Travel adaptive capacity assessment for particular geographic, demographic and activity cohorts

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Abbreviations and acronyms

AA:	Automobile Association
AEMSLab:	Advanced Energy and Material Systems Laboratory, a research group at UoC
IEA:	International Energy Agency
MoT:	Ministry of Transport
NZTA:	NZ Transport Agency
NZHTS:	New Zealand Household Travel Survey
RECATS:	Risk of Energy Constrained Activity Transport Systems; computer software
Travel Sim:	A virtual reality sim game survey; used in previous research
TACA survey:	Travel adaptive capacity assessment survey; a web-based survey used in this study
TDM:	Travel demand management
UoC:	University of Canterbury
UK:	United Kingdom
USA:	United States of America
VKT:	Vehicle kilometres travelled
VTBC:	Voluntary travel behaviour change

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Executive summary

Oil shocks, peak oil and long-term oil supply reduction are emerging as major issues in transportation planning. Over the last decade, the price of oil in real terms increased nearly ten-fold. Currently, world oil production has little spare capacity. The large conventional oil fields around the world are either unable to increase production or are in decline. New oil extraction tends to be from more expensive resources such as offshore, deep water, oil sands and remote locations. A survey of international government, economic and military analyses reveals a consensus that alternatives to conventional oil will not fill the gap between flat or declining oil production and increasing demand. All sources of analysis predict destabilising trends that will put downward pressure on demand.

Data and analysis methods available for assessing the vulnerability, responsiveness and sustainability of personal vehicle transportation in the future climate of constrained world oil supply are lacking. Nearly all published studies of fuel price elasticity were conducted in times of surplus world oil supply capacity. These studies examine costs and social drivers for behavioural change when the option of the convenient personal car is readily available and when no fuel crisis is occurring. Research into behaviour change as fuel prices spike is nearly impossible to carry out because participants cannot be artificially subjected to these disruptions under controlled conditions. Researchers examined the travel behaviour change of drivers during the 1970s oil embargo in the USA and the 2000 petrol shortage in the UK. These events had very high levels of behaviour change even though real fuel costs changed only slightly. Some important findings were that the work trip and other trips which were important to family wellbeing were the least likely to be changed, and that cities that had effective public and cycling transport infrastructure had much higher levels of mode change than cities where people did not have these options.

We propose that **travel adaptive capacity** to reduce fuel use is a key metric for future resource allocation, asset management, safety and transport engineering. Travel adaptive capacity is a measure of the resilience of transport activity systems to a reduction in fuel use for personal vehicle trips while not reducing participation in activities. Travel adaptive capacity characterises the vulnerability to oil shocks of a particular urban area, organisation, socioeconomic or demographic group.

The long-term potential demand growth for public transport, ride sharing or active modes is measured by the **travel adaptive potential** for mode change. The travel adaptive potential is a measure of the alternative mode uptake currently possible for private travellers. We propose that the currently perceived options, while not strictly predictive, provide a relevant indication of the shifts that can be expected as pressure on fuel supply increases for a given urban form.

A web-based interactive travel adaptive capacity assessment survey (the TACA survey) was used for this project. The TACA survey collects habitual or 'normal' weekly travel activity patterns and does not attempt to capture all random or occasional trips. After recording a normal trip (mode, origin, destination, purpose, time, route and importance), the TACA survey participants are simply asked to indicate up to three alternative modes for each trip. The survey asks 'Do you have an alternative mode for this trip?' The first alternative selection in the drop-down menu is 'no alternative'. This is different from surveys that ask about choices between alternatives at particular prices.

The TACA survey resulted from previous research that developed a virtual reality sim game survey (Travel Sim). The adaptive capacity data from the TACA survey was calibrated to the sim game survey results. The Travel Sim game price elasticity with fuel prices rising up to 3.5 times the current price was –0.22, commensurate with many published studies. However, at 4 and 5 times the current price, the Travel Sim game elasticity becomes sharply higher. Using the Travel Sim price rise, we calibrated the travel adaptive capacity data found in this survey to represent the fuel demand reduction associated with a five-fold increase in fuel price. Thus the TACA survey adaptive capacity represents what the participants *could do* if a fuel emergency arose and not what they *would do* under normal circumstances. The TACA survey results also indicate the relative adaptive capacity of the urban form to long-term pressure for change resulting from fuel insecurity and scarcity. Many factors influence the availability of alternative modes for carrying out activities, the geography of the urban from being chief among these. The TACA survey results are not meant to predict the long-term future of travel behaviour. However, the results indicate which populations and urban areas will experience greater pressure for change, and which are more resilient and adaptable.

This research makes a contribution to stakeholders, planners and engineers in providing data and models of travel adaptive capacity. The data can be used to understand possible future trends in urban development, network designs, motor vehicle use and active transport mode share. Urban transport demand modellers using the traditional four-step approach can use the long-run adaptive capacity and adaptive potential to reconsider the trip generation, trip distribution and modal split functions in the event of a fuel shock or in the long-term context of declining world oil supply. If transport models are based on the trip-consumer approach, then modellers can incorporate the understanding of behaviour adaptation under fuel supply pressure.

The data presented in this report was collected from 555 participants in three urban areas in several sampling exercises between October 2008 and August 2010. The TACA survey was deployed in Christchurch and Dunedin, and the rural town of Oamaru. In Christchurch, the surveys focused on a major activity system, the University of Canterbury. Academic staff, general staff and students were surveyed, representing different income and age groups. In Oamaru, elderly and retired citizens were targeted during one of three surveys. In Dunedin and Oamaru, the survey solicited random participation from people who were visiting the central business area of the town. Only one sampling exercise was conducted in Dunedin. In Dunedin, a group of employees at the Dunedin City Council and residents of nearby commuter settlements were also surveyed.

The objective of this study was to present the concepts of adaptive capacity and adaptive potential, the survey method and the data for three different urban areas. The data is available for in-depth analysis by other researchers, and is being further studied by the Advanced Energy and Material Systems laboratory investigators. In this report, we present the data as collected and the adaptive capacity, but no in-depth analysis.

The results indicate that the travel adaptive capacity of the South Island cities with good bus service is quite high. This result should not be too surprising, given the historical character of the urban forms that were developed with lower vehicle travel demand than today.

Students in Christchurch have the highest travel adaptive capacity. They currently carry out 50% of trips without a car and could adapt 88% of their current single passenger vehicle trips to car-pooling, bus, walking or biking. The higher-income university academics currently carry out 38% of their trips without a car, and 60% of their car trips have lower-energy alternative modes. Oamaru residents have the lowest adaptive capacity. Oamaru has a lower adaptive potential for mode shift, mainly because no public bus service is available. In Oamaru, currently 25% of trips do not use a car and 43% of single passenger vehicle trips have an alternative mode. Dunedin participants indicated that 22% of their current vehicle trips could be made by bus but they had much lower adaptive potential for cycling than Christchurch or Oamaru participants.

People in all demographic categories residing in all parts of the cities have the potential to adapt most of their current vehicle trips to other modes. In general, young people have the highest adaptability. The largest share of adaptive potential is bus trips, but walking and biking feature nearly as prominently. Conversely, some people have no adaptability. While these people are found in all demographic categories, a higher proportion was found among the elderly and higher income participants. Participating in the activity without travelling, as in working from home or conducting a social visit by telephone, was selected for less than 1% of trips by all participants.

The fuel consumption associated with the alternative modes can be calculated from the travel distances associated with each individual's adaptive potential and the vehicle information. Not counting the trip adaptations that involved cancelling a trip or participating without travel, the adaptive capacity for fuel use reduction is 55% in Christchurch, 18% in Oamaru and 40% in Dunedin. This suggests that voluntary travel behaviour change in response to a fuel shock could be substantial, but does necessarily predict long-term behaviour.

We recommend that the focus of transport policy should shift away from subsidies for measures like alternative fuels or electric vehicles, as the adaptive capacity for fuel reduction is larger than the capacity for uptake of new vehicles or making biofuel. Many people are currently aware of their alternatives, which is the first requirement for future behaviour change.

The high fuel prices of 2008 are likely to be followed by more price shocks and continued high prices. The world transport fuel supply will continue to be tight and will contract in the future. Further analysis of TACA survey data could help shape transport policy. Policy needs to deal with the need for reduced fuel consumption and should focus on facilitating adaptation through providing safe, affordable active mode and electric public transport infrastructure, and promotion of urban forms with high adaptive capacity. Other important policy implications are the need for access to affordable housing near activity centres for low-income people, public transport, cycle and walking infrastructure, and access to activities for elderly people. Sustainable transport advocates have been calling for these types of measure for many years. The TACA survey data provides new cost/benefit analysis capability that should be useful in planning for sustainable transport investments. Adaptive capacity data could be used to allocate infrastructure expenditure for energy-efficient modes in order to gain the most resilience and adaptive capacity benefits.

The TACA survey has added interesting new insights about adaptive capacity to reduce fuel use, and the adaptive potential of different modes in Christchurch, Dunedin and Oamaru. The survey is the first of its kind in the world, and more research is needed to fully analyse the data and use it in adaptation modelling. We recommend that other urban areas throughout New Zealand conduct TACA surveys to provide travel adaptive capacity data for specific areas and activity systems. Travel behaviour change with increased fuel prices is very complex and depends on a whole range of factors, including urban form and accessibility, income and age, and the political and media situations at the time. More research is needed in this area, as the context for future urban planning and asset management changes from the historical pattern of abundant low-cost fuel to the future trend of constrained high-price fuel.

Abstract

Transport infrastructure and network planning must now consider oil shocks and future demand growth for more energy efficient transport modes. However, data and models for this type of fuel reduction planning are not available. *Travel adaptive capacity* is proposed as a measure of the resilience of travel demand to a reduction in fuel use for personal vehicle trips while not reducing participation in activities. Travel adaptive potential characterises the ways that populations can change modes to reduce fuel use without reducing participation in activities. The travel adaptive capacity assessment (TACA) survey can capture the data needed to assess adaptive capacity and the preferred mode alternatives. The survey asks for the essentiality of each trip and the alternative travel modes currently available. TACA surveys were carried out in Christchurch, Oamaru and Dunedin. Over 550 participants completed the survey in 2008–2010. The survey participant demographics, trip generation and mode data compared well with government data. The report found that for these three South Island centres, some adaptive capacity is possible, with Christchurch participants showing the greatest adaptive capacity. The TACA survey is a useful tool for further research into travel behaviour and mode choice.

1 Introduction

1.1 Context

1.1.1 Why oil shocks must be considered

Oil shocks, peak oil and long-term planning for oil supply decline are becoming mainstream transport and urban planning issues (Smith 2010). However, no data and no modelling methods are available for assessing short-term oil shock vulnerability and informing long-term investments for an integrated, safe, responsive and sustainable land transport system in the context of peak oil issues. Public resources are primarily being allocated in New Zealand for increasing the capacity of the road transport network. It is quite probable that personal travel demand and freight movements will not increase significantly from 2007 onward, and fuel use is likely to be at least 50% less than current levels by 2050 (Krumdieck et al 2010). No mitigation measures for oil supply decline are known (Hirsch et al 2005) and alternative vehicles such as electric cars will not be in great demand because of their high price and manufacturing constraints (Delucchi and Lipman 2001). All transportation depends on oil and the world supply is constrained, with major producers declining (Aleklett et al 2008; Höök et al 2009). Therefore, transportation and urban land use planners must consider oil shocks as a risk and recognise that travel demand for energy-intensive modes will be declining throughout any long-term planning horizon. In order to allocate resources to meet future growth in demand for more energy-efficient modes (public transport, cycling, walking and rail), the NZ Transport Agency (NZTA) requires data and analysis that clearly show what the adaptive potential is for personal transport in each city and region.

1.1.2 Key definitions

- **Travel adaptive capacity:** Current indicated fuel reduction capacity available through alternative mode choices with no reduction in participation in activities
- **Mode adaptive potential:** Current indicated potential increase in demand for trips by alternative modes with no reduction in participation in activities
- **Adaptability:** Non-dimensional number indicating the relative resilience of current travel behaviour and the ability to reduce fuel use without reducing participation in essential activities.

1.1.3 Previous research on fuel supply risk and travel adaptability

In our previous work (Dantas et al 2007), we developed a method to assess peak oil risks. The method applies a transport energy constraint to a future transportation planning scenario for a given city plan and calculates a risk factor related to an oil supply decline scenario. The 'risk of energy-constrained activity transport systems' (RECATS) method requires an adaptation model of private travel demand behaviour. No such model is available in the literature, although a sizeable body of work has been written on price elasticity and adaptation to travel demand management (TDM) measures (Loukopoulos et al 2006). Long-term adaptation are likely to be influenced by policy, economics, technological development and social norms, but the deterministic effects would be difficult to quantify. A simple adaptation model was used in the RECATS algorithm, based on hierarchical choice saturation (Krumdieck et al 2010). The cost minimisation principle of adaptation was combined with the assumed adaptation goal of maintaining participation in activities. The percentage of car trips that are ultimately adaptable to save fuel was roughly estimated from the active and public transport mode capacity of the urban form. Negative impacts of the adaptive changes were assigned to loss of activities. In the RECATS model, the unconstrained travel demand frequency, distance and mode were modified via a Monte Carlo random selection of trips to adapt the pattern until the modified fuel demand matched the constraint value. A certain percentage of short car trips are adapted to active mode, and medium and long car trips are adapted to car-pooling and public transport. However, it became clear that real data about travel adaptive potential amongst a particular population in a given urban form would be needed for accurate oil supply risk assessment. In addition, this type of adaptation potential data would be highly valuable for transportation and urban planning.

1.1.4 Previous research on surveying for travel adaptation to oil shocks

Our interdisciplinary research group at the Advanced Energy and Material Systems Laboratory (AEMSLab) developed a novel virtual reality sim game survey method (Travel Sim) where oil shocks are simulated and adaptation of normal travel behaviour is recorded (Watcharasukarn 2010). The Travel Sim game uses an immersive environment to prompt participants to respond to a steep fuel price rise as they carry out their weekly activities (Watcharasukarn et al 2010). The Travel Sim game has two-dimensional environments, avatars and simulations of travel to work, shopping, socialising and recreation (Watcharasukarn et al 2009a). Travel Sim runs from a basic visual platform on a CD. A survey of 155 participants was conducted in Christchurch, showing that people responded to the simulated fuel price rise (Watcharasukarn et al 2011). Travel Sim has three levels:

1 personal, household and vehicle information

2 normal weekly travel activities

3 simulation of three weeks of normal activities while fuel price rises sharply.

A web-based personal travel adaptive capacity assessment (TACA) survey was developed that only used the first two levels of the original sim game survey. The TACA survey was found to produce similar travel adaptive capacity results to the Travel Sim game survey (Watcharasukarn et al 2009b). In the TACA survey, participants fill in an online diary with their typical or habitual activities and then use Google Maps™ to locate the origin, destination and route of the trip. They report departure and arrival times, and the importance of each the trips. Finally, a drop-down menu prompts participants to answer the question, 'Do you have another way to get to this activity?' The resulting data records the current habitual travel pattern for a week and the alternatives that participants reported. Participants are not asked to consider price or environmental issues, and they are not encouraged to reduce vehicle travel or use an alternative mode. We have no way to test the hypothesis, but we propose that the TACA survey assessment of travel adaptive capacity is a proxy for emergency fuel reduction behaviour and for long-term trends induced by pressure from a decline in fuel supply.

1.2 Research objectives

The NZTA funded the AEMSLab, an interdisciplinary research group at the University of Canterbury (UoC), to undertake this programme of research, aiming to break new ground in the area of future travel demand adaptation in response to oil shocks, fuel price pressure and peak oil issues. The research programme included the following objectives:

- to review the literature on travel behaviour change in response to fuel shocks, price spikes or scarcity
- to conduct statistically relevant TACA surveys of UoC students and staff in Christchurch, and citizens of Oamaru (a TACA survey in Dunedin was added to the project scope in 2010 at the request of the Dunedin City Council)

- to produce a well-organised and searchable database of the data that can be used by other researchers and practitioners
- to propose analysis methods for adaptability and carry out basic analysis of the data, including travel adaptive capacity and personal adaptability assessment
- to report the results to UoC, city councils and regional councils.

1.3 Study overview and outputs

1.3.1 Data collection

The research programme focused on conducting surveys in urban and rural communities, and reporting the data in a format that allows other stakeholders to use the data for further analysis. This research deployed the TACA survey in three South Island centres, Christchurch, Oamaru and Dunedin over 2008–2010. During the study period, the price of petrol and diesel for private transport remained relatively constant at $1.60–1.80 per litre. Over 550 participants were surveyed. The data was collected and organised into a searchable database. A basic adaptive capacity analysis was conducted by plotting in the data. A method for calculating personal adaptability was also developed.

1.3.2 TACA survey data

The TACA survey was carried out in Christchurch at UoC. The subjects were all participants in one of the city's largest activity centres. Surveys were also conducted in Oamaru and Dunedin. The sample sizes were statistically valid and the demographics of the participants compared well with census data. The trip generation and travel demand patterns were validated against New Zealand travel survey data. A searchable database has been constructed along with a data dictionary describing the logic codes used to search in different fields.

1.2.3 Travel adaptive capacity analysis

The travel demand patterns for each cohort showing the current and adapted mode splits are presented. The adaptive potential for fuel savings is analysed by looking at the current vehicle travel that could be adapted to lower energy modes. The essentiality of trips is examined against trip purpose. A method for calculating personal adaptability from the data is presented and analysed according to participant income levels. The personal adaptability for participants is calculated and plotted on a map of the town at their location of residence to illustrate the relationship between adaptability and urban form.

1.4 Structure of this report

Chapter 2 of this report describes the literature available on voluntary behaviour change and adaptation of travel behaviour. The literature review focuses on existing work around personal travel adaptive capacity, essentiality of travel activities and previous studies of fuel shocks. This section reviews the background and literature in the areas of future fuel supply issues, behaviour change during fuel shocks, and progress in surveying and modelling travel behaviour change. The literature is rather thin in this area. The background includes a discussion of the Travel Sim virtual reality survey and the calibration of the web-based TACA survey using previous results from the sim game surveys at UoC.

Chapter 3 describes the TACA survey and the survey methods used in the three target centres. The section also gives analysis to validate the survey including comparisons with existing statistics. The database structure is described and the database dictionary provided.

Chapter 4 presents the data collected from the surveys. Graphs of the travel demand patterns and adaptations are presented for each of the centres and for different groups in the survey. The essentiality data is also presented.

Chapter 5 presents a method to calculate personal adaptability. A computer program was developed to calculate the personal adaptability of participants, geocode their personal residence and produce maps using a geographic information system. Finally, the adaptive potential for mode change is examined.

Chapter 6 provides a summary, discussion and suggestions for future work. In this section of the report, we also discuss the policy implications of the findings regarding allocation of resources for the safety, resilience and sustainability of the transport network.

2 Literature review and background

2.1 Transport fuel supply issues

2.1.1 Context

Energy researchers have been analysing future oil supply for the past 40 years. Peak oil – the inflection point between increasing and decreasing world oil production – has been discussed since the 1970s when oil production peaked in the United States of America (USA) and the Organisation of Petroleum Exporting Countries oil embargo caused widespread transport disruption and economic recession. The timing of peak oil from expert analysts ranges from 2006 to after 2025 (Campbell and Laherrere 1998; Davis 2003; Deffeyes 2003; World Energy Council 2003; Bakhtiari 2004; Skrebowski 2004; Hirsch et al 2005). All of the expert analysts agree that the production rate of conventional oil will be in permanent decline within 10 years. This is a short timeframe for transportation planning and urban development.

New Zealand is dependent on imported fossil fuels. Around 50–60% of the crude oil and feedstock processed by the New Zealand Refining Company is imported from the Middle East to combine with 30–40% from the Far East/Northern Australia and indigenous production (Colegrave et al 2004). Imported oil accounted for approximately 41.4% (321.59PJ) of total primary energy supplied (776.6PJ) in New Zealand in 2009 (Ministry of Economic Development (MED) 2010a). The MED reported that the net oil import dependency of New Zealand in 2009 was 63%. It increased from 2008 because of a drop in domestic oil production (MED 2010b). The domestic oil consumption by the transport sector has increased at an average annual rate of 0.3% between 2005 and 2009. A recent New Zealand parliamentary report forecasted that oil shocks will be likely because oil supply will not increase in the next five years while demand will continue to rise (Smith 2010).

2.1.2 Alternatives do not mitigate fuel supply issues

Peak oil will cause significant travel behaviour change (Campbell 2003). The world oil supply outlook indicates that high prices will continue and thus put pressure on personal transport, as will carbon emission pricing and increasing media coverage of oil supply issues (International Energy Agency (IEA) 2010). The IEA points out that resources of unconventional oil are possibly several times larger than conventional resources. However, Canadian oil sands, coal-to-liquids, Venezuelan extra-heavy oil and gas-to-liquids are all significantly more capital intensive and more environmentally damaging, and have higher emissions per unit of consumer energy delivered than conventional oil. The IEA also notes that carbon capture and storage, as well as other new improved water and land management technologies, would be needed to make unconventional oil acceptable. However, carbon capture and storage technology is not viable and coal-to-liquids are likely to be very expensive (Page et al 2009).

Hirsch et al (2005) was one of the first government-sanctioned reports to state definitively that a sizeable gap exists between projected future fuel demand and known or alternative fuel supply. Alternative fuels and electric vehicles are not available, or ready to bring into the market at prices and in the quantities that will replace declining oil production (Barker 2010). The United States Joint Forces Command (2010) has identified oil supply as one of the 10 major security issues for the next quarter century, stating: ‘By 2012, surplus oil production capacity could entirely disappear, and as early as 2015, the shortfall in output could reach nearly 10 [thousand barrels per day]’. This Joint Operating Environment report also expects that biofuels will not supply more than 1% of global liquid transport fuel demand, and wind and solar energy will supply less than 1% of global energy supply by 2030. Hydrogen is not a feasible transport fuel and the technologies to use it are not available (Page et al 2009).

Automobiles that are much more efficient than the current average fleet fuel consumption of over 10 litres per 100km are currently available in the market in New Zealand and are usually priced lower than the larger, less efficient vehicles. Reducing fuel demand through more efficient vehicles is currently an available travel behaviour adaptation that requires a capital investment, but results in fuel cost savings (MED 2010c). Through simple depreciation and fuel savings calculations, urban travellers can determine whether purchasing a more fuel-efficient vehicle will reduce their costs. In general, if the current vehicle has poor efficiency and the driving distances are large, then cost savings can be realised.

Urban travellers can effectively control their transport costs by choosing a residential location with active mode access to shopping and services, and a short distance or low-cost public transport link to the work location (Handy et al 2005). The decision to reduce fuel costs or increase walking or biking activity can be hampered by the availability of affordable residential locations and by urban form. Where such residential locations exist, they are usually in high demand.

The probability of fuel shortage events and price shocks are likely to increase as oil supplies tighten. According to economic utility theory, the lowest cost choice for urban travellers to reduce fuel costs is travel behaviour change (Oppenheim 1995). Transportation planners need information on how people will carry out their activities when they choose to reduce fuel use or not to use their car. Urban planners and land use planners will need to understand the long-range trends in personal urban travel in their city in order to accurately model future travel demand and inform investments in infrastructure and urban development. This literature review investigates this critical issue of travel behaviour adaptability in relation to fuel shocks and pressure from the long-term fuel supply contracting. The probability of fuel shortages and price shocks are likely to increase as oil supplies tighten (Chatterjee and Gordon 2006).

2.2 Travel behaviour adaptation

2.2.1 Causes of shocks

Transportation infrastructure currently supports fossil fuel-based technologies nearly exclusively. Individual private vehicle transport is the most energy-intensive mode of transport in urban settings. Systematic investigation of travel mode choice in response to fuel issues is rare because of the unpredictability and rarity of fuel supply disruption events. Fuel-conserving travel behaviour adaptation can be studied by looking at historical oil shocks. This section reviews the literature around the 1970s oil shocks and the more recent 2000 United Kingdom (UK) tax revolt fuel shortage.

A fuel shock can arise from any number of events causing a price spike, a fuel shortage or government action to curb consumption. Clearly, the doubling of the price at the pump in New Zealand over the 2007–2008 timeframe would constitute a fuel price spike. A fuel crisis refers to a supply shortage experienced by end users. Again, the perception of a fuel crisis can be heightened by media coverage. Government action to curb consumption could be in response to high prices or IEA international agreement. Government actions can include relatively innocuous measures like lowering the speed limit or giving incentives for public transport, but may also include restrictions on vehicle use or fuel rationing. A fuel shock may cause temporary as well as long-term effects on personal travel behaviour.

The price elasticity of travel demand and fuel use has been found to be relatively consistent over many studies through the 1990–2004 timeframe. For a 10% fuel price rise, the volume of fuel consumed will fall by about 2.5% within a year and continue to fall to 6% in the longer run (Goodwin et al 2004). This typical price elasticity can be expected for a situation like a gas tax increase but does not include the effect of fuel shortages. The fuel price spike of 2007–2008 was followed by fuel demand contraction of 2% in 2009 (British Petroleum 2010). It is highly likely that the transport fuel supplies available to end users will contract steadily, if not precipitously, for any planning horizon considered (Krumdieck et al 2010). This continuous contraction will be experienced as periodic fuel price and economic shocks (Rubin 2009). How will travel behaviour and travel demand change as price and supply security issues continue to apply pressure on end users? An obvious place to look for answers is research into previous oil shocks.

2.2.2 Fuel supply issues and travel behaviour change

2.2.2.1 Recent New Zealand experience

Retail petrol prices in New Zealand rose sharply in 2000–2001 and then continued rising steadily from 2005. Historically, traffic volumes and vehicle kilometres travelled (VKT) in New Zealand have responded consistently to price increases. Urban travellers have responded quickly to fuel price rises, with a statistically significant reduction in petrol consumption occurring within a year. In a study of the past fuel price rises by Kennedy and Wallis (2007), a petrol price increase of 1% caused at least a 0.15% reduction in petrol consumption and 0.3% reduction in car and van traffic on state highways. The 2001 and 2005 price rises were not accompanied by supply shortages at the pumps, or by news about shortages elsewhere in the world.

2.2.2.2 Experience of the 1970s fuel shocks

The 1970s oil shocks involved both price rises and issues with supply security. In 1973, the Arab oil embargo dramatically affected transport fuel supply in the USA and allied nations. Earlier, natural gas shortages had led to increased demand for oil for power generation, increased car ownership had led to increased petrol demand, increased freight movement had led to increased demand for diesel, and the oil production in the USA had already peaked and was declining, despite development of the new massive Alaskan resources (Franssen 1980). In response to the embargo, in 1974, the US government developed, for the first time, an energy policy called 'Project Independence', which aimed to have the country independent of foreign oil imports by 1980.

The fuel shocks of the 1970s provide historic examples of how events gave rise to pressures on fuel demand (Peskin 1980). Research on the response of urban travellers to the oil shocks in the USA gives the following observations, which appear to be consistent across the country and over time:

- **Accessibility to fuel is a much stronger driver for conservation behaviour than price increase.** Travellers were more likely to decide to conserve fuel if gas stations were out of gas, when long lines at filling stations were portrayed in the media or when fuel purchase limits were imposed (Peskin et al 1975; Skinner 1975; Sacco and Hajj 1976).
- **Both high-income and low-income urban travellers changed to more energy-efficient travel modes during the fuel shock.** However, low-income households that changed were more likely to remain changed after the crisis ended (Becker et al 1975; Sterns 1975).
- **The journey to work was the least flexible trip.** Shopping trips were changed or reduced long before any car pooling or mode change was made to the work trip as the fuel crisis deepened. Holiday and recreation travel would be curtailed before the work trip would be altered. Only in areas with very good public transportation systems were changes to work trip mode observed (Hartgen 1975; Lessieu and Karvasarsky 1975; Peskin et al 1975; Corsi and Harvey 1979; Hartgen 1979).
- **Trip chaining of non-work trips was a common adaptation,** particularly for shopping trips (Peskin et al 1975; Kostyniuk and Recker 1977).
- **Walking or biking was one of the first changes observed** during the gasoline shortage, depending on automobile availability, prior use of the alternative mode, and employment status and income; and

was seen as a relatively easy way to conserve energy (Hartgen 1975; Opinion Research Corporation 1976; Neveu 1977).

- **Driving at a reduced speed was one of the most common adaptations to reduce fuel consumption.** Researchers found that the public preferred easily taken personal actions over restrictive government actions or punitive measures like increased gas taxes (Neveu 1977; Hargten 1979).
- **Public transport use was found to surge during the energy crisis.** However, numerous researchers found considerable reluctance to change mode to public transportation as a first choice. Automobile use was usually modified first (eg driving slower, tuning up the car) and public transport was taken up as a last resort (Keck 1974; Peskin et al 1975; Sterns 1975; Sacco and Hajj 1976).
- **Car-pooling was not found to be an action taken in response to either fuel price rises or fuel shortages**. The only study that found an increase in vehicle occupancy was among people who also purchased high-efficiency, smaller automobiles, indicating that energy conserving individuals were the only group willing to share an automobile ride (Trentacost and Milic 1974; Beglinger and Behnam 1975; Peskin et al 1975; Hartgen 1979).
- **Urban travellers adapt to use less fuel through consistently adjusting small, unobtrusive and frequently taken actions.** The public is receptive to policy actions that encourage fuel savings by increasing travel options and offering incentives for their use (Rappaport and Labaw 1975; Meyers 1979; Hartgen 1979).

Lessons learned from the 1970s fuel shock are still important for urban planners and policymakers where the main focus of transport planning is in the trip to work. The fact that all research from the 1970s shows that the journey to work was the least adaptable is important when considering investment in commuter infrastructure. People shifted mode to public transport, but only where well-established services were present and where the travellers had some previous experience with the system, such as in New York City. It should be noted that many cities in the USA were not well served with public transport systems, which may account for the observed unwillingness to change mode for an important work trip. The willingness to reduce speed may not be as applicable to New Zealand because our urban areas do not have the same number of kilometres of high-speed freeways as US cities. Travellers were willing to change to walking and biking, but only where these modes were possible. Again, in an urban area like New York City, walking access is possible, whereas in a sprawling western city like Los Angeles, the distances are too great for active modes.

Reducing the number of parking places at work destinations was thought to be a way to put pressure for change on the work trip, but no parking restriction measures were put in place during the energy crisis. The researchers in 1980 noted a need for further research to develop analytical tools to do long-range planning under energy constraints, and for modelling land use and energy relations (Peskin 1980).

2.2.2.3 The 2000 UK fuel crisis

Contingency planning for fuel shortages and fuel price shocks gained substantial attention in the early 1980s, but recent fuel shortages induced by natural disasters or civil unrest have proven that the transport activity system has little or no resilience. Recent fuel shortages, particularly during the fuel tax protest in the UK in 2000, provide a case study for an unexpected fuel crisis and the resulting travel behaviour change. Widespread protests against high petrol and diesel prices had taken place in several European countries, including the UK, in the first half of the year 2000. The world oil price had risen rapidly to the record level of $35 a barrel and the 91 unleaded price in the UK was over 80p/L. Fuel taxes in the UK had put even more pressure on the consumer price, as they had recently increased to 81.5% of the total cost of unleaded petrol. This caused the fuel prices in the UK, which were previously amongst the lowest in Europe, to become the most expensive in a short period (Hammar et al 2004). (For reference, the price of 95 octane petrol in the UK at the time of writing was 122–144p/L (Whatprice 2009).)

On 7 September 2000, about 100 farmers and lorry drivers from Wales and northwest England set up a blockade of the Stanlow Shell oil refinery. The next day, a further 100 bus drivers blockaded the Texaco refinery in Pembroke. By 10 September, motorists started to stockpile fuel, causing a run on petrol stations. Media coverage of lines of anxious motorists at petrol stations sparked further panic buying. Petrol stations began rationing fuel sales by limiting purchases to £5. It is estimated that by 13 September, more than 90% of petrol stations had run out of fuel (Chatterjee and Lyons 2002). Eight days after the initial fuel disruption, the protesters called off the blockade and fuel supplies returned to normal during the following week.

The temporary fuel shortage caused car users to change their travel behaviour. This resulted in a significant reduction in car traffic of, on average, 39% on motorways, 25% on major roads and 16% on minor roads, as measured on 14 September 2000 at 135 sites throughout the UK (Polak et al 2001). The number of public transport users increased markedly, but the government reduced bus services as fuel supplies ran low. The year 2000 marked a turnaround in the continuous trend of decreasing bus ridership in the UK (Department for Transport 2010).

Chatterjee and Lyons (2002) surveyed car users 34 days after the 2000 fuel crisis in five areas of England: Hampshire/Wiltshire, West Yorkshire, the London boroughs of Hillingdon, Leicester and Hertford. Ten thousand mail-back questionnaires were distributed with a 16% response rate. The results showed that 12% of 1065 car users reduced their trips to or from work, and 16% reduced their business trips. A further 14% changed their destination for grocery shopping trips. Respondents reported shifting 12% of work trips to other modes. Walking was the most popular mode shift choice for school travel (21%). The reduction of work trips seems to contrast with the travel behaviour seen during the 1970s oil shock. The availability of access to computers and the internet in the home may have facilitated the reduction of work trips in 2000, but this is speculation, as the questions were not asked in the survey.

The travel behaviour change observed during both the Organisation of Petroleum Exporting Countries embargo and the UK tax revolt fuel crises included mode shifting, reducing travel distance, reducing unnecessary trips made by car and changing destination (Habermann 1980; Chatterjee and Lyons 2002). Previous studies showed that it is not easy for car commuters to adapt without feasible public transport services. For example, in a survey conducted in the UK, over 50% of 563 respondents who normally drove to work, school or college declared that they had difficulties in using another mode. In addition, 15% stated that they did not go to work during the UK 2000 fuel crisis (Thorpe et al 2002).

2.2.3 Travel behaviour change surveys

2.2.3.1 Limitations of predicting actual change

Investigating adaptation behaviour in travel demand research is a recent topic and mostly concentrates on activity scheduling adaptation processes which may not be related to fuel shortage or even a price rise (Roorda and Andre 2007). Few of the conventional travel surveys that are regularly conducted by the government include an adaptability measurement, as the survey aim is to capture current travel behaviour only (de Dios Ortuzar and Willumsen 2001). The best way of modelling travel behaviour change when a fuel shock occurs is not known as yet. It is also not known whether behaviour change during an actual fuel supply disruption would give an indication of future trends in response to long-term price or supply pressure. Several factors are in play during a short-term fuel supply crisis that would not be present over a longer period of gradual fuel price increases. For example, panic buying and fuel purchase quantity limits were not experienced in New Zealand during the doubling of the world oil price between July 2007 and July 2008. In fact, the anecdotal evidence is that many drivers voluntarily limited the volume of fuel purchase because they could not afford to fill up the car. The actions households take when they are concerned about not getting fuel may be quite different from the actions they take when the fuel price rises.

2.2.3.2 Evaluating travel demand management programmes

Rush hour road congestion issues in nearly all major cities have led to efforts to manage travel behaviour for the work commuting trip. It may be possible to gain some insight into future travel demand adaptation to fuel supply contraction by examining these studies. TDM is a programme that aims to reduce personal vehicle use to alleviate congestion and pollution. TDM refers to strategies or policies to reduce vehicle travel in order to relieve congestion. TDM measures include ‘hard measures’ like reducing available parking, instituting congestion charges or building dedicated high-occupancy vehicle lanes, as well as ‘soft measures’ like incentives, information and education. Telecommuting and flexible work hours are institutional TDM measures. It can be difficult to measure the direct effectiveness of TDM programmes, as traveller decisions are complex, but Vlec and Michon (1992) suggest that TDM can lead to travel behaviour adaptation. New economic evaluation methods and case studies have shown that well-designed measures can reduce VKT, and increase active and public transport mode choices, often with large cost/benefit ratios as high as 15:1 (Florida Department of Transportation 2007).

2.2.3.3 Evaluating voluntary travel behaviour change interventions

Voluntary travel behaviour change (VTBC) refers to interventions aimed at encouraging people to choose alternative modes to private vehicles. Gärling et al (2000) surveyed 770 respondents and asked them to rate how likely they would be to choose car-pooling, public transport, cycling, trip chaining, closer destinations, etc if their goal was to reduce car driving. Respondents stated they were more likely to switch mode for work trips but more likely to choose closer destinations and combining trips for shopping. However, the authors suggest that much more research is needed to understand the factors that affect preferences. For the past decade, numerous VTBC projects have been set up around the world. For example, the TravelSmart programme has been used as an active intervention with tens of thousands of participants in Australia, Europe and America.

Evaluating the vehicle demand reduction produced by VTBC interventions is necessarily problematic, as it is hard to isolate a control group and to isolate the effect of the intervention only. A review by Brög et al (2009) found a range of behaviour change levels, from less than a 1% increase in public transport trips per year in some studies to as high as 13% in others. Stopher et al (2009) explain the issues involved in understanding the stated intentions elicited in surveys, and particularly in finding reliable ways to measure the actual behaviour change and how it relates to perceptions of possible change. Van Exel and Rietveld (2009) recently used a survey similar to the TACA survey that asked about current perceived alternatives rather than preferences or attitudes about future behaviour change. This survey of Swedish commuters focused on the work commuting trip and asked vehicle drivers if they could take the train. Kingham et al (2001), a recent UoC survey (undertaken 2009; unpublished) and others have asked about preferences and perceptions of the likely options to reduce car use. The bulk of studies reported in the literature focus on understanding which options would get people out of their cars. However, systematic investigation of how people adapt their behaviour regarding travel mode in response to possible fuel supply issues is not a common theme in transport literature.

Demand restraint measures (also called traffic restraint) are primarily aimed at congestion control (Yang and Bell 1997). These types of measures also have the potential to produce fuel demand reduction, but the behavioural elements of demand restraint have not been as widely examined as have the economic aspects. The most common demand restraint measures include:

- driving bans and restrictions
- speed limit reductions
- public transit services, fares and facilities
- parking supply reduction
- road pricing and congestion pricing
- car-pooling or ride sharing
- working from home
- changes in work schedules
- information on 'eco-driving'.

Demand restraint measures could be enacted in response to a supply crisis on an international scale, as in the case of a natural disaster or political unrest. Demand restraint was also used to reduce air pollution during the Beijing Olympics (Wang et al 2008). The goal for demand restraint is to have rapid implementation at low cost and to preserve mobility options in order to have minimal economic effect.. Pre-planning of demand restraint measures tailored to a specific urban area, and the availability of alternative modes such as telecommuting and fuel-efficient alternatives, are essential to successful implementation during an emergency (IEA 2005).

2.3 TACA survey calibration using the Travel Sim game

2.3.1 The Travel Sim game

This research report presents a method for evaluating the adaptability of travel behaviour. The method can be used in a given urban form, a specific neighbourhood or suburb, or for a group of people who participate in a particular activity system. The TACA survey online survey tool was used for this research. The TACA survey tool was calibrated with data from a previous study that used the Travel Sim virtual reality game survey tool. The computer-based Travel Sim game survey tool is a simulation of a severe price spike situation such as might be experienced during an oil shock (Watcharasukarn 2010). The TACA survey tool is essentially the first two levels of the Travel Sim game.

The Travel Sim game has three levels:

1 **Personal information:** Individuals are asked to choose a personal role-playing character and provide their personal details such as age, sex, occupational status, family status, personal income, number of people in the household, number of children of school age and number of vehicles in the household. Then the respondents provide information about their vehicles: vehicle type, make, model, year, type of fuel and engine size.

2 **Normal travel behaviour:** The participants' weekly travel activities are filled into fields structured like a personal daytime planner. Multimodal trips and trip chains are recorded as separate trips. Departure and arrival time, origin, destination, mode and route are recorded for each trip leg. Trip purpose, the origin and the departure and arrival times are entered into a Google Maps™ interface. The respondents continue to provide details of each trip by clicking the 'Mode' button. First, the respondents are asked to rate the importance of the activity associated with each trip. Then the question, 'Could you get to

the activity another way?' is asked and participants provide three alternatives to the trip from a drop-down list which includes the answer set: 'no alternative', a range of other modes, cancelling the activity or carrying out the activity without leaving home.

3 **Virtual reality sim game:** The respondents are shown their selected character in a two-dimensional scene with scores of their car dependence, fuel intensity and risk in a score panel as shown in figures 2.1 and 2.2. These scores are calculated from the previous level's survey and are provided to aid personal decision-making. A time clock begins counting at 0:00 hours (midnight) on Monday and counts rapidly through to the first activity from the travel diary at the stated time. The overall game structure is to play through three consecutive weeks where the price increases dramatically after each week. Trips can be added, deleted or changed each time the activity arises. Each activity is prompted using the respondent's description from level 2. Participants have options for changing mode, changing destination, curtailing trips, moving location of residence and participation at home. A different vehicle can be used or a new vehicle can be purchased. If the respondents persist in using their car, they will be required to refuel their tank at the given price when the car gets low on fuel as calculated from trip distance and engine size data for the trips taken. The fuel price in the first week is \$1.64/L, close to the fuel price at the time of the survey. The fuel price increases to \$5.65/L at the beginning of the second week and increases to \$9.64/L at the beginning of the third week. At the end of the game, the respondents are shown how they changed their behaviour and their car dependence over the three weeks.

Figure 2.1 Screen shot from Travel Sim game that simulates the situation of a fuel shock with escalating fuel price while using the participant's own weekly travel activities

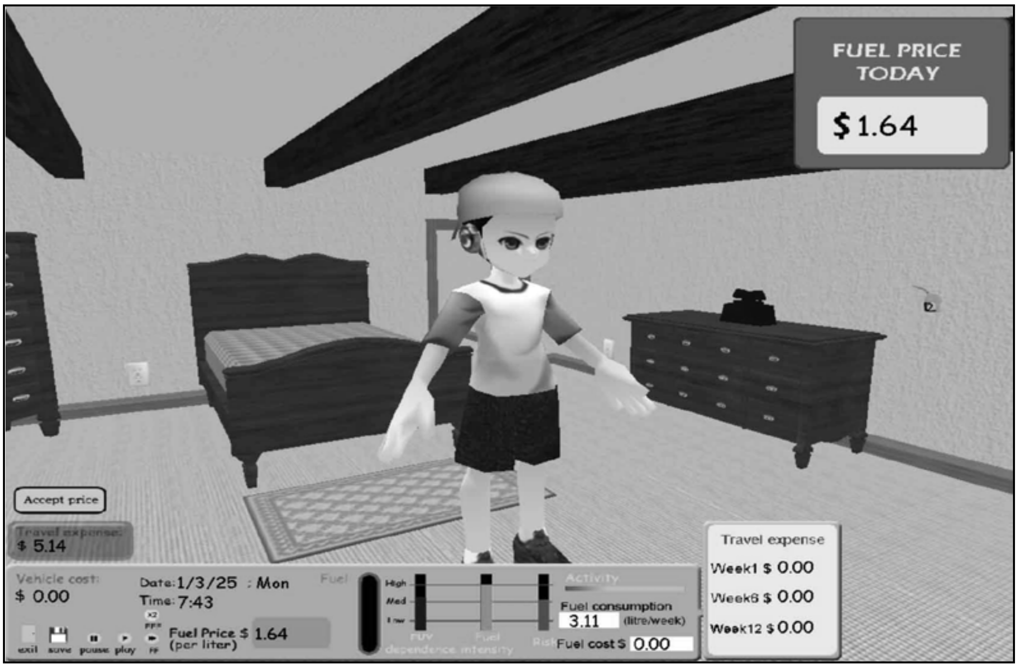
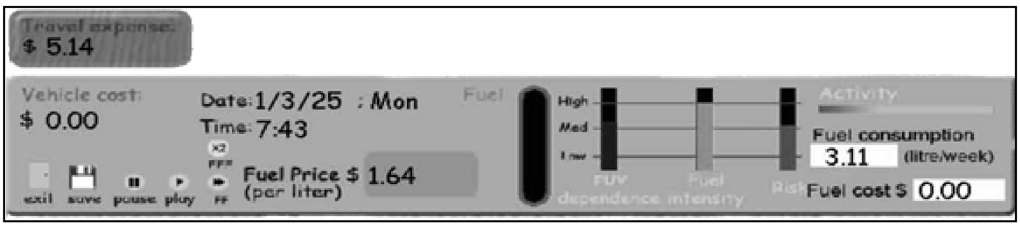


Figure 2.2 Detailed view of the Travel Sim screen shot, showing the interactive panel



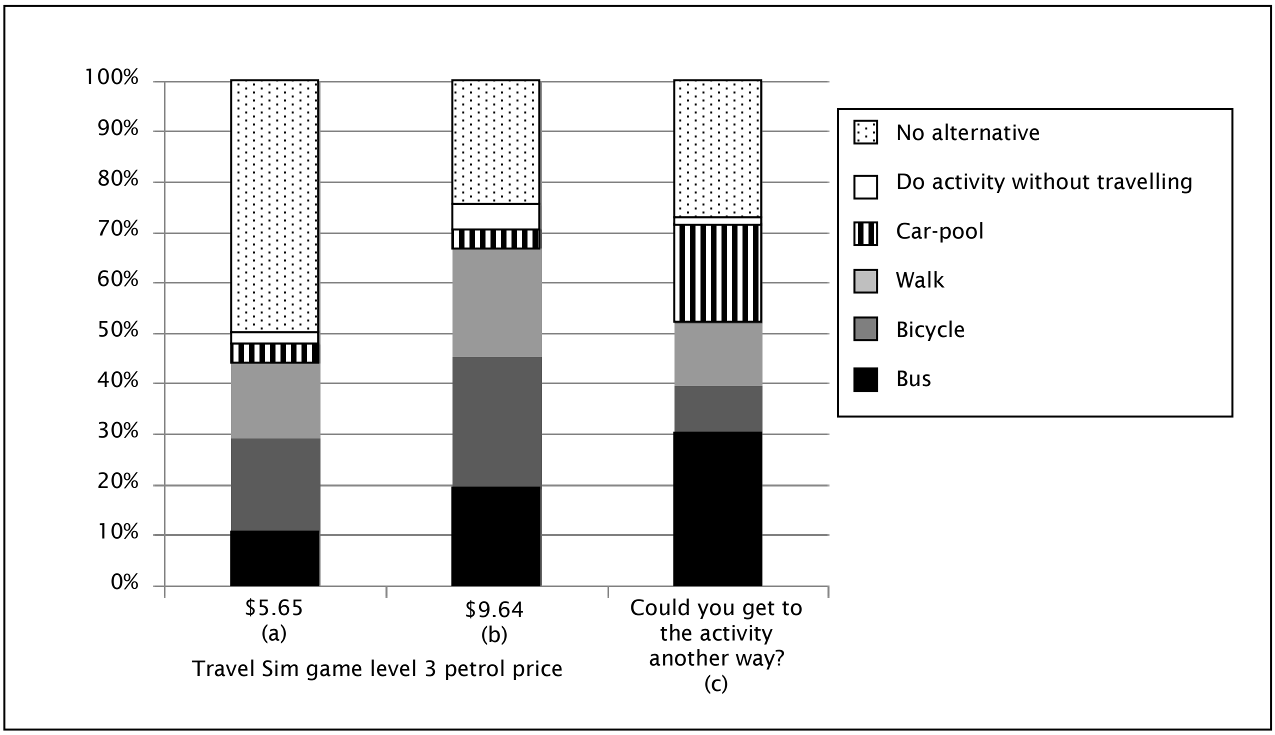
The context for the game – the third level of Travel Sim – is set out as a sequence of future weeks starting from the present. This is to confine the respondents' perceptions so they focused on adapting their current situation to the situation of a fuel price shock. During the development of the Travel Sim game design, researchers found strong obstacles to participants being able to consider the possibility of a steep fuel price rise. When asked about choices they would make if the fuel price doubled, respondents would mentally compensate for the distress of the high fuel price by devising overly optimistic perceptions that such a price rise could only happen in the distant future, and that their income would be raised in step with the fuel price increase. The person could then assume that they can afford to purchase fuel and would not consider any alternatives to reduce fuel use. The design objective of the Travel Sim game was to put people into the situation of a fuel price shock by using the virtual reality environment (Watcharasukarn et al 2010). Clearly, it is not possible to verify the actual behaviour change of participants in the case of a real five-fold fuel price increase in order to verify the Travel Sim survey results. However, we can compare the current stated alternatives to personal vehicle mode choice in the preliminary part of the survey to the behavioural responses to the steep fuel price rise in the Travel Sim game to get an indication of the types of adaptive choices people might make in response to fuel price escalation.

In the Travel Sim game, participants can change mode to a range of options, but they can also work from home, cancel the trip, shift residence, purchase/choose a more efficient vehicle or change the location of the destination. As participants take car trips during the week, the game calculates how much fuel they use. A fuel gauge is shown on the game panel and, as in real life, when the car is low on petrol, participants have to fill the car with fuel before they can drive again. People were more likely to make changes in travel behaviour after fuelling the car at high cost. Bus fares did not rise during the simulation. In the Travel Sim game, participants are clearly responding to price pressure in their choices, as it is the only variable.

In the TACA survey, all of the data in the first two levels is collected and a feedback score is provided to the participant that shows their fuel usage, distance travelled and car dependence. The travel adaptive potential in the TACA survey is taken as the selection of alternatives to car travel. Simply responding to a question about existing alternatives can produce different travel behaviour than would occur in reaction to high fuel prices. Thus, in this section we 'calibrate' the adaptive capacity results from the level 2 selection of alternatives with the level 3 voluntary behavioural changes under pressure from progressively high fuel prices.

Figure 2.3 compares the mode shift adaptations from the second and third high-price weeks in the Travel Sim game with the TACA survey results for participants from UoC. These results are for participants who carried out all three levels. The total adaptation of car trips for participants who played the Travel Sim game was very close to the total adaptation from the simple selection of alternatives as in the TACA survey. The total percentage of car trip adaptation between the high fuel price simulation and the survey of alternatives was similar. However, in the high fuel price simulation, participants avoided fuel-using modes more than in the survey about available alternatives. Participants reasoned that the high fuel price would also affect bus fares and the ability to share rides.

Figure 2.3 Travel adaptation choices from (a) week 1 and (b) week 2 of the Travel Sim game results for high fuel price simulation conditions compared to (c) the TACA survey results



The travel adaptive capacity for personal travel is defined as the alternatives to normal single occupancy vehicle travel. Thus adaptive capacity is a measure of <u>reduction</u> of fuel use in normal car trips. The travel adaptive capacity is focused on fuel reduction, but can also be evaluated with several different measures:

- fuel adaptive capacity: the percentage of normal weekly fuel energy saved by taking the nominated higher efficiency modes or by eliminating the trip by participating without travel
- activity adaptive capacity: the percentage of normal weekly trips that had any kind of alternative
- VKT or distance adaptive capacity: the percentage of normal weekly kilometres that had any kind of alternative.

The adaptive potential is defined as the percentage of normal weekly trips or distance nominated as having one of the three choices as the alternative mode. Thus the adaptive potential is a measure of the <u>increased</u> demand for alternative, lower-energy travel modes.

Short-run price elasticity using the straightforward shrinkage ratio method (percent change in fuel use divided by percent change in price) was calculated for the UoC Travel Sim game participants. The consumption elasticity was –0.22 for a petrol price increase to $5.65 per litre and –0.61 for a petrol price increase to $9.64 per litre. The short-run consumption elasticity for the Travel Sim game compared reasonably well with other general price elasticity values reported in the literature for the lower price increase range (Kennedy and Wallis 2007). The fuel reduction represented by the fuel efficiency adaptive capacity calculated for the TACA surveys would be commensurate with a five-fold increase. Thus we calibrate the travel adaptive capacity from the TACA survey to represent the behaviour change expected in response to a five-fold increase in fuel price, although fuel price was never mentioned in the TACA survey process.

2.3.2 Future planning for petrol price pressure and reduced oil supply

Long-term oil production decline will necessarily cause increasing pressure for reduced transport fuel use. The world's oil supply has not increased since 2006, and fell by 2% in 2009 (British Petroleum 2010). Table 2.1 gives the year-end price for 91 octane petrol at stations around New Zealand as reported by the Automobile Association (AA) Petrolwatch website (AA 2010). Often, a great deal of media coverage focuses on oil supply and fuel price movements. During the fuel price shock of 2008, the level of media focus was much higher than at the time of writing, when the retail price has reached the same level (eg the May 2011 price for 91 octane was $2.13 per litre). The highest price for 91 octane during the 2007–2008 price shock was $2.11 per litre in June 2008 (AA 2010). The current account deficit for the year ending June 2010 was $5.6 billion, which represented 3% of gross domestic product (Statistics NZ 2010). During the 2008 world oil price spike, the current account deficit in the year ending December 2008 reached a high of $16.1 billion (8.9% of gross domestic product). This high deficit level was largely caused by high freight costs and high oil prices, plus reduced tourist arrivals. New Zealand, like the rest of the world, could not sustain this level of spending on oil without a detrimental impact on monetary supply and economic activity.

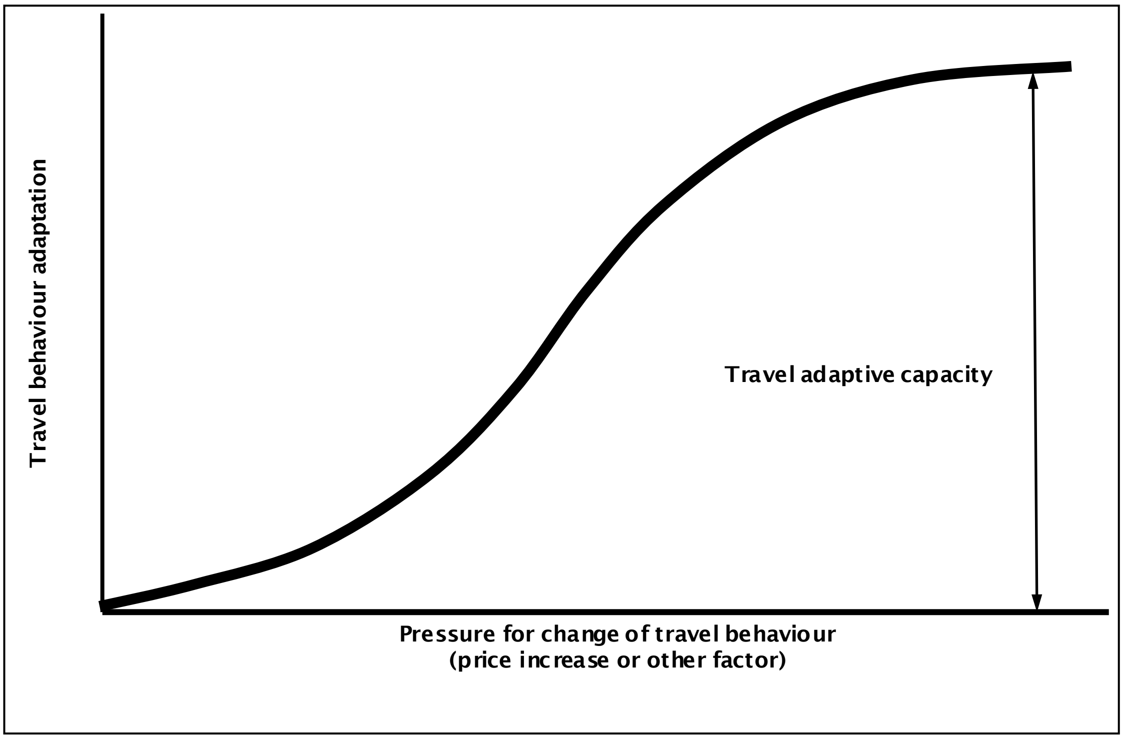
Table 2.1 Average 91 octane petrol price in New Zealand (AA 2010)

Date	Price per litre
December 2005	$1.36
December 2006	$1.43
December 2007	$1.71
December 2008	$1.33
December 2009	$1.66
December 2010	$1.96

The relationship between world oil supply and household travel behaviour choices is complex and has not been studied outside of the fuel crisis situations noted earlier. We propose that the travel adaptive capacity measured by the TACA survey represents a baseline scenario of the potential for long-term fuel demand reduction caused by fuel price and other pressures, as illustrated in figure 2.4. Of course, ancillary economic effects, urban form, weather, availability of public transport modes and even social conditions will continue to influence household travel decisions. But the current travel adaptive capacity of residents in a given urban area provides at least a baseline diagnostic measure of the vulnerability of that city to the risks of peak oil and future fuel supply decline.

Note that the TACA survey measures adaptive capacity. Further research would be required to correlate the measured adaptive capacity to the actual patterns of behaviour change that would develop as a result of short-term oil shocks and long-term price and supply pressure.

Figure 2.4 Illustration of the concept that travel adaptive capacity, as measured by the TACA survey, could represent a baseline scenario for long-range adaptation under continuously increasing downward pressure on world oil supply and upward pressure on price



Asking the participants 'Could you get to this activity another way?' is a straightforward way to measure the potential flexibility that underpins decision-making and mode choice for a given urban form. The query does not introduce externally imposed value judgements (eg environmental concerns), convenience issues (eg congestion problems) or price signals (eg what if the price of using the bus were lower?). The query does not ask under which conditions the participant would choose to take an alternative. It does not ask the participant to reduce vehicle use or to indicate their preference for doing so. The TACA survey query simply elicits a response regarding currently known alternatives for each travel activity. We propose that the survey results for a given demographic cohort in a given urban area indicate the general ability to participate in the activity with a different travel mode or to carry out the activity without travelling. The degree to which people might actually change behaviour in future conditions would depend on a complex range of factors and the severity of the pressures for change, as well as on any changes in the urban form and transportation networks. As no existing models or methods predict future travel behaviour in response to fuel supply contraction, we propose that the baseline information provided by the TACA survey could be an illuminating starting point.

The TACA survey data can be used to represent a baseline scenario for long-term travel adaptive capacity under the conditions expected for peak oil if urban form, public transport services, active mode infrastructure or availability and settlement patterns of residential locations do not change. In a long-range scenario, the pressures for change would be expected to include price pressures, economic recession, concerns about environmental issues and social values. The actual future travel behaviour would develop toward the measured long-term travel adaptive capacity over time as these pressures for change increase.

The degree to which urban form, transportation networks and public transport services affect the current travel adaptive capacity can also provide an understanding of the degree to which oil shocks or policy decisions may incrementally influence travel behaviour in different areas and for different types of people.

The adaptive potential for mode changes for a given urban form and different types of people can be used to develop the adaptation model used in the RECATS risk assessment method (Krumdieck et al 2010) for a given study area. The purpose of the RECATS assessment is to inform investments in transport infrastructure and urban planning. The ability to change to active modes and public transport identified in a TACA survey can help planners understand the potential demand growth in these modes in the future. The demand for private vehicle transport will continue into the future. However, it will not grow if the fuel price pressure and supply uncertainty continue to increase. The growth in demand for alternative modes, as people take up options that they already have available, will put pressure on inadequate walking, cycling and public transport infrastructure. As a by-product of this situation, an increase in serious injuries and casualties among pedestrians and cyclists in the short term would occur if traffic engineering, policy and regulations are not improved to cope with growing active mode demand (Florida Department of Transportation 2007).

2.4 Summary of background and literature review

- The world oil supply has not increased since 2004, and the probability of price shocks and pressure from high fuel prices is high for the foreseeable future.
- Alternative fuels and vehicle technologies are not viable mitigation measures for oil shocks because of their long development and uptake lead times.
- Methods to model travel behaviour adaptation are limited to price elasticity.
- Research into behaviour change during the oil shocks of the 1970s and 2000 indicate that emotional reaction to the fuel crisis is a stronger factor than price, the journey to work was the least flexible trip, trip chaining for shopping was the most common adaptation, walking and biking were adopted early, reducing driving speed was common, the public preferred easily taken personal actions over government controls or taxes, public transport use experienced a surge during times of crisis but, in general, the public was reluctant to use public transport, and car-pooling was not a common response.
- Historically, TDM, VTBC and demand restraint programmes have aimed at reducing congestion.
- The Travel Sim game prompts decision-making about travel adaptive capacity using virtual reality and correlates well with TACA survey results.
- The TACA survey measures travel adaptive capacity by asking a simple question.
- The TACA survey measures mode adaptive potential by querying current options.
- The current travel adaptive capacity to reduce fuel use and mode adaptive potential to increase higher energy efficiency modes can be useful for long-term planning.

3 Description of the TACA survey tool and survey methodology

3.1 Introduction

This chapter describes the TACA survey tool in some detail. It also describes the survey methodology used and the validation of the participant cohort. The reader is invited to take the survey, which is available at http://www.tacasim.aemslab.org.nz.

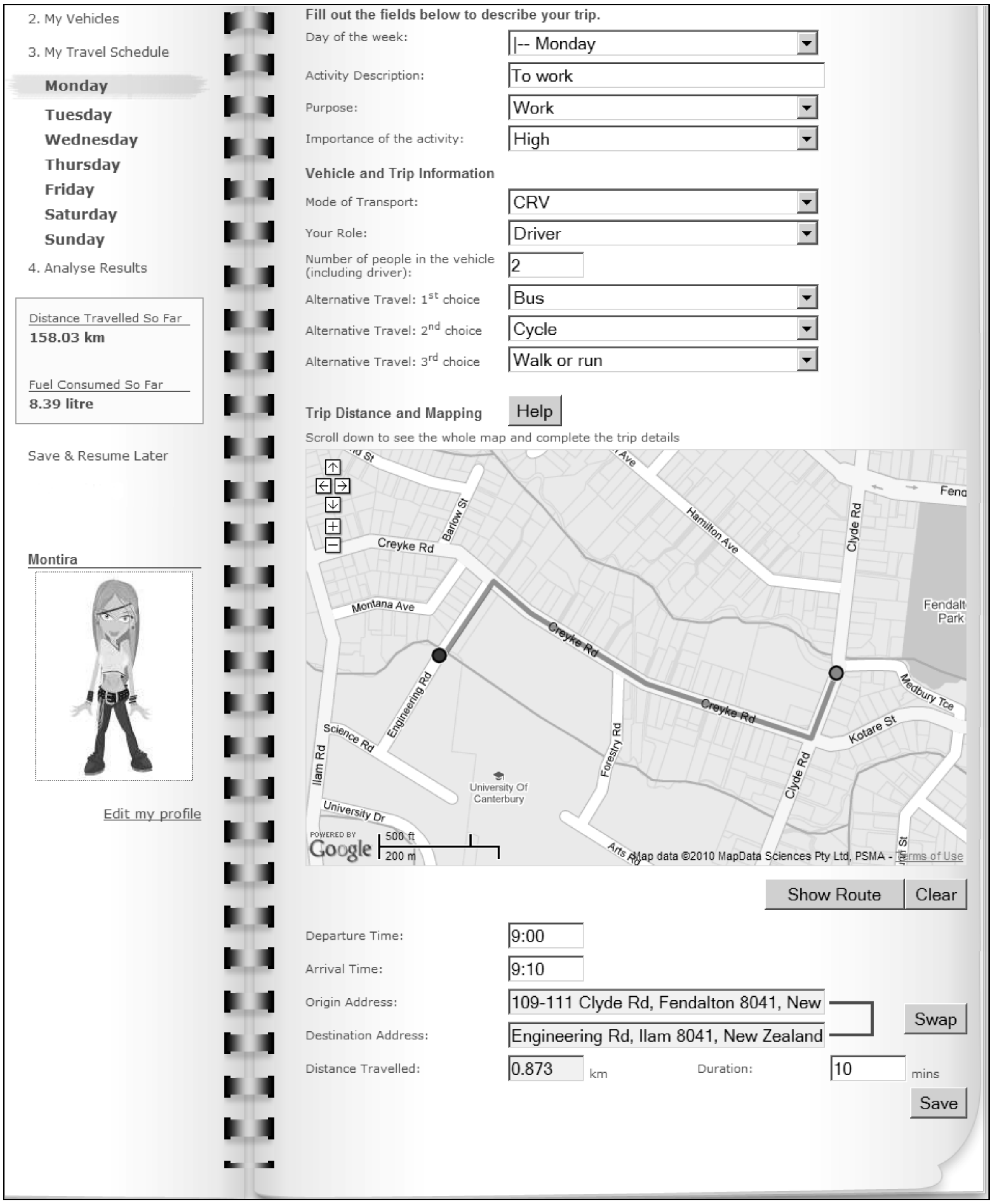
The TACA survey and the assessment of the travel adaptive capacity of an urban form is a new idea that was developed through research at the AEMSLab and was deployed for the first time in this NZTA research project. The adaptability score calculated from equation 5.1 is a new contribution to the emerging field of transition engineering (Krumdieck and Dantas 2008; Krumdieck 2010). Transition engineering is an interdisciplinary field that synergises the connections between energy systems engineering and the engineering of the infrastructures that require energy for normal function. The main objectives of transition engineering analysis are to identify risks in the short and long term, and to work on projects to change existing systems to improve sustainability, security, resilience and adaptability. The research group at UoC, in collaboration with Lincoln University, will continue to develop the TACA survey for widespread use in New Zealand and around the world. We are also developing other new analysis tools for urban forms to understand energy reduction resilience and to inform urban redevelopment and asset management (Rendall et al 2011).

3.2 The web-based TACA survey tool

The TACA survey is designed as a travel survey that captures the activity-based travel behaviour for a participant's typical week plus the currently known alternatives. Figure 3.1 shows a screenshot of one of the scenes in the survey and shows the friendly, atypical feel of the TACA survey tool. Google Map technology and pop-up questions related to travel behaviour are part of the design. The Google Map allows the TACA survey platform to acquire the coordinates of the origin and destination, and the route of each trip. Travel distance is generated via Google Maps and recorded in the database.

The TACA survey is not intended to provide the type of travel demand data that conventional travel surveys seek in order to determine traffic flow patterns. The TACA survey is designed to focus on the participant's perspective about their own normal activities and travel habits. Perturbation of the 'normal' travel behaviour is accomplished by asking about alternatives to car trips as they are entered into the survey form. Participants focus on their own interests and activities. However, they are then presented with a possible situation most have probably experienced – what if you couldn't take your car? The survey does not suggest why the car would not be available. Participants may remember a time when a battery was run down, a mechanical failure occurred or a member of the family unexpectedly took the car to another activity. The participants easily considered this question and had no problem providing first, second and third alternatives to the normal car trip.

Figure 3.1 A screenshot travel schedule on Monday in the TACA survey with travel activity questions for a trip



Notes to figure 3.1:

The avatar on the left-hand side is chosen by the participant from a range of personality icons.

The drop-down menu for ‘Mode of Transport’ is pre-populated with the vehicles entered by the participant as well as the standard ‘bike’, ‘bus’ etc.

The trip distance is calculated by Google Maps.

We propose that letting people mentally insert their own experience of not being able to take their car simulates the real situation and prompts a realistic problem-solving thought process. This simulated situation approach has been previously identified in studies of human cognition (Warren et al 2005). According to the theory of planned behaviour, attitudes and norms, which partially affect individual intention, are controlled by the participant (Ajzen 1988). These two elements are assumed to be constant, as the person will only change their attitudes and norms when they receive new external information. No new or unknown situations are introduced by the TACA survey or the facilitator.

The TACA survey simply poses the familiar situation of not being able to take a car as a 'change signal'. The change signal works as a constraint that has an effect on the participant's intention in addition to their attitudes and norms. Therefore, the participants analyse their ability to perform the same travel patterns when they receive the change signal. They draw on past experience and their current perception of what is possible for them for each type of trip. They are not asked about the likelihood of their changing modes, but simply whether any alternatives are available and possible.

Survey participants were taken through the TACA travel survey by a trained facilitator. The facilitator provided help to participants as needed by entering in data, operating the mouse, operating Google Maps, clarifying the meaning of questions and prompting the participants to recall their travel activities. The TACA survey records personal information, vehicle information and the travel schedule. The personal information section records information such as age, sex, occupational status, family status, personal income, number of people in the household, number of children of school age and number of vehicles in the household.

The TACA survey is designed to be participant-centred. Initially, individuals choose a personality avatar character, and fill in their details and information about their vehicles, including their 'pet names' for their vehicles. Subsequently, participants fill in a travel demand survey that is structured like a personal daytime planner or desk diary. The vehicle information section records vehicle information such as type, make, model, year, engine size and type of fuel.

This study collected the 'normal' or habitual travel behaviour that is associated with typical weekly activities. The participants were asked to fill in their travel schedule, using the activity description to prompt their memory because people have a better memory of what they do than where they go, particularly for non-home trips (Stopher 1992). Trip legs and multimodal trips are recorded separately, but are connected to the departure and arrival time, origin, destination, mode and route that the participants normally take. Participants can enter in any one-off activities they engaged in over the previous week as being representative of normal random errands, social engagements or entertainment activities. Participants are also asked to rate the essentiality of each trip, select the travel mode and specify up to three alternative modes that they currently have. Participants then use a Google Map to locate the origin, destination and routes for each trip. Google Maps lays out the path from origin to destination, and the participant can change it in order to represent the actual route taken. The participants then return to the travel activity schedule, and may add more trips or continue to the schedule for the next day. Return trips and recurring trips like work or school can be copied and pasted into other times and days to save time. Walking and cycling trips are facilitated in Google Maps wherever data allows; otherwise the route must follow a road.

During the survey, whenever a participant enters a trip, they are asked: 'If you couldn't use your normal mode, how many other ways could you travel?' They then select up to three transport alternatives from a list as shown in table 3.1, ranking their alternatives in order of preference. No indication is given in the survey about why an alternative might be needed, and the participant is not asked how likely he/she would be to take an alternative. Nothing is asked about what might be an incentive for the participant to actually take the alternative mode. The answer to the mode alternative query is not an indication of intention but is rather an assessment of existing known alternatives.

The survey facilitators took notes regarding the participants' reactions to the question about alternatives. The consensus among the facilitators is that people did not perceive any coercion to report alternative modes in order to please the facilitators. People did not seem to have any difficulty thinking about the situation of not using their car. If they did not have an alternative, they simply selected that option from the list.

The actual wording of the entire TACA survey and all of the questions are given in appendix A.

Table 3.1 Essentiality and adaptability question and answer sets in the TACA survey

Questions	Answer set
Could you get to this activity another way? (Choose three, rank in order of preference)	None (returns to survey)
	I could do this activity without travelling
	I could get a ride with someone
	Cycle
	Walk or run
	Rollerblades/skateboard/scooter
	Bus
	Train
	Ferry
	Plane
	Other

3.3 The TACA survey methodology

3.3.1 The survey locations

The TACA survey was conducted in two larger urban areas (UoC as an activity centre in Christchurch and the city of Dunedin) and the small rural town of Oamaru. The motivation to collect data in these areas was the difference in urban forms, land use and public transportation systems.

Christchurch is the largest city in the South Island of New Zealand. At the time of writing, Christchurch had a population of 372,600 (Statistics NZ 2009) with a spatial size of 141,260 hectares (Christchurch City Council 2007). UoC is a destination for work and education for 24,075 people (UoC 2010) and is located approximately 6km west of the Christchurch city centre[1]. The campus is surrounded by suburban residential areas and is less than 1.5km from major shopping centres in three directions. Dormitory housing is available at the campus boundary, but this housing is generally only available to a portion of the first-year students. Thus most students live in shared houses or 'flats' around the city.

Oamaru is a smaller centre with a population 12,750 (Statistics NZ 2009) and a median income of $19,700, which is below the national average of $24,400 (Statistics NZ 2006). Oamaru is about 250km south of Christchurch and 120km north of the city of Dunedin. Oamaru's main service and commercial

1 Data about Christchurch's population, area and urban form was collected prior to the series of major earthquakes in September 2010 to June 2011, as was the survey data.

areas are located in the town centre along the main street (Thames Street) and State Highway 1. Oamaru provides commercial services for surrounding remote rural areas and communities in North Otago, and some tourist activities (Tourism Waitaki 2012).

The Dunedin City territorial authority has a population of 118,683 (Statistics NZ 2009). It contains 44,349 households with a median age of 34 and a median personal income of $19,400. The University of Otago is a major employer in Dunedin, with 1174 employees. The pay scales at the university range from $26,000 to $87,600 for non-academic staff, and from $41,000 to $186,000 for academic staff (University of Otago 2011).

3.3.2 Survey approach

The computer-based TACA survey was carried out in public spaces, with researchers facilitating the survey with participants to keep the time spent under 20 minutes. Many of the participants could comfortably carry out the survey on their own using the normal mouse-click pull-down menu and Google Map functions. However, older participants or those unfamiliar with computers required researcher assistance to complete the survey within the target 20-minute timeframe. This was found to be a reasonably enjoyable experience for the participants, as the survey is focused on their activities and many of the participants seemed to enjoy the social interaction with the researchers. Figure 3.2 shows Dr. Shannon Page carrying out a survey with a participant in Dunedin in 2010.

Figure 3.2 One of the authors, Dr Shannon Page, assisting a TACA survey participant in Dunedin

The UoC survey was carried out over the course of 18 months in three survey periods durring different seasons, but all during term time. During the TACA survey at UoC, 1369 invitation emails and letters were sent to students, staff and academics. In addition, advertisements with pull-off contact details were posted around campus for students to take part in the survey and to enter the draw to win an iPod. A $10 grocery voucher or a gift voucher at a popular campus café was offered for general staff and academic staff who took the survey. The Canterbury cohort is not representative of the general population of the city of Christchurch because 33% of the respondents are 18–24 years old, 66% are employed full-time with a higher than average salary, and no retired participants or home-makers were included. The cohort did fit the demographic profile for the university within 2%.

The Oamaru survey was carried out over the course of 18 months in three survey periods during different seasons. In Oamaru, 870 invitation postcards were sent to randomly selected addresses of ratepayers (people who own homes) from a list provided by the regional council. A letter provided information about the survey project and asked people to return the postcard with their preferred day and time to participate in the survey. People who responded were then contacted with a reminder email or phone call. The regional council arranged for an interview between a reporter from the *Oamaru Mail* newspaper and Dr Krumdieck. The article appeared on the front page during the first survey. People were also randomly approached on the main street of Oamaru with an offer of a chocolate bar and a $10 supermarket voucher for their participation. The surveys in both areas were successful at achieving a statistically valid sample with response rate of 19.8% for UoC and 13.8% for Oamaru. The total number of participants for Christchurch and Oamaru was 391 participants, which is 17.5% of the total invitations. It should be noted that nearly half of all academics who were sent the invitation email posted an automatic reply that they were not at the university. In Oamaru, the invitation to ratepayers resulted in responses that were nearly exclusively from retired people. Thus in the Oamaru data, a large contingent of participants were over 65 years of age and with an income below the national average. However, the method of general solicitation of participants from the streets of the town produced a cohort that has a demographic that is consistent with the statistics for Oamaru.

The Dunedin survey was carried out in 2010 over the course of five days. In Dunedin, the city council was active in promoting the survey. Newspaper articles and a radio interview were conducted several days before the survey period. The survey was conducted by random solicitation of people on the streets of Dunedin and Mosgiel, and of students at the University of Otago. Rooms at the Dunedin Art Gallery and at the City Library were used to conduct the surveys. A pot-luck evening in Port Chalmers was advertised and had a good turn-out. The city council randomly selected council workers and arranged appointments for them to take the survey. A total of 164 surveys were conducted over a four-day period. The Dunedin TACA survey cohort is consistent with the New Zealand Household Travel Survey (NZHTS) (MoT 2009) and with the population statistics for Dunedin.

Further details of the demographics for each cohort are given in section 3.5.

3.4 The TACA survey database

All data is stored in a CSV file, and the data dictionary is given in appendix B. The residential location, occupation, income and other personal details are recorded. The database has 20 data fields, arranged in columns, and 1869 entries for the records of 555 participants.

The survey interacts with Google Maps so that a participant can either type in an address or locate it on the map interface with a mouse. Google Maps lays out the path from origin to destination. If necessary, the participant can change the route by dragging the mouse in order to represent the actual route taken. The latitude and longitude of the location are recorded.[2] A text field for every address is recorded, as well as the distance between every origin and destination.

The purpose for each trip is recorded in two ways. Firstly, as the participants work through their normal weekly schedule, they fill in the daily diary with their own expressions for activities, eg ‘take Jack to soccer practice’ or ‘weekly groceries’. Further on, in the process that includes registering the importance of the trip, the trip purpose is selected from a drop-down menu, which has the standard trip classifications used

2 Because of some programming issues in the first survey round, some of the surveys do not have latitude and longitude data.

in the NZHTS. This method allows people to register their weekly travel activities in their own words and thus increase their engagement with the survey while still providing standard data for researchers.

3.5 Survey validation

3.5.1 General overview

The TACA survey methodology was validated by comparing cohorts and data collected with other sources. The trip generation and mode distribution of TACA survey participants agreed well with the NZHTS and the UoC travel survey.

It is recognised that we ask for a typical week of travel activity, and we will not capture all trips that would have been done in a particular week. Even if people attempt to put in all trips that they took in the past week, they will no doubt forget some of their activities without the aid of travel diaries. The under-represented trips are typically expected to be irregular travel activity for personal business, social visits, shopping or holidays. Thus TACA survey trip generation results are not recommended as a source for traditional travel demand modelling. The TACA survey was designed to assess travel adaptive capacity, not trip generation.

Both the number of trips and the kilometres travelled were found to be lower in the TACA survey compared with other sources. This is because the TACA survey focuses on habitual travel activities. The variance has not been examined in depth. However, a small sample of participants was asked to provide their licence plate registration numbers and their actual VKT was calculated from warrant of fitness data available from the MoT website. In this sample, the variable trips not captured by the TACA survey represented 25–50% of actual VKT.

3.5.2 Dunedin TACA survey data compared to NZHTS data

The TACA survey does not count walking to the bus or to the parking garage as a separate trip in a trip chain. Some people did actually include these ‘change mode’ trip chains, but because of the activity focus of the survey, a single activity was reported as a single trip most of the time. In order to perform the validation comparison, the NZHTS data has been analysed to combine the trip chains that involve walking to another mode on the same trip. The percentages of trips according to purpose or activity were calculated from the TACA survey data and from the NZHTS. The NZHTS has 16 trip purpose categories, which were agglomerated for comparison to the TACA survey responses by combining the different types of shopping and social trips into one category. Table 3.2 shows that the Dunedin TACA survey records basically the same travel patterns as the NZHTS. The percentage of trips for work agrees well within 2%. Recreation and medical visits also agree well, indicating that these might be regularly scheduled activities. The percentage of trips for education was much higher in the TACA survey because of the additional cohort of university students targeted in Dunedin. As expected, the generally more random purposes of shopping, personal business and social visits were lower for the TACA survey than for the NZHTS.

Table 3.2 Travel purpose reported from the NZHTS and the TACA survey in Dunedin

Trip purpose	TACA survey (%)	NZHTS (%)
Work	23	21
Education	25*	6
Shopping	11	27
Social welfare	4	0
Personal business	3	8
Medical care or consultation	1	2
Social visit	16	21
Recreation	14	15

* The Dunedin TACA survey includes a cohort of University of Otago students

3.5.3 TACA survey validation using the UoC travel survey

The TACA survey method was validated by comparing the UoC staff and student data with the travel mode data from the UoC survey (UoC 2009). The mode choices for trips to the university in both surveys were considered. The UoC survey was developed by engineering consultants GHD Ltd as an online survey in order to collect information about staff and student travel to the UoC, and was calibrated with parking lot counts on a particular day. The UoC survey aimed to understand the existing travel patterns of UoC staff and students, and provided information for sustainable transportation planning. The questions in the UoC survey were focused on the transport modes that the participants usually take to the university, their travel purposes and their travel times.

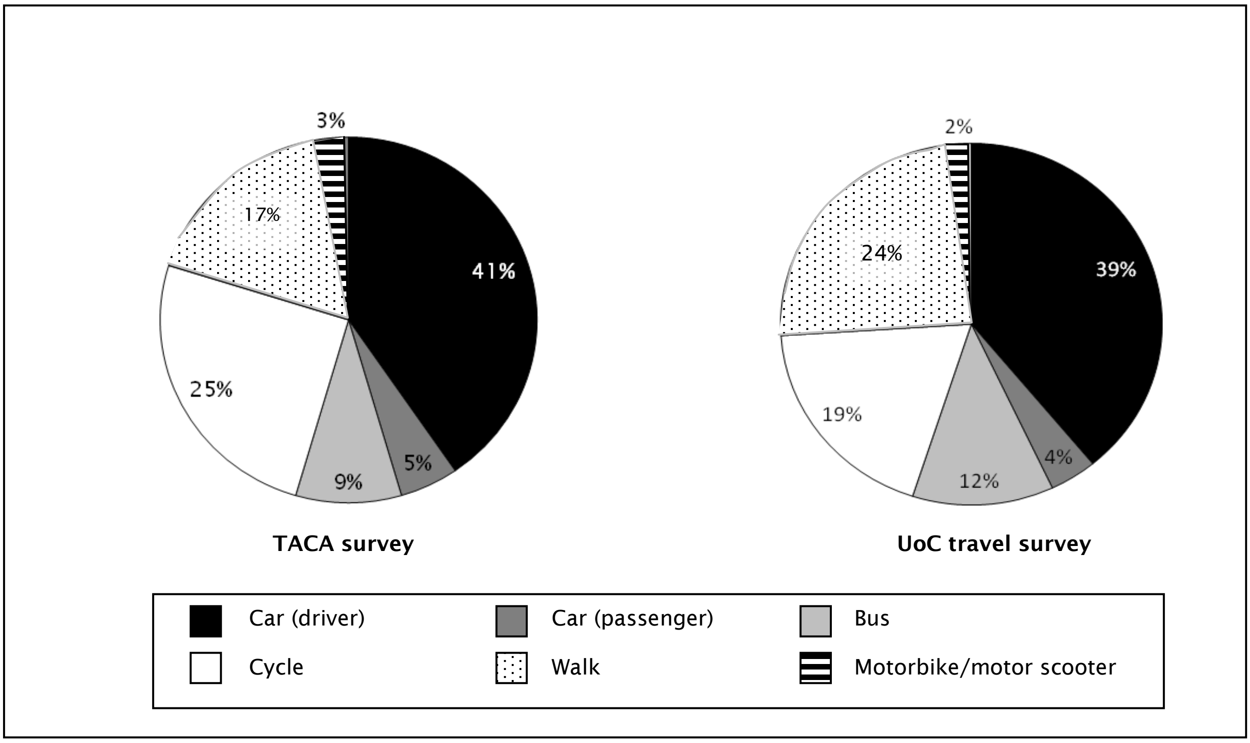
Examples of questions from the UoC travel survey are as follows:

- What is your usual (ie 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 UoC survey was conducted in July 2008 (winter) by sending out an email that contained the survey link to all 1874 UoC staff and 14,860 students. Reminder emails and publicity were also used in the week prior to the survey closing date. The UoC travel survey obtained 4772 responses (1027 staff and 3745 students), representing a 28% response rate.

The transport mode to the university was selected from the TACA survey dataset for comparison with the UoC survey. The results of both surveys agree that the car is the major transport mode taken to the university, as shown in figure 3.3. The TACA survey's mode share results were within 1–3% of the UoC survey results for bus, car and active modes. The reason for the difference in the mode share of cycling and walking between the two surveys might be because the surveys were conducted in different periods. The TACA survey was conducted in spring to autumn, and the UoC survey was conducted in winter.

Figure 3.3 Validation of the TACA survey method by comparing the mode share of trips to university with the U0C survey conducted in 2008



3.6 Data quality

3.6.1 Demographic profile of TACA survey participants

Two important measures of the quality of the data being representative of the population of a given urban form or activity cohort are the demographic profile and the residential locations of the participants.

Thirty randomly selected participant groups were developed to represent a statistically valid survey sample (Sekaran and Bougie 2009). In each survey, where a particular demographic cohort was identified, the TACA survey was conducted until 30 full response surveys were achieved. A full response survey refers to a survey where a full week of activities was given and the amount of missing information was minimal. The number of participants in the survey was also increased until it achieved a sample of 30 who had an average daily number of trips within the confidence limit of 95%.

The Christchurch survey focused on the participants at the university. The demographic profile is not the same as the city as a whole, as the TACA survey cohort does not include people aged under 18 years or over 65. The Oamaru survey had a nearly exclusive participation from retired people in response to the invitation sent randomly to ratepayers in the first round of surveys. We postulate that this invitation provided an activity in itself for retired people, whereas it represented an intrusion into a busy schedule for people involved in working and raising children. When we solicited participation randomly on the street of Oamaru, we gained a demographic profile much closer to that of the NZHTS. In Dunedin, random solicitations were conducted at the university and around the library to get 30 participants, who were university students and high school students. Working professionals were another target group, and city council workers were randomly selected to represent this cohort. Thus the dataset for Dunedin has a larger proportion of young people than the demographic profile. However, the group of young travellers is large enough to use the data to understand this group's travel adaptive capacity. We also did not use the postcard method and so had a low level of participation by retired people. The randomly solicited people from the city centre were a good fit with NZHTS participants. The database for the three surveys can be analysed to understand the cohorts targeted, or it can be adjusted through statistical analysis to get an idea of the travel adaptive capacity of particular groups or the population as a whole.

3.6.2 Geographic locations of TACA survey participants

Participants provide their home address and personal details in the TACA survey. Any researchers seeking access to the data from the NZTA will be required to agree to confidential treatment of the data. The usefulness of the survey data for analysing relationships between residential location and travel behaviour adaptation depends on getting a representative distribution of participants around the urban area. Figures 3.4–3.6 show maps of Oamaru, Dunedin and Christchurch, respectively, with the geocoded residential addresses reported by the participants indicated by dots. The Christchurch participants show some concentration near the university, particularly for students and academic staff, but the data still shows a wide distribution of residential locations around the city, and in the rural areas and neighbouring settlements. The Oamaru data shows a good distribution, as does the Dunedin participation data.

Figure 3.4 Location of the residential addresses of Oamaru participants

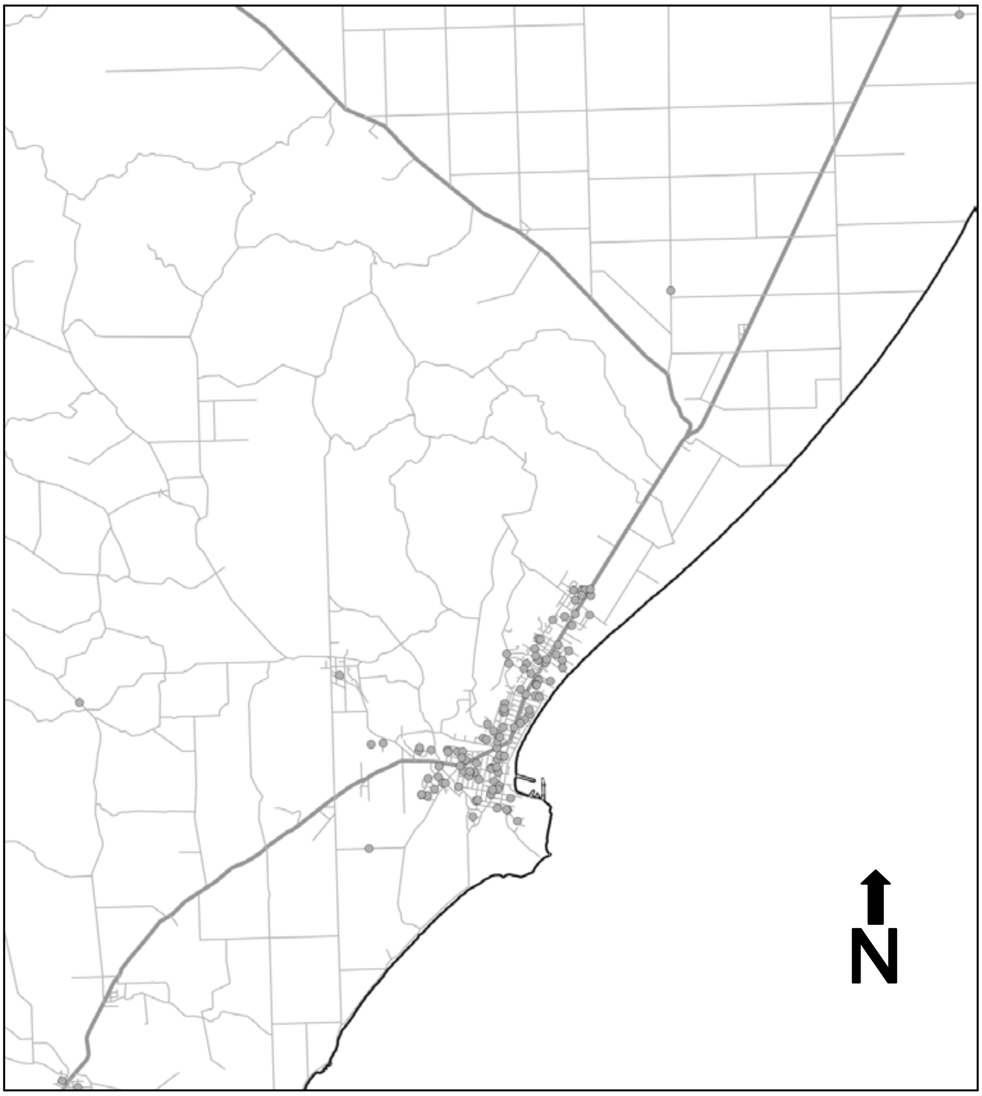


Figure 3.5 Location of the residential addresses of Dunedin participants

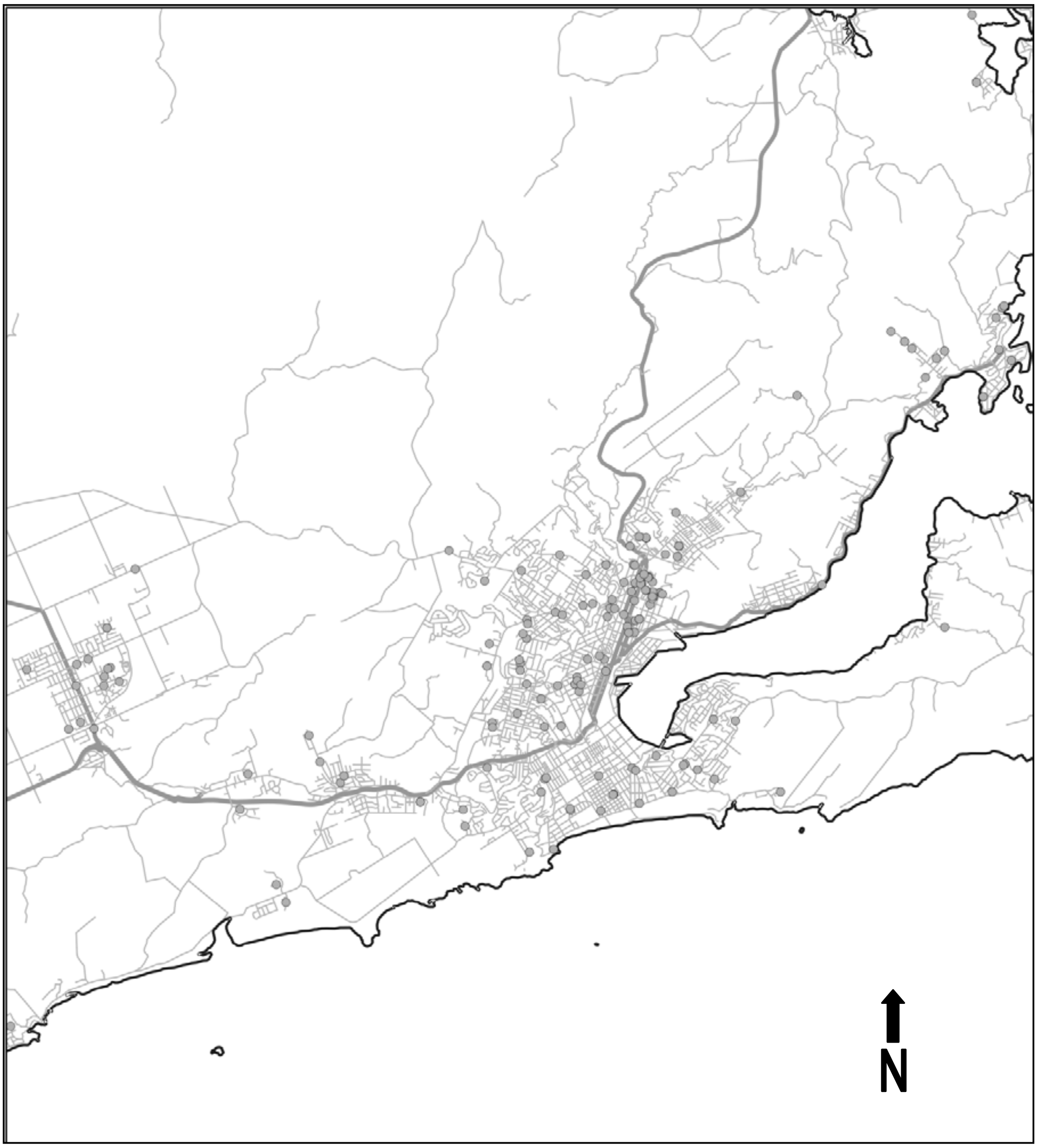
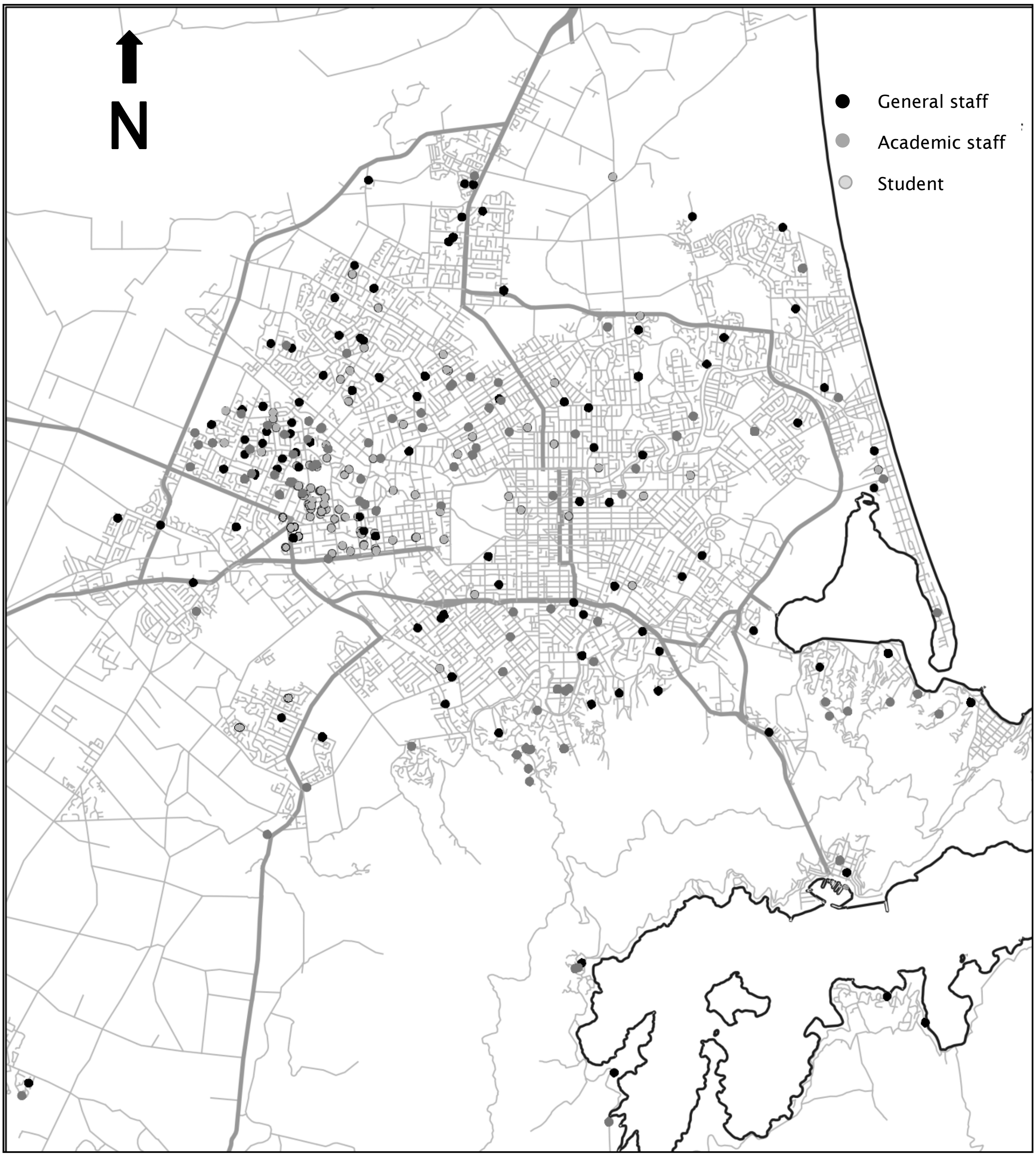


Figure 3.6 Location of the residential addresses for general staff, academics and students attending UoC who participated in the survey



3.7 Summary

- The web-based TACA survey tool is a new approach that surveys 'normal' or habitual travel behaviour, the importance of activities and the alternative modes.
- The normal travel recorded in three TACA surveys correlates well with other survey methods.
- The normal travel recorded by the TACA survey represents 50–75% of the actual fuel consumption, as the survey does not capture holiday or random trips.
- The survey requires about 20 minutes to complete.
- The survey method produced a statistically significant dataset.
- The geographic locations of participants' residences show good distribution across the urban areas.

4 Travel adaptive capacity data

4.1 Overview

This section presents the raw data collected during the TACA surveys conducted in Oamaru and Dunedin, and with the UoC participants in Christchurch. Statistical analysis is not included here, and the data is presented as collected without cohort analysis or correlation with demographic or geographic factors. The data could be analysed in many ways. This research project's scope was to do the work of collecting a good quality dataset that could reveal both short-term adaptive capacity to oil shocks and long-term vulnerability to peak oil. The research group is continuing with in-depth analysis of the data and will publish papers or carry out consulting work to disseminate this information.

4.2 Essentiality of trips

Participants were asked to indicate the purpose of each trip via a pull-down menu and to rate each travel activity according to importance. Figures 4.1–4.5 show the essentiality splits for the survey participants. Clearly, the seeking of medical treatment or advice is widely considered an essential transport activity. Some interesting results are the rating of recreation and social visits as essential or necessary for the majority of the activities.

Figure 4.1 Oamaru participants' trip essentiality data by trip purpose

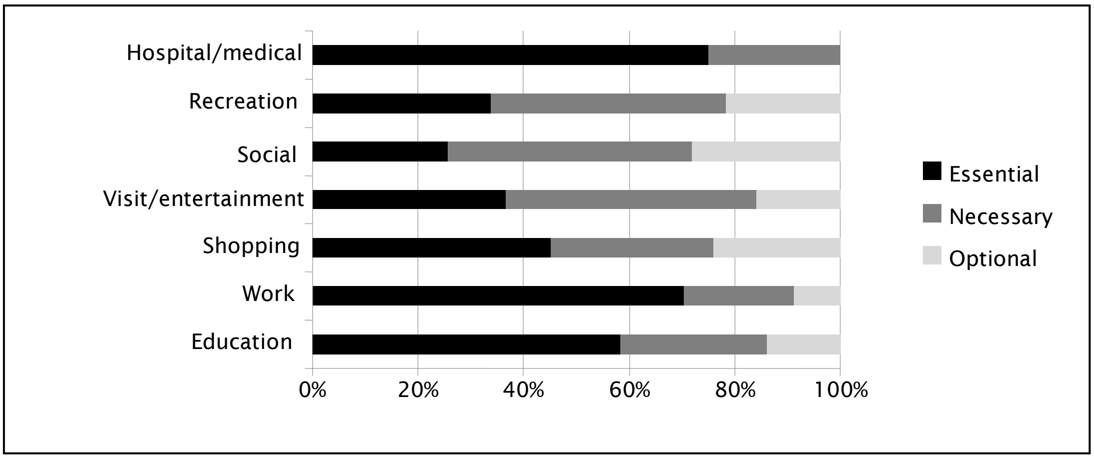


Figure 4.2 Dunedin participants' trip essentiality data by trip purpose

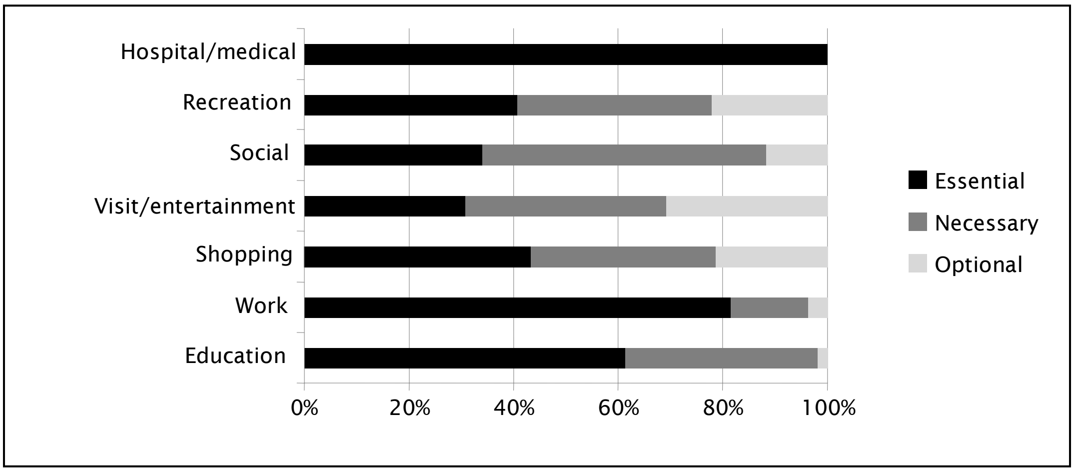


Figure 4.3 UoC student participants' trip essentiality data by trip purpose

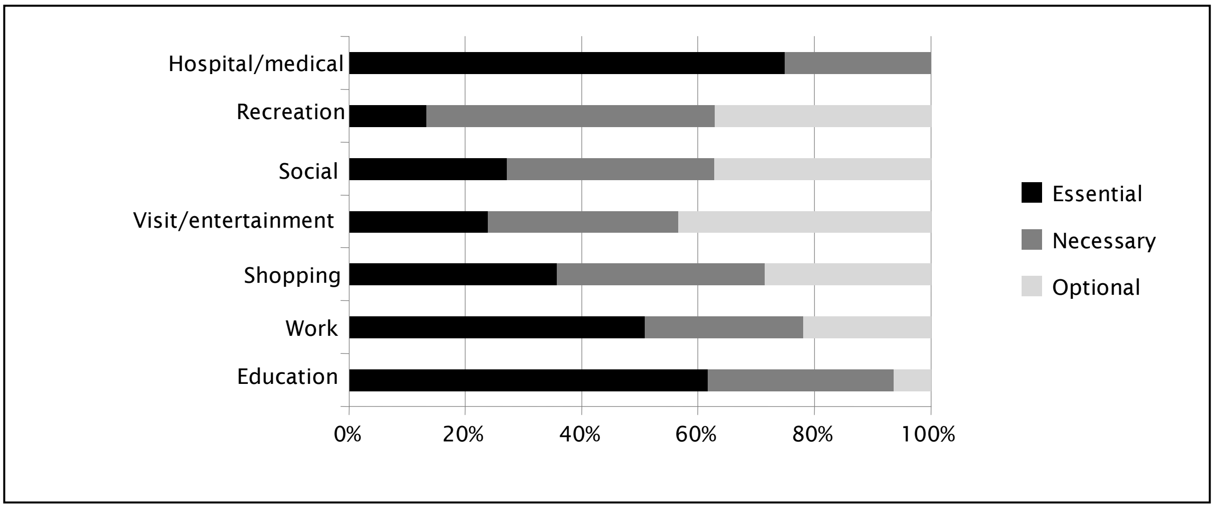


Figure 4.4 UoC general staff participants' trip essentiality data by trip purpose

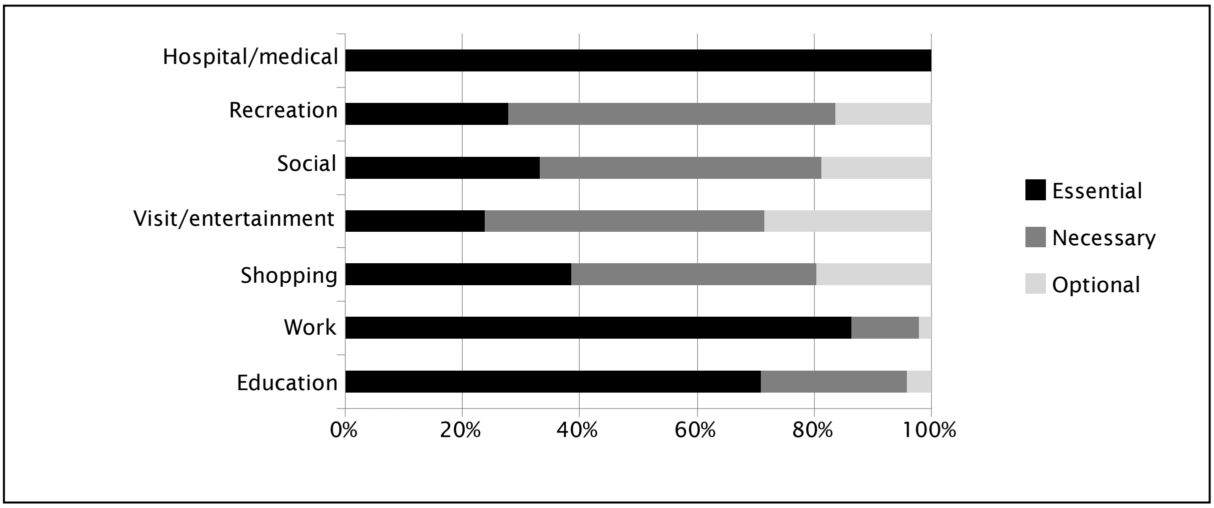
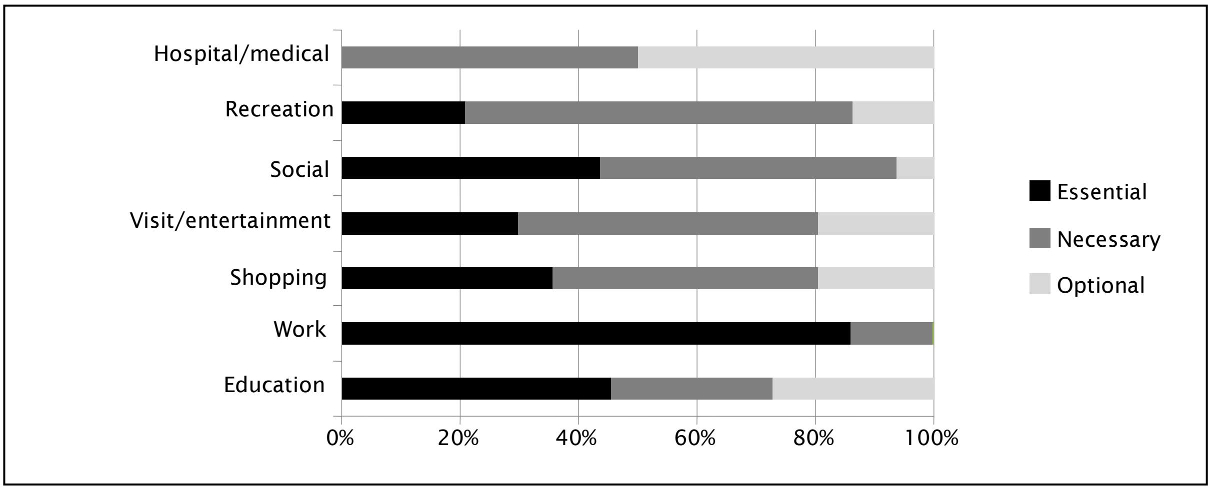


Figure 4.5 UoC academic staff participants' trip essentiality data by trip purpose



4.3 Travel demand patterns

Frequency, mode and distance data is shown for each of the five survey groups in figures 4.6–4.10. The left-hand set of bars for each distance represents the 'normal' or habitual transport activities reported in the TACA survey; the right-hand set of bars shows the mode splits of the first-choice alternative reported in response to the question of available alternatives. The normal travel demand pattern shows the same dominance of private vehicle transport as reported in the NZHTS. The alternatives to the car trips are predominantly bus and active modes, with nearly negligible reporting of participation in the activity from home as an alternative. The differences between the normal travel demand and the possible alternative travel demand are analysed to understand travel adaptive capacity in the following section. These figures group the responses 'I could do the activity without travelling' and 'Other' together as 'Other'.

Figure 4.6 Oamaru participants' (*n* = 120) normal (left-hand bars) and first-choice alternative (right-hand bars) travel behaviour as shown in the TACA survey

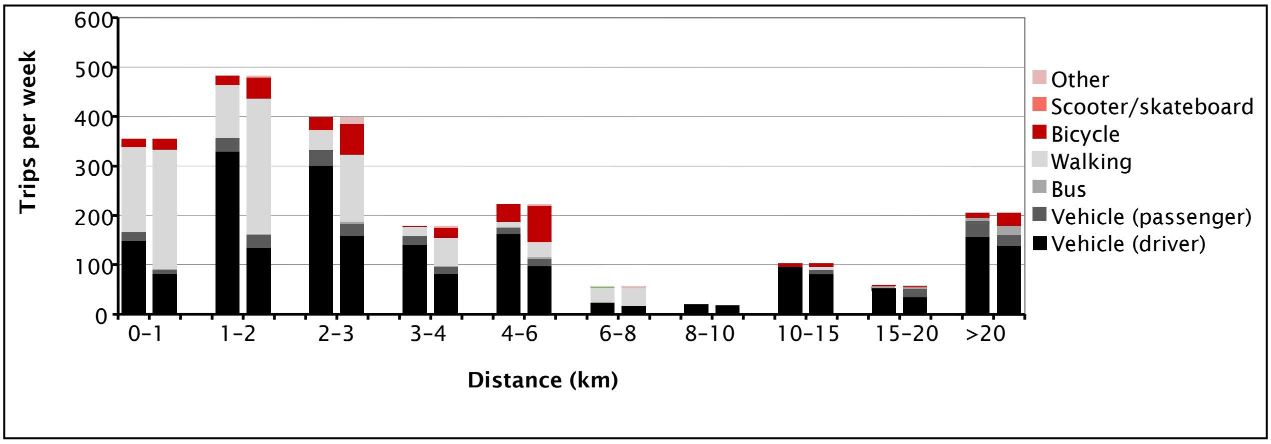


Figure 4.7 Dunedin participants' (*n* = 164) normal (left-hand bars) and first-choice alternative (right-hand bars) travel behaviour as shown in the TACA survey

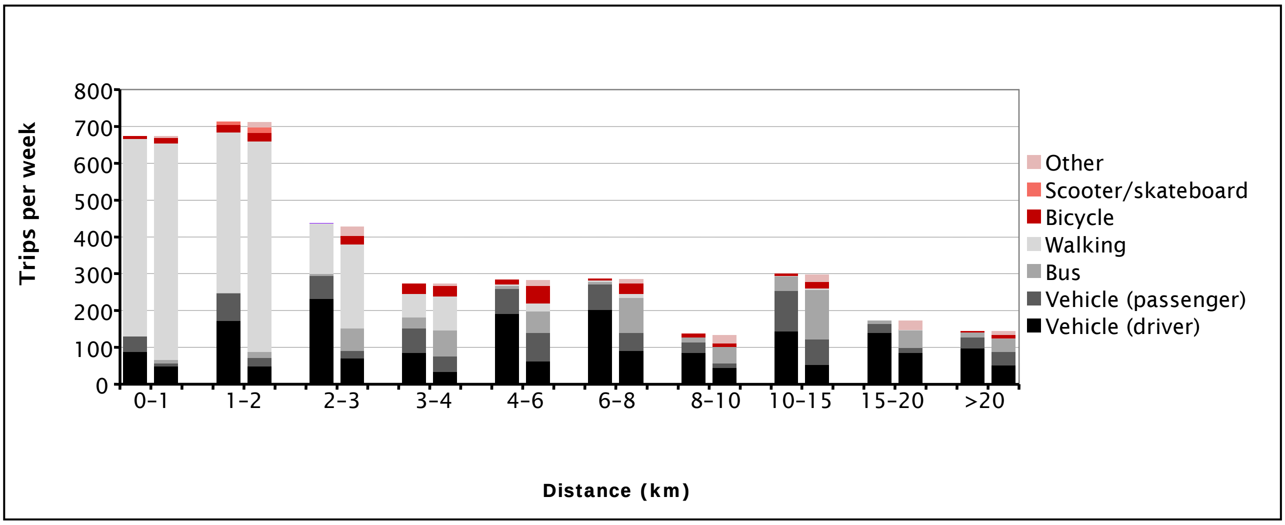


Figure 4.8 UoC students' (*n* = 60) normal (left-hand bars) and first-choice alternative (right-hand bars) travel behaviour as shown in the TACA survey

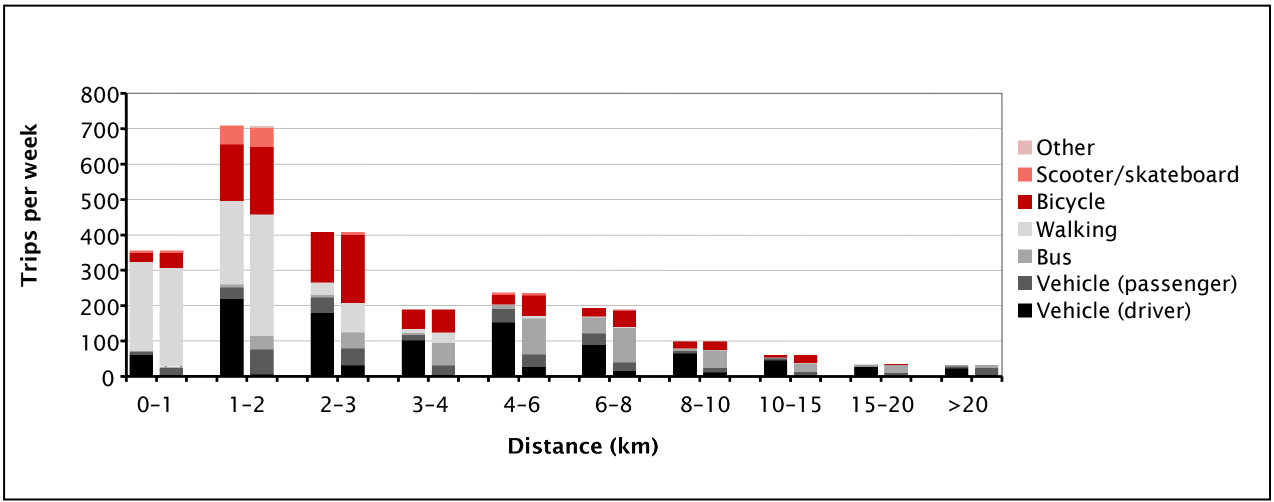


Figure 4.9 UoC general staff's (*n* = 113) normal (left-hand bars) and alternative (right-hand bars) travel behaviour as shown in the TACA survey

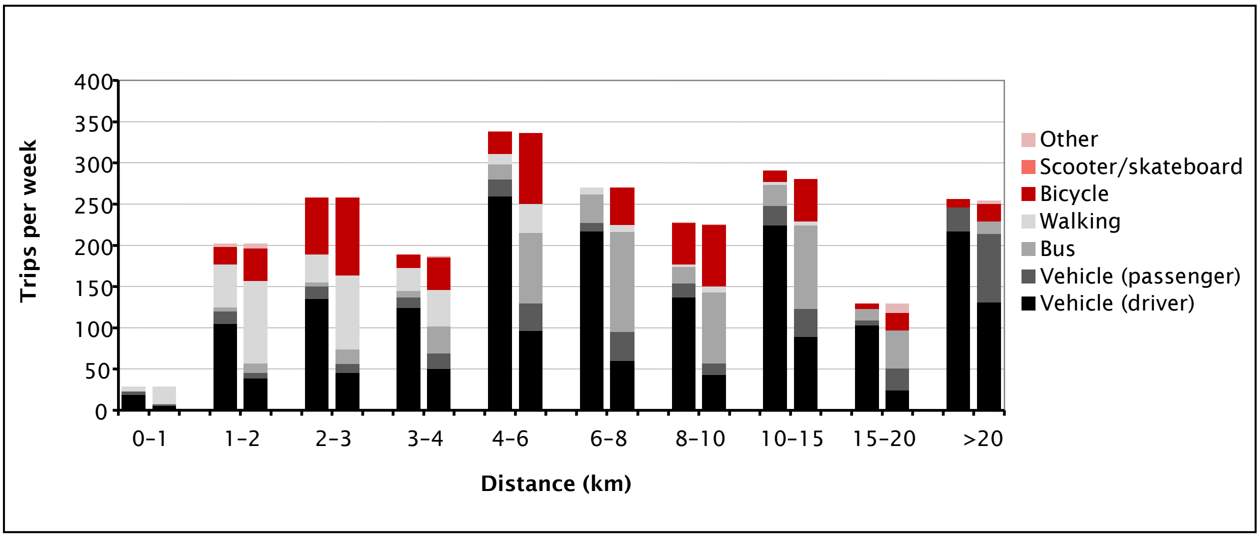
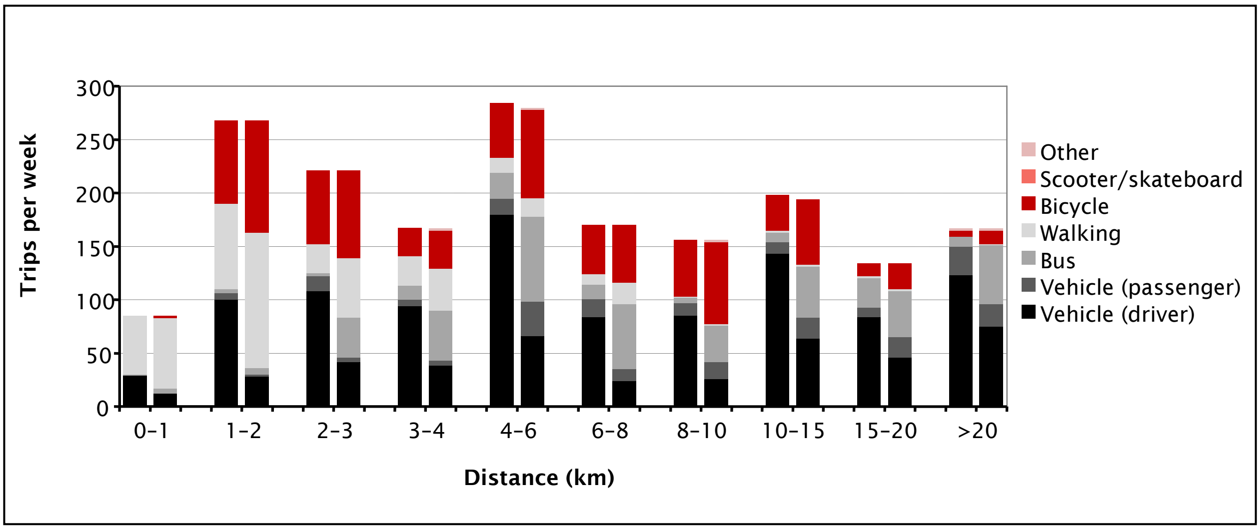


Figure 4.10 UoC academic staff's (*n* = 98) normal (left-hand bars) and alternative (right-hand bars) travel behaviour as shown in the TACA survey



4.4 Adaptive potential

4.3.1 All study groups

The alternative modes reported in the survey were recorded with their related trip distances for each travel activity. Figures 4.11–4.15 show the adaptive potential in terms of percentage of kilometres and percentage of total trips for the participants in each study. The percentage of trips that were reported as being normally made by modes other than private vehicle is shown as the first category from the left. The percentage of normal car trips that had no alternative is the category on the far right shown in black. The rest of the data shown between these extremes represents the first choice of alternative mode to private vehicle.

The trips that do not normally use a car provide reduced exposure to fuel shocks for the cohort. The normal car trips that do not have an alternative present a vulnerability to high fuel prices. The normal car trips that have a lower fuel intensity alternative represent the adaptive potential. For all of the survey groups, the adaptive potential in terms of kilometres travelled is smaller than for percentage of trips. This is because the walking and cycling trips, and most of the bus trips, were relatively short. As distance in kilometres is a good proxy for fuel use, we can clearly see the high potential to reduce fuel use by students at UoC and the relatively high level of vulnerability to a fuel price shock that is faced by the residents of Oamaru.

Figure 4.11 Travel adaptive potential for the participants in Oamaru, showing the percentage of normal travel kilometres and trips that were not made by car as well as adapted private vehicle travel

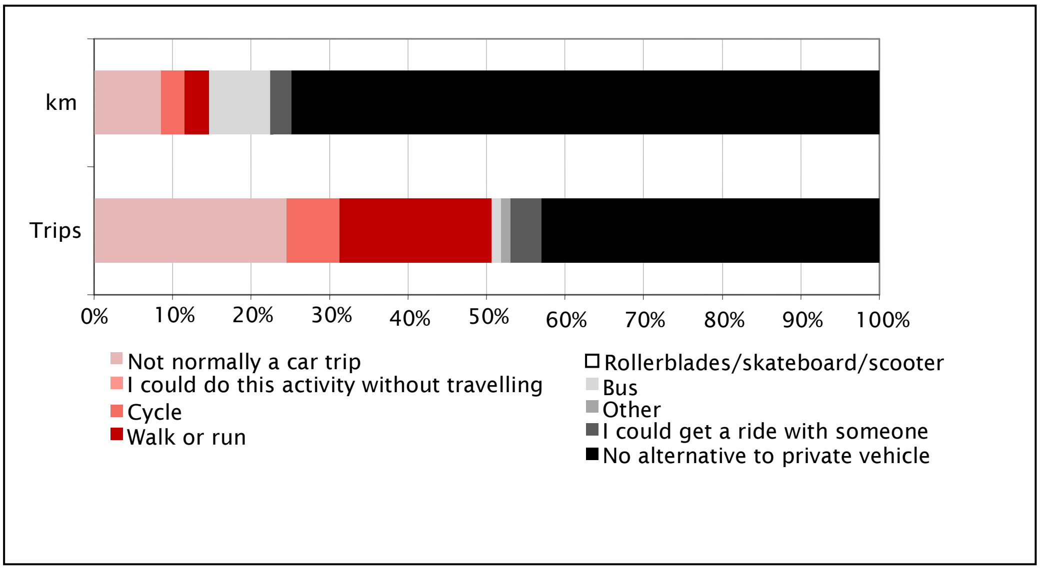


Figure 4.12 Travel adaptive potential for the participants in Dunedin showing the percentage of normal travel kilometres and trips that were not made by car as well as adapted private vehicle travel

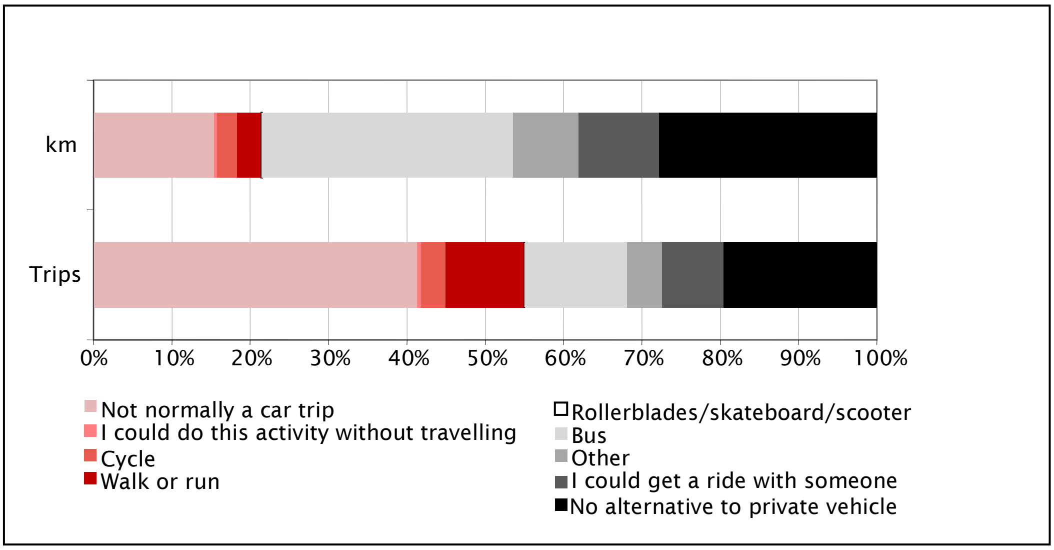


Figure 4.13 Travel adaptive potential for the UoC student participants showing the percentage of normal travel kilometres and trips that were not made by car as well as adapted private vehicle travel

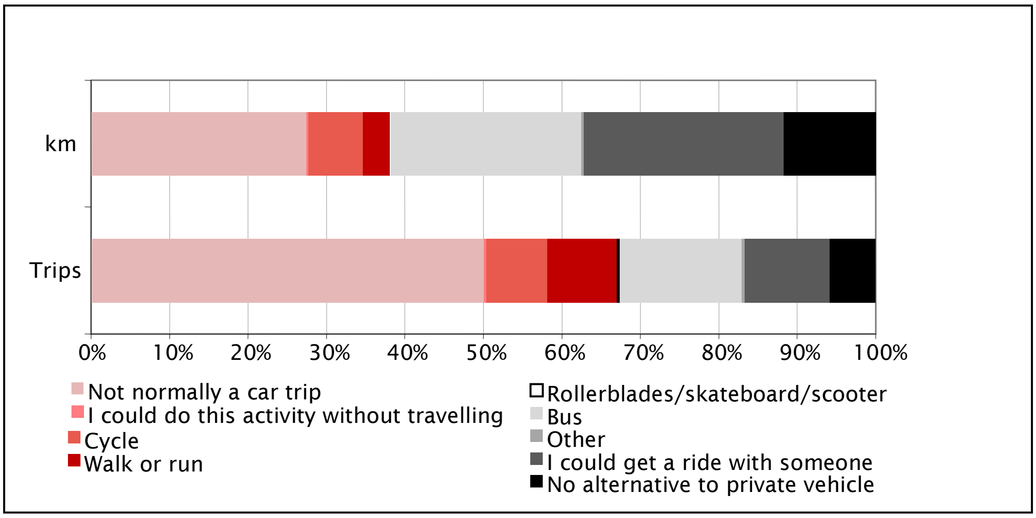


Figure 4.14 Travel adaptive potential for the UoC general staff participants showing the percentage of normal travel kilometres and trips that were not made by car as well as adapted private vehicle travel

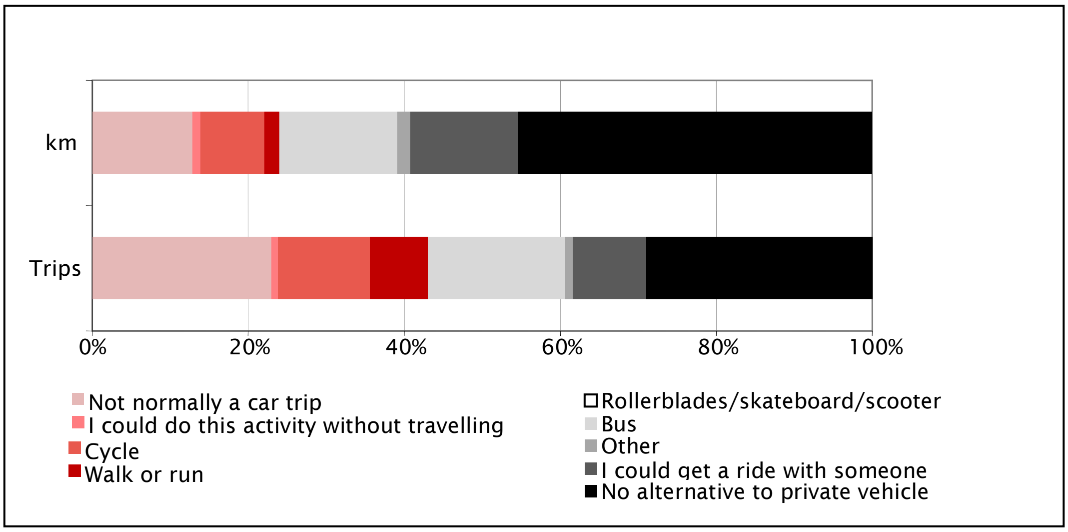
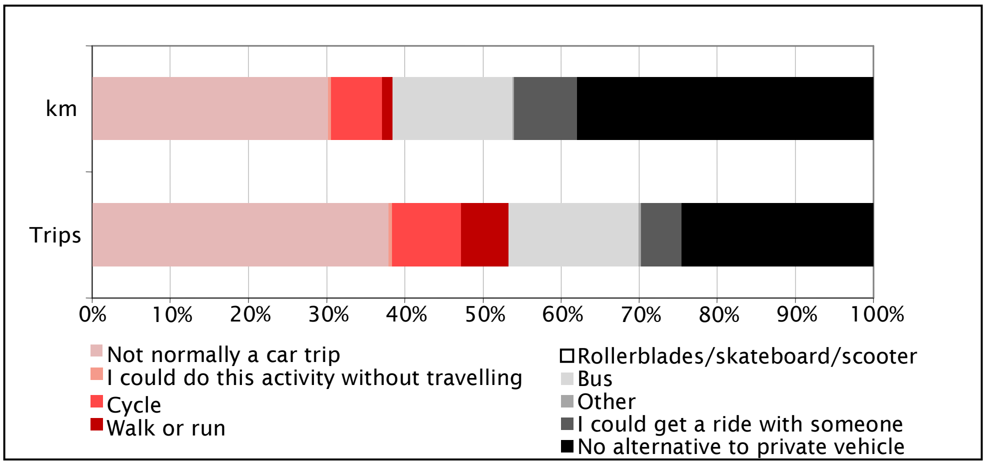


Figure 4.15 Travel adaptive potential for the UoC academic staff showing the percentage of normal travel kilometres and trips that were not made by car as well as adapted private vehicle travel

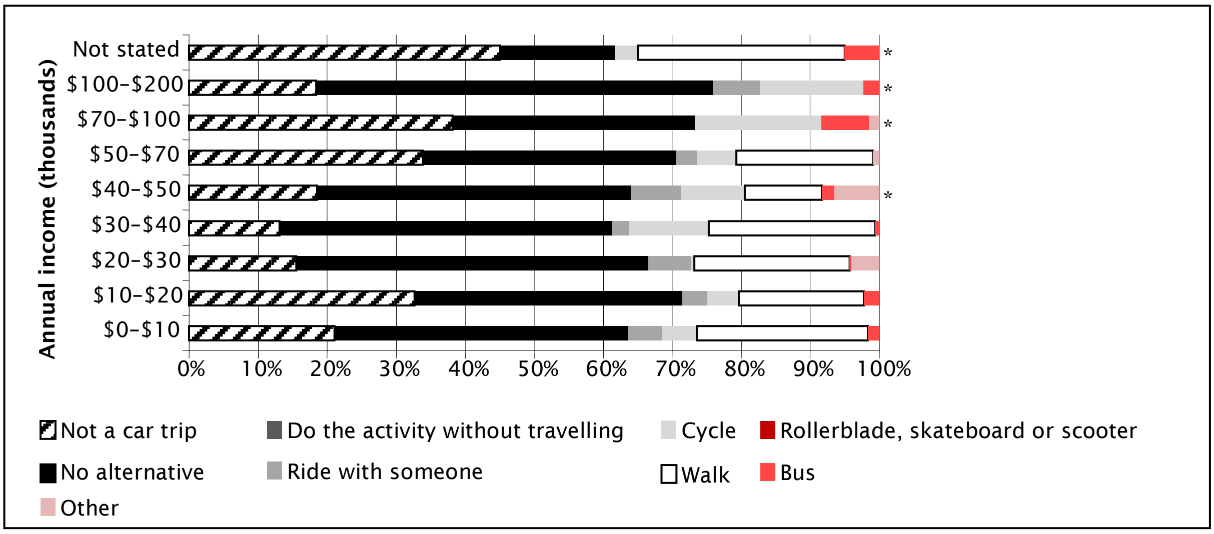


4.3.2 Adaptive potential and income

The alternative modes reported in the survey are also connected with personal data in the TACA survey database. Figures 4.16–4.20 show the adaptive potential according to income level for each of the survey cohorts. The three different survey groups at UoC represent different income levels, with the students having significantly lower incomes than staff. The first category, shown in black and white stripes, is the normal travel carried out by modes other than car. The second category, shown in solid black, is the percentage of normal car trips reported as having no alternative. Income groups that have fewer than 10 participants are marked with an asterisk.

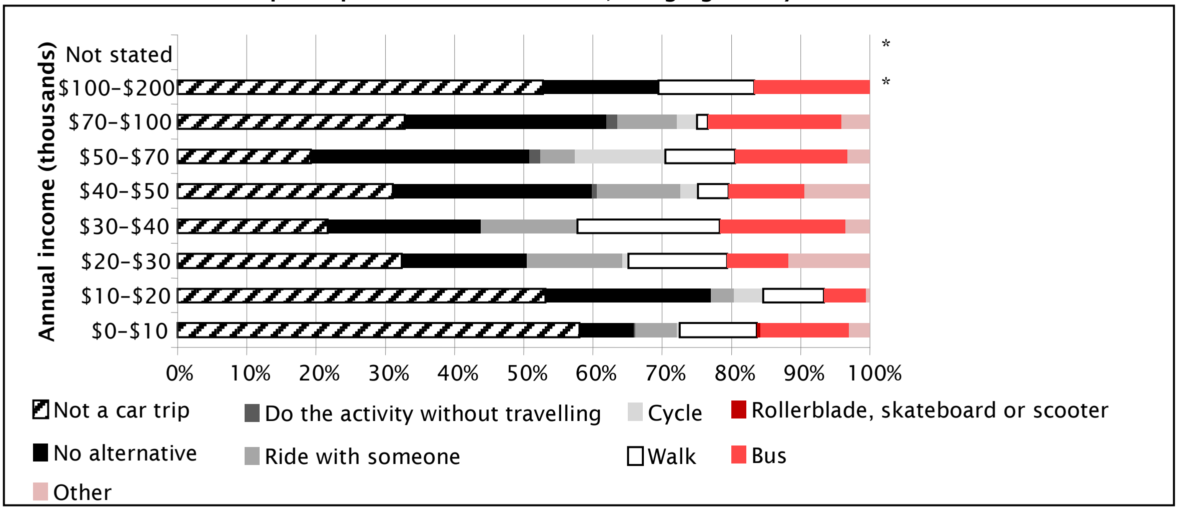
The lower-income student participants in Christchurch and Dunedin have low usage of a personal vehicle for transport, and higher adaptive potential to carry out transport activities without using a personal vehicle. However, the lower-income (mostly retired) participants in Oamaru are much more dependent on personal vehicles. The lack of a bus service in Oamaru has a marked effect on Oamaru's adaptive potential compared to that of Christchurch.

Figure 4.16 Adaptive potential, in percent, of non-car trips, car trips with no alternative and first choice of alternative mode for the participant cohorts in Oamaru, disagregated by income level



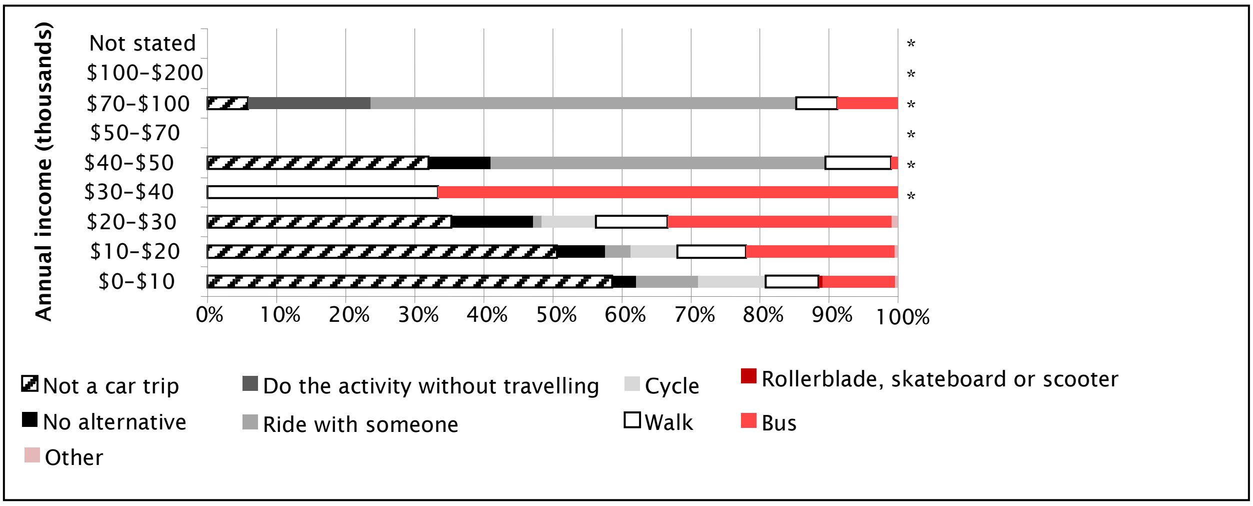
* Indicates fewer than 10 participants in the sample category.

Figure 4.17 Adaptive potential, in percent, of non-car trips, car trips with no alternative and first choice of alternative mode for the participant cohorts in Dunedin, disagregated by income level



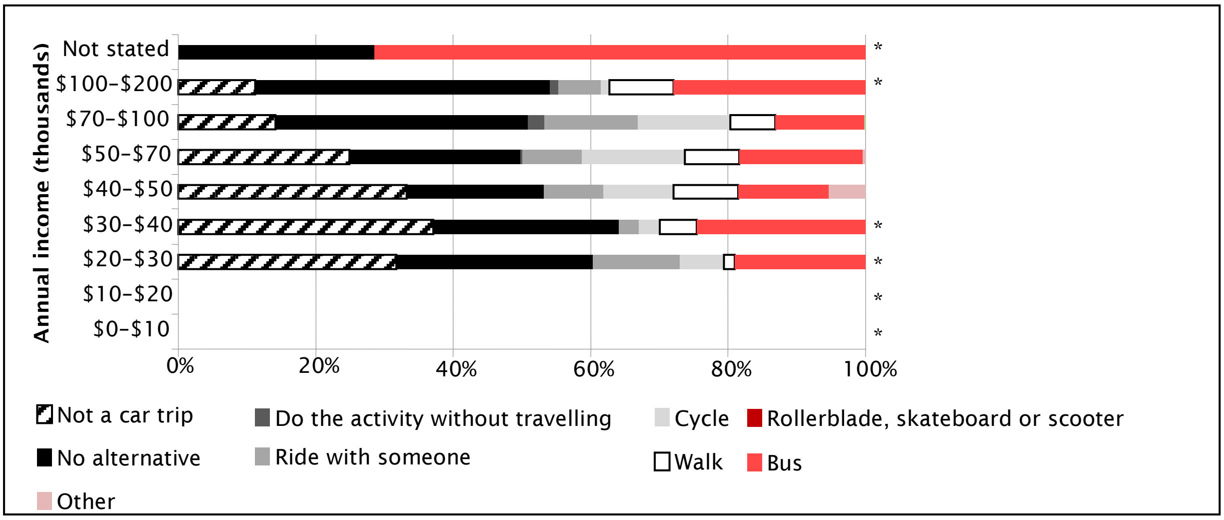
* Indicates fewer than 10 participants in the sample category.

Figure 4.18 Adaptive potential, in percent, of non-car trips, car trips with no alternative and first choice of alternative mode for the student participant cohort in UoC, disagregated by income level



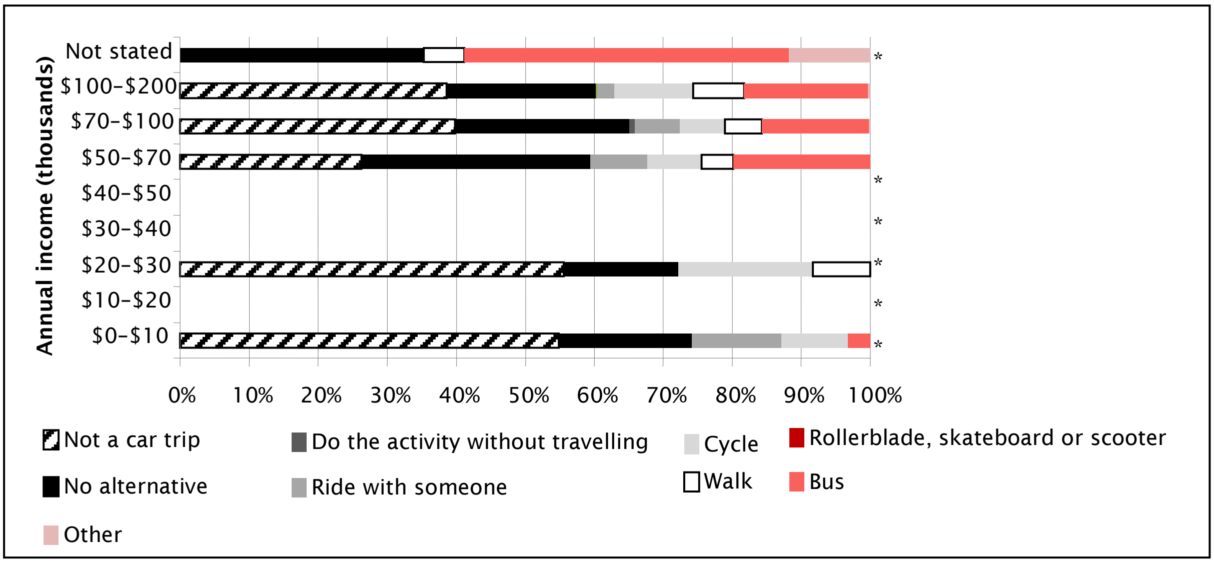
* Indicates fewer than 10 participants in the sample category.

Figure 4.19 Adaptive potential, in percent, of non-car trips, car trips with no alternative and first choice of alternative mode for the general staff participant cohort in UoC, disagregated by income level



* Indicates fewer than 10 participants in the sample category.

Figure 4.20 Adaptive potential, in percent, of non-car trips, car trips with no alternative and first choice of alternative mode for the academic staff participant cohort in UoC, disagregated by income level



* Indicates fewer than 10 participants in the sample category.

5 Adaptability analysis

5.1 Calculating adaptability

In this chapter, a method is proposed to characterise the overall adaptive capacity of an individual, a group or a cohort in terms of a calculated adaptability. Adaptability is a quantitative, non-dimensional measure of fuel intensity, potential fuel reduction and the exposure of important activities to non-adaptable travel. Fuel intensity of travel behaviour refers to the fuel use per week to carry out normal activities (MJ/week). Adaptability is tied to the potential to reduce fuel use, and is calculated based on the normal weekly kilometres travelled. Each trip was either carried out by a single-occupant car or by a more energy-efficient mode. Each trip was rated according to its importance to the participant. Each car trip had up to three possible mode alternatives registered in the database.

The parameters from the TACA survey data used to calculate the adaptability, A_p, of a participant are:

- D_i: distance in kilometres of trip *i* (one way or segment)
- E_i: the essentiality of trip *i*, where $E_i = 1$ if the trip was optional, $E_i = 2$ if the trip was necessary and $E_i = 3$ if the trip was essential
- δ_i: equals 1 if the trip was carried out by car and no alternatives were indicated; $\delta_i = 0$ otherwise (ie trip *i* was not normally a car trip or the option of a non-car mode)
- t_p the number of trips for participant *p* recorded over the week.

The adaptability score is calculated from TACA survey data according to equation 5.1:

$$A_p = 1 - \frac{\sum_{i=1}^{t_p} D_i E_i \delta_i}{\sum_{i=1}^{t_p} D_i E_i} \qquad (5.1)$$

The score has a numerical value between 1 (highly adaptable) and 0 (not adaptable). A high adaptability score would mean either that most travel that the participant rates as important is carried out without using a car or that the normal car trips are adaptable to a mode with lower energy intensity. A low adaptability score would mean that all of the important activities are accessed by car and that very few trips have reported mode alternatives.

The adaptability score is a new concept for transportation engineering and urban planning, so we investigate the concept with several simple examples. Consider the four following hypothetical residents of pre-quake Christchurch:

- **Green Jack** is an avid bike rider, grows his own vegetables, has no children, likes to go surfing or tramping on weekends, and has a well-paying professional job in the central business district which he bikes to from his home in Saint Albans. He travels 96km a week to work (essential) by bike, and gets to all of his recreation and shopping and socialising during the week by bike (36km). However, on a typical weekend, he drives 80km and has no alternative to the car for his recreation, which he rates as optional. Green Jack would have a perfect adaptability score of 1 if he could car-pool or take a bus to his weekend recreation activities.
  - **Green Jack's adaptability score = 0.61.**
- **Red John** is a high-income professional who loves his sports car that he drives to his job at UoC from his lifestyle home in Redcliffs (a 34km round trip). He has two children whom he drives to activities on weekends, but not in the sports car. He likes to go fishing in the mountains on the weekends (140km)

and to dine in the central business district several times a week. He records no alternative for any of his car trips.

  - **Red John's adaptability score = 0.00.**

- **Mother Mary** is a single working mother with a part-time job at the supermarket near her home in Avonside. She has three children of school age, whom she drives to the neighbourhood elementary and middle schools (2km from home; essential) as she is concerned for their safety, but records cycling and walking as alternatives. She also drives to her job (2km from home; essential) and to the shops because of the large loads to carry. She normally drives to the numerous activities involving the children around the city, but these trips often have bus alternatives.

  - **Mother Mary's adaptability score = 0.62.**

- **Old Sam** is retired, living on superannuation at his home of 30 years in Burnside. Sam does not own a bike, does not take the bus and he never walks. He and his wife drive to the shops (1km from home) every day, and drive to meet friends in Burnside, have a coffee in the city or go into the countryside for lunch. He rates his twice-weekly trip to medical facilities and his twice-weekly trips to his church as essential. For several of his social trips into town or the countryside, he reports he could get a ride with friends.

  - **Old Sam's adaptability score = 0.21.**

5.2 Adaptability of TACA survey participants

The values of the personal adaptability calculated from equation 5.1 for each participant are plotted on a map of the city at the site of the residence. It is difficult to see visual evidence from the results of the three cities that adaptability is geographically determined. Some people with very high adaptability live right next to people who have no adaptability in the same urban form, and participate in the same activity system at UoC. For display of the data, the adaptability scores were classified as 'very low', 'low', 'medium', 'high' and 'very high', with an equal number of participants in each group. Figures 5.1–5.5 show the adaptability of each cohort. As some participants lived outside the city/town areas displayed, figure 5.6 shows the adaptability of all survey participants, allowing the adaptability of those living in rural areas to be observed.

Figure 5.1 The adaptability scores of Oamaru residents

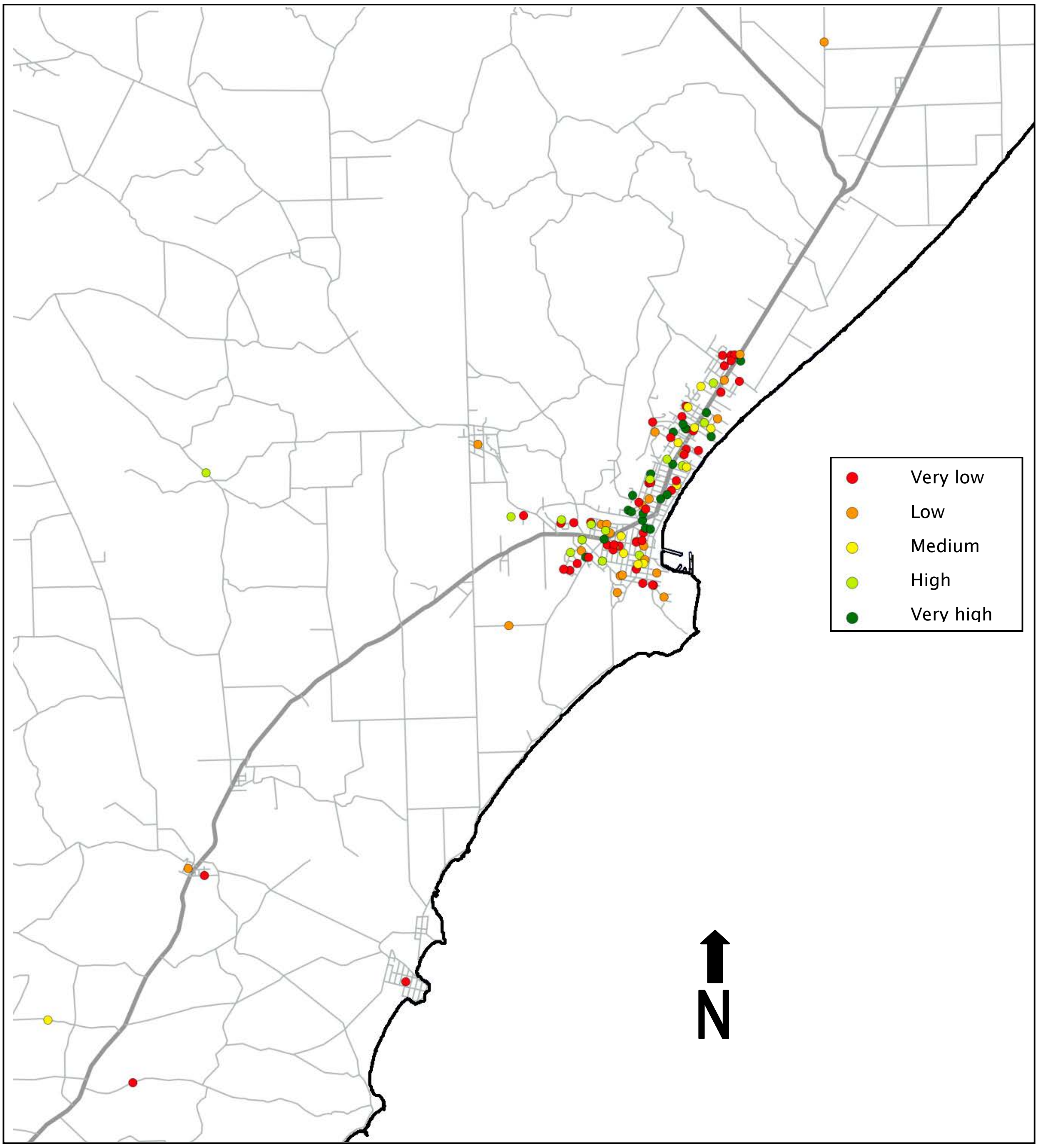


Figure 5.2 The adaptability scores of Dunedin residents

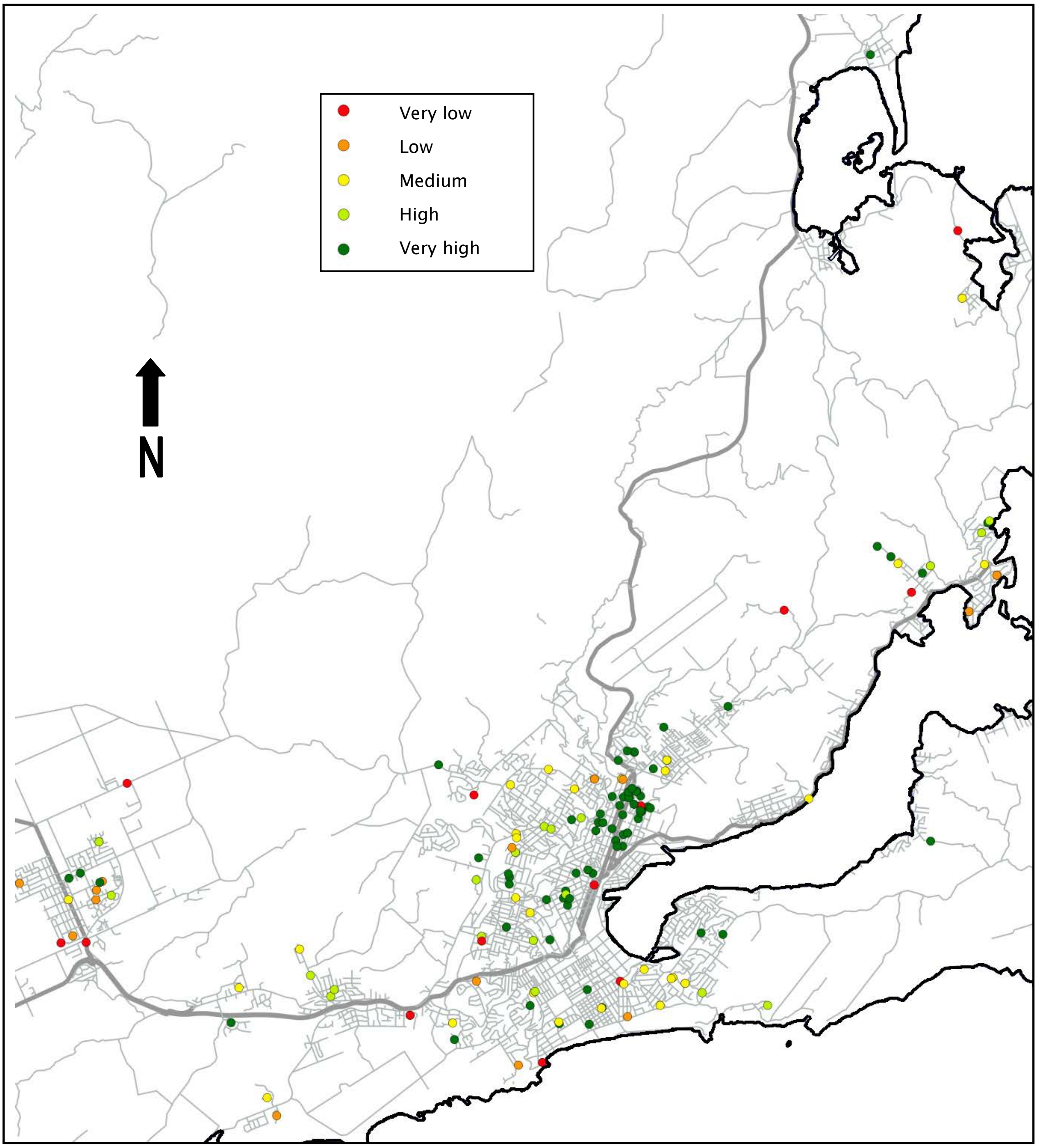


Figure 5.3 The adaptability scores of UoC students

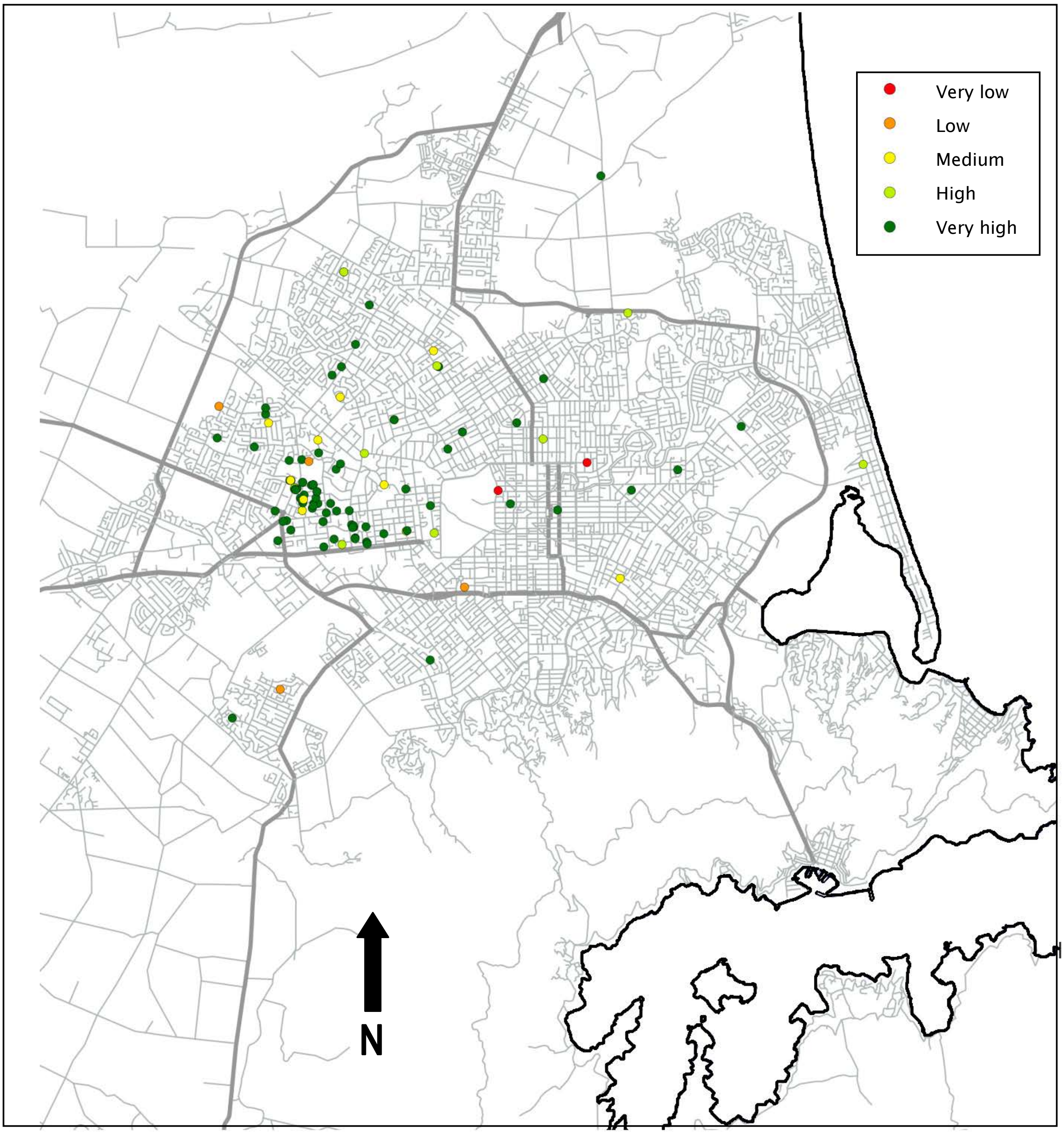


Figure 5.4 The adaptability scores of UoC general staff

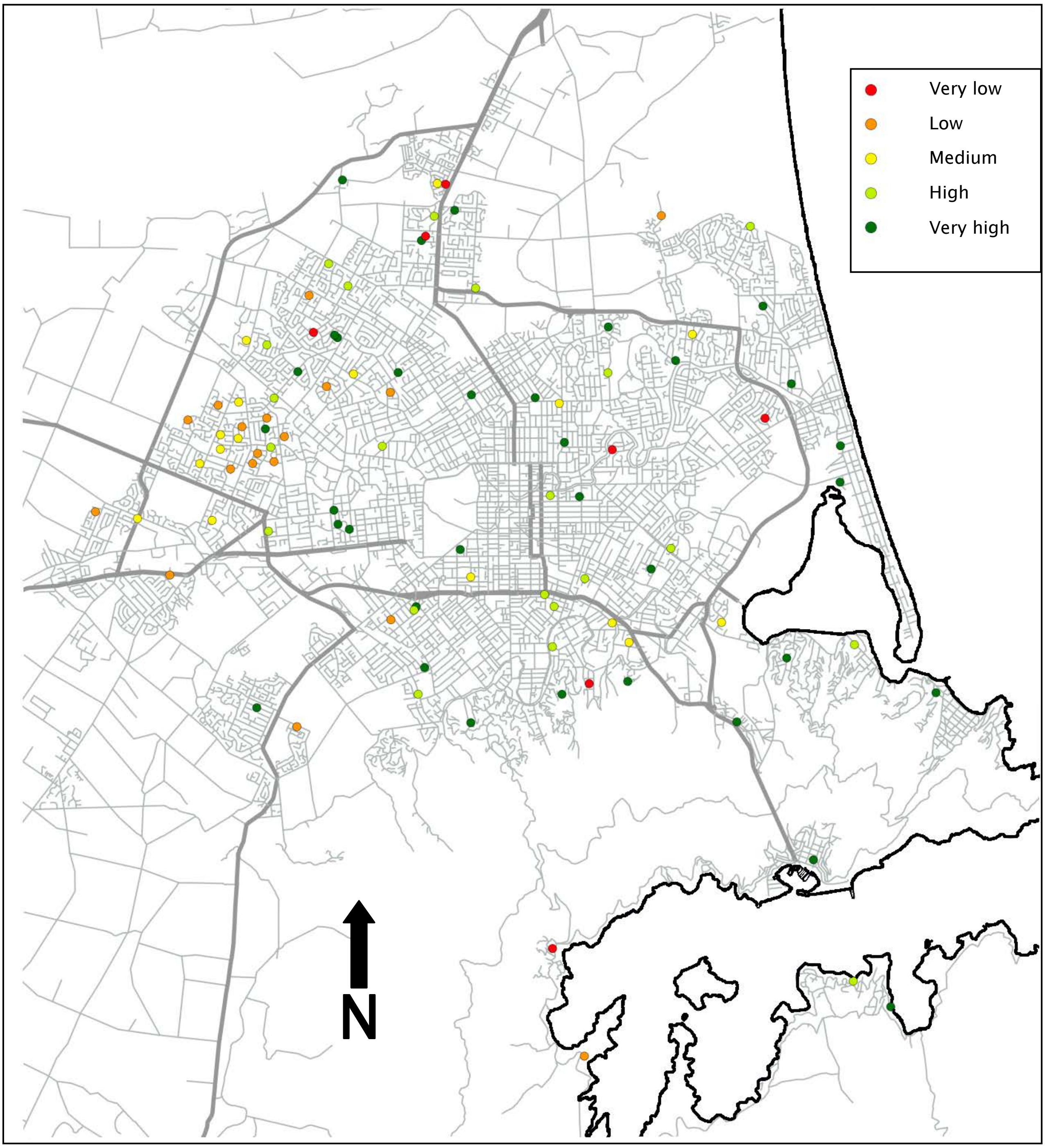


Figure 5.5 The adaptability scores of UoC academic staff

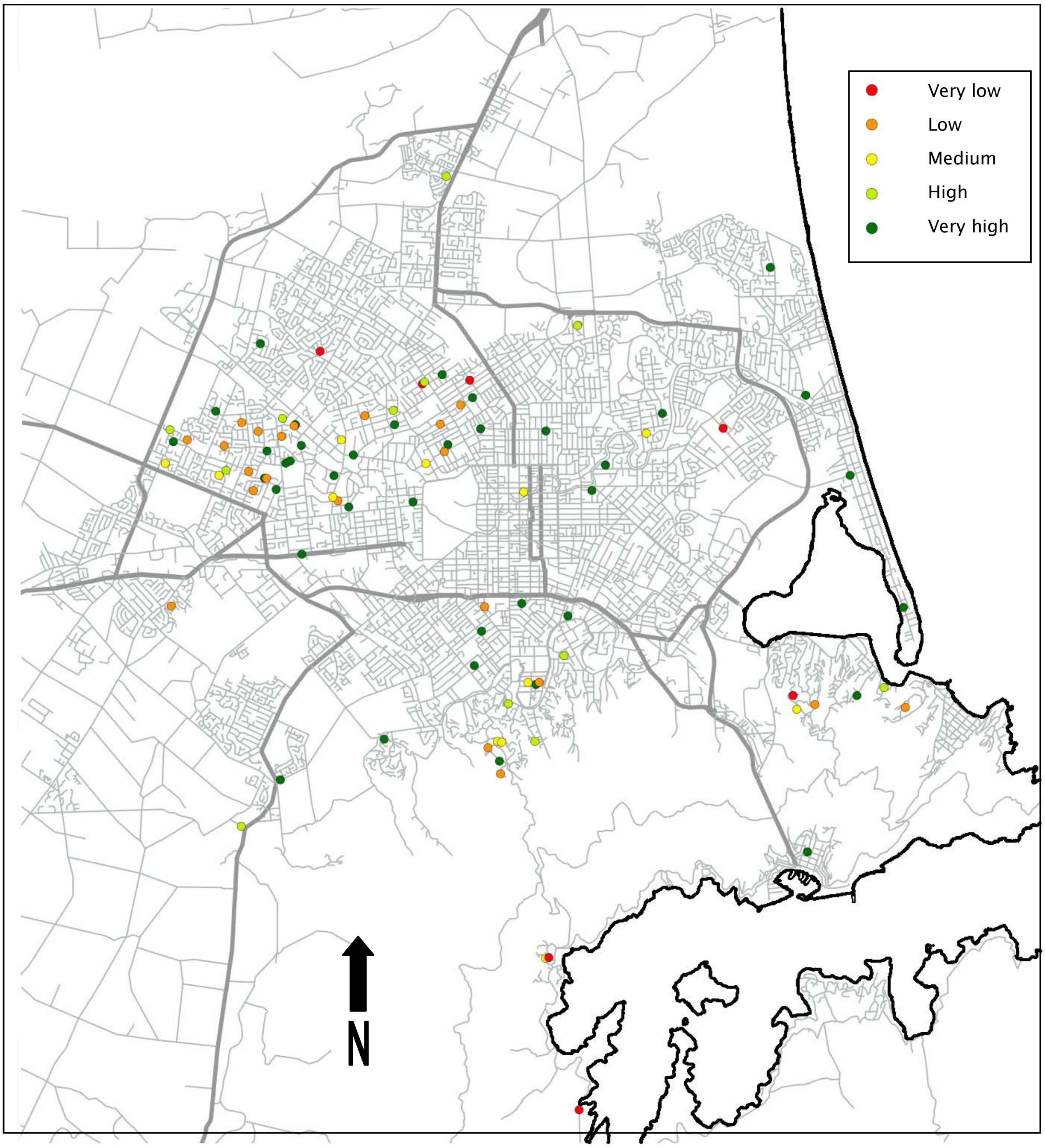
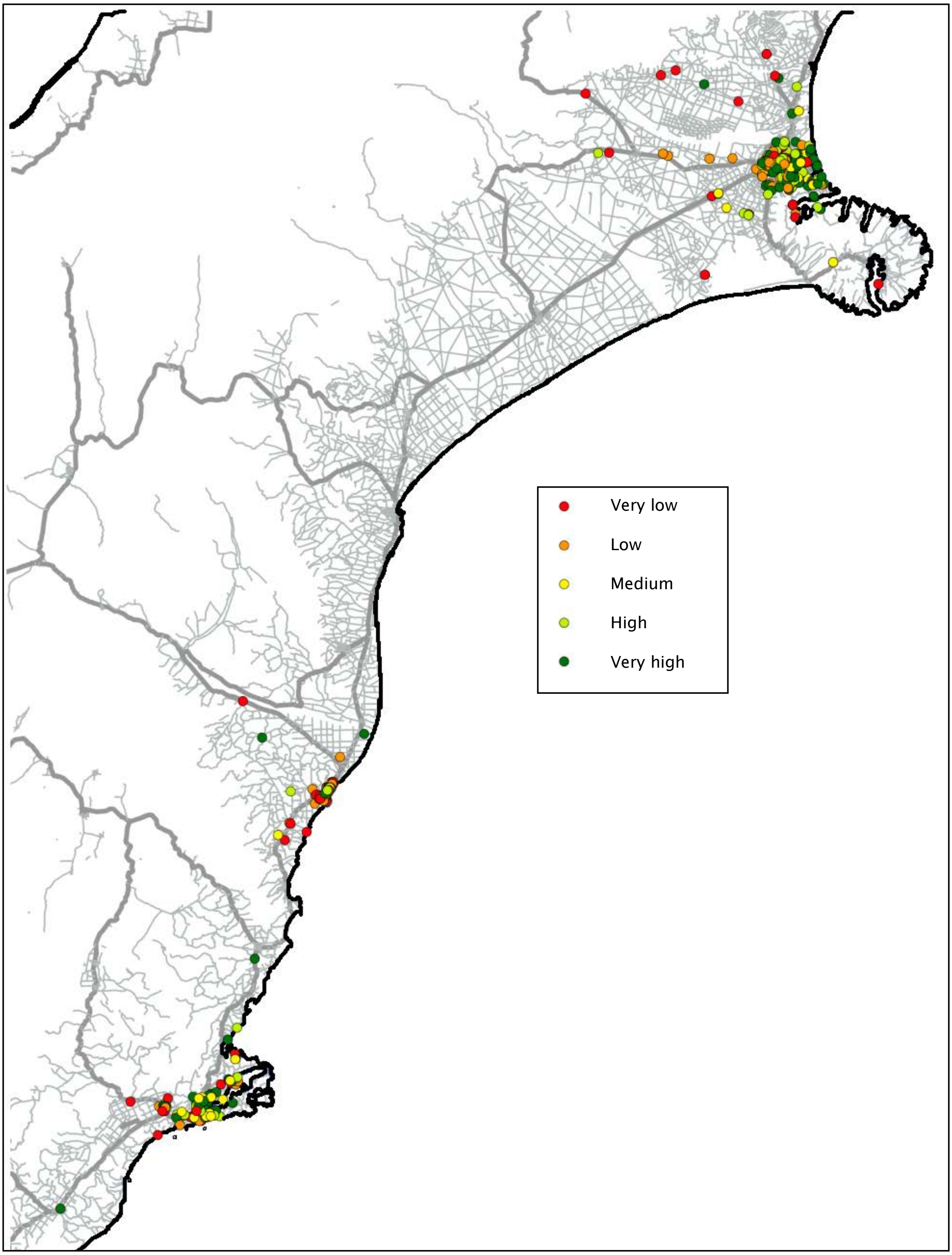


Figure 5.6 All surveyed adaptability scores, showing those who live in rural areas



The adaptability score is calculated for each participant and provided to them on the feedback screen at the end of the TACA survey alongside the total distance travelled and fuel used. Many of the participants explored the reasons for their scores and considered how they use their cars and what options they might have. As seen in the examples, the adaptability of their current personal lifestyle depends on their choice of activities, travel distances, access to alternative modes, and willingness or perception of alternative modes. Several participants in the survey, like Red John, simply stated they would not do anything but drive, and had established lifestyles and residence locations that were a long distance from activities. Others, like Mother Mary, said that they normally drive – and have reasons why – but they do have another way.

In-depth analysis of the data collected in the TACA survey was outside the scope of this research project. The data can be looked at in many other ways rather than the simple plots of the adaptability scores for the participants given in this section. Underlying demographic factors account for many of the observed patterns in the data. For example, the low-income university students tend to live close to the university and to be highly adaptable. However, they also live around the city, possibly with parents or in cheaper flats farther from the university, and they are still highly adaptable, as they report bus and riding with friends as common options. The small town of Oamaru does not appear to have a geographical pattern of adaptability. However, if the low-adaptability senior residents were removed from the sample, would we get another picture? The participants who lived in the rural areas would be expected to have low adaptability, yet a significant number of people living outside of the cities report high adaptability. What are the factors related to this?

The authors invite other researchers and councils to explore the data in more depth. The database is easily searchable, and other calculations and analysis can be performed that give insights into the range of factors that affect current fuel use and travel behaviour, as well as the adaptability or risk exposure to fuel price spikes.

6 Summary and conclusions

6.1 Summary overview

TACA surveys were conducted for randomly selected students, general staff and academic staff at the UoC over 2008–2010. Although the petrol price at the pump was high before the surveys began, it had stabilised around $1.65 per litre for 91 octane unleaded over the course of the study period. Three surveys were conducted for randomly selected residents of Oamaru over 2009–2010. One of these surveys had nearly exclusive participation by retired residents. One survey of 164 residents of Dunedin was conducted at the end of August 2010. The survey had a cohort of university and high school students, as well as Dunedin City Council workers.

The quality of the data was verified by comparison with existing NZHTS statistics and the UoC travel survey. The distribution of participants around the three cities makes the results useful for many different kinds of studies. The adaptive capacity measured by the TACA survey was calibrated to the responses to simulated high fuel prices from the virtual reality Travel Sim game survey. The adaptive potential for mode shift from the Travel Sim game showed more tendencies to eliminate fuel-intense modes, including taking the bus and riding with someone, than did the TACA survey results. The simulated experience of fuel price rises may cause Travel Sim participants to think about how high fuel prices would affect the affordability of all modes as well as their own ability to afford fuel for their vehicle. The TACA survey records the response to the question 'If you couldn't use your normal mode, how many other ways could you travel?' for each trip. The total adaptive capacity was found to be the same for the simulated five-fold price increase and for the TACA survey.

The data has been organised into an Excel database that is searchable by fields and easily extracted by an external program for further analysis. The AEMSLab research group wrote such search program in Matlab and produced sets of graphs portraying the data in several ways in Chapter 4.

The essentiality of trips according to purpose for each of the surveys was presented. The travel demand patterns for current travel were shown along with the travel demand patterns of the activity system with all of the nominated trip adaptations. The adaptive potential for mode change was presented for the aggregate of all participants for each city in terms of percent of trips and total kilometres that could be changed to reduce the use of personal vehicles. The adaptive potential of trips was also presented for each cohort in terms of participants' income range.

A method for quantifying the adaptive potential of a person, a cohort, or a city was presented in Chapter 5. The method uses the essentiality of each trip to weight the adaptability of the trip and uses the kilometres that could be changed to a mode that uses less fuel. The adaptability score was plotted on the maps of the survey areas at the location of the participants' residences. A great deal of future work was indicated, eg investigation of demographic and geographical factors, lifestyle choices, and access to active mode or public transit infrastructure.

6.2 Main findings

The TACA survey can be used to study the response of personal travel demand to fuel shocks. The TACA survey data can also provide a baseline scenario for the adaptation of travel demand to long-term pressures for changes brought about by fuel price increase and peak oil issues. The data collected during this survey is delivered in a useful and searchable database.

Participants indicate that work trips are generally considered to be essential. Shopping and recreation have lower essentiality, but still about one-third of these trips were considered to be essential. The most consistently essential trips were for medical treatment.

Travel adaptive capacity is the highest for young low-income participants, most of whom were students at the time of the survey and who were living near the university in Christchurch, which is flat and has a good bus access. The main adaptive mode was bus, but walking, biking and riding with a friend were also important. This cohort reported the ability to eliminate all but 7% of current private vehicle trips.

Travel adaptive capacity is the lowest for retired people and high-income working people. Oamaru also has a lower adaptive capacity than Dunedin and Christchurch because of its predominantly retired population and the lack of a bus service in the town. The Dunedin cohort reported no alternative to 82% of all current private vehicle kilometres, compared to 46% of car trips with no alternative mode for the Christchurch cohort.

Adaptive potential depends on the objective perception of the ability to use a different mode, and the subjective influences of urban form and transport networks. While some relationship could be seen between where participants lived in the city and their adaptive potential, people who could adapt nearly all trips could be found living in all areas. Conversely, some people with self-reported low adaptive potential also reported that most of their trips were less than 2km, which is a distance considered to be within walking range. The TACA survey is designed not to ask what alternative modes the participant would choose. Rather, the survey asks if the participant has another way to make the trip. This distinction was found to be important in recent surveys reported in the literature as a way to get beyond preference, to some degree, and to be able to measure actual adaptive capacity.

Fuel price pressure and fuel supply issues will continue to influence travel behaviour in the future. The literature review of the transport fuel situation indicated that it is highly likely that VKT will not increase substantially from this point forward. The travel adaptive capacity data collected in this research using the TACA survey gives some insight into the ways that travellers might choose to shift to more fuel-efficient travel. Literature on historical oil shortages shows that people have used a range of adaptive strategies.

Over the past 30 years, international research has focused on voluntary travel behaviour change through TDM intervention programmes to try to convince people to take public transport, share car rides, walk, ride bikes, or consider alternative times and destinations for trips. The main driver for these efforts has been road traffic congestion. The TACA survey was developed in order to gather data, which could be used to understand how demand growth for alternative modes may develop as fuel price pressures continue to increase. The potential for increased active mode or public transport choices indicates new considerations for transport planners in order to ensure that current transport network investments can support a safe, sustainable and less intense transport system in the future.

6.3 Main limitations

Neither the Travel Sim virtual reality game survey nor the TACA survey data can be verified with participant travel behaviour change in an actual steep fuel price rise situation until that situation actually occurs and the resulting behaviour change is studied. However, since completion of this research, the petrol price has risen 15–20% in less than 6 months. We may be able to verify some of the adaptive potential indicated by the survey data retrospectively if data is available. The point is that if transportation planners, asset managers and city councils wish to start dealing with the issue of peak oil vulnerability, the TACA survey will be necessary to diagnose the current travel adaptive capacity and to understand the adaptive potential for more energy-efficient modes in their particular urban area. The data will also be necessary to identify the groups at risk and the need for new investments in cycling and walking infrastructure or other measures specific to the particular city.

The design of the survey is novel and thus is not well established in the travel behaviour research field. Behaviour science research has standard methods to probe participants' choices between known or proposed alternatives. These choices are normally understood to be representative of real intent: 'Would you change if...?' The TACA survey probes current known alternatives ('Do you have another way?'), which minimises the contextual limitations to participants' consideration of their answer. We assert that this data represents future relative potential for adaptation under non-specific pressures for change. The travel behaviour literature in this area is not established, so the method must be taken as unproven at this point.

The TACA survey data is not meant to be used in lieu of travel demand data to determine trip generation or traffic flows on the networks, or price elasticity. Rather, the TACA survey captures the 'normal' or habitual weekly travel activities of the participants. The TACA survey seeks the alternatives to using a private vehicle for the core transport activity system in a particular city. The data can be analysed in a wide variety of ways depending on the objectives and concerns of the city council planners. It is important to gather data for specific locations, organisations and socioeconomic groups in each city, and to be able to monitor the adaptability as changes to transport networks are made or urban land use changes.

6.4 Future directions

We recommend that TACA surveys be conducted for all cities in New Zealand as part of the process of planning for adaptation to world oil supply issues. The TACA survey can be conducted for about 250 participants over a three-day timeframe in a particular location for about $5000. If the participants are randomly solicited in the activity area of interest, then the information about travel adaptive capacity and the travel adaptive potential could be very important in planning and operation of the local urban transport networks. The TACA survey can be targeted at organisations, such as a large business or a shopping mall. TACA surveys can also be targeted at certain urban areas or at particular demographic groups. The cost of acquiring the data is reasonable, and the benefit to urban areas such as Wellington or Auckland could be great. For example, are the students and staff at Auckland University much more susceptible to fuel price pressures because of the lack of affordable and desirable housing near the university? The latent demand for non-vehicle access to the university and the central business/ commercial district, as potentially indicated by a TACA survey, could help the regional transport authority understand the benefit of enhanced public transport access to the central city through dedicated train lines.

Each location has its unique circumstances and travel needs. For example, Queenstown has the issue of a high-end resort destination where service workers cannot afford to live within or near the town. A TACA survey could help with quantifying the adaptability of different groups in the current system, and the potential benefit of either resort-incorporated worker housing or dedicated outlying worker housing developments connected to the city via public transport.

We have received requests from three research groups in Australia to use the TACA survey. Future research on travel adaptive capacity in other countries, particularly the United States, Asia and Europe, could yield fascinating insights into the role of urban form, social norms and transportation network characteristics.

We recommend that further analysis be performed on the TACA survey data collected during this study. In this research project, the main deliverable was the quality survey data with the new survey data of trip essentiality. The AEMSLab research group is currently collaborating with Professor Khandker M. Nurul

Habib, University of Toronto, who is an expert in travel behaviour. It would be of great benefit to New Zealand to develop collaborations with council staff, consultants and other researchers in New Zealand to bring the analysis methods Professor Habib has developed into use by stakeholders.

The fact that travel adaptive potential is an intrinsic characteristic of individuals indicates that much more research should be done into understanding the role of adaptation for developing effective transportation policies. It is clear from the literature review that 'promotion' of active modes or public transport has had much lower impact than fuel shortages in affecting travel behaviour change. As the future will certainly see pressures on fuel use in private vehicle transport, it will be important to understand the adaptation mechanisms and how they will affect future demand growth for fuel-efficient modes. It will also be critical for investment in infrastructure and safety to understand the potential for growth of active modes, and the levelling off and future decline of VKT as the fuel supply contracts.

Analysis of the data is continuing, but the results comparing Christchurch and Oamaru provide an early indication that active mode and public transport availability in network design, operation and regulation will be important in improving a town's adaptive potential. Much more research in cities around New Zealand could be done to understand vulnerability to fuel price spikes, or how adaptation may tend toward future demand growth for active and public transport modes. Further analysis needs to be done to understand why some people are highly adaptable while others report no adaptability at all. What is the importance of the choice of residential location in travel behaviour and energy intensity in Hamilton? Will the rural property boom in Timaru reduce adaptive capacity and thus put those residential property values at risk in the future? This is a critical time for travel adaptive potential information for urban land use planning, cost–benefit analysis and investment decisions that will have long-term implications for the service, safety and sustainability of New Zealand's urban areas.

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Appendix A TACA survey questions

A1 Format

The following screenshots show the TACA survey. While a participant answers certain questions, yellow information boxes pop up providing further instructions. These are shown in this appendix in boxes beside the screenshots. For some questions, the participant selects options from a drop-down list. Options in the drop-down list are shown in tables A1–A3.

A2 Welcome screen

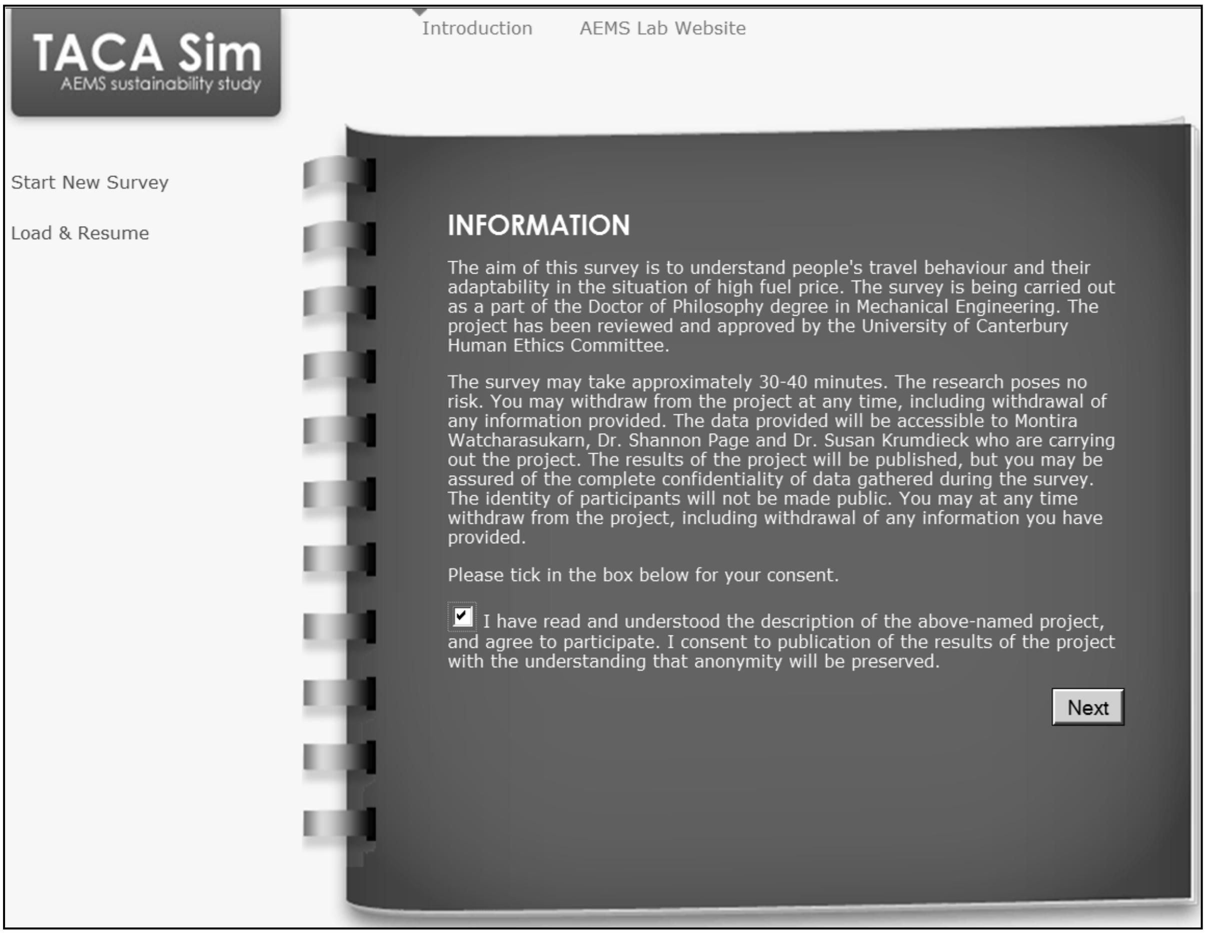
The participants log into the survey at http://www.tacasim.aemslab.org.nz/ and see the welcome screen shown in figure A1.

Figure A1 Welcome screen of the TACA survey

A3 Information page

The Ethics Committee of UoC has given approval for the TACA survey questions and the purpose of the survey as described on the information page (figure A2). Participants must tick that they have read and understood the purpose and what will be done with the data collected.

Figure A2 Information page of the TACA survey, including consent and a guarantee of anonymity



After this information page, the participant progresses to the personal information page.

A4 Personal information page

Figure A3 Screenshot of the registration form for participants in the TACA surface

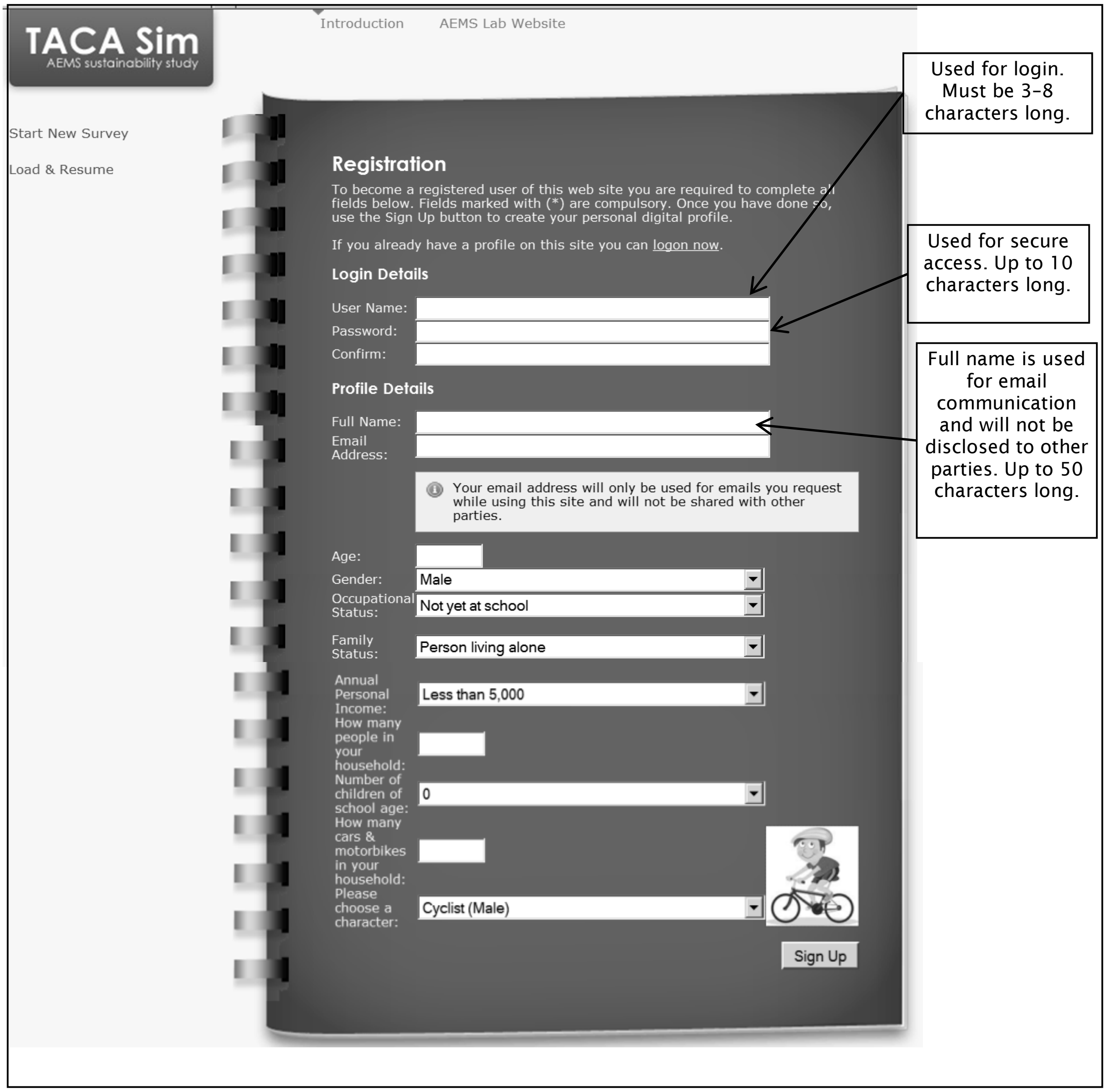


Table A1 Options presented in the drop-down boxes on the personal information page of the TACA survey

Question	Options
Gender	• Male • Female
Occupational status	• Not yet at school • Student – full time • Student – part time • Work – full time • Work – casual • Looking for work/unemployed • Looking after home and family • Retired • Other beneficiary • Other (specify)
Family status	• Person living alone • Married/de facto couple only • Other adults only (eg flatmates) • Family (including extended) with children • Family with adults only • Single adult living with children • Family with child(ren) plus flatmates/boarders
Annual personal income	• Under $10,000 • $10,001–$20,000 • $20,001–$30,000 • $30,001–$40,000 • $40,001–$50,000 • $50,000–$70,000 • $70,001–$100,000 • $100,001 or more

A5 Successful launch and start of transport information

The participant is informed of successful registration (figure A4) and given instructions for entering the next level of information (figure A5).

Figure A4 Screenshot of successful registration page in the TACA survey

Figure A5 Screenshot of the first page of the vehicle information section

A6 Vehicle creation

Participants can use a pet name for their car, then give its details (figure A6 and table A2). After entering the data, a successful progress screen is shown with options (figure A7).

Figure A6 Screenshot of the form used for creating a vehicle

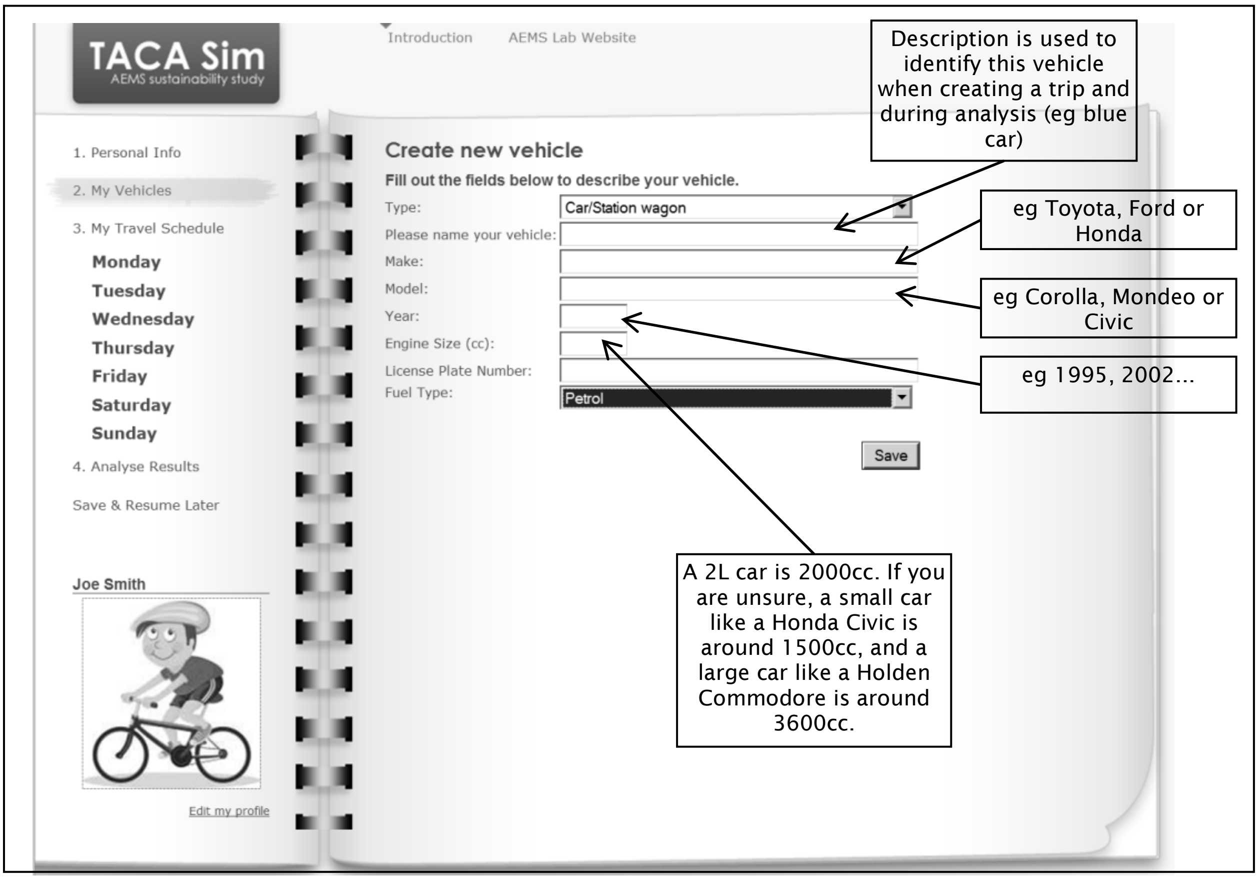
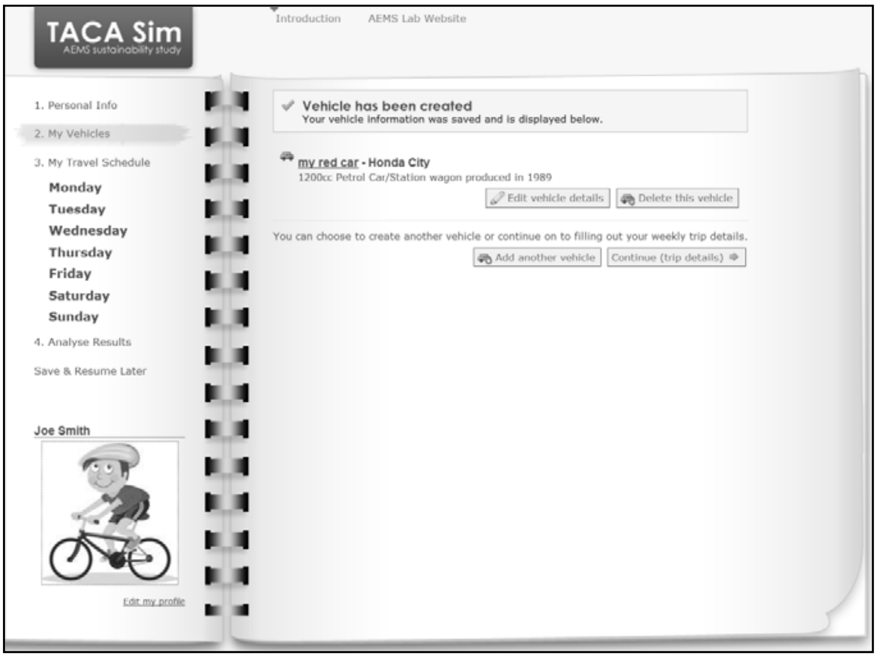


Table A2 Options for the drop-down boxes when creating a vehicle

Question	Options
Vehicle type	• Car/station wagon • People mover • Motor scooter or motorbike • Minibus/bus • Ute/cab-chassis/pickup • Van/light truck • SUV*/four-wheel drive
Fuel type	• Petrol • Diesel • LPG/CNG • Dual fuel • Electric • Other (specify)

* SUV = sports utility vehicle

Figure A7 Progress screen during the vehicle creation process



A7 Trip creation worksheet

After all vehicles are created, instructions on entering weekly schedule are given (figure A8). Figure A9 shows the trip creation worksheet; options for the drop-down boxes are shown in table A3.

Figure A8 Instruction screen for creating a weekly travel schedule

Figure A9 Form used for creating a weekly trip, using Monday as an example

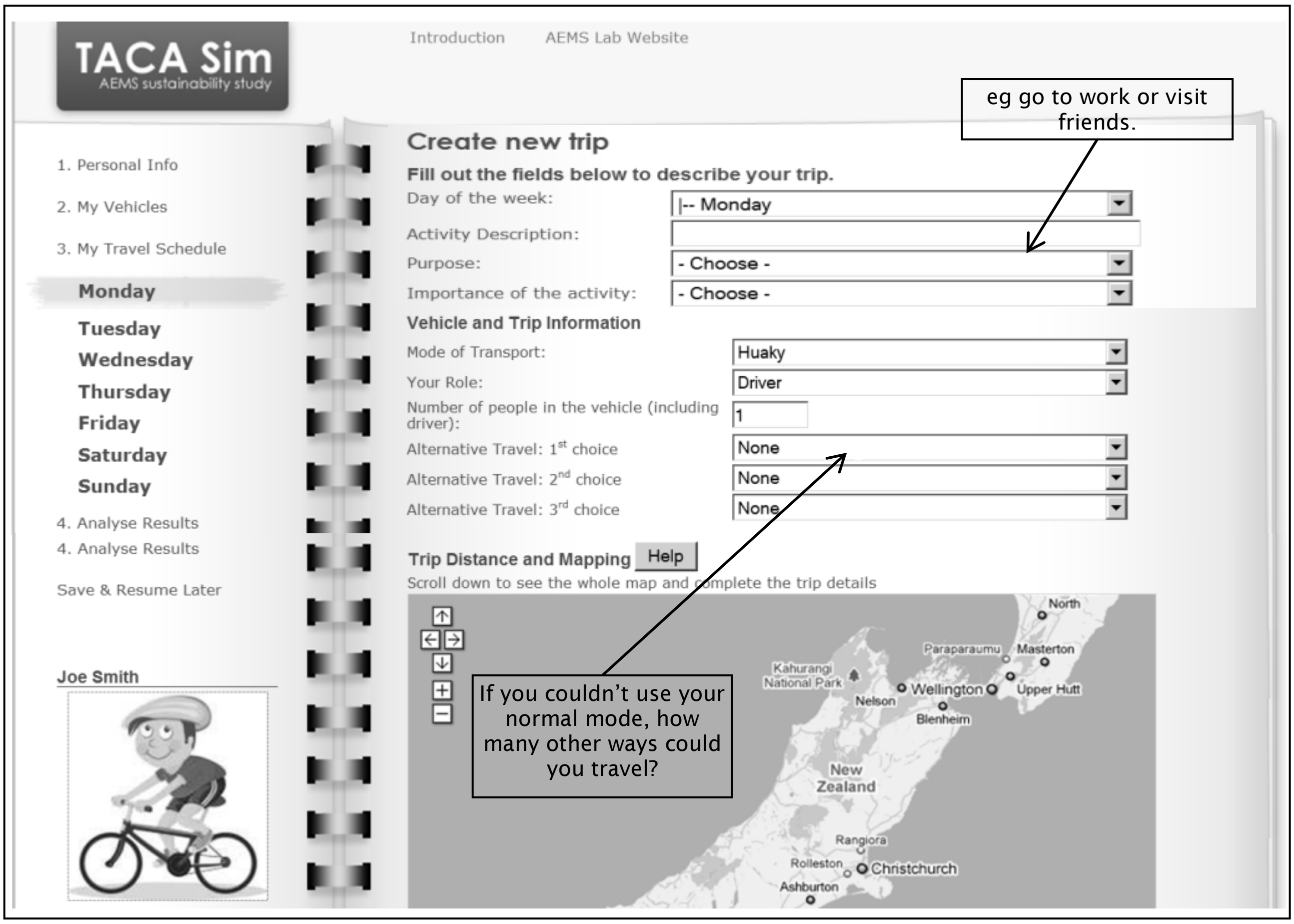


Table A3 Options for drop-down boxes in the trip creating worksheet

Question	Options
Purpose	• Home • Education • Personal business/services • Change mode • Work • Hospital/medical • Accompanied someone else • Shopping • Social visit/entertainment • Social • Left country/city • Recreation
Importance of the activity[a]	• Low • Medium • High

Question	Options
Mode of transport	My vehicles: • *(Car one named here* • *(Car two named here)* Other transport options: • Vehicle (driver) • Vehicle (passenger) • Bus • Walking • Bicycle • Rollerblades/skates/scooter • Train • Ferry • Plane
Your role	• Driver • Passenger
Alternative travel choices[b]	• None • I could do this activity without travelling • I could get a ride with someone else • Cycle • Walk or run • Rollerblades/skateboard/scooter • Bus • Train • Ferry • Plane • Other

Notes to table A3:

a The levels of importance were defined as follows: Low: I could curtail it without suffering. Medium: My quality of life would be reduced if I could not do this activity, but I would not suffer real harm. High: My wellbeing would suffer and my quality of life would be reduced.

b This question appeared three times; see figure A9.

Survey participants followed the instructions below for entering the address and route taken to travel in the trip distance and travel mapping part of the trip creation worksheet:

1 Left click where you departed from.

2 Left click where you went to.

3 Adjust the address in the departure and arrival addresses if needed.

4 Click ‘Show route’.

Participants can change their route by dragging the blue line if needed. They may bypass the map by typing the distance and addresses, and hitting save.

After the details of the trip are filled in, the trip is mapped to the Google Maps (figure A10) and saved. Next, the ‘Trip Created’ screen (figure A11) appears with questions about the next journey.

Figure A10 Form for adding trip details for calculating the distance travelled

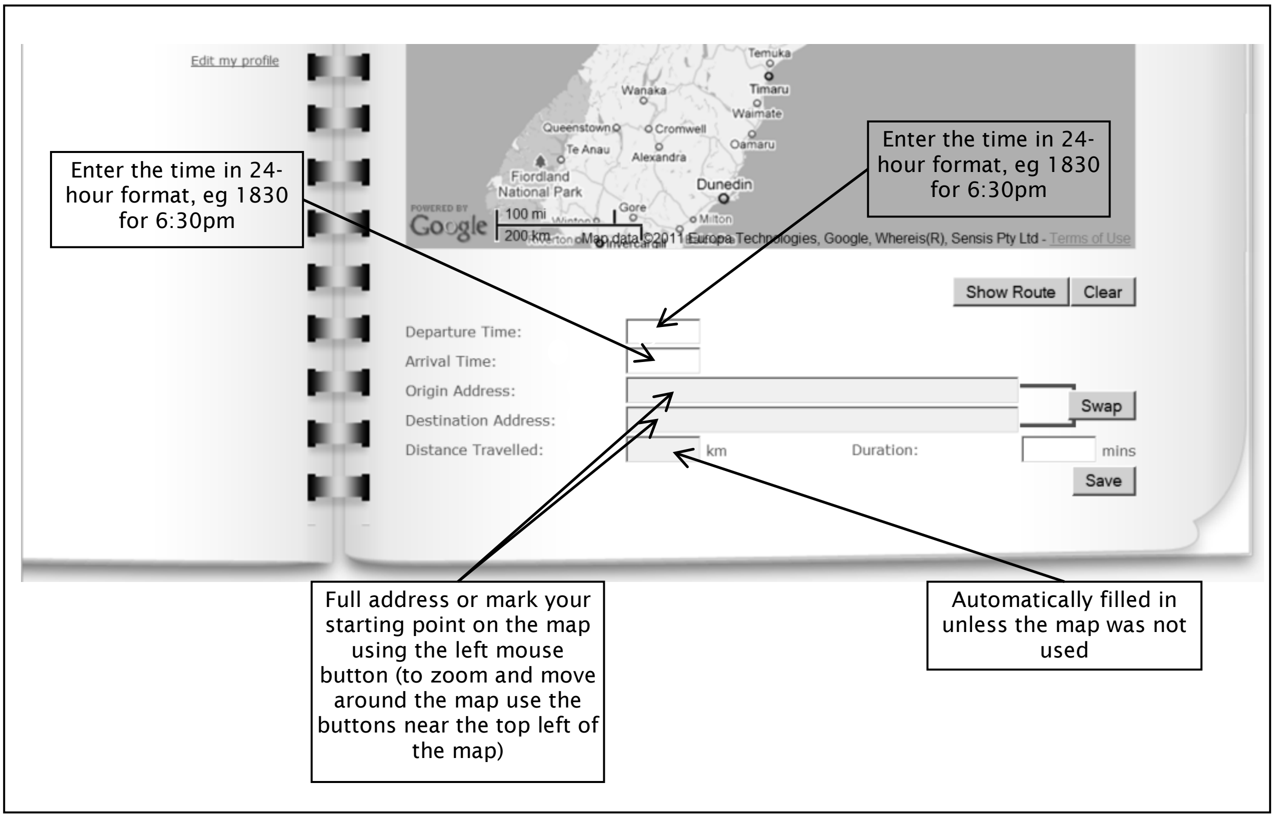
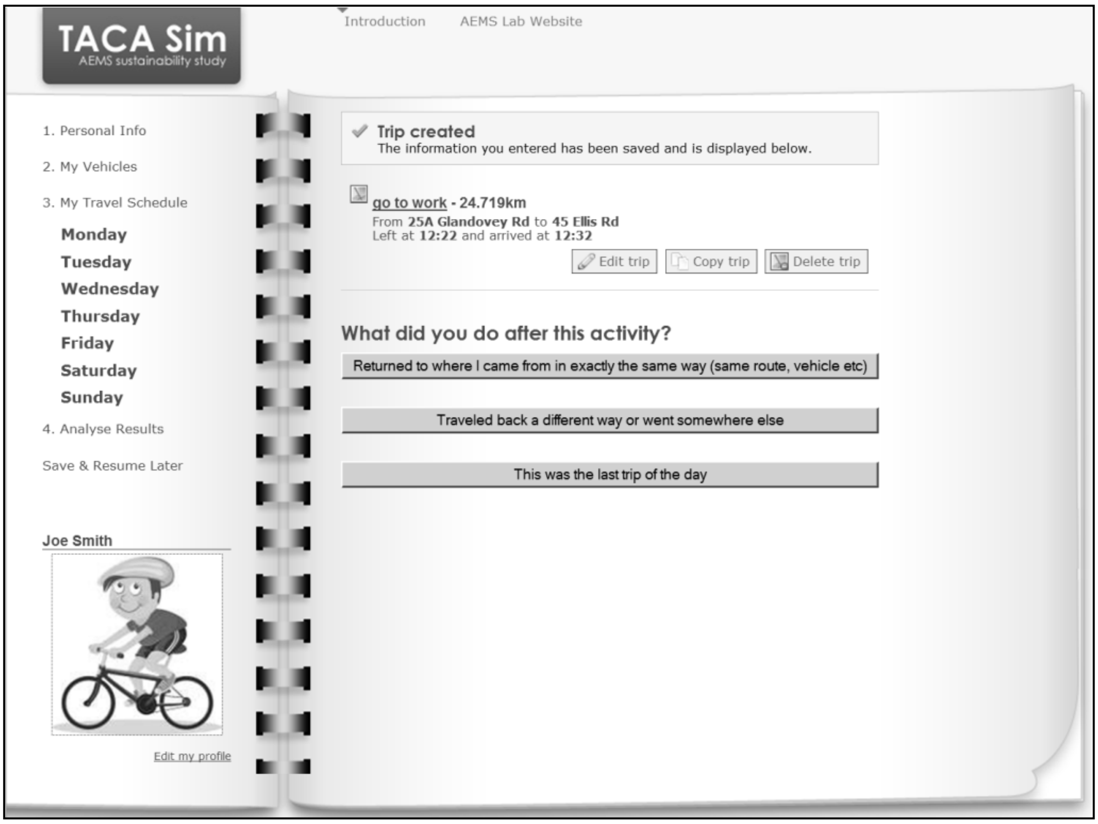


Figure A11 Screenshot appearing after a trip is created successfully



A8 Feedback and results

After all of the trips have been entered on all of the days, a feedback screen appears (figure A12). On this screen, participants get feedback about their weekly travel habits.

Figure A12 Screenshot of the results page

Appendix B Data dictionary

B1 Data coding

The data collected from the TACA surveys is stored as a simple tab separated file, with each row recording an individual trip. An explanation of the data recorded in each column is provided in table B1.

Table B1 Description of codes used for collating and storing TACA survey data

Column header	Description and data form
Id	**Participant identification** Number/letter combination code for each individual that took the survey Data form: string Examples: Acad034, stu001, 85795
ty	**Participant classification** Data form: integer, where: • 1 = academic staff at UoC • 2 = general staff at UoC • 3 = student at UoC • 4 = resident of Oamaru • 5 = resident of Dunedin
date	**Survey date** Date the person was surveyed Data form: string Example: 19/10/2009
pdie	**Diesel price** Price of diesel at the time the person was surveyed Data form: decimal number Example: 1.066
ppet	**Petrol price** Price of petrol at the time the person was surveyed Data form: decimal number Example: 1.801
trip	**Trip number** Label for each trip a person makes Data form: integer Examples: 1, 2, 3...

Column header	Description and data form
day	**Day of week** The day of the week a trip was made Data form: integer, where: • 1 = Monday • 2 = Tuesday • 3 = Wednesday • 4 = Thursday • 5 = Friday • 6 = Saturday • 7 = Sunday
tdep	**Departure time** Trip departure time in 24-hour form Data form: string Example: 20:15
tarr	**Arrival time** Trip arrival time in 24-hour form Data form: string Example: 20:55
ttra	**Travel time** Time in minutes Data form: integer
O_{tx}	**Trip origin** A description of the trip origin/address Data form: string Examples: • 4 Hillcrest Place, Avonhead, Christchurch • Waiwetu St/Fendalton Rd, Fendalton, Canterbury 8052
O_{co}	**Trip origin coordinates** The latitude and longitude of the trip origin (decimal degrees) Data form: string Example: -43.59104,172.38745 If value = 0, data was not recorded or was missing
D_{tx}	**Trip destination** A description of the trip destination/address Data form: string Examples: 4 Hillcrest Place, Avonhead, Christchurch Waiwetu St/Fendalton Rd, Fendalton, Canterbury 8052
D_{co}	Trip destination coordinates The latitude and longitude of the trip destination (decimal degrees) Data form: string Example: -43.59104,172.38745 If value = 0, data was not recorded or was missing

Column header	Description and data form
dis	**Trip distance** Distance of trip in km Data form: decimal Example: 7.34
P_{use}	**Purpose of trip** The purpose of the trip (activity description) as described by the user Data form: string Example: going to work
P_{sor}	**Purpose classified** Classification of the trip (activity) Data form: integer, where: • 1 = home • 2 = education • 3 = personal business/services • 4 = change mode • 5 = work • 6 = hospital/medical • 7 = accompanied someone else • 8 = shopping • 9 = social visit/entertainment • 10 = social • 11 = left country/city • 12 = recreation
ess	**Activity importance** The importance of the activity Data form: integer, where: • 1 = high • 2 = medium • 3 = low
occ	**Vehicle occupancy** Number of people in the vehicle including the driver. Only relevant for vehicle trips Data form: integer, where: • 0 = mode was something other than a car • 1 = just the driver • 2 = driver and one passenger • 3 = driver and two passengers • etc

Column header	Description and data form
mode	**Trip mode** Mode of travel Data form: integer, where: • 1 = vehicle (driver) • 2 = vehicle (passenger) • 3 = bus • 4 = walking • 5 = bicycle • 6 = rollerblades/skates/scooter • 7 = train • 8 = ferry • 9 = plane • 10 = other
TV_{ty}	**Trip vehicle type** The type of vehicle the person travelled in for the trip Data form: integer, where: • 0 = vehicle not specified (ie participant did not travel in one of the household vehicles entered) • 1 = car/station wagon • 2 = people mover • 3 = motor scooter or motorbike • 4 = minibus/bus • 5 = pickup/ute/cab chassis • 6= van/light truck • 7 = SUV or four-wheel drive
TV_{ma}	**Trip vehicle make** The make of vehicle the person travelled in for the trip Data form: string Example: Ford If TV_{ma} = 0, the vehicle was not specified, ie the participant did not travel in one of the household vehicles entered
TV_{mo}	**Trip vehicle model** The model of vehicle the person travelled in for the trip Data form: string Example: Corolla, Civic If TV_{mo} = 0, the vehicle was not specified, ie the participant did not travel in one of the household vehicles entered
TV_{ye}	**Trip vehicle year** The year of vehicle the person travelled in for the trip Data form: integer Example: 2000 If TV_{ye} = 0, the was vehicle not specified, ie the participant did not travel in one of the household vehicles entered

Column header	Description and data form
TV_{fu}	**Trip vehicle fuel type** The vehicle fuel used for the trip Data form: integer, where • 0 = vehicle not specified (ie participant did not travel in one of the household vehicles entered) • 1 = petrol • 2 = diesel • 3 = LPG/CNG • 4 = dual fuel • 5 = electric • 6 = other
TV_{en}	**Trip vehicle engine size** The engine size in cubic centimetres of the vehicle for the trip Data form: integer Example: 1500 If TV_{en} = 0, the vehicle was not specified, ie the participant did not travel in one of the household vehicles entered
AI_1	**Alternative one** Alternative travel option if the user could not travel by their usual mode Data form: integer, where: • 0 = data not recorded or missing • 1 = none • 2 = I could do this activity without travelling • 3 = I could get a ride with someone • 4 = cycle • 5 = walk or run • 6 = rollerblades/skateboard/scooter • 7 = bus • 8 = train • 9 = ferry • 10 = plane • 11 = other
AI_2	**Alternative two** Same data form as AI_1
AI_3	**Alternative three** Same data form as AI_1
sex	**Sex of participant** Data form: integer, where: • 1 = male • 2 = female
age	**Age of participant** Data form: integer

Column header	Description and data form
Inc_rc	**Participant income** Annual gross personal income of participant Data form: integer, where: • 1 = Under $10,000 • 2 = $10,001–$20,000 • 3 = $20,001–$30,000 • 4 = $30,001–$40,000 • 5 = $40,001–$50,000 • 6 = $50,001–$70,000 • 7 = $70,001–$100,000 • 8 = $100,001 or more • 9 = not stated
Wsta	**Working status** Data form: integer, where: • 1 = not yet at school • 2 = student – full-time • 3 = student –part-time • 4 = work – full-time • 5 = work – part-time • 6 = work – causal • 7 = looking for work/unemployed • 8 = looking after home and family • 9 = retired • 10 = other beneficiary • 11 = other
Fsta	**Family status** Data form: integer, where: • 1 = person living alone • 2 = married/de facto couple only • 3 = other adults only (eg flatmates) • 4 = family (including extended) with children • 5 = family with adults only • 6 = single adult living with children • 7 = family with child(ren) plus flatmates/boarders • 8 = other
n_{peh}	**Household size** Number of people in the household Data form: integer
n_{sch}	**Household children** Number of school-aged children in the household Data form: integer

Column header	Description and data form
n_{vih}	**Vehicles in the household** Number of cars and motor bikes in the household Data form: integer
$V1_{ty}$	**Vehicle 1's type** Same data type as TV_{ty} If $V1_{ty}$ = 0, no vehicles are listed in the household
$V1_{ma}$	**Vehicle 1's make** Same data form as TV_{ma} If $V1_{ma}$ = 0, no vehicles are listed in the household
$V1_{mo}$	**Vehicle 1's model** Same data form as TV_{mo} If $V1_{mo}$ = 0, no vehicles are listed in the household
$V1_{ye}$	**Vehicle 1's year** Same data form as TV_{ye} If $V1_{ye}$ = 0, no vehicles are listed in the household
$V1_{fu}$	**Vehicle 1's fuel type** Same data form as TV_{fu} If $V1_{fu}$ = 0, no vehicles are listed in the household
$V1_{en}$	**Vehicle 1's engine size** Same data form as TV_{en} If $V1_{en}$ = 0, unknown or no vehicles are listed
$V2_{ty}$	**Vehicle 2's type** Same data form as TV_{ty} if $V2_{ty}$ = 0, less than two vehicles are listed in the household
$V2_{ma}$	**Vehicle 2's make** Same data form as TV_{ma} if $V2_{ma}$ = 0, less than two vehicles are listed in the household
$V2_{mo}$	**Vehicle 2's model** Same data form as TV_{mo} if $V2_{mo}$ = 0, less than two vehicles are listed in the household
$V2_{ye}$	**Vehicle 2's year** Same data form as TV_{ye} if $V2_{ye}$ = 0, less than two vehicles are listed in the household
$V2_{fu}$	**Vehicle 2's fuel type** Same data type as TV_{fu} if $V2_{fu}$ = 0, less than two vehicles are listed in the household
$V2_{en}$	**Vehicle 2's engine size** Same data form as TV_{en} If = $V2_{en}$ = 0, unknown or less than two vehicles are listed in the household
$V3_{ty}$	**Vehicle 3's type** Same data type as TV_{ty} if $V3_{ty}$ = 0, less than three vehicles are listed in the household

Column header	Description and data form
$V3_{ma}$	**Vehicle 3's make** Same data form as TV_{ma} if $V3_{ma}$ = 0, less three vehicles are listed in the household
$V3_{mo}$	**Vehicle 3's model** Same data form as TV_{mo} if $V3_{mo}$ = 0, less than three vehicles are listed in the household
$V3_{ye}$	**Vehicle 3's year** Same data form as TV_{ye} if $V3_{ye}$ = 0, less than three vehicles are listed in the household
$V3_{fu}$	**Vehicle 3's fuel type** Same data form as TV_{fu} if $V3_{fu}$ = 0, less than three vehicles are listed in the household
$V3_{en}$	**Vehicle 3's engine size** Same data form as TV_{en} If $V3_{en}$ = 0, unknown or less than three vehicles are listed in the household
$V4_{ty}$	**Vehicle 4's type** Same data type as TV_{ty} if $V4_{ty}$ = 0, less than four vehicles are listed in the household
$V4_{ma}$	**Vehicle 4's make** Same data form as TV_{ma} if $V4_{ma}$ = 0, less than four vehicles are listed in the household
$V4_{mo}$	**Vehicle 4's model** Same data form as TV_{mo} if $V4_{mo}$ = 0, less than four vehicles are listed in the household
$V4_{ye}$	**Vehicle 4's year** Same data form as TV_{ye} if $V4_{ye}$ = 0, less than four vehicles are listed in the household
$V4_{fu}$	**Vehicle 4's fuel type** Same data form as TV_{fu} if $V4_{fu}$ = 0, less than four vehicles are listed in the household
$V4_{en}$	**Vehicle 4's engine size** Same data form as TV_{en} If $V4_{en}$ = 0, unknown or less than four vehicles are listed in the household

B2 Trip purpose categories

In the TACA survey, a person must categorise the purpose of each trip from the list below. A paper list giving examples of each is given in table B2.

- home
- education
- personal business/services
- change mode
- work
- hospital/medical
- accompanied someone else
- shopping
- social visit/entertainment
- social
- left country/city
- recreation.

Table B2 Examples of activities for each trip purpose

Purpose	Examples of activity
Home	• Return home • Stay at home
Education	• School • University • Special training
Personal business/services	• Personal services (salon, 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 work

Purpose	**Examples of activity**
Hospital/medical	• Doctor • Dentist • Pharmacy • 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 • Takeaway 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	• Leaving country/city
Recreation	• Exercise or active sports • Golf • Spectator sports • Movies/theatre • Other spectator events • Playing with kids • Parks, recreation areas • Regular TV programmes • Unspecific TV • Movie/video • Browsing websites/using internet • Relaxation/rest • Relaxing/pleasure reading/napping • Hobbies (crafts, gardening, etc) • Other recreation/entertainment
Other	Pleasure driving