.24	7.31	7.45
	7.00	7.09	7.21	7.32	7.39	7.48	7.54	8.01	8.15
	7.30	7.39	7.51	8.02	8.09	8.18	8.24	8.31	8.45
	8.00	8.09	8.21	8.32	8.39	8.48	8.54	9.01	9.15
	8.30	8.39	8.51	9.02	9.09	9.18	9.24	9.31	9.45
	9.00	9.09	9.21	9.32	9.39	9.48	9.54	10.01	10.15
	9.30	9.39	9.51	10.02	10.09	10.18	10.24	10.31	10.45
	10.00	10.09	10.21	10.32	10.39	10.48	10.54	11.01	11.15
	10.30	10.39	10.51	11.02	10.09	11.18	11.24	11.31	11.45

Appendix H.2: Timetable for Metrostar

HALSWELL to New Brighton

MONDAY to FRIDAY

	1 Halswell	2 The Hub Hornby	3 University of Canterbury	4 Westfield Riccarton	5 Merivale Mall	6 The Palms	7 QEII Park	8 New Brighton
AM	6.13	6.28	6.43	6.49	7.02	7.15	7.23	7.35
	6.28	6.43	6.58	7.04	7.17	7.30	7.38	7.50
	6.43	6.58	7.13	7.19	7.32	7.45	7.53	8.05
	6.58	7.13	7.28	7.34	7.47	8.00	8.08	8.20

Then every 15 minutes between 6.58am and 5pm

From 5pm to 6pm

	1	2	3	4	5	6	7	8
PM	5.18	5.33	5.48	5.54	6.05	6.16	6.24	6.36
	5.33	5.48	6.03	6.08	6.19	6.30	6.38	6.50
	5.48	6.03	6.16	6.21	6.32	6.43	6.51	7.03

Then at these minutes past the hour between 6pm and 10pm (every 30 minutes)

	1	2	3	4	5	6	7	8
	.12	.25	.38	.43	.54	.05	.13	.25
	.42	.55	.08	.13	.24	.35	.43	.55

From 10pm onwards

	1	2	3	4	5	6	7	8
PM	10.12	10.25	10.38	10.43	10.54	11.05	11.13	11.25
	10.42	10.55	11.08	11.13	11.24	11.35	11.43	11.55

FRIDAY ONLY

	1	2	3	4	5	6	7	8
PM	10.57	11.10	11.23	11.28	11.39	11.50	11.58	12.10

SATURDAY

	1 Halswell	2 The Hub Hornby	3 University of Canterbury	4 Westfield Riccarton	5 Merivale Mall	6 The Palms	7 QEII Park	8 New Brighton
AM	6.28	6.43	6.56	7.01	7.14	7.27	7.35	7.47
	6.43	6.58	7.11	7.16	7.29	7.42	7.50	8.02
	6.58	7.13	7.26	7.31	7.44	7.57	8.05	8.17
	7.13	7.28	7.41	7.46	7.59	8.12	8.20	8.32

Then every 15 minutes between 7.13am and 5.13pm

From 5.13pm to 7pm

	1	2	3	4	5	6	7	8
PM	5.28	5.43	5.56	6.01	6.12	6.23	6.31	6.43
	5.43	5.58	6.11	6.16	6.27	6.38	6.46	6.58
	6.12	6.25	6.38	6.43	6.54	7.05	7.13	7.25
	6.42	6.55	7.08	7.13	7.24	7.35	7.43	7.55

Then at these minutes past the hour between 7pm and 10pm (every 30 minutes)

	1	2	3	4	5	6	7	8
	.12	.25	.38	.43	.54	.05	.13	.25
	.42	.55	.08	.13	.24	.35	.43	.55

From 10pm onwards

	1	2	3	4	5	6	7	8
PM	10.12	10.25	10.38	10.43	10.54	11.05	11.13	11.25
	10.42	10.55	11.08	11.13	11.24	11.35	11.43	11.55

SUNDAY

	1 Halswell	2 The Hub Hornby	3 University of Canterbury	4 Westfield Riccarton	5 Merivale Mall	6 The Palms	7 QEII Park	8 New Brighton
AM	6.35	6.50	7.03	7.08	7.19	7.30	7.38	7.50
	7.05	7.20	7.33	7.38	7.49	8.00	8.08	8.20
	7.35	7.50	8.03	8.08	8.19	8.30	8.38	8.50
	8.05	8.20	8.33	8.38	8.49	9.00	9.08	9.20
	8.35	8.50	9.03	9.08	9.19	9.30	9.38	9.50

Then every 15 minutes between 9.05am and 2.50pm

From 3pm to 6pm

	1	2	3	4	5	6	7	8
PM	3.05	3.20	3.33	3.38	3.49	4.00	4.08	4.20
	3.35	3.50	4.03	4.08	4.19	4.30	4.38	4.50
	4.05	4.20	4.33	4.38	4.49	5.00	5.08	5.20
	4.35	4.50	5.03	5.08	5.19	5.30	5.38	5.50
	5.05	5.20	5.33	5.38	5.49	6.00	6.08	6.20
	5.35	5.50	6.03	6.08	6.19	6.30	6.38	6.50

Then at these minutes past the hour between 6pm and 10pm (every 30 minutes)

	1	2	3	4	5	6	7	8
	.05	.18	.31	.36	.47	.58	.06	.18
	.35	.48	.01	.06	.17	.28	.36	.48

From 10pm onwards

	1	2	3	4	5	6	7	8
PM	10.05	10.18	10.31	10.36	10.47	10.58	11.06	11.18

NEW BRIGHTON to Halswell

MONDAY to FRIDAY

	8 New Brighton	7 QEII Park	6 The Palms	5 Merivale Mall	4 Westfield Riccarton	3 University of Canterbury	2 The Hub Hornby	1 Halswell
AM	6.57	7.03	7.12	7.24	7.36	7.41	7.56	8.16
	7.12	7.18	7.27	7.39	7.51	7.56	8.11	8.31
	7.27	7.33	7.42	7.54	8.06	8.11	8.26	8.46
	7.42	7.48	7.57	8.09	8.21	8.26	8.41	9.01

Then every 15 minutes between 7.42am and 5pm

From 5pm to 7pm

	8	7	6	5	4	3	2	1
PM	5.12	5.18	5.27	5.39	5.51	5.56	6.11	6.31
	5.27	5.33	5.42	5.54	6.06	6.11	6.24	6.44
	5.42	5.48	5.57	6.09	6.21	6.26	6.39	6.59
	5.57	6.03	6.10	6.21	6.33	6.38	6.51	7.11
	6.12	6.18	6.25	6.36	6.48	6.53	7.06	7.26
	6.27	6.33	6.40	6.51	7.03	7.08	7.21	7.41
	6.42	6.48	6.55	7.06	7.18	7.23	7.36	7.56
	6.59	7.05	7.12	7.23	7.35	7.40	7.53	8.13

Then at these minutes past the hour between 7pm and 10pm (every 30 minutes)

	8	7	6	5	4	3	2	1
	.29	.35	.42	.53	.05	.10	.23	.43
	.59	.05	.12	.23	.35	.40	.53	.13

From 10pm onwards

	8	7	6	5	4	3	2	1
PM	10.29	10.35	10.42	10.53	11.05	11.10	11.23	11.43

FRIDAY ONLY

	8	7	6	5	4	3	2	1
PM	10.59	11.05	11.12	11.23	11.35	11.40	11.53	12.13

SATURDAY

	8 New Brighton	7 QEII Park	6 The Palms	5 Merivale Mall	4 Westfield Riccarton	3 University of Canterbury	2 The Hub Hornby	1 Halswell
AM	6.55	7.01	7.10	7.21	7.33	7.38	7.51	8.11
	7.10	7.16	7.25	7.36	7.48	7.53	8.06	8.26
	7.25	7.31	7.40	7.51	8.03	8.08	8.21	8.41
	7.40	7.46	7.55	8.06	8.18	8.23	8.36	8.56

Then every 15 minutes between 7.40am and 7pm

Then at these minutes past the hour between 7pm and 10pm (every 30 minutes)

	8	7	6	5	4	3	2	1
	.27	.33	.40	.51	.03	.08	.21	.41
	.57	.03	.10	.21	.33	.38	.51	.11

From 10pm onwards

	8	7	6	5	4	3	2	1
PM	10.27	10.33	11.40	10.51	11.03	11.08	11.21	11.41
	10.57	11.03	11.10	11.21	11.33	11.38	11.51	12.11

SUNDAY

	8 New Brighton	7 QEII Park	6 The Palms	5 Merivale Mall	4 Westfield Riccarton	3 University of Canterbury	2 The Hub Hornby	1 Halswell
AM	7.25	7.31	7.40	7.51	8.02	8.07	8.20	8.40
	7.55	8.01	8.10	8.21	8.32	8.37	8.50	9.10
	8.25	8.31	8.40	8.51	9.02	9.07	9.20	9.40
	8.55	9.01	9.10	9.21	9.32	9.37	9.50	10.10
	9.25	9.31	9.40	9.51	10.02	10.07	10.20	10.40
	9.55	10.01	10.10	10.21	10.32	10.37	10.50	11.10

Then every 15 minutes between 10.10am and 3.55pm

From 4pm onwards

	8	7	6	5	4	3	2	1
PM	4.25	4.31	4.40	4.51	5.02	5.07	5.20	5.40
	4.55	5.01	5.10	5.21	5.32	5.37	5.50	6.10
	5.25	5.31	5.40	5.51	6.02	6.07	6.20	6.40
	5.55	6.01	6.08	6.19	6.30	6.35	6.48	7.08
	6.25	6.31	6.38	6.49	7.00	7.05	7.18	7.38
	6.51	6.57	7.04	7.15	7.26	7.31	7.44	8.04
	7.20	7.26	7.33	7.44	7.55	8.00	8.13	8.33
	7.50	7.56	8.03	8.14	8.25	8.30	8.43	9.03
	8.20	8.26	8.33	8.44	8.55	9.00	9.13	9.33
	8.50	8.56	9.03	9.14	9.25	9.30	9.43	10.03
	9.20	9.26	9.33	9.44	9.55	10.00	10.13	10.33
	9.50	9.56	10.03	10.14	10.25	10.30	10.43	11.03

Appendix H.3: Timetable for Bus number 3

AIRPORT to Sumner via Avonhead

BUS EXCHANGE: Departs Platform B

MONDAY to FRIDAY

	Depart Airport	Avonhead Mall	University Of Cant'y	Westfield Riccarton	City Bus Exchange	W'worths Ferry Rd	Sumner
AM		6.00	6.06	6.11	6.20	6.38	6.55
		6.28	6.36	6.41	6.50	7.08	7.25
	6.33	6.43	6.51	6.56	7.05	7.23	7.40
		6.58	7.06	7.11	7.20	7.38	7.55
	7.00	7.10	7.20	7.25	7.35	7.53	8.10
		7.25	7.35	7.40	7.50	8.08	8.25
	7.30	7.40	7.50	7.55	8.05	8.23	8.40
		7.55	8.05	8.10	8.20	8.38	8.55
	8.00	8.10	8.20	8.25	8.35	8.53	9.10
		8.25	8.35	8.40	8.50	9.08	9.25
	8.30	8.42	8.50	8.55	9.05	9.23	9.40
		8.57	9.05	9.10	9.20	9.38	9.55
	9.00	9.12	9.20	9.25	9.35	9.53	10.10
		9.27	9.35	9.40	9.50	10.08	10.25
	9.30	9.42	9.50	9.55	10.05	10.23	10.40
		9.57	10.05	10.10	10.20	10.38	10.55
	10.00	10.12	10.20	10.25	10.35	10.53	11.10
		10.27	10.35	10.40	10.50	11.08	11.25
	10.30	10.42	10.50	10.55	11.05	11.23	11.40
		10.57	11.05	11.10	11.20	11.38	11.55
	11.00	11.12	11.20	11.25	11.35	11.53	12.10
		11.27	11.35	11.40	11.50	12.08	12.25
	11.30	11.42	11.50	11.55	12.06	12.24	12.41
		11.57	12.05	12.10	12.21	12.39	12.56
PM	12.00	12.12	12.20	12.25	12.36	12.54	1.11
		12.27	12.35	12.40	12.51	1.09	1.26
	12.30	12.42	12.50	12.55	1.06	1.24	1.41
		12.57	1.05	1.10	1.21	1.39	1.56
	1.00	1.12	1.20	1.25	1.36	1.54	2.11
		1.27	1.35	1.40	1.51	2.09	2.26
	1.30	1.42	1.50	1.55	2.06	2.24	2.41
		1.57	2.05	2.10	2.21	2.39	2.56
	2.00	2.12	2.20	2.25	2.36	2.54	3.11
		2.27	2.35	2.40	2.52	3.10	3.27
		2.35	2.43	2.48	3.00	3.20	3.37
	2.30	2.42	2.50	2.55	3.07	3.27	3.44
		2.57	3.05	3.10	3.22	3.42	3.59
		3.05	3.13	3.18	3.30	3.50	4.07
	3.00	3.12	3.20	3.25	3.37	3.57	4.14
		3.27	3.35	3.40	3.52	4.12	4.29
	3.30	3.42	3.50	3.55	4.07	4.27	4.44
		3.50	3.58	4.03	4.15	4.35	4.52
		3.58	4.06	4.11	4.23	4.43	5.00
		4.05	4.13	4.18	4.30	4.50	5.07
	4.00	4.12	4.20	4.25	4.38	4.58	5.15
		4.27	4.35	4.40	4.53	5.13	5.30
	4.30	4.42	4.50	4.55	5.08	5.28	5.45
B					5.15	5.35	5.52
		4.54	5.02	5.07	5.20	5.40	5.57
B					5.27	5.45	6.02
	5.00	5.12	5.20	5.25	5.36	5.54	6.11
		5.27	5.35	5.40	5.51	6.09	6.26
	5.30	5.42	5.50	5.55	6.05	6.23	6.40
		5.57	6.05	6.10	6.19	6.37	6.54
	6.00	6.10	6.18	6.23	6.32	6.50	7.07
		6.25	6.33	6.38	6.47	7.05	7.22
	6.30	6.40	6.48	6.53	7.02	7.20	7.37
		6.57	7.03	7.08	7.17	7.35	7.52
Then at these minutes past the hour between 7pm and 11pm							
	.05	.15	.21	.26	.35	.53	.10
	.35	.45	.51	.56	.05	.23	.40
From 11pm onwards							
PM	11.05	11.15	11.21	11.26	11.35	11.53	12.10
FRIDAY ONLY							
PM	11.35	11.45	11.51	11.56	12.05	12.23	12.40

SATURDAY & SUNDAY

	Depart Airport	Avonhead Mall	University Of Cant'y	Westfield Riccarton	City Bus Exchange	W'worths Ferry Rd	Sumner
SATURDAY ONLY							
AM	6.22	6.32	6.38	6.43	6.52	7.10	7.27
SATURDAY and SUNDAY							
AM	6.52	7.02	7.08	7.13	7.22	7.40	7.57
	7.22	7.32	7.40	7.45	7.54	8.12	8.29
	7.52	8.02	8.10	8.15	8.24	8.42	8.59
	8.22	8.32	8.40	8.45	8.54	9.12	9.29
	8.52	9.02	9.10	9.15	9.24	9.42	9.59
	9.22	9.32	9.40	9.45	9.54	10.12	10.29
	9.52	10.02	10.10	10.15	10.24	10.42	10.59
	10.22	10.32	10.40	10.45	10.54	11.12	11.29
	10.52	11.02	11.10	11.15	11.24	11.42	11.59
	11.22	11.32	11.40	11.45	11.56	12.14	12.31
	11.52	12.02	12.10	12.15	12.26	12.44	1.01
PM	12.22	12.32	12.40	12.45	12.56	1.14	1.31
	12.52	1.02	1.10	1.15	1.26	1.44	2.01
	1.22	1.32	1.40	1.45	1.56	2.14	2.31
	1.52	2.02	2.10	2.15	2.26	2.44	3.01
	2.22	2.32	2.40	2.45	2.56	3.14	3.31
	2.52	3.02	3.10	3.15	3.26	3.44	4.01
	3.22	3.32	3.40	3.45	3.56	4.14	4.31
	3.52	4.02	4.10	4.15	4.26	4.44	5.01
	4.22	4.32	4.40	4.45	4.54	5.12	5.29
	4.52	5.02	5.10	5.15	5.24	5.42	5.59
	5.22	5.32	5.40	5.45	5.54	6.12	6.29
	5.52	6.02	6.10	6.15	6.24	6.42	6.59
	6.25	6.35	6.43	6.48	6.57	7.15	7.32
	6.55	7.05	7.11	7.16	7.25	7.43	8.00
	7.25	7.35	7.41	7.46	7.55	8.13	8.30
	7.55	8.05	8.11	8.16	8.25	8.43	9.00
	8.25	8.35	8.41	8.46	8.55	9.13	9.30
	8.55	9.05	9.11	9.16	9.25	9.43	10.00
	9.25	9.35	9.41	9.46	9.55	10.13	10.30
	9.55	10.05	10.11	10.16	10.25	10.43	11.00
SUNDAY ONLY AFTER 10pm							
PM B	10.25	10.35	10.41	10.46	10.55		
B	10.55	11.05	11.11	11.16	11.25		
SATURDAY ONLY AFTER 10pm							
PM	10.25	10.35	10.41	10.46	10.55	11.13	11.30
	10.55	11.05	11.11	11.16	11.25	11.43	12.00
	11.25	11.35	11.41	11.46	11.55	12.13	12.30
B	11.55	12.05	12.11	12.16	12.25		

Appendix H.4: Timetable for Bus number 3 (continue)

SUMNER to Avonhead and Airport

BUS EXCHANGE: Departs Platform C

MONDAY to FRIDAY

	Sumner	W'worths Ferry Rd	City Bus Exchange	Westfield Riccarton	University Of Cant'y	Avonhead Mall	Arrive Airport
AM	5.52	6.05	6.21	6.30	6.34	6.49	
	6.07	6.20	6.36	6.45	6.49	6.57	7.13
	6.22	6.35	6.51	7.00	7.04	7.19	
	6.37	6.50	7.06	7.16	7.20	7.28	7.44
	6.50	7.05	7.21	7.31	7.35	7.50	
	7.01	7.16	7.36	7.46	7.50	7.58	8.14
	7.11	7.31	7.51	8.01	8.05	8.20	
	7.18	7.36 LIMITED STOPS	7.54	8.04	8.08	8.23	
	7.26	7.46	8.06	8.17	8.21	8.29	8.45
	7.35	7.55	8.15	8.26	8.30	8.45	
	7.41	8.01	8.21	8.32	8.36	8.51	
B	7.48	8.06 LIMITED STOPS	8.24				
	7.56	8.16	8.36	8.47	8.51	8.59	9.15
	8.05	8.25	8.45	8.56	9.00	9.15	
	8.11	8.31	8.51	9.02	9.06	9.21	
B	8.26	8.41	8.58				
	8.34	8.49	9.06	9.17	9.21	9.29	9.45
	8.49	9.04	9.21	9.32	9.36	9.51	
	9.04	9.19	9.36	9.47	9.51	9.59	10.15
	9.19	9.34	9.51	10.02	10.06	10.21	
	9.34	9.49	10.06	10.17	10.21	10.29	10.45
	9.49	10.04	10.21	10.32	10.36	10.51	
	10.04	10.19	10.36	10.47	10.51	10.59	11.15
	10.19	10.34	10.51	11.02	11.06	11.21	
	10.34	10.49	11.06	11.17	11.21	11.29	11.45
	10.49	11.04	11.21	11.32	11.36	11.51	
	11.04	11.19	11.36	11.47	11.51	11.59	12.15
	11.19	11.34	11.51	12.02	12.06	12.21	
	11.34	11.49	12.06	12.17	12.21	12.29	12.45
	11.49	12.04	12.21	12.32	12.36	12.51	
PM	12.04	12.19	12.36	12.47	12.51	12.59	1.15
	12.19	12.34	12.51	1.02	1.06	1.21	
	12.34	12.49	1.06	1.18	1.22	1.30	1.46
	12.49	1.04	1.21	1.33	1.37	1.52	
	1.04	1.19	1.36	1.48	1.52	2.00	2.16
	1.19	1.34	1.51	2.03	2.08	2.23	
	1.34	1.49	2.06	2.18	2.23	2.31	2.47
	1.49	2.04	2.21	2.33	2.38	2.53	
	2.04	2.19	2.36	2.48	2.53	3.01	3.17
	2.19	2.34	2.51	3.03	3.08	3.23	
	2.34	2.49	3.06	3.18	3.23	3.31	3.47
	2.49	3.04	3.21	3.33	3.38	3.53	
	3.04	3.19	3.36	3.48	3.53	4.01	4.17
	3.19	3.34	3.51	4.03	4.08	4.23	
	3.34	3.49	4.06	4.18	4.23	4.31	4.47
	3.49	4.04	4.21	4.34	4.39	4.54	
	4.04	4.19	4.36	4.49	4.54	5.02	5.18
	4.19	4.34	4.51	5.04	5.09	5.24	
	4.34	4.49	5.06	5.19	5.24	5.32	5.48
	4.49	5.04	5.21	5.34	5.38	5.53	
	5.04	5.19	5.36	5.48	5.52	6.00	6.16
	5.19	5.34	5.51	6.03	6.07	6.22	
	5.34	5.49	6.06	6.15	6.19	6.27	6.43
	5.51	6.04	6.21	6.30	6.34	6.49	
	6.07	6.20	6.36	6.45	6.49	7.04	
	6.22	6.35	6.51	7.00	7.04	7.12	7.28
	6.49	7.02	7.18	7.27	7.31	7.39	7.55
Then at these minutes past the hour between 7pm and 10pm							
	.19	.32	.48	.57	.01	.09	.25
	.49	.02	.18	.27	.31	.39	.55
From 10pm onwards							
PM	10.19	10.32	10.48	10.57	11.01	11.09	11.25
	10.49	11.02	11.18	11.27	11.31	11.46	

B = Service starts or ends at the City Bus Exchange

SATURDAY & SUNDAY

	Sumner	W'worths Ferry Rd	City Bus Exchange	Westfield Riccarton	University Of Cant'y	Avonhead Mall	Arrive Airport
AM	6.39	6.52	7.08	7.17	7.21	7.29	7.43
	7.08	7.21	7.38	7.47	7.51	7.59	8.13
	7.38	7.51	8.08	8.17	8.21	8.29	8.43
	8.08	8.21	8.38	8.47	8.51	8.59	9.13
	8.38	8.51	9.08	9.17	9.21	9.29	9.43
	9.08	9.21	9.38	9.47	9.51	9.59	10.13
	9.38	9.51	10.08	10.17	10.21	10.29	10.43
	10.08	10.21	10.38	10.48	10.52	11.00	11.14
	10.38	10.51	11.08	11.18	11.22	11.30	11.44
	11.01	11.14	11.31	11.42	11.46	11.54	12.10
	11.29	11.44	12.01	12.12	12.16	12.24	12.40
	11.59	12.14	12.31	12.42	12.46	12.54	1.10
PM	12.29	12.44	1.01	1.12	1.16	1.24	1.40
	12.59	1.14	1.31	1.42	1.46	1.54	2.10
	1.29	1.44	2.01	2.12	2.17	2.25	2.41
	1.59	2.14	2.31	2.42	2.47	2.55	3.11
	2.29	2.44	3.01	3.12	3.17	3.25	3.41
	2.59	3.14	3.31	3.42	3.47	3.55	4.11
	3.29	3.44	4.01	4.11	4.16	4.24	4.40
	4.06	4.21	4.38	4.47	4.52	5.00	5.14
	4.36	4.51	5.08	5.17	5.22	5.30	5.44
	5.08	5.23	5.40	5.49	5.53	6.01	6.15
	5.38	5.53	6.10	6.19	6.23	6.31	6.45
	6.11	6.24	6.40	6.49	6.53	7.01	7.15
	6.41	6.54	7.10	7.19	7.23	7.31	7.45
	7.11	7.24	7.40	7.49	7.53	8.01	8.15
	7.41	7.54	8.10	8.19	8.23	8.31	8.45
	8.11	8.24	8.40	8.49	8.53	9.01	9.15
	8.41	8.54	9.10	9.19	9.23	9.31	9.45
	9.11	9.24	9.40	9.49	9.53	10.01	10.15
	9.41	9.54	10.10	10.19	10.23	10.31	10.45
SUNDAY ONLY AFTER 10pm							
PM	10.11	10.24	10.40	10.49	10.53	11.08	
SATURDAY ONLY AFTER 10pm							
PM	10.11	10.24	10.40	10.49	10.53	11.01	11.15
	10.41	10.54	11.10	11.19	11.23	11.31	11.45
	11.11	11.24	11.40	11.49	11.53	12.08	
	11.41	11.54	12.10	12.19	12.23	12.38	

Appendix H.5: Timetable for Bus number 21

ILAM to Mount Pleasant

BUS EXCHANGE: Departs Platform E2

MONDAY to FRIDAY

	Ilam Terminus	University Of Cant'y	Westfield Riccarton	Moorhouse / Selwyn	City Bus Exchange	Eastgate	W'worths Ferry Rd	Mt Pleasant
AM	6.15	6.25	6.30	6.37	6.43	6.56	7.04	7.22
	6.45	6.55	7.00	7.07	7.13	7.26	7.34	7.52
	7.12	7.23	7.28	7.37	7.43	7.56	8.04	8.22
R	7.24	7.35	7.40	7.49	7.55	8.08	8.16	8.34
	7.54	8.05	8.10	8.19	8.25	8.38	8.46	9.04
	8.20	8.31	8.36	8.45	8.51	9.06	9.14	9.32
	8.53	9.04	9.09	9.17	9.23	9.38	9.46	10.04
Then at these minutes past the hour between 9am and 2pm								
	.23	.34	.39	.47	.53	.08	.16	.36
	.53	.04	.09	.17	.23	.38	.46	.06
From 2pm onwards								
PM	2.23	2.34	2.39	2.47	2.53	3.08	3.16	3.36
	2.52	3.03	3.08	3.17	3.23	3.38	3.46	4.06
	3.22	3.33	3.38	3.47	3.53	4.08	4.16	4.36
	3.42	3.53	3.58	4.07	4.13	4.28	4.36	4.56
	4.12	4.23	4.28	4.37	4.43	4.58	5.06	5.26
	4.33	4.43	4.48	4.57	5.03	5.18	5.26	5.46
	4.53	5.03	5.08	5.17	5.23	5.38	5.46	6.06
	5.25	5.35	5.40	5.47	5.53	6.08	6.16	6.36
	5.56	6.06	6.10	6.17	6.23	6.38	6.46	7.06
Then at these minutes past the hour between 6pm and 10pm								
	.26	.36	.40	.47	.53	.06	.14	.32
From 10pm onwards								
PM	10.26	10.36	10.40	10.47	10.53	11.06	11.14	11.32
FRIDAY ONLY								
PM	11.26	11.36	11.40	11.47	11.53	12.06	12.14	12.32
B	11.56	12.06	12.11	12.18	12.24			

B = Bus terminates at City Bus Exchange *R = Travels to Redcliffs School*

SATURDAY

	Ilam Terminus	University Of Cant'y	Westfield Riccarton	Moorhouse / Selwyn	City Bus Exchange	Eastgate	W'worths Ferry Rd	Mt Pleasant
AM	6.15	6.25	6.30	6.37	6.43	6.56	7.04	7.22
	6.45	6.55	7.00	7.07	7.13	7.26	7.34	7.52
	7.15	7.25	7.30	7.37	7.43	7.56	8.04	8.22
	7.45	7.55	8.00	8.07	8.13	8.26	8.34	8.52
	8.15	8.25	8.30	8.37	8.43	8.56	9.04	9.22
	8.45	8.55	9.00	9.07	9.13	9.26	9.34	9.52
	9.15	9.25	9.30	9.37	9.43	9.56	10.04	10.24
	9.44	9.54	9.59	10.07	10.13	10.26	10.34	10.54
	10.14	10.24	10.29	10.37	10.43	10.56	11.04	11.24
	10.44	10.54	10.59	11.07	11.13	11.27	11.35	11.55
Then at these minutes past the hour between 11am and 4pm								
	.14	.24	.29	.37	.43	.57	.05	.25
	.44	.54	.59	.07	.13	.27	.35	.55
From 4pm onwards								
PM	4.14	4.24	4.29	4.37	4.43	4.57	5.05	5.25
	4.45	4.55	5.00	5.07	5.13	5.26	5.34	5.54
	5.15	5.25	5.30	5.37	5.43	5.56	6.04	6.24
	5.46	5.56	6.00	6.07	6.13	6.26	6.34	6.54
Then at these minutes past the hour between 6pm and 11pm								
	.16	.26	.30	.37	.43	.56	.04	.22
From 11pm onwards								
PM	11.16	11.26	11.30	11.37	11.43	11.56	12.04	12.22

SUNDAY

	Ilam Terminus	University Of Cant'y	Westfield Riccarton	Moorhouse / Selwyn	City Bus Exchange	Eastgate	W'worths Ferry Rd	Mt Pleasant
AM	7.15	7.25	7.30	7.37	7.43	7.56	8.04	8.22
	8.15	8.25	8.30	8.37	8.43	8.56	9.04	9.22
	9.15	9.25	9.30	9.37	9.43	9.56	10.04	10.24
	10.14	10.24	10.29	10.37	10.43	10.56	11.04	11.24
Then at these minutes past the hour between 11am and 5pm								
	.14	.24	.29	.37	.43	.57	.05	.25
From 5pm onwards								
PM	5.15	5.25	5.30	5.37	5.43	5.56	6.04	6.24
	6.16	6.26	6.30	6.37	6.43	6.56	7.04	7.22
	7.16	7.26	7.30	7.37	7.43	7.56	8.04	8.22
	8.16	8.26	8.30	8.37	8.43	8.56	9.04	9.22
	9.16	9.26	9.30	9.37	9.43	9.56	10.04	10.22

MOUNT PLEASANT to Ilam

BUS EXCHANGE: Departs Platform D2

MONDAY to FRIDAY

	Mt Pleasant	W'worths Ferry Rd	Eastgate	City Bus Exchange	Moorhouse / Selwyn	Westfield Riccarton	University Of Cant'y	Ilam Terminus
AM	6.35	6.48	6.57	7.07	7.13	7.20	7.25	7.40
	7.05	7.23	7.32	7.42	7.48	7.55	8.00	8.15
	7.33	7.51	8.00	8.12	8.18	8.26	8.31	8.46
	8.07	8.21	8.30	8.42	8.48	8.56	9.01	9.16
	8.25	8.39	8.48	9.00	9.06	9.14	9.19	9.34
	8.55	9.09	9.18	9.30	9.36	9.44	9.49	10.04
Then at these minutes past the hour between 9am and 1pm								
	.25	.39	.48	.00	.06	.14	.19	.34
	.55	.09	.18	.30	.36	.44	.49	.04
From 1pm onwards								
PM	1.25	1.39	1.48	2.00	2.06	2.14	2.19	2.34
	1.55	2.09	2.18	2.30	2.36	2.45	2.50	3.05
	2.25	2.39	2.48	3.00	3.06	3.15	3.20	3.35
	2.55	3.09	3.18	3.30	3.36	3.45	3.50	4.05
R	3.08	3.26	3.35	3.47	3.53	4.02	4.07	4.22
	3.25	3.39	3.48	4.00	4.06	4.15	4.20	4.35
	3.55	4.09	4.18	4.30	4.36	4.45	4.50	5.05
	4.25	4.39	4.48	5.00	5.06	5.15	5.20	5.35
	4.55	5.09	5.18	5.30	5.36	5.43	5.48	6.03
	5.27	5.41	5.50	6.00	6.06	6.13	6.18	6.33
	5.57	6.11	6.20	6.30	6.36	6.43	6.47	7.02
	6.28	6.41	6.50	7.00	7.06	7.13	7.17	7.32
	7.00	7.13	7.22	7.32	7.38	7.45	7.49	8.04
	8.00	8.13	8.22	8.32	8.38	8.45	8.49	9.04
	9.00	9.13	9.22	9.32	9.38	9.45	9.49	10.04
	10.00	10.13	10.22	10.32	10.38	10.45	10.49	11.04
FRIDAY ONLY								
PM	10.37	10.50	10.59	11.09	11.15	11.22	11.26	11.41

R = Departs from Redcliffs School

SATURDAY

	Mt Pleasant	W'worths Ferry Rd	Eastgate	City Bus Exchange	Moorhouse / Selwyn	Westfield Riccarton	University Of Cant'y	Ilam Terminus
AM	6.35	6.48	6.57	7.07	7.13	7.20	7.25	7.40
	7.02	7.15	7.24	7.34	7.40	7.47	7.52	8.07
	7.32	7.45	7.54	8.04	8.10	8.17	8.22	8.37
	8.02	8.15	8.24	8.34	8.40	8.47	8.52	9.07
	8.32	8.45	8.54	9.04	9.10	9.17	9.22	9.37
	9.02	9.15	9.24	9.34	9.40	9.47	9.52	10.07
	9.32	9.45	9.54	10.04	10.10	10.18	10.23	10.38
	10.02	10.15	10.24	10.34	10.40	10.48	10.53	11.08
	10.31	10.44	10.53	11.04	11.10	11.18	11.23	11.38
Then at these minutes past the hour between 11am and 4pm								
	.01	.14	.23	.34	.40	.48	.53	.08
	.31	.44	.53	.04	.10	.18	.23	.38
From 4pm onwards								
PM	4.02	4.15	4.24	4.34	4.40	4.48	4.53	5.08
	4.32	4.45	4.54	5.04	5.10	5.17	5.22	5.37
	5.02	5.15	5.24	5.34	5.40	5.47	5.52	6.07
	5.32	5.45	5.54	6.04	6.10	6.17	6.21	6.36
	6.02	6.15	6.24	6.34	6.40	6.47	6.51	7.06
	6.49	7.02	7.11	7.21	7.27	7.34	7.38	7.53
	7.49	8.02	8.11	8.21	8.27	8.34	8.38	8.53
	8.49	9.02	9.11	9.21	9.27	9.34	9.38	9.53
	9.49	10.02	10.11	10.21	10.27	10.34	10.38	10.53
	10.49	11.02	11.11	11.21	11.27	11.34	11.38	11.53

SUNDAY

	Mt Pleasant	W'worths Ferry Rd	Eastgate	City Bus Exchange	Moorhouse / Selwyn	Westfield Riccarton	University Of Cant'y	Ilam Terminus
AM	6.45	6.58	7.07	7.17	7.23	7.30	7.35	7.50
	7.45	7.58	8.07	8.17	8.23	8.30	8.35	8.50
	8.45	8.58	9.07	9.17	9.23	9.30	9.35	9.50
	9.45	9.58	10.07	10.17	10.23	10.31	10.36	10.51
Then at these minutes past the hour between 10am and 4pm								
	.44	.57	.06	.17	.23	.31	.36	.51
From 4pm onwards								
PM	4.45	4.58	5.07	5.17	5.23	5.30	5.35	5.50
	5.45	5.58	6.07	6.17	6.23	6.30	6.34	6.49
	6.45	6.58	7.07	7.17	7.23	7.30	7.34	7.49
	7.45	7.58	8.07	8.17	8.23	8.30	8.34	8.49
	8.45	8.58	9.07	9.17	9.23	9.30	9.34	9.49
	9.45	9.58	10.07	10.17	10.23	10.30	10.34	10.49

Appendix H.6: Timetable for Bus number 23

HYDE PARK to Woolston

BUS EXCHANGE: Departs Platform B

MONDAY to FRIDAY

	Hyde Park	Avonhead Mall	University of Cant'y	City Bus Exchange	Eastgate	Woolston Terminus
AM	6.08	6.11	6.17	6.29	6.39	6.55
	6.38	6.41	6.47	6.59	7.09	7.25
	7.06	7.09	7.17	7.29	7.39	7.55
	7.36	7.39	7.47	7.59	8.09	8.25
	7.59	8.02	8.10	8.24	8.34	8.50
BH *	8.09	8.12	8.24	8.37		
	8.37	8.40	8.47	8.59	9.09	9.25
	9.07	9.10	9.17	9.29	9.39	9.55
	9.37	9.40	9.47	9.59	10.09	10.25
	10.07	10.10	10.17	10.29	10.39	10.55
	10.37	10.40	10.47	10.59	11.09	11.25
	11.07	11.10	11.17	11.29	11.39	11.55
	11.37	11.40	11.47	11.59	12.09	12.25
PM	12.07	12.10	12.17	12.29	12.39	12.55
	12.37	12.40	12.47	12.59	1.09	1.25
	1.07	1.10	1.17	1.29	1.39	1.55
	1.37	1.40	1.47	1.59	2.09	2.25
	2.07	2.10	2.17	2.29	2.39	2.55
	2.37	2.40	2.47	2.59	3.09	3.25
	3.07	3.10	3.17	3.29	3.39	3.55
	3.37	3.40	3.47	3.59	4.09	4.25
	4.07	4.10	4.17	4.29	4.39	4.55
	4.37	4.40	4.47	4.59	5.09	5.25
	5.07	5.10	5.17	5.29	5.39	5.55
	5.37	5.40	5.47	5.59	6.09	6.25
	6.08	6.11	6.17	6.29	6.39	6.55
	7.08	7.11	7.17	7.29	7.39	7.55
	8.08	8.11	8.17	8.29	8.39	8.55
	9.08	9.11	9.17	9.29	9.39	9.55
	10.08	10.11	10.17	10.29	10.39	10.55

SATURDAY

	Hyde Park	Avonhead Mall	University of Cant'y	City Bus Exchange	Eastgate	Woolston Terminus
AM	6.30	6.33	6.39	6.51	7.01	7.17
	7.30	7.33	7.39	7.51	8.01	8.17
	8.30	8.33	8.39	8.51	9.01	9.17
	9.30	9.33	9.39	9.51	10.01	10.17
	10.29	10.32	10.39	10.51	11.01	11.17
	11.29	11.32	11.39	11.51	12.01	12.17
PM	12.29	12.32	12.39	12.51	1.01	1.17
	1.29	1.32	1.39	1.51	2.01	2.17
	2.29	2.32	2.39	2.51	3.01	3.17
	3.29	3.32	3.39	3.51	4.01	4.17
	4.29	4.32	4.39	4.51	5.01	5.17
	5.30	5.33	5.39	5.51	6.01	6.17
	6.30	6.33	6.39	6.51	7.01	7.17
	7.30	7.33	7.39	7.51	8.01	8.17
	8.30	8.33	8.39	8.51	9.01	9.17
	9.30	9.33	9.39	9.51	10.01	10.17
	10.30	10.33	10.39	10.51	11.01	11.17

SUNDAY

	Hyde Park	Avonhead Mall	University of Cant'y	City Bus Exchange	Eastgate	Woolston Terminus
AM	7.45	7.48	7.54	8.06	8.16	8.32
	8.45	8.48	8.54	9.06	9.16	9.32
	9.45	9.48	9.54	10.06	10.16	10.32
	10.44	10.47	10.54	11.06	11.16	11.32
	11.44	11.47	11.54	12.06	12.16	12.32
PM	12.44	12.47	12.54	1.06	1.16	1.32
	1.44	1.47	1.54	2.06	2.16	2.32
	2.44	2.47	2.54	3.06	3.16	3.32
	3.44	3.47	3.54	4.06	4.16	4.32
	4.44	4.47	4.54	5.06	5.16	5.32
	5.45	5.48	5.54	6.06	6.16	6.32
	6.45	6.48	6.54	7.06	7.16	7.32
	7.45	7.48	7.54	8.06	8.16	8.32
	8.45	8.48	8.54	9.06	9.16	9.32

BH = *Travels via Burnside High School*

* = *Service ends at the City Bus Exchange*

WOOLSTON to Hyde Park

BUS EXCHANGE: Departs Platform B

MONDAY to FRIDAY

	Woolston Terminus	Eastgate	City Bus Exchange	University of Cant'y	Avonhead Mall	Hyde Park
AM	6.35	6.45	6.57	7.09	7.17	7.24
	7.05	7.15	7.27	7.39	7.47	7.54
	7.32	7.45	7.57	8.09	8.17	8.24
	8.01	8.14	8.27	8.40	8.48	8.55
	8.31	8.44	8.57	9.10	9.18	9.25
	9.02	9.14	9.27	9.40	9.48	9.55
	9.32	9.44	9.57	10.10	10.18	10.25
	10.02	10.14	10.27	10.40	10.48	10.55
	10.32	10.44	10.57	11.10	11.18	11.25
	11.02	11.14	11.27	11.40	11.48	11.55
	11.32	11.44	11.57	12.10	12.18	12.25
PM	12.02	12.14	12.27	12.40	12.48	12.55
	12.32	12.44	12.57	1.10	1.18	1.25
	1.02	1.14	1.27	1.40	1.48	1.55
	1.32	1.44	1.57	2.10	2.18	2.25
	2.02	2.14	2.27	2.40	2.48	2.55
BH	2.32	2.44	2.57	3.11	3.21	3.28
	3.02	3.14	3.27	3.41	3.49	3.56
	3.32	3.44	3.57	4.11	4.19	4.26
	4.02	4.14	4.27	4.41	4.49	4.56
	4.32	4.44	4.57	5.11	5.19	5.26
	5.02	5.14	5.27	5.40	5.48	5.55
	5.32	5.44	5.57	6.10	6.16	6.23
	6.05	6.15	6.27	6.39	6.45	6.52
	7.05	7.15	7.27	7.39	7.45	7.52
	8.05	8.15	8.27	8.39	8.45	8.52
	9.05	9.15	9.27	9.39	9.45	9.52
	10.05	10.15	10.27	10.39	10.45	10.52

SATURDAY

	Woolston Terminus	Eastgate	City Bus Exchange	University of Cant'y	Avonhead Mall	Hyde Park
AM	7.26	7.36	7.48	8.00	8.06	8.13
	8.26	8.36	8.48	9.00	9.06	9.13
	9.25	9.36	9.48	10.00	10.06	10.13
	10.24	10.35	10.48	11.00	11.07	11.14
	11.24	11.35	11.48	12.01	12.08	12.15
PM	12.24	12.35	12.48	1.01	1.08	1.15
	1.24	1.35	1.48	2.01	2.08	2.15
	2.24	2.35	2.48	3.01	3.08	3.15
	3.24	3.35	3.48	4.01	4.07	4.14
	4.26	4.36	4.48	5.00	5.06	5.13
	5.26	5.36	5.48	6.00	6.06	6.13
	6.26	6.36	6.48	7.00	7.06	7.13
	7.26	7.36	7.48	8.00	8.06	8.13
	8.26	8.36	8.48	9.00	9.06	9.13
	9.26	9.36	9.48	10.00	10.06	10.13
	10.26	10.36	10.48	11.00	11.06	11.13

SUNDAY

	Woolston Terminus	Eastgate	City Bus Exchange	University of Cant'y	Avonhead Mall	Hyde Park
AM	7.41	7.51	8.03	8.15	8.21	8.28
	8.41	8.51	9.03	9.15	9.21	9.28
	9.39	9.50	10.03	10.15	10.21	10.28
	10.39	10.50	11.03	11.16	11.23	11.30
	11.39	11.50	12.03	12.16	12.23	12.30
PM	12.39	12.50	1.03	1.16	1.23	1.30
	1.39	1.50	2.03	2.16	2.23	2.30
	2.39	2.50	3.03	3.16	3.23	3.30
	3.40	3.51	4.03	4.15	4.21	4.28
	4.41	4.51	5.03	5.15	5.21	5.28
	5.41	5.51	6.03	6.15	6.21	6.28
	6.41	6.51	7.03	7.15	7.21	7.28
	7.41	7.51	8.03	8.15	8.21	8.28
	8.41	8.51	9.03	9.15	9.21	9.28
	9.41	9.51	10.03	10.15	10.21	10.28

BH = *Travels via Burnside High School*