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**A Co-Benefit Analysis of Alternative Transportation in  
Adelaide, Australia:  
Integrating Perspectives from Communities and  
Stakeholders for Sustainable Change**

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## PUBLICATIONS DURING CANDIDATURE

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### *Peer-reviewed Journals:*

1. Ting Xia, Monika Nitschke, Ying Zhang, Pushan Shah, Shona Crabb, Alana Hansen. Traffic-Related Air Pollution and Health Co-Benefits of Alternative Transport in Adelaide, South Australia, *Environmental International*. 2015, vol 74.pp. 281-290
2. Ting Xia, Ying Zhang, Pushan Shah, Shona Crabb. Co-benefits of replacing car trips with alternative transportation: A review of evidence and methodological issues, *Journal of Environmental and Public Health*, P 2013, vol. 2013.

### *Conference paper:*

3. Ting Xia, Pushan Shah, Monika Nitschke, Ying Zhang, Shona Crabb, Evaluating the PM concentration and the health benefits from reducing urban vehicle usage in Adelaide, South Australia: 21st International Clean Air and Environment Conference, 7 – 11 September, 2013, Sydney.

## CONFERENCE PRESENTATIONS DURING CANDIDATURE

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1. Ting Xia, Ying Zhang, Shona Crabb, Monika Nitschke, Pushan Shah. *Encouraging Alternative Transport Use in Adelaide: Public Perception of Traffic, Environment and Health (Poster)*. The 20th IEA World Congress of Epidemiology. Alaska, USA, August 2014
2. Ting Xia, Ying Zhang, Annette Braunack-Mayer, Shona Crabb, Pushan Shah. *Understanding community's perceptions towards active transportation and the policy implications (Invited speaker)*. The 5th Asia-Pacific Conference on Public Health, Seoul, Korea, April 2014.
3. Ting Xia, Pushan Shah, Ying Zhang, Shona Crabb. *Evaluating the PM change and health impact due to urban vehicle emissions reduction in Adelaide, South Australia (Oral)*. 21st International Clean Air and Environment Conference, Sydney, Australia, September 2013
4. Ting Xia, Ying Zhang, Pushan Shah, Shona Crabb. *Air quality and health Co-Benefits from reduced car travel in Adelaide, South Australia (Oral)*. Conference of International Society for Environmental Epidemiology, Basel, Switzerland, August 2013.
5. Ting Xia, Ying Zhang. *Health co-benefit modelling study on active transportation: Model evaluations and sensitivity Analyses (Oral)*. The XIX International Conference of the Society for Human Ecology jointly with IV International Conference on Sustainability Science in Asia Conference, Canberra, Australia, February 2013.

## AWARDS ARISING OUT OF THIS THESIS

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- Swiss TPH Conference Fellowship Program. Swiss Tropical and Public Health Institute. 2013.
- Postgraduate Travelling Fellowships. Faculty of Health Sciences Research Committee, University of Adelaide. 2013.
- Adelaide Scholarship International, University of Adelaide. 2010-2014.

## LIST OF ABBREVIATIONS

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ABS	Australian Bureau of Statistics
ACS	American Cancer Society
ADM	Atmospheric Dispersion Modelling System
AF	Attributable fractions
ARI	Acute respiratory infections
BAU	Business-as-usual
BenMAP	Environmental Benefits Mapping and Analysis Program
BITRE	The Australian Bureau of Infrastructure, Transport and Regional Economics
CATI	Computer aided telephone interviewing
CI	Confidence interval
CNG	Compressed natural gas
CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
CO <sub>2</sub> -e	Carbon dioxide equivalent
CRA	Comparative Risk Assessment
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DALY	The disability-adjusted life year
dB	Decibel
DPTI	Department for Transport, Energy and Infrastructure
EC	Elemental carbon
EMMM	Expansion of the multi-city mortality and morbidity study
EPA	Environmental Protection Agency
EPA-MVEI	Environmental Protection Authority Motor Vehicle Emission Inventory database

ERG	Environmental Research Group
FPM/APM	Fine Particles/Aerosol Particle Mass Analyzer
GDP	Gross domestic product
GHGs	Greenhouse gases
HAPiNZ	Application of Health and Pollution in New Zealand
HEAT	Health Economic Assessment Tool
IPCC	International Panel on Climate Change
ITHIM	Integrated Transport and Health Impact Modelling Tool
LAEI	The London Atmospheric Emissions Inventory
LPG	Liquefied petroleum gas
MET	Metabolic equivalent task hours
Mton	Metric ton
NAEI	National Atmospheric Emission Inventory
NAM	Norm-activation model
NO <sub>2</sub>	Nitrogen dioxide
NO <sub>x</sub>	Nitrogen oxides
O <sub>3</sub>	Ozone
OECD	Organisation for Economic Co-operation and Development
OSPM	Operational Street Pollution Model
PAFs	Population attributable fractions
PBC	Perceived behavioural control
PM	Particulate matter
PM <sub>10</sub>	Particles with an equivalent aerodynamic diameter $\leq 10 \mu\text{m}$
PM <sub>2.5</sub>	Particles with an equivalent aerodynamic diameter $\leq 2.5 \mu\text{m}$
PROS	Population Research and Outcome Studies
QoL	Quality of life
RR	Relative risk



SA	South Australia
SDM	System dynamics modelling
SEM	Meta-analytic structural equation modelling
SIM-air	Simple Interactive Models for better air quality
SO <sub>2</sub>	Sulphur dioxide
TAPM	The Air Pollution Model
TAT	Towards Alternative Transport
TPB	Theory of planned behaviour
VAPIS	Vehicle Air Pollution Information System
VEPM	Vehicle Emissions Prediction Model
VKT	Vehicle kilometres travelled
VOCs	Volatile organic compounds
WHO	World Health Organization
YLD	Years lost due to disability
YLL	Years of life lost

# ABSTRACT

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## **Background**

The increasing number of motor vehicles in urban areas has a significant impact on the environment, as well as, on human health. Motor vehicle emissions contribute a considerable amount of energy-related greenhouse gases and cause non-negligible air pollution. In addition, over-dependence on cars has also encouraged a sedentary lifestyle and an obesity epidemic, which may lead to increased burden of diseases. These health and environmental costs of motor vehicle usage can be reduced by encouraging individuals to change their travel behaviours in order to increase their use of alternative transport. Such a strategy provides an opportunity for collaboration between people working in the transportation, environment and public health areas. However, limited studies currently exist to provide sufficient evidence for policy and interventions relating to this issue.

## **Aims**

The aims of the research presented in this thesis are to improve our understanding of the co-benefit effects of alternative transport and to investigate perspectives from communities and stakeholders on sustainable travel behaviour change in Adelaide, South Australia.

## **Methods**

A mixed-method study design was employed, with three interrelated studies conducted: two quantitative and one qualitative. The first study was focussed on a scenario-based modelling analysis. Separate models, including air pollution, health impact assessment, and traffic injury models, were developed in relation to scenarios for car reduction with

possible environmental and health outcomes, in order to evaluate the overall potential benefits of alternative transport.

The second study involved a cross-sectional survey conducted in the Adelaide metropolitan area. A total of 381 residents were interviewed using the computer-assisted telephone interviewing (CATI) system. Descriptive statistical analysis, factor analysis, Pearson correlations, and multiple logistic regressions were performed to investigate the relationships between participants' attitudes and their travel behaviours and to explore predictors of participants' intention to reduce car use.

The third study presented in the thesis adopted a qualitative approach to explore the perspectives of stakeholders relevant to changing transport behaviours. In-depth interviews with key stakeholders (n=13) were conducted, and a thematic analysis of the resulting transcripts identified some of the particular challenges that must be overcome in order to promote alternative transport.

## **Results**

Results of the first study indicated that the major health benefits associated with the promotion of alternative transport policies related to increased physical activity. In the increased cycling scenarios, it was found that a small shift from car travel to cycling would reduce the burden of disease related to physical inactivity by 17-34% (1991-4132 disability-adjusted life years [DALYs] prevented), compared with a Business As Usual scenario by 2030. Results indicated that important health benefits can also be achieved by increasing public transport use, which involves increasing walking distance and a possible reduction in serious traffic injuries. Although findings from this study do not suggest a large reduction in PM<sub>2.5</sub> concentration (0.1-0.4 µg/m<sup>3</sup>) associated with alternative

transport use, health benefits (39-118 DALYs prevented) from the reduction of air pollution exposure for the general population should not be ignored.

The results of the cross-sectional survey suggest that there are socio-demographic differences in people's dominant mode of transport, annual driving distance and car use frequency. In general, "Push" measures to reduce car use (e.g., increasing costs associated with driving) were considered less efficient than "Pull" measures (e.g., making alternative transport more attractive). In addition, people's attitudes towards traffic, the environment and health may influence their travel behaviours and intentions to reduce car use. Those who highly rated the importance of safety and comfort and who reported having more negative emotions towards public transport were likely to use cars more often and less likely to shift their travel mode. In contrast, those who indicated a high level of awareness of the benefits of alternative transport and of the problems of traffic were more likely to report an intention to shift travel mode and favour car reduction measures.

Key themes identified in the final qualitative study suggested that barriers to promoting active transport fall into four main areas: (1) existing gaps in knowledge of transport emission impacts, strategies from other countries and the overall benefits of alternative transport, (2) striking a policy balance between alternative transport strategies and economic viability, feasibility, population density, traffic demands, and budget distribution issues, (3) shared ownership of responsibilities, funding and regulations among governments and departments, and (4) public resistance to using alternative transport. Potential solutions suggested by participants to resolve these barriers included government actions, "Push" and "Pull" policy interventions, educational approaches, culture change and evidence-based research.

## **Conclusion**

Findings from the first study reveal that alternative transport use can produce considerable health benefits associated with increased levels of physical activity. This may lead policy makers to pay more attention to transport strategies which especially favour active transport, rather than strategies aimed solely at reducing vehicular emissions (e.g. elevating standards for emissions). The study also revealed that, to achieve significant health benefits through transport policy, travel behaviour change at the population level is essential. Findings from the second study provided a better understanding of current travel behaviour in the study setting. This study also suggested that public education and community campaigns focusing on local residents with sufficient knowledge of traffic issues and benefits of alternative transport, combined with car reduction barriers, could encourage less driving and more pro-environmental travelling. To take the alternative transport agenda forward, high level leadership and commitment from governments are needed to assist in establishing and building collaborative efforts. The findings of the third study fill a gap between policy intention and implementation, and highlight the importance of a ‘whole-of-government’ policy approach which can strengthen collaborations across relevant policy-makers.

## STATEMENT

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I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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# **CHAPTER 1**

## **Introduction**

---

## **1.1 Background**

With the rapid development of modern technology and urbanisation, there has been a progressive increase in the influx of motor vehicles into urban areas and a decrease in the use of public transport and active transports. Motor vehicles provide people with much greater mobility and accessibility in their daily life, but they also cause serious environmental and health issues (Gan et al. 2012; Lee et al. 2011; Tsai et al. 2010; Uherek et al. 2010).

Because of the significant consumption of fossil fuels, motor vehicles have been regarded as a major contributor of greenhouse gases (GHGs). With high levels of motor vehicle ownership, per capita GHG emissions due to transport in Australia are the fourth highest amongst Organisation for Economic Co-operation and Development (OECD) countries and more than four times the world average. Transport-related emissions contribute approximately 15% of Australia's net emission with passenger vehicles as the largest source (Australian Government Department of Climate Change and Energy Efficiency 2011). It has been estimated that emissions from the transport sector will increase rapidly and double by 2050 from the 2006 level (Garnaut 2008). According to Kyoto Protocol, Australia's national GHG target is to reduce 80 percent below 2000 levels by 2050 (Department of the Environment 2014). To achieve this target, each sector should have significant inputs in GHG management and strategies for the reduction of transport emission are required.

A second environmental problem caused by motor vehicle usage is air pollution. It is widely acknowledged that exhaust fumes from motor vehicles contain air pollutants such as nitrogen dioxide (NO<sub>2</sub>), volatile organic compounds (VOCs), carbon monoxide (CO) and particulate matter (PM). In Australia, transport-related emissions are also a major

source of air pollution (BITRE 2005). Significant associations have been found between population health and ambient air pollution in Australia (Hansen et al. 2009; Hinwood et al. 2006; Petroeschevsky et al. 2001; Simpson, R et al. 2000; Simpson, RW et al. 1997). The Australian Bureau of Infrastructure, Transport and Regional Economics (BITRE) (2005) reported that there were 900 to 2,000 premature deaths caused annually by transport-related ambient air pollution in Australia.

In addition to environmental issues, reliance on motorised vehicle transport also encourages a sedentary lifestyle, which is a major risk factor for non-communicable diseases. Researchers have been seeking ways to encourage people to drive less and be more active. As the most traditional travel modes, walking and cycling not only generate zero emissions but also help people to achieve the 30-min physical activity per day that is recommended (WHO 2010). Public transport, with large carrying capacity and low per capita emissions, is also recommended as an alternative to car use. Furthermore, walking in relation to public transport use also provides an opportunity to gain potential health benefits. However, researchers and policy-makers remain concerned that increasing numbers of pedestrians and cyclists might lead to more traffic injuries. Thus, investigation is continuing into whether the benefits of alternative transport outweigh the risks.

There are three main rationales for this research. First, whilst an increasing number of studies have been conducted to quantify the environmental and overall health impacts of car reduction and an increased in alternative transport travelling, most studies have been undertaken in the major cities of Europe and U.S. With Australia's specific landscape, traffic fleet, population density, and health status, the outcomes from alternative transport promotion may differ from previous studies conducted in other countries. A few

evaluations have also been carried out in Australia (Cobiac et al. 2009; Fishman et al. 2011; Mulley et al. 2013), but these studies were limited by focusing on cost and health benefits of active transport only and none of them factor in benefits from air pollution reduction or the use of public transport. Therefore, this thesis focuses on assessing the environmental and health impacts of alternative transport to facilitate transport policy decisions that are more effective in achieving co-benefit outcomes based on accurate and meaningful Australian evidence.

Secondly, Australia is overly dependent on motor vehicles, and this situation appears not to be levelling off. While nearly all Australian states have included alternative transport in their transport policy framework in an attempt to achieve further environmental outcomes, the modal share percentages of public transport and cycling have not increased significantly in recent years (Australian Bureau of Statistics 2012b). Consequently, a second area of focus for this thesis is how to effectively promote alternative transport use in Australia. Understanding the travel behaviour of the local community, especially the various factors that might affect transport choice, can be beneficial for setting out car reduction strategies and increasing the propensity of adopting alternative modes including public and active transport.

Third, responsibility for alternative transport promotion is shared among individuals, community groups, and governments. Travel behaviour change at a population level cannot take place overnight, especially when the broader environment (e.g. social, physical and policy environment) does not support change. In order to build a supportive environment, the role of governments must be strengthened since they are central to resource allocation, and the introduction appropriate transport policies, interventions and legislation. Currently, there is a large body of literature citing the key barriers that have an

impact on travel behaviour change. However, explorations of barriers to government policy-making and implementation are insufficient. Therefore, a third area of focus of this thesis is to improve our understanding of relevant stakeholders' perspectives.

## **1.2 Research aim and questions**

The overall aim of this thesis is to quantify the co-benefits of promoting alternative transport on the environment and population health, and to investigate community and stakeholders' perceptions of alternative transport use, in order to inform future health promotion campaigns, as well as transport policies and urban planning for a sustainable future.

The research questions addressed in this thesis are as follows:

1. Comparing to business-as-usual (BAU), what are the future environmental and health benefits in choosing alternative transport scenarios, and to what extent can such co-benefits be obtained?
2. What are the key factors that can affect individuals' current travel behaviour and predict their intention to change travel behaviour?
3. What are relevant stakeholders' perceptions and knowledge regarding facilitators and barriers in promoting alternative transport in this area?

## **1.3 Thesis outline**

This thesis is set out in following six chapters:

Chapter 2, published as a paper in the *Journal of Environmental and Public Health*, provides further background on the evidence regarding the health and economic co-

## *Chapter one*

benefits of alternatives to motor vehicles travel through a comprehensive literature review of international and Australian studies. The methodological issues faced in previous studies in this field are also been discussed in Chapter 2.

Chapter 3 summarises current knowledge about the factors which influence individual travel behaviour, and discusses how transport policy can facilitate car use reduction and alternative transport promotion.

Chapter 4 presents an overview of the study design for the research presented in this thesis. It includes a description of the geography, demographics and transport use of study region, an explanation of the research framework, and a justification of methodologies used in this project.

Chapter 5, published as a paper for publication in *Environmental International*, focuses on addressing the first research question of the thesis. It uses a air pollution model to quantify GHGs and PM reductions from replacing passenger vehicle usages with public transport and active transport. It also assesses potential health impacts associated with this change to alternative transport by using health impact assessment and traffic injury models.

The second research question of the thesis is addressed in Chapter 6 through the presentation of results of a cross-sectional survey. The survey's objectives were to investigate residents' current travel behaviour in the study region, and to examine how demographic and attitudinal factors affect their travel behaviour and their intention to reduce car use.

Chapter 7 addresses the third research question by engaging key stakeholders' perspectives as they are relevant to changing transport behaviours. This qualitative study

seeks to identify some of the particular barriers that need be overcome to promote alternative transport in Australia.

The final chapter (Chapter 8) provides a general discussion and summary of the previous chapters, highlighting the key findings, strengths, limitations, and providing recommendations for policy making and further research directions.

This thesis is presented as a combination of text in chapter format (Chapter 3-4 and Chapter 5-8) and peer-reviewed journal papers that have been already published (Chapter 2 and Chapter 5).





## CHAPTER 2

### Literature review one

#### Co-benefits of replacing car trips with alternative transportation: a review of evidence and methodological issues

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##### Preface

This chapter contains the first of two in-depth literature reviews contributing to this thesis. It is a comprehensive literature review of recently published international and Australian studies regarding the environmental, health and economic impacts of alternatives to car travel. The epidemiological evidence is presented and methodological issues faced in previous studies are discussed. The chapter also provides some recommendations for further research. This review has been published in *Journal of Environmental and Public Health* (Appendix H) .

## STATEMENT OF AUTHORSHIP

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### **Co-benefits of replacing car trips with alternative transportation: A review of evidence and methodological issues**

*Journal of Environmental and Public Health*, 2013: 1-14

#### **Ting Xia (Candidate)**

Conceived and designed the review and the manuscript orientation and structure, carried out the literature review, extracted findings from literature, interpreted findings, drafted and critically revised the manuscript.

Signed.....Date.....

#### **Ying Zhang**

My contribution to this paper involved: Contribution to conception and design of the review, assistance with extraction of findings from literature and manuscript evaluation. I give consent for Ting Xia to present this paper for examination towards the Doctor of Philosophy.

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My contribution to this paper involved: Contribution to conception and design of the review, and manuscript evaluation. I give consent for Ting Xia to present this paper for examination towards the Doctor of Philosophy.

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## **2.1 Abstract**

It has been reported that motor vehicle emissions contribute nearly a quarter of world energy-related greenhouse gases and cause non-negligible air pollution primarily in urban areas. Reducing car use and increasing eco-friendly alternative transport, such as public and active transport, are efficient approaches to mitigate harmful environmental impacts caused by a large amount of vehicle use. Besides the environmental benefits of promoting alternative transport, it can also induce other health and economic benefits. At present, a number of studies have been conducted to evaluate co-benefits from greenhouse gas mitigation policies. However, relatively few have focused specifically on the transport sector. A comprehensive understanding of the multiple benefits of alternative transport could assist with policy making in the areas of transport, health and environment. However, there is no straightforward method which could estimate co-benefits effect at one time. In this review article, the links between vehicle emissions and air-quality, as well as the health and economic benefits from alternative transport use, are considered, and methodological issues relating to the modelling of these co-benefits are discussed.

## **2.2 Introduction**

Over the last century, the number of motor vehicles built, purchased and used on roads globally has dramatically increased to meet people's travel demands. Although alternative fuels have been developed, more than 95% motor vehicles are still dependent on fossil fuels; a dependency which does not seem to be abating (Fulton 2004; Priddle 2002). Because of the large consumption of fossil fuels, transportation is regarded as a major contributor of greenhouse gases (GHGs). According to research conducted by Ribeiro and colleagues (2007), a quarter of world energy-related GHG can be attributed to transportation and nearly 85% of transportation-related GHG is exhausted by land transportation. Furthermore, it is predicted that transport energy usage will continue to increase at a rate of about 2% per year worldwide, whilst total transport energy usage and carbon emissions will be 80% higher than its current levels by 2030 (Kahn Ribeiro et al. 2007).

It is widely acknowledged that exhaust fumes from motor vehicles contain a variety of air pollutants such as nitrogen dioxide (NO<sub>2</sub>), volatile organic compounds (VOCs), carbon monoxide (CO) and particulate matter (PM). Although the contribution of road transport to local pollution may vary depending on distinct local features, such as geographic and climatic features, the technology distribution of the national fleet, driving patterns and density (Huo et al. 2011), vehicle emission is no doubt a significant source of air pollution, especially in highly car-dependent cities. The European Topic Centre on Air and Climate Change 2005 data (2005) demonstrate that road transport accounts for about 42% of total NO<sub>x</sub> (NO and NO<sub>2</sub>), 47% of total CO and 18.4% of total PM emissions at European Union of 15 member states.

To reduce the emissions from motor vehicles, mitigation strategies have been implemented in various countries. These mitigation strategies could be summarised as falling into three main approaches: 1) renovation of new vehicle technology, such as developing new energy sources for motor vehicles and elevating standards for emissions (Cao and Emadi 2012; Tanaka et al. 2012); 2) improvement of land use and urban planning, such as an establishment of bus rapid transit systems (Sayeg and Bray 2012); and 3) travel behaviour change promotion in terms of promoting sustainable alternative transport use, such as public transport and active transport (e.g., cycling and walking), which has been a common approach in some European cities (Buehler and Pucher 2012b). Besides the direct-core environmental benefit, the mitigation strategies of reshaping transport patterns via promoting mass transit and active transport have been increasingly recognised as an opportunity to gain great co-benefits. The definition of a co-benefit is “an additional benefit arising from an action that is undertaken for a different principal purpose” (OEH 2011). For example, both public transport and active transport will result in less dependency on fossil fuels and a reduction in traffic congestion. As a result of restricting vehicle use, air quality could be significantly improved and the health issues caused by air pollution could be alleviated. Additionally, active transport, in particular, also provides health benefit through regular physical activities. Moreover, economic improvements could also be gained from reduction of car use.

Exploring and understanding these co-benefits might provide invaluable information to policy makers in transport and land planning. However, to date, little research has been conducted in these areas. In order to improve understanding of the advantages of alternative transport, this paper aims to review, (1) the evidence regarding the health and economic co-benefits of alternatives to car travel, and (2) the methodological issues faced in previous studies in this field. Recommendations for further research are then discussed.

## **2.3 Method**

A literature search for reviewing papers published in English between 2002 to March 2013 was conducted using the main research databases PubMed, Scopus, Web of Science and Google scholar along with searching of references on relevant organisations' websites including World Health Organization, the International Panel on Climate Change (IPCC) and relevant transport department websites. The search focused on two purposes: first, a review of the broad literature relevant to effects of vehicle emissions in order to summarise benefits of alternatives to car travel. The search was conducted using a combination of keywords as follows: land/road transportation, vehicle emission, transport/traffic emission, air pollution, air quality, car trips, alternative transport, public transport, active transport, bicycling, cycling, and walking. The second purpose of focus was "co-benefits" studies, specifically in the transport sector. The major goal at this stage was to identify specific studies which conduct multiple benefits evaluation of alternative transport scenarios. These "co-benefits" papers were reviewed for specific issues within the methodology of modelling co-benefit effects from alternative transport scenarios. Review of methodological issues in the "co-benefits" studies were identified according to following criteria: (i) whether the studies focused on transport sector; (ii) whether multiple benefits of alternative transport scenarios were evaluated, and (iii) whether projective models were used. Exclusion criteria were applied: First, those focused on the whole energy system rather than transport system; second, studies only evaluating single benefit of alternative transport scenarios and review papers. Except for unavailable papers, five "co-benefits" studies were identified and are listed in Table 2.1 with a summary of the scenario design, target populations, modelling method/tools, environmental and health indicators and main findings.

Table 2.1: Summary of co-benefits studies in transport area

Reference	Study design	Methodological of modelling									Results
		Environmental impact assessment			Health impact assessment			Economic impact assessment			
Author, Year, study sites	Scenarios	Method/tools	Indicators	Key parameters resource	Method/tools	Indicators	Key parameters resource	Method/tools	Indicators	Key parameters resource	Main finding
Woodcock et al. (2009)	BAU 2030	London: ERG Emissions Toolkit ADMS OSPM v5.0.64	Annual mean PM <sub>10</sub> & PM <sub>2.5</sub> concentrations	London: LAEI 2006	CRA	Annual preventable DALYs of Cardio-respiratory Lung cancer Acute respiratory infections (air pollution reduction)	Global Burden of Disease Database Meta-analyses from an exhaustive literature review	London: London-area travel demand models			London : 60% reduction in transport CO <sub>2</sub> emissions from 1990 levels; 7439 DALYs per million per million population would be avoided (Towards sustainable transport scenarios)
London, UK, and Delhi, India	Lower-carbon-emission motor vehicles (more efficient engines and fuels switching)  Increased active travel (increasing walking and cycling)  Towards sustainable transport (lower-carbon-emission motor vehicles and increased active transport scenarios)	Delhi: SIM-air Version 1.3		Delhi: Inventory of aerosol and sulphur dioxide emissions from India		Diabetes Dementia Hypertensive heart disease Cerebrovascular disease Breast cancer Colorectal cancer Depression (increased physical activity)	London: London Area Travel Survey			Delhi: 199% increase in CO <sub>2</sub> emissions from 1990; 12,995 DALYs per million population would be avoided (Towards sustainable transport scenarios)	
Lindsay et al. (2010)	Moving short urban trips (<7 km) from cars to bicycles by 1%, 5%, 10% and 30%	VEPM version 2.3	Vehicle emissions per km for CO <sub>2</sub> , NO <sub>x</sub> , VOC, and PM <sub>10</sub>	HAPiNZ study	HEAT	Annual reduction in deaths Energy expenditure	New Zealand Household Travel Survey HAPiNZ study	HEAT	Value of Statistical Life Fuel savings (\$NZ)	HAPiNZ study Ministry of Transport's Value of Statistical Life	Shifting 5% of vehicle kilometres to cycling would: save 22 million litres of fuel; reduce transport-related GHGs by 0.4%; avoided 122 deaths annually due to increased physical activity and local air pollution reduction; save \$200 million per year from health effect.

Table 2.1: Continued.

Reference	Study design	Methodological of modelling									Results
		Environmental impact assessment			Health impact assessment			Economic impact assessment			
Author, Year, study sites	Scenarios	Method/tools	Indicators	Key parameters resource	Method/tools	Indicators	Key parameters resource	Method/tools	Indicators	Key parameters resource	Main finding
Rojas-Rueda et al. (2012)	BAU Replacing car trips (20%, 40%) by bicycle Greater Barcelona metropolitan area Replacing car trips (20%, 40%) by public transport (bus, tram, train and metro) Replacing car trips (20%, 40%) by bicycle and public transport	Barcelona Air-Dispersion Model	PM <sub>2.5</sub> concentration CO <sub>2</sub> emission	Barcelona City council report 2009 Local transportation departments	RR functions in PM <sub>2.5</sub> HEAT	All-cause mortality	Daily Mobility Survey of Catalonia Statistical Institute of Catalonia Published literature				A shifting of 40% car trips to cycling and public transport would: avoid 98.5 deaths in total and reduce 203,251 t/CO <sub>2</sub> emissions per year.
Grabow et al. (2012)	Replacing short car trips (≤ 8 km round trip) in urban areas by bicycle Midwestern United States	Community Multiscale Air Quality Model version 4.6 BenMAP version 4.0.35	Mean annual PM <sub>2.5</sub> and O <sub>3</sub> concentration	2001 National Emissions Inventory U.S. EPA	BenMAP HEAT	Air pollution reduction: Mortalities of Asthma Chronic bronchitis Respiratory problems Cardiovascular problems Work-loss days Acute respiratory symptoms ER visits Mortality HA (respiratory) School-loss days Worker productivity  Increased physical activity: All-cause mortality	1996 National Health Interview Survey Published literature U.S. EPA	BenMAP HEAT	Cost savings	U.S. EPA	Eliminating short car trips and completing 50% of them by bicycle would: decline mean annual PM <sub>2.5</sub> by 0.1 µg/m <sup>3</sup> ; decline mortality by 1,295 deaths/year in 31.3 million people because of improved air quality and increased exercise.  Combined benefits of improved air quality and physical fitness would exceed \$8 billion/year.

Table 2.1: Continued.



Reference	Study design	Methodological of modelling									Results
Author, Year, study sites	Scenarios	Environment impact assessment			Health impact assessment			Economic impact assessment			Main finding
		Method/ tools	Indicators	Key parameters resource	Method/ tools	Indicators	Key parameters resource	Method/ tools	Indicators	Key parameters resource	
Maizlish. et al (2013) San Francisco Bay Area	BAU 2035 Low-carbon driving (increased hybrid vehicles and light-duty diesel, biofuel, and electric vehicles) Active transport (50% of BAU miles travelled in car trips less than 1.5 miles are walked and 50% of BAU miles travelled in car trips 1.5 to 5 miles are bicycle)	EMFAC2007 BAAQMD air shed model	CO <sub>2</sub> emissions Annual PM <sub>2.5</sub> concentration	California Air Resources Board Bay Area Air Quality Management District	CRA	Air pollution reduction: Lung cancer, Respiratory disease  Increased physical activity: Annual preventable DALYs of Cardiovascular diseases, Colon cancer, Breast cancer, Diabetes, Dementia	Global Burden of Disease Database 2000 Bay Area Travel Survey Meta-analyses				Increasing active transport scenario would: reduce 5,952 DALYs per million people in total; increased the traffic injury burden by 39% (5,907 DALYs); decrease GHGE by 14%.  Low-carbon driving scenario would: reduce 31 DALYs per million people in total; reduce GHGs by 33.5% .

Abbreviations: BAU: Business as usual;  
 ERG : Environmental Research Group;  
 ADMS : Atmospheric Dispersion Modelling System;  
 OSPM: Operational Street Pollution Model;  
 SIM-air: Simple Interactive Models for better air quality;  
 LAEI: The London Atmospheric Emissions Inventory;  
 DALY: The disability-adjusted life year;  
 VEPM: Vehicle Emissions Prediction Model;  
 HAPiNZ: Application of Health and Pollution in New Zealand;  
 HEAT: Health Economic Assessment Tool;  
 BenMAP: Environmental Benefits Mapping and Analysis Program;  
 EPA: Environmental Protection Agency;  
 EMFAC: Emission Factors model;  
 BAAQMD: Bay Area Air Quality Management District

## **2.4 Public transport**

Public transport, such as bus and train, is extensively used as a dominant travel mode in developing countries. Compared to private cars, public transport has a larger carrying capacity. Trams, trains and subways rarely get stuck in traffic congestion and bus schedule can be flexibly arranged, with multiple buses able to travel the same route simultaneously, in response to peak times or to cater for special events (Hickman et al. 2010; Parikesit and Susantono 2013). Although public transport is not defined as a “zero-pollutant” travel mode, its average emissions per passenger are far lower than that from cars. Furthermore, cleaner and more fuel efficient public transport is becoming more common in many countries, supporting a further reduction of GHG emissions and air pollution. For example, Compressed Natural Gas (CNG) buses have been used in several countries, such as U.S., Brazil, Argentina, Italy, Pakistan and New Zealand, for many years (Bhattacharjee et al. 2010). Additionally, walking to and from public transportation may help physically inactive populations achieve the recommended level of daily physical activity. A U.S. study found that 29% of people who use public transit could achieve  $\geq 30$  minutes of physical activity a day solely by walking to and from transit (Besser and Dannenberg 2005). A systemic review conducted by Rissel et al (2012) reported that public transport usage could increase physical activity per day by a range of 8–33 minutes. Public transport may not be attractive for local residents as private cars because it is less flexible and can take longer to travel to one’s destination. Therefore, buses or trams are often not considered as a real alternative to cars. However, these problems could be counteracted by creating priority systems for public transport for traffic lights, and building quality bus corridors or priority routes, which have been implemented in many countries such Korea, U.S. and Australia (Jun 2012; Mees and Dodson 2011; Panero et al. 2012; Poole Jr et al. 2012). Despite such government

initiatives, public transport trips continue to account for only a small portion of total trips in many urban areas. In London and Sydney, for example, only about 10% of all trips are made by public transport, while over 70% of all trips are made by car (Avery 2011; Bureau of Transport Statistics 2012).

## **2.5 Active transport**

Active transport is another attractive environmentally-friendly transport alternative, particularly for short journeys. Active transportation, including travelling on foot, and by bicycle and other non-motorised transport, is recognised as largely “zero-pollutant”, with respect to emissions of the travel itself (emissions are produced in the building, distributing and servicing of bicycles, for example). The other advantage of the active transportation is flexible (or non-existent) parking considerations and lower cost. At the moment, a large proportion of the total trips in most European cities are shorter than 2.5 km which is a distance relatively easy to be replaced by active transport: 44% in the Netherlands, 37% in Denmark, 41% in Germany, and 30% in UK (Pucher and Buehler 2008). Short trips also occupy a considerable percentage of total travel trips in major Australian cities. Taking Sydney as an instance, 20% of all trips made on an average weekday are less than 1 km, 35% are less than 2 km and 60% are less than 5 km, which has been considered to be a suitable distance for walking or cycling (Bureau of Transport Statistics 2012). However, the number of trips made by walking and cycling have declined significantly over the last 20 years (UK Department for Transport 2004). It has been reported that cycling only occupies less than 3% of the total travel trips in some cities in UK, USA and Australia (Bureau of Transport Statistics 2012; Pucher and Buehler 2008; South Australian Government 2002). This decline in cycling strongly reflects a high reliance on motor cars in modern society.

Despite the significant decline in the number of trips made by active transport, government efforts can play a considerable role in active transport promotion. It is estimated that a 52% increase in bicycle trips could be achieved in Australia by 2016, and a 71% rise by 2026 under a collaboration among the Australian Local Government Associations (2010). Given growing environmental concerns, many developed countries have conducted cycling promotion programmes to encourage active transportation. Countries like Netherlands, Denmark, and Germany have been very successful in this endeavour. From 1950 to 1975, the percentage of trips using cycling decreased significantly by two-thirds in Netherlands (from 50%–85% of trips in 1950 to only 14–35% of trips in 1975) and Germany (fell by 78% from 1950 to 1975), as car ownership surged and cities started spreading out (Pucher and Buehler 2008). However, during that 25-year period, the governments of these countries focused on improving their cycling infrastructure, whilst imposing restrictions on car use; subsequently, the cycling share of trips increased by 25%. Currently, over 30% of trips to work or school are made by bicycles in Netherlands and Denmark, whilst this percentage in Germany is 28% (Pucher and Buehler 2008).

## **2.6 Evidence of potential benefits of promoting alternative transport**

### **2.6.1 Environmental benefits**

More than half of the world's population lives in urban areas and it has been estimated that the global urbanised population will reach five billion by 2030 (Martine and Marshall 2007). Accordingly, air quality will be significantly affected due to increasing travel demands and related motor vehicle usage. However, air quality could be largely improved by implementing appropriate traffic controlling strategies especially in urban areas.

During the 2008 Beijing Olympic Games (Wang, T and Xie 2009), for instance, most Beijing residents chose public transit or cycling as their dominant mode of transport because a large portion of private and business cars were restricted in use by Olympic traffic management. Consequently, a noteworthy reduction of traffic flow was noticed during the Olympic traffic control days and on-road air quality improved significantly: The average reduction rates of PM<sub>10</sub>, CO, NO<sub>2</sub> and O<sub>3</sub> reached 28%, 19.3%, 12.3% and 25.2%, respectively (Wang, T and Xie 2009). Similarly, a three-month traffic restriction implemented during the Sino-African Summit was a remarkable success in air pollution control, reducing 40% NO<sub>x</sub> emissions in Beijing (Wang, Y et al. 2007). Throughout the period of the 1996 Atlanta Olympic Games, as a result of traffic restrictions, peak daily ambient ozone concentrations dropped by 30% from the baseline measure, which led to a significant decrease of asthma cases (Martine and Marshall 2007). Therefore, reducing motor vehicle usage can improve air quality with immediate short-term effect.

## **2.6.2 Health benefits**

### **2.6.2.1 Health benefit from mitigation of vehicle emission reduction**

Transportation has been identified as being partly responsible for GHG effects, given that the emissions from motor vehicles contain large amounts of CO<sub>2</sub>, NO<sub>x</sub> and CH<sub>4</sub>. Furthermore, it has been proven that GHG effect is the main cause of global warming. Cross-sectional studies conducted in different regions have shown that thousands of excess deaths could be caused with the increased frequency and intensity of extreme weather (Bai et al. 2013; Gamble et al. 2013; Nitschke et al. 2011). On the other hand, according to a recent WHO report, approximately 1.3 million premature deaths worldwide are attributed to outdoor air pollution in 2009 (WHO 2012). Therefore, health impacts of vehicular air pollution have also attracted more and more public attention and

academic research, with an increasing number of studies investigating the association between proximity to roads and population health. They reported that pollutant concentrations are higher in areas closer to motorways and decline gradually with distance from motorways (Gordon et al. 2012; Van Poppel et al. 2012) and increasing mortality and morbidity have been observed in populations living near major roads (Gan et al. 2012; Gan et al. 2010; Tsai et al. 2010). Particularly, a Dutch cohort study enrolling 12,852 subjects with 10 years follow up illustrated that traffic intensity on the nearest road would increase mortality of natural causes, cardiovascular, respiratory, and lung cancer by 5%, 4%, 22% and 3%, respectively (Beelen et al. 2008). Similarly, people living close to major roadways have an increased risk of coronary mortality (Gan et al. 2011). In contrast, the risk has been found to decrease gradually when people move away from major roadways.

Transport-specific behavioural change programmes, including increasing mass transit use and active travel, are essential in relieving these adverse health effects. Woodcock and colleagues (2009) evaluated the environmental and health benefits of various alternative transport scenarios by 2030 in London, UK, and Delhi, India. Their research indicated that about hundreds premature deaths and thousands of disability-adjusted life-years (DALYs) caused by air pollution could be saved under alternative transport scenarios by 2030. Another study conducted in Mexico City evaluated five control options for the Program to Improve Air Quality in the Valley of Mexico: taxi fleet renovation, metro expansion, hybrid buses, Liquefied Petroleum Gas (LPG) and cogeneration (McKinley et al. 2005). The results showed that these five measures together could reduce approximately 1% PM<sub>10</sub> exposure, 3% maximum ozone exposure and more than 1.5 Mton (Metric Ton) CO<sub>2</sub> equivalent emissions. Additional to the environmental benefits, these

measures could also save nearly 100 lives and reduce 700 cases of chronic bronchitis each year.

### **2.6.2.2 Health benefit from active transport**

Another potential health co-benefit comes from increased physical activity associated with active transport. According to *Global Recommendations* (WHO 2010), adults aged 18–64 years should do at least 150 minutes of moderate-intensity aerobic activity per week. A person who walks or cycles 150 minutes a week or 30 minutes per week day could be grouped in the population conducting regular physical exercise on the basis of the World Health Organization (WHO) recommendation. Although such guidelines for physical activity have been provided for a long time, sedentary lifestyles still remain a global public health problem. To date, physical inactivity has been regarded as one of the most risky behavioural factors contributing to disease burden, especially in developed countries (Begg, S. et al. 2007b).

#### *2.6.2.2.1 Active transport, physical activity and health benefits overall*

Active transport such as walking and cycling provide an opportunity to incorporate frequent physical activity into daily living, which could help people achieve recommended levels of physical activity. Moreover, various evidence of a positive association between active transport and health outcomes has been published (Faulkner et al. 2009; Knut et al. 2011; Rissel et al. 2012; Thompson et al. 2003; Wen and Rissel 2008; Woodcock et al. 2011). For example, a recent systematic review (Oja et al. 2011) summarised evidence of the health benefits of cycling and reported a strong inverse relationship between commuter cycling and all-cause mortality, cardiorespiratory fitness, cancer mortality and morbidity, and a clear positive dose–response relationship between the amount of cycling and body fitness, and incidence of overweight and obesity decrease.

Another systematic review conducted by Woodcock et al (2011) reported a reduction in mortality risk of 19% in populations who have 30 minutes daily of moderate intensity activity on 5 days per a week, compared with those people with no activity. A longitudinal study among Scandinavian adults, for example, found that all-cause mortality rates in moderately and highly active persons decreased by 50% when compared to a sedentary group of people (Andersen et al. 2000). In addition, this study suggested that cycling to work would reduce the risks of all-cause mortality by approximately 40%. A study conducted in Copenhagen followed up a health cohort including 13,375 women and 17,265 men for nearly 15 years. The main finding of this study suggested that cycling to work can decrease the risk of all-cause mortality by 40%, including leisure time physical activity (Andersen et al. 2000). A similar result was reported in a Chinese cross-sectional study showing that women who regularly did physical exercise or used a bicycle as transportation could attain a 20–50% lower risk of premature mortality (Matthews et al. 2007). Furthermore, Australian research revealed that a 5% increase in the proportion of people doing 30 minutes moderate activity each day could save around 600 lives per year, which could significantly reduce health expenditure to the health system (Stephenson et al. 2000).

#### *2.6.2.2.2 Active transport, physical activity and benefits relating to specific conditions*

Moderate intensity physical activities, including walking and cycling, have also been demonstrated to decrease the morbidity of many chronic diseases such as diabetes, cardiovascular disease, breast cancer, colon cancer and dementia (Hamer and Chida 2009; Jeon et al. 2007; Monninkhof et al. 2007; Oguma and Shinoda-Tagawa 2004; Woodcock et al. 2009). Jeon and colleagues (2007) reviewed 10 prospective cohort studies to estimate the effect of physical activity of moderate intensity on type II diabetes. They



found that the risk of type II diabetes was 31% less for participants who engaged in regular moderate intensity physical activity, with 30% less risk among a regular walking population compared with almost no walking (Jeon et al. 2007). Xu et al (2013) systematically examined the relationship between active transport to work or school and cardiovascular health. A significantly positive association between active transport to work or school and cardiovascular health have been found in this review. Furthermore, another systematic review conducted by Monninkhof and colleagues reported regular exercise might reduce the risk of postmenopausal breast cancer by 20%-80%, with each additional hour of physical activity per week potentially resulting in a further 6% reduction in breast cancer risk (Monninkhof et al. 2007).

### **2.6.2.3 Active transport, physical activity and benefits relating to fitness and weight**

Body fitness can also be strengthened by prompting active transport. A British study compared the physical condition of children who walked or cycled to school compared with those who travelled by bus or car. Their finding revealed that the former group was fitter than the latter one, with 30% higher vigour in boys who took active transport and seven times higher in girls (Voss and Sandercock 2010). It is estimated that approximately 40 million children and 1.4 billion adults are either overweight or obese worldwide (WHO 2013b). Active travelling may be regarded as an efficient approach to combat obesity. Indeed, a synthesised result from the systematic review conducted by Xu et al also reported that more active transport to work or school have been found associated with lower body weight (Xu et al. 2013). Moreover, an Australia study conducted by Wen and Rissel (2008) suggested that men who drove to work were more likely to be obese or overweight compared with those who chose cycling. Recent research investigating the obesity levels in Europe, North America and Australia established an inverse relationship

between active transport levels and obesity levels in the population (Bassett et al. 2008). The results suggested that active transport might be one of the important factors contributing to international differences in obesity rates (Bassett et al. 2008).

### **2.6.3 Economic co-benefits**

In addition to environmental and health benefits, economic benefits can also be obtained through alternative transport promotion. At the moment, the majority of motorised vehicles are highly dependent on fossil oil and consume almost 50% of total fossil oil usage (Woodcock et al. 2007). The over-reliance of motorised vehicles on petroleum not only causes concern regarding GHG emissions but also leads to non-renewable energy sources diminishing. Apparently, the fossil oil cost would be reduced with the reductions of vehicle kilometres travelled and the increase of alternative transport (Bollen et al. 2009). In addition, with the decrease in the vehicle kilometres travelled and fuel use, the costs of air pollution control would also be reduced correspondingly. Although the per kilometre air pollution and climate change costs of public transport are higher when compared with private transport, the costs per passenger of public transport are significantly less than that of private transport due to the large number of private cars (Jakob et al. 2006).

A New Zealand case study estimated the total costs of private and public transport in Auckland, with particulate matter as the transport-related air pollution indicator. Their finding demonstrated that a  $PM_{10}$  value of  $16 \text{ mg/m}^3$  caused by motor vehicle exhaust led to additional illnesses and amounted to a cost of \$422 million in 2001, which was equal to 57% of the total health cost arising from  $PM_{10}$  in the Auckland region (Jakob et al. 2006). Further analysis on these additional costs revealed that \$211.6 million (of the \$422 million) came from private transport, whereas only \$17.2 million was contributed by

public transport. A similar trend was also observed when the authors calculated the total climate change costs from private cars and public transport using a unit cost per tonne CO<sub>2</sub>. By this standard, the total costs from transport were \$58.4 million, with \$0.67 million coming from public transport and \$57.8 million from private transport (Jakob et al. 2006). In addition to the cost reduction in fossil oil usage and air pollution control, economic benefits of alternative transport may also be achieved by reducing mortality and morbidity. In Australia, it has been reported that the combined economic cost of traffic-related mortality and morbidity was approximately \$2.7 billion in 2000. More than 85% of this cost was incurred in capital cities, which covered 80% of Australian populations (Bureau of Transport and Regional Economics 2005).

Previous studies have also suggested that negative health outcomes caused by physical inactivity (related to car travel, rather than alternative transport) might lead to increased medical expenditure as well. Recent estimates indicate the direct and indirect costs are \$13.8 billion for physical inactivity (Stephenson et al. 2000), and \$21 billion for obesity and overweight in Australian (Colagiuri et al. 2010). To investigate the economic benefit from active transport, Grabow et al (2012) modelled the impact on the health budget of eliminating short motor vehicle trips in 11 metropolitan areas in the upper mid-western United States. They estimated that the combined benefits of improved air quality and physical fitness would exceed \$8 billion/year.

## **2.7 Methodology issues in co-benefit analysis**

### **2.7.1 Scenarios**

To predict the co-benefits of alternative transportation modes, it is fundamental to set up alternative/active transportation scenarios for analysis. Alternative scenarios are designed

not only based on the researcher's assumptions but also in relation to local transport circumstances. Although there are a variety of alternative transport choices, such as bus, taxi, hybrid vehicle and bicycle, most researchers tend to choose eco-friendly and healthy modes to evaluate the co-benefit effects. In current co-benefit studies (as seen in Table 2.1), the alternative transport scenarios were built from different perspectives and different assumptions were made with a consideration of uncertainties. However, those assumptions must be reliable, practical and achievable. For instance, in a U.S. study (Grabow et al. 2012), all short car trips ( $\leq 8$  km) were assumed to be eliminated and they made this scenario based on a census-tract level travel. Similarly, Woodcock et al (2009) compared a BAU with alternative scenarios in 2030 in London, UK, and Delhi, India for their co-benefit analysis. In their study, because of the different traffic structure, they then modelled different alternative transport scenarios for each city. Obviously, it is not practical to assume that 100% of car trips will be made by cycling or public transport. It would be preferable, instead, to base scenarios on an understanding of local traffic conditions and future transport plans or policies of local authorities, although the challenges in doing this are acknowledged

## **2.7.2 Modelling method and tool**

### **2.7.2.1 Environmental benefit assessment**

In transport related co-benefit studies, the estimation of the emissions change from motor vehicle reduction is a vital component of the environmental impact assessment. There are various vehicle emission models which could be used in co-benefit analysis appropriately. However, data requirements and modelling approaches may vary for each model and it is difficult to judge which one is the best. Generally, the ideal model should be adapted to the target application and the changing demand. In addition, the model should be used

either to examine relative changes from different scenarios or to predict absolute levels of emissions under a given period and location (Wang, H and Iain 2009). Furthermore, it is also vital for researchers to model emissions with tools corresponding to local traffic situations. For example, the UK study (Woodcock et al. 2009) modelled the vehicle emissions in London by using the Emissions Toolkit developed by the Environmental Research Group from King's College, which provided detailed transport emission data for over 6,000 roads in London. In the New Zealand study (Lindsay et al. 2010), the researchers used the Vehicle Emissions Prediction Model (VEPM), which was developed by Auckland Regional Council as their own emission model, to calculate the average light vehicle emissions. Rojas-Rueda (2012) and Grabow, M.L (2012) also used local air pollution model to assess the health impacts of changing in PM concentrations in Barcelona and Midwestern United States under the car trips reduction scenario.

Other general tools could be used to estimate the change in emissions if there is a lack of local air pollution modelling tools. A new generation of emission models, including the Vehicle Air Pollution Information System (VAPIS) model and the Simple Interactive Models for better air quality (SIM-air), have been developed recently (Guttikunda 2011) as user-friendly spread sheet based tools. One of the advantages of these models is that only basic local traffic parameters are required, such as baseline vehicular numbers, average annual vehicle growth rates, average vehicle travelled kilometres and emission factors. Therefore, these models can still be applied when available data are limited. For example, the SIM-air Model was used to estimate PM<sub>2.5</sub> for Delhi where local traffic data were incomplete in the UK study (Woodcock et al. 2009). Although the emission trends analysis can be performed easily, the estimations generated from these tools are relatively crude. It is also impossible for the SIM-air Model to assess the impact on emissions induced by traffic-management schemes, such as speed

restriction, roundabouts, signal coordination, or road widening. Despite the limitations, however, these tools still remain a substitute when detailed local traffic information is not available for co-benefit analyses.

In co-benefit studies, the selection of an air pollutant index related to vehicles should have a close association with population health impact. Although air pollutants are various, it is not necessary to model all the vehicle pollutant emissions since air pollution-related diseases are often caused by one or two dominated pollutants (Jalaludin et al. 2009). PM is a complex mixture of extremely small particles and liquid droplets. It can be of organic or inorganic origin and includes airborne dust particles, soot and hydrocarbons from combustion processes, metal residues, fibres, and sulphate or nitrate compounds (Government of South Australia 2005). Moreover, there have been much strong evidences, relating to proving the dose-response relationship between PM and health outcomes (Dominici et al. 2006; Gan et al. 2011; Hertel et al. 2008; Wong et al. 2002). Thus, to avoid double counting, the WHO suggests using PM<sub>10</sub> and PM<sub>2.5</sub> as the indicators of air pollution exposure. All co-benefit studies we reviewed in this review chose PM<sub>10</sub> or PM<sub>2.5</sub> concentration as the major air pollution exposure indicator in their health impact assessment section.

### **2.7.2.2 Health benefit assessment**

Health benefit assessment is another critical element in co-benefit studies. A scoping method was recently developed by the IPCC and WHO, in conjunction with other international organisations, to estimate the health impact from greenhouse mitigation strategies (Zhao et al. 2007). This method was then modified slightly by Smith and Haigler to remain consistent within energy co-benefit studies (Smith and Haigler 2008). The development of these scoping methods has made it possible to extend co-benefits

analyses to more sophisticated assessments. In the scoping methods, Comparative Risk Assessment (CRA) plays an essential role evaluating the health benefits of interventions in the energy sector. Developed by WHO, CRA is defined as the systematic evaluation of the changes in population health which result from modifying the population distribution of exposure to a risk factor or a group of risk factors (U.S. Environmental Protection Agency 2006). In simple terms, this parameter could be used to evaluate the change of attributable fractions (AF) of risk factors and translate the changed AF into burdens of disease which can be applied to the projection by the researchers. Therefore, this approach can not only be used to assess the health benefits from enhanced physical activity by increasing active transport but also can be adapted to evaluate the change in disease burden of air pollution reduction. As we can see from Table 2.1, both the UK study (Woodcock et al. 2009) and the Bay Area study (Maizlish et al. 2013) used this approach to comprehensively estimate health impacts of alternative transport scenarios. In addition, the CRA has been used to evaluate the health co-benefits of many mitigation activities for GHG emissions and air pollution (Markandya et al. 2009; Smith et al. 2009; Wilkinson et al. 2009; Woodcock et al. 2009). However, it is notable that assumptions and values of key parameters have an important effect on the model outcomes. For example, it is necessary to obtain the values of RR of risk factor like air pollution or physical inactivity. If there is no local statistical data available, the RR could be estimated by doing meta-analysis like the UK (Woodcock et al. 2009), and Bay Area studies (Maizlish et al. 2013). As seen in Table 2.1, other studies used an indirect approach with the Health Economic Assessment Tool (HEAT) to evaluate the health impact. We will discuss this tool in the following section.

The respiratory and cardiovascular systems appear to be the most affected by urban air pollution. The WHO estimates the disease burden of air pollution based on the

contributions of three health outcomes: mortality from cardiopulmonary disease in adults, mortality from lung cancer, and mortality from acute respiratory infections (ARI) in children aged 0–4 years (WHO 2009a). According to the global burden of disease calculated by the WHO, diseases having the most significant association with physical inactivity include diabetes, dementia, hypertensive heart disease, ischemic heart disease, cerebrovascular disease, breast cancer, colorectal cancer and depression. Therefore, as shown in Table 2.1, most of studies reviewed conducted the health impact assessment on air pollution reduction based on the cardiopulmonary disease and lung cancer health outcomes, and the health impact assessment on active transport based on major chronic diseases outcomes. Health outcomes could be considered in terms of the number of deaths, mortality and morbidity rates, and the Disability Adjusted Life Years (DALYs). DALY is a metric that combines premature mortality and morbidity, which can provide an overall picture of burden of disease.

One issue in health benefit assessment is that enhanced physical activity improves health effects gradually over time and those effects will be maintained in a certain time period. Therefore, how quickly the health benefit of increasing an individual's active transport level appears remains uncertain. As such, current co-benefit studies only projected the health co-benefits that occurred in one “accounting year”.

Another controversial issue concerns whether active transport is associated with more physical activity in reality. One systemic review conducted by Faulkner et al suggested that children and youth who actively travel to school tend to be more physically active than passive commuters (Faulkner et al. 2009). However, another recent systematic review concluded that evidence that active transport users necessarily have more physical activity than others is limited due to a lack of longitudinal studies (Wanner et al. 2012).



Therefore, it remains uncertain whether active transport commuters can gain health benefits solely from their active transport use.

Furthermore, the UK and Bay area studies (Maizlish et al. 2013; Woodcock et al. 2009) assumed everyone in the population aged over 15 years would possibly use active transport as an alternative; a goal very hard to achieve because older people constitute a group that may find it difficult to start cycling for various reasons. In Denmark, cycling trips declined with age, but even among 70-74 years old people, cycling still accounts for 12% of all their trips, double that percentage have been found in Dutch elderly (Pucher and Buehler 2008). Thus, it is worth considering whether elder people should be included in the health impact model. On the other hand, considering those people already achieved the criteria of sufficient physical activity, they may not gain more health benefit from active transport since physical inactivity was no longer a risk factor of some diseases for them. Accordingly, the largest health benefits from active transport may be gained from those people who are completed sedentary but become active travellers.

### **2.7.3 Economic benefit assessment**

Economic benefit assessment in a co-benefits study can be conducted from different perspectives, such as investment cost on environmental protection, fuel savings and cost of medical expenditure. A standard “value of a statistical life” approach is commonly used in transport appraisals, which reflects the willingness of a middle-aged person to pay to avoid sudden death (willingness-to-pay) (Cavill et al. 2008). The value of willingness-to-pay could vary considerably between different regions. Alternatively, Smith and Haigler (2008) recommended a simpler way to assess the cost-effectiveness of possible interventions by comparing local gross domestic product (GDP) with DALYs. If the health-related investment is less than local \$GDP/capita per DALY, the intervention is

considered to be very cost-effective and should be promoted quickly and widely (Smith and Haigler 2008). The intervention is cost-effective if the health-related investment is between one and three times of the local \$GDP/capita per DALY. When an investment is over three times of the local \$GDP/capita per DALY, the intervention is not considered to be cost-effective.

WHO has developed a specific Health Economic Assessment Tool (HEAT) to evaluate the health effects related to increased cycling (Rutter et al. 2007). This Excel-based tool sets the relative risk as 0.72 for all-cause mortality of regular adult commuter cyclists. The HEAT also contains a default value of a statistical life, based on the Copenhagen Centre for Prospective Population studies which controlled for gender, smoking, education, leisure time physical activity, body mass index and other risk factors for chronic disease (Andersen et al. 2000). Therefore, reduced mortality could be used as an indicator to estimate the mean annual benefit from cycling. The total value of economic savings due to the reductions in all-cause mortality among these cyclists could also be calculated with the data entered by the user. Those studies (Grabow et al. 2012; Lindsay et al. 2010; Rojas-Rueda et al. 2012) that conducted the health impact assessment by the HEAT have not considered the age issue of beneficiaries. Because HEAT is only designed for adult population (aged approximately 20-64 years) and it is generally accepted that this group of people is most suitable for cycling. However, the HEAT is not suitable for assessing the economic benefits of other alternative transport, such as walking, as the Copenhagen study only compared the relative risk of all-cause mortality between cyclists and non-cyclists. In addition, the HEAT only investigates the impact on mortality but not on morbidity and it does not consider mental health issues. It also cannot be applied to children.

#### **2.7.4 Data issues**

One of the challenges in conducting a co-benefit study is the establishment of a series of modelling work to project the multiple benefits. To establish effective modelling relies on multiple high quality datasets. For instance, to estimate environmental benefit, it is essential to collect transport data, such as annual vehicle kilometres travelled, emission factors of vehicle types and public travel patterns. For health benefit estimations, various health data are needed, such as prevalence of insufficient physical activity, local mortality and morbidity of relevant diseases, and relative risks of air pollution and physical inactivity. When projecting long-term effects of alternative transport plans, baseline data quality is crucial. To date, data between different countries have shown heterogeneity. In addition, transferability between diverse populations is challenging for researchers, who need to consider the comparability and differences between populations and regions. Theoretically, it is ideal to use local data as the baseline when calculating the estimations. However, the available local databases of transport, emissions and health system are updated in different years, and it would be acceptable to use databases in different years to build the baseline scenario. For studies which tend to make projective models, researchers also need to consider the development trend in the study population. Like the UK and Bay area studies (Maizlish et al. 2013; Woodcock et al. 2009), they took account into population growth, changes in emission standards when they designed the 2030 scenarios. Moreover, vehicular emission factor, a key parameter for air pollution modelling, varies with ageing vehicle fleets, engine types or on the cold start/driving/brake, which should be considered in order to adjust the model.

## **2.8 Summary and recommendations**

It is well known that alternative transport can bring cost-effective benefits to environmental protection and population health. However, current analyses of transport mitigation strategies in terms of health and economic aspects are still at an early stage. Most of the previous research regarding the transport sector has only focused on one of those possible benefits and has rarely quantified the overall co-benefits of alternative transport planning. Additionally, most of the current co-benefit studies are more interested in the long-term effect of alternative transport while the short-term effect has not been considered adequately. Some other benefits, such as social benefits from alternative transport are also valuable for further investigation. For example, both cycling and walking could enhance social/neighbourhood interaction. It has been shown that active transport can increase activity in local neighbourhoods and the passive surveillance of private and community infrastructure (Hume City Council 2010).

The health effects of active transport could involve physical, mental and psychological aspects. At the moment, studies thoroughly investigating all these aspects are relatively rare. The majority of the conclusions from existing co-benefit studies only indicate that active transport has positive influences on preventing chronic disease. It is still uncertain how much mental and psychological health benefits could be achieved by promoting alternative transport. Moreover, the benefits of noise mitigation have also been commonly neglected, which is a particular effect induced by motor vehicle reduction. There are also some gaps in health benefit research when taking different age groups into consideration. Although researchers could assume that people of all the ages would be affected by air pollution reduction and increased physical activity due to reduced usage of motor vehicles,

such hypotheses may lead to inaccurate conclusions for certain population, such as children, for which few studies have considered the health benefits.

At the moment, the investigation of economic benefits of transport strategies, especially for active transport, is insufficient. The assessment tools currently available for economic benefits analyses can be limited when applied to different scenarios. For example, WHO has provided HEAT, which is a specific economic assessment tool for cycling. However, how to apply it to other active transport modes (such as walking) still needs to be explored. The range of current economic benefit assessment is also somewhat incomplete. Fuel saving, decreasing investment in environmental protection and medical expenditure reduction are the aspects which have been most commonly studied. Beyond these, other economic benefits related to reducing traffic congestion, such as car space requirements and oil demands, should also be taken into account in the future.

To date, most of the co-benefits research has been conducted in developed societies. Relevant studies in under-developed societies are insufficient, especially in countries such as China and India where motor vehicle emissions have become a significant source of air pollution due to the recent sharp increase in vehicle numbers. As different types of cities have dissimilar populations, traffic situations, transportation modes, weather types and infrastructures, co-benefit studies specific to individual regions are essential and further research should be applied to cities with different characters. Furthermore, as well as considering alternative transport, co-benefits of mitigation strategies in other energy consuming sectors, such as industry, agriculture and electricity generation, are also significant and warrant further exploration.

In addition to study design, choice of methods may also cause bias in the research of co-benefits. While quantitative methods are the most frequently used, qualitative methods

## *Chapter two*

have been rarely used in studying co-benefits. Although public behaviour and stakeholder attitudes may influence transport choice and policy making, little information has been provided in this area, which is well-suited to in-depth qualitative analysis. Thus, further investigation should adopt qualitative methods, such as interviews and focus group discussions, in order to address these gaps in knowledge. Findings from the combination of both quantitative and qualitative methods may provide stronger evidence to assist policy-makers in decision making and policy implementation.

# **CHAPTER 3**

## **Literature review two**

### **Travel behaviour and transport policy**

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#### **Preface**

The previous literature review (Chapter 2) summarised potential benefits of alternative transport in terms of environmental, health and economic outcomes, and identified major methodological issues faced in previous studies in the field. All hypothetical scenarios in previous chapter were related to a travel behaviour change at the population level.

This chapter contains the second literature review of the thesis. The aim of this review is two-fold. The first section describes the current knowledge about individual travel behaviour and its influencing factors. Next, I review research on how transport polices facilitate alternative transport promotion. Finally, gaps in current knowledge are also discussed.

### **3.1 Introduction**

There are a few key considerations when citizens choose their transport mode, for example: environmental protection, economic concerns, safety, comfort, convenience, attitude and personality, as well as socioeconomic status. To make public transport and active transport a real alternative for local communities, understanding residents' travel behaviour and associated factors that may impact their travel behaviour is essential. Nevertheless, transport choices and travel attitudes are complex. People may make different choices regarding transport for each trip as every transport model has its own specific features, including advantages and disadvantages. Additionally, the choice of one specific transport mode may vary depending on time management and/or destination of journey (Gärling et al. 2002; Gärling et al. 2000). The purpose of this review is to summarise current knowledge about the factors which influence individual travel behaviour, and discuss how transport policy can facilitate car use reduction and to alternative transport promotion.

### **3.2 Factors affecting travel behaviour**

#### **3.2.1 Socio-demographic factors**

Several studies have been carried out on the impact of socio-demographic characteristics on travel behaviour (Antipova et al. 2011; Buehler 2010; Steinbach et al. 2011). The results have identified factors associated with travel behaviours, such as gender, age, household income and household location.

Compared with males, females are found to be more likely to use alternative travel methods and less likely to use a car. For instance, Bergstad et al. (2011) studied travel behaviours in Sweden to explore the effects of socio-demographic variables on daily car



use. Based on data collected from 1,134 posted questionnaires, they showed that males made more car trips as drivers than females did, while females were more likely to be car use a car passengers than males were. Similarly, a recent household travel survey conducted in Sydney, Australia, concluded that, compared to males, females were slightly less likely to be a driver and more likely to be a passenger; and females were also more likely to walk on a daily basis than males (Bureau of Transport Statistics 2012). Employment status may explain this phenomenon because women may be more likely to work in part-time employment or have home duties and therefore be travelling less. For instance, findings from a German study (Best and Lanzendorf 2005) suggested that females took fewer work trips by car but more ‘maintenance’ activity trips (e.g. shopping, personal business, errands) than males, while there were no significant differences in the total number of trips or distances travelled between males and females. Another Swedish study (Polk 2004) found there was no gender differences in access to the car in the household, but being female still significantly decreases the log odds of using a car on a daily basis. They also found the willingness to reduce car use was higher in females than in males (Polk 2004).

Age is another important factor that could influence individuals’ travel behaviour. A survey on journeys to work conducted in Adelaide, South Australia (Australian Bureau of Statistics 2009), found that the proportion of workers using private cars to get to work increased with age, whilst the proportion of those using public transport and active transport decreased with age. Specifically, after the age of 10 years old, a person’s car use keeps increasing until reaching their fifties and then declines. Walking shows a reverse pattern, decreasing until people are aged in their fifties then increasing. The highest public transport use is found among those in their teens and twenties and those aged over 70 years in Adelaide (Australian Bureau of Statistics 2009). Similar trends were also

reported by the Sydney Household Travel Survey (Bureau of Transport Statistics 2012). Further, Giuliano and Dargay (2006) conducted a comparative study to investigate car ownership and travel pattern in Great Britain and US. They found the daily travel distance of people over 65 years old in Britain was only half that of people as those aged 18 to 64. A similar pattern was also found in the US population (Giuliano and Dargay 2006). Overall, elderly people make fewer daily trips and are less likely to use cars than younger people do. This may be due to differences in employment and health status that occur with increasing age, as well as, the demands of outside trips and duration of trips (Nobis and Lenz 2005).

Household income and type have also been identified as major influences on choices of travel behaviour by several studies. In general, households with children may be more likely to use cars than those without children (Bergstad et al. 2011), while those unemployed and in part-time employment without children are the most likely to use active transport (Ryley 2006). For instance, Dieleman et al (2002) used the Netherlands National Travel Survey, which included 150,000 participants aged 12 years or older, to study the influence of the characteristics of the residential context on travel mode choice and distance travelled. Their major findings were that households with children were more likely to use a car to travel than one-person households; and that households with a higher income were more likely to own and use a car (Dieleman et al. 2002). Similarly, the total daily travel distances were also found to increase with income in Giuliano and Dargay's previously mentioned study (2006). This trend was more significant when comparing the lowest and middle income groups in the US, and the middle and highest income groups in Britain. Thus, higher income is usually correlated to an increase in travel distance and car use. In contrast, a Swedish study (Polk 2004) found that income did not significantly affect car use on a daily basis, but it may significantly decrease the willingness to reduce car use in males. The country-specific

differences, such as public transport quality and availability, fuel process, social and cultural difference, may cause different results from above studies.

Furthermore, studies have found that residential environment could be another influential factor on transport use. A lack of good public transport facilities, a low population density and a diverse land use may affect demand for car use. For example, households in rural areas may have more car users than households in semi-rural areas, while the latter use cars more often than those living in urban areas (Bergstad et al. 2011). It has also been suggested that people living in large and medium-sized cities may be more likely to use public transport and active transport than people living in remote areas (Dieleman et al. 2002). In addition, some researchers found that the choice of transport mode might vary, depending on purpose of the trip. Results from the Sydney Household Travel Survey (Bureau of Transport Statistics 2011) suggested that while the majority of individuals' 'all purpose' trips were made by private cars, their work related business trips were most likely to be undertaken by car and their shopping, social/recreation and personal business trips were more likely to be accessed by active transport. A similar pattern was also found in the German population, with 57% of commuting trips and 36% of shopping and other social activity trips covered by car (Best and Lanzendorf 2005). However, for those countries with a strong culture of walking and cycling such as Netherlands, almost half of the work-related trips were undertaken by active transport, although a slightly lower percentage of using active transport use was reported in relation to shopping trips (Scheepers et al. 2013).

### **3.2.2 Land use factors**

Various 'land use' factors, such as population or building density, regional accessibility, and roadway connectivity, can also affect travel behaviours. Antipova et al (2011) used a multilevel modelling approach, including individual and neighbourhood levels, to study the interrelationship between land use and travel behaviour in Baton Rouge, US. They

have found that people who live in commercial areas and medium-density residential areas spend less time on commuting compared to those in low-density residential areas. However, the high-density residential land use was not found to be related to less travel time and distance in their study. They argued that high-density residential land use should encourage shorter commuting trips, however, the high-density residents were predominantly low-income and minority residents. Therefore, other non-spatial factors, such as discrimination in the housing and job markets, lack of access to information, and dependency on public transits, may influence their travelling. (Antipova et al. 2011).

A land use and travel study conducted in the South Bay area of Los Angeles region concluded that in comparing between corridor areas, trips in centres were more likely to be undertaken by walking (Boarnet et al. 2011). The authors suggested that the concentration of local shopping and service could be a key to increasing active transportation. Similarly, Soltani and Primerano (2005) conducted a study in Adelaide, which included 9,000 randomly selected suburban households, to investigate how community design influenced travel behaviours among local people. Their results implied that active transport for daily trips could be limited in low-density and large street blocks. They suggested that proximity to local shopping and business centre would encourage a wider choice of alternative transport modes, whereas the residential location far away from major activity centres required more use of the private cars and thus decreased the use of alternative travel modes.

Another comparison study conducted by Owen et al. (2010) used logistic regression models to examine the associations between adults' bicycle use for travelling and measures of neighbourhood walkability in two settings: an Australian city (Adelaide) and a Belgian city (Ghent) (Owen, N et al. 2010). Overall, the rates of bicycle ownership and

prevalence of bicycle use for travelling amongst Ghent residents were much higher than amongst Adelaide residents. However, after adjusting for relevant confounding factors (e.g. age, gender, education), a significant association between living in a highly-walkable neighbourhood and a higher likelihood of bicycle use for transport was observed in both cities. A recent meta-analysis (Ewing and Cervero 2010) summarised empirical results on associations between built environment and travel mode, especially for non-work related trips. They found that measures of accessibility to destinations and street network design variables (e.g. population density, street density and distance to transit) were strongly associated with individuals' vehicle travel distance. Meanwhile, walking was found to be significantly related to land use diversity (e.g. land use mix and jobs-housing balance), intersection density and the number of destinations within walking distance, whilst public transport use was related to proximity to transit, street network design variables and land use diversity. Results suggested that built-environment innovations, which are increasingly being advocated by health authorities and transport planners, primarily to promote a higher rate of walking for transport, could also impact positively on bicycle use (Ewing and Cervero 2010).

### **3.2.3 Psycho-social factors**

Literature has shown that those people who use cars as their dominant travel mode usually give more consideration to convenience, speed, comfort and individual freedom (Anable 2005; Hagman 2003). For instance, a survey on travel attitudes and behaviour conducted among Tbilisi residents in Georgia illustrated that over 80% of the public transport users expressed their willingness to use a private car instead of using public transport because of saving travel time and convenience (Grdzlishvili and Sathre 2010). Another qualitative study conducted by Hagman et al (2003) explored people's

perceptions of positive and negative aspects of car use amongst a Swedish population. Semi-structured interviews were conducted with 30 car users, who stated freedom, flexibility and time saving as the main strengths of car use, with costs as their biggest concern. Likewise, Gardner and Abraham (2007) adopted a grounded theory study design to identify five core motivations for driving in a small English city including concerns of journey time, journey based affect (positive or negative feelings experienced during the journey, such as comfort, enjoyment and stress), effort minimisation, concerns of personal space and monetary costs. Thus, it has been suggested that, within the context of changing societal and lifestyle patterns, cars are far more than just a means of transport (Steg 2005). People associate sensation, power, freedom, status and superiority with cars.

It should also be noticed that there is growing public awareness amongst the public of climate change as the world's greatest environmental challenge (Kurukulasuriya and Rosenthal 2013; Revich 2008). However, some researchers have found that it is difficult for people to reduce their car use even when they recognised motor vehicles as a major contributor to environmental issues. For instance, a qualitative study carried out by Line et al (2010) focused on factors influencing the future travel behaviour intentions of British young people (aged from 11 to 18). They found that although young people were aware of climate change as an environmental issue, their understanding of the link between transport and climate change was weak (Line et al. 2010). The majority of study participants were unwilling to change their travel behaviour intentions and they did not think climate change would modify their travel behaviour. Desire to drive and own a car in the future was found to dominate young people's travel behaviour intentions (Scottish Executive 2003), which may explain young people's low level of willingness to change travel behaviour.

It is not only young people who are driven by their desires when they make the transport choices, but also adults may be reluctant to change their travel behaviours regardless that most of them claim that they wish to live greener life styles (Chatterton et al. 2009). Based on a research project that the UK Department for Transport commissioned to improve understanding of how the public engage with environmental terminology and personal carbon emissions, Chatterton et al. (2009) discussed the key factors determining an individual's transport choices by using a tool named a "carbon calculator". This tool allows people to estimate their personal behaviours' impact on the environment through putting daily activities information to an estimation of carbon dioxide system. Their study indicated that despite considerable awareness of climate change, personal transport choices were not likely to be influenced by the level of carbon emissions linked to various transport modes. The travel behaviour of participants was highly influenced by the issues of cost, comfort and convenience (Chatterton et al. 2009).

In contrast with the above results, Shen et al. (2008) examined negative impacts on the environment as one of the attributes of transport mode in analysing survey data from Saito and the Onohara Area in Northern Osaka of Japan. Their results indicated that an individual's environmental consciousness played a significant role in his/her decision on transport mode (Shen et al. 2008). People were more likely to choose a mode that has less negative impact on the environment if they had a high level of environment consciousness. In addition, they predicted changes in choice shares of transport modes in response to an increase in negative impact caused by each transport mode. Results showed that transport modes which may cause environmental deterioration would be less accepted and the reduced share would shift to a 'cleaner' mode (Shen et al. 2008). Similarly, Ibrahim (2003) examined the attitude of car owners and non-car owners towards transport modes in Singapore and found that these groups had different attitudes towards various transport

modes. The results showed that non-car owners seemed to recognise the negative effects of cars on the environment, whilst car owners had less awareness of the environmental consequences of car use (Ibrahim 2003). These contrasting study results coming from the UK, Japan and Singapore may be explained by particular population sub-groups based on age differences, geographic locations and cultural diversity.

Furthermore, some researchers reported on those internal and social considerations, especially personal attitudes and perceptions, and gained importance in determining individuals' pro-environmental travel behaviour (Steg and Vlek 2009). Heinen et al (2011) used an internet survey to analyse the influence of commuters' attitudes toward transport modes among Netherlands' residents. Overall, three underlying attitudinal factors toward cycling were identified, including awareness of environmental benefit, direct trip-based benefits and safety. The majority of participants made their transport choice based on direct benefits in terms of time, comfort and flexibility. However, individuals who consider cycling environmentally friendly, healthy and mentally relaxing are more inclined to cycle to work (Heinen et al. 2011). Similarly, a Spanish study (Fernández-Heredia et al. 2014) selected 14 factors that promote or inhibit bicycle use to investigate cyclists' perceptions towards bicycle, including efficiency, flexibility, economical, ecological, healthy fun, distance, danger, orography, fitness, climate, vandalism, facilities and comfort. They concluded that convenience (flexible, efficient) and exogenous restrictions (danger, vandalism, facilities) were the major determinants of bicycle use (Fernández-Heredia, Monzón & Jara-Díaz 2014).

In addition to personal attitudes, public perspectives and images of active transport also play an important role in active transport use. Daley et al. (2011) conducted a qualitative study amongst Australian residents specifically on the public images and perceptions of



cycling, their potential influence on cycling and whether views differed between regular, occasional and non-riders. Their study also revealed that while the analytic themes linked to images of cycling were more positive and environmentally friendly, the actions of some 'cyclists' were disliked, which influenced views about cycling, particularly among non-riders. Furthermore, riding for transport was not viewed as a mainstream activity (Hansen et al. 2009). This study suggested that there was a need to improve public acceptability of cycling.

Bamberg and Möser (2007) performed meta-analytic structural equation modelling (SEM) to synthesise psycho-social determinants of pre-environmental behaviour (e.g. travel model choice, household recycling, and waste composting) based on two theoretical models: norm-activation model (NAM) and the theory of planned behaviour (TPB). The NAM recognises that personal norms, such as feelings of strong moral obligations, are direct determinants of engaging in a pro-environmental behaviour which refers to behaviour that harms the environment as little as possible, or even benefits the environment (Schwartz 1977). The TPB assumes that behaviour is guided by behavioural beliefs, normative beliefs and control beliefs (Ajzen 1991). It was usually adopted by those researchers recognising that self-interest was more important motive for a pro-environmental behaviour (Bamberg and Möser 2007). Their meta-analytical results confirmed that pro-environmental behaviour was a mixture of self-interest and pro-social motives. They also found that attitudes, behavioural control and personal moral norms were the most important direct determinants of 'pro-environmental intention', whilst 'problem awareness' was another significant, albeit, an indirect determinant (Bamberg and Möser 2007).

With an increase in travel demand and energy consumption expected in the coming decades in Australia, it is important that strategies are in place to encourage travel behaviour change at the population level. Previous sections of this chapter have concluded that socio-demographic, land use and psycho-social factors can play significant roles in influencing travel patterns and behaviours. The literature reviewed here exposes the complexity of travel behaviour, and thus highlights the necessity for researchers and planners of transport and urban development to have a more informed understanding of people's transport decisions for addressing the sustainability agenda and implementing appropriate policies to facilitate behaviour change. With specific population density, landscape and urban form, the Australian population has a relative low travel modal share of public transport and active transport. Information on the travel patterns of residents are surveyed regularly in some Australian major cities, such as Melbourne and Sydney, but such investigation has not taken place in Adelaide (the site of the current research) in the last 15 years. In addition, further explorations of the factors impacting on local travel behaviour and people's intention to reduce their car use are insufficient in Australian studies.

### **3.3 Transport policies to promote alternative transport**

The previous section described the current knowledge about individual travel behaviour and its influencing factors. Given the fact that private car use is one of the greatest threats to the human environment, increasing efforts have been made to develop and implement the transport policy measures aiming at shifting private car use to more active transport behaviour. These measures have been classified into two types as "Push measures" and "Pull measures" by Steg and Vlek (1997). The following section will further discuss how those transport policies facilitate alternative transport promotion

### 3.3.1 Push measures

“Push” measures generally influence individual travel decisions through imposing measures on individuals’ car travel; “pushing” them into more active travel. These can be divided into pricing measures (e.g. increasing cost of car use, raising fuel prices, car parking charges and road tolls) and technical and regulatory constraints (e.g. decreasing availability of infrastructure to support car use such as no city centre car access and reducing or eliminating city centre parking).

To date, a number of cities have implemented urban road pricing successfully. For example, a congestion pricing program has been in place in London since February 2003. It requires drivers to pay £5 (the standard charge is £11.50 in 2014) for driving in central London on weekdays between 7:00 a.m. and 6:30 p.m.. Prior to the program about 12% of peak-period trips were made by private cars and this percentage declined approximately 20% (to just below 10%) in the first few months after the program being released. Consequently, this resulted in a reduction of 20,000 vehicles driving in central London per day (Litman 2006b). Most people who changed their travel patterns due to increasing charges transferred to public transport, particularly bus travel.

However, in some other cities, the public acceptability of these types of policies is low. Steg and Gifford (2005) concluded that if transport policies have significant negative impacts on quality of life (QoL), they might be less acceptable, less feasible and less effective. For instance, De Groot and Steg (2006) conducted a survey in five countries (Austria, Czech Republic, Italy, Netherlands and Sweden) to examine how transport pricing policies, including doubling the price of car use, increasing the cost of parking, fuel levies, transport pricing measures, and increases in insurance costs, affected participants’ quality of life. Some relatively large negative changes were stated according

to measures of comfort, money, freedom (aspects of QoL), but living environment that were perceived to improve included environmental quality, nature and biodiversity. However, the hypothetical stringent measures, such as doubling costs of car use, were shown to minimally affect people's overall general wellbeing (De Groot and Steg 2006). Additionally, respondents were unsure whether they would accept the doubling costs policy and whether they would change their car use if the policy was implemented. However, their study only focused on one general transport measure-pricing adjustments and thus results might be different in relation to other measures.

Similarly, a Swedish study (Loukopoulos et al. 2004) explored public beliefs and evaluations of the consequences of implementing three travel demand management measures from other countries. They were (1) prohibiting car traffic in city centre in UK, (2) road pricing in Singapore, and (3) individualised marketing such as the TravelSmart program in Australia which was used to provide information about the alternative transport to those people who were interested in beginning to use them. The results confirmed that public attitudes were more negative towards road pricing than other measures targeted at decreasing car use. Prohibition of car traffic was most popular, followed by individualised marketing. Therefore, policy makers should consider which and how some aspects of QoL would be affected (positively or negatively) by those "Push" measures, in order to facilitate the implementation of such sustainability policies and guarantee effective and efficient decision making.

### **3.3.2 Pull measures**

"Pull" measures are defined as those encouraging individuals to use cars less by promoting more attractive alternatives, such as a better public transport system or an integration of active transport with transport planning.

In contrast to “Push” measures which restrict individual’s opportunities, “Pull” measures provide individuals with more choices, including either improved alternatives or newly created alternatives. For example, decreasing the price of public transport services provides additional options to travel. However, people can still choose to travel by car.

An example of a “Pull” measure was investigated by an experimental analysis conducted in Japan (Fujii and Kitamura 2003), which examined the impact of a temporary structural change on habitual drivers. In their study, free bus tickets were provided for drivers in the experimental group but not for those in control group. After a one-month intervention period, drivers’ attitudes towards buses (e.g. measured as negative-positive and uncomfortable-comfortable) were improved and an increase in the frequency of bus use was found in the experimental group. In addition, participants’ car use decreased during the intervention, and even after the intervention (Fujii and Kitamura 2003). Similarly, a study conducted by Thøgersen (2009) in the greater Copenhagen area randomly assigned selected car owners into a control group with no intervention or an experimental group with a free month’s travel card either alone or along with a customised travel timetable. Participants’ attitudes, car habits and travel behaviour were assessed before and immediately after the intervention and again six months later. Results from this study indicated that the price reduction doubled public transport use in the experimental group. Although the effect gradually diminished after the promotion offer had expired, a positive effect was found to last for five months after the intervention (Thøgersen 2009).

Safety issues have been identified as a major barrier of active transport (Bauman et al. 2008). Therefore, installing safe walking/bicycle paths and lanes are considered as the key approach to increasing active transport use. A US study (Buehler and Pucher 2012a) used a regression analysis to explore the relationship between bicycle lanes/paths and

cycling prevalence in 90 large US cities based on the 2008 American Community Survey. The results showed that cities with a better supply of bicycle paths and lanes had a significantly higher cycling-commuting level after controlling for confounding factors such as land use and climate. Specifically, they found that a 10% greater supply of bicycle lanes and paths was associated with a 2.5-3.1% greater number of bicycle users per 10,000 people (Buehler and Pucher 2012a). However, in some other countries, the positive correlations between bike lanes and cycling levels have not been found to be significant (Cervero et al. 2009; De Geus et al. 2008).

A review study conducted by Pucher and Buehler (2008) summarised successful “Pull” policies in Netherlands, Denmark, and Germany, which have a relatively high prevalence of cycling among almost all social groups. They noticed that a great expansion of separate cycling facilities had been made in all three countries from the mid-1970s to the mid-1990s. During that period, bicycle networks had been established, including a large number of off-street short cut connections between streets and traversing city blocks, which increased the efficiency of cycling. More importantly, those facilities have been continually improved and maintained to ensure quality and safety. Apart from bicycle lanes and paths, detailed maps and guides are provided to residents in almost all large and medium-sized cities in these three countries, and cyclists are given absolute traffic priority on the narrow streets. Moreover, cycling networks are well designed to integrate with the whole transport system in most cities in these three countries. Bicycle parking in the aforementioned countries is provided at train stations, allowing residents to ride to the nearest station and take the train to city centres or other destinations (Pucher and Buehler 2008).

In summary, both “Push” and “Pull” traffic measures can be important for reshaping individuals’ travel behaviour. However, some studies have reported that “Push” measures might be less efficient in encouraging an increase in the use of sustainable modes of transport, compared with “Pull” measure. In general, “Push” measures may be less accepted by the public, as they limit people’s perceptions of freedom and choice associated with owning and using a car. Thus, only using one type of measures, especially “Push” measures, may not be sufficient to encourage travel behaviour change and a joint effort of “Push” and “Pull” measures is highly recommended (Eriksson et al. 2008).

### **3.4 Conclusion**

As shown in the previous chapter, studies have suggested that promoting a shift from motor vehicle use to alternative transport can be beneficial for the environment, public health, and health expenditure. To achieve these co-benefit goals, re-shaping individuals’ travel behaviour is fundamental. This review chapter has shown that travel behaviour can be influenced by various factors including socio-demographic factors, psycho-social factors, land use and urban design, and transport policies.

Australia covers a vast territory but with a sparse population. Therefore, motorised vehicles, and especially private cars, are the most attractive transportation mode for Australians and a large portion of population now rely heavily on them. The Australian Government has gradually increased its attention on environmental issues, such as climate change, and promoting sustainable travel behaviour is starting to emerge on the political agenda. Although household travel surveys are updated regularly in some Australian major cities, a further exploration of the relevant factors impacting on local travel behaviours is required. In addition, current knowledge about individuals’ intention to reduce their car use and change to alternatives is not sufficient. On the other hand,

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government departments play a vital role in introducing sustainable transport policies to the public. However, little research has been carried out regarding the perceptions of alternative transport promotion among stakeholders or local authorities. To date, understanding of the potential barriers impacting the implementation of alternative transport policy implementation is still uncertain. Further qualitative research needs to be undertaken to explore possible solutions to overcoming these barriers, thus addressing these gaps in knowledge.



# **CHAPTER 4**

## **Research design and methodology**

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### **Preface**

The previous two chapters reviewed the literature guiding the research described in this thesis. This chapter provides a general outline of the research design including aims and research questions, the general framework of the research, and a justification of methods used in the three distinct studies that make up the research.

## **4.1 Introduction**

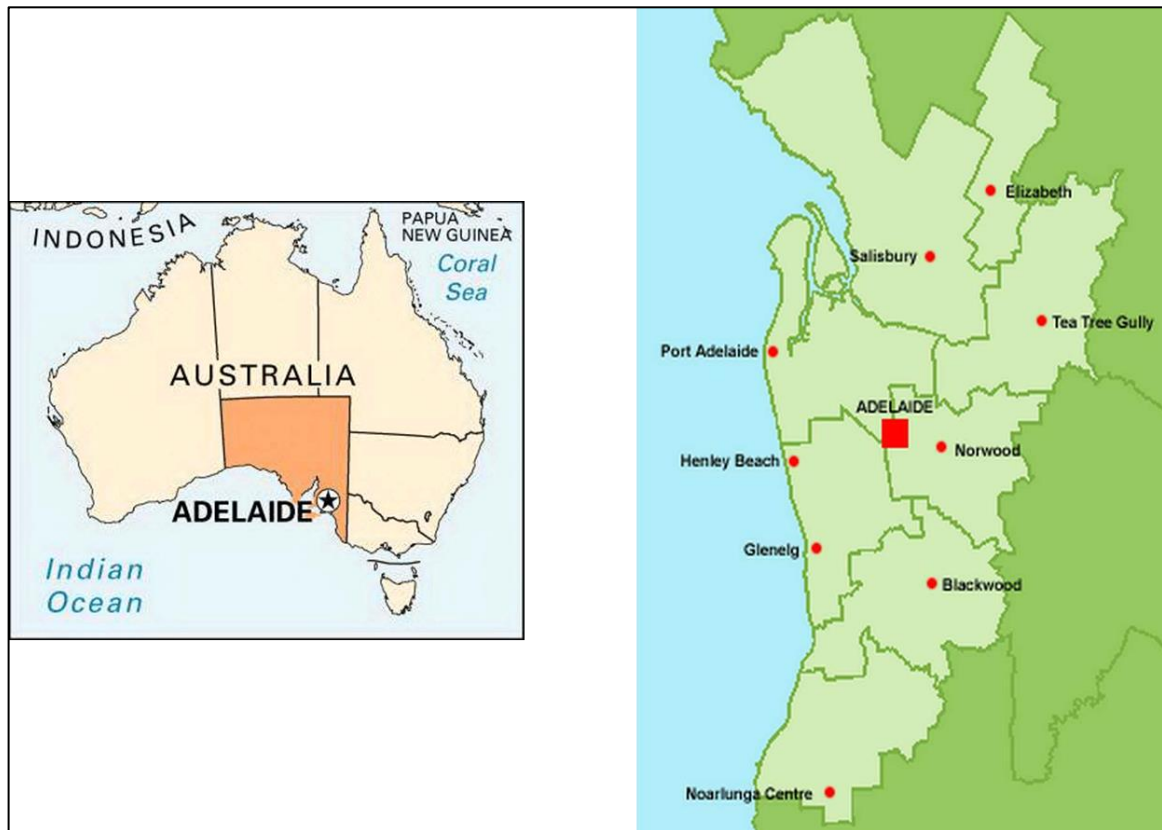
In Chapters 1, 2 and 3, the overall aim and research questions addressed in this thesis and a review of literature relevant to co-benefit effects of alternative transport and travel behaviour were presented. This chapter first describes the geography, demographics and transport use of the research region (Adelaide, South Australia). In section 4.3, I outline the aims and objectives, and research questions of the thesis as a whole and explain the development of the framework used in answering research questions. In section 4.4, ethical considerations are discussed, before I summarise the chapter in section 4.5.

## **4.2 Context of the research**

Adelaide, the capital city of South Australia, is the fifth-largest city in Australia. It is located at 34° S and 138° E (Figure 4.1 A). The metropolitan area (Figure 4.1 B) occupies around 870 km<sup>2</sup> with a population of 1.1 million in 2010 (Australian Bureau of Statistics 2012c). The population is expected to increase to 1.4 million by 2030 (Melhuish and Steele 2011). The conditions in Adelaide are ideal for cycling and walking during most of the year, with an annual average maximum temperature of 22.3°C and an average minimum around 12.2 °C, and an average rainfall of just 544.9 millimetres per year (Bureau of Meteorology 2014). In addition, the topography has only small differences in altitude in most parts of the Adelaide city (average elevation of 50 metres above sea level), with the exception of the hills at the edges of the city.

As a major Australian city, Adelaide has one of the highest rates of motor vehicle ownership in the world (Australian Bureau of Statistics 2012b). According to the estimates of household car ownership in metropolitan Adelaide in 2011, only 9.2% of the

population did not have a car; 36.6% of households owned one car; 34.5% had two cars; and 14.5% owned three cars or more (Australian Bureau of Statistics 2011).



**Figure 4.1: A: location of Adelaide, South Australia. B: metropolitan Adelaide**

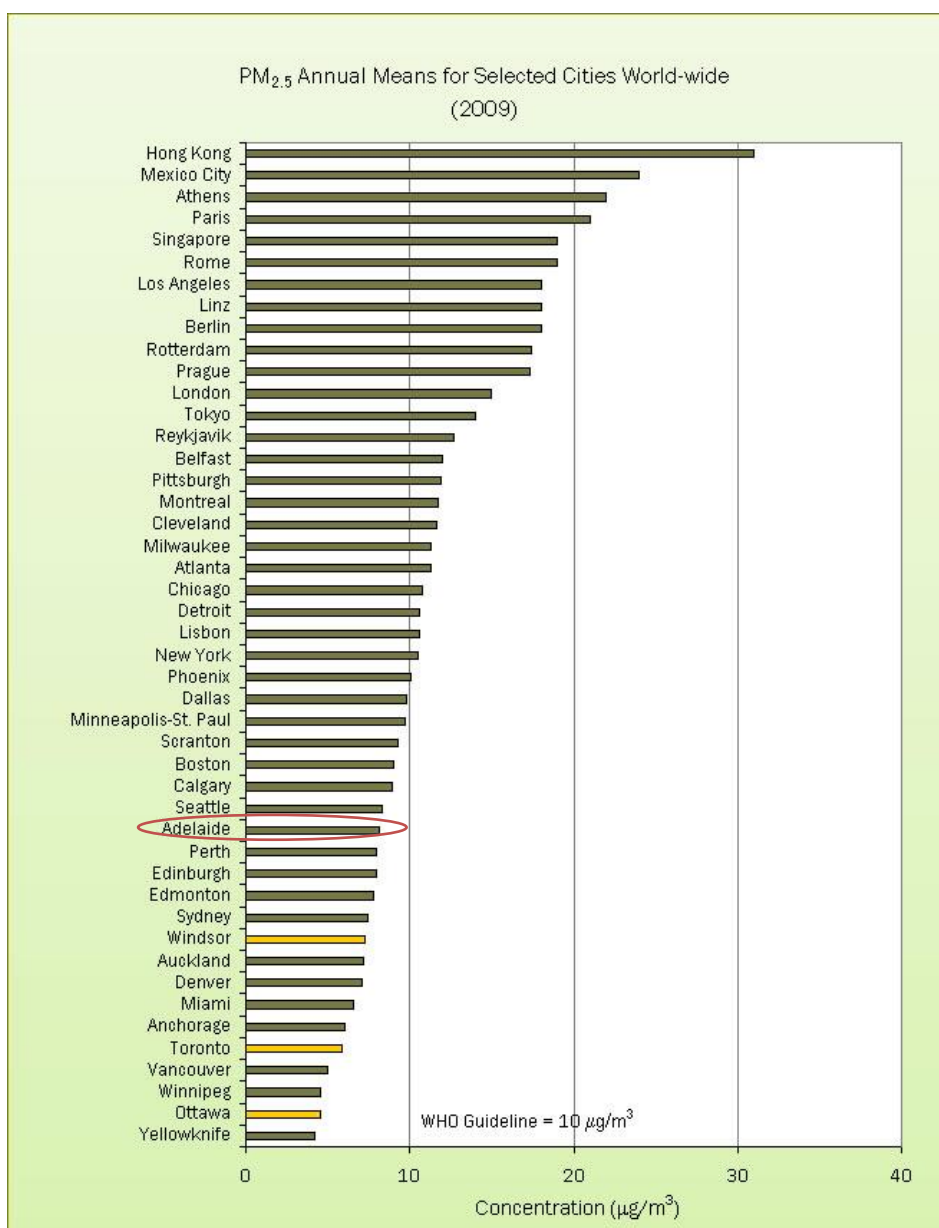
The public transportation infrastructure in metropolitan Adelaide includes over 4,500 km of bus routes, 120 km of train lines, 15 km of tram lines and 770 km network of bicycle lanes (Government of South Australia 2013). In other bigger cities in Australia, the total length of train and tram lines is much longer than in Adelaide. For instance, the metropolitan Melbourne area covers 7,694 km<sup>2</sup> and has 6,254 km of bus routes, 837 km of train lines, 245 tram lines, and 3,000 km network of bike lanes (Bicycle Victoria 1996; Public Transport Victoria 2014).

The most recent local Travel Pattern Survey in Adelaide was carried out in 1999 (South Australian Government 2002). It reported that the number of trips undertaken by all

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individuals per day in Adelaide was approximately 3 million and 81% of these trips were travelled by car. Public transport only accounted for 3.7% of total trips made; cycling accounted for 1% of total trips. The purpose of trips was reported to be: 24% for social/recreation reasons; 32% for personal business/work reasons; and 15.5% for shopping (South Australian Government 2002). In addition to these data, a National Transport and Motor Vehicle Usage report is provided by the Australian Bureau of Statistics regularly. According to the latest report (Australian Bureau of Statistics 2012b), Adelaide residents' transport use has been dependent on cars, with over 80% of people travel occurring via private motor vehicles, whilst public transport and active transport accounted for only 12% and 3% of travel respectively. Approximately 40% of usual trips are shorter than 7.5 km (Australian Bureau of Statistics 2012b).

Major sources of airborne particulate matter (PM) in Adelaide are domestic solid fuel burning (e.g. wood heating) and motor vehicles, which contribute to 25.6% and 20.2% of total amount respectively (Environmental Protection Authority 2012). Particulate matter as PM<sub>2.5</sub> (particles with an equivalent aerodynamic less than 2.5 micrometres) is measured by the Environment Protection Authority (EPA), South Australia, at one site, Netley, in the Adelaide airshed. The annual average PM<sub>2.5</sub> concentration measured at this site was found to be 7.9 µg/m<sup>3</sup>, with the maximum concentration measured being 21.9 µg/m<sup>3</sup> (Rivett 2008). Thus, compared to other world cities, PM<sub>2.5</sub> levels in Adelaide are relatively low (Figure 4.2). Despite this, a recent local study found that PM concentrations are associated with increases in morbidity in Adelaide (Hansen et al. 2012).



**Figure 4.2: PM<sub>2.5</sub> annual means for selected cities world-wide (2009)**

**Source: Environmental Protection Authority (2009)**

### **4.3 Framework for the methods used in this thesis**

As discussed, land transportation have been considered as one of the main sources of air pollutants that pose serious threats to human health. Reducing car use and promoting alternative transport use would not only lead to environmental benefits but also achieve favourable health outcomes via better air quality and enhanced physical activities.

As noted in the Chapter 1, the overall aim of this thesis is to quantify the co-benefits of promoting alternative transport on environment and population health, together with an investigation of community and stakeholders' perceptions of alternative transport use. These findings may be used to inform future health promotion campaigns, as well as, transport policies and urban planning for a sustainable future. To fulfil this research aim, three research questions are posed within this thesis:

- Comparing to business-as-usual (BAU), what are the future environmental and health benefits in choosing alternative transport scenarios, and to what extent can such co-benefits be obtained?
- What are the key factors that can affect individuals' current travel behaviour and predict their intention to change travel behaviour?
- What are relevant stakeholders' perceptions, and knowledge, regarding facilitators and barriers in promoting alternative transport in this area?

Following my research aim and questions, the scientific, social and political aspects of promoting alternative transport were given attention, making this research multi-disciplinary. This research began as a purely quantitative modelling study to evaluate the environmental and health outcomes of hypothetical transport scenarios with a greater

emphasis on alternative transport use, in order to gain an understanding of why promoting alternative transport has realistic significance. However, the need for a second phase became clear, focussing on how to implement the program initially examined in practice, by drawing on community and stakeholders' perspectives. Thereby, in addition to the quantitative modelling study, this thesis also presents a quantitative cross-sectional survey study and a qualitative study of stakeholders.

This mixed methods approach, combining quantitative and qualitative methods, has been defined as “the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration” (Johnson et al. 2007). The rationale for using a mixed methods design in this research was that each of the quantitative and qualitative approaches utilised allowed access to a different range of data and provided a better understanding of the overall research issue than either research approach alone.

Specifically, quantitative methods in this research are used to quantify the environmental and health impacts of alternative transport, and to investigate residents' travel behaviours, attitudes, opinions towards alternative transport use. The strength of a quantitative approach for the community study enabled the collection of data and the identification of attributes from a large population sample rather than a small group of individuals that would be more likely using a qualitative method. In addition, the results generated from the quantitative approach could be utilised not only for the purposes of answering the research questions within this research, but also for the possibility of making a comparison to other published studies that employed similar methods to measure factors

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influencing travel behaviour. In contrast, qualitative methods are appropriate for gaining rich, detailed data from a small group of participants. The study of stakeholders required an approach that enabled an exploration and understanding of each individual's opinion (rather than measuring their opinions). Therefore, a qualitative approach was considered as most appropriate for this phase of the research. It provided an opportunity to have an in-depth discussion with stakeholders about alternative transport based on their professional experience, with the aim of gaining an understanding of why widespread promotion of alternative transport is difficult.

Overall, this research roughly followed a triangulation design so that diverse viewpoints could shed light upon my research questions. Triangulation refers to the process of combining more than one approach to the investigation of a research question in order to validate findings (Olsen 2004), but can also be used to produce innovative conceptual frameworks (Flick 1992). In this research, triangulation was achieved through the use of three separate studies investigating different aspects of the topic of interest. This design led to a multiple-perspective exploration of scientific, social and political aspects of alternative transport use, and assisted in making sure that the research was interdisciplinary and holistic.

The three studies of this thesis are set out in the research framework illustrated in Figure 4.3 below. The subsequent sections of this chapter discuss these three studies in more detail. A full description of each study's methods is given in Chapters 5, 6 and 7, in which the study findings are also discussed.



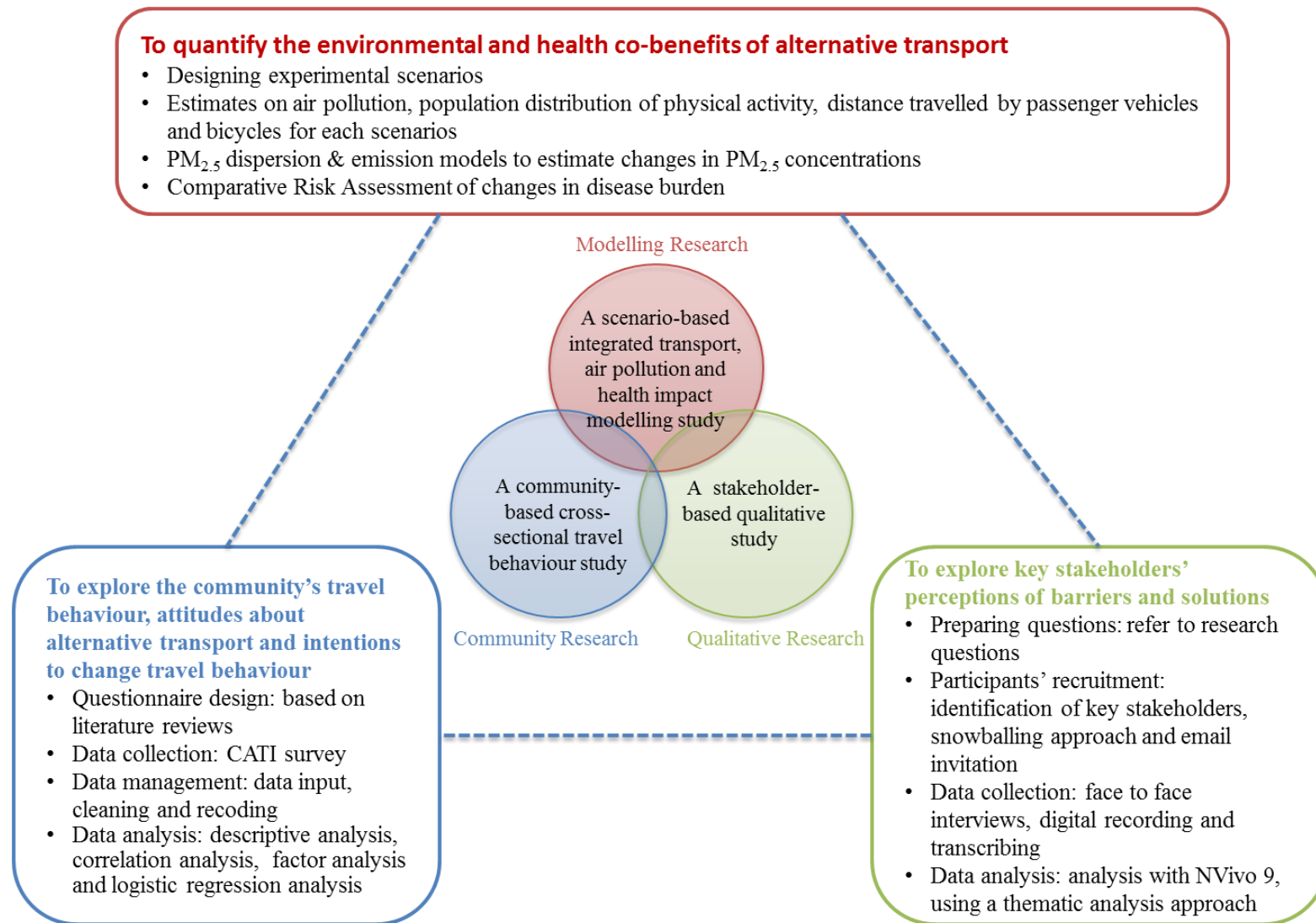


Figure 4.3: The framework of the study: multidisciplinary alternative transport promotion

### **4.3.1 The scenario-based modelling study**

The first study presented in the thesis (see Chapter 5) is a scenario-based modelling analysis. The objectives of this study were to estimate the extent to which PM<sub>2.5</sub> emissions would be reduced in various alternative transport scenarios (promoting public transport and active transport) compared with a business-as-usual (BAU) scenario in metropolitan Adelaide by 2030, and to quantify the health benefits of alternative transport as a result of improved air quality and increased physical activity.

The methodology adopted in this study followed the scoping methods for evaluation of co-benefits of climate mitigation and health protection in the energy sector (Smith and Haigler 2008). This study presented in this thesis began with a scenario setting, which refers to findings from a prior evaluation and local government urban planning. Second, the integrated transport, air pollution and health impact modelling was performed to assess both health and environmental benefits of the alternative transport scenarios compared with BAU scenario. Changes in annual average PM<sub>2.5</sub> concentrations associated with the reduction of passenger vehicle usage in metropolitan Adelaide were simulated by using a combination of two models: 1) the Environmental Protection Authority Traffic Emissions Inventory, which was used to calculate annual daily traffic emissions forecasts; and 2) the Air Pollution Model (TAPM), which was used to model population-weighted annual mean concentration of PM<sub>2.5</sub>. Comparative Risk Assessment were used to conduct the health impact assessment on alternative transport scenarios. This study incorporates traffic data obtained from the EPA, South Australia, and population health data obtained from the South Australian Department for Health and Ageing.

### 4.3.2 The community-based cross-sectional study

In order to change people's behaviour to increase the use of alternative transport and decrease the use of cars, it is important to understand the views of individuals within the community. Having established the benefits of alternative transport in the first study, the second study presented in this thesis (see Chapter 6) aimed to improve understanding of the relationship between residents' attitudes and their current travel behaviour, their acceptance of car reduction measures, and their intention to change their travel behaviour. To obtain a representative sample of community travel behaviours and perspectives, and to minimise selection bias, a random sample of residents from the general population was recruited. A cross-sectional survey was chosen as an appropriate tool to collect the data.

An extensive literature review (Chapter 3) was conducted on factors which influence individual travel behaviour and car-reduction intervention. This review was the basis for the questionnaire design and development. To fulfil the study objectives, an original questionnaire was developed including responses concerning four categories of information (see summary in Table 4.1): demographic characteristics and travel behaviour; perceptions of, and attitudes towards traffic, environment and health; effectiveness of potential traffic measures; and intentions to reduce car use.

**Table 4.1: Survey components**

<b>Demographic variables</b>	<b>Attitudinal variables</b>	<b>Traffic measures variables</b>	<b>Intentions variables</b>
16 questions about socio-demographic and current travel behaviour characteristics	16 statements regarding participants' perceptions of the effect of traffic on the environment and health, and their attitudes towards alternative transport, measured on a 5-point Likert Scale.	9 questions measuring the effectiveness of car reduction measures including three car restriction measures ("Push" measures) and six alternative transport measures ("Pull" measures).	2 questions asked about participants' reasons for change of travel behaviour and which alternative transport modes they would prefer to use in the future.

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The data were collected in collaboration with the Population Research and Outcome Studies (PROS) Unit, at the University of Adelaide, in conjunction with Harrison Health Research, using a computer aided telephone interviewing (CATI) system. The sample group of respondents for the survey was derived from a random selection of households detailed in the Electronic White Pages for nominated localities. Approximately 1,750 households in South Australia are sampled with the aim of attaining approximately 500 completed interviews. A pilot survey of 30 respondents was conducted to validate the questionnaire. A number of question framings were identified as problematic and subsequently reformulated to aid interpretability. In total, 381 residents from metropolitan Adelaide area completed the survey. Descriptive statistics (presented in Chapter 6) outline participants' demographic and travel behaviour information, and their overall attitudes towards traffic, environment, health and car reduction measures. Attitudinal variables were entered into an explorative factor analysis in order to find the smallest number of sets of highly correlated variables and to create a set of factors. Then, the Spearman's correlation analysis was performed with the variables produced by the factor analysis, which aimed to explore the association between attitudinal factors and travel behaviour and car reduction measures. Logistic regression analysis was then performed to identify the predictors of participants' intentions regarding future choice of transport mode.

### **4.3.3 The qualitative study of stakeholders' perspectives**

The third study sought to examine stakeholders' perspectives about the potential barriers to alternative transport promotion in Australia and corresponding strategies to overcome such barriers from a policy perspective. Stakeholders from government, local council and other relevant non-government organisations were considered as potential participants for this study. As I argued earlier in section 4.3, a qualitative approach can be used to gain

rich, in-depth information, and thereby was ideally suited to an exploration of stakeholders' experiences and perceptions in my research. In addition, the qualitative approach adopted contributed to a deeper and extended understanding of the policy-making processes, which are of importance during policy implementation.

There are several means of data collection for qualitative research including observation, individual interviews, reviewing document texts, focus groups and open-ended surveys. This study focused on an investigation of personal views of barriers and solutions around alternative transport use. It involved probing the stakeholders about the challenges for their departments/organisations in encouraging car use and promoting alternative transport use, and about their suggestions to overcome these barriers. Therefore, individual semi-structured interviews were chosen as the appropriate means for qualitative data collection, since they provided a space in which individual stakeholder could discuss their opinions freely with no influence from stakeholders from other sectors. A face to face in-depth interview method was also considered as it can elicit rich, detailed material that can be used in analysis (Lofland and Lofland 2006). Another advantage of conducting interviews is that they make it possible to probe each individual for clarity or further information following the initial questions, more so than in a group interview (Berg and Lune 2004). In addition, this approach allowed interviews in this study to occur at a time convenient for participants' schedules, which was especially important for those in senior positions. Focus groups would have been a potential alternative approach for data collection. However, this approach may have inhibited stakeholders' responses due to perceived vested interests amongst the different group members. Moreover, focus groups require a number of participants in one location, but, in the context of my research, it may have been impracticable to get stakeholders in very senior positions together at the same time for a focus group.

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The semi-structured interviews were conducted based around a topic guide, and made up of a series of open-ended questions. In total, 13 interviews were completed with stakeholders working in transportation planning, urban designing, health promotion, air pollution regulation and other sectors. Data were analysed using a thematic analysis approach to identify patterns of meaning across the dataset.

### **4.4 Ethics**

Approval of each component of the research was obtained from the University of Adelaide Human Research Ethics Committee (No. H-2011-201).

Before implementing the CATI survey for study two, the sampled households were mailed an invitation letter detailing their selection and broad purpose of the study with instructions for opting out of the survey. If participants did not receive the letter before the interview, the interviewer would be informed about the aim of the study, how the interview would be conducted, and privacy and confidentiality issues. Assurance was provided to potential participants that participation in the study was voluntary and that they could withdraw at any stage without giving their reasons. Survey data entered on the computer were password protected with files accessible only to authorised personnel. Only de-identified, aggregated data were collated, analysed and then published (in this thesis and, subsequently, scientific journals) and presented (at scientific conferences).

For study three, all qualitative interview participants were first sent an invitation email (Appendix A), with an information sheet (Appendix B) outlining the overall aim of the study, how the discussion and interview would be conducted, the expected duration of the discussion/interview, and participants' right to withdraw from the study. Potential participants also could ask for the interview questions prior to deciding whether they

would participate. Once they had consented and a time had been arranged, the interview took place. With participants' permission, all interviews were digitally recorded and subsequently transcribed verbatim. During this process, transcripts were de-identified to ensure anonymity and confidentiality. Participants' names were changed to numbers when interviews were transcribed. The data set, consisting of transcripts and recordings, was stored on a university-owned computer with password protection.

## **4.5 Conclusion**

This chapter outlined the approach of each phase of the three studies that were conducted for this research. I have described the rationale for the use of a mixed methods approach. The summary of steps for modelling establishment for the first study, and recruitment, data collection and data analysis for study two and three were presented. The ethical considerations related to this research are also described.

In the following chapters (Chapter 5-7), the results of these studies are presented. Each chapter describes the aims, methods, results, discussion and conclusion for each study in turn as part of the overall thesis. The final general discussion chapter (Chapter 8) draws together the findings of each study into an overall conclusion.





# CHAPTER 5

## Scenario-based modelling study

### Traffic-related air pollution and health co-benefits of alternative transport in Adelaide, South Australia

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#### Preface

This chapter presents the results of the scenario-based modelling study in this thesis. It has been published in *Environment International* (Appendix H) and addresses the first research question for this thesis:

- Comparing to business-as-usual (BAU), what are the future environmental and health benefits in choosing alternative transport scenarios, and to what extent can such co-benefits be obtained?

This article investigates greenhouse gases and particulate matter reductions from replacing passenger vehicle usages with public transport and active transport by using an air pollution model. It also qualifies potential health impacts associated with this change to alternative transport via health impact assessment and traffic injury models.

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## 5.1 Abstract

**Background:** Motor vehicle emissions contribute nearly a quarter of the world's energy-related greenhouse gases and cause non-negligible air pollution, primarily in urban areas. Changing people's travel behaviour towards alternative transport is an efficient approach to mitigate harmful environmental impacts caused by a large number of vehicles. Such a strategy also provides an opportunity to gain health co-benefits of improved air quality and enhanced physical activities. This study aimed at quantifying co-benefit effects of alternative transport use in Adelaide, South Australia.

**Method:** We made projections for a business-as-usual scenario for 2030 with alternative transport scenarios. Separate models including air pollution models and comparative risk assessment health models were developed to link alternative transport scenarios with possible environmental and health benefits.

**Results:** In the study region with an estimated population of 1.4 million in 2030, by shifting 40% of vehicle kilometres travelled (VKT) by passenger vehicles to alternative transport, annual average urban PM<sub>2.5</sub> would decline by approximately 0.4 µg/m<sup>3</sup> compared to business-as-usual, resulting in net health benefits of an estimated 13 deaths/year prevented and 118 disability-adjusted life years (DALYs) prevented per year due to improved air quality. Further health benefits would be obtained from improved physical fitness through active transport (508 deaths/year prevented, 6,569 DALYs/year prevented), and changes in traffic injuries (21 deaths and, 960 DALYs prevented).

**Conclusion:** Although uncertainties remain, our findings suggest that significant environmental and health benefits are possible if alternative transport replaces even a relatively small portion of car trips. The results may provide assistance to various

government organisations and relevant service providers and promote collaboration in policy-making, city planning and infrastructure establishment.

## **5.2 Introduction**

Fossil fuel combustion by motor vehicles is a major source of greenhouse gases (GHGs). It is estimated that 23% of the world's energy-related GHG emissions are attributed to transport systems, and nearly three quarters of these emissions are due to land transportation (Kahn Ribeiro et al. 2007). Meanwhile, exhaust fumes from motor vehicles contain air pollutants such as nitrogen dioxide (NO<sub>2</sub>), volatile organic compounds (VOCs), carbon monoxide (CO) and particulate matter (PM), which disperse ubiquitously. Epidemiological and toxicological studies have recently provided strong evidence that vehicle-related emissions have a relationship with clinically significant health outcomes (Gan et al. 2011; Tsai et al. 2010; Ye et al. 2000). A large portion of PM is contributed to the ambient environment through combustion processes and according to the European Topic Centre on Air and Climate Change data (2005), road transport accounts for 18.4% of total PM emissions worldwide. The last 20 years have brought more certainty about the range of health outcomes associated with PM (Barnett et al. 2006; Hansen et al. 2012). High concentrations of PM have been found to be associated with the risk of lung cancer (Vineis et al. 2006), respiratory (Medina-Ramon et al. 2006) and cardiovascular diseases (Gan et al. 2011). Therefore, PM is a major environmental risk factor to global public health and has been used by the World Health Organization (WHO) as an indicator of air pollution exposure (WHO 2009a).

Programs to change travel behaviours, including the increased use of public transit and active travel, are essential in reducing transport GHG emissions and the adverse health effects of air pollution. Aside from improving air quality, active transport options also

encourage individuals to achieve recommended levels of physical activity. Daily, moderately intense physical activity of approximately 30 min duration can contribute to the reduction of all-cause mortality, and especially to a decreased risk of cardiovascular disease, type II diabetes, breast cancer, colon cancer and dementia (Penedo and Dahn 2005; Warburton et al. 2006). Similar associations between active transport and population health have also been identified (Oja et al. 2011; Xu et al. 2013).

Recently, a number of studies have attempted to quantify the overall health co-benefits of replacing car travel with alternative transport (Macmillan et al. 2014; Maizlish et al. 2013; Rojas-Rueda et al. 2012). For instance, a UK study (Woodcock et al. 2009) projected the environmental and health benefits of various alternative transport scenarios for 2030 in London. The study indicated that over 500 premature deaths and over 7,000 disability-adjusted life-years (DALYs) could be saved under alternative transport scenarios. Similarly, Grabow, et al (2012) found that by eliminating short motor vehicle trips in 11 metropolitan areas in the upper mid-western United States, the annual average urban rate of PM<sub>2.5</sub> would decline by 0.1 µg/m<sup>3</sup>, resulting in net health benefits of 1,295 fewer deaths/year because of improved air quality and enhanced physical activity.

It has been estimated that urban air pollution contributes approximately 1% to the total burden of disease in Australia (Begg, S. et al. 2007a), with 900 to 2,000 premature deaths annually attributed to traffic-related ambient air pollution (BITRE 2005). Australia has one of the highest rates of motor vehicle ownership, with over 90% of Australian households having one or more registered motor vehicles (Australian Bureau of Statistics 2012b). Public transport and active travel trips only account for a small portion of total trips in Australia (Australian Bureau of Statistics 2012b) despite the fact that in major cities, approximately 20% of trips to work are less than 5 km (Australian Bureau of

Statistics 2012b), a distance that could easily be replaced by active transport such as bicycle riding or even walking.

Recently, several studies have been carried out to assess the cost-benefit of active transport use in Australia, both at the city and country levels (Cobiac et al. 2009; Fishman et al. 2011; Mulley et al. 2013). However, none of these studies factor in benefits from air pollution reduction or use of public transport. In the present study, we aim to not only assess health benefits of replacing the use of passenger vehicles with cycling, but also quantify GHG reduction and potential health impacts associated with a travel model change to public transport and active transport.

## **5.3 Materials and methods**

### **5.3.1 Study setting**

Adelaide, the capital city of South Australia, is the fifth-largest city in Australia. As a medium sized city, the metropolitan area occupies around 870 km<sup>2</sup> with a population of 1.1 million in 2010. The public transportation infrastructure includes over 4,500 km of bus routes, 120 km of train lines, 15 km of tram lines and a 770 km network of bicycle lanes (Government of South Australia 2013). However, over 80% of the residents in South Australia travel by private motor vehicle, whilst public transport and active transport only account for 12% and 3% respectively (Australian Bureau of Statistics 2012b). Approximately 18% of private car trips are shorter than 5 km, and 20% are 5-10 km. Thus, short trips in metropolitan areas could be relatively easily replaced by cycling. Although Adelaide has relatively low levels of air pollution, a recent local study suggested an increased cardiorespiratory morbidity associated with increases in ambient levels of PM<sub>2.5</sub> (Hansen et al. 2012).

### **5.3.2 Theoretical framework**

This case study explored the effect on health outcomes in Adelaide of replacing a proportion of the vehicle kilometres travelled (VKT) by passenger vehicles, with public transport and cycling. First, we designed a number of experimental scenarios based on the baseline VKT. We used  $PM_{2.5}$  as the major indicator of air pollution, due to the association with all-cause mortality and because the effects of other vehicular pollutants on mortality become less significant when controlling for  $PM_{2.5}$  (Pope III et al. 2002). Second, we used the Motor Vehicle Emission Inventory to calculate changes in the GHG and  $PM_{2.5}$  emissions generated by motor vehicles and then included the findings into the air pollution dispersion model (TAPM) to estimate the traffic-related  $PM_{2.5}$  concentrations for each scenario. Third, a health impact assessment model based on the comparative risk assessment approach (CRA) (Ezzati et al. 2004) was adapted to quantify changes in the burden of disease associated with a reduction of particulate air pollution, and increased physical activity (taking into account future population projections). Changes in traffic injuries were estimated by using a traffic injury matrix approach. Sensitivity analysis was then conducted to estimate the degree of uncertainty in our modelling. Figure 5.1 shows the overall theoretical framework used for assessing the co-benefit effects of alternative transport in this study.



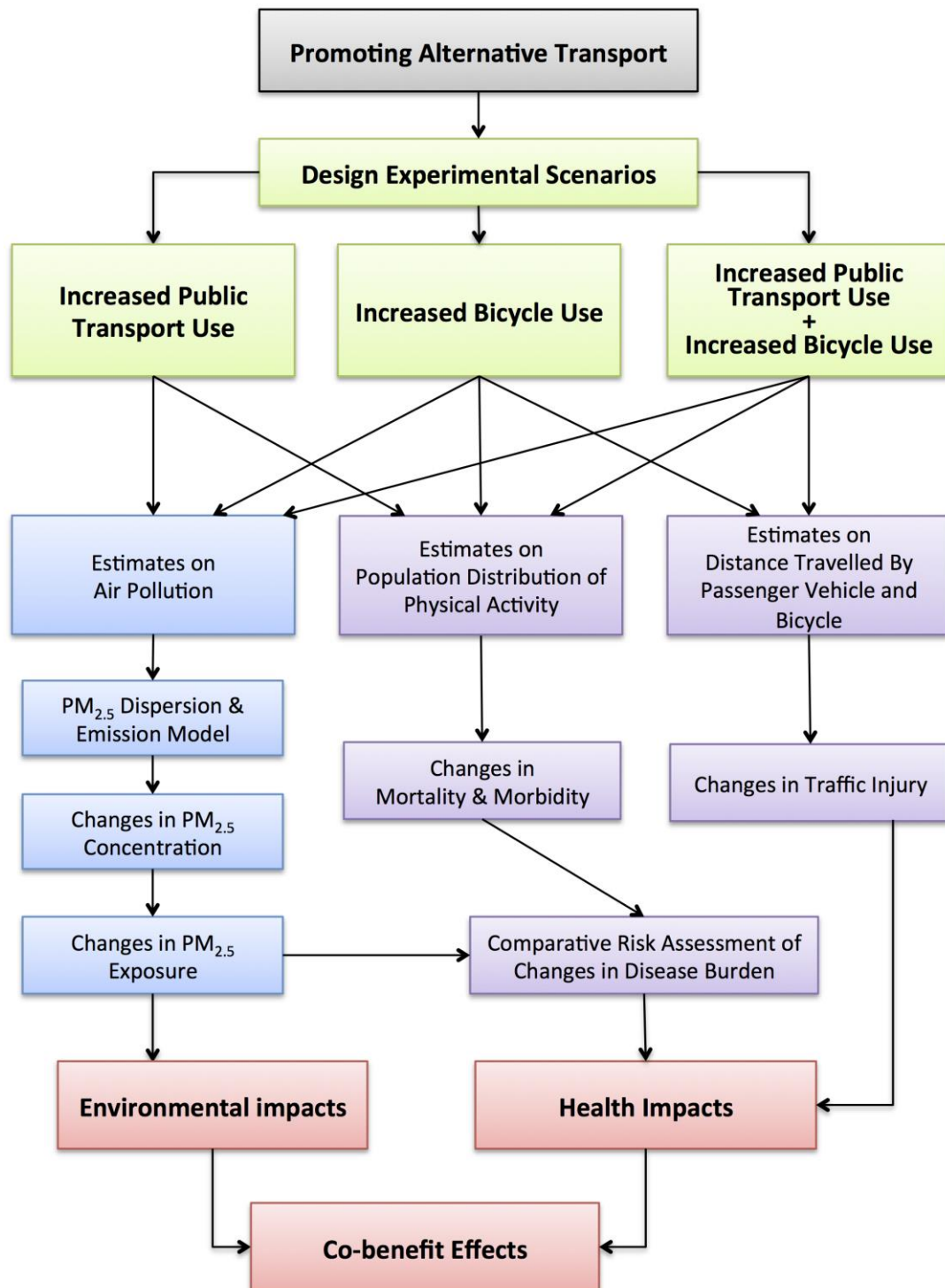


Figure 5.1: Theoretical framework model.

### **5.3.3 Baseline vehicle kilometre travelled and emissions**

We selected 2010 as the baseline year. Baseline VKT and vehicular emissions were estimated using the Motor Vehicle Emission Inventory provided by the Environment Protection Authority (EPA) in South Australia. This inventory contains local traffic information including annual average daily traffic counts and percentage distribution of different vehicle types for over 1,5000 road links derived from the Adelaide strategic transport model. Emission factors for PM<sub>2.5</sub> (gram/km) calibrated to Australian vehicles and traffic data were used to calculate exhaust-related PM<sub>2.5</sub> emissions (grams/per day) for each link.

### **5.3.4 Scenarios**

The scenarios refer to the 30-Year Plan for Greater Adelaide (Government of South Australia 2010) and use transport behaviour in the Netherlands, a country with high levels of walking and cycling, as a scenario example. Hence, we used five scenarios of reductions in passenger vehicle VKT, ranging from 5% to 40%. These were based on the Motor Vehicle Emission Inventory and the latest Transport Use Survey (Australian Bureau of Statistics 2012b).

Table 5.1 presents data relating to VKT at baseline 2010, business-as-usual (BAU) by 2030 and each of the five scenarios. The BAU estimates represent the potential future trajectories for land transportation in the absence of reduction options. Accordingly, the total VKT by all types of vehicle in the 2030 BAU scenario were projected using the 2010 baseline allowing for an annual growth rate of 2.4% in all types of vehicles as indicated in the Bureau of Infrastructure, Transport and Regional Economics report (2011). The reduction in passenger vehicle use scenarios included various hypotheses

regarding the extent of VKT reductions. For each reduction scenario, we assumed that only VKT for passenger vehicles would be replaced by alternative transport, while VKT for other commercial vehicles (e.g. heavy-duty vehicles) would keep increasing at a stable annual growth rate.

The increase in cycling scenarios for 2030 assumed a shift from passenger vehicles to cycling by additional cyclists, resulting in a 5% and 10% reduction in passenger VKT in Scenarios 1 and 2 respectively. The increased public transport use scenarios assumed that 20% and 30% of passenger VKT would shift to public transport. The 'Towards Alternative Transport' scenario (TAT) assumed that a total of 40% of the kilometres travelled by passenger vehicles would be replaced by alternative transport options (including public transport and cycling), presenting a significant change in travel patterns.

**Table 5.1: Scenarios and calculated daily VKT in the metropolitan Adelaide area**

	Baseline		BAU2030 <sup>a</sup>		Increased Cycling <sup>b</sup>				Increased Public Transport <sup>c</sup>				Towards Alternative Transport <sup>d</sup>		
	PV	CV	PV	CV	5% (Scenario 1)		10% (Scenario 2)		20% (Scenario 3)		30% (Scenario 4)		40% (Scenario 5)		
Passenger vehicle VKT reduction															
Calculated Total VKT <sup>e</sup> (million km /per day)	20.6	1.0	33.5	1.6	31.8	1.6	30.2	1.6	26.8	1.6	23.4	1.6	20.1	1.6	

<sup>a</sup> We assumed that the total VKT from all types of vehicles in 2030 will increase the baseline with an annual growth rate of 2.4%.

<sup>b</sup> We assumed that 5% and 10% of passenger vehicle VKT in 2030 will be replaced by cycling.

<sup>c</sup> We assumed that 20% and 30% of passenger vehicle VKT in 2030 will be replaced by public transport.

<sup>d</sup> We assumed that 10% of passenger vehicle VKT in 2030 will be replaced by cycling and 30% will be replaced by public transport.

<sup>e</sup> The results were rounded to one decimal place

**Abbreviations:**

VKT: vehicle kilometres travelled

BAU: business-as-usual

PV: passenger vehicle

CV: commercial vehicles including rigid heavy goods vehicles (HGV), Artic trucks and buses

### 5.3.5 Air pollution estimates

#### 5.3.5.1 Traffic-related PM<sub>2.5</sub> and CO<sub>2</sub> emission model

We used the 2010 baseline emission data to project the PM<sub>2.5</sub> emissions in 2030 BAU and each reduction scenario (Table 5.2). Firstly, we multiplied emission factors by estimated VKT to calculate the amount of daily PM<sub>2.5</sub> emissions. Since emission factors are representative of engine design, fuel use and vehicle size, average PM<sub>2.5</sub> emission factors for passenger vehicles and commercial vehicles were estimated separately using linear regression analysis on total VKT and total emissions (Supplemental material Section A-Figure S5.4). The PM<sub>2.5</sub> emission factors from tyre wear, brake wear and road abrasion were adapted from the UK National Atmospheric Emission Inventory (NAEI) (Walker 2012) (Supplemental material Section A-Table S5.4).

CO<sub>2</sub> emission estimates were calculated based on the Adelaide metropolitan vehicle fleet from the Motor Vehicle Emission Inventory, and emission factors provided by the Australian National Transport Commission (NTC 2013) and NAEI (Walker 2012).

#### 5.3.5.2 PM<sub>2.5</sub> dispersion model

The Air Pollution Model (TAPM) (Hurley 2008) was used to model the dispersion of PM<sub>2.5</sub> and hence population exposure by simulating hourly estimates of surface-level PM<sub>2.5</sub> for one year. Concentrations of PM<sub>2.5</sub> originating from vehicle exhaust, as well as from tyre wear, brake wear and road abrasion, were modelled for the Adelaide metropolitan area for each scenario using the TAPM specific grid selection (1 km × 1 km inner grid and 30 km × 30 km outermost grid). Emissions from other sources and background (i.e., industry, residential heating, biogenic) were excluded in this model.

Meteorological data for 2009 (Bureau of Meteorology Office, Kent Town) were selected for all scenarios. Hourly meteorological data for wind speed, wind direction, average temperature, and average relative humidity were included.

Annual mean PM<sub>2.5</sub> concentrations in metropolitan Adelaide were calculated by modelling concentrations at 26 locations in the model grid.

### 5.3.5.3 Health impact assessment

The CRA (Ezzati et al. 2004) framework was adopted to evaluate the health impacts from a reduction in air pollution and an increase in physical activity (Supplemental material-Section B). By modifying the population distribution of exposure to a risk factor or a group of risk factors, this method facilitates a systematic evaluation of the changes in health impacts attributable to a change in exposure between baseline and each experiment scenario. All the population attributable fractions (PAFs) were translated into the burden of disease specified by age, gender and cause. The burden of disease in this study is quantified in terms of premature deaths and DALYs (Supplemental material-Section B). The differences in burden of disease were then calculated between the reduction scenarios and the BAU scenario.

### 5.3.5.4 Air pollution

#### **PM<sub>2.5</sub> exposure and the concentration-response relationships with health outcomes**

The relative risk (RR) as determined by the concentration response relationship is calculated thus:

$$RR = \exp(b(x_1 - x_2))$$

where *RR* is the relative risk of PM<sub>2.5</sub>, *b* is the estimated risk coefficient, *x*<sub>1</sub> is the mean PM<sub>2.5</sub> concentration of the BAU and *x*<sub>2</sub> is the mean PM<sub>2.5</sub> in each scenario.

The risk coefficients for exposure to PM<sub>2.5</sub> are associated with the likelihood of certain health outcomes including cardiovascular disease, respiratory disease after short-term exposure (Gan et al. 2011), and lung cancer after long-term exposure (Pope III 2007). The risk coefficients for short-term exposure were obtained from the Expansion of the Multi-city Mortality and Morbidity study (EMMM) conducted in Australia (Environment Protection and Heritage Council 2010), whilst the risk coefficients for long-term PM<sub>2.5</sub> exposure were obtained from the American Cancer Society (ACS) cohort study (Pope III et al. 2002) (Supplemental material -Section B Table S5.6).

### **5.3.5.5 Physical activity and health outcome exposure response relationships**

#### **Insufficient physical activity and the dose-response relationships with health outcomes**

Ischemic heart disease (IHD), type 2 diabetes, stroke, colorectal cancer and breast cancer account for a major part of the health burden associated with insufficient physical activity (Begg, S. et al. 2007a) which is also linked to falls and depression (Begg, S. et al. 2007a). The RRs associated with insufficient physical activity for these five major diseases were adopted from a WHO report outlining the health effects of a range of exposures (Ezzati et al. 2004), whilst RRs associated with falls and depression were adopted from the Australian Burden of Disease and Injury Study (Begg, S. et al. 2007a) (Supplemental material -Section B-Table S5.7).

#### **Baseline physical activity**

To estimate the baseline level of physical activity in the general population, data from the Physical Activity Among South Australian Adults survey (Gill et al. 2008) were used in our modelling. This survey describes the overall physical activity using three levels:

sedentary, insufficient and sufficient, which are consistent with the risk levels set by WHO (Ezzati et al. 2004).

### **Estimation of additional alternative transport use**

Under the increased cycling scenario, we assumed that 5% or 10% of VKT travelled by passenger vehicles would be replaced by bicycles. Total numbers of additional cyclists per thousand people were estimated by transferring total cycling distance into daily person cycling length, and those cyclists were evenly distributed into each age and gender category:

$$N = \frac{RVKT_{\text{Scenario}} \times P}{365 \times CTL} \div \text{Pop} \times 1000$$

*N: numbers of new cyclists per thousand people*

*RVKT: replaceable VKT in km*

*CTL: intermediate values of cycling trip length in km*

*P: percentage of each cycling level including short, medium and long-distance ride*

*Pop: total population ( $\geq 15$  years old) in 2030 (Melhuish and Steele 2011)*

Under the increased public transport scenario, 20% or 30% of VKT travelled by passenger vehicles would be replaced by bus, tram and train. According to a recent systematic review conducted by Rissel et al (2012), each public transport trip involves on average 15 min walking. Therefore, increased public transport scenarios would also likely lead to greater increases in population physical activity.

Further information about the estimated changes in population physical activity level and assumptions are provided in Supplemental material-Section C.

### **5.3.5.6 Population projection and burden of disease**

The 3-year average burden of disease data (2006-2008) for metropolitan Adelaide were provided by the South Australian Department for Health and Ageing for each health outcome, and population projections for age and gender were sourced (Melhuish and



Steele 2011). We assumed that the mortality and morbidity rate per 1000 population for each disease and age group would not change for the 2030 scenarios.

#### **5.3.5.7 Estimates of traffic injury**

We adopted the injury matrix method from Woodcock (2009) to estimate changes in traffic injuries, (Supplemental material-Section D). We used historical injury data to derive the injury risk per unit of distance travelled by each type of road user and the vehicles that could cause injury. Since Adelaide metro-specific data were not available, we used the traffic accident data from Causes of Death, South Australia (2007 to 2012) as the baseline (Australian Bureau of Statistics 2012d). The annual mean distance travelled by each transport mode was obtained from 'Road Crashes' in South Australia reported by Department for Transport, Energy and Infrastructure (DPTI) (2010), while the annual mean distance travelled by bicycle was estimated based on the ratio of passenger vehicle travel distance to cycling travel distance reported by the Transport Use Survey (Australian Bureau of Statistics 2012b). Then, we modelled the number of expected traffic injuries based on the assumptions of distance travelled by all the included road users under each scenario.

#### **5.3.5.8 Sensitivity analysis**

In order to estimate the degree of uncertainty in our modelling, we conducted a sensitivity analysis by adjusting five key assumptions in the scenarios. Sensitivity analyses S1-S5 were: (S1) PM<sub>2.5</sub> concentrations using maximum and minimum (derived from TAPM) rather than average values; (S2) conservative and optimistic estimates of changes in physical activity among additional cyclists; (S3) conservative and optimistic estimates of changes in physical activity among additional public transport users; (S4) changes in the age distribution of cyclists (excluding those over 70 years of age); and (S5) calculated

health benefits using the upper and lower confidence intervals of the air pollution and physical inactivity risk estimates (Supplemental material-Section E).

Main data sources and model inputs are summarized in Supplemental material-Section F-Table S5.8.

## **5.4 Results**

Compared with the BAU 2030, the reduction scenarios indicated a decrease of daily total VKT by passenger vehicles ranging from 1.7 million km (Scenario 1) to 13.4 million km (Scenario 5) (Table 5.1). In addition, the total amount of PM<sub>2.5</sub> emissions produced by motor vehicles would reduce by 0.05 tons to 0.45 tons per day (3.3%-20.3% reduction) in the reduction scenarios when compared with BAU 2030 (Table 5.2). The annual reduction of road traffic-related CO<sub>2</sub> emissions would range from 191,313 to 954,503 tons per year depending on the reduction scenarios.

Figure 5.2 indicates that the estimated concentrations of PM<sub>2.5</sub> vary depending on the location of the selected sites. Under BAU 2030, land transportation was predicted to contribute to an annual average of 1.51 µg/m<sup>3</sup> (95% confidence interval (CI) 0.95-3.69 µg/m<sup>3</sup>) increase in PM<sub>2.5</sub> concentration across the Adelaide metropolitan area (Supplemental material-Section A -Table S5.5). As shown in Table 5.2, it was estimated that the 'Increased Cycling' scenarios would lead to around 0.13 µg/m<sup>3</sup> decrease in PM<sub>2.5</sub> concentration, whilst the 'Increased Public Transport' scenarios would reduce PM<sub>2.5</sub> concentration by 0.17 µg/m<sup>3</sup> (0.12-0.48 µg/m<sup>3</sup>, Scenario 3) and 0.33 µg/m<sup>3</sup> (0.21-0.70 µg/m<sup>3</sup>, Scenario 4) compared with the BAU 2030 scenario. The maximum PM<sub>2.5</sub> reduction was estimated to be 0.39 µg/m<sup>3</sup> (0.27-0.91µg/m<sup>3</sup>) in the TAT scenario. Overall, the reduction scenarios showed a range of 8.5-26% decrease in total PM<sub>2.5</sub> emissions from motor vehicles.

**Table 5.2: Estimated PM<sub>2.5</sub> and CO<sub>2</sub> changes, compared to BAU in 2030**

	Baseline	BAU2030	Increased Cycling	Increased Public Transport			Towards Alternative Transport
Passenger vehicle VKT reduction			5% (Scenario 1)	10% (Scenario 2)	20% (Scenario 3)	30% (Scenario 4)	40% (Scenario 5)
	<b>PM<sub>2.5</sub></b>						
Calculated total PM <sub>2.5</sub> emission (tons/per day)	0.88	1.65	1.60	1.54	1.43	1.38	1.21
Annual average PM <sub>2.5</sub> concentration (µg/m <sup>3</sup> ) <sup>a</sup>	0.99 (0.63-2.42)	1.51 (0.95-3.69)	1.38 (0.85-3.44)	1.38 (0.84-3.44)	1.34 (0.85-3.21)	1.19 (0.74-2.98)	1.12 (0.68-2.77)
Reduction (µg/m <sup>3</sup> )			0.13 (0.10-0.24)	0.13 (0.11-0.24)	0.17 (0.12-0.48)	0.33 (0.21-0.70)	0.39 (0.27-0.91)
Percentage reduction (%) <sup>b</sup>			8.5%	8.6%	11.5%	21.6%	26.0%
	<b>CO<sub>2</sub></b>						
Calculated total CO <sub>2</sub> emission (tons/per day)	5060.35	8131.67	7804.78	7477.89	6824.12	6170.35	5516.59
Annual Reduction (tons/per year)			191,313	238,626	477,252	715,878	954,503

<sup>a</sup> Outputs from The Air Pollution Model (TAPM). These results represent simulated traffic-related PM<sub>2.5</sub> concentrations.

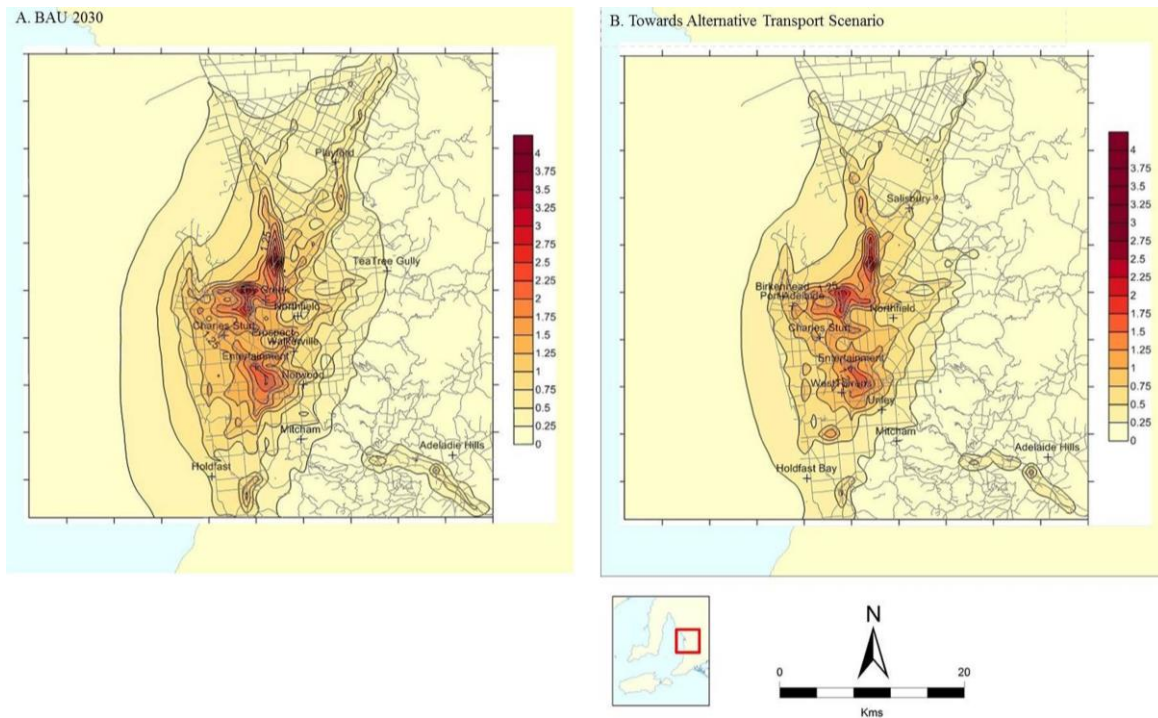
<sup>b</sup> Percentage of reduction represented the reduction of total traffic-related PM<sub>2.5</sub> emissions.

**Abbreviations:**

PM<sub>2.5</sub>: Particulate matter < 2.5 µm.

VKT: Vehicle kilometres travelled

BAU: Business-as-usual



**Figure 5.2: Results of air quality for PM<sub>2.5</sub> due to traffic by location.**

(A) Estimated annual average PM<sub>2.5</sub> concentration (µg/m<sup>3</sup>) for BAU 2030 Scenario. (B) Estimated annual average PM<sub>2.5</sub> concentration due to 40% reduction of passenger vehicle VKT (Scenario 5).

The health impacts calculated as population attributable fractions (PAFs) for short-term and long-term PM<sub>2.5</sub> exposures were estimated to decrease, in line with the PM<sub>2.5</sub> concentration reduction. Furthermore, PAFs for physical inactivity were also estimated to decrease (Supplemental material-Section F-Table S5.9 and Table S5.10).

Table 5.3 shows that among the projected 1.4 million people in metropolitan Adelaide in 2030, the number of estimated deaths prevented from air pollution-related disease per year ranges from 5 (Scenario 1) to 13 (Scenario 5). The total burden of disease prevented from air pollution reduction was estimated to be 39 DALYs in both ‘Increased Cycling scenarios’ (Scenario 1 and Scenario 2), and varied from 52 to 98 DALYs in the ‘Increased Public Transport’ scenarios (Scenario 3 and Scenario 4).

In one “accounting year”, a 5% VKT shift from passenger vehicles to cycling is estimated to prevent a total of 155 deaths and 1,991 DALYs associated with five major chronic

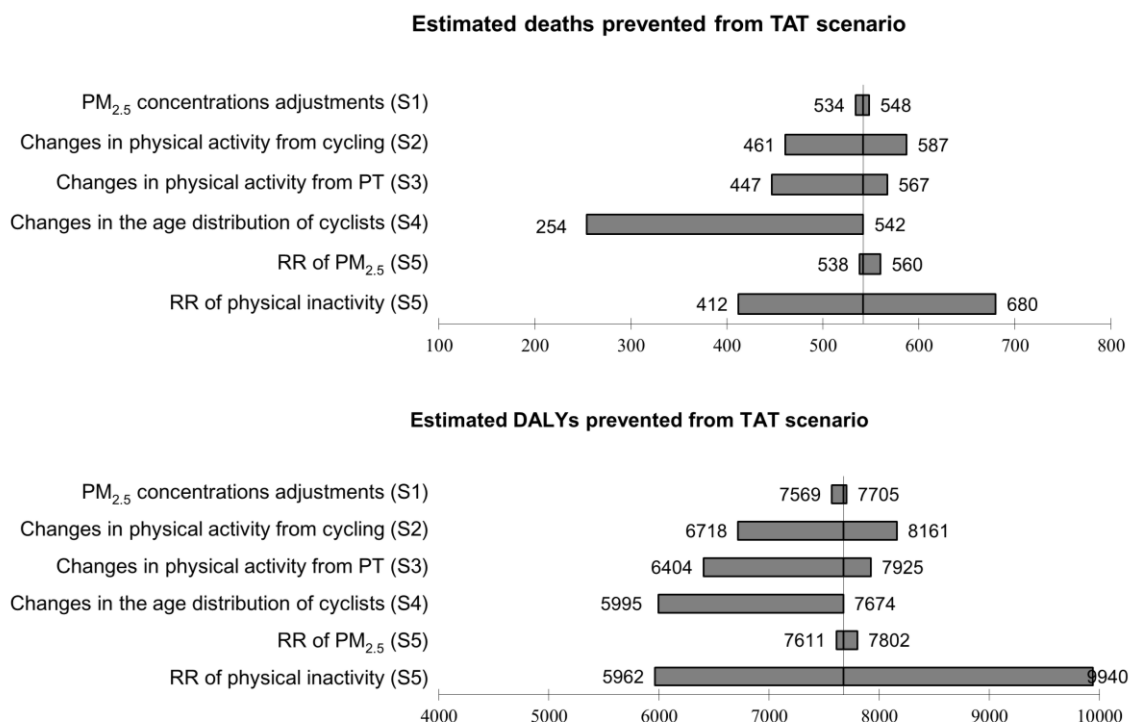
diseases, falls and depression, compared with BAU 2030 (Table 5.3). The most substantial health benefits came from the reductions in disease burden associated with ischaemic heart disease and stroke. Moreover, a 10% VKT shift to cycling would prevent 321 deaths and 4,132 DALYs per year. In addition, the increased public transport scenarios would prevent 104 to 158 deaths and 1,381 to 2,097 DALYs due to an overall decline in the number of people with sedentary and insufficient activity, together with an increase in the number of people with sufficient activity.

Overall, the estimated burden of disease prevented per year for the TAT scenario would be 542 less deaths and 7,674 less DALYs due to changes in air pollution, physical activity and traffic injuries. Detailed information about changes in the distribution of physical activity in the population is shown in Supplemental material-Section B-Figure S5.7 and Section F-Table S5.12.

Figure 5.3 illustrates the impact of uncertainty from the sensitivity analysis. The PM<sub>2.5</sub> concentration adjustments did not affect the model output significantly. The conservative estimate of the effect of increased physical activity among additional cyclists reduced the number of deaths prevented and DALYs saved to 461 and 6,718 respectively, compared to an optimistic estimate of 587 deaths and 8,161 DALYs. Similarly, the output from the conservative and optimistic estimates for additional public transport use were 447 and 567 deaths prevented, and 6,404 and 7,925 DALYs saved, respectively. When the over-70 age group was excluded from the model the total number of estimated deaths prevented reduced from 542 to 254 and the DALYs saved reduced from 7,674 to 5,995. Calculating health benefits using the upper and lower confidence intervals showed a narrower range of health outcomes for air pollution exposure (538-560 deaths and 7,611-7,802 DALYs) than for physical activity (412-680 deaths and 5,962-9,940 DALYs).

**Table 5.3: Estimated annual changes in burden of disease of 2030 reduction scenarios compared with 2030 BAU scenario in Adelaide, South Australia.**

Passenger vehicle VKT reduction	Increased Cycling		Increased Public Transport		Towards Alternative Transport
	5% (Scenario 1)	10% (Scenario 2)	20% (Scenario 3)	30% (Scenario 4)	40% (Scenario 5)
Potential additional user for this mode of transport (per 1,000 people)	218	436	190	285	721
<b>PM<sub>2.5</sub></b>					
<b>Deaths</b>					
Cardiovascular disease	-3	-3	-4	-8	-9
Respiratory disease	-1	-1	-1	-1	-2
Lung cancer	-1	-1	-1	-2	-2
<b>Subtotals</b>	-5	-5	-6	-11	-13
<b>DALYs</b>					
Cardiovascular disease	-22	-22	-29	-55	-66
Respiratory disease	-8	-8	-11	-21	-25
Lung cancer	-9	-9	-12	-22	-27
<b>Subtotals</b>	-39	-39	-52	-98	-118
<b>Physical Activity</b>					
<b>Deaths</b>					
Colon cancer	-12	-24	-8	-13	-38
Breast cancer	-5	-11	-4	-6	-17
IHD	-91	-190	-59	-90	-297
Stroke	-30	-61	-23	-35	-100
Type 2 diabetes	-8	-16	-5	-8	-24
Falls	-9	-19	-5	-8	-31
Depression	0	0	0	0	-1
<b>Subtotals</b>	-155	-321	-104	-158	-508
<b>DALYs</b>					
Colon cancer	-148	-306	-109	-165	-494
Breast cancer	-95	-194	-69	-104	-306
IHD	-807	-1685	-530	-806	-2646
Stroke	-249	-510	-192	-291	-833
Type 2 diabetes	-309	-636	-215	-326	-1003
Falls	-91	-202	-52	-81	-326
Depression	-292	-599	-214	-324	-960
<b>Subtotals</b>	-1991	-4132	-1381	-2097	-6569
<b>Traffic injury</b>					
<b>Deaths</b>	0	-2	-12	-18	-21
<b>DALYs</b>	-83	-192	-459	-753	-960
<b>Total change</b>					
<b>Deaths</b>	-160	-326	-122	-187	-542
<b>DALYs</b>	-2113	-4363	-1892	-2948	-7674



**Figure 5.3: Results from the sensitivity analysis (S1-S5) of the health co-benefits for the Towards Alternative Transport scenario compared to BAU 2030: estimated death and DALYs prevented**

**Abbreviations:** PT: Public transport

## 5.5 Discussion

This study has not only investigated the effects of changes in transport on local air quality, but also assessed the additional health co-benefits associated with alternative transport. Our findings suggest that in the study region with an estimated population of 1.4 million in 2030, a sole travel mode-shift towards public transport would reduce the annual average PM<sub>2.5</sub> concentration by 0.3-0.4  $\mu\text{g}/\text{m}^3$ . Although a sole mode-shift towards cycling would not have a noticeable impact on air quality, it would generate a considerable health co-benefit through improved physical activity. The largest health benefits would occur when increased public transport and cycling are combined, which is

estimated to result in a 55% reduction of total disease burden attributed to physical inactivity.

Our findings are consistent with other recent studies. A U.S. study (Grabow et al. 2012) found that eliminating short car trips in Midwestern U.S. cities would reduce the mean annual  $PM_{2.5}$  by  $0.1 \mu\text{g}/\text{m}^3$ , leading to 608 fewer deaths because of improved air quality and 1,295 fewer deaths because of increased exercise in a population of 31.3 million. Another study conducted in Spain (Rojas-Rueda et al. 2012) reported that a shifting of 40% of car trips to public transport and cycling would lead to a  $0.14 \mu\text{g}/\text{m}^3$  decrease in  $PM_{2.5}$  concentration and avoid 77 deaths per year in a population of 1.6 million. Although the benefits per capita are different in these studies, which are most likely due to the differences in scenario design and underlying population parameters, the significant health co-benefits of active transport are evident.

South Australia's net greenhouse gas emission was estimated to be 30 million tons of carbon dioxide equivalent ( $\text{CO}_2\text{-e}$ ) in 2011/12, which was 10% lower than the 1990 baseline (Commonwealth of Australia 2014). However, transport-related  $\text{CO}_2\text{-e}$  has been growing from 1990 to 2011 (Commonwealth of Australia 2014), and will be doubled by 2050 from the 2006 level in Australia (Garnaut 2008). Findings from our study suggest that shifting 5% to 40% passenger vehicle VKT to alternative transport could achieve reductions of 0.15-0.95 million tons of  $\text{CO}_2$  in metropolitan Adelaide compared with BAU as calculated for the year 2030. Therefore, interventions on travel behaviour can be important in facilitating Australia's greenhouse gas strategy and tackling climate change.

Rapid urbanisation is generally accompanied with an increasing demand for motor vehicles (Cervero and Murakami 2010). To alleviate the negative effects, the mitigation strategies that have been implemented in several countries include the introduction of new vehicle technologies (Cao and Emadi 2012), and improvements of land use and urban



planning (Dulal et al. 2011). However, compared with the policies that focus only on improving fuel efficiency and modifying vehicles to reduce greenhouse gas emissions, encouraging travel behaviour change will generate much greater health co-benefits by integrating more physical activity into the lifestyle. A recent WHO systematic review of health research found that one of the most effective ways to encourage physical activity was implementing transport and urban planning policies (WHO 2009b). Our findings suggest that shifting 5-10% of passenger vehicle travel distances to cycling would generate 200-450 additional cyclists per 1000 people, which could be achievable since the figure is similar to the current prevalence of cyclists in some European cities. For instance, nearly half of the commuting trips are travelled by cycling among Copenhagen residents (Traffic Department 2011), and 57% of people living in Amsterdam use their bike on a daily basis (I Amsterdam 2014). Therefore, it is not an unachievable target to replace a portion of car trips with cycling in a city like Adelaide, but would necessitate more bicycle lanes, inner suburb bicycle routes, secure bicycle parking end-point facilities and sustainable land use planning. Our study also considered increased public transport scenarios for long distance commuting. Although public transport is not a “zero-pollutant” travel mode, its average emission per passenger is far lower than that from private car use. Our findings have also shown additional health benefits of using public transport, since walking to and from public transport can also help physically inactive people to achieve the recommended level of daily physical activity.

Our study is the first attempt to assess air quality improvement and health outcomes based on change in travel behaviour towards alternative transport modes through inclusion of air pollution dispersion, health impact assessment and traffic injury models in an Australian setting. Data sources for the model, including traffic flow, traffic-related PM<sub>2.5</sub>, prevalence of physical inactivity, age-gender specific disease burden and traffic injuries

were obtained from local databases. This makes the estimates as reliable as possible. Although, there were only two transport modes as alternatives, the methodology of the air pollution and the health impact assessment could be adjusted and expanded to other transport modes in future studies. A strength of the study is the comparison of five different levels of reduction in terms of passenger vehicle VKT, including a sole option and a combination option of alternative transport modes. This study will provide local government organisations and relevant service providers with an array of options when planning for a sustainable future transport policy. Moreover, despite geographic and demographic differences between locations, this study in a medium-sized city with developing cycling and public transport strategies, may provide an example to regions with similar urban characteristics.

### **Uncertainty and limitations**

It is acknowledged that many different pollutants released into the atmosphere contribute to air pollution such as NO<sub>2</sub>, VOCs, CO and PM<sub>10</sub> and PM<sub>2.5</sub> (Jalaludin et al. 2009). Since PM<sub>2.5</sub> is a complex mixture of extremely small particles and liquid droplets, the WHO has suggested using PM<sub>10</sub> and PM<sub>2.5</sub> as indicators of air pollution exposure to avoid double counting. In this study, to provide the most reliable estimates possible, we only chose risk estimates of health outcomes related to short-term PM<sub>2.5</sub> exposure based on the EMMM study (Environment Protection and Heritage Council 2010), as well as lung cancer mortality for long-term exposure (Cohen et al. 2004).

Similar to other studies (Grabow et al. 2012; Maizlish et al. 2013; Rojas-Rueda et al. 2012), the findings from this study did not suggest a large decrease in PM<sub>2.5</sub> concentration associated with car use reduction. However, our estimation of pollution reductions does not take into account specific sub-populations that are potentially exposed to higher levels

of air pollution. The concentration-response relationships used in this and other air quality studies are all based on previous research into general population-based exposures and do not include people who live or work near major roads or those who are exposed to air pollution in their respective travel mode. Improvements in air quality due to active and public transport would probably benefit both sub-populations. Furthermore, by averaging concentrations of  $PM_{2.5}$  from 26 selected sites, the result may not represent the true reduction at some locations. In addition, motor vehicles also produce non-exhaust-related PM emissions from tyre wear, brake wear and road abrasion. Although we included non-exhaust  $PM_{2.5}$  emissions into the TAPM model, there still remains a degree of uncertainty with the accuracy of the model, especially whether it represents the total traffic-related exposure in metropolitan Adelaide.

There is evidence that the health improvements from enhanced physical activity tend to occur gradually over time and may be long-term. However, it is hard to predict precisely how soon individuals or whole populations could gain health benefits by increasing their active transport level. Therefore, this research, and most previous studies, only project the health co-benefits occurring in one “accounting year”. Also, potential changes in mortality and morbidity rates over time were not included in our model. How to incorporate such factors in to the health impact assessment is worthy of investigation in the future. Moreover, when establishing a series of models to quantify the overall health co-benefits from alternative transport in this study, it is necessary to make a set of assumptions. Each assumption may have a significant impact on the inputs and may lead to substantial variations in the outputs of this model. Therefore, a series of sensitivity analyses were performed to assess the uncertainty of some parameters and the impact of key assumptions on the outcomes.

## *Chapter five*

The CRA approach has been recommended as the method to estimate the potential health co-benefits of climate mitigation strategies (Zhao et al. 2007). When performing this type of CRA analysis, the key assumption is that travellers' physical activity levels would be affected by travel behaviour change. Both the UK and the U.S. studies (Maizlish et al. 2013; Woodcock et al. 2009) converted active travel distance to transport related median hours of metabolic equivalent task hours (MET), which in turn increased population median MET values. Different from their methods, our study categorized the physical activity levels into "inactivity", "insufficient" or "sufficient", referring to the Comparative Quantification of the health risks study conducted by WHO (Ezzati et al. 2004). Our analysis assumed that physical activity levels for people who cycled or used public transport instead of driving would increase to a higher level, thereby changing the population distribution of each level. Widely used by many cost-benefit studies of cycling programs (De Hartog et al. 2010; Giles-Corti, B et al. 2010), this method assumed that people who were inactive or insufficiently active would increase their exercise through cycling. People who are already sufficiently active and for whom physical inactivity is not a risk factor, would not necessarily benefit from regular cycling. Our model does not address those additional health benefits from extra physical activity beyond the 'sufficient' threshold. On the other hand, some people may reduce other non-transport-related physical activities because of increased cycling and walking, which would make their total amount of physical activity remain unchanged.

As mentioned previously, a sensitivity analysis was performed to assess the uncertainty of population changes in physical activity levels. When comparing differences with the moderate estimations, a more significant change was observed in the conservative estimates than in the optimistic estimates. One of the major reasons was that the values of RRs associated with being total sedentary were significantly higher than that of RRs

associated with having insufficient activity. Accordingly, a greater health benefit of travel behaviour change is to be gained for those people who are sedentary, whereas relatively smaller health benefits will be obtained from those people who are currently insufficiently active and are on the trajectory of becoming sufficiently active (Figure 5.3).

We also have found that the numbers of total estimated deaths prevented would drop significantly from 542 to 254 if the over-70 age group was excluded from the model in the sensitivity analysis. This change can be attributed to the fact that mortality rates from major chronic diseases are higher among older people. Interestingly, a less than 40% reduction occurred in the absolute change in DALYs, which can be interpreted by the fact that young people lose more healthy life years than older people due to premature death. In addition, whether older people could gain health benefits from a change in travel mode is debatable since age-related reasons could make it difficult for them to move to cycling (Ruth 2011). Notwithstanding, in many European cities people continue to cycle in older age. For instance, cycling accounts for 12% of the trips in the older population in Germany and Denmark, and that percentage has been found to be twice as high in the Dutch elderly (Pucher and Buehler 2008). Overall, age is an important contributor to the model.

In our study, we also consider the possible change of road traffic fatalities because of the shift in travel mode. It should be noted that a slight reduction in alternative transport elevates DALYs as a result of collisions with other motor vehicles. We not only took these changes into consideration for cyclists and car occupants, but also considered pedestrians, motorcyclists, and occupants of commercial vehicles. Jacobsen et al (2003) found that a doubling in the prevalence of cycling would lead to a 34% reduction in the injury risk per km cycled. We incorporated this 'safety in numbers' effect into the traffic

injury estimation in our model. However, the risk to other transport users injured by cars might be reduced as well due to a reduction of car-related VKT. Therefore, our method may over-estimate the risk of injury to remaining users of all other modes. In addition, the relationship between travel distance and road traffic injuries was found to not be necessarily linear. This may cause inevitable uncertainties in the estimation of traffic injuries.

This work has addressed the co-benefits of active transport. However, there remain considerable knowledge gaps in the current literature. This requires future research which should focus on expanding the modelling of air pollution to other vehicular pollutants, especially to NO<sub>x</sub> and black carbon, which would enhance our ability to estimate the health benefits of improved air quality. The current emission inventory estimate can be improved in the future by taking into account emission data of other pollutants and speed-dependent emission factors. The air pollution modelling approach can be improved by also considering dry/wet depositions and secondary particle formation in the atmosphere. Moreover, the modelling undertaken in this study could be applied to assess co-benefits of shifting very short car trips to walking. A future analysis could perhaps also include PM<sub>2.5</sub> confounders such as noise, increases in UV radiation, increased social capital, changes in diet and even in crime patterns that may be associated with changes in travel behaviour and may have an effect on health outcomes. Previous studies have concluded that the health benefits of shifting to active modes of transport, would over time, be much greater than the associated costs of additional alternative transport infrastructures. Therefore, an economic justification of such a travel behaviour intervention should be further investigated.

## **5.6 Conclusion**

In conclusion, promoting alternative transport use can produce considerable health benefits mainly from increased levels of physical activity. Although findings from this study do not suggest a large reduction in PM<sub>2.5</sub> concentration, health impacts from the reduction of the air pollution exposure for the general population cannot be neglected. These changes in transport behaviour can also mitigate greenhouse gas emissions from road transport. Our results also suggest that the number of road traffic injuries might not increase due to the safety factor provided by the large number of cyclists and pedestrians. Therefore, the overall benefits of replacing passenger vehicle travel distance with alternative transport may far outweigh the risks. This may interest policy makers in support of transport strategies which especially favour active transport over those aimed solely at reducing vehicular emissions. This study may also provide useful information for a number of government organisations and relevant stakeholders and policy-makers, and may inform city and infrastructure planning that aims to promote better public health outcomes.





**Supplemental Material**

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## Section A- Air Pollution Model Description and Output

All air pollution model predictions were estimated based on a combination of the Environmental Protection Authority Motor Vehicle Emission Inventory database (EPA-MVEI) and the Air Pollution Model (TAPM) version 4.0 which was developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Hurley 2008). EPA-MVEI was used to obtain annual daily traffic emissions forecasts, while TAPM was used to calculate model predicted annual mean concentration of  $PM_{2.5}$ .

Providing detailed local traffic emission data for over 15,000 road links and for different vehicle types, the EPA-MVEI also estimates exhaust  $PM_{2.5}$  emissions (grams/per day) based upon emission factors (grams/km), annual average daily vehicle kilometres travelled (VKT) and average speed along each of the road links as per the baseline Adelaide vehicle fleet data (2006).

We used the baseline emission data to project the emission data for 2030 Business as Usual (BAU) and for each mitigation scenario. Average emission factors for passenger vehicles exhaust and other heavy vehicles exhaust were estimated using linear regression on total VKT and total  $PM_{2.5}$  emissions including all road links. Accordingly, emission factors of  $PM_{2.5}$  in passenger vehicles and other heavy vehicles were calculated as 0.021g/km and 0.2945g/km, respectively (

Figure S5.4). The emission factors of  $PM_{2.5}$  from tyre wear, brake wear and road abrasion were adopted from UK National Atmospheric Emission Inventory (NAEI) (Table S5.4) (Walker 2012).

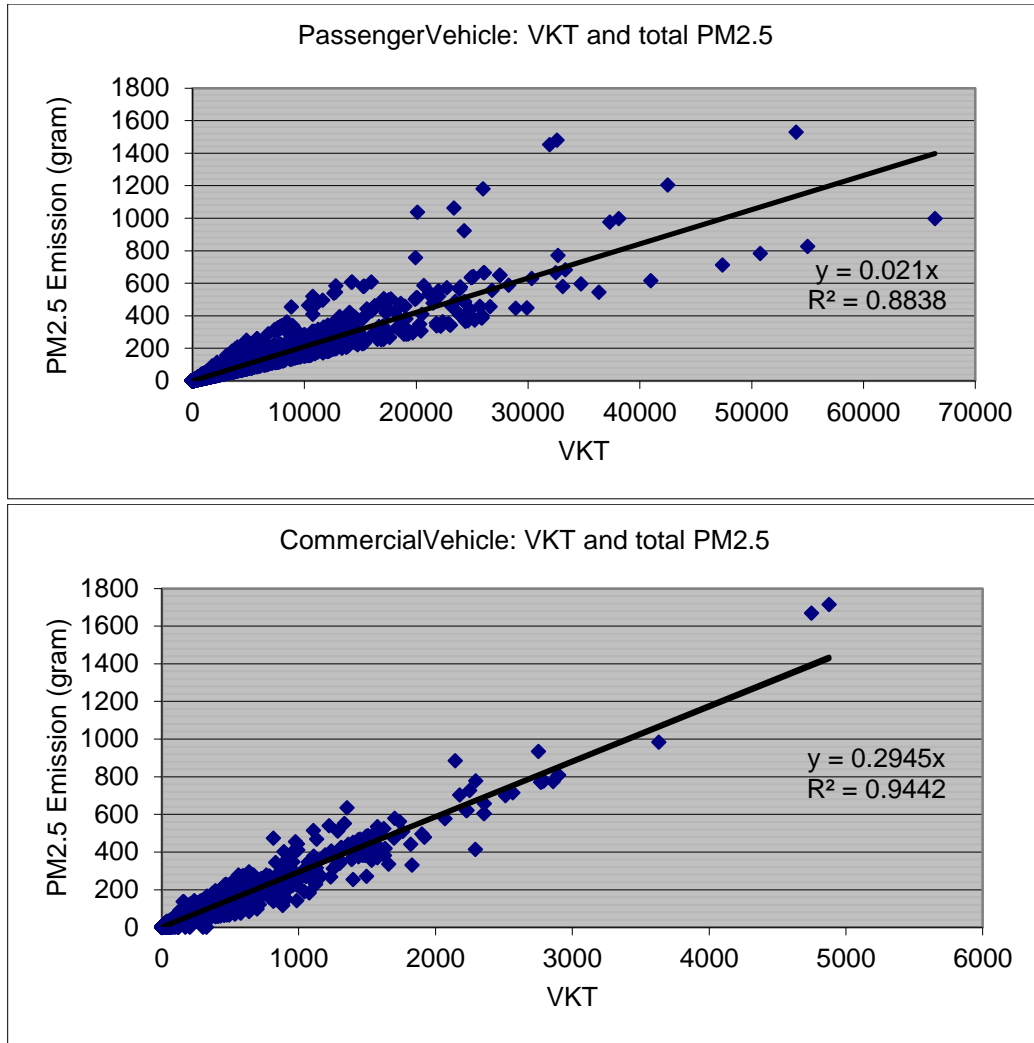
We estimated changes in ambient air  $PM_{2.5}$  concentrations using hourly simulations with the TAPM model which assists in predicting three-dimensional meteorology and air pollution concentrations caused by different individual sources and estimates the annual

mean concentration of PM<sub>2.5</sub>. We adjusted the model configuration with boundary conditions from a 50 × 50 km<sup>2</sup> simulation over metropolitan Adelaide. (Grid Centre Coordinate Latitude: 34°50.5' and Longitude: 138°35.5').

Road transport emission sources were modelled as line sources. The imported line source file contained parameters such as start and end point coordinates of road links, fraction of Nitrogen oxide/Nitrogen oxide (NO/NO<sub>x</sub>), fraction of Fine Particles/Aerosol Particle Mass Analyser (FPM/APM) and emission rates calculated in grams/second. Output files from the EPA-MVEI database were formatted to suit the TAPM line source input file. New line source files for 2030 BAU scenario and each mitigation scenario were created and imported into the model. Emissions from other point sources and diffuse sources such as industrial processes were not included and were assumed to remain unchanged. The purpose of this model was to estimate the reduction of air pollution attributed to decreasing passenger vehicle usage and air pollution caused by other sources was not included in this study.

We selected 2009 synoptic data as reference meteorology, which was considered to be a year with typical local conditions. TAPM Model input included 6-hourly meteorological data collected at synoptic scale (Bureau of Meteorology Office, Kent Town). The parameters calculated for local scale meteorology included wind speed, wind direction, average temperature, and average relative humidity.

Model performance was evaluated using annual mean concentrations at 26 sites. Six of those sites, including Netley, Birkenhead, Elizabeth, Northfield, Kensington and Christies Downs are the EPA official air quality monitoring sites in Adelaide. The rest of the sites were selected according to local government areas geographical locations (Figure S5.5). Output from the TAPM is shown in Table S5.5.



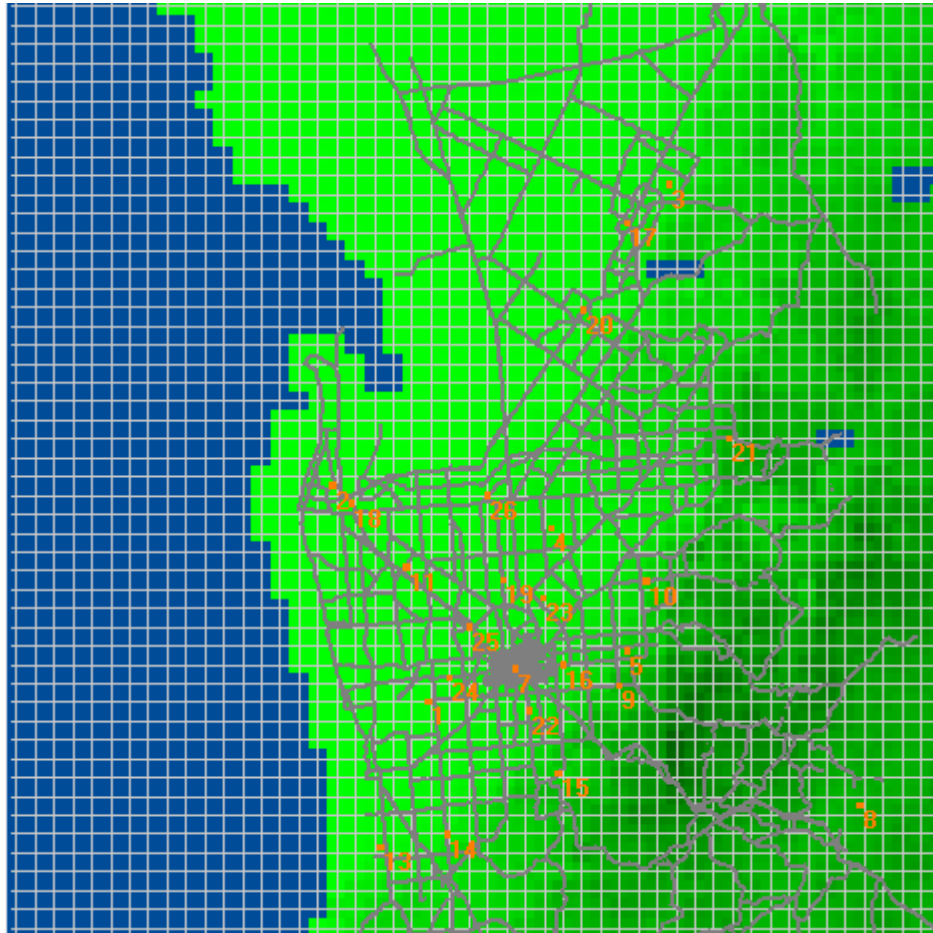
**Figure S5.4: Linear relationship function for PM<sub>2.5</sub> emission and VKT in g/km**

\* Passenger vehicles including cars and light commercial vehicles (LCG); and commercial vehicles including rigid heavy goods vehicles (HGV), arctic trucks and buses

**Table S5.4: Tyre wear, Brake wear and Road abrasion emission factors by vehicle type**

Type of vehicle	Emission factors of PM <sub>2.5</sub> (g/km)		
	Type wear	Brake wear	Road abrasion
Cars	0.005	0.003	0.004
LGVs	0.008	0.004	0.004
Rigid HGVs	0.012	0.011	0.021
Arctic trucks	0.025	0.007	0.021
Buses	0.014	0.017	0.021
M/cycle	0.002	0.002	0.002

\*LGV: light goods vehicles HGV: heavy goods vehicles



**Figure S5.5: Line source on the TAPM Interface and selected sites**

EPA monitoring sites in the Adelaide metropolitan area: (1) Netley, (2) Birkenhead, (3) Elizabeth, (4) Northfield (5) Kensington, (6) Christies Downs.

Local government areas: (7) City of Adelaide (Victoria square), (8) Adelaide Hills Council, (9) City of Burnside, (10) City of Campbelltown, (11) City of Charles Sturt, (12) Town of Gawler, (13) City of Holdfast Bay, (14) City of Marion, (15) City of Mitcham, (16) City of Norwood Payneham & St Peters, (17) City of Playford, (18) City of Port Adelaide Enfield, (19) City of Prospect, (20) City of Salisbury, (21) City of Tea Tree Gully, (22) City of Unley, (23) Town of Walkerville, (24) City of West Torrens, (25) Entertainment Centre, (26) Dry Creek.

**Table S5.5: Estimated annual mean PM<sub>2.5</sub> concentrations (µg/m<sup>3</sup>) by selected sites**

Selected sites	Scenarios					
	2030BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Netley	2.05(1.24-3.82)	1.91(1.14-3.57)	1.90(1.14-3.57)	1.75(1.05-3.33)	1.59(0.96-3.09)	1.44(0.87-2.85)
Birkenhead	1.54(1.21-3.82)	1.47(1.23-3.57)	1.49(1.07-3.57)	1.38(1.16-3.33)	1.31(0.94-3.09)	1.18(0.95-2.85)
Elizabeth	0.90(0.50-3.82)	0.83(0.23-3.57)	0.84(0.26-3.57)	0.82(0.54-3.33)	0.77(0.50-3.09)	0.67(0.29-2.85)
Northfield	2.11(1.02-3.82)	1.97(0.95-3.57)	1.96(0.95-3.57)	1.83(0.87-3.33)	1.70(0.80-3.09)	1.57(0.72-2.85)
Kensington	0.89(0.37-3.82)	0.83(0.35-3.57)	0.83(0.35-3.57)	0.76(0.32-3.33)	0.68(0.29-3.09)	0.61(0.26-2.85)
Christies Downs	0.50(0.31-2.10)	0.47(0.29-1.97)	0.47(0.29-1.97)	0.44(0.27-1.84)	0.40(0.24-1.71)	0.35(0.22-1.59)
City of Adelaide	2.58(1.99-3.82)	2.40(1.83-3.57)	2.40(1.83-3.57)	2.22(1.68-3.33)	2.04(1.53-3.09)	1.85(1.36-2.85)
Adelaide Hills Council	1.10(1.05-3.82)	1.05(1.05-3.57)	1.05(1.05-3.57)	1.00(1.00-3.33)	0.95(0.95-3.09)	0.91(0.91-2.85)
City of Burnside	0.74(0.21-3.82)	0.69(0.29-3.57)	0.69(0.29-3.57)	1.38(0.48-3.33)	0.57(0.24-3.09)	0.51(0.22-2.85)
City of Campbelltown	0.78(0.36-3.82)	0.64(0.37-3.57)	0.65(0.37-3.57)	0.59(0.34-3.33)	0.54(0.31-3.09)	0.53(0.26-2.85)
City of Charles Sturt	1.96(1.35-3.82)	1.83(1.26-3.57)	1.83(1.26-3.57)	1.71(1.17-3.33)	1.59(1.08-3.09)	1.47(0.99-2.85)
Town of Gawler	0.50(0.42-2.10)	0.48(0.40-1.97)	0.47(0.39-1.97)	0.44(0.37-1.84)	0.42(0.35-1.71)	0.38(0.32-1.59)
City of Holdfast Bay	0.75(0.58-3.82)	0.68(0.39-3.57)	0.68(0.39-3.57)	0.62(0.36-3.33)	0.56(0.32-3.09)	0.50(0.33-2.85)
City of Marion	1.15(0.76-3.82)	1.04(1.52-3.57)	1.07(0.70-3.57)	0.97(0.64-3.33)	0.88(0.58-3.09)	0.75(0.43-2.85)
City of Mitcham	0.71(0.36-3.82)	0.49(0.23-3.57)	0.49(0.23-3.57)	0.61(0.31-3.33)	0.41(0.20-3.09)	0.36(0.18-2.85)
City of Norwood	1.65(0.57-3.82)	1.52(0.53-3.57)	1.51(0.53-3.57)	1.38(0.48-3.33)	1.26(0.44-3.09)	1.13(0.39-2.85)
City of Playford	1.00(0.85-3.82)	0.90(0.73-3.57)	0.98(0.57-3.57)	0.90(0.54-3.33)	0.84(0.51-3.09)	0.76(0.46-2.85)
City of Port Adelaide Enfield	1.93(1.41-3.82)	1.85(1.43-3.57)	1.85(1.43-3.57)	1.74(1.33-3.33)	1.64(1.24-3.09)	1.51(1.08-2.85)
City of Prospect	2.33(1.15-3.82)	1.92(0.98-3.57)	1.92(0.98-3.57)	2.04(0.99-3.33)	1.89(0.90-3.09)	1.66(0.80-2.85)
City of Salisbury	1.17(0.85-3.82)	1.10(0.80-3.57)	1.10(0.80-3.57)	1.02(0.74-3.33)	0.93(0.68-3.09)	0.84(0.62-2.85)
City of Tea Tree Gully	0.49(0.28-3.82)	0.52(0.32-3.57)	0.36(0.17-3.57)	0.49(0.30-3.33)	0.31(0.15-3.09)	0.29(0.13-2.85)
City of Unley	2.34(0.89-3.82)	1.78(0.51-3.57)	1.78(0.51-3.57)	1.98(0.76-3.33)	1.47(0.42-3.09)	1.40(0.45-2.85)
Town of Walkerville	1.84(1.03-3.82)	1.85(0.89-3.57)	1.85(0.89-3.57)	1.53(0.91-3.33)	1.40(0.83-3.09)	1.30(0.72-2.85)
City of West Torrens	2.46(1.36-3.82)	2.29(1.26-3.57)	2.29(1.26-3.57)	2.11(1.16-3.33)	1.94(1.06-3.09)	1.76(0.96-2.85)
Entertainment Centre	2.56(2.29-3.82)	2.38(2.15-3.57)	2.38(2.15-3.57)	2.20(2.01-3.33)	2.02(1.86-3.09)	1.84(1.70-2.85)
Dry Creek	3.31(2.21-3.82)	3.11(2.08-3.57)	3.11(2.08-3.57)	2.92(1.95-3.33)	2.73(1.83-3.09)	2.54(1.71-2.85)
Total average	1.51(0.95-3.69)	1.38(0.85-3.45)	1.38(0.84-3.44)	1.34(0.84-3.21)	1.19(0.74-2.98)	1.12(0.68-2.77)

## Section B- Comparative Risk Assessment

The framework of the Comparative Risk Assessment (CRA) is adopted in this study to assess the health impacts. This method is a systematic evaluation of the changes in population burden of disease resulting from modified population distribution of exposure to a risk factor or a group of risk factors (U.S. Environmental Protection Agency 2006). It enables the comparison of health impacts between different scenarios, either the same scenario in different years or different scenarios in the same year. Therefore, CRA has been recommended as an appropriate method to estimate the potential health co-benefits of climate mitigation strategies (Smith and Haigler 2008).

The total disease burden was estimated following the steps described previously (Ezzati et al. 2004). Briefly, the exposure distribution was assessed in the Adelaide population and relevant relative risk estimates were determined from a recent meta-analysis. The fractions of each disease attributable to a change in population based exposure between baseline and each experiment scenario were then calculated based on the formula below (Ezzati et al. 2004):

$$PAF = \frac{P(RR - 1)}{P(RR - 1) + 1}$$

where PAF is the population attributable fraction

$P$  is the specific health outcomes distribution in the Adelaide metropolitan population and  $RR$  is the relative risk associated with the relevant exposure difference.

With multiple ( $n$ ) exposure categories, the  $PAF$  is given by the following generalized formula:

$$PAF = \frac{\sum_{i=1}^n P_i(RR_j - 1)}{\sum_{i=1}^n P_i(RR_j - 1) + 1}$$

If the exposure distributions or relative risks were age or gender specific, the attributable fractions were also estimated by age or gender.

All the attributable fractions were translated to the attributable disease burden ( $AB$ ) specified by age, gender and cause as:

$$AB = PAF \times B$$

where  $B$  is the total burden from this disease.

The burden of disease in this study is quantified in terms of premature deaths and disability-adjusted life years (DALYs). DALY is as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability. This is calculated as the sum of the Years of Life Lost (YLL) due to premature mortality and the Years Lost due to Disability (YLD) for people living with the health condition or its consequences (WHO 2013a).

The risk factors in this study were  $PM_{2.5}$  exposure and physical inactivity. The risk coefficients of short-term  $PM_{2.5}$  exposure were obtained from the expansion of the multi-city mortality and morbidity (EMMM) study (Environment Protection and Heritage Council 2010), whilst the risk coefficients for long-term  $PM_{2.5}$  exposure were obtained from the American Cancer Society (ACS) cohort study (Pope III et al. 2002) (Table S5.6). The  $RR$ s of physical inactivity for five major diseases were adopted from a WHO report (Ezzati et al. 2004), and the  $RR$ s of falls and depression were adopted from Australian Burden of Disease and Injury Study (Begg, S. et al. 2007a) (Table S5.7) . The total disease burden attributable to  $PM_{2.5}$  exposure and physical inactivity related diseases in the baseline was estimated based on the 3-year average burden of disease (2006-2008) for



metropolitan Adelaide which was provided by the South Australian Health Department. Although the population is likely to rise and the age structure is likely to change in the coming decades, we assumed that the mortality and morbidity per 1000 population in each age group would remain unchanged for the 2030 scenarios. Therefore, the total disease burden in the BAU scenario is projected based on the baseline and population growth.

**Table S5.6: Increases in mortality and morbidity (and 95% confidence intervals) associated with a one  $\mu\text{g}/\text{m}^3$  increase in  $\text{PM}_{2.5}$  (unit of air pollution change)**

Health outcome*	Percent increase (95% CI)
<b>Mortality</b>	
Total Cardiovascular <sup>a</sup>	
<75	0.40 (0.20,0.60)
75+	0.50 (0.20,0.70)
Total Respiratory (75+) <sup>a</sup>	0.60 (0.00,1.10)
Lung cancer (30+) <sup>b</sup>	0.13 (0.04-0.17)
<b>Morbidity</b>	
Total Cardiovascular (65+)	0.30 (0.10,0.50)
Total Respiratory	
0-4	0.40 (0.20,0.70)
5-14	0.30 (0.00,0.50)
15-64	0.30 (0.00,0.60)
65+	0.40 (0.20,0.60)
Lung cancer <sup>A</sup> (30+)	0.13 (0.04-0.17)

\* International Classification of Disease 10th revision cause code: total cardiovascular disease (I00-I99), total respiratory disease (J00-J99), lung cancer (C33-C34)

<sup>a</sup> The risk coefficients of short-term  $\text{PM}_{2.5}$  exposure were obtained from the expansion of the multi-city mortality and morbidity (EMMM) study (Environment Protection and Heritage Council 2010).

<sup>b</sup> The risk coefficients for long-term  $\text{PM}_{2.5}$  exposure were obtained from the American Cancer Society (ACS) cohort study (Pope et al. 2002).

**Table S5.7: Summary of the relative risk estimates for physically inactive related diseases for level 1 (sedentary), level 2 (insufficiently active) and level 3 (sufficient active) exposures, by age and sex\***

Relative risks #	15- 70 years			70+ years		
	Sedentary	Insufficient	Sufficient	Sedentary	Insufficient	Sufficient
<b>Male</b>						
Colon cancer <sup>a</sup>	1.68 (1.55-1.82)	1.18 (1.05-1.33)	1	1.48 (1.36-1.60)	1.13 (1.01-1.27)	1
Breast cancer <sup>a</sup>	NA	NA	NA	NA	NA	NA
IHD <sup>a</sup>	1.71 (1.58-1.85)	1.44 (1.28-1.62)	1	1.50 (1.38-1.61)	1.31 (1.17-1.48)	1
Stroke <sup>a</sup>	1.53 (1.31-1.79)	1.10 (0.89-1.37)	1	1.38 (1.18-1.60)	1.08 (0.87-1.33)	1
Type 2 diabetes <sup>a</sup>	1.45 (1.37-1.54)	1.24 (1.10-1.39)	1	1.32 (1.25-1.40)	1.18 (1.04-1.32)	1
Falls <sup>b</sup>	2.50 (2.00-5.00)	2.50 (2.00-5.00)	1	2.50 (2.00-5.00)	2.50 (2.00-5.00)	1
Depression <sup>b</sup>	1.30 (1.25-1.66)	1.30 (1.25-1.66)	1	1.30 (1.25-1.66)	1.30 (1.25-1.66)	1
<b>Female</b>						
Colon cancer	1.68 (1.55-1.82)	1.18 (1.05-1.33)	1	1.48 (1.36-1.60)	1.13 (1.01-1.27)	1
Breast cancer	1.29 (1.25-1.35)	1.13 (1.04-1.22)	1	1.25 (1.21-1.30)	1.09 (1.01-1.18)	1
IHD	1.71 (1.58-1.85)	1.44 (1.28-1.62)	1	1.50 (1.38-1.61)	1.31 (1.17-1.48)	1
Stroke	1.53 (1.31-1.79)	1.10 (0.89-1.37)	1	1.38 (1.18-1.60)	1.08 (0.87-1.33)	1
Type 2 diabetes	1.45 (1.37-1.54)	1.24 (1.10-1.39)	1	1.32 (1.25-1.40)	1.18 (1.04-1.32)	1
Falls	2.50 (2.00-5.00)	2.50 (2.00-5.00)	1	2.50 (2.00-5.00)	2.50 (2.00-5.00)	1
Depression	1.30 (1.25-1.66)	1.30 (1.25-1.66)	1	1.30 (1.25-1.66)	1.30 (1.25-1.66)	1

# Incidence and mortality

\*Classification of physical activity:

**Sedentary:** no participation in physical activity in one week.

**Insufficient activity:** between those who met 150 minutes of moderate-intensity physical activity accumulated from one or more domains in one week from those who did not.

**Sufficient activity:** at least 150 minutes of moderate-intensity physical activity accumulated from one or more domains in one week.

<sup>a</sup> The RRs of physical inactivity for five major diseases (colon cancer, breast cancer, IHD, type 2 diabetes) were obtained from the comparative quantification of health risks reported by WHO (Ezzati et al. 2004).

<sup>b</sup> The RRs of falls and depression were obtained from Australian Burden of Disease and Injury Study (Begg, S. et al. 2007a)

## Section C- Physical activity of cyclists and pedestrians

### A. The physical activity of cyclists:

#### 1. *Determination of cycling trip length*

Cycling trips were classified into three levels: short distance (less than 5 km), medium distance (5-10 km), and long distance (10-20 km). Over 95% of cycling trips made in Adelaide were shorter than 20 km according to data from the Transport and Motor Vehicle Usage Survey conducted in Australia (Australian Bureau of Statistics 2012b).

#### 2. *Assumptions on replaceable vehicle kilometres travelled (VKT)*

In scenarios 1 and 2, we assumed that 5% and 10% VKT by passenger vehicle would be replaced by cycling. Fifty percent of the replaceable VKT was short distance, 25% was medium distance and 25% was long distance, similar to the settings from the above survey. To simplify the calculation, the intermediate values of the three trip distances in (1) i.e. 2.5, 7.5, and 15km, respectively were used in the study.

#### 3. *Estimating replaceable VKT*

By multiplying the percentage of trips by the intermediate trip distance, the ratio of the total distance of short, medium and long distance trips is 2:3:5. The total replaceable VKT were then allocated to short, medium and long distance trips according to this ratio.

#### 4. *Estimating numbers of additional cyclists*

- The number of additional cyclists/per thousand people in Adelaide (population 1.4 million) was estimated based on two assumptions. Firstly, all the replaceable VKT would be undertaken by new additional cyclists. Secondly, all additional cyclists

were evenly distributed into each age and gender category. Total numbers of additional cyclists per thousand people were calculated by using the formula in the main text (see Section 5.3.5.5).

- The results showed that, to achieve the goal set in scenario 1 (i.e. 5% reduction of VKT by car), 114 additional cyclists per thousand people would have to ride bicycles for short distances, 57 for medium distances and 47 for long distances. The numbers of additional cyclists for all trips need to double to achieve the goal set in scenario 2 (i.e. 10% reduction of VKT by car).

5. *Making assumptions about cyclists' physical activity levels:*

Physical activity levels were categorized into “sedentary”, “insufficient” and “sufficient”, according to the Comparative Quantification of Health Risks study conducted by WHO (Ezzati et al. 2004).

Our assumptions regarding cyclists' physical activity levels (Figure S5.6) were:

- (a) The average cycling speed was assumed to be 15 km/h. At such speed, people riding 7.5 km per day would get 30 minutes exercise and reach the “sufficient” physical activity level as classified by WHO.
- (b) For future short distance cyclists (i.e. less than 5 km), the amount of exercise would increase to the next level (e.g. from total sedentary to insufficient, or from insufficient to sufficient) as a result of a daily ride.
- (c) For future medium distance cyclists (i.e. 5-10 km), half of them would achieve one level up in physical activity, while the other half would increase by two levels of physical activity (e.g. from sedentary to sufficient).
- (d) For future long-distance cyclists (i.e. 10-20 km), they were assumed to increase their amount of physical activity by two levels. In other words, those

who are sedentary would move to the group of sufficient activity level, if they cycled over 10 km per day.

### **B. The physical activity of Pedestrians:**

For increased public transport scenarios, we also took into account additional amounts of physical activity related to walking to and from public transport in the model.

#### *1. Estimating numbers of additional public transport trips in scenarios.*

In the increased public transport scenarios, we assumed that 20% and 30% of VKT by passenger vehicle would be replaced by public transport including train, tram and bus. We assumed that the mean passenger vehicle trip length was 15 km based on the transport use survey (Australian Bureau of Statistics 2012b). Then, the number of additional public transport trips were calculated by dividing replaced VKT by the mean passenger vehicle trip length.

#### *2. Estimating numbers of additional public transport users in scenarios.*

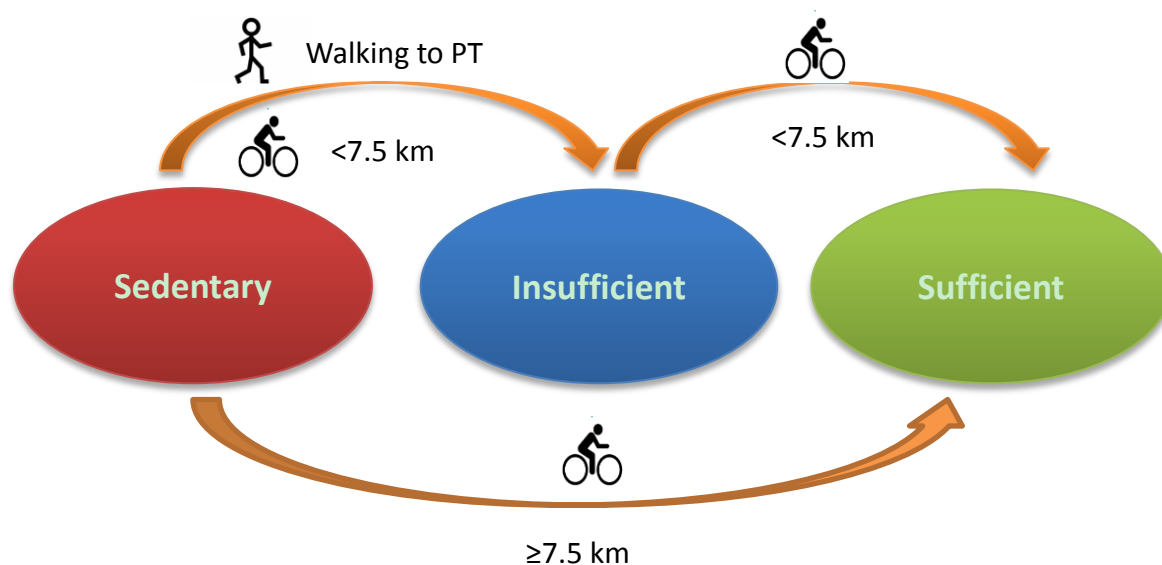
We assumed that those additional public transport users would take the public transport to their destination and return. Therefore, the number of additional public transport users was calculated by halving the number of public transport trips.

#### *3. Making assumptions on public transport users' physical activity levels*

According to a recent systematic review conducted by Rissel et al (2012), each public transport trip involves 15 minutes walking. Based on their finding, we considered all additional public transport users would do additional walking to public transport, and their levels of physical activity would move to the next level (e.g. from total sedentary to insufficient, or from insufficient to sufficient) (Figure S5.6). However, some people may gain sufficient physical activity solely by walking to and from public transport, but some people may only gain negligible physical activity related to public transport. Therefore, in

the sensitivity analysis, we also adjusted the assumption on public transport users' physical activity levels.

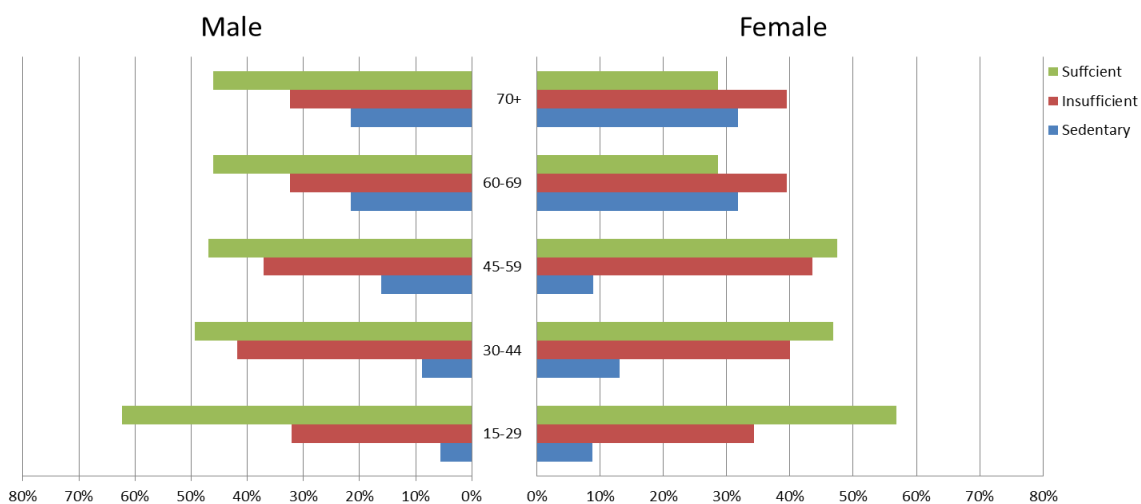
We incorporated our assumptions on physical activity into scenario 5 for both additional cyclists and public transport users. Baseline population distribution of physical activity was obtained from the South Australian Adults Survey (Gill et al. 2008), and also applied to the BAU scenario. The population prevalence of physical inactivity among all scenarios would reduce due to changes in physical activity levels among additional cyclists (Figure S4).



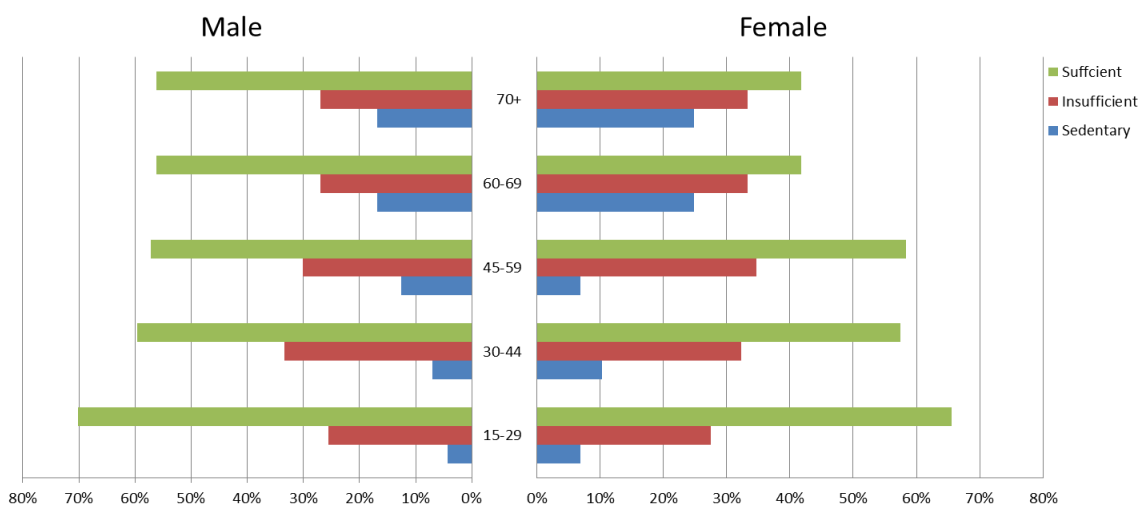
**Figure S5.6: Assumptions on changes in physical activity levels for cyclists and pedestrians**

Abbreviation: PT: Public transport

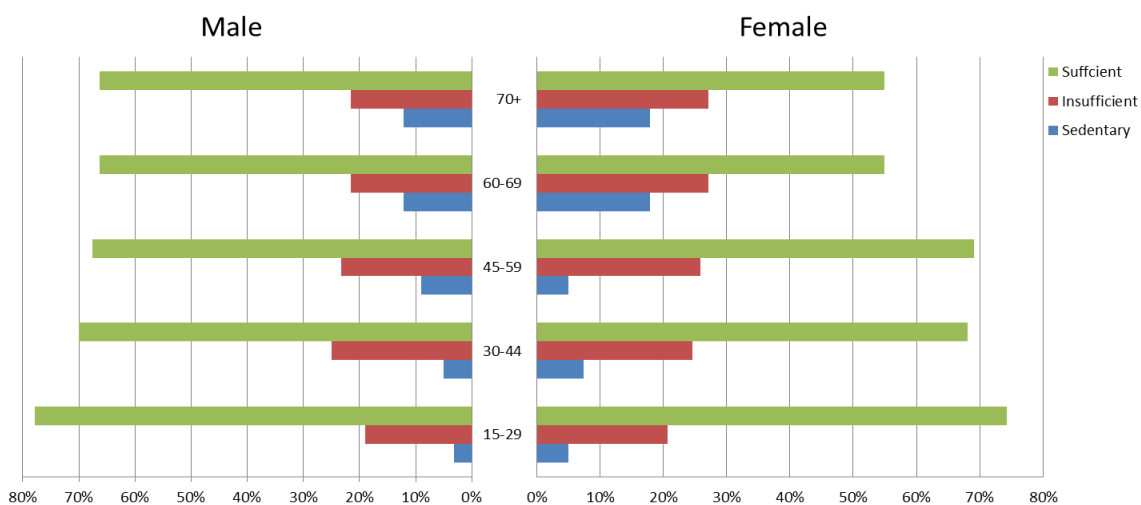
**A. Baseline & BAU**



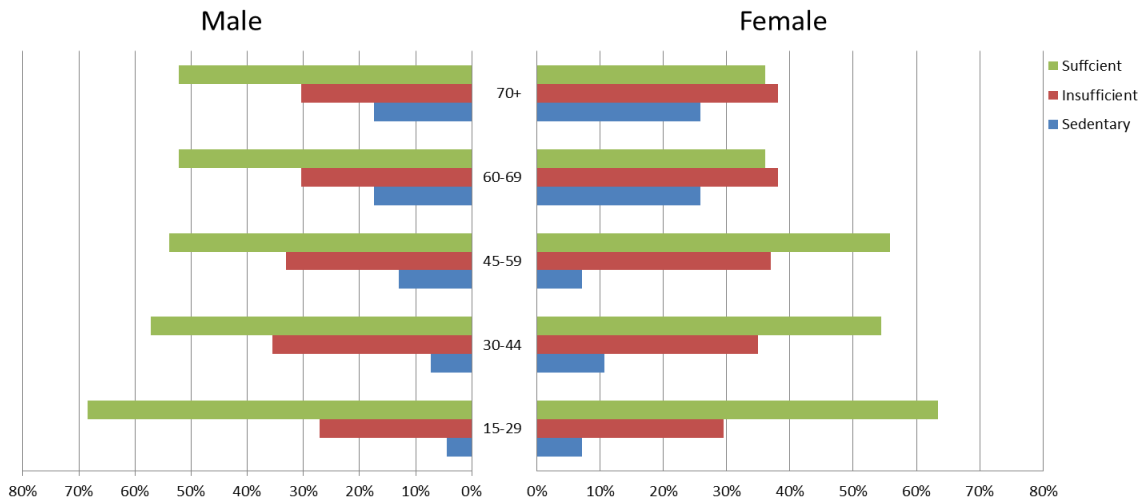
**B. Scenario 1**



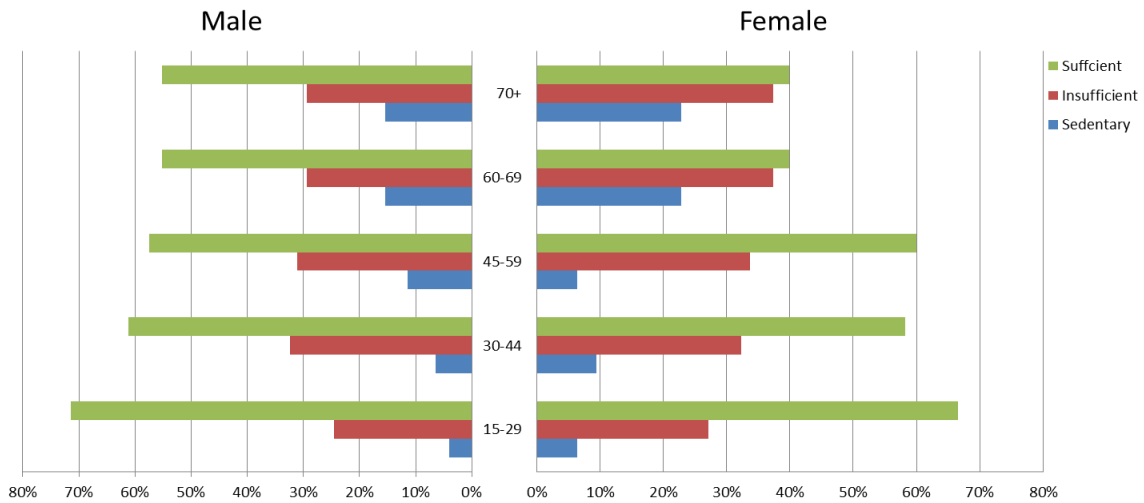
**C. Scenario 2**



**D. Scenario 3**



E. Scenario 4



F. Scenario 5

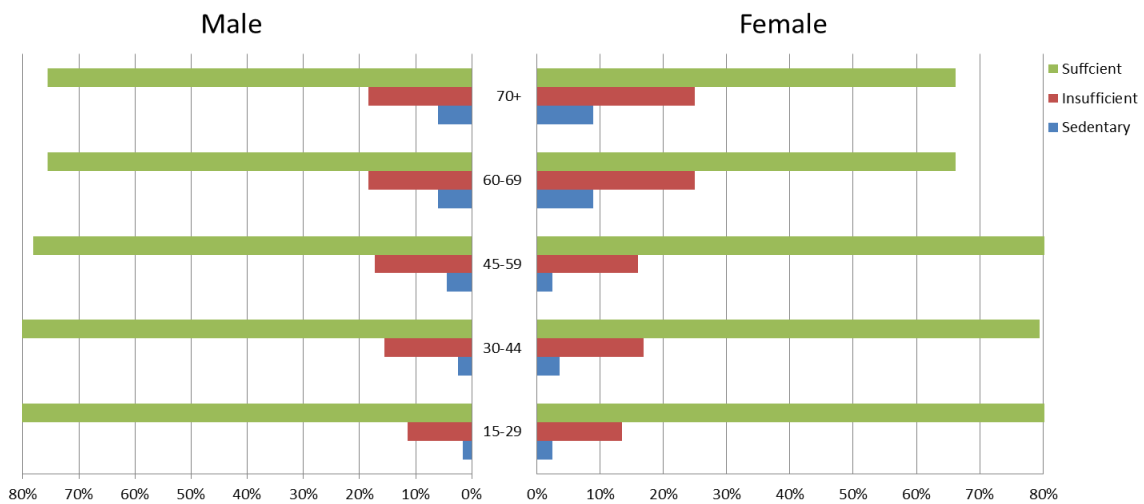


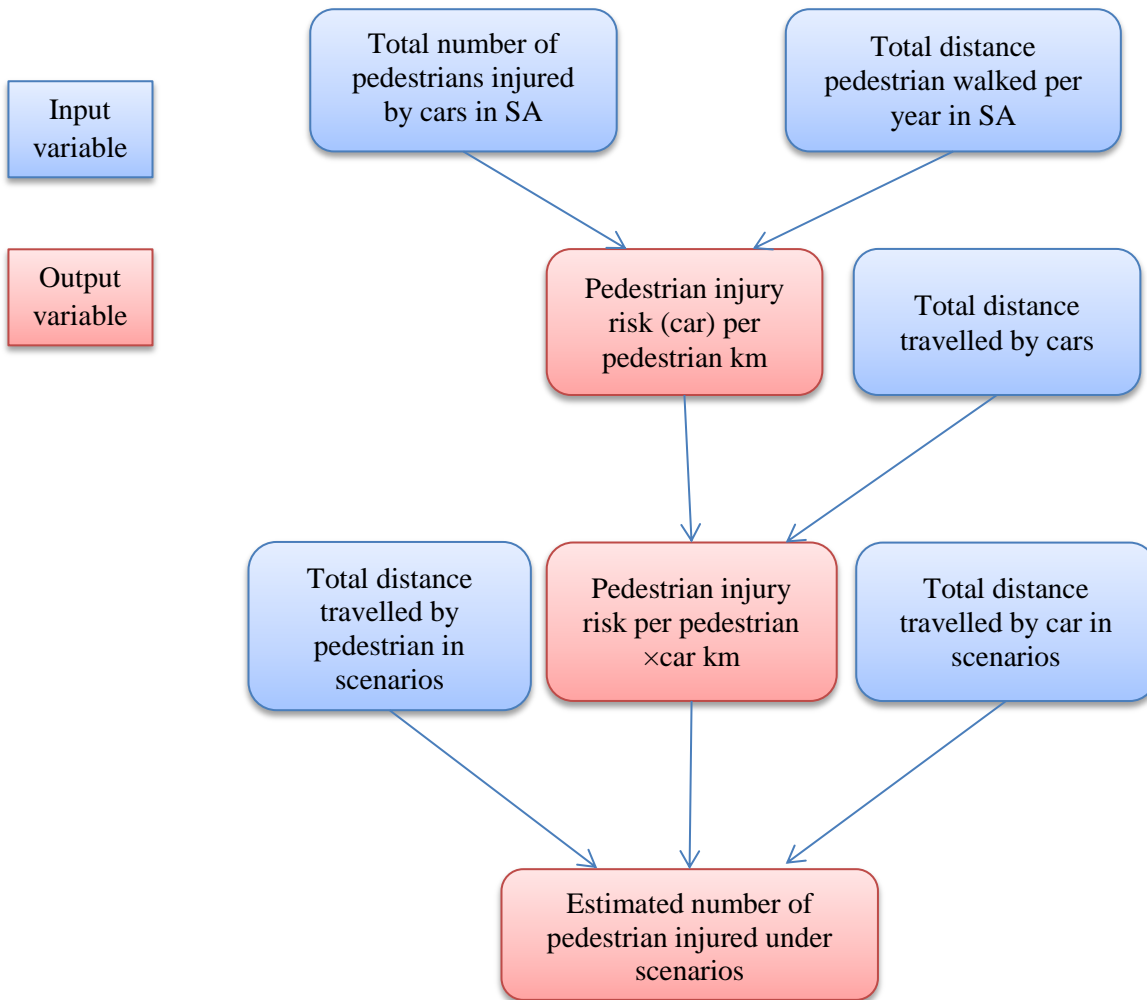
Figure S5.7: Population distribution of physical activity in Increased Cycling Scenarios compared with BAU2030, metropolitan Adelaide



## Section D- Estimates of Traffic Injury

To estimate changes in traffic injuries, we adopted the road traffic injury matrix approach from Woodcock (2009) (Figure S5.8). We obtained the numbers of travellers injured by various vehicles from Causes of Death, South Australia (2007 to 2012) reported by the Australian Bureau of Statistics (ABS) (2012d). The data contained the number of people injured categorised as pedestrian, cyclist, motorcyclist, car occupant, and heavy vehicle occupant, and whether they had collided with a bicycle, car, motorcycle, heavy vehicle and bus or no other vehicle. First, we estimated the probability of a traveller being injured by a striking vehicle per kilometre travelled by this traveller. The next step was to estimate the traveller injury risk per kilometres travelled by the striking vehicle that caused the injury. The annual mean distance travelled by each transport mode was obtained from Road Crashes in South Australia reported by the Department for Transport, Energy and Infrastructure (2010), while the annual mean distance travelled by bicycle was estimated based on the ratio of passenger vehicle travel distance to cycling travel distance, reported by the Transport Use Survey (Australian Bureau of Statistics 2012b). Then, the new absolute number of traffic injuries (deaths and DALYs) in scenarios was calculated by multiplying the traveller injury risk by the striking vehicles taking into account the total distance travelled by the travellers, and the offending vehicles, based on the assumptions under each scenario. Since we assumed that each public transport trip would involve 15 min walking (equal to 1 km walking), the risk of a pedestrian as a potential extra public transport user was also integrated into the model. Under our scenarios, the number of additional pedestrians and cyclists would increase substantially, which could reduce the injury risk for pedestrians and cyclist according to the “safety in number” effect (Jacobsen 2003; Robinson 2005). Therefore, the ‘safety in number’ concept was incorporated into the final step estimation. We assumed that injury risk per

km cycled would reduce by 50% in scenario 1, and by 75% in scenario 2 and 5. The injury risk per km walked would also reduce by 50% in scenario 3, and by 75% in scenario 4 and 5.



**Figure S5.8: Traffic injury model (considering the number of pedestrians injured by cars)**

## Section E-Sensitivity analyses

The changes in attributable fractions depend on changes in exposure, which in this study were affected by key inputs into the model. We carried out sensitivity analyses in scenario 5 to test the impact of key inputs on the health impact assessment model outcomes:

- Sensitivity analysis 1 (S1):

Air quality may vary in different periods of time or locations. Therefore, we used the values of local minimum PM<sub>2.5</sub> and maximum PM<sub>2.5</sub> concentrations to estimate the uncertainty in the change of air quality.

- Sensitivity analysis 2 (S2):

It was uncertain as to what extent cycling-related activity would lead to a shift upwards in the overall level of activity. Instead of assuming that 50% medium-distance cyclists and all long-distance cyclists increase their physical activity by two levels, a conservative estimate and an ambitious estimate for shifting physical activity levels were made to address this question. In the conservative estimate, it was assumed that all cyclists would only improve by one level. Those at total inactivity level were assumed to move to the insufficient activity level and those at the insufficient activity level would move to the sufficient activity level. The optimistic estimate was applied to project the maximum health benefits of increased cycling, which assumed that all cyclists would move into the sufficient active category regardless of which active level they previously belonged to.

- Sensitivity analysis 3 (S3):

Evidence shows that walking to and from public transport would provide an additional amount of physical activity. However, without a local investigation, the average walking

time related to public transport use still remains uncertain. Therefore, similar to sensitivity analysis 2, instead of assuming all additional transport users increase their physical activity to the next level, we assumed that 50% would only gain negligible physical activity in the conservative estimate. In the optimistic estimate, we assumed that 50% of them might gain sufficient physical activity solely by walking to and from public transport and 50% would increase their physical activity to the next higher level.

- Sensitivity analysis 4 (S4):

Based on the data and statistics from *Transport Use Australia*, people aged over 70 rarely use bicycles for travelling (Australian Bureau of Statistics 2012b). In this research, the CRA method was used to estimate the health impact only for one “accounting” year. Although being active in middle age can have benefits in later life, the effect of age on the model could not be ignored. Thus, this analysis was applied to investigate the impact of excluding the over-70 age group from the study outcomes.

- Sensitivity analysis 5 (S5):

The lower and upper limits of the 95% CI for the RRs on physical inactivity and air pollution were adopted to estimate the health impact assessment model. It is noteworthy that insufficient activity may not be a risk factor for stroke according to the lower limits of the 95% CI for the RRs.

## Section F- Supplementary Tables and Figures

Table S5.8: Summary of Data Sources and Model Inputs

Model Parameter	Data Source(s)
VKT by vehicle type for Baseline/BAU/Scenarios <sup>1</sup>	<ul style="list-style-type: none"> <li>Environmental Protection Authority Motor Vehicle Emission Inventory</li> </ul>
Average annual vehicle growth rates <sup>1,2</sup>	<ul style="list-style-type: none"> <li>BITRE, 2011. Road vehicle-kilometres travelled: estimation from state and territory fuel sales</li> </ul>
Total PM <sub>2.5</sub> emission exhausted <sup>1</sup>	<ul style="list-style-type: none"> <li>Environmental Protection Authority Motor Vehicle Emission Inventory</li> </ul>
Average exhaust emission factors for PM <sub>2.5</sub> and CO <sub>2</sub> <sup>1</sup>	<ul style="list-style-type: none"> <li>Linear regression analysis on total VKT and total PM<sub>2.5</sub> by vehicle type</li> <li>Carbon Dioxide Emissions from New Australian Vehicles 2012</li> <li>UK National Atmospheric Emission Inventory</li> </ul>
Tyre wear/ Brake wear/ Road abrasion emission factors for PM <sub>2.5</sub> by vehicle type <sup>1</sup>	<ul style="list-style-type: none"> <li>UK National Atmospheric Emission Inventory</li> </ul>
PM <sub>2.5</sub> concentration <sup>1,2</sup>	<ul style="list-style-type: none"> <li>Air Pollution Model Graphical User Interface</li> </ul>
Disease specific RRs for PM <sub>2.5</sub> exposure <sup>2</sup>	<ul style="list-style-type: none"> <li>Expansion of the multi-city mortality and morbidity (EMMM) study</li> <li>Pope et al. 2002</li> </ul>
Disease specific RRs for physical inactivity <sup>2</sup>	<ul style="list-style-type: none"> <li>Comparative Quantification of Health Risks, WHO, 2004</li> </ul>
Distribution of levels of physical activity <sup>2</sup>	<ul style="list-style-type: none"> <li>Physical activity among south Australian Adults, SA Health, 2007</li> </ul>
Age-gender specific mortality rate and disease burden <sup>2,3</sup>	<ul style="list-style-type: none"> <li>Adelaide Burden of Disease 3 year average estimates 2006-2008, SA Health, 2010</li> </ul>
Adelaide population 2010,2030 <sup>2,3</sup>	<ul style="list-style-type: none"> <li>Age-Sex Population Projections by Statistical Local Area 2006-2026, Government of South Australia, 2011</li> </ul>
Transportation mode sharing <sup>1,3</sup>	<ul style="list-style-type: none"> <li>Environmental Issues: Waste Management and Transport Use, ABS, 2012</li> </ul>
Road Fatalities and Serious Injuries <sup>3</sup>	<ul style="list-style-type: none"> <li>Underlying cause of death, all causes, South Australia (2007-2012)</li> <li>Road crashes in South Australia, DPTI, 2010</li> </ul>

<sup>1</sup> Air pollution model input

<sup>2</sup> Health impact assessment model input

<sup>3</sup> Estimates of traffic injury input

**Table S5.9: Estimated relative risk and the attributable fraction (AF) for annual short-term and long-term PM<sub>2.5</sub> exposure (BAU scenario compare to reduction scenarios)**

Health outcome	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	RR	PAF	RR	PAF	RR	PAF	RR	PAF	ΔRR	PAF
<b>Mortality</b>										
Total Cardiovascular										
<75	1.0005	0.0005	1.0005	0.0005	1.0007	0.0007	1.0013	0.0013	1.0016	0.0016
75+	1.0006	0.0006	1.0007	0.0007	1.0009	0.0009	1.0016	0.0016	1.0020	0.0020
Total Respiratory (75+)	1.0008	0.0008	1.0008	0.0008	1.0010	0.0010	1.0020	0.0020	1.0024	0.0024
Lung cancer (30+)	1.0016	0.0016	1.0017	0.0017	1.0022	0.0022	1.0042	0.0041	1.0050	0.0050
<b>Morbidity</b>										
Total Cardiovascular (65+)	1.0004	0.0004	1.0004	0.0004	1.0005	0.0005	1.0010	0.0010	1.0012	0.0012
Total Respiratory										
0-4	1.0006	0.0006	1.0007	0.0007	1.0009	0.0009	1.0016	0.0016	1.0020	0.0020
5-14	1.0004	0.0004	1.0004	0.0004	1.0005	0.0005	1.0010	0.0010	1.0012	0.0012
15-64	1.0004	0.0004	1.0004	0.0004	1.0005	0.0005	1.0010	0.0010	1.0012	0.0012
65+	1.0005	0.0005	1.0005	0.0005	1.0007	0.0007	1.0013	0.0013	1.0016	0.0016
Lung cancer (30+)	1.0016	0.0016	1.0017	0.0017	1.0022	0.0022	1.0042	0.0041	1.0050	0.0050

**Table S5.10: Attributable Fractions of BAU2030 and Increased Cycling 2030 Scenario by cause of annual death and disability, metropolitan Adelaide**

Item by cause <sup>#</sup>	15-29						30-44						45-59					
	BAU 2030	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	BAU 2030	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	BAU 2030	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
<b>Male</b>																		
Colon cancer	0.09	0.07	0.05	0.07	0.07	0.030	0.12	0.10	0.07	0.10	0.09	0.04	0.15	0.12	0.09	0.13	0.12	0.06
Breast cancer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IHD	0.15	0.12	0.09	0.13	0.12	0.06	0.20	0.16	0.12	0.17	0.16	0.08	0.22	0.18	0.14	0.19	0.18	0.10
Stroke	0.06	0.05	0.03	0.05	0.04	0.02	0.08	0.07	0.05	0.07	0.06	0.03	0.11	0.09	0.06	0.09	0.08	0.04
Type 2 diabetes	0.09	0.07	0.05	0.08	0.07	0.03	0.12	0.10	0.07	0.11	0.10	0.05	0.14	0.11	0.09	0.12	0.11	0.06
Falls	0.36	0.31	0.24	0.32	0.30	0.16	0.43	0.37	0.30	0.39	0.37	0.21	0.44	0.39	0.32	0.41	0.39	0.25
Depression	0.10	0.08	0.06	0.09	0.08	0.04	0.13	0.11	0.08	0.11	0.10	0.05	0.14	0.11	0.09	0.12	0.11	0.06
<b>Female</b>																		
Colon cancer	0.11	0.09	0.06	0.09	0.08	0.04	0.14	0.11	0.08	0.12	0.11	0.05	0.12	0.10	0.07	0.10	0.09	0.04
Breast cancer	0.07	0.05	0.04	0.06	0.05	0.02	0.08	0.07	0.05	0.07	0.06	0.03	0.08	0.06	0.04	0.06	0.06	0.03
IHD	0.18	0.14	0.11	0.15	0.14	0.07	0.21	0.18	0.14	0.19	0.17	0.09	0.20	0.17	0.13	0.18	0.16	0.08
Stroke	0.08	0.06	0.04	0.06	0.06	0.03	0.10	0.08	0.06	0.08	0.08	0.04	0.08	0.07	0.05	0.07	0.06	0.03
Type 2 diabetes	0.11	0.09	0.07	0.09	0.09	0.04	0.13	0.11	0.08	0.12	0.11	0.05	0.13	0.10	0.08	0.11	0.10	0.05
Falls	0.39	0.34	0.27	0.35	0.33	0.19	0.44	0.39	0.32	0.41	0.39	0.24	0.44	0.38	0.31	0.40	0.38	0.22
Depression	0.11	0.09	0.07	0.10	0.09	0.05	0.14	0.11	0.09	0.12	0.11	0.06	0.14	0.11	0.08	0.12	0.11	0.05

<sup>#</sup> International Classification of Disease 10<sup>th</sup> revision cause code: colon cancer (C19), breast cancer (C50), IHD (I20-I25), stroke (I60-I69), type 2 diabetes (E10-E14), depression (F32,F33)

**Table S5.11: Attributable Fractions of BAU2030 and Increased Cycling 2030 Scenario by cause of annual death and disability, metropolitan Adelaide -continued**

Item by cause <sup>#</sup>	60-69						70+					
	BAU 2030	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	BAU 2030	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
<b>Male</b>												
Colon cancer	0.17	0.14	0.11	0.15	0.14	0.07	0.13	0.10	0.08	0.11	0.10	0.05
Breast cancer	-	-	-	-	-	-	-	-	-	-	-	-
IHD	0.23	0.19	0.15	0.20	0.19	0.11	0.17	0.14	0.11	0.15	0.14	0.08
Stroke	0.13	0.10	0.08	0.11	0.10	0.05	0.10	0.08	0.06	0.08	0.08	0.04
Type 2 diabetes	0.15	0.12	0.09	0.13	0.12	0.07	0.11	0.09	0.07	0.10	0.09	0.05
Falls	0.45	0.40	0.33	0.42	0.40	0.27	0.45	0.40	0.33	0.42	0.40	0.27
Depression	0.14	0.12	0.09	0.13	0.12	0.07	0.14	0.12	0.09	0.13	0.12	0.07
<b>Female</b>												
Colon cancer	0.22	0.19	0.14	0.20	0.18	0.10	0.12	0.09	0.07	0.10	0.10	0.05
Breast cancer	0.13	0.10	0.08	0.11	0.10	0.05	0.10	0.08	0.06	0.09	0.08	0.04
IHD	0.29	0.24	0.19	0.26	0.25	0.15	0.22	0.18	0.15	0.20	0.19	0.11
Stroke	0.17	0.14	0.11	0.15	0.14	0.07	0.13	0.11	0.08	0.11	0.10	0.05
Type 2 diabetes	0.19	0.16	0.12	0.17	0.16	0.09	0.15	0.12	0.09	0.13	0.12	0.07
Falls	0.52	0.46	0.40	0.49	0.47	0.34	0.52	0.46	0.40	0.49	0.47	0.34
Depression	0.18	0.15	0.12	0.16	0.15	0.09	0.18	0.15	0.12	0.16	0.15	0.09



**Table S5.12: Annual health co-benefit of Increased Cycling 2030 Scenarios compared to BAU 2030 by cause of death and disability, metropolitan Adelaide**

	Male										Female									
	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	$\Delta B$	%R	$\Delta B$	%R	$\Delta B$	%R	$\Delta B$	%R	$\Delta B$	%R	$\Delta B$	%R	$\Delta B$	%R	$\Delta B$	%R	$\Delta B$	%R	$\Delta B$	%R
<b>Premature deaths</b>																				
Colon cancer	6	18.0	13	37.2	5	13.5	7	20.5	22	60.3	5	17.4	11	35.8	4	12.1	5	18.3	17	56.5
Breast cancer	-	-	-	-	-	-	-	-	-	-	5	18.3	11	37.3	4	13.1	6	19.8	17	58.9
IHD	43	16.5	90	34.2	29	10.9	43	16.5	140	53.4	48	15.6	101	32.6	31	9.9	47	15.1	157	50.7
Stroke	10	18.9	20	38.7	8	14.6	12	22.1	33	62.8	20	18.3	41	37.7	15	14.0	23	21.2	67	61.6
Type 2 diabetes	4	17.6	8	36.1	3	11.9	4	18.0	12	55.9	4	16.9	8	34.9	3	11.1	4	16.8	13	53.9
Falls	3	11.4	7	25.0	2	6.7	3	10.3	12	40.2	5	9.9	12	22.1	3	5.4	5	8.4	19	35.1
Depression	0	16.6	0	34.1	0	10.0	0	15.1	0	50.9	0	15.7	0	32.5	0	8.8	0	13.4	0	47.8
<b>YLL</b>																				
Colon cancer	65	18.0	134	37.1	49	13.5	74	20.5	219	60.4	52	17.4	108	35.9	37	12.4	57	18.8	173	57.5
Breast cancer	-	-	-	-	-	-	-	-	-	-	61	18.4	125	37.5	44	13.3	67	20.0	198	59.3
IHD	332	16.4	691	34.0	222	10.9	338	16.6	1089	53.6	279	15.6	584	32.6	178	10.0	272	15.2	911	50.9
Stroke	64	18.9	131	38.7	50	14.6	75	22.2	213	62.9	115	18.3	236	37.7	88	14.1	133	21.3	386	61.7
Type 2 diabetes	30	17.6	62	36.0	20	11.9	31	18.1	96	56.1	28	16.9	57	34.9	18	11.2	28	17.0	89	54.2
Falls	19	11.4	41	25.2	11	6.8	17	10.5	67	40.7	30	10.0	67	22.3	17	5.6	26	8.7	107	35.8
Depression	0	16.6	1	34.1	0	10.0	0	15.1	1	51.0	1	15.7	2	32.5	0	8.8	1	13.4	3	47.8

Table S5.12 Continued.

	Male										Female										
	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		
	$\Delta$ B	%R	$\Delta$ B	%R	$\Delta$ B	%R	$\Delta$ B	%R	$\Delta$ B	%R	$\Delta$ B	%R	$\Delta$ B	%R	$\Delta$ B	%R	$\Delta$ B	%R	$\Delta$ B	%R	
<b>YLD</b>																					
Colon cancer	16	18.0	34	37.1	12	13.5	19	20.6	55	60.4	14	17.4	29	36.0	10	12.6	16	19.1	47	57.9	
Breast cancer	-	-	-	-	-	-	-	-	-	-	33	18.4	68	37.7	24	13.4	37	20.3	108	59.7	
IHD	87	16.3	181	34.0	58	10.9	88	16.6	285	53.6	109	15.5	229	32.6	71	10.1	108	15.4	361	51.3	
Stroke	32	19.0	66	38.8	25	14.8	38	22.4	107	63.4	38	18.5	77	38.0	29	14.3	44	21.7	127	62.4	
Type 2 diabetes	124	17.7	255	36.4	88	12.5	133	19.0	403	57.6	127	17.3	262	35.7	89	12.1	135	18.4	415	56.6	
Falls	17	11.5	36	25.3	10	6.9	15	10.7	59	41.0	26	10.0	58	22.4	15	5.6	23	8.7	93	36.0	
Depression	131	18.2	268	37.4	97	13.5	146	20.4	431	60.1	160	18.0	328	37.0	117	13.1	177	19.9	526	59.2	
<b>DALYs</b>																					
Colon cancer	81	18.0	168	37.1	61	13.5	93	20.5	274	60.4	67	17.4	138	35.9	48	12.4	72	18.9	221	57.6	
Breast cancer	-	-	-	-	-	-	-	-	-	-	95	18.4	194	37.6	69	13.3	104	20.1	306	59.5	
IHD	419	16.3	872	34.0	280	10.9	426	16.6	1374	53.6	388	15.5	813	32.6	250	10.0	380	15.2	$\frac{127}{3}$	51.0	
Stroke	96	18.9	197	38.7	75	14.7	113	22.2	320	63.1	152	18.4	314	37.8	117	14.1	178	21.4	513	61.8	
Type 2 diabetes	154	17.7	317	36.3	108	12.4	164	18.8	499	57.3	155	17.2	319	35.6	107	11.9	162	18.1	504	56.1	
Falls	35	11.5	78	25.2	21	6.9	33	10.6	126	40.8	56	10.0	125	22.4	31	5.6	48	8.7	200	35.9	
Depression	131	18.2	269	37.4	97	13.5	147	20.4	432	60.0	161	18.0	330	36.9	117	13.1	177	19.8	528	59.1	

 $\Delta$  B difference in disease burden

% R percentage of reduction

# CHAPTER 6

## Community-based cross-sectional study

### Understanding the urban travel behaviour and attitudes of Adelaide adult residents

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#### **Preface**

In the research presented in Chapter 5, the importance of promoting alternative transport was evident. The study also revealed that to achieve such significant health co-benefits, a travel behaviour change at the population level is essential. The second literature review (Chapter 3) in this thesis has presented a complex account of travel behaviour, which highlights the necessity for researchers and planners to understand individuals' transport decisions in order to push this sustainability agenda forward.

This next chapter presents the results of the statistical analyses of a cross-sectional survey investigating the relationship between attitudinal factors and individuals' current travel behaviour, and predictors of their intention to reduce car use. These analyses aim to answer the second research question in this thesis:

- What are the key factors which will impact individuals' current travel behaviour and predict their intention to change travel behaviour?

## **6.1 Introduction**

Motorised vehicles, especially cars, are considered the most attractive transportation mode by many people and a large portion of the population rely heavily on them (Anable 2005). However, increased motorised vehicle use has caused many environmental and health issues, which are associated with greenhouse gas emissions and air and noise pollution. Transportation is one of the largest emitters of air pollutants (David and David 2006), with thousands of premature deaths potentially attributable to traffic-related ambient air pollution per year worldwide (Künzli et al. 2000). Apart from environmental issues, reliance on motorised vehicle transport also encourages a sedentary lifestyle which is a major risk factor for non-communicable diseases. The environmental, health and social costs of car driving are also substantial, including air pollution, traffic noise, traffic injury, congestion and energy consumption.

The cost of motor vehicle usage can be addressed through technical improvements such as renewable fuel and land use management such as compact urban planning (Baudains et al. 2001). In addition, changing travel behaviour by increasing active transport provides a further opportunity for collaboration between the transportation, environment and public health areas. Since achieving successful technological innovations and efficient land use planning require a large investment of time and money, some researchers advocate the necessity for travel behaviour change at a population level (Hickman and Banister 2007; Litman 2006a). Therefore, promoting alternative forms of transport has been on the policy agenda for a number of governments (Christensen and Kjær 2011; City of Melbourne 2012; The city of Amsterdam 2011).

However, convincing individuals to adopt more environmentally-friendly travel behaviour patterns is a challenging task, as there are a variety of considerations affecting

personal travel behaviour as discussed in the literature review in Chapter 3. Gardner and Abraham found (2007) that attitudes towards flexibility, comfort, and time could all influence one's choice of transport. People may also make different transport choices for each trip depending on time management and/or destination (Buehler 2010; Gärling et al. 2000). Furthermore, previous research has shown that the car is not only a means of transport but also has important symbolic and affective functions (Steg 2005).

While there is a growing awareness and concern amongst the public about environmental issues, the question of whether environmental awareness impacts on individuals' travel behaviour remains controversial. The results from a survey conducted in Northern Osaka by Shen et al (2008) in Japan suggested that environmental consciousness played a significant role in local residents' decisions regarding transport choice, therefore people were more likely to choose a transport mode with less negative impact on the environment. Another study suggested that non-car owners tend to recognise the negative effects of cars on the environment more than car owners (Ibrahim 2003). Moreover, a Netherlands study found that although socio-demographic and socio-economic variables explained one fifth of the variance in car use (Steg et al. 2001), awareness of car-attributable environmental pollution was also an important explanatory factor, suggesting that awareness of environmental issues may be an important contribution to personal travel behaviours. By contrast, another UK study indicated that, although people recognised climate change as a threat to human health, carbon emission related to transport mode was not their major consideration (Chatterton et al. 2009). The travel behaviour of participants was still highly dominated by cost, comfort and convenience (Chatterton et al. 2009), with more weight given to certain and short-term advantages, (i.e. saving, over uncertain and long-term risks such as environmental problems) (Kahneman and Tversky 1984; Steg and Vlek 1997).

In addition, policy interventions are also important to enforce travel behaviour change on a population level. Steg and Vlek (1997) have identified two approaches to implement transport measures, referring to 'push' and 'pull' forms, as discussed in section 3.2.1 and 3.2.2 (Chapter 3). "Push" measures generally influence individual travel decisions through imposing measures on them, which can be further divided into pricing measures (e.g. increasing cost of car use, raising fuel prices, car parking charges and road tolls) and technical and regulatory constraints (e.g. decreasing ease of car use such as restricting city centre car access, and reducing or eliminating city centre parking). "Pull" measures are those encouraging individuals to use cars less by making alternatives more attractive, such as a better service of public transport service and integration of active transport with transport planning. Both "Push" and "Pull" traffic measures have been found to be important for reshaping individuals' travel behaviour (Fujii and Kitamura 2003; Litman 2006b).

In brief, travel behaviour is a function that of both internal and external factors, and the process of making choices about transport is a complex psychological activity, which can be explained by several behaviour theories. Currently, one of the most popular theoretical framework applied to predict an individual's intention to engage in a health behaviour is the Theory of Planned Behaviour (TPB) (Conner and Sparks 1996). The TPB states that an individual's attitude toward the behaviour, together with their perception of a subjective norm and their level of perceived behavioural control (PBC), determines an intention to act (Armitage and Conner 2001). This theory emphasises that individuals' attitudes and beliefs may not directly determine travel behaviour but indirectly via behavioural intention (Armitage and Conner 2001).

Australia has the second highest level of car ownership rate in the world with over 90% of Australian households having one or more registered motor vehicle (Australian Bureau of

Statistics 2012b; CSIRO 2012). Although Australia only accounts for around 1.4% of global emissions of CO<sub>2</sub>, its average emissions (per head) are higher than other Organisation for Economic Co-operation and Development (OECD) countries (Australian Bureau of Statistics 2010). In 2000, a National Travel Behaviour Change Project named TravelSmart was launched by the Australian Federal Government in collaboration with State Governments and local councils, with the aim of encouraging Australians to change their travel choices voluntarily from private car use to alternative transport. To assist households to reduce their car use, tools were provided to each participant household to address their specific needs such as access guide, kids pages and kilometre monitor. An evaluation of this project has reported varied levels of decrease in car use and short-term in walking, cycling and public transport use (Australian Greenhouse Office 2005). However, according to the latest statistics (2012), nearly 80% of Australians still commute by private car, while active transport makes up only less than 6% of total trips (Australian Bureau of Statistics 2012b). Therefore, it seems the Travel Behaviour Change Project has not achieved a significant change in reducing private car use and more effort and strategies are needed to motivate people to change their travelling behaviours.

This chapter reports on a cross-sectional study that was conducted in the city of Adelaide, the capital of South Australia. Currently, the Government of South Australia has begun to promote sustainable travel behaviour. The 30-Year Plan for Greater Adelaide launched in 2010 set clear targets to increase public transport use by 10% and double the number of people cycling by 2018 (Government of South Australia 2010). In order to take this plan forward, the first step is to understand the travel behaviour of local residents. Some information is available about travel behaviour from a range of sources. The latest Travel Pattern Survey in Adelaide was carried out in 1999 (South Australian Government 2002). Although the survey summarised information regarding the number of person trips

undertaken per day, travel mode share and trip purpose, the survey is now somewhat dated, and it is unclear whether the results are still applicable. Another ‘journey to work’ survey conducted in Adelaide in 2006 only investigated people’s modes of transportation to work and factors related to method of travel (Australian Bureau of Statistics 2009). In addition, the transport and motor vehicle usage report is updated by the Australian Bureau of Statistics regularly. It provides some information about Australian residents’ travel patterns such as the average distance of usual trips to work and the main form of transport used (Australian Bureau of Statistics 2012b). However, detailed demographic information has not been reported.

Thus, the first aim of the current study was to provide an insight into residents’ current travel behaviour in Adelaide, including how demographic characteristics affect people’s travel behaviour. This study also aimed to examine how individuals’ attitudinal factors are correlated with their current travel behaviour and how acceptable they find transport policy measures, and to investigate the factors that predict individuals’ intentions to reduce car use and their choice of alternative transport. Findings from this study may provide policy-makers with important information and evidence for decision-making and transport policy implementation in Australia.

## **6.2 Methods**

### **6.2.1 Study Setting and Data Collection**

This cross-sectional study was conducted in the Adelaide metropolitan region with a population of 1.16 million, representing 70% of the state population. Chapter 4 provides more information about Adelaide .



Data collection was undertaken via the Population Research and Outcome Studies (PROS), University of Adelaide in conjunction with the Harrison Health Research. The survey was administered using a Computer Assisted Telephone Interviewing (CATI) system whereby respondents' answers were entered directly into the computer by the interviewer. The CATI system enforced a range of checks on each response with most of the questions having a set of pre-determined response categories. In addition, the CATI automatically rotated response categories to minimise bias associated with the order of response options.

A pilot survey was conducted on 8th June 2012. Appropriate changes were made for some understanding difficulties. A number of question framings were identified as problematic and subsequently reformulated to aid interpretability.

The survey was carried out in conjunction with another Perception of Climate Change Risks Survey from 14th June to 20th July 2012. Telephone calls were made from 10:00 am to 8:30 pm on weekdays and 10:00 am to 5:00 pm on weekends. All interviews were conducted by professional health interviewers and 10% of each interviewer's work was monitored by their supervisors. On contacting the household, the interviewer initially identified themselves and the purpose of the survey.

### **6.2.2 Questionnaire**

A questionnaire was developed after a literature review (Chapter 3) on travel behaviour and car-reduction interventions was conducted. All the questions aimed to investigate participants' travel behaviours, their attitudes towards transport modes and alternative transport promotion measures. (Appendix C)

### **6.2.2.1 Demographic characteristics and travel behaviour**

The first part of the questionnaire asked socio-demographic and current travel behaviour characteristics. Socio-demographic data - including age, gender, employment status, educational level and gross annual household income - were collected. Individual travel behaviour was measured by asking participants to self-report their bicycle use, annual kilometres driven (as driver), frequency of car use (as driver or passenger), and their primary mode of transportation for (1) daily commuting and (2) shopping/other social activities. Following Nilsson's method (2000), we created an index of the environmental impact of participants' travel behaviour according to their primary mode of transportation. Impact caused by car use (as a driver or passenger) was scored "3", whilst public transport or combined transport use (e.g. by car first then public transport) was scored "2", with bicycling/walking scored "1". To assess the impact of individuals' travel behaviour on the environment, a new variable labelled "environmental impact" was then created by summing participants' transport mode scores for their daily commuting and shopping/other social activities.

### **6.2.2.2 Perceptions and, attitudes towards traffic, environment and health**

The second section of the questionnaire contained 16 attitudinal questions regarding participants' perceptions of the effect of traffic on the environment and health, their attitudes towards alternative transport, and any possible barriers to the use of alternative transport. Their level of agreement with the attitudinal statements was assessed by 5-point Likert-scales (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree; scored from "1" to "5" respectively). A "Don't Know" option was also given. The attitudinal questions were developed based on previous literature (Anable 2005; Nilsson and Küller 2000; Stradling et al. 2000), and modified in order to make them easy to understand.

### **6.2.2.3 Effectiveness of potential car reduction measures**

The third section of the questionnaire measured participants' views of the effectiveness of nine traffic measures for car reduction and alternative transport promotion. Measures contained both car restriction measures (e.g. "How effective would limiting car access and parking to the city be in promoting a reduction in car use?") and measures to promote and facilitate alternative transport use (e.g. "How effective would more reliable public transport services be in promoting public transport use?"). Effectiveness was rated from "1" to "4" as "not at all effective", "don't know", "fairly effective" and "very effective". The scores of nine measures were then calculated to obtain a "total score of perceived effectiveness" for each participant, which represented the extent to which they accept alternative transport promotion measures.

### **6.2.2.4 Intentions to reduce car use**

The final section of the questionnaire examined participants' intentions to reduce their car use and included two multiple choice items. One inquired their reasons for choosing another mode of transport in order to reduce car use, including the option "I won't use another mode of transport instead of my car". The other asked which alternative transport modes the participants would prefer to use in the future.

### **6.2.3 Participation rates**

The target population was the metropolitan Adelaide residents older than 18 years old. All households in South Australia (SA) with a telephone number listed in the Electronic White Pages (the local telephone directory) were eligible for selection. Only respondents over the age of 18 years within the household were selected to be interviewed and only one interview was conducted per household. Initially, 1,750 households were randomly

selected from the White Page and sent a posted information sheet outlining the study. In total, 500 telephone interviews were successfully conducted with a participant rate of 48% (Appendix D). Among them, 381 participants surveyed lived in the metropolitan areas and therefore were included in this study.

#### **6.2.4 Statistical analysis**

To ensure the sample was representative of the metropolitan age group and gender distribution of the target population, survey data were weighted by the inverse of the individual's probability of selection and then re-weighted to age group by sex by state benchmarks derived from 2010 (SA) Estimated Residential Population figures.

In the first instance, descriptive statistics including frequencies and percentages of demographic and travel behaviour information were calculated. Chi-square tests were performed to compare the mean annual driving distances and driving frequency among different demographic groups. Second, the 16 attitudinal variables from section two were entered into an explorative factor analysis (principal components analysis, varimax rotation) (Suhr 2005) in order to find the smallest number of sets of highly correlated variables and to create a set of factors. The "Don't know" response was treated as "neutral" and scored as "3". The internal consistency was measured by Cronbach's alpha. Factor scores for each factor were generated and saved for further analyses. The variables produced by the factor analysis were entered into a Spearman's correlation analysis, which aimed to explore the relationship between attitudinal factors and driving distance, driving frequency, environmental impact, and total acceptance of alternative transport measures.

Logistic regression analysis was performed to identify predictors of participants' intentions regarding their future choice of transport mode. A binary variable was coded as

“0” representing “low intentions” (referring to participants who chose the option, “I won’t use another mode of transport instead of my car”), with “higher intentions” coded as “1” (participants who chose at least one reason for reducing car use). Predictor variables were: demographic characteristics, including age, gender, employment status, and educational level; travel behaviour characteristics, including bicycle usage and annual driving distance; and factors extracted from the factor analysis. A univariate logistic regression analysis was first conducted with all the predictor variables. The multivariable logistic regression analysis was then performed to identify the independent predictors, including plausible influential variables with a p-value less than 0.5 from univariate analyses. However, income factors were considered *a priori* and entered into the multivariate mode.

The survey data were analysed using the Stata 12 statistical package and the level of significance was set to  $p=0.05$ .

## **6.3 Results**

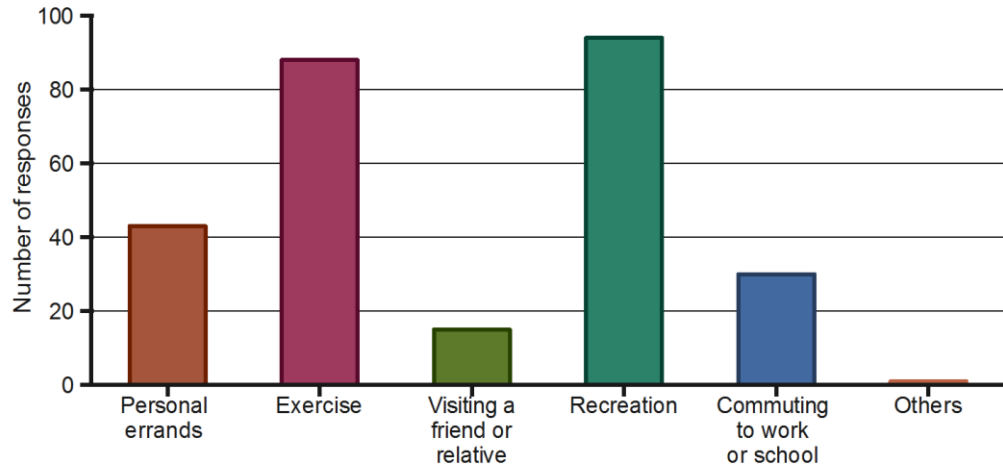
### **6.3.1 Socio-demographic and travel behaviour characteristics**

The sample consisted of 52% males and 48% females (Table 6.1). The mean age was 45.6 years (SD, 16.7), with 29.5% of participants 18-34 years old, 50.7% 35-64 years old, and 19.8% aged over 65. Over one third (37.3%) of the participants only had schooling up to secondary level, while 62.7% had a trade certificate, diploma or higher education level. Most of the participants (64.7%) were salaried and 35.3% were unemployed, retired, engaged in home duty or students. The annual household income was categorised into three levels. Fifteen percent of the survey households received less than \$40,000, 20% were in the \$40,000-80,000 level and 53.2% earned more than \$80,000 annually, whilst 21.3% did not state this information.

Half of the participants did not own a bicycle, and 12% of participants owned a bicycle but did not use it. As shown in Figure 6.1, the major purposes of cycling trips were recreation and exercise, followed by personal errands. Only 20% of cyclists (4% of whole sample) used their bicycle for commuting to work/school. Figure 6.2 illustrates participants' comfortable cycling and walking trip distance. Nearly half of the participants stated that they would be comfortable cycling up to 5 km for one trip. However, many of them reported being comfortable riding more than 7 km (28%), or even more than 10 km for one trip (14%). Similarly, most participants felt comfortable with a short-distance walking for one trip (up to 3 km), but one third of them would be comfortable with like to walk up to or more than 5 km for one trip.

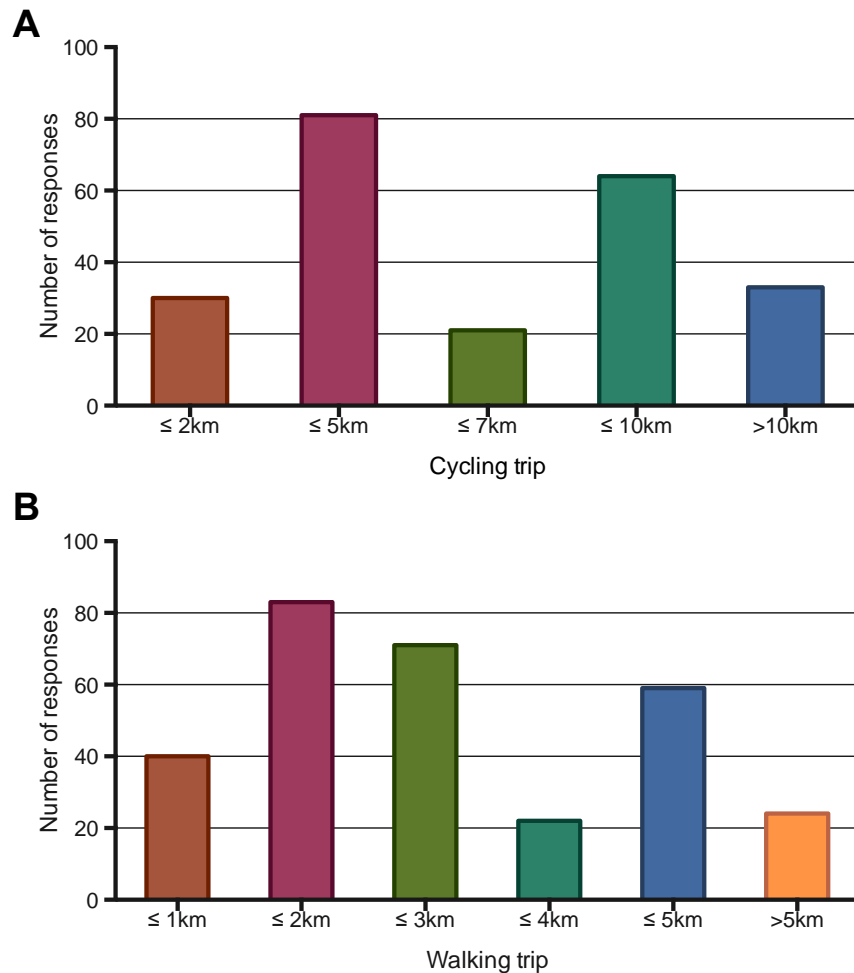
**Table 6.1: Demographic of the study participants (weighted)**

	Counts	Precent (%)
N	394	
Male	205	52.1
Female	189	47.9
<b>Age group</b>		
18-34 years	116.	29.5
35-64 years	200	50.7
>65 years	78	19.8
<b>Education</b>		
No schooling beyond secondary school level	147	37.3
Trade, certificate, diploma	124	31.5
Bachelor degree or higher	123	31.1
<b>Work status</b>		
Unemployed	139	35.3
employed	255	64.7
<b>Annual household income</b>		
Up to \$40,000	62	15.6
\$40,001-\$80,000	91	23.1
≥\$80,001	157	39.8
Not stated/don't know	84	21.3



**Figure 6.1: Cycling trip purposes\***

\* Multiple response



**Figure 6.2: (A) Cycling and (B) walking trip lengths perceived to be 'comfortable' for one trip\***

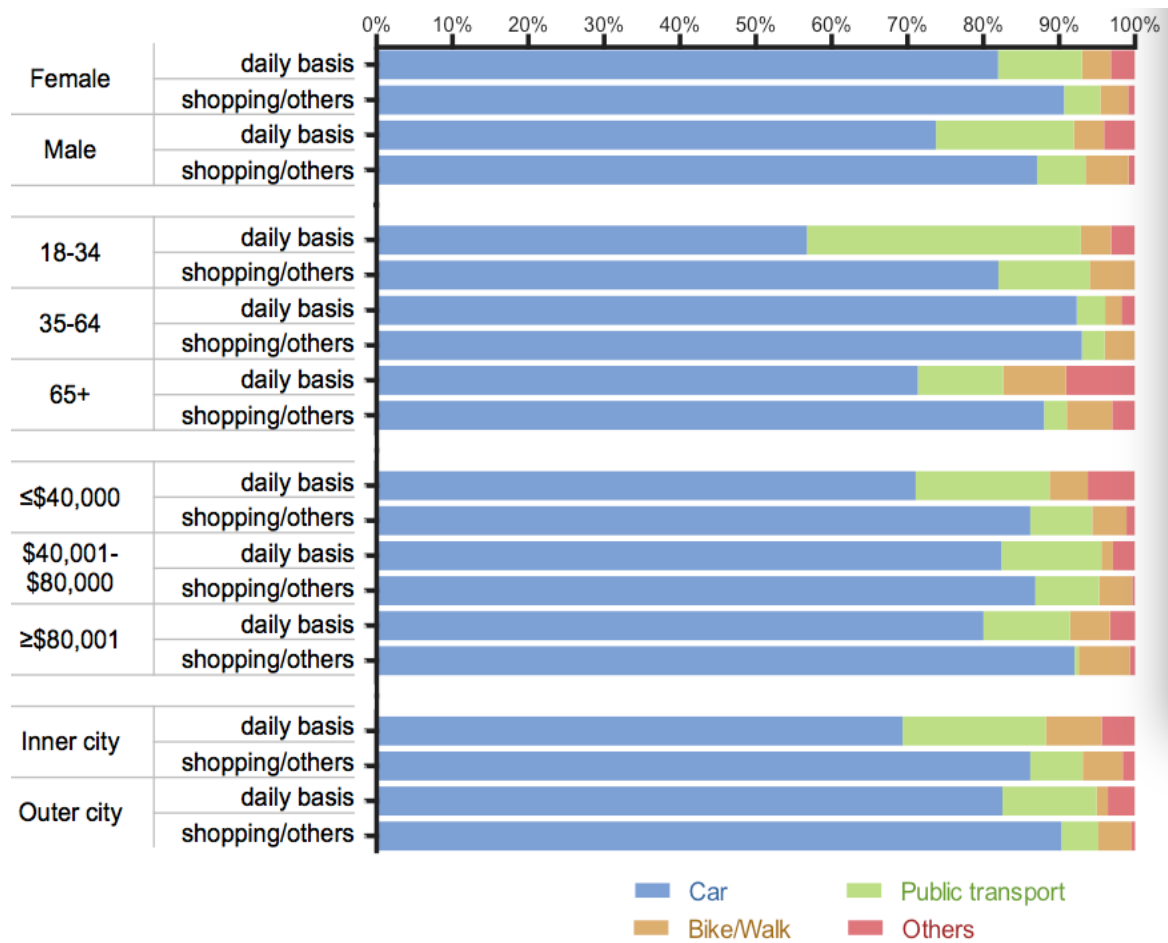
\* Single response

## *Chapter six*

Participants with different socio-demographic characteristics showed slight differences in their travel patterns. As shown in Figure 6.3, although the primary mode of transportation varied with different destinations, the majority of participants conducted most of their journeys by car, with less than 2% travelling primarily by bicycle. For daily commuting, nearly 15% participants took public transport. More females than males travelled by car on a daily basis or for shopping (82% of females, 74% of males) and other social activities (91% of females, 87% of males). On the other hand, males (18% of them) were more likely to take public transport to travel than females (11% of them). Fifty seven percent of participants aged 18-34 used cars on a daily basis, compared to 92% of people aged 35-64 and 71% of participants aged over 65. In contrast, the proportion of young people using public transport to travel was higher than other age groups. However, older participants (aged over 65 years) were more likely to travel by cycling or walking (8% of them).

Furthermore, there was minimal difference of car use for individuals with different annual household income. Of participants who lived in households earning an annual income of \$40,000-\$80,000, 83% used a car on a daily basis, compared with 71% of those living in households earning less than \$40,000 annually and 80% of those who earned more than \$80,000 annually. There was a clear trend that the proportion of participants who used public transport on a daily basis decreased with increased annual household income. The location where people lived also informed travel behaviour. Participants who lived in the inner city travelled by public transport and active transport on a daily basis more than participants who lived in the outer city (18.8% and 7.4% respectively, compared with 12.4% and 1.5%).





**Figure 6.3: Demographics and primary mode of transport**

\* Inner city includes: Adelaide CBD, inner north, south, west and east areas.

\*\* Outer city includes: Port Adelaide, Outer west, Airport, Brighton, Outer south, Outer east, North east, Salisbury and Elizabeth areas. (Appendix E)

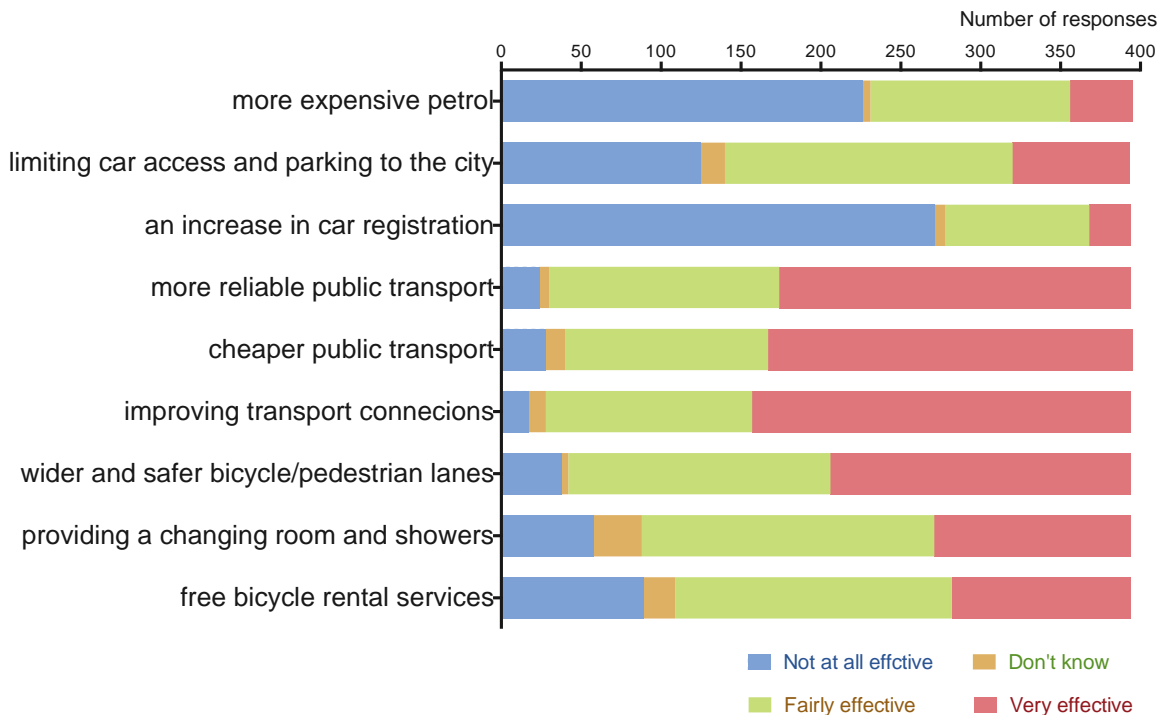
Table 6.2 shows that nearly half of the participants (53.6%; 95%CI, 46.5%–60.4%) had an annual driving distance less than 10,000 km and 13% (95%CI, 9.5%–19.0%) drove more than 20,000 km in one year. Approximately 78% of participants used a car more than three times per week and only one person did not use a car at all. The results from Chi-squared test indicate that 17.6% (95%CI, 11.5%–25.9%) of males and 18.7% (95%CI, 12.9%–26.2%) of people employed, compared to 8.9% (95%CI, 4.5%–17.0%) of females and 4.0% (95%CI, 1.2%–12.3%) unemployed, were more likely to drive more than 20,000 km annually ( $p=0.01$ ,  $p<0.001$ ). Participants in the highest annual household income level were almost twice as likely to drive more than 20,000 km annually compared with participants with mid-level household incomes ( $p<0.001$ ), and ten times more likely than those living in low-level household incomes ( $p<0.001$ ). In addition, participants with a bachelor degree qualification (or higher) were also twice as likely to drive more than 20,000 km annually, compared with people with no schooling beyond secondary school level ( $p=0.02$ ). Nearly 70% (95%CI, 61.6%–74.7%) of participants used a car more than five times per week. Participants who were employed were more likely to be in the highest car use frequency level than unemployed participants ( $p=0.02$ ).

Table 6.2: Demographics and car use

	Counts	Kilometres driven annually % (95% CI)				Car use frequency % (95% CI)		
		Do not have a car	≤10,000	10,001-20,000	≥20,0001	0-3 times /month	1-4 times /week	≥5 times /week
<b>Gender</b>								
Male	205	10.4 (4.4, 22.5)	43.1 (33.6, 53.2)	28.9 (21.2, 38.1)	17.6 (11.5, 25.9)	1.6 (0.7, 3.6)	27 (18.4, 37.8)	71.4 (60.1, 80.2)
Female	189	6.1 (3.8, 9.8)	65.4 (56.3, 73.5)	19.5 (13.6, 27.1)	8.9 (4.5, 17.0)	2.6 (1.2, 5.4)	32.1 (23.9, 41.6)	65.4 (56.0, 73.7)
<b>Age</b>								
18-34	116.	17.3 (7.0, 36.8)	61.1 (43.5, 76.1)	10.8 (4.3, 24.6)	10.9 (4.4, 25.5)	0 (0.0, 0.0)	41.4 (25.7, 59.1)	58.6 (40.1, 74.3)
35-64	200	1.6 (0.6, 4.1)	44.9 (36.5, 53.6)	34.9 (27.2, 43.4)	18.6 (12.5, 26.8)	1.6 (0.7, 3.7)	16.9 (11.6, 24.1)	81.5 (74.3, 87.0)
65+	78	12.6 (7.9, 19.5)	64.8 (55.8, 72.8)	18.4 (12.3, 26.7)	4.2 (1.9, 9.1)	6.3 (3.0, 12.5)	43.6 (34.9, 52.6)	50.2 (41.2, 59.1)
<b>Education</b>								
No schooling beyond secondary	147	12.4 (6.2, 23.2)	60.9 (48.9, 71.7)	17.0 (10.2, 26.9)	9.8 (4.8, 18.7)	4.0 (2.0, 7.9)	38.9 (27.7, 51.3)	57.1 (44.9, 68.4)
Trade, certificate, diploma	124	6.2 (1.1, 28.1)	42.9 (31.2, 55.1)	35.8 (25.4, 47.7)	15.1 (8.5, 25.6)	0.9 (0.2, 4.4)	23.3 (14.7, 37.2)	74.9 (62.0, 84.5)
Bachelor degree or higher	123	5.9 (2.1, 15.4)	55.7 (43.4, 66.9)	22.0 (14.5, 32.1)	16.4 (8.9, 28.1)	0.7 (0.2, 2.6)	23.4 (14.9, 34.7)	75.8 (64.6 84.4)
<b>Working status</b>								
Unemployed	139	20.1 (1.7, 34.8)	61.5 (48.5,72.9)	14.4 (8.5, 23.3)	4.0 (1.2, 12.3)	4.5 (2.3, 8.6)	56.5 (4.5, 6.7)	39.0 (28.6, 50.6)
Employed	255	2.1(0.1, 5.6)	49.3 (40.9, 57.8)	29.9 (23.1, 37.8)	18.7 (12.9, 26.2)	0.7 (0.2, 2.1)	14.7 (9.8, 21.5)	84.6 (77.9, 89.6)
<b>Annual household income</b>								
Up to \$40,000	62	10.8 (4.9, 22.4)	59.0 (44.6, 72.0)	29.5(17.6, 44.9)	0.7 (0.6, 3.0)	5.7 (2.8, 11.4)	44.1 (31.7, 57.2)	50.2 (37.3, 63.1)
\$40,001-\$80,000	91	3.7 (1.4, 9.2)	58.7 (45.1, 54.5)	26.8 (16.5, 40.5)	10.8 (5.5, 20.2)	1.3 (0.3, 5.7)	24.0 (14.3, 37.4)	74.7 (61.3, 84.6)
≥\$80,001	157	6.3 (1.6, 22.2)	43.1 (32.5, 58.2)	28.0 (19.8, 34.9)	22.6 (14.5, 33.3)	0.0 (0.0, 0.0)	25.1 (10.4, 29.9)	73.4 (70.1, 89.6)
<b>Total</b>	394	8.4 (4.7, 14.7)	53.6 (46.5, 60.4)	24.5 (19.4, 30.4)	13.5 (9.5, 19.0)	2.0 (1.2, 3.6)	29.4 (23.3, 36.5)	68.5 (61.6, 74.7)

### 6.3.2 Effectiveness of car-reduction measures

Figure 6.4 illustrates participants' responses to a range of car-reduction measures. The participants regarded the most ineffective solution to reduce car use as 'more expensive petrol', followed by 'an increase in car registration' and 'limiting car access and parking to the city'. In contrast, providing more reliable and cheaper public transport and improving transport connection were regarded as the most effective measures for car reduction. 'Wider and safer bicycle/pedestrian lanes' were perceived to be more effective than 'providing a changing room and showers' and 'free bicycle rental services'. In general, public acceptability of car restriction measures as "Push" measures (Mean=2.04, SD=0.63) was much lower than those "Pull" measures to promote and facilitate public transport (Mean=3.44, SD=0.04) and bicycle use (Mean=2.99, SD= 0.05).



**Figure 6.4: Sores on the effectiveness of car reduction measures**

### **6.3.3 Scores on the statements related to transport use**

Participants' responses to statements on different transport modes and any possible barriers to use alternative transport are shown in Table 6.3. The majority of participants agreed that the environmental and health benefits of active transport (item 1-3), and their own personal norm of being environmentally friendly. Statements less agreed with by participants were related to public transport price and services, active transport infrastructure and safety (items 13-16). Most participants agreed that traffic related air pollution could cause environmental and health issues (items 5-8), and public transport was considered to be more environmentally friendly than car use. In addition, around 40% of participants perceived that public transport was expensive to use, but a similar number of participants took the opposite view (40.8%). Overall, most participants agreed with the statements that 'I feel more comfortable in private cars than other travel modes' and 'a car is essential to my needs'.

**Table 6.3: Participants' responses to attitude statements\***

Statements*	Percentage (%)					Response Average
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
1. Increase walking and cycling, which can help me to keep fit and healthy	0.1	0.39	0.48	49.5	49.5	4.48
2. Cycling and walking are more environmentally friendly options than driving a car	0	1.6	0.4	55.4	42.5	4.38
3. Cycling and walking would have a positive effect on environment	0.3	3.8	3.8	55.8	36.3	4.24
4. Being environmentally responsible is important to me	0.3	1.8	3.4	64.3	30.1	4.23
5. Traffic related air pollution is dangerous to our health	0.4	3.1	3.1	64.8	28.7	4.18
6. Traffic emissions are a threat to the environment	0.2	2.9	4	68.6	24.3	4.13
7. Traffic can cause noise pollution	1.4	4.3	3.2	65.9	25.1	4.09
8. The more cars on the road, the more traffic injuries	0.5	7.3	3.2	61.4	27.5	4.08
9. A car is essential to my needs	0.4	11.6	1.1	62.5	24.4	3.98
10. From an environmental point of view, it is important we reduce car use	1.6	7.2	3.9	66.7	20.5	3.97
11. Public transport is a more environmentally friendly option than driving a car	0.7	11.1	6	66.4	15.8	3.85
12. I feel more comfortable in private cars than other travel modes	1.3	17.3	10.9	57.8	12.7	3.63
13. Public transport is expensive to use	2.4	38.4	19.7	32.6	6.9	3.03
14. Public transport services are not reliable	20.6	35.9	17.4	24.2	1.9	3.02
15. We have enough infrastructure that supports cycling and walking	14.1	49.3	10.5	24.1	2	2.51
16. Cycling is a safe transport option	15.4	58.1	9.2	15	2.4	2.3

\* Attitude statements were measured with 5-point Likert-scales. (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree; scored from "1" to "5" respectively)

### 6.3.4 Factor analysis and correlations

The factor analysis identified four attitude factors in total, with the Cronbach's alpha varying from relatively low (0.44) to satisfactory (0.76) (Table 6.4). Factor I could be interpreted in terms of participants' awareness of the benefits of alternative transport ('benefits awareness'), while factor II described awareness of the problems of traffic ('problems awareness'). Factor III indicated a personal concern for safety and comfort ('safety and comfort'), and factor IV involved negative emotions towards public transport ('negative emotion').

**Table 6.4: Factor analysis of Perception, awareness of traffic, environment and health (principal component analysis, varimax rotation, loading <0.40 not given)**

Attitude Statements	Factors*			
	I	II	III	IV
From an environmental point of view, It is important we reduce car use	0.71			
Public transport is a more environmentally friendly option than driving a car	0.57			
Cycling and walking are more environmentally friendly options than driving a car	0.77			
Walking and cycling can help me to keep fit and healthy	0.59			
If more people walked and cycled, this would have a positive effect on our environment	0.72			
Being environmentally responsible is important to me	0.63			
Traffic related air pollution is dangerous to our health		0.80		
Traffic can cause noise pollution		0.71		
Traffic emissions are a threat to the environment		0.54		
The more cars on the road, the more traffic injuries		0.43		
Cycling is a safe transport options for me <sup>#</sup>			0.68	
I feel more comfortable in private cars than other travel modes			0.63	
A car is essential to my needs			0.70	
Public transport services are reliable for me <sup>#</sup>				0.75
Public transport is expensive to us				0.60
Cronbach's alpha	0.76	0.67	0.46	0.44
Proportion of total variance (%)	26.2	11.1	8.6	1.2

\* Factor I: benefit awareness; Factor II: problems awareness; Factor III: safety and comfort;

Factor IV: negative emotion

<sup>#</sup> Items were reverse coded

As shown in Table 6.5, alternative transport benefit awareness had a positive relationship with the total score of perceived effectiveness of car reduction measures ( $r=0.33$ ,  $p<0.001$ ). Problems awareness had a weak positive association with perceived effectiveness of car reduction measures ( $r=0.28$ ,  $p<0.001$ ). No significant association was found between benefit awareness or problem awareness and driving distance or frequency. Furthermore, concerns for safety and comfort were positively correlated with driving distance ( $r=0.23$ ,  $p=0.001$ ), driving frequency ( $r=0.28$ ,  $p<0.001$ ), and environmental impact ( $r=0.42$ ,  $p<0.001$ ), but negatively correlated with the perceived effectiveness of car reduction measures ( $r=-0.24$ ,  $p<0.001$ ). Likewise, a positive association was found between negative emotion towards public transport and driving distance ( $r=0.25$ ,  $p=0.006$ ), driving frequency ( $r=0.19$ ,  $p<0.001$ ), and environmental impact ( $r=0.26$ ,  $p=0.007$ ), whereas the association with acceptability worked in the opposite direction ( $r=-0.11$ ,  $p=0.02$ ).

**Table 6.5: Correlations (Spearman's) between factors and driving distance, frequency and perceived effectiveness of car reduction measures**

Variables	Benefit awareness	Problem awareness	Safety and comfort	Negative emotion
Driving distance	-0.02	-0.11	0.23*	0.25*
Driving frequency	-0.06	-0.10	0.28*	0.19*
Environmental impact	-0.11	-0.16*	0.42*	0.26*
perceived effectiveness of car reduction measures	0.33*	0.28*	-0.24*	-0.11*

\*Significant at p-value <0.05

### 6.3.5 Predictors of the intention to change travel behaviour

Table 6.6 shows the results of the multivariate logistic regression analyses for the predictors of intention to change travel behaviour. The results suggest that participants who had high scores on awareness of benefits (OR = 2.15; 95% CI, 1.10–4.20) and



awareness of traffic problems (OR = 1.79; 95% CI, 0.98–3.30) would be more likely to shift their travel mode towards alternative transport, and those who had high scores on safety and comfort (OR = 0.37; 95% CI, 0.15–0.97) would be less likely to change. Furthermore, participants who drove 10,000-20,000 km annually (OR = 0.28; 95% CI, 0.078–0.96) and over 20,000 km annually (OR = 0.07; 95% CI, 0.01–0.43) would be less likely to change, compared to those who drove less than 10,000 km annually. Meanwhile, those who had either an educational level of trade, certificate, diploma, or a bachelor degree or higher (OR = 0.24; 95% CI, 0.07–0.83 and OR = 0.24; 95% CI, 0.01–0.93) were also less likely to change. Current bicycle use was a significant predictor of intention to reduce car use (OR = 7.16; 95% CI, 1.81–28.1). Gender, age, annual house income and employment status were not found to be significant predictors of high intention to reduce car use.

**Table 6.6: Multiple logistic regression analyses for predictors of travel behaviour change (adjusted for car ownership)**

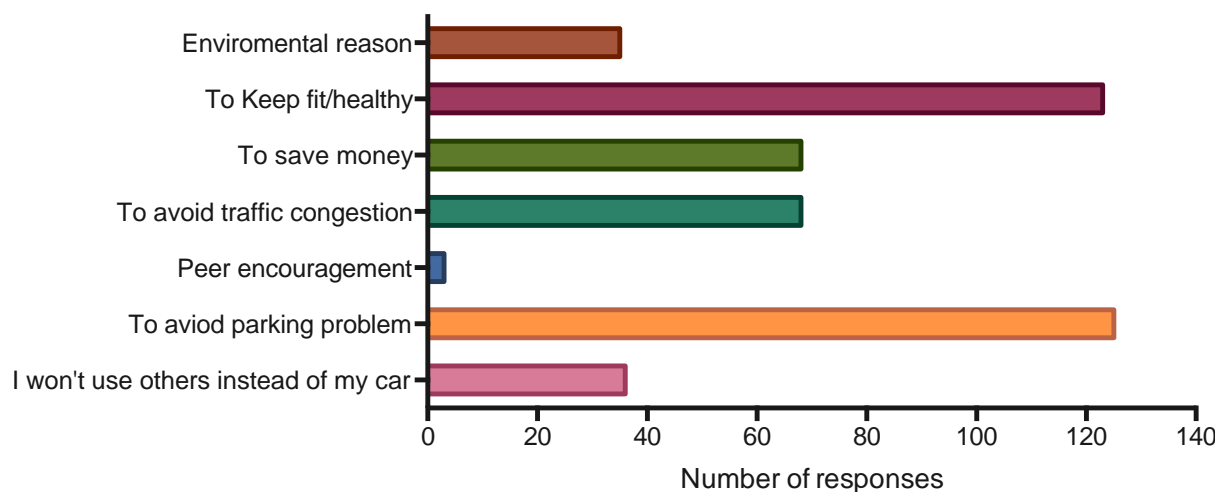
Predictor variables	Category	Univariate		Multivariate	
		OR (95% CI)	p-value	OR (95% CI)	p-value
Factor I	continuous	1.81 (1.14, 2.86)	0.011*	2.15 (1.10, 4.20)	0.024*
Factor II	continuous	1.34 (0.94, 1.89)	0.104	1.79 (0.98, 3.30)	0.059
Factor III	continuous	0.40 (0.25, 0.64)	<0.001*	0.37 (0.15, 0.97)	0.043*
Factor IV	continuous	1.15 (0.77, 1.75)	0.483	1.38(0.86, 2.25)	0.182
Gender	Male	1(ref)			
	Female	1.06 (0.36, 2.31)	0.903		
Age	continuous	0.98 (0.96, 1.00)	0.244	0.98 (0.95, 1.02)	0.410
Income	≤ \$40,000	1(ref)		1 (ref)	
	\$40,001-\$80,000	1.42 (0.38, 5.30)	0.600	1.50 (0.34, 6.60)	0.592
	≥ \$80,001	0.81 (0.25, 2.62)	0.725	1.00 (0.18, 5.51)	0.997
	Not stated/don't know	0.81 (0.20, 3.25)	0.761	0.49 (0.10, 2.35)	0.375
Education	No schooling to secondary	1(ref)		1(ref)	
	Trade, certificate, diploma	0.26 (0.77, 0.89)	0.033*	0.24 (0.68, 0.83)	0.025*
	Bachelor degree or higher	0.40 (0.10, 1.72)	0.220	0.24 (0.61, 0.93)	0.039*
Employment status	Not employed	1 (ref)			
	Employed	0.77(0.32, 1.88)	0.566		
Bicycle user	No	1(ref)		1(ref)	
	Yes	5.18 (1.10, 24.25)	0.037*	7.16 (1.81, 28.26)	0.005*
Drive distance	Less than 10,000 km	1 (ref)		1 (ref)	
	10,000-20,000 km	0.25 (0.10, 0.68)	0.007*	0.28 (0.078, 0.96)	0.044*
	>20,000 km	0.09 (0.03, 0.32)	<0.001*	0.07 (0.013, 0.43)	0.004*

\*Significant at p-value ≤0.05; Factor I: benefit awareness; Factor II: problems awareness; Factor III: safety and comfort; Factor IV: negative emotion

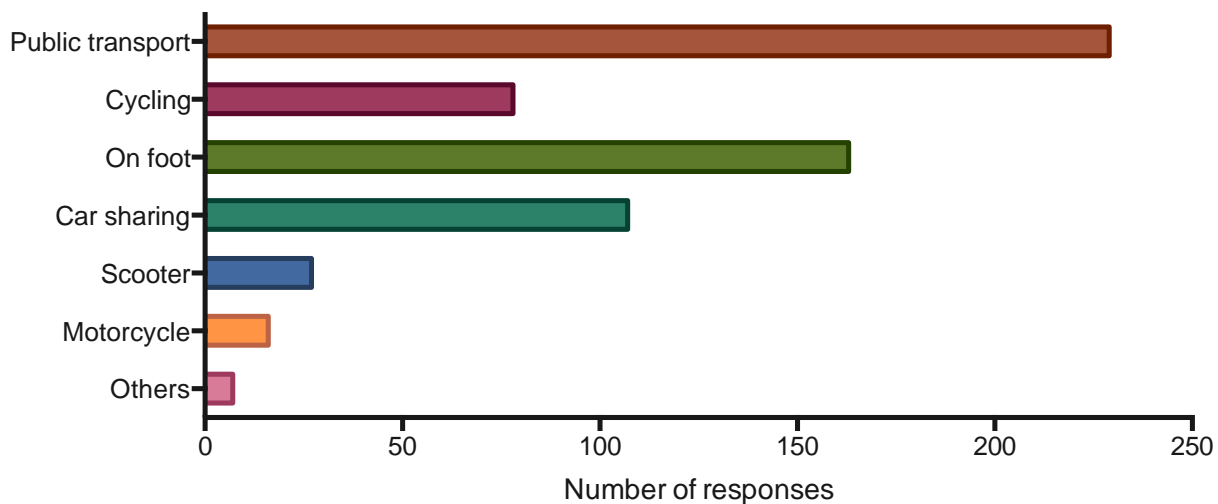
### 6.3.6 Reasons and preferences relating to alternative transportation

As indicated in Figure 6.5, keeping fit/healthy and avoiding parking problems were the main reasons for participants to choose a mode of transport other than cars. Sixty-eight participants (18%) considered money saving and traffic congestion. Being environmental-friendly was not an important motive for people to choose another mode of transport instead of their car, and peer encouragement seemed to be the least likely reason. In addition, approximately 10% of participants indicated that they would not use other transport mode as an alternative to their cars.

Figure 6.6 presents participants' preferred alternative travel modes. Compared to other transport modes, public transport appeared the most popular alternative, followed by walking. Car sharing was more likely to be considered by participants than cycling, but less likely than public transport and walking. Additionally, a minority of participants indicated an interest in using scooters or motorcycles as alternatives.



**Figure 6.5: Reasons for Alternative Transportation for travelling**



**Figure 6.6: Participant’s choice of their prefer alternatives**

## 6.4 Discussion

This study reveals that people’s travel behaviours are strongly dependent on car use for both work journeys and shopping. This is largely consistent with findings from previous travel surveys conducted in Adelaide in 1999. (South Australian Government 2002), although there have also been some differences in travel patterns among some groups of people. People living in the inner city were more likely to use public and active transport than those who lived in the outer city. Males, employed people, and people with high annual household income, were more likely to use a car more often. Compared with “Pull” measures (measures to promote and facilitate public transport and bicycle use), scores on the perceived effectiveness of “Push” measures (measures to restrict car use) were much lower. Furthermore, most participants in the current study acknowledged the effects of traffic on the environment and our health, and agreed that alternative transport would mitigate the effects.

Contrary to findings from an earlier survey of journeys to work in the city of Adelaide (Australian Bureau of Statistics 2009), this study indicated that females were more likely to use private transport to travel than males. However, females in both studies used active transport less than males, which was also similar to the findings from a recent study conducted in Sydney (Rissel et al. 2013). People's choice of transport can be influenced by demographic, psychographic and land use factors (Anable 2005; Australian Bureau of Statistics 2009; Best and Lanzendorf 2005; Hagman 2003). According to the latest national transport survey (Australian Bureau of Statistics 2012b), concern about safety is an important factor for Australian residents who choose to not cycle to work or study. In addition, perceptions of safety may varied between genders. For instance, Krizek et al (2005) found significant gender differences in reporting cycling safety issues. Women were more likely than men to report lack of cycling lanes and poor road conditions, but men were more likely focus on unsafe behaviours of drivers and cyclists. This may explain why fewer females travelled by active transport than males in our study, since Adelaide transport infrastructures were considered to be insufficient for supporting active transport.

The study findings also indicated that people aged 35-65 years had the highest proportion of private car use for travelling and the lowest proportion of public transport use, which could be related to working status and household structure. At this age, most people commute to work or take their children to school on a daily basis. In our study, young people (18-34 years old) used public transport more and used a car less than the other age groups. One factor possibly related to this is car ownership. Almost 63% of the persons belonging to the group of 18-34 year olds in my study did not own a car. On the other hand, older people (aged over 65 years) in our study were more likely to choose active

transport, as most people at this age are retired or do not own a car, and thus have more time to engage in walking and/or cycling.

It has been shown that household income can affect the affordability of transportation costs (Litman 2002). In the current study, people in the highest household income group had the second highest proportion of private transport use on a daily basis and the highest proportion of private transport use for shopping and other social activities. In addition, we also found that people with a bachelor degree or higher were more likely to drive. A possible explanation for this may be found in previous studies, which have shown that people with a higher educational level and relatively higher wages may commute more (Watts 2009). However, people in the highest household income group also had a higher proportion of active transport use for travel in Adelaide. The reason for this may be that wealthier people have the resources to pay more attention to their health, and therefore walk or cycle more. It also might be related to the communities in which they live may have low crime rate and better infrastructures for active transport, which are relatively safer for walking and cycling.

We have observed that people living in inner Adelaide were more likely to use active transport and public transport than people living in outer Adelaide. Similar results have been reported in a study in Netherlands (Scheepers et al. 2013). This phenomenon suggested that travel distance and duration are both key factors that can influence transport mode choice, discouraging people who live in the outer sections of cities from using active transport. Furthermore, outer Adelaide neighbourhoods have relatively fewer public transport routes and active transport facilities, which may also explain the fact that people living in outer Adelaide showed a higher level of car dependency.

Many studies have suggested that reshaping individuals' travel behaviour towards alternative travel modes can be encouraged by using both "Push" and "Pull" policy measures (De Groot and Schuitema 2012; Pucher and Buehler 2008). Some researchers have reported that "Pull" measures may be more effective at encouraging an increase in the use of sustainable modes of transport (Eriksson et al. 2008). In this study, nine car reduction measures were provided and scored by participants, which included three "Push" measures (measures 1 to item 3) and six "Pull" measures (measures 4 to item 9). Similar to previous research, I found that "Push" measures were considered less effective than "Pull" measures by participants. It seems that "Push" policies tend to be unpopular, perhaps because many people are reluctant to give up the perceived freedom associated with owning and using a car (Rietveld and Stough 2005). Many studies on the acceptability of policies have shown that the perceived effectiveness of these policies is an important determinant of their acceptability (e.g. Bamberg and Schmidt, 2003; Eriksson et al., 2008; Jakobsson et al., 2000; Schade and Schlag, 2003). However, "Pull" measures alone may not be sufficient to effect a change in transport behaviour. Instead, a joint effort of "Push" and "Pull" measures is needed, and "Push" measures should be assessed before implementation to minimise public opposition as to make the unpopular popular.

There was common agreement on the traffic-related environmental and health issues among our participants, suggesting that people are aware that alternative transport can be used to achieve multiple benefits. However, participants indicated that they were concerned about cycling safety. In addition, they disagreed there was adequate infrastructure for active transport in South Australia. This may explain the low proportion of participants using bicycles to travel even though half the participants reported that they own a bicycle. Bicycle culture is an important factor that can influence people's bicycle

use (Handy et al. 2010; Xing et al. 2010). This study also found that most cycling trips were for recreation and exercise, reflecting a different mainstream bicycle culture from those in countries where a large proportion of travel is by bicycle. Furthermore, the study findings indicate that people's perception of comfortable cycling and walking distances varied. Most participants reported feeling comfortable with less than 5 km cycling trips and 3 km walking trips, which is a distance suitable for daily active commuting. Those participants who accept longer cycling ( $\geq 10$  km) or walking trips ( $\geq 5$  km) may use active transport as a means to exercise.

The major findings from this study also suggest that people who report being very concerned about safety and comfort, and who have more negative perceptions towards public transport tend to have longer annual driving distances, higher driving frequency, and higher scores on environmental impacts. This result is consistent with conclusions from Grdzlishvili and Sathre (2010) and Nilsson and Kuller (2000) that people preferred to use a private car because of time, comfort and safety issues. Furthermore, the findings suggest that participants' awareness of the benefits of alternative transport and the problems of traffic were not strongly related to their car use. This is similar to the results reported by Flamm (2006) indicating that environmental knowledge may only have small and indirect impact on individuals' vehicle ownership and use. However, Bamberg and Schmidt (2003) have suggested that travel mode choice may also be determined by habits, and development of a car use habit is facilitated by the perceived advantages of car use. A meta-analysis has been conducted to evaluate associations between modifiable psychological constructs (e.g. attitude to car use and environmental concern) and driving (Gardner, Benjamin and Abraham 2008). The study findings also highlighted that habit produced a strong average effect on travel behaviour especially for longer time periods, but there was a lack of evidence regarding the effects of pro-environmental cognitions on



individuals' travel behaviour. Therefore, even though people perceive the negative effects of motor vehicles and the benefits of alternative transport, the principal considerations in travel mode choice are still the perceived advantages of car use such as cost, time, safety and convenience.

As a result of habitual behaviours, people may not consider environmental or health impacts of their activities and may be less likely to consider other options if they settle into a routine such as using the car for certain journeys (Owen, R et al. 2008). Making the automatic execution of the habit impossible or at least unattractive may be crucial in changing habitual behaviour (Ronis et al. 1989). Therefore, car restriction measures or facilitating alternative transport measures may diminish people's willingness to drive. The study findings suggest that participants' awareness of benefits of alternative transport and awareness of the traffic problems were more strongly related to their perception of the effectiveness of traffic measures than to their personal transport use. Furthermore, people who were more concerned about safety or dissatisfied with public transport were less likely to recognise the effectiveness of traffic measures. Proposed here is that improving people's understanding of alternative transport and of the negative impacts of car use may bring indirect benefit for pro-environmental traffic policy implementation.

According to this study, most demographic characteristics, including gender, age, annual house income, and employment status, were not significant predictors of a strong intention to reduce car use. Previous research has shown that travel mode choice is constrained by the travel distance (Lo et al. 2013), which explains our findings that the more the further participants had to travel, the less they are likely to change. Moreover, this study identified that household income could be a determinant of travel mode choice.

Although it was not found as a significant predictor of a strong intention to reduce car use in our study, we found that people with a salary of over AUD\$80,001 per annum had a lower intention to reduce car use. Similarly, compared to those who had a secondary school education or less, more highly educated people showed a lower intention to reduce car use.

Not surprisingly, the findings indicate that bicycle users were seven times more likely to reduce their car use than non-bicycle users. A bicycle is a relatively traditional alternative transport solution. However, only 2% of Adelaide residents use bicycles on a daily basis, and a larger portion of residents uses bicycles for recreation and exercise rather than commuting purposes. Therefore, it may be easier to encourage people to reduce their car use by shifting from recreational cycling for commuting cycling.

According to the Theory of Planned Behaviour (TPB), attitude towards the behaviour have a directly impact on individual's intention to engage in a behaviour at a specific time and place. This may explain the study findings that individuals with a high score on 'benefits awareness' show a greater intention to shift travel mode towards alternative transport since they had a positive evaluation of the travel behaviour of interest. In addition, the TPB also suggests that perceptions of societal norms also influence intentions (Bamberg and Möser 2007). One study concluded that a specific awareness of negative environmental consequences of car traffic and the seriousness of these problems are important for activating and establishing personal norms (Nordlund and Garvill 2003). In a similar way, participants in this study were more likely to change behaviour if they had a higher score on 'problems awareness'. The results are also partly in line with Stern's value-belief-norm theory (Stern 2000) which concluded that awareness of environmental problems and the perceived possibility to reduce these problems were

important antecedents to pro-environmental behaviour. However, compared with being environmentally conscious, more participants reported that being healthy and having flexible transport options were their major reasons to use alternative transport. From a psychological point of view, health and flexibility benefits from active transport can be experienced by individuals directly in the relative short term, whereas positive impacts on the environment can only be improved gradually. Such changes are likely to be beneficial for the whole population but may not be perceived at the individual level.

The factor 'safety and comfort' not only influenced individuals' current transport choice but also had an impact on their intention to change. In general, participants did not consider cycling a safe option. Therefore, participants were less likely to change if they cared more about safety and comfort. The TPB suggests that perceived behavioural control (PBC) is another direct predictor of intentions and actions (Conner and Sparks 1996); it refers to the perceived possibilities to perform the behaviour, that is, how easy or difficult the behaviour is perceived to be and to what extent the actor has control over the behaviour. Safety and comfort factors may indirectly influence perceived behavioural control as it would be difficult for people to choose other modes of transport if they do not perceive them to be better options than cars. In addition, individuals may have unfavourable evaluations of alternative transport because of safety and comfort issues, thereby have negative attitudes towards this pro-environmental travel behaviour. We also found that, although being healthy is an important motive for people to use another mode of transport, participants prefer public transport and walking rather than cycling. This also could be due to cycling not being perceived as a safe option. In addition, both safety (e.g. being safe at home and in the streets) and comfort (e.g. having a comfortable and easy daily life) are considered as important indicators of quality of life (QoL) (Steg and Gifford 2005). Reducing car use may require people to reach a compromise between pro-

environmental travel behaviour and a comfortable lifestyle. Therefore, some people may refuse to use alternative transport measures that negatively affect their quality of life.

The results of this study have potential implications for government and transport departments. First, an unsupportive physical environment could be a significant barrier to the public using alternative transport. Solutions to achieve car use reduction should therefore explore transport options in conjunction with strategies related to land use and urban planning. It means that a range of stakeholders need to be involved from all levels of government, as well as from different departments. Thus they can support strategic objectives and the complementary implementation policies. Second, the public have different degrees of acceptability for different car reduction measures. Therefore, introducing appropriate measures needs consideration of what will be accepted amongst the public. Third, planners and policy makers who seek to encourage less driving, and greater use of alternatives forms of transport will have a greater impact if they target messages about the environmental and health issues of motor vehicles and the benefits of such behavioural changes for the majority of people.

Some limitations in this study should be noted. First, as a cross-sectional survey, it could not provide any basis for establishing causal inference. Second, this survey was conducted by telephone interviewing which potentially restricted the length of interviews. Within the short time of an interview, participants may not have understood some questions adequately. Third, a study conducted in Sydney explored response rates in household telephone surveys (O'Toole et al. 2008). They found that the average CATI response rate for eligible households (target and control households) contacted by telephone was 39%. The response rate from this survey is 48%, which could be considered moderately acceptable. However, the increasing prevalence of households

without landline telephone may limit the generalizability of findings of this study. Moreover, although all the telephone calls were made from 10:00 am to 8.30 pm on weekdays and 10am to 5pm on weekends, business people or people with full time work can be hard to reach. Therefore, the unweighted age distribution had a higher proportion of older people and a lower proportion of younger people with inevitable selection bias. Last, response bias is another issue since all analysis was based on self-reported data.

## **6.5 Conclusion**

Public transport and active transport, as a form of eco-friendly and healthy transportation, can be a valuable alternative to replace existing car trips. This chapter provides an account of people's current travel behaviour in Adelaide and how demographic characteristics affect their travel behaviour. It also reports on people's attitudes towards different transport modes, reveals some possible barriers to alternative transport use, and generates findings about significant indicators of people's intention to reduce their car use. These findings draw attention to the importance of increasing public awareness of traffic problems and perceived benefits of alternative transport, in order to reduce car use. To abate problems resulting from increased car use, transport policy measures, including, in some places, increased costs of car use, prohibition or rationing of car use and physical improvements of infrastructure have been introduced. These measures may, however, show low acceptability and feasibility, and they will not be effective alone. Therefore, when designing and implementing sustainable transport policies, policymakers should consider a range of approaches in addition to the above, including education in schools, communities, workplaces and in the media to raise awareness of the impacts of private car use as well as provide detailed information about the benefits of alternatives.



# CHAPTER 7

## Qualitative study with stakeholder

### Stakeholders' perspectives on barriers and solutions

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#### **Preface**

The first phase of this thesis identified that increasing alternative transport would lead to significant environmental and health benefits. As outlined in Chapter 1, the second phase of this project focused on how to implement the promotion program and policies initially examined in practice. In Chapter 6, I used a cross-sectional study to explore factors related to the travel behaviour of local residents in the study region. In addition to individual factors, it is widely acknowledged that government plays a crucial role in influencing travel behaviours. This chapter describes the findings of a series of qualitative semi-structured interviews with 13 key relevant stakeholders, including people working in government. The thematic analysis of these interviews has identified particular challenges for stakeholders in promoting alternative transport, which answers the final research question of this thesis:

- What are relevant stakeholders' perceptions and knowledge regarding facilitators and barriers in promoting alternative transport in this area?

## **7.1 Introduction**

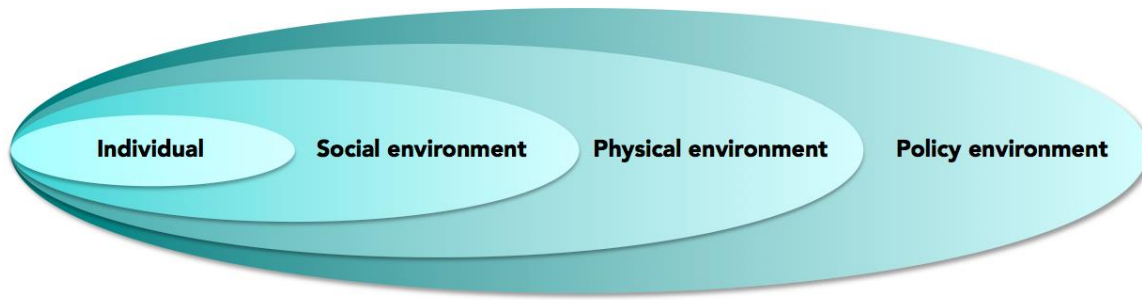
This chapter details a qualitative study, which aimed to explore the perspectives of stakeholders relevant to changing transport behaviours. After first providing relevant background, the chapter will focus on an analysis of transcribed interview data, investigating stakeholders' perceived potential barriers to alternative transport promotion in Adelaide and corresponding strategies to overcome such barriers.

As discussed throughout this thesis, the increasing use of motor vehicles in urban areas is having a significant impact on the environment as well as on human health. Therefore, increasing attention is being paid to sustainable transport development. A key element of sustainable transport development in urban areas is to encourage residents to reduce their car use and shift to alternatives, such as public transport and active transport, which are more effective and less polluting.

The benefits of alternative transport have been identified by an increasing amount of research (Grabow et al. 2012; Macmillan et al. 2014; Woodcock et al. 2009) and Chapter 5 in this thesis, ranging from air quality, disease burden, health expenditure, and traffic injury prevention. However, the use of alternative transport is not yet widespread, especially in many developed countries. For instance, in major Australian and U.S. metropolitan areas, public transport trips account for less than 20% of all trips (Bureau of Transport Statistics 2012; Pucher and Buehler 2008; South Australian Government 2002; U.S. Census 2012). Active transport use has also declined significantly over the last 20 years (UK Department for Transport 2004). Cycling only occupies less than 3% of the total travel trips in U.S., UK and Australian cities (Bureau of Transport Statistics 2012; Pucher and Buehler 2008; South Australian Government 2002; U.S. Census 2012).



In exploring the reasons behind car dependency, researchers have found a range of factors that may influence people's travel behaviour as discussed in Chapter 3, including socio-demographic factors (Bergstad et al. 2011; Giuliano and Dargay 2006), land use factors (Antipova et al. 2011; Owen, N et al. 2010), psycho-social factors (Gardner, B. and Abraham 2007; Heinen et al. 2011), and policy interventions (Steg and Vlek 1997). As shown in Figure 7.1, the Social Ecological Model (Stokols 1992, 1996) provides a systematic approach to understanding the dynamic interrelationships that exist among determinants of individuals' participation in health behaviours. This model has been widely used as a theoretical basis to guide physical activity interventions in various populations (Brownson et al. 2001; Fleury and Lee 2006; Giles-Corti, Billie and Donovan 2002). Researchers have found that some determinants have direct impacts on people's physical activity at an individual level, such as attitudes towards exercise, habits and motivation (Brownson et al. 2001). However, appropriate changes in the social environment may produce changes in an individual. For instance, an Australian study (Giles-Corti, Billie and Donovan 2002) reported that peer encouragement and dog ownership was associated with achieving recommended levels of walking. Meanwhile, aspects of the physical environment also appear to be important. For example, good access to attractive open spaces and facilities can be beneficial in promoting physical activity among the population at higher risk for inactivity (e.g. women and people of low socioeconomic status) (Brownson et al. 2000). As the most distal level, the policy environment can shape behaviour change through resource allocation, legislation and the introduction of appropriate interventions. Thus, this framework reveals that efforts to change people's behaviour are more likely to be successful when interventions work within all spheres of influence.



**Figure 7.1: Social Ecological Model**

It was suggested in the previous Chapter 6 that attitudinal factors at the individual level would influence travel behaviour and the intention to reduce car use. The survey study also revealed some potential local barriers, occurring at the social and physical environment levels, affecting the public's use of alternative transport in the study region, such as safety concerns, distances people need to drive, and insufficient alternative transport infrastructures and services. Policy is recognised as an important tool for practice change since it has vertical impacts through adjoining levels of influence, which is particularly important for addressing problems at all levels. However, transport researchers found that introducing a sustainable transport policy was relative new and of a non-incremental nature. Therefore, some difficulties may have occurred at the policy environmental level in order to reduce the potential of implementation or make the implementation less effective (Rietveld and Stough 2005).

Rietveld and Stough (2005) have identified six main barriers that may prevent a policy from being implemented in its ideal form including: (1) resource barriers such as unavailable financial and physical resources; (2) institutional and policy barriers such as issues with coordinated actions between different organizations or levels of government; (3) social and cultural barriers such as public acceptability of measures; (4) legal barriers such as legal requirements complicating policy implementation; (5) side effects of the

expected outcomes (e.g. a change in the frequency and severity of traffic accidents); and (6) other physical barriers (e.g. inadequate space for the introduction of large parking areas for bicycles). Resource barriers are most common, followed by institutional/policy and social/cultural barriers. However, a direct translation of these generalised findings to a Australia context may not be fully applicable (Rietveld and Stough 2005).

In Australia, transport and urban planning can be influenced by various effects. First, the federal parliament, eight state/territory parliaments and over 500 local councils are involved in the design and implementation of policy and programs in relation to transport (ANAO and Department of the Prime Minister and Cabinet 2006; Parliament of Australia 2014). Main roads or footpath/bicycle lane construction are undertaken by different levels of government. Generally, state governments are responsible for metropolitan arterial roads, while local governments are responsible for footpaths and local roads. In addition to the federal governance system, the automotive industry in Australia has become a key manufacturing industry as a result of the combination of industrial stimulus and diversification since the early 20th century (Clark et al. 1996). Although several auto makers have confirmed that they will withdraw from car production in Australia in the next few years, the role of industrial influence on transport policies was important due to its significant contribution to the national economy. Furthermore, because of a wide range of benefits, a number of departments and sectors, private organisations and partnerships have incorporated the promotion of alternative transport as their strategic objectives in Australia. For example, reducing air pollution and greenhouse gas via alternative transport motivates the environment sector, while preventing chronic diseases via active transport affects the health sector (Cole et al. 2010). The involvement of multiple stakeholders has been found to be important in governance around transport policy sustainability in a range of different ways, such as enhancing the legitimacy of

policy, reducing the risk of conflict, and offering an additional source of ideas and information (Coenen 2001). However, having all stakeholders involved in transport policy can also be very challenging due to potentially jeopardized interests or additional cross-sector responsibilities.

An Australian study (Cole et al. 2010) has further investigated institutional and personal barriers particularly for active transport by interviewing representatives from the public, private, and community sectors. The authors identified several concerns that may influence delivering community-level active transport existed across formal, informal, government, and other decision-making institutions such as human and disability services. These concerns included challenging of integrated planning and development across agencies and governments, inefficient public transport and active transport infrastructure, a lack of high-level political commitment and whole-of-government support, and the ‘car culture’. It was also argued that the factors which contributed to those barriers existed at the highest governmental and institutional levels (Cole et al. 2010). Specifically, there was a lack of political will, state government leadership, and a policy framework for active transport, lack of cross-government coordination, and a lack of a supportive institutional culture. This previous study provides an understanding of the barriers to active transport for key players from multiple sectors. However, it only focused on active transport and opinions from the health sector were absent.

Currently, most Australian states have included alternative transport in their development planning to help to achieve environmental outcomes (Government of South Australia 2010; Transport for New South Wales 2013). However, compared with the heavy allocation of government funds to roads, investment in public transport and active transport remains poor. Thus, there is still some distance between policy intentions and

implementation which needs to be shortened. Although there is currently a large body of literature citing the key barriers that impact on travel behaviour change, little empirical research has been conducted in Australia to explore perceptions of those stakeholders who are involved in policy-making and implementation relating to alternative transport. The motivation for this study was to explore both stakeholders' perceived potential barriers to alternative transport promotion in Adelaide and corresponding strategies to overcome such barriers.

## **7.2 Method**

### **7.2.1 Study participants**

Potential participants were selected according to the following criteria: participants were employed within the state or local government or private sectors, and his/her professional role contributed in some way to transportation planning, urban design, health promotion or air pollution regulation. A snowballing approach was adopted to recruit potential participants. Initially, I collaborated with the research team supporting my PhD (comprising of university researchers, scientific officers from the South Australian Department for Health and Ageing, and Environment Protection Authority) to identify key transport, health, environment and private sector stakeholder groups. In order to gain a broad spectrum of knowledge and insight, two to three employees of each organisation or group, who were deemed to have the best working knowledge of their organisation's priorities and initiatives, were invited to be interviewed. Further participants – from a relevant local bicycle organisation, and transport policy consultancy services – were suggested by respondents who had already agreed to participate.

In total, 17 invitation letters were sent to potential participants via email (Appendix A), with an information sheet attached to provide detailed information about the study (Appendix B). Participants were informed that their involvement was voluntary and that the research process would be anonymous and their identity kept confidential. Thirteen respondents consented to be interviewed, representing experience in transport and infrastructure planning, sustainable transport planning, travel behaviour change programs, transport policy, public health services and promotion, sustainability and climate change policy, air pollution management, environmental legislation and policy, local government and cycling promotion programs.

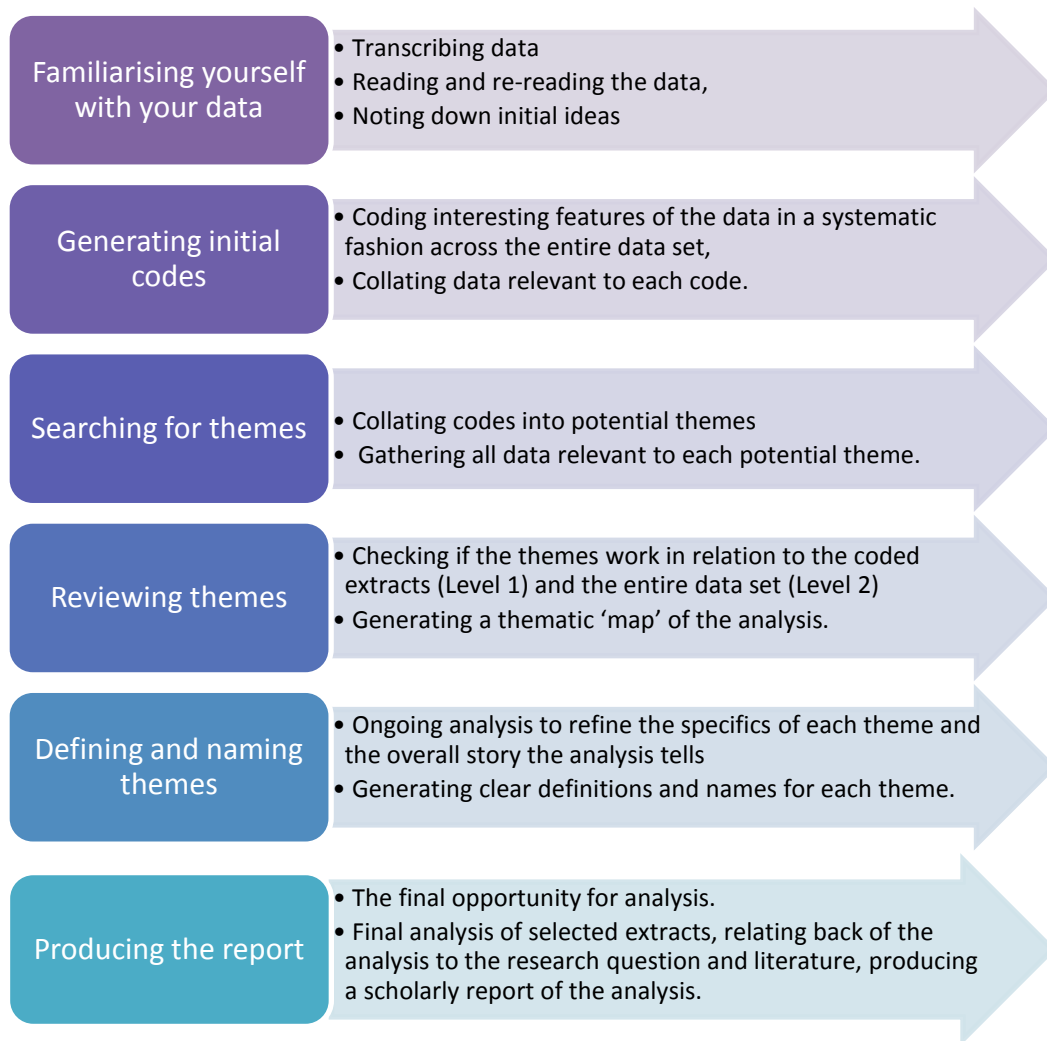
### **7.2.2 Data Collection and Analysis**

Twelve face-to-face, in-depth, semi-structured interviews were conducted from April to June 2013. One participant provided their answers in writing based on my guide questions. Among the face-to-face interviews, 11 were undertaken in the workplaces of the participants whilst one was interviewed at a meeting room in the University of Adelaide. Prior to interviewing, consent forms were obtained from all respondents (Appendix F). An interview guide was used during the interview process (Appendix G). Participants were asked questions regarding their perceptions of barriers to the promotion alternative transport use: for example, “From your personal perspective, what are the difficulties and barriers for your department/organization to promoting alternative transport/public transport/active transport use?”. Two further questions were asked about approaches to promoting alternative transport: (i) “What kinds of strategies do you think are most effective to encourage the public to use cars less?” and (ii) “How can local government, communities and businesses work together to promote alternative transport use?”. During the interview, the conversation was not limited to the given questions and the participants

were given an opportunity to raise other relevant topics or issues. The average interview length was 30 minutes (ranging from 20 to 60 minutes).

All interviews were digitally recorded and subsequently transcribed verbatim and de-identified to assure confidentiality. I replaced the participants' identity with a numeric ID as *S-1* to *S-13*. The data set, consisting of transcripts and recording, was stored on a university-owned computer with password protection.

Data were analysed using a thematic analysis approach. Thematic analysis is a foundational method for qualitative analysis, which can be used to identify patterns of meaning across a dataset to provide an answer to the research question being addressed (Braun and Clarke 2006). I conducted analysis of the data following the guidelines recommended by Braun and Clarke (2006) which involve six phases including: familiarizing data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report (Figure 7.2).



**Figure 7.2: The six phases of thematic analysis**

*Source: Braun and Clarke (2006)*

To gain an overview of all the interviews gathered, the data were read and re-read. Transcripts were then imported into NVivo 9 (QSR International, Melbourne, Australia) to facilitate coding. Initial codes were generated by coding interesting features of the data across the entire data set, and then sorting into potential themes. In order to ensure that those themes reflected the interview data, the initial codes and sub-themes were reviewed and refined in collaboration with two of my supervisors (Annette Braunack-Mayer and Shona Crabb). After many discussions, the final themes were identified and named.



## **7.3 Findings**

The findings of this study are set out as follows: first, results are presented from the exploratory phase of analysis with attention to the main question focused on participants' perceptions of difficulties and barriers for their departments/organisations to promote public transport and bicycle use in Adelaide. Second, results from the follow-up phase are presented, which summarise how those difficulties and barriers (described in the first section) can be overcome. Anonymous quotes that identify key participants' views and perspectives identified through our iterative process of review and discussion are presented in the following sections.

### **7.3.1 Barriers**

Analysis of the interview data generated four themes around participants' perceived barriers to the promotion of alternative transport use, which were: (1) Insufficient translation of knowledge and evidence gaps, (2) Difficulties in getting the policy balance right, (3) Lack of shared ownership of alternative transport policy and programs, and (4) Public resistance. Each of the major themes, and related sub-themes are summarised in Table 7.1.

**Table 7.1: Participants’ perceived barriers to promoting alternative transport use**

Themes	Sub-themes
Insufficient translation of knowledge and evidence gaps	Transport emission impact
	Benefits of alternative transport
	Lack of local evidence
Difficulties the policy balance right	Economic viability vs. Alternative transport strategies
	Feasibility vs. Alternative transport strategies
	Population density vs. Alternative transport strategies
	Demands of different transport user type
	Insufficient budget and unequal distribution
Lack of shared ownership of alternative transport	Responsibility silos
	Lack of cross-departmental collaboration
Public resistance	Road lobby
	Lifestyle preferences
	Public knowledge of transport-related air pollution and its health impacts
	Stigma towards alternative transport
	Lack of motivation amongst general public

### 7.3.1.1 Insufficient translation of knowledge and evidence gaps

Although there has been growing evidence showing that the risks of alternative transport far outweighed overall benefits, such evaluations have not been conducted widely in Australian cities and, therefore, the participants perceived that the knowledge translation was insufficient either within relevant sectors or between research and practice. A lack of integrated knowledge about transport, health and environment was reported as another key barrier. This section summarises the main gaps in knowledge raised by participants.

### **Transport emission impact**

Participants from the environment and health sectors discussed how their work related to transport. Due to the complexity of vehicle exhaust and dynamic effects of pollutants, they thought that it was difficult to measure transport-related air pollution effects:

*I think the effects [health impact of transport emissions] are demonstrated...but I don't think we will ever get a sort of ...definitive exposure curve or whatever, for any of this sort of stuff. Because it is such a dynamic thing as well, fleet composition and all that sort of thing it's going to be really difficult. (S-05)*

More importantly, participants recognised that transport and urban planners may have underestimated the health impact from transport-related particulate matter emissions as the spreading range of particulate matter could be much larger than their current understanding.

*I think there has been a bit of difficulty I guess, having the transport people in particular understand that for major roads, and that's the corridors that they deal with, that they impact at a far greater distance than they believe...that we were originally talking about of within 20 metres you can just put a house up too close. (S-01)*

### **Benefits of alternative transport**

During the interview, many participants discussed numbers of potential benefits of alternative transport in terms of environmental and health aspects, and few of them argued that state government's concept of transport was narrow and limited. It seemed that cars were seen as much more important than other travel modes in the government's political agenda. In addition, it was reported that it was as not uncommon for the

government to neglect the economic benefits of alternative transport via reducing health impact of massive financial expenditure on cars.

*I think it's in a too hard basket. I think they don't really realize yet or the government or the whole department of transport has not realized that transport is not just cars, and the cars cost a lot of money in terms of health, accidents, and that maybe overtime actually the population will go away from cars, this is the development. (S-2)*

In the meantime, participants were uncertain about to what extent those benefits could be gained by such government assessments, mainly due to limited and the scientific evidence supporting those benefits was missing at the moment. For example:

*There is the attractiveness or perceived expense of public transport when really it is a much much cheaper option, in fact there is no tool or very much of an understanding as to the amount of money and time you can save catching public transport and for the active transport. (S-08)*

*I think we can sort of expect some of that [benefits]...but that translation of evidence and seeing where some of the benefits can lie about those...the environments that we set up for example, and you know planning interventions and transport interventions probably a...where a lot more benefit is. (S-05)*

### **Lack of local evidence**

Most participants acknowledged that some cities overseas (such as Copenhagen, Denmark) had achieved great success in promoting alternative transport. Some departments attempted to learn from those cities or countries by sending their staff there and by studying reports of success. However, participants were not confident about applying others' experiences directly to local transport planning or urban planning. They were also concerned that they might not have a comprehensive understanding of transport systems

overseas or the potential challenges they might face. Furthermore, some participants were unsure about whether the transport system in Australia lagged behind other nations or, in fact, might be better than them. Therefore, they were typically not keen to adopt overseas practices:

*we try and understand what's been done overseas. Some people would go have a look at it and we would read the reports but, I am just saying that and you do the best you can but it's not like having an intimate understanding of how that system came about and what challenges it faced, that becomes impossible to get... (S-12)*

*I don't think we have a good understanding even if, something is being done better in Australia or particularly if something is being done better in a similar sort of country: United States, Canada and the United Kingdom perhaps. I don't feel that we, coming from where we are and the changes that are realistic, whether we are doing well or doing poorly (S-12)*

In conclusion, in this theme of 'Insufficient translation of knowledge and evidence gaps' participants highlighted gaps within relevant departments in terms of understandings of transport-related emissions, benefits of alternative transport, and specific local evidence.

### **7.3.1.2 Difficulties in getting the policy balance right**

Participants recognised that car reduction and alternative transport promotion strategies may not only have impact on people's travel patterns, but also influence urban planning, road upgrading and even local businesses. Some of these impacts can be positive and some can be negative. Therefore, there was a lot of discussion by participants focusing on various possible conflicts that may occur during policy implementation, especially with respect to balancing alternative transport strategies and economic viability, feasibility, population growth and different transport user demands.

### **Economic viability vs. Alternative transport strategies**

Participants mentioned that the automotive industry is one of Australia's key manufacturing sectors and an important part of the economy. Since announcements regarding the closures of Australia's major car manufactures had not been declared during the time of the interviews, several stakeholders were concerned that improving alternative transport would have a long-term adverse impact on the local economy.

*Economically (important) to South Australia is the car industry, so clearly there is going to be a balance between efforts to improve public transport and keeping the industry alive. (S-1)*

Some participants suggested that encouraging reductions in car use could be facilitated by certain "Push" transport policies such as limiting car access to the central business district (CBD) and reducing street car parking. However, they were also concerned that such policies would restrict people's access to retail stores and cause immediate dissatisfaction among retailers.

*"It's a question of public space so you're going to provide that and you'd probably have to remove car parking and the first thing the business retailer is going to say is 'it's going to kill my business. It's going to kill it. I'll have no money for my business. " (S-13)*

### **Feasibility vs. Alternative transport strategies**

Participants agreed that expanding the public transport system could speed up public transport and facilitate the public's use of alternative transport. However, some participants were also concerned about the feasibility of such strategies. For example, introducing priority bus lanes or bicycle lanes on existing roads may reduce road space available for motorists and lead to additional delays to other road users. Although such

problems could be resolved by widening the roads for bus or bicycle lanes, it was reported to be unacceptable to sacrifice public green space or individuals' properties.

*That would be a bad idea (to have bus lane or bicycle lane) we would lose trees along the highway or it would restrict traffic. (S-10)*

*I can't see any cheap ways to greatly expand the public transport system in existing areas without going underground or knocking over a lot of houses (S-12)*

### **Population density vs. Alternative transport strategies**

Most participants discussed how population density affects transport and urban planning. In their view, Adelaide is a stretched out city with very low population density in some remote suburbs. Public transport services in those areas are currently limited. Any future development of public transport systems in remote areas was deemed as uneconomical. In addition, active transport was viewed as being impractical for local residents.

*transport task is going up all the time..., putting money into the public transport infrastructure helps that but unfortunately for growing the city on a continuous basis because there is cheap land outside that is not a solution because, ultimately you have got to service those people and it's very hard to service a public transport bus system if there is only two or three passengers on the bus. (S-07)*

*if you are working at Holden's out at Elizabeth, probably everybody drives or a large percentage of people drive just because it's not as well serviced with public transport and the population density isn't there for walking so it's got a lot to do with the big spread of Adelaide and the lack of density.(S-08)*

Participants also mentioned that increasing population density might be a future direction for Adelaide. However, participants expressed reservations about this proposal since there

had been much debate around it, and it was suggested that local residents may resist living in high density areas, as this participant discussed:

*You know a lot of this urban density debate is very concerned about overcrowding (S-05)*

### **Demands of different transport user types**

In most Adelaide metropolitan areas, cars, buses, and bicycles share the road. On one hand, transport planning should take alternative transport users' demands into account and build more bus and bicycle lanes. However, if installing a new bus or bicycle lane requires occupying the existing car lane, it is highly possible that car users will be dissatisfied. This point is illustrated in the following narrative:

*There is a lot of um....I guess that is something the department and some councils are afraid to do, they haven't quite got the courage to take the space away from the car yet, but that's what....it should be a balance...the road should be a balance and if there is a road that is a good direct route for cyclists, a cycle lane should be put on there and if that means removing a car lane well that be difficult, it because, there needs to be a balance for all transport user (S-9)*

Participants were also concerned about commuting inconvenience in remote suburbs, especially for people who do not have cars. In communities such as these, public transport may be the only choice.

*when you compound by knowing that a lot of those out of fringe suburbs are where your most socio-economically deprived communities live, who don't have cars. A lot of them are reliant on public transport so they are caught, absolutely caught. (S-12)*



Because of these competing demands, government and councils may be indecisive about car restrictions because finding a balance between the various road users is challenging.

### **Insufficient budget and unequal distribution**

There was a consistent view across most of participants that promoting alternative transport use should be facilitated by road reconstruction and urban planning. Participants described how increasing attention had been paid to alternative transport plans within current urban planning. For instance, the 30-Year Plan for Greater Adelaide was mentioned by several participants, which contained proposals to increase public transport and bicycle use. At the same time, participants also suggested that a great deal of funding was necessary to ensure these plans would be implemented and that this funding might not be available.

*We have a long way to go. I mean the plans (30-Year Plan for Greater Adelaide) are there. You would have seen that they are looking at an integrated bicycle plan and a whole range of other things but at some point there is a major capital investment there that's needing to be made. (S-3)*

*So once again if you could build the city from scratch you would put in big natural cycle lanes or walkways but it would require quite a lot of money to do that. (S-12)*

Furthermore, participants thought allocating funding to active transport over motorized vehicle use was not easy. These participants suggested that the budget allocated to such projects is very limited when compared with the expenditure on roads for motor vehicles.

*I think for every million dollars you perhaps invest in some of that cycling infrastructure you will get lobby groups arguing, that is money that should have gone onto roads or parking or something like that. (S-5)*

*If you were to ask transport how much money do they actually spend annually on new roads, compared to how much money they spend on bicycle lanes and infrastructure their ratio would be something like almost one to a hundred if not a thousand, so it's a small proportion of the budget actually goes towards cycling infrastructure and I think that is a problem.(S-7)*

Moreover, with limited funds, participants reported that local governments needed to consider their priorities. This entailed that investment in an alternative transport programmes might normally means funds allocated to other programmes will demand reduction:

*So we are going to have to cut programmes, we won't in local government it's going to be very difficult to do anything extra, instead we are going to be cutting stuff and we are going to have to really look at our priorities and so to put a lot of money into cycling infrastructure it will mean cutting from something else. (S-6)*

The participants from local government stated that they had drafted a new bicycle plan to promote cycling and had estimated the budget of this plan comprehensively. However, they were not confident that their plan would be funded by state government or federal government due to limited financial resources.

*These are the cost estimates (on a brand new bicycle plan) so it's like how much of this will we actually implement and how long will it take to implement it, considering at some point we are going to have to spend some big bucks and so then you can say, 'oh you know we could try and get some funding from the state government department of transport or maybe from the federal government maybe, but maybe they won't give it to us because they are going to be strapped for cash' (S-6)*

In brief, participants thought that many conflicts need to be seriously considered in order to ensure a balanced between alternative transport strategies and many other physical issues.

### **7.3.1.3 Lack of shared ownership of alternative transport policy and programs**

All participants acknowledged that promoting alternative transport should be a task not only for the transport department but also for other departments such as urban planning, health and environment. I found that silos within institutions, including in relation to the distribution of responsibilities as well as resources, makes the lack of shared ownership even worse. Cross-departmental collaboration and communication thus become very important. Other issues relevant to this theme mainly related to transport emission regulation.

#### **Responsibility silos**

Most of the participants noted that cycling promotion could be included in multiple departments' planning. This would require that cooperative partnership and coordination be established among relevant departments. However, participants did not think that this was currently the case.

*At the moment there's always a lack of co-ordination amongst different department bodies...you know that's sports, that's health, that's transport and so there's a lack of co-ordination of bicycles in their policy, that's for sure. (S-13)*

In the meantime, divided responsibilities between different levels of governments were also reported by many participants. The transport network is complicated for footpaths and bicycle lanes which are also expected to integrate with both main and local roads. However, there are three levels of government (federal, state and local) in Australia that

have responsibility for metropolitan transport systems in varying proportions. Main roads or footpath/bicycle lane construction are undertaken by different levels of government. The metropolitan arterial roads, bicycle lanes and footpaths were managed by state governments and local governments respectively. Therefore, the issue of building bicycle lanes on arterial roads would cause disagreement about responsibility between state and local governments, as mentioned by these participants:

*One of our big problems is that the local government... is in charge of local road but the state is in charge of the arterial roads but, of course, to get around safely on a bike you use a lot of local road but you definitely have to use some arterial roads even if just to get across them (S-6)*

On the other hand, when discussing financial sources for an alternative transport scheme, there were moments that different levels of government could pass responsibility to each other. Some participants mentioned that local government thought that state or federal governments should share some responsibility for cycling infrastructure investment. However, state and federal governments could still insist that it should be a local government responsibility.

*I mean we do work in consultation with them. I mean part of the problem too when it comes to cycling is that often it's sort of – people say look, it's a local level competency so you'll be asking for money on the state level and often the state level will say 'look, we'll match dollar for dollar any infrastructure spend which is done at the local level but it's a local responsibility to do it. (S-13)*

The other common aspect to these discussions with participants was that most acknowledged that promoting alternative transport would bring not only substantial environmental benefits but also significant health benefits. However, the multidisciplinary

evaluation and assessment would difficult to be implemented because of the issue of being silos across relevant departments in terms of funding resources.

*Well, see, we have never really looked at that because we never received any money from Health, so it is not that we don't see that there is a benefit we absolutely see that there is a physical activity benefit but, because we don't get any money from Health now there is no Health connection. Therefore there is no funding to do any sort of health based evaluation, so we measure what we need to report on. (S-11)*

A final important issue raised by some participants from the environment sector was transport emission regulation. Though these participants understood that transport emissions should be monitored and regulated, traffic-related issues (e.g. motor vehicle emissions) did not fall under the jurisdiction of their department because of people working in silos.

*Motor vehicles are the key contributors to air pollution in Adelaide, but we don't regulate them. They are regulated by transport department. So how we can interact is very limited because we don't have the authority to make any changes to how vehicles are registered or the engine requirements those sorts of things. They are all done by a different Minister and a different department. (S-10)*

*It is really important and because the EPA doesn't regulate transport and in fact transport emissions per se are not regulated by any agency in South Australia, it is something that we need to be conscious of and clearly have an understanding of. For example our regulatory work with other activities interact with transport emission (S-01)*

### **Cross-departmental collaboration**

Participants had a range of views about collaboration across departments and agencies.

One participant identified that, in fact, some cooperative relationships had already been

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established on some programs. For instance, the Active Living Coalition is a collaborative forum to deliver active living in South Australia, which involves a number of government and other agencies such as Department of Health, Heart Foundation, Office of Recreation and Sport, and Planning SA. However, the commitment from highest level of government is still absence.

*Well agencies do work together through the Active Living Coalition, I think sometimes there are opportunities for agencies to work together but that collaboration at the high level doesn't seem to happen so therefore it doesn't filter down. (S-11)*

Other participants thought the collaboration across different departments was insufficient for alternative transport promoting. More importantly, such lack of collaboration does not only exist across different departments, but can also happen within a single department. For instance, communication between different departmental branches is supposed to be well established in the Department of Planning, Transport and Infrastructure. However, some participants thought internal communication was still not as good as expected yet.

*They are one department –Planning, Transport, Infrastructure- so they should be talking within the department but they don't, it just doesn't seem that they are on the same page as many others the whole department. (S-10)*

Participants also described their experience working in large bureaucracies and pointed out that people might be hardly aware of others' work due to the large number of employees, which made it difficult for them to develop cooperative relationships with their colleagues.

*I think what tends to happen in government a lot is there are silos all over the place and you don't know what other people are doing unless you find out about it and that is really hard when you are working in a massive bureaucracy. I mean our department has got 4000 people that work in it and*

*that is just our department, so you know Health is I think Health is bigger than that so.....it's hard to keep a handle on how [people in those department] is doing what and where the connections are.... (S-11)*

Most of the participants reported their strong intention and willingness to engage with other departments, but they also saw the difficulties in doing so. For instance, some participants worried that involvement from outside the department might jeopardize other agencies' policy agenda, as expressed by this participant:

*It's an area where I think there needs to be some consideration given as to whether the EPA [Environmental and Protection Agency] should be doing those things but, it would be very tough history to break down because the transport department is the transport department, so making transport an environmental issue rather than a transport issue would be very difficult politically and culturally. Cars are transport, cars are not necessarily environment, and environment is a part of it. (S-10)*

#### **7.3.1.4 Public resistance**

Many participants pointed out that communities and government departments should play equally significant roles in successful traffic policy implementation. However, participants thought that the culture for alternative transport had not been well built in Australia. Beliefs and values in Australian culture were all described as making policy uptake challenging.

#### **Road lobby**

A number of participants believed that a large proportion of private car users would complain about alternative transport measures such as establishing bus lanes on arterial roads, increasing parking fees or registration fees. The reason for this was that the public believed their rights to use cars would be violated by these measurements.

*if you are going to do anything that impinges on someone's right to use their car they will scream and yell and complain and politically they won't go near it because it is bad for votes. So if you were to require bus lanes on every arterial road into Adelaide it would be a total vote loser, you would lose lots of votes because you are impinging on the individuals rights to use their car.(S-10)*

*No-one likes it, no, and I think part of the things with Adelaide, I think if – I mean any mayor that says we're going to restrict car use is going to be hated. (S-13)*

Thus, politicians would be unlikely to pursue policies they believe the public to be against .

### **Lifestyle preferences**

During the interviews, participants often linked cars with a way of life. They described people as desiring both a convenient way to travel and also a larger inhabited space to live. Participants noted that people valued their cars and houses greatly and considered this 'deep-seated culture' as an important barrier when trying to change their travel behaviour.

*Australians and Americans expect convenience, and value the big car with the big house on the big block. (S-4)*

*I think there is a deep seated ingrained car culture as well. You know, it's people's own space and it's interesting to sort of look at, you know, how people treat their cars and how people sort of treat their house. You know, in South Australia because we've had the quarter acre block and some were very much very big on our own personal spaces. (S-5)*



### **Public knowledge of transport-related air pollution and its health impacts**

Participants suggested that Australians also lacked knowledge of the impact of air pollution on their health even though there was a possibility that air pollution could cause more deaths than traffic injuries.

*In Australia people are much more aware of motor vehicle accidents rather than motor vehicle related health issues, so people don't recognise that when someone gets cancer that might actually in a way be related to the pollution that the motor vehicle has created... but the issue here is that more people probably die from pollution related health impacts than from motor vehicle accidents. (S-07)*

### **Stigma towards alternative transport**

The participants also discussed public perceptions towards alternative transport. They thought that people who travelled via public transport or bicycle might be labelled as poor and less successful. In general, there was considerable stigma attached to alternative transport, as described by this participant:

*It showed a nerdy guy on a bike showing him as a loser. So then you could say that isn't in government policy to try and make cycling as attractive and easy as possible, it's making you...it's putting some members of the community offside, so it's about having a picture that praises public transport user and cyclists and walkers not the people that are losers because they haven't got a car, it's a lot to do with culture as well as just infrastructure and policies. (S-8)*

*I believe culture is an issue – people are likely influenced by the 'stigma' of PT, which is that it is 'not cool' or 'dirty' or something that poor people do. (S-4)*

### **Lack of motivation amongst general public**

A lack of motivation to change travel behaviour was also raised during interviews. Interestingly, some participants thought that Adelaide's small size and relatively smooth traffic flow might undermine promoting alternative transport. Participants described a situation where residents often neglect other travel options, as they do not currently feel the inconvenience of massive congestion problems.

*What I would say is that I think in general, you know, Adelaide has always been considered a 20 minute city so you could go from A to B in very little time by car and I think in some way that's its weakness as well, in that when you can travel anywhere you like around the city in very little time. It basically means I don't look at options like public transport or cycling or walking, for example, as an alternative. (S-7)*

*I think it is probably indicative that there is not a lot of that push from massive congestion problems and things like that, which in other states they are a real driver for investment (S-5)*

Furthermore, people were described to be likely to underestimate the running costs of their cars, as this participant described.

*I don't think people understand the actual cost of their motor vehicle, so they might see their registration and how much petrol they put in but they are not really seeing the true running costs or the cost of paying back for the car. (S-08)*

#### **7.3.1.5 Summary of barriers**

In summary, all participants cited the importance and necessity of encouraging local residents to use alternative forms of transport instead of cars. Based on the following participants' narratives, four main themes can be derived for implementing sustainable

transport policies and interventions. First, there was an insufficient integrated knowledge translation across relevant sectors. Second, achieving a balance between alternative transport strategies and other practical problems will have been challenging for government. Third, silos of responsibility and finance within government and institutions can facilitate the issue of shared ownership. Last, people may refuse to change their travel behaviour since various reasons including unsustainable lifestyle preferences, lack of knowledge of transport-related environmental and health issues, negative stigma towards alternative transport and lack of motivation. During interviews, participants also offered a number of potential solutions that could be adapted to overcome those barriers, as presented in the next section.

### **7.3.2 Solutions**

Themes from the interviews that were relevant to solutions included: government actions, policy interventions, education approaches, cultural change and evidence-based research. Each of these themes will be explored in this section.

#### **7.3.2.1 Government actions**

The importance of government efforts to promote sustainable development across all levels of government was emphasised in all interviews. Some participants suggested that a national policy framework should be established to advocate for alternative transport. They believe this would provide a stable policy direction with vertical and horizontal integration across government. Local councils could produce their own distinctive local and neighbourhood plans, which would reflect their own conditions and priorities.

*You have got different levels of government that deal with this you might have the state government delivering the broader planning requirement, and the government does develop these strategic plans for different regions,*

*regional plans but ultimately, it is down to the council level and councils are represented by the local population quite often with vested interests in what happens in that council area. (S-07)*

Besides a national policy framework, participant thought that it is also important to have vertical integration across all levels of government. They believed that efficient integration would require effort to bring policymakers at all levels of government to work together in order to change the social environment for alternative transport.

*So it's not only multi-department but it's also multi government, especially looking at local government and state government working together and potentially the federal government as well. (S-07)*

*That's the thing. It does have to be an integrated approach because in order to create a suitable climate for cycling we need to have that integrated infrastructure so the network has got to work across local government boundaries and across local government and state government jurisdiction. (S-06)*

In addition, efficient horizontal coordination and integration was also clearly important. Participants pointed out that leadership was critically important to develop common interests across departments and sectors for travel behaviour change initiatives. They mentioned that the funding to support alternative transport programs can come from different levels of financial resources, and well-funded and coordinated branches of the government can support policy integration of traffic, environment, urban planning, and health.

*Has to be a leader, has to be across government because, for example, the education department would have to have a role as well.(S-02)*

*I think you almost need someone to co-ordinate – I know – I think in DIPT there is someone that does co-ordinate – a pedestrian and cycling officer, I*

*think, within there, so I think they need sort of like a – they need to have a well-funded co-ordinator, you know, someone to co-ordinate, which goes from transport to urban planning to health, which sort of draws – because there's lots of different funding. (S-13)*

Other participants mentioned a unique provision in South Australia that provides formal identification of public health partner authorities. Participants pointed out that more departments should be involved in this official partnership. This would ensure that individual departmental decision-making would be facilitated and supported by other departments.

*As well as being aware of the social and environmental impacts of how it is functioning, so what that means from a practical point of view that means we need to engage with department of planning, transport and infrastructure. How do we do it you say. One is through this, the act, the act has a facility within it which is unique in the Australian context although there is a similar provision in some UK legislation, which calls for the formal identification of what are called public health partner authorities and these are formal. It's by regulation. (S-03)*

*I think that is where we perhaps need to be asking transport and planning what information they need to do what they need to do and feed that back into them or do that work for them and help them out with that and also supporting their decisions and so on. (S-05)*

Participants suggested that urban planning should not only focus on motor vehicles; an alternative transport strategy should also be a key component. Some participants raised examples to explain how other cities make urban planning more sustainable. Compared with those cities, it was suggested that the current urban design in Adelaide could be improved.

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*Greater support for initiatives that increase the uptake of greener vehicles should be a key part of Adelaide's transport strategy. (S-04)*

*They have just put that in Adelaide in Pulteney Street/South Terrace intersection where there is a bike component where the bikes can go across; yeah, it is about re-engineering the city. Amsterdam was built around the bicycles, it wasn't built around cars, whereas, Adelaide is built around cars. It's a modern city which is built around cars. (S-10)*

Other participants advised that essential facilities and infrastructure should be built proximal to residential districts in future urban planning. Moreover, making those facilities more attractive to people would also help to create a cycling or walking friendly environment.

*Homes need to be better clustered with childcare facilities, schools, shops, and where possible, workplaces. (S-04)*

*Then somebody finally worked out that they needed to stop doing that [building more roads]and think about changing the environment, so they took a strip of a street and actually turned it into essentially a fun place, so they were able to get the cars off. (S-11)*

Another important government action mentioned by participants was increasing the investment in active transport infrastructure. They commented that sufficient funding was the premise of alternative transport development.

*There could be some strategies that we could put in place that looks at maximising our investment particularly in cycling infrastructure that we put in or you when we are building new things, whether it's a new land development or whatever, that we need to make sure that we are putting in opportunities for people to walk and cycle. (S-11)*

### 7.3.2.2 Policy interventions

Participants frequently commented that in order for the public to reduce their car use, some structural policy interventions would need to be implemented. As described in Chapter 3, according to Steg and Vlek (1997), those interventions can be summarised into two categories - “Push” and “Pull” measures. “Push” measures generally influence individual travel decisions through measures imposed on them, and “Pull” measures are more likely to encourage individuals to use cars less by making alternatives more attractive (Steg and Vlek 1997). The policy solutions suggested by participants in the current study can also be categorised into “Push” and “Pull” measures.

#### “Push” measures

As previously mentioned, increasing fuel cost was described as a possible intervention for reducing car use. Participants also noted that the cost of alternative transport, especially public transport, should be reduced. A metro-card (one travel card used for all forms of public transport) with discount fares and a ‘zoned’ ticketing system were highly recommended.

*Introduce varied vehicle registration charges based on Green Vehicle Guide ratings. (S-04)*

*The savings associated with catching public transport compared to driving and parking every day should be promoted. Tolls may also assist. (S-04)*

*I mean it could ... making parking in the city prohibitively expensive is one. (S-01)*

*I tend to think it is going to be governed by price and economic decisions that people make. So, should the price of oil that we face increase several fold, I think that will drive a major shift in transport mode whether that is*

*just scarcity, cost of extraction or whether it's regulated because, you know global if you put a massive carbon tax on fossil fuel sources it will make oil much more expensive, so I think when people have to change financially they will that may offer the substantial change in mode. (S-12)*

Participants suggested that legislation to encourage drivers to behave more safely around cyclists and pedestrians might be a useful measure. Specifically, driver behaviour should be regulated in order to increase awareness of cyclists.

*It's around infrastructure and the law, if cars had to give way to cyclists at every point then there may be a different consideration given to how you drive when you are near a cyclist. (S-10)*

Another measure, which might encourage car reduction was to restrict motor vehicles in some certain areas. The following extract illustrates this point of view:

*Of course the only other things that are more powerful is legislation and taxation in certain areas but when you get into murkier areas where it's not simply about banning dangerous products or more restrictions on tobacco and alcohol. (S-03)*

### **“Pull” measures**

As previously mentioned, pricing measures were described as likely to be an efficient intervention to make people to reduce their car use. Participants also felt that the cost of alternative transport, especially public transport, should be reduced. A metro-card (one travel card used for all forms of public transport) with discount fares and a ‘zoned’ ticketing system were highly recommended.

*Making the bus services as good as they can be, perhaps making the fees cheaper although with the current metro-card you can actually travel quite cheaply on the bus.(S-01)*



*In some countries they have zones where different ticketing prices apply where the outer zone people it costs more whereas, the inner zones cost less. (S-10)*

Financial incentives were considered a feasible intervention to change people's transport choice for commuting trips. Like some participants recommended, employers and companies could be mobilised by tax incentives to participate in alternative transport programs. On the other hand, employees could be rewarded by their employers if they ride to work, and companies could offer cheap bus tickets to encourage use of public transport. The quotes below illustrate some of these ideas expressed by participants.

*I mean there are some soft measures too which the government could put in place, things like tax incentives potentially or workplace – you know, for example in Belgium you get paid per kilometre cycled to go to work. (S-13)*

*Well you know I guess the policies there are ways of encouraging people to not choose their car to drive to work. For instance, a lot of councils are now have in their development plans, that if a new office is built there must be showers and lockers and bicycle parking, some businesses are giving cheap bus tickets, yeah I guess incentives... policies that can be incentives to people. (S-09)*

There was a widespread perception among all participants that facilities and infrastructures were the most important conditions to maintain alternative transport use. A separated and advanced bicycle lane was needed to ensure cyclists' safety.

*I think obviously the first thing is to really promote cycling and provide really nice state-of-the-art cycle lanes along major corridors. (S-02)*

*I think if I compare how cycling works in some of the other major cities I think there is probably much that can be done in the city of Adelaide itself but as well, externally, to link all those networks together and particularly about trying to take the bicycle lanes away from the major traffic sites. (S-07)*

They also suggested that active transport should be integrated with public transport, and bicycles should be allowed on every train, which would help people to use alternative transport for short-distance as well as long-distance trips:

*Allowing carry bike on train. I think there is some additional work that we can do particularly around linking active transport to public transport. There is opportunities for those short trips from home to a public transport interchange for example. (S-11)*

*I think for that what we need to do is for every train should have dedicated bike carriage which is what they do in Europe. (S-06)*

*You can't always go to everywhere with your bicycle, but you can go to hubs, leave the bike there and get the public transport. (S-02)*

Participants also noted that cycling can impact negatively on people's appearance upon arrival at their workplace. However, end of trip facilities in the workplace would offer a solution to this problem. Another participant described the bicycle parking system in Amsterdam and how cramped bicycle storage facilities had surprised her.

*Putting in much more sophisticated end of trip facilities for cyclist, so I feel like there is an opportunity there. (S-11)*

*Yeah in places like Amsterdam I've been there and it's quite an eye opener to see how many people use bicycle. There are hundreds of bicycles in the city so it's basically you have these... On roads around the city you have these massive storage facilities where people have got, you know, a hundred bikes parked one next to the other. (S-07)*

### **7.3.2.3 Educational approaches**

As described previously, the majority of the participants identified that there was a lack of knowledge about the impact of traffic-related air pollution even amongst government staff.

Participants suggested that people with a better understanding of the health impacts of air pollution would be more likely to change their behaviour.

*I think that is what researchers need to be able to show on a much bigger basis so people are aware that pollution is actually a killer as well, because that is going to start changing people's behaviour it's going to get the political awareness I guess and that is what you need to create. (S-07)*

Some participants emphasised that public understanding of the benefits of alternative transport could be improved. They suggested that consistent positive messages would draw public attention to alternative transport, and help people to recognize that alternative transport would be a better travel mode choice. In addition, people should be encouraged to see everyone as playing a role in the campaign for air pollution reduction.

*All sectors promoting consistent messages about the benefits (cost and environment) of alternative transport and leaner, greener, 'best in class' vehicles. (S-03)*

*There are other things that have to change to make people figure that public transport or walking or riding is a better option, currently we have very cheap car parking in the city, it doesn't cost much. It's \$10 - \$12 per day parking very cheap so why wouldn't you. (S-10)*

*I think there is some cultural changes that need to be brought about within government and within the community, I think the message is perhaps.... Look we all contribute to air pollution, it's not a question of blaming people but it's a question of saying, look, you can help improve. (S-01)*

Furthermore, participants noted the recommended guidelines for physical activity by the World Health Organisation and they believed that people could achieve the required physical activity level by active transport. Some participants suggested that the

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government and community, in conjunction with health professionals, should deliver those messages.

*I think when the message gets out there that fitness can be achieved through 30 minute walk, I know the Let's Be Active or whatever promote it but, it is really not out there that much but whether you need to engage with gyms or doctors or people that the general population will listen. (S-10)*

A majority of participants agreed that safety was a major barrier for people not using bicycles. Therefore, participants discussed the possibility of cycling training and even licensing for cycling, as expressed here:

*I think it is really important to look into the education system and also the licensing...I mean drivers' licenses I strongly believe should require that anyone going for a driver's license should have actually done cycle training as well before they can go for their driver's license (S-06)*

Furthermore, participants commented on current work on cycling maps which had been conducted by the Department of Transport, as an example. In their opinion, an effective guide, especially for cycling, could assist people with journey planning.

*But I know transport has done a lot of work around trying to facilitate that with cycling maps and things like that to try and sort of map out the best way to get to central locations like Adelaide from various parts of the state. (S-05)*

Moreover, participants emphasised the importance of children's involvement in cycling programs:

*If you want to get the community to get behind cycling they need to do it from very early on. You need to do it from a 10 years old or earlier, so you have to bring young people into it. (S-07)*

This was further explored by some participants who identified the significance of cycling training programs in conjunction with school education. The opportunity for children participating in cycling programs at school could help them learn riding skills, road rules and road safety. This gave them the confidence that they could ride on cycling lanes or footpaths.

*It's imbedded within the curriculum resource so that the teacher can use that within the class room environment and that's complemented with some bicycle education, so for kids that are 9 years old and how they actually get out and ride on the road, get out into the streets because I think they can be up to 12 and they can still ride on the footpath, so yeah, that is one of the programmes we are doing. (S-11)*

#### **7.3.2.4 Cultural change**

There was some recognition by participants that the cycling culture in Australia is different to that in many European cities and needs to change. For instance, one participant commented that people in Australia tended to identify themselves as motorists or cyclists, which was not common in Europe:

*I think when you go overseas to perhaps places like Denmark there's that kind of lack of identity, you're just somebody that – I wouldn't call myself necessarily a motorist even though I do have a car. I wouldn't call myself all the time a pedestrian when I walk over there so I think it's part of making bicycles really an easy part of the transportation mix and making it seem less as something which is for the elite few, that's for sure. (S-13)*

Furthermore, currently, most cycling trips in Adelaide were described as being for sport and recreation, and participants affirmed the achievements in these aspects. However, participants felt that what should be improved is people's perceptions towards cycling. People should use cycling not only for recreation but also for commuting.

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*There's a push for change but I think cycling in Adelaide tends to be something which is sport and leisure, which does very well. Adelaide's very good at sport cycling, very good at leisure cycling. (S-13)*

*I mean cycling seems to have a natural appeal in South Australia it's just if we can translate from that you know recreational approach to the commuting type approach. (S-05)*

In particular, one participant pointed out that cyclists' appearance could influence the cycling culture. This participant encouraged people to wear ordinary clothes, rather than special clothes in order to change the stigma towards cycling.

*It's also really important to not wear cycling specific clothes when cycling because that's a real us and them issue and, non-cyclists and even a lot of cyclists, get very intimidated by the whole lycra set up and it's very easy to then objectify the cyclist who are wearing lycra as being other, and people... it's actually even hard to recognise people when they are wearing their lycra. (S-06)*

*The more women you get cycling in ordinary clothes, then the closer you know you are to actually having a truly equitable and effective cycling culture and cycling network. (S-06)*

There were lots of discussions across the interviews about building a cycling culture in Australia. Interestingly, many participants frequently commented about labelling cycling as a fashionable life-style. Participants expected that cycling would be described as a "cool" or "sexy" activity by people, especially young people. The following extracts represent this point of view:

*Does it make cycling more fashionable or does it make... and if you do want to make cycling more fashionable how do you do so, is it a physical exercise thing, is it a style thing. (S-12)*

*I do think there is a cycling culture, I think there is some stuff... it's become a bit hip/cool especially with all of Uni students (S-11)*

*They're just people, normal people that ride their bikes and look good doing so, so definitely on a cultural level I think making it sexy would be great. (S-13)*

### **7.3.2.5 Evidence-based research**

There was consistent acknowledgement across all interview participants that promoting alternative transport would be beneficial to the environment, human health and the economy. However, participants wanted more evidence-based research to be conducted to quantify those benefits. In particular, the necessity of cost benefit analysis was emphasized by several participants. Although the government and public might show some awareness of the benefits of alternative transport, it was considered that they would be more likely to see those benefits if they were measured financially.

*I suppose from a particularly a cycling point of view you get the road safety research and then you active health research, air quality and you have all these little things and how much money you can save. (S-08)*

*If people are driving their car because it's cheap, then you need to do some studies on the relative costs of car parking in Adelaide and, for example, the benefits of reducing or of increasing car parking tariffs in Adelaide to offset transport infrastructure maintenance. (S-10)*

*I think quantitative study and cost benefit analysis are useful to government and help push along government policy. (S-12)*

The importance of research for policy-making was outlined by most participants. Participants reported that research could assist in identifying issues or problems. Meanwhile, it was also seen as helpful for the government to highlight research to support or evaluate their proposed plans or solutions.

*So that is where research would play a role in providing that information because governments don't have that ability to go offline for a year and consider a research topic in any great details (S-10)*

*But in the end, the decision has not to be made without looking at the science. (S-02)*

*I think research has the potential to dispel myths and direct policies and subsequent activities towards those solutions which offer the greatest benefits (public and private). (S-04)*

As described above, participants acknowledged that research is an important part of the policy making progress. Information supporting a proposed plan of action can lead to the best solution to the problem and increase the chances of that solution being implemented.

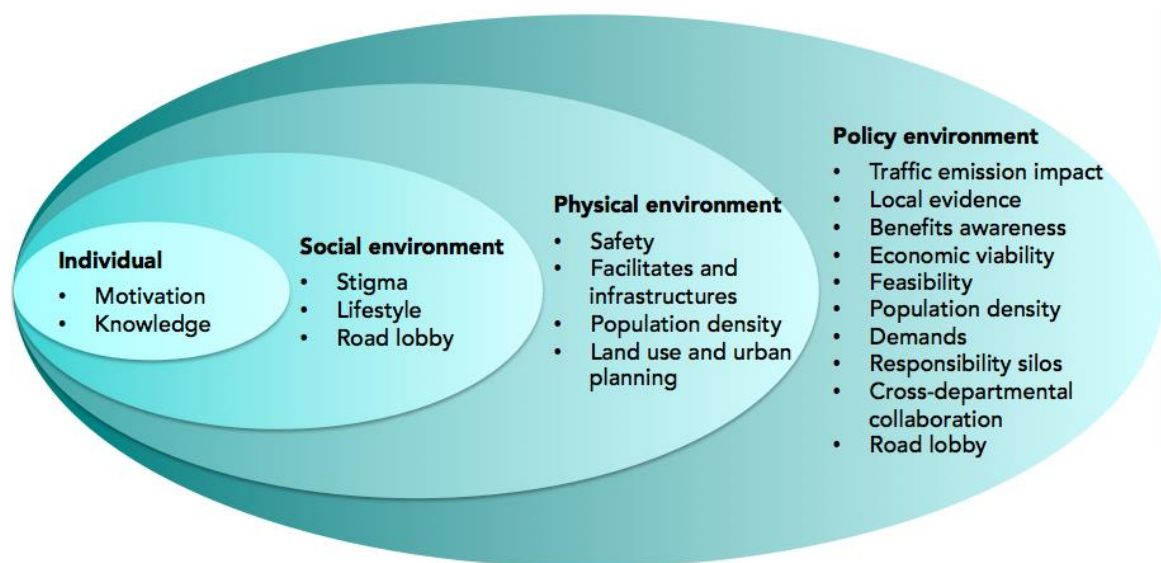
## **7.4 Discussion**

The aim of this study was to explore key barriers and possible solutions to promoting alternative transport in a local region of Australia from key stakeholders' perspectives. Overall, the development of alternative transport was viewed as a part of a major responsibility for the Department of Transport, and was also considered important for other stakeholders such as the environment sector, the health sector and private developers. There was general agreement from most stakeholders about the co-benefits of alternative transport in terms of environmental, health, economic and social aspects. Although most participants recognized the necessity of promoting alternative transport in Australia, they also acknowledged that this common goal had not yet been fully established across relevant state/ territory governments.



### 7.4.1 The impacts of barriers

The major barriers to implementing alternative transport policy that were frequently discussed by participants fell into four main areas labelled as: insufficient translation of knowledge and evidence gaps, difficulties in getting the policy balance right, lack of shared ownership of alternative transport policy and programs, and public resistance. The Social Ecological Model suggests that the likelihood of individuals participating in a sustainable activity can be influenced at a number of levels including social, physical and policy environments, where each layer has an impact on the next level (Stokols 1996). Despite the fact that my guide questions for participants mainly focused on institutional level barriers, I noted that the impacts of these barriers were relevant to all levels of the Social Ecological Model (Figure 7.3)



**Figure 7.3: The impacts of barriers on social ecological model**

#### 7.4.1.1 Individual

In the Social Ecological Model, the individual is at the centre of the model, with personal factors increasing or decreasing the likelihood of individual change being sustainable. In

the current study, as well as in previous research, individual characteristics relating to transport choice were commonly attributed to age, gender, household income and type, environment knowledge and attitudinal factors (see Chapter 3 and Chapter 6). During interviews, participants did not discuss barriers at the individual level in much depth since this was not the major aim of this study. However, they raised the issue of ‘public resistance’ which includes some individual fact such as public knowledge and motivation. The causes of this barrier are not purely individual, rather, they are more influenced by social, physical factors, and policy and environmental factors, as discussed in the following sections.

#### **7.4.1.2 Social environment**

In the Social Ecological Model, the social environment surrounding the individual, which comprises the relationships, the culture and the society within which the individual interacts, is also important. Similar to another Australian study (Daley and Rissel 2011), the participants in this study thought that cycling was more likely to be viewed by ordinary community members as unusual or as a “fringe activity”, and people who use alternative transport would be associated with negative stereotypes, such as “poor” or “loser”. By contrast, the car was generally viewed be the mainstream travel mode, with the number of motorists far outweighing public transport users and cyclists. In addition, the dominant lifestyle is characterized by a culture without constraints and with more hedonism (Abidi 2012). My participants reported that Australian lifestyle preferences tend toward the speed, comfort, freedom and pleasure that cars can bring, which is incompatible with the lower levels of efficiency and the inconvenience that is associated with public transport or cycling. For this reason it may be challenging to build environmental transformation for alternative transport within a short period of time.

### 7.4.1.3 Physical environment

A number of researchers (Boarnet et al. 2011; Ewing and Cervero 2010) have suggested that various factors relating to the physical environment, such as population or building density, regional accessibility, and roadway connectivity, can affect individual transport choices. In this study, participants identified barriers to promoting alternative transport which related to the physical environment in a range of ways.

First, common motivational factors for car use reduction in other countries, such as severe air pollution and traffic congestion, are perhaps less serious in Australia according to participants' descriptions. Due to better air quality in Australia compared with many other similar countries, Australians tend to overlook the health burden caused by air pollution. In addition, participants believed that public dissatisfaction with traffic congestion is relatively low, especially in Adelaide. This may be an influencing factor in preventing necessary behaviour change.

Second, Australia is one of the least densely populated countries in the world with only 2.9 people per square kilometre (Australian Bureau of Statistics 2012a), which makes it difficult to provide an efficient public transport system for a low density population.. In addition, Australia has experienced a rapid increase in motor vehicle ownership since the post-war period until now. The number of registered passenger vehicles has increased from 76,000 in 1919 to 13 million in 2013 (Australian Bureau of Statistics 2013). The ratio of Australians owning a car has increased from 398 vehicles per 1,000 residents in 1971 to 750 in 2013 (Australian Bureau of Statistics 2013), making it a country with one of the highest rates of motor vehicle ownership (Australian Bureau of Statistics 2012b). Road and urban design has been influenced by low population density, urban sprawl and high car ownership. However this continuing trend is unsustainable. New road creation

and maintenance receive massive government funding, whereas only small funds are allocated to alternative transport infrastructures and facilities.

#### **7.4.1.4 Policy environment**

The policy environment is shaped by decisions made by local, state and federal governing bodies. There is no doubt that governments are responsible for making policy decisions to improve the quality of life for individuals and the population, and evidence-based decisions can produce more effective policy decisions and, as a result, better outcomes for the community (Sanderson 2002). However, different levels of government and different departments show varying degrees of interest in alternative transport development in Australia. Although participants regarded higher levels of government, (the Department of Transport in particular), as being principally responsible for promoting alternative transport, it appeared that these levels showed less willingness than local government and non-transport departments, probably due to the increasing challenges and concerns that would come with their greater responsibilities.

According to the stakeholders interviewed in this study, there are a number of reasons for the lack of progress in policy development. First, the lack of evidence about alternative transport has hindered the development of policies. While there is growing evidence showing that the overall benefits of alternative transport far outweigh the risks, such evaluations have not been conducted widely in Australian cities. Many transport planners with an engineering background may find that health impact assessments on traffic emissions are beyond their area of specialization. Although these knowledge limitations can be improved by effective coordination and collaboration within and across departments, interdepartmental communication is insufficient at present, making it more difficult to build cross-departmental partnerships. This barrier has also been found in

other studies (Cole et al. 2010; Rietveld and Stough 2005). Another approach to bridge the evidence gap, as discussed by participants, is to draw lessons from countries such as the Netherlands. However, the Department of Transport is often concerned about the feasibility of generalising from external experience.

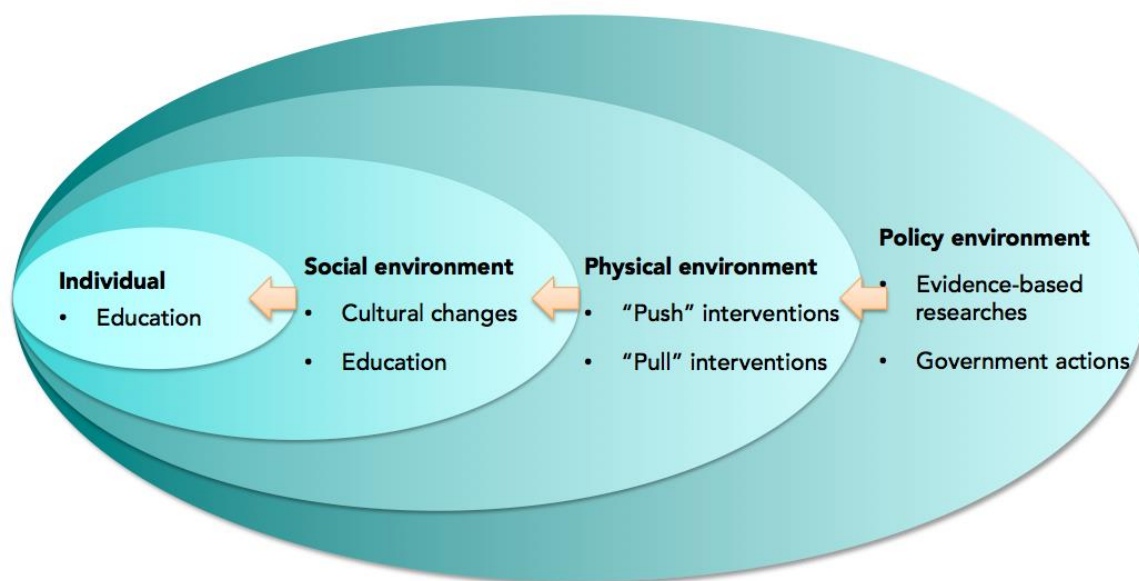
Second, political influence can also greatly affect the agenda setting for alternative transport promotion. Despite car manufacturers' withdrawal from Australia, the entire economy still benefits from the automotive industry. This economic interest, in combination with other factors such as nationwide low population density and increasing travel demands, is a significant obstacle to reaching an agreement on promoting alternative transport at the higher levels of government. As the dominant transport mode is car travel in Australia, participants concerned that policies which restrict car use will continue to be unacceptable.

Third, responsibility for funds for urban transport systems are shared in varying proportions by three levels of government in Australia. Debate will inevitably occur among governments to concerning responsibility for developing and maintaining urban transport systems. These institutional barriers themselves limit investment in an alternative transport-orientated physical environment, which has been highlighted by several studies conducted in Australia (Cole et al. 2010).

Generally, evidence-based decision-making processes should integrate available research evidence, practitioner expertise and other available resources, as well as the characteristics, needs, values, and preferences of those who will be affected by the intervention (Satterfield et al. 2009). As described by participants in this study, the inadequacies in each component of this process contribute to the poor policy environment for alternative transport promotion.

### 7.4.2 Solutions

Efforts to increase alternative transport use are more likely to be successful when multiple levels of influence are exerted at the same time (Brownson et al. 2001). During the interviews, a number of possible solutions to barriers were recommended by our participants. These solutions are summarised in (Figure 7.4).



**Figure 7.4: Potential solutions to barriers**

Although it is an individual who does the driving (or cycling, walking, or catching of public transport), personal factors that shape an individual's transport behaviours are embedded within the contexts of social, physical and policy environments. Therefore, strategies that aim to bring changes at the individual level through changing knowledge, attitudes and motivations can be achieved through changes at other levels.

For example, the social environment – including, for example, peer relationships, cultural background and social networks can be changed through multiple approaches including community education, support groups, peer programs, workplace incentives and social marketing campaigns. To achieve this type of change, participants in this study suggested

focusing on culture and education. Unlike some European cities with a strong cultural background in cycling, the proportion of cyclists who use their bike to commute is lower than those who ride for recreation and exercise in major Australian cities including Adelaide (Australian Bicycle Council 2013). Participants suggested that government and communities should promote commuting cycling as well as recreational cycling. More “regular” cyclists on the road could foster more positive of cycling. In addition, to make cycling genuinely appealing and accessible, using role models could help non-cyclists to imagine themselves on a bicycle. Therefore, riding a bicycle while wearing ‘normal’ clothing, instead of bicycle-specific clothing, could attract a broader range of people to cycling and contribute to building a cycling culture. In addition, the “Push” measures suggested by our participants, including increasing car ownership cost and appropriate legislation (e.g. increasing cyclists’ priority on roads and restricting motor vehicles in certain areas) could also encourage culture change.

Furthermore, several studies have indicated that individual environmental consciousness plays a significant role in people’s decision about transport mode choice (Shen et al. 2008). Improving people’s knowledge of transport emissions may draw their attention to the carbon footprint they make, and encourage them to think about low carbon living and reducing car use. More importantly, participants suggested that governments should work with schools, parents, communities and other organisations to build a supportive alternative transport culture for students. For instance, parents could encourage their children to be more involved in active transport, while schools could implement free practical bicycle education activities based on proper guidelines on road safety education policy and support.

Community campaigns that aim to improve the social environment may be less likely to be effective if the surrounding physical environments are not supportive. A National Travel Behaviour Change Project named TravelSmart was launched in 2000 by the Australian Federal Government in collaboration with state governments and communities, with the aim of influencing a shift in personal transport behaviour towards safer, greener and more active travel choices (Zhang et al. 2013). In South Australia, this project has provided a range of tools to participants such as a kilometre monitor, local activity guides and journey plans. An evaluation of this project reported varied levels of decrease in car use and short-term increases in walking, cycling and public transport use (Australian Greenhouse Office 2005). However, findings from our cross-sectional survey study (Chapter 5) suggest that people's travel behaviours have remained unchanged since 1999 and that cars still dominate mobility patterns. In addition, participants in my second study were not totally satisfied with current public transport services and costs, as well as active transport infrastructure and safety. These results revealed that changes in social environment alone may not be sufficient to lead to behaviour change. Therefore, further efforts are needed at other level of influence as shown in Figure 7.4.

There is no doubt that alternative transport choices can be made convenient, easier, safer and more enjoyable through initiatives designed to create a physical environment (both natural and built) for encouraging alternative transport. Since there are few opportunities to modify the natural environment, thereby efforts should be made to ensure that transport systems are designed to enable people to use public transport or active transport for daily commuting.

A supportive physical environment can be seen in all countries which have been successful in promoting active transport (e.g. Netherlands, Denmark, and Germany). For



instance, cycling facilities have been established, such as separated bicycle lanes and sufficient parking racks, together with cycling networks that are well designed to integrate with the whole transport system. In addition, cyclists are given absolute traffic priority on narrow streets in Dutch and German cities, while cars are limited to 30 km/hour and cannot rush bicyclists or otherwise interfere with them. Therefore, as my participants suggested, separated and advanced bicycle lanes, end of trip facilities (such as showers, parking racks), and an integrated public transport systems are exactly what people need in Adelaide.

Land use and urban planning can also improve the physical environment. For instance, Soltani and Primerano (2005) suggested that proximity of residence to local shopping and business centres would encourage a wider choice of alternative transport modes, whereas residential locations away from major activity centres require more use of private cars and decrease use of other travel modes. Therefore, the literature maintains that essential facilities, infrastructure and shopping centres should be located in close proximity to residential districts to shorten necessary commuting trips (Badland et al. 2012; Dieleman et al. 2002). Low-density urban areas often have high levels of car ownership, whereas medium to higher density residential areas may have higher levels of alternative transport use as origin-destination points are relatively close (Saelens et al. 2003). Thus sustainable land use and urban planning should encourage development around existing infrastructure and discourage continued urban sprawl via increasing housing density (Shill 2012). However, one challenge for the population density approach that must be considered is that local communities may strongly resist high-density developments like my participants concerned. Therefore, when providing sufficient available infrastructure, there will need to be changes in culture and attitudes.

The final component of the Social Ecological Model is the policy environment. Policy can be responsible for erecting or removing barriers to encouraging alternative transport use. For example, lung cancer incidence in men decreased by 32% between 1982 and 2007 in Australia (Australian Institute of Health and Welfare and Australasian Association of Cancer Registries 2010), after comprehensive tobacco control policies were implemented, such as simultaneously raising taxes on tobacco, banning smoking in all public places, health warnings on cigarette packs and advertising bans. Likewise, without formal political actions taken by local, state or federal governments, a key component of the holistic approach to promote alternative transport use will be missing. Developing the political will to implement policies (such as “Pull” and “Push” measures mentioned above) for promoting alternative transport can sometimes be difficult due to an unsupportive policy environment. Some recommendations suggested by participants could be adopted to overcome these barriers.

As discussed in 7.3.2.1, one of the major barriers at the policy level identified by participants is the ‘evidence gap’. Russell et al. (2008) highlighted in their study that, although selection, evaluation and implementation of research evidence did not equate to the policy-making process, they were indispensable components. Therefore, one solution offered by participants to facilitate alternative transport promoting policy was the generation of evidence. Conventional transport project cost benefit evaluation studies often consider the savings from travel time and vehicle operation, but ignore the health benefits of improved air pollution and increased physical activity, as well as safety benefits from reduced car use (Fishman et al. 2011). Researchers have suggested that the inclusion of environmental and health related benefits in transport planning could assist in justifying mobility management approaches (Litman 2003), and prioritising travel behaviour change investments. For example, the findings from Chapter 4 suggested that

shifting 40% passenger vehicle travel distance to alternative transport would prevent 542 deaths and 7674 DALYs in metropolitan Adelaide in one year (Xia et al. 2015). Another Australian study reported that the overall financial benefits of household travel behaviour change would be three to seven times more than the required investment (Fishman et al. 2011). Therefore, evidence-based research on alternative transport could provide policy-makers with an improved understanding of the overall benefits of promoting alternative transport use, which may mitigate their concerns about economic viability.

‘Responsibility silos’ were also identified as an important barrier to policy environment. A national policy framework was considered essential by our participants to address this problem. It could provide the vision and objectives for transport development, highlight the vital leadership role of all levels of government, and integrate the range of state/territory interests with planning processes. At present, although promoting alternative forms of transport has been on the policy agenda for a number of state governments, it has not been formally well documented in the National Transport Policy Framework. In addition, participants acknowledged that there is an intertwined relationship between transport and land use. Therefore, ecological urban planning should take into account the development of alternative transport. A land use and urban transport strategy integrating the concept of sustainable development, which includes more comprehensive planning for housing, public green space, commercial and retail use, may encourage alternative transport and reduce the difficulties in road reconstruction such as installing more bicycle lanes and bus lanes.

In addition to a national policy framework and ecological urban planning, participants also suggested that more efforts should be made from the highest level of government to build greater integration of alternative transport development into national transport

policy. Therefore, the federal government's role in leading, guiding, dissemination and funding should be further strengthened, in line with what Netherlands, Denmark and Germany have done in their National Bicycling Master Plans (Danish Ministry of Transport 2000; German Federal Ministry of Transport 2002; Netherlands Ministry of Transport 1999). Moreover, launching transport development projects through horizontal coordination across all levels of government would ensure greater efficiency and mitigate disagreements on budget management and funding distribution among governments. In order to achieve the co-benefit outcomes, a better balance between transport, health, environmental and economic agendas needs to be developed. Sectors such as health and environment can contribute to a 'whole-of-government' policy approach by funding benefits evaluation and providing relevant skills and experience (Fishman et al. 2011).

Participants were also concerned about the impacts of reducing car use on the local automotive industry. Although the participants did not directly discuss how to address this problem, this barrier might be addressed indirectly through technical improvements. The development of clean energy and alternative transport can reduce the expenditure on controlling air pollution and the reliance on imported fossil fuels; it can also provide new commercial opportunities for the local economy. For instance, new jobs could be created with the development and production of technology and equipment consuming clean energy. The Green Gold Rush study (Australian Conservation Foundation 2008) indicated that 500,000 new jobs could be created in Australia by 2030 in new industries such as solar, wind, water and recycling. At the same time, international cooperation with other countries based on clean energy could also be beneficial to national and local economic development.

The common goal of positive environment and health outcomes was shared by multiple participants. Participants' accounts of barriers mainly focused on the policy environment, acknowledging that this top level influences other levels of influence. This makes sense, because policies and interventions that do not address the political imbalances, shared ownership and social contexts are unlikely to achieve successful implementation. However, I also noticed that participants' solutions to barriers at the policy level were vague and superficial, in contrast to their much more practical solutions for addressing public resistance. However their suggestions for building a suitable policy environment tended to be political objectives rather than practical solutions. Undoubtedly, achieving policy change is difficult and not an 'overnight' process, and requires long-term commitment, adequate financial support and cross-sectorial collaboration. Therefore, we need governments with ambition, vision, and determination to implement the changes we know to be necessary.

It is important to highlight the strengths and limitations of this study. The strengths included the involvement of those involved directly in the policy-making process, and the breadth of stakeholders interviewed. This project has investigated the local and state government tiers. Further analysis could be undertaken into how policies and actions between governance tiers could be more closely aligned once federal government data are available.

There are also limitations to the study. First, the study was undertaken in the South Australian context of low population density and high urban sprawl, limiting the transferability of findings. Although we guaranteed anonymity, it is also possible that participants, as representatives of their departments and organizations, did not provide completely transparent opinions because of the risk that they could be identified.

Additionally, it is possible that non-interviewed stakeholders could have provided different opinions.

## **7.5 Conclusion**

A more developed understanding of the perceived barriers and possible solutions to alternative transport for key stakeholders can assist in establishing and building collaborative efforts to take the alternative transport agenda forward. The findings of this study may assist in filling the gap between alternative transport-oriented policy intention and implementation in various ways. First, the findings highlight that the achievement of successful transport policy implementation requires leadership and commitment from a high level. This is particularly important for alternative transport promotion because there are many potentially conflicting interests which can influence policy-making. Alternative transport promotion needs to be prioritised not only as a key strategy to reduce greenhouse gas emission and air pollution but also an important intervention for health promotion and disease prevention. Therefore, the health sectors' role in alternative transport promotion should be strengthened. In addition, horizontal and vertical collaboration across governments and departments, as a 'whole-of-government' policy approach, needs to be enhanced in order to get all stakeholders involved to share responsibility. Furthermore, beyond approaches targeting government effort, practices working within the community to change public attitudes and opinions in favour of alternative transport may positively influence travel behaviour change at the population level. Finally, research can play a significant role in the policy-making process and there is little doubt that greater emphasis needs to be placed on alternative transport research to assist future transport and urban planning decisions.

# CHAPTER 8

## General discussion and conclusion

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### **Preface**

This thesis explored three perspectives on alternative transport: (1) a modelling study to quantify the co-benefits of promoting alternative transport on the environment and population health; (2) a cross-sectional survey to explore factors affecting their travel behaviour and their intention to reduce car use; and (3) a qualitative study to investigate relevant stakeholders' perceptions and knowledge regarding facilitators and barriers in promoting alternative transport. This chapter concludes the thesis with a comprehensive discussion of the key findings, strengths and limitations of the studies undertaken, policy implications, and a range of recommendations for further research aimed at facilitating alternative transport promotion.

## **8.1 Introduction**

This chapter concludes the thesis with a general discussion concerning the project as a whole. It begins by addressing key findings from each phase of the project, and follows with a discussion on the strengths of the project as well as limitations. Finally, the policy implications on the basis of findings are discussed and recommendations for further research are provided in this chapter.

## **8.2 Key findings of this project**

This thesis aimed to quantify the co-benefits of promoting alternative transport on environment and population health, together with an investigation of community and stakeholders' perceptions of alternative transport use. Specifically, it addressed the following three questions (which will be addressed in turn):

- 1. Comparing to business-as-usual (BAU), what are the future environmental and health benefits in choosing alternative transport scenarios, and to what extent can such co-benefits be obtained?**

The first study of this thesis used an approach combining air pollution modelling, health impact assessment and traffic injury modelling to quantify greenhouse gases (GHGs) and particulate matter (PM) reductions from replacing passenger vehicle usage with public transport and active transport. It provided an integrated view of the multiple impacts of alternative transport use in an Australian setting.

My results indicate that co-benefits for health (as well as for the environment) can be achieved from policies focused on reducing air pollution and greenhouse gases. The major benefit associated with the promotion of alternative transport policies is to assist



people in fulfilling physical activity recommendations. In the example scenarios of increased cycling, a small shift from car travel to cycling was associated with the prevention of 160-326 deaths, and 2,113-4,363 DALYs, associated with five major chronic diseases, falls and depression. In total, it made 17-34% reduction in the burden of disease related to physical inactivity, when compared with BAU by 2030. Important health gains could also be achieved by increasing public transport use, which also involves a walking component.

Findings from this study do not suggest a large reduction in PM<sub>2.5</sub> concentration under the hypothetical transport scenarios considered. Therefore, health gains from the reduction of air pollution exposure for the general population are less than the physical activity-related health benefits associated with the change in transport use. In addition, those transport policies favouring active transport may bring greater health benefits than strategies which aim solely at reducing vehicular emissions (e.g. elevating standards for emissions).

My results also intimate that the number of road traffic injuries might not increase with the rising numbers of pedestrians and cyclists if the concept of “safety in numbers” is taken into account in the model. In all of reduction scenarios, the burden of disease attributed to traffic injury would reduce compared with BAU2030. Therefore, it can be contended that overall benefits of replacing the distance travelled by vehicles with alternative transport outweigh the potential risks.

## **2. What are the key factors that can affect individuals’ current travel behaviour and predict their intention to change travel behaviour?**

The Chapter 5 revealed that, in order to achieve significant health benefits through transport policy, it is essential to change travel behaviour at the population level. Better understanding of individuals’ travel behaviour will help in designing and implementing

interventions to promote alternative transport use widely. This research question was addressed in the second study – the cross-sectional survey – which had a number of key findings.

First, results from the survey suggested that people's travel behaviour (in the study region) has been contingent on cars in the last ten years. Participants with varying socio-demographic characteristics showed slight differences in their travel patterns. Moreover, people living in inner city areas were more likely to use alternative transport than those who lived in the outer city. More females than males travelled by car on a daily basis or for shopping and other social activities, while males were more likely to drive more than 20,000 km annually. In addition, people who were employed, had better education, or had higher annual household income were more likely to report the highest kilometres driven annually and the highest car use frequency.

Furthermore, participants' perceived effectiveness of different car reduction measures was different. Overall, participants considered that "Push" car reduction measures would be less efficient than "Pull" measures. Measures targeted at improving public transport were considered as the most effective for car reduction. These findings suggest that a joint effort of "Push" and "Pull" measures may be needed and that "Push" measures should be presented in such a way as to minimise public opposition to minimise public opposition and to make the unpopular increasingly popular.

Four attitude factors were extracted from the factor analysis, including awareness of the benefits of alternative transport ("benefits awareness"), awareness of the problems of traffic ("problems awareness"), a personal concern for safety and comfort ("safety and comfort") and negative emotions towards public transport ("negative emotion"). Findings from correlation analyses suggested that people who reported being more concerned

about safety and comfort or had more negative perceptions towards public transport tended to use cars more, and were less likely to recognise the effectiveness of traffic measures (Table 6.5). Furthermore, after adjusting for car ownership, the logistical regression results (Table 6.6) showed the predicting socio-demographic factors associated with an intention to reduce car use were education level, bicycle user, annual drive distance. In addition, individuals who had greater awareness of benefits of alternative transport and problems of traffic showed greater intentions to reduce car use, whereas those who had high annual driving distance, a bachelor degree and higher and who had greater concern for safety and comfort were less likely to change.

This study reveals that the numbers of current alternative transport users are far from reaching the hypothetical number in the alternative transport scenarios adopted in Chapter 5. Therefore, the transformation from a car dominated travel pattern to alternative transport cannot be expected to occur quickly. Although individuals' travel behaviour can be shaped by different types of factors, our findings from this second study draw attention to the importance of the influences at the individual level, such as attitudes towards transport, environment and health.

### **3. What are relevant stakeholders' perceptions and knowledge regarding facilitators and barriers in promoting alternative transport in this area?**

Described in the above section, Chapter 6 focused on community views in order to promote a travel behaviour change towards alternative transport. Findings from the second study not only point to the importance of raising public awareness of the benefits of alternative transport, but also reveal some potential barriers affecting the public's use of such transport (e.g. safety, the distance people need to travel, public transport service).

## *Chapter eight*

To create a more supportive external environment for alternative transport, the role of governments needs to be strengthened.

Addressing the latter research question could help in understanding how to take the alternative transport agenda forward into policy. Key themes identified in the final qualitative study suggested that barriers to promoting alternative transport fell into four main areas: (1) insufficient translation of knowledge and evidence gaps in transport emission impacts, strategies from other countries and quantifying the overall benefits of alternative transport; (2) striking a policy balance between alternative transport strategies and economic viability, feasibility, population density, traffic demands, and budget distribution issues; (3) shared ownership of responsibilities, funding and regulations among governments and departments; and (4) resistance because of public beliefs and values of using alternative transport. Potential solutions suggested by participants to resolve these barriers included government actions, “Push” and “Pull” policy interventions, educational approaches, culture change and evidence-based research.

There are certain conjunctions between the results from the second study and the third study. For example, in relation to the findings from the community study, individuals’ concerns for safety and comfort not only decrease the likelihood of travel behaviour change to alternative transport at the individual level, but could also be a potential barrier to the promotion at the policy level because of ‘public resistance’. Moreover, as discovered in the community study, 80% of people use car as their dominant travel mode. Consequently, government initiatives relating to alternative transport promotion are particularly swayed by the road lobby’s interest, given this is relevant to many in the general public. In addition, the stakeholder study identified that a cost efficient balance has not yet been established between alternative transport strategies and low population

density and urban sprawl. This may partly explained why participant in the community study were not totally satisfied with current public transport services and price, as well as active transport infrastructure because of insufficient investment.

Although many recommendations suggested by stakeholders in this study are aimed at overcoming barriers at the policy level, some of them can be applied to the issues identified by the second study. For instance, the findings from the community study implied the necessity of improving the community's knowledge and attitudes towards alternative transport use. Accordingly, stakeholders also highlighted approaches to achieve this goal including community education, support groups, peer programs, workplace incentives and social marketing campaigns. Furthermore, both "Push" and "Pull" measures were mentioned in the third study, and can be applied to improve social and physical environments in order to facilitate a culture change.

It is worth remembering that although there has been growing evidence showing the considerable health co-benefits of alternative transport, such evaluations have not been conducted widely in Australian cities and, therefore, the participants perceived that evidence gaps remain. The first modelling study presented in this thesis can assist fill those gaps to some degree. Additionally, evidence from this stakeholder study may provide policy-makers in making more informed evidence-based decisions about alternative transport policies, programs and interventions.

## **8.3 Strengths and limitations of the project**

### **8.3.1 Strengths**

The first strength of this research lies in the triangulated mixed methods study design, which utilised three separate studies to investigate different aspects of the topic of interest. This design enabled an examination of the research topic from multiple perspectives (e.g. scientific, social and political perspectives), as well as, poignantly addressing the relevant issues. Findings from this thesis, therefore, provide a valuable contribution to local and international alternative transport knowledge; secondly, the findings have various implications for transport policy development and practical travel behaviour interventions.

My first study integrated a series of models, including air pollution, health impact assessment and traffic injury models, which to assess environmental and health outcomes from promoting alternative transport programs in an Australian setting. Although the outputs of the models were limited by the availability of data and necessary assumptions, most of the key model inputs – including traffic fleet, traffic-related PM<sub>2.5</sub> emissions, and prevalence of physical inactivity, age-sex specific disease burden, and traffic injuries – derived from reliable local databases (e.g. from SA Health, EPA, and DPTI), which made the analyses adaptive to the local context. Second, the Air Pollution Model (TAPM) (Hurley 2008) is an advanced air pollution model with a strong scientific basis and verified performance. It is connected to databases of terrain, vegetation and soil type, leaf area index, sea-surface temperature and synoptic-scale meteorological analyses, therefore making it suitable for use in various regions around the world. It also incorporates the latest advances in air pollution science, gained through theoretical studies, laboratory experiments and field measurements, which made the estimates in my study as reliable as possible. Third, several sensitivity analyses were also carried out to assess the robustness

of the outputs and the impact of key assumptions in this study. In addition, scenarios in the first study included five different levels of reduction in car travel, including a sole alternative transport option and a combination option of alternative transport modes. The use of such a scenario design may provide local government organisations and relevant service providers with an array of options when planning for a sustainable future transport policy.

The strengths of the second study were that participants were selected from a random sample of the general South Australian population. In addition, survey data were weighted by the inverse of the individual's probability of selection and then re-weighted to age group by sex by state benchmarks derived from 2010 (SA) Estimated Residential Population figures. Therefore, weighted data analyses adjusted the raw survey data to properly represent the population.

The strength of the third study lies in its qualitative approach. This qualitative approach encouraged participants to provide rich and in depth information concerning barriers to the promotion of alternative transport. Furthermore, the participants were sampled from a wide range of different governments and sectors, giving a breadth of perspectives.

### **8.3.2 Limitations**

This research project includes three studies, which can provide useful information in different respects as summarized in the above section. However, given the time constraints associated with a PhD, there was still room for improvement in each study. For instance, a cost-benefit analysis was absent in this project. Therefore, this project did not provide any economic justification of travel behaviour interventions. Recently, some updated methods for health impact assessment of active transport have been published, such as the Integrated Transport and Health Impact Modelling Tool (ITHIM) developed

by Woodcock et al. (2013) and system dynamics modelling (SDM) developed by Macmillan et al. (2014). However, data used in my study may not have been sufficient for implementing these new methods and collating appropriate data since these are time consuming. Moreover, the modelling study of this project had been finalised before those new methods were published. Therefore, these updated methods have not been adapted in this study. In addition, a further qualitative investigation of perceived barriers to alternative transport use in the general population was not included in this research project. Moreover, the qualitative study was initially designed to interview stakeholders from all levels of government involved in the process, but the federal government data collection phase has not yet been completed and so is not presented in this thesis.

It was also noteworthy that difficulty obtaining data and recruiting participants was an issue impacting every stage of this project and therefore affected the timelines of the whole thesis. Initially, it was intended that findings from the modelling study would be used to facilitate the questionnaire design and interview question preparation. However, traffic and emission data extraction for the modelling study was postponed due to personnel changes in the EPA. Consequently, opportunities to investigate of public and stakeholders' response to the modelling results were missed.

In the next sections, I address some specific limitations associated with each study.

### **8.3.2.1 Modelling study**

Limitations in the modelling study mainly lie in the methodologies of model selection and model assumptions. They have been discussed briefly in Chapter 4. In short, the chosen indicator for air pollution was relatively narrow. Although the effects on mortality of other vehicular pollutions (e.g. NO, CO, and SO<sub>2</sub>) become less significant when controlling for PM<sub>2.5</sub> (Pope III et al. 2002), reduction in PM<sub>2.5</sub> may not completely



represent improvements of air quality. It has been shown that changes in air pollution indicators may affect the estimation of health outcomes resulting from air pollution exposure. For instance, Dhondt et al (2013) used elemental carbon as a predictor of health effects and found a five times greater health effect than the sensitivity analysis using  $PM_{2.5}$ . Additionally, our estimation of  $PM_{2.5}$  concentration reduction was based on outputs from TAPM. Therefore, the simulation data may have uncertain relationships with realistic  $PM_{2.5}$  exposure in the study region.

In this project, the selection of different health outcomes for air pollution exposure and physical inactivity was based on systematic reviews (Begg, S. et al. 2007a; Ezzati et al. 2004). However, the estimation of health benefits from improved physical activity may be conservative. Firstly, this model did not include health benefits from additional extra physical activity beyond the 'sufficient' threshold, due to the lack of evidence from population-based Australian surveys on sophisticated relationships between physical activity and health outcomes. Therefore, some leeway has to be given to assumptions that may be later specialised on the basis of more sophisticated exposure response studies into the benefits of physical activity. In addition, mortality and morbidity rates of physical inactivity related diseases were assumed to be consistent with baseline year, which may gradually change in the future. For example, there has been an increase in the incidence of colon cancer in approximately 40% in males and 6% in females over the past 30 years in South Australia (South Australian Cancer Registry 2010). However, mortality rates in colon cancer have decreased by 40% in females and by 15% in males over the same time period (South Australian Cancer Registry 2010). Therefore, how best to incorporate this factor in to a health impact assessment is worthy of investigation.

Moreover, due to the lack of available data, a set of assumptions was required in this model. Each assumption may have had a significant impact on the inputs and may have led to substantial variations in the outputs. For this reason, sensitivity analyses were performed to assess the robustness of our results. Overall, significant health benefits have been consistently found for all the car use reduction scenarios.

### **8.3.2.2 Cross-sectional survey study**

The cross-sectional survey presented in this thesis is from a relatively small sample size, which may have reduced the statistical power and the ability of the data to provide a solid basis for causal inference. In addition, participants' transport use was self-reported, leading to the possibility of recall bias. This survey was also limited to English speakers, as the telephone interviewing was conducted in English only. Furthermore, the electronic white pages were used as the sampling frame for the telephone survey. However, due to the increasing number of people living in mobile phone-only households, dialling only landlines would have led to some people (mainly in younger age groups) being excluded from the sample, which may further limit the generalizability of our findings. Another limitation of this study is that responses to the survey questions have not been validated independently, which makes it difficult to assess respondents' understandings of each question.

### **8.3.2.3 Qualitative study**

Although face-to-face interviews provide an opportunity to gather more detailed and in depth information, a number of limitations should be highlighted in relation to Study Three. First, we acknowledge that participants in this study may have volunteered to attend because they were more interested in promoting alternative transport, whereas those who did not participate might have different perspectives and opinions. Second,

participants were not required to represent their professional organisations. Therefore, their comments and opinions may only reflect their personal views but not official statements. It should be noted, however, that this is also a strength of the study. Third, this study did not achieve a balanced representation of stakeholders from each level of government and each sector. Representatives of federal agencies were not interviewed, and the study was undertaken in the South Australian context with low population density and high urban sprawl. Therefore caution should be taken when transferring our findings to different settings.

## **8.4 Policy implications and recommendations**

As summarised in Chapter 2, there was an increasing amount of research identified the benefits of alternative transport use ranging from air quality, disease burden, health expenditure, and traffic injury prevention (Grabow et al. 2012; Macmillan et al. 2014; Woodcock et al. 2009). By quantifying the co-benefit effects of alternative transport and investigating perceptions among community and stakeholder, findings of the present project provide valuable implication for greater alternative transport promotion in Australia as follows.

### **8.4.1 Integrating promotion of alternative transport into greenhouse gas strategy**

Following the Kyoto accounting rules, Australia's greenhouse gas emissions are targeted to reach around 106% of 1990 levels over the Kyoto period (2008-2020). Current statistics demonstrate that Australia is on track to achieve its target of limiting GHG emissions over the period 2008–2012 (Department of Climate Change and Energy Efficiency 2012). However, the emissions from transportation, which is Australia's third largest contributor and second fastest growing source of GHG emissions, has been found

to have increased notably from 1990 to 2007, and road transport emissions are predicted to increase by 64% from 1990 to 2020 (Department of Climate Change 2008).

A carbon pricing mechanism was introduced on 1 July 2012 aimed at limiting all emissions within Australia. Under the carbon pricing mechanism, total carbon dioxide equivalent (CO<sub>2</sub>-e) emissions from the transport sector were projected to slightly increase from 85 metric ton (Mton) as Kyoto period average (2008-2012) to 92 Mton in 2020, and will decrease to 88 Mton in 2030. However, this policy only operated for two years and was repealed by the Australian Federal Senate on 17 July 2014. Instead, a 'Direct Action' policy has been implemented as the strategy to reach the Australian emission reduction target, primarily through the Emission Reduction Fund. As described in the Emissions Reduction Fund Green Paper (Commonwealth of Australia 2013), activities recommended to reduce transport emissions include: switching to lower emission fuels, using more efficient vehicles; improving management practices (e.g., driver training or supply chain optimisation); and shifting between transport modes (e.g., from road to rail).

In our modelling study (Chapter 5), a shifting of 40% car vehicle kilometres travelled (VKT) to alternative transport in 2030 will achieve a reduction of 950,000 tons of CO<sub>2</sub> in one year compared with BAU, which only accounts for 9% increase in CO<sub>2</sub> from the 2010 baseline level. Therefore, interventions on travel behaviour can facilitate the Australia's greenhouse strategy implementation to tackle climate change.

#### **8.4.2 Integrating health into transport policymaking**

Transport emissions are a major source of air pollution in Australia, and cause 900-2000 premature deaths annually (BITRE 2005). By comparison, physical inactivity is the second largest contributor to the cancer burden in Australia behind tobacco smoking, and accounts for 6.6% of the total disease burden in the Australian population. It is estimated

that over 13,000 deaths from breast and colon cancers, diabetes, ischaemic heart disease and stroke are caused by physical inactivity annually (Begg, S et al. 2007). These data suggest that we should be considering health gains from reductions in PM<sub>2.5</sub> concentration in a broad context. Transport policies favouring active transport may bring about greater health benefits than strategies aiming solely at reducing vehicular emissions. Policy makers should evaluate the total net benefit of transport policies, including health benefits. To achieve this end, experts from the health sector should be included in policy planning and implementation to highlight transport-related physical activity and evaluate the possible effects of interventions on health outcomes.

### **8.4.3 Building supportive physical environments for ‘safety in numbers’**

The concept of ‘safety in numbers’ is “by being part of a large physical group or mass, an individual is less likely to be the victim of a mishap, accident, attack, or other bad event” (Wikipedia 2014). This concept was first verified in the transport field by Smeed’s study in 1949, which reported that road fatalities per vehicle were lower in countries where more people drove (Smeed 1949).

For many years, anecdotal evidence has suggested that the principle of ‘safety in numbers’ can also be applied to vulnerable road users, such as cyclists or pedestrians. Jacobsen (2003) conducted the first formal analysis to examine the relationship between the numbers of people walking or bicycling and the frequency of collisions between motorists and walkers or bicyclists. This study confirmed that a motorist was less likely to collide with a person walking and cycling when there are more people walking or cycling (Jacobsen 2003). Jacobsen’s growth rule predicted that if cycling doubled, the risk of collisions per cyclist would be 34% less. Conversely, if cycling halves, the risk per cyclist would increase by 52% (Jacobsen 2003). This theory also has been verified by an

Australian study conducted by Robinson (2005). In Chapter 4 of the current thesis, the possible changes in road traffic fatalities took into account a shift in travel mode. Results from that study suggested a slight reduction in alternative transport elevated DALYs as a result of collisions with other motor vehicles when this ‘safety in numbers’ effect was incorporated into the traffic injury model.

It should be noted that this increase in DALYs was not simply caused by changes in the numbers of people who chose alternative transport, but was also associated with the changes in the physical environment for cycling and walking. As Woodcock et al. argued in their study (Woodcock et al. 2009), the large potential health and environmental gains would not be achieved without strong policies to increase acceptability, appeal, and safety of walking and cycling.

Chapter 7 makes three recommendations for building supportive environments to achieve ‘safety in numbers’: (1) the governments should divert investment from roads for motorists towards provision of infrastructure for pedestrians and cyclists; (2) road rules should favour pedestrians and cyclists, such as by giving them prioritisation compared with motorists and through reductions in road speed limits; and (3) urban design and land use should take efficiency and sustainability into account, in order to enable high mode shares for walking and cycling.

#### **8.4.4 “Push” or “Pull” interventions**

Section 7.3.2.2 described stakeholders’ recommendations to use “Push” and “Pull” interventions to encourage reductions in car use and increase the use of alternative transport. However, it is worthwhile noting that section 6.3.2 showed that “Push” measures are less likely to be accepted by the public than “Pull” measures. Stakeholders were also concerned about the negative consequences of enforcing car reduction through

“Push” measures. Therefore, carefully combining “Push” and “Pull” measures might be of great value in removing barriers for the implementation of transport policy measures, although consideration should be given to the implementation process of such combinations of measures, especially the side-effects. For instance, the introduction of mandatory helmet legislation has generally been perceived to enhance cyclists’ safety. However, Dr Dorothy Robinson from the University of New England found that helmet laws did not produce a significant reduction in the percentage of head injuries and actually discouraged Australians from riding (Robinson et al. 2006). Alternatively, she suggested that governments should focus on aspects such as speeding limits for cars, drink-driving, violation of traffic rules, road design, and safety for riding at night, in order to create a safety environment for cyclist.

#### **8.4.5 Community participation**

Local communities can play an important role in promoting alternative transport. Population-level travel behaviour change cannot be successful without understanding and input from the community. Genuine and active involvement of the community is essential to make local views and expectations available to the decision makers (Berkman 1995). Active transport policies can then be made based on local needs and therefore be more acceptable to the local community. Government officials should keep seeking connections with neighbourhood groups in order to implement appropriate and coordinated interventions to promote alternative transports strategies (Edwards and Tsouros 2006).

Local councils and non-government organisations should also be encouraged to play a greater role in building sustainability, delivering health messages and providing travel behaviour change strategies. A number of social marketing and behaviour change programs (e.g. Travel Smart, Ride to Work in Victoria, and Heart Foundation Walking)

have proven effective in encouraging and motivating individuals to make changes to their lifestyles and increase their physical activity levels through walking, cycling and use of public transport (Rose and Marfurt 2007; Zhang et al. 2013). However, in order to achieve maximum efficiency and public acceptance, private sectors and government should consider avoiding replication of promotion programs. More importantly, assistance programs should be maintained and constantly developed, otherwise they may only bring about a temporary boost of alternative transport use but not a fundamental or sustainable change.

#### **8.4.6 A call for culture change around cycling**

It was highlighted in Chapter 7 that successful cycling promotion requires a supportive culture. This cultural change involves an encouragement of all types of cycling across the whole community, especially commuting cycling. It is also important that all sectors of the community embrace cycling, including families, workers, young and old, men and women.

Some recommendations provided by stakeholders in my qualitative study (see Chapter 7) focused on cultural change. These included making cycling genuinely appealing and accessible, and encouraging riding bicycles with ‘everyday’ clothing. In addition to these suggestions, there are other means that may help to change attitudes toward cycling. For example, positive values associated with cycling, such as joy, pleasure and health, should be spread to the public through the internet and social media. In some European cities, cycling has actually become a symbol of personal energy in recent years (Ministry of Foreign Affairs of Denmark 2014). Moreover, modern scientific ways can be employed to assist people in building up a sustainable and healthy lifestyle. For instance, with people’s increasing concern about their health, wearable electronic devices have become more and



more popular because of the monitoring functions for sleeping, physical activity, even diet. In order to increase people's attention to their carbon footprint, a carbon calculation function could be developed and built in to those devices. In addition, a well-developed bicycle manufacturing and repair industry is needed to provide population-wide cycling with a solid base.

#### **8.4.7 A call for government actions**

The recent increase in evidence and awareness of the multiple benefits of alternative transport has kept pushing a recommendation for the formulation of alternative transport strategies into real actions. As the Active Transport for Healthy Living Coalition in UK emphasises in their brochure titled 'Take action on active travel' (Sustrans et al. 2008):

*"The evidence is strong; existing policies are clear; the need is demonstrated and the potential to benefit public health is immense. Nothing here is radical or new, except the call to implement in practice what policies already say."*

This appeal is also reflected in this thesis. According findings from Chapter 7, a coalition of leading professional bodies in health, environment, transport, sport and local councils has called for political support from the highest levels in order to make public transport, cycling and walking as real alternatives for travelling in Australia. However, the reality in Australia is that progress on implementing action plans has been slow and no significant changes in people's travel behaviour have been observed so far. Therefore, it is critical that federal and local governments are willing to be involved in alternative transport changes and provide long-term approaches and commitments. The federal government needs to take responsibility in a political leadership role and propose a cross-governmental action plan for active transport strategies in all relevant departments. In addition, secure, long-term dedicated funding streams, which contribute to sustainable

urban design, may allow active transport to become the favoured choice for shorter journeys. Changes in individual travel behaviour also require a comprehensive, integrated multi-year work program, which should include major travel behaviour programs, wide spread training and professional development across all relevant disciplines.

## **8.5 Further research**

There are several aspects of investigation which could be followed to continue with the important research undertaken within this thesis.

### **8.5.1 Expanding air pollution modelling to other vehicular pollutants**

It is well known that vehicular emissions contain a mass of other air pollutants including CO, sulphur dioxide (SO<sub>2</sub>), NO<sub>2</sub>, ozone (O<sub>3</sub>) and elemental carbon (EC). Since there is strong evidence that PM<sub>2.5</sub> exposure is associated with serious health outcomes, PM<sub>2.5</sub> has been the most commonly considered pollutant in air pollution model in previous studies. However, there has also been some evidence showing the effects of pollutants such as CO, NO<sub>2</sub> and O<sub>3</sub> on mortality. Therefore, some studies have considered a different pollutant as a determinant of health in their sensitivity analysis, and different outcomes were generated.

As with most previous studies, PM<sub>2.5</sub> was selected as the major air pollution indicator in the research presented here. Future research could focus on expanding the modelling of air pollution to other vehicular pollutants, which would enhance the ability to estimate the health benefits of improved air quality.

### **8.5.2 Health impact assessment of reduction in traffic-related noise**

Noise pollution is a significant environmental problem in urban areas, and it is associated with a range of short-term and long-term health issues such as hypertension, cardiovascular effects, high stress levels, hearing loss and sleep disturbances (Daniel 2007; Jakovljević et al. 2006; Muzet 2007; Stansfeld and Matheson 2003). Traffic noise is recognized as the most important contributor to noise pollution in people's daily life.

In recent years, there has been growing concern that negative effects from traffic noise have become more and more serious. A lot of public facilities (e.g. schools, offices, hospitals and commercial business centres) and personal dwellings being located close to main roads, for easy access but without adequate soundproofing facilities. According to the EPA's guidelines (Authority 2013), noise levels should not exceed 52 decibel (dB) between 7 am-10 pm and 45 dB between 10 pm-7 am. However, a road noise study reported that 8-20% of dwellings in Australian capital cities were exposed to levels above 63 dB and 5-11% registered above 68 dB (Brown and Bullen 2003). Similarly, a recent Australian study found that noise annoyance was common in the South Australian general population (Nitschke et al. 2014).

Reducing traffic flow is the fundamental measure to mitigate adverse impacts from road noise. Therefore, future analysis could perhaps include this health determinant into health impact assessment models to investigate potential health benefits from reductions in road noise by promoting alternative transport.

### **8.5.3 Economic justifications for promoting alternative transport in Australia**

Promoting alternative transport will need a significant investment in facilities and infrastructure such as bus lanes and bicycle lanes. Motorised vehicles are highly

dependent on oil and consume almost 50% of total oil usage (Woodcock et al. 2007). Apparently, fossil fuel costs could be reduced through reductions in vehicle kilometres travelled and increases in alternative transport (Bollen et al. 2009). In addition, positive health outcomes associated with air pollution reduction and physical activity enhancement may lead to a decrease in medical costs (Australia Department of Climate Change 2008). For instance, a recent New Zealand study concluded that the benefits of all the traffic intervention policies' benefits would be 10–25 times greater than costs (Macmillan et al. 2014). Therefore, further economic analysis on a regional scale may also be politically important.

#### **8.5.4 Alternative transport and quality of life**

It is acknowledged that the negative impact of cars on the environment can be mitigated through technological improvements and travel behaviour change strategies. Some people believe that these two strategies will not only be beneficial for the environment, but will also affect people's quality of life (QoL) in various ways (Steg and Gifford 2005). Individual QoL depends on both physical and psychological factors, such as family, income, freedom, safety and comfort. Cars can enhance people's freedom, safety and comfort which makes travel behaviour change more challenging. In general, technological innovation does not need to be associated with behaviour change (e.g. more efficient engine or clean-energy cars), and has less negative impacts on personal QoL, thereby may be more preferred by people (Steg and Gifford 2005). In contrast, reducing car use may evoke resistance since it requires an adjustment of lifestyle with relatively lower levels of freedom, comfort and convenience. However, building a supportive physical environment for alternative transport can also positively affect QoL. For instance, it has been found that active community environments not only enhance walkability but

also decrease crime rates (Doyle et al. 2006). Thus, whether and how alternative transport strategies affect QoL are still open questions. Further studies will be necessary to investigate individuals' perceptions towards costs and benefits they may accrue from alternative transport *versus* the compromises and sacrifices they may need to make for travel behaviour changes.

### **8.5.5 The public and the policy makers: A comparative perspective on how to promote alternative transport**

The research has suggested that stakeholders were concerned about public resistance. However, they also indicated that appropriate interventions and legislation could encourage the public to use alternative transport more. Therefore, a dialogue needs to occur between the public and policy makers. Further qualitative work could explore the gap between the public's actual needs for using alternative transport (e.g. separate cycling lanes, bicycle parking, cheap bus ticket) and policy makers' responses to their requirements.

## **8.6 Concluding remarks**

The increasing number of motor vehicles in urban areas has a significant impact on the environment as well as on human health. This research, with implications that extend beyond Adelaide, South Australia, has highlighted the considerable health benefits associated with alternative transport use, and the importance of public education, community campaigns and a 'whole-of-government' policy approach for alternative transport promotion. Across three diverse but interrelated studies, this thesis has provided valuable information for the development and implementation of strategies to reduce greenhouse gases and air pollution, and to promote health , as well as providing a foundation to inform future studies.



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# **APPENDICES**

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## **APPENDIX A: Email invitation to be sent to participants for qualitative interviews**

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Dear [Name],

My name is Shona Crabb, and I work in the Discipline of Public Health at the University of Adelaide. I am writing to let you know about a research project conducted by myself and Ms Ting Xia, a PhD student at the University of Adelaide, and to see if you or one of your colleagues might be interested in participating. Your name was provided to me by XXX, who suggested you might be interested in being involved.

The project is entitled “Alternative transportation, air pollution and population health: a co-benefit study in Australia”, and the researcher, Ms Ting Xia, seeks to learn more about opinions regarding alternative and active transportation to improve future urban planning. The overall aim of the research is to provide inform policy recommendations for improving transportation services in Adelaide.

Participation in this research project would involve a face-to-face interview with Ting of about 30 to 45 minutes in a place convenient for you. We are interested in your own perspective on the topic, as someone with informed views, rather than as a representative of your organisation. Further information about the study is attached with this email.

If you are interested in participating in this research, please let me know, or contact Ting Xia directly (e-mail: [t.xia@adelaide.edu.au](mailto:t.xia@adelaide.edu.au); phone: 8313 3573; mobile: 0424431002). She will provide you with further details, including examples of the kinds of questions she would like to ask in an interview.

If you are currently unavailable, we would appreciate you considering whether any of your colleagues may be able to participate. Please feel free to forward this email on to anyone you think might be interested and available.

Many thanks for considering participating in our research project. We look forward to hearing from you.

Yours sincerely

Shona Crabb

## APPENDIX B: Qualitative interview information sheet

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### PARTICIPANT INFORMATION SHEET

Project Title: *Alternative transportation, air pollution and population health: a co-benefit study in Australia*

Researcher: Ting Xia

Principle Supervisor: Dr Shona Crabb, Discipline of Public Health, University of Adelaide

You are invited to participate in this research project entitled “Alternative transportation, air pollution and population health: a co-benefit study in Australia” conducted by the Discipline of Public Health at the University of Adelaide. This research forms part of Ting Xia’s PhD project.

#### **Purpose of the study**

The purpose of the study is to obtain a comprehensive understanding of the multiple benefits of, and barriers to, alternative transport use in Adelaide, and to provide useful policy recommendations to increase alternative transport use. Given your expertise, we are interested to hear your personal views on this topic (rather than those of your organisation), including your attitudes towards car use, public transport and active transport; your ideas about the barriers to promoting eco-friendly transport; and your suggestions for future policy implication. You are more than welcome to discuss any additional concerns about the issues. The results will provide important information and help form suggestions for multi-sector cooperation in sustainable transport policy.

#### **What will participation involve?**

If you agree, we would like you to participate in a face to face interview conducted by Ms Ting Xia. The interview is scheduled to last 30 and 45 minutes and will be conducted at a time and place suitable to you. Participation is voluntary and you are free to withdraw at any time. Examples of the kinds of questions we are interested in can be made available in advance of the interview.

#### **Data collection**

The interview will be audio-recorded with your consent and later transcribed. Only the interviewer will have access to the recordings; the other researchers involved will have access to the transcripts. Your name and any other identifying information will be removed from the transcript and will not appear in any papers, reports or other publications. If you wish, you can elect to check and amend the transcript after your interview.

#### **Your contribution**

It is unlikely that you will experience any personal benefit as a result of participating in this study. However, by giving us your perspective on the main factors affecting public travel behaviour and the barriers to using alternative transport, we will be able to inform relevant transport policy and urban planning.

**Contact information**

This study has been approved by the University of Adelaide's Human Research Ethics Committee. If you have any issues you would like to discuss, you are welcome to contact the Secretary of this Committee:

**Ms Sabine Schreiber**

Secretary, Human Research Ethics Committee  
The University of Adelaide  
Ph: 8313 6028  
Email: [sabine.schreiber@adelaide.edu.au](mailto:sabine.schreiber@adelaide.edu.au)

You should also feel free to contact the researchers with any queries:

**Ms Ting Xia**

Discipline of Public Health  
The University of Adelaide  
Ph: 8 8313 3573  
Email: [t.xia@adelaide.edu.au](mailto:t.xia@adelaide.edu.au)

**Dr Shona Crabb**

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## APPENDIX C: Perception of Climate Change Risks and Travelling Behaviour Survey June 2012

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### Perception of Climate Change Risks and Travelling Behaviour Survey June 2012

#### INTRODUCTION

Good ..... My name is ..... I'm calling from Harrison's Health Research on behalf of the University of Adelaide. We are conducting a survey on your perceptions about climate change and travelling behaviours. We recently sent you a letter about the survey on behalf of the University.

Did you receive the letter?

(Single response)

Yes

No

Don't know

**Interviewer note: If respondent did not receive letter, offer to read the following:**

**"The survey will be conducted by Harrison's Health Research on behalf the University of Adelaide. This particular survey will ask you about how you think and feel about climate change and also the quality of the air. We understand that within the community there exists a range of opinions about climate change. Importantly, we are interested in hearing about YOUR opinions on climate change. There is no right or wrong answers to the questions. So, please, provide answers that reflect your personal opinion**

Could I please speak with the person in the household, aged 18 or over, who was the last to have a birthday? Your phone number has been selected randomly from residential telephone numbers in the Electronic White Pages.

I can assure you that all information given will remain confidential. The answers from all people interviewed will be gathered together and presented in a report. No individual answers will be passed on.

The questionnaire will take approximately 20 minutes to complete, but may take longer depending on the number of questions that are relevant to you.

Whilst your input to the survey is very important to us, participation is voluntary and you can choose not to answer any particular question or any section and you are free to withdraw from the survey at any time. Are you willing to participate in this survey?

Please be aware that this phone call may be listened to by my Supervisor for quality control and training purposes.

(Single response)

1. Respondent
2. Foreign language interviewer required - enter language
3. Refusal - enter reasons

#### A. Demographics

As some of the next questions relate to certain groups of people only, could you please tell me...

##### A.1 How old you are?

(Single Response. Interviewer note enter 998 Don't know, 999 refused)

1. Enter age
2. Not stated
3. Don't know

Sequence Guide: If A.1 <998 Go to A.3



**A.2 Which age group are you in? Would it be...**

(Read options. Single response)

1. **18 to 24 years**
2. **25 to 34 years**
3. **35 to 44 years**
4. **45 to 54 years**
5. **55 to 64 years**
6. **65 to 74 years**
7. **75 years or over**
8. Refused (End interview)

**A.3 Sex (ask if unsure)**

1. Male
2. Female

**A.4 Including yourself how many people aged 18 or over live in this household?**

(Single Response. *Enter number of people 18 years or over*)

1. *Enter number*
2. Not stated

**A.5 What is the Postcode of the house?**

(Single Response. *If postcode is not known enter 5999*)

1. Enter number
2. Not stated

(Sequence Guide: If A.5 ≠ 5999 Go to NS)

**A.6 What town or suburb do you live in?**

(Single Response. Enter town/suburb)

1. Enter town/suburb

**B. Travel Behaviour**

**Now to change the subject, the next few questions are about alternative transportation, air pollution and their effects on health:**

**B.1 Do you own a bicycle (excluding children's bicycles for those aged less than 12 years old)?**

(Single Response).

1. Yes
2. Yes I do, but I don't ride
3. No
4. Don't know
5. Refused

Sequence Guide: if H.1 <=2 go to H.3

**B.2 What are the purposes of your cycling trips?**

(Read Options, Multiple Response)

1. **Commuting to work or school**
2. **Recreation**
3. **To visit a friend or relative**
4. **Exercise**
5. **Personal errands**
6. Other (specify) .....

**B.3 Can you estimate how many kilometres you drive a car annually?**

(Read Options. Single Response).

1. **Less than 5000 kilometers**
2. **5000 to 10000 kilometers**
3. **10,000 to 20,000 kilometres**
4. **> 20,000 kilometres**
5. **Do not have a car**
6. Don't know
7. Refused

Sequence Guide: if H.2=4 go to H.5

**B.4 How often do you use the car as a driver or passenger for any type of trip?**

(Read Options. Single Response).

1. **Never**
2. **Occasionally, e.g. 1 to 3 times per month**
3. **1 to 2 times per week**
4. **3 to 4 times per week**
5. **5 or more times per week**
6. Don't know
7. Refused

**B.5 What is your primary mode of transportation when travelling on a daily basis?**

(Read Options. Single Response).

1. **Car (driver/passenger)**
2. **Public transport (bus/train/tram)**
3. **Bicycle**
4. **Walk**
5. **Combined, e.g. car first then public transport**
6. Other (specify) .....
7. Don't know
8. Refused

**B.6 What is your primary mode of transportation when shopping or other social activities?**

(Read Options. Single Response).

1. **Car (driver/passenger)**
2. **Public transport (bus/train/tram)**
3. **Bicycle**
4. **Walk**
5. Other (specify).....
6. Don't know
7. Refused

**C. Attitude, Awareness of traffic, environment and health**

Please tell me how you agree with the following statements

**C.1 Traffic related air pollution is dangerous to our health**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.2 Traffic can cause noise pollution**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.3 Traffic emissions are a threat to the environment**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.4 The more cars on the road, the more traffic injuries**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.5 From an environmental point of view, It is important we reduce car use**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.6 Public transport is a more environmentally friendly option than driving a car**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.7 Cycling and walking are more environmentally friendly options than driving a car**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.8 Walking and cycling can help me to keep fit and healthy**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.9 If more people walked and cycled, this would have a positive effect on our environment**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.10 Being environmentally responsible is important to me**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.11 Public transport services are reliable for me**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.12 Public transport is expensive to use**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.13 Cycling is a safe transport options for me**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.14 We have enough infrastructure that supports cycling and walking in SA**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.15 I feel more comfortable in private cars than other travel modes**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

**C.16 A car is essential to my needs**

(Read options. Single response)

1. **Strongly disagree**
2. **Disagree**
3. **Neutral**
4. **Agree**
5. **Strongly Agree**
6. Don't know
7. Refused

## **D. Acceptability of Alternative Transport Promotion Measures**

Please indicate how effective each of the following measures might be in promoting a reduction in car use and an increase in more eco-friendly transport use.

**D.1 How effective would more expensive petrol be in promoting a reduction in car use?**

(Read options. Single response)

1. **Not at all effective**
2. **Fairly effective**
3. **Very effective**
4. Don't know
5. Refused

**D.2 How effective would limiting car access and parking to the city be in promoting a reduction in car use?**

(Read options. Single response)

1. **Not at all effective**
2. **Fairly effective**
3. **Very effective**
4. Don't know
5. Refused

**D.3 How effective would an increase in a car registration be in promoting a reduction in car use?**

(Read options. Single response)

1. **Not at all effective**
2. **Fairly effective**
3. **Very effective**
4. Don't know
5. Refused

**D.4 How effective would more reliable public transport services be in promoting public transport use?**

(Read options. Single response)

1. **Not at all effective**
2. **Fairly effective**
3. **Very effective**
4. Don't know
5. Refused

**D.5 How effective would much cheaper public transport be in promoting public transport use?**

(Read options. Single response)

1. **Not at all effective**
2. **Fairly effective**
3. **Very effective**
4. Don't know
5. Refused

**D.6 How effective would improved transport connections be in promoting public transport use?**

(Read options. Single response)

1. **Not at all effective**
2. **Fairly effective**
3. **Very effective**
4. Don't know
5. Refused

**D.7 How effective would wider and safer bicycle and pedestrian lanes be in promoting walking and cycling?**

(Read options. Single response)

1. **Not at all effective**
2. **Fairly effective**
3. **Very effective**
4. Don't know
5. Refused

**D.8 How effective would providing a changing room and showers in the workplace for cyclists be, in promoting cycling?**

(Read options. Single response)

1. **Not at all effective**
2. **Fairly effective**
3. **Very effective**
4. Don't know
5. Refused

**D.9 How effective would better free bicycle rental services be in promoting cycling?**

(Read options. Single response)

1. **Not at all effective**
2. **Fairly effective**
3. **Very effective**
4. Don't know
5. Refused

**E. Behaviour change**

**E.1 Think about a time you have chosen not to drive recently and used another mode of transport instead. Please indicate why you chose this mode?**

(Read Options, Multiple Response)

1. **Environmental reasons**
2. **To keep fit / healthy**
3. **To save money**
4. **To avoid traffic congestion**
5. **To avoid parking problems**
6. **Peer encouragement**
7. Other (specify) .....
8. I won't use another mode of transport instead of my car
9. Not Applicable
10. Don't know
11. Refused

**E.2 If you decided to limit the use of your car, which alternatives would you use?**

(Read Options, Multiple Response)

1. **Public transport**
2. **Cycling**
3. **On foot**
4. **Car sharing**
5. **Scooter**
6. **Motorcycle**
7. Other (specify) .....
8. Not Applicable
9. Don't know
10. Refused

**E.3 How far would you be comfortable cycling for one trip to work or study?**

(Read options. Single response)

1. **Up to 2 km**
2. **Up to 5 km**
3. **Up to 7 km**
4. **Up to 10 km**
5. **More than 10 km**
6. Not Applicable
7. Don't know
8. Refused

**E.4 How far would you be comfortable walking for one trip to work or study?**

(Read options. Single response)

1. **Up to 1 km**
2. **Up to 2 km**
3. **Up to 3 km**
4. **Up to 4 km**
5. **Up to 5 km**
6. **More than 5 km**
7. Not Applicable
8. Don't know
9. Refused

**F. Demographics**

**Now to finish with some general questions.**

**F.1 What is your work status?**

(Read Options If Necessary. Single Response. *Interviewer note: self-employed is either full or part time*)

1. **Full time employed**
2. **Part time/casual employment**
3. **Unemployed**
4. **Home duties**
5. **Retired**
6. **Student**
7. **Unable to work because of disability/ workcover / invalid**
8. Other (specify) .....
9. Don't know
10. Refused

**F.2 Which best describes the highest educational qualification you have obtained?**

(Read options. Single response)

1. **Still at school**
2. **Left school at 16 years or less**
3. **Left school after age 16**
4. **Left school after age 16 but still studying**
5. **Trade / Apprenticeship**
6. **Certificate / Diploma**
7. **Bachelor degree or higher**
8. Refused

**F.3 The next question is about housing. Is this dwelling ....**

(Read Options. Single Response)

1. **Owned or being purchased by the occupants**
2. **Rented from the Housing SA**
3. **Rented privately**
4. **Retirement village**
5. Other (specify) .....
6. Refused

**F.4 I would now like to ask you about your household's income. We are interested in how income relates to lifestyle and access to health services. Before tax is taken out, which of the following ranges best describes your household's income, from all sources, over the last 12 months?**

(Read Options. Single Response)

- 1. Up to \$12,000**
- 2. \$12,001 - \$20,000**
- 3. \$20,001 - \$30,000**
- 4. \$30,001 - \$40,000**
- 5. \$40,001 - \$50,000**
- 6. \$50,001 - \$60,000**
- 7. \$60,001 - \$80,000**
- 8. \$80,001 - \$100,000**
- 9. \$100,001 - \$150,000**
- 10. \$150,001 - \$200,000**
- 11. More than \$200,000**
12. Not stated/refused
13. Don't know

**That concludes the survey. On behalf of the University of Adelaide, thank you very much for taking part in this survey.**

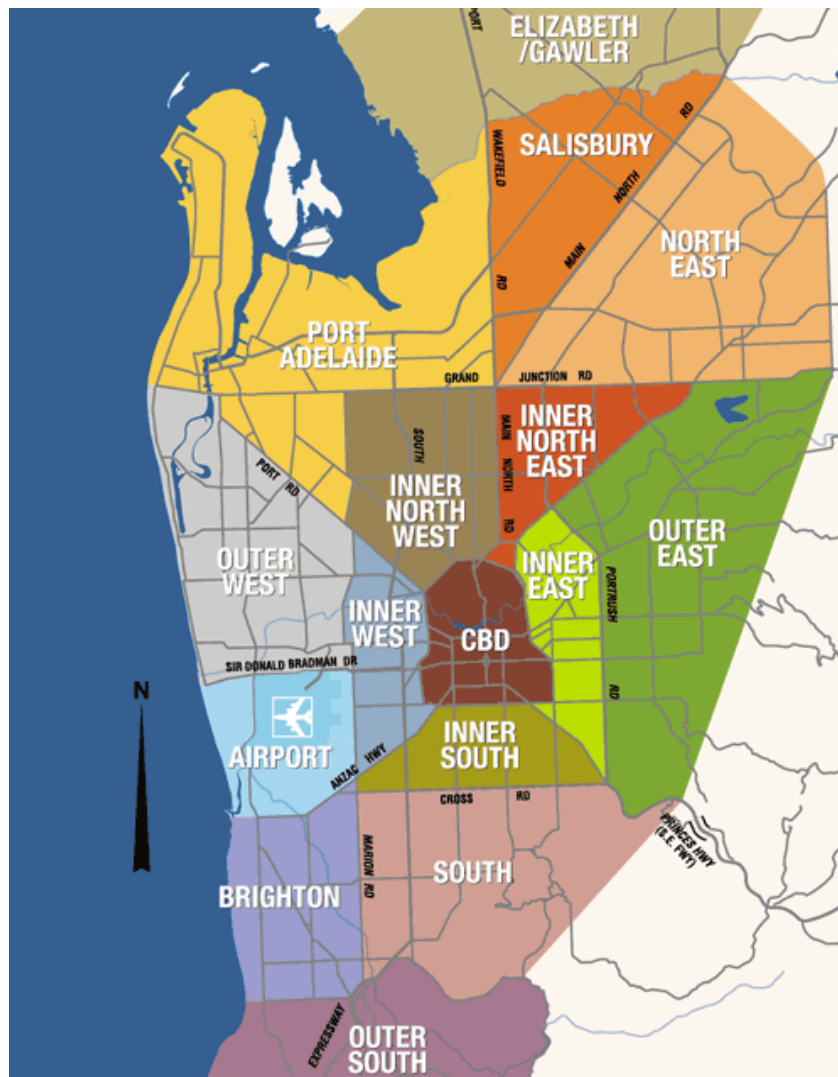
**APPENDIX D: Participation rate of the Perception of Climate Change  
Risks and Travelling Behaviour Survey**

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<b>Initial sample drawn</b>	1750
Minus	
<b>Sample Loss</b>	
Non residential numbers	18
Telstra message/disconnected	426
Fax/modem	7
Do not reside in South Australia	11
Contact could not be established after 15 calls (at different times of day/evening and different days of the week)	248
 Remaining sample	 1288
Minus	
<b>Non Response</b>	
Refusal (not interested, too busy etc)	420
Respondent unable to speak English	43
Illness/hearing impaired	53
Terminated interview	5
Deceased	0
Total interviews	500
Interviews as a ratio of contacts	48.0%



**APPENDIX E: Map of Adelaide metropolitan area**



**Figure E.1: Map of Adelaide metropolitan area**

\* Inner city includes: Adelaide CBD, inner north, south, west and east areas.

\*\* Outer city includes: Port Adelaide, Outer west, Airport, Brighton, Outer south, Outer east, North east, Salisbury and Elizabeth areas.

## APPENDIX F: Qualitative interview participant consent form



HUMAN RESEARCH ETHICS COMMITTEE

PARTICIPANT CONSENT FORM

### Alternative transportation, air pollution and population health: a co-benefit study in Australia

1. I .....*(please print name)*  
consent to take part in the research project entitled :  
Alternative transportation, air pollution and population health: a co-benefit study in Australia
2. I acknowledge that I have read the attached Information Sheet
3. I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.
4. Although I understand that the purpose of this research project is to improve the quality of medical care, it has also been explained that my involvement may not be of any benefit to me.
5. I have been given the opportunity to have a member of my family or a friend present while the project was explained to me.
6. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.
7. I understand that I am free to withdraw from the project at any time and that this will not affect medical advice in the management of my health, now or in the future.
8. I am aware that I should retain a copy of this Consent Form, when completed, and the attached Information Sheet.

.....  
*(signature)* *(date)*

**WITNESS**

Name: .....

.....  
*(signature)* *(date)*

## APPENDIX G: Interview guide for the qualitative interviews

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### Guide for interview

#### Theme one

*Attitudes towards car, public transport and active transport*

Guide questions:

- Do you think when bringing convenience to us, motor vehicle/car also brings some issues in our lives? Tell me about the positives and negatives of car use, from your perspective.
- From your perspective, what are the main issues of increasing motor vehicle/car use in Adelaide?
- What means of transport do you think could be realistic alternatives to private car use?
- What are the benefits do you think of alternative transport? Tell me about the positives and negatives of alternative transport?

#### Theme two

*Barriers of promoting alternative transport*

- What do you think influences people's travel behaviour ?
- For the public, what are the main barriers do you think to using alternative forms of transport to cars? From your perspective, what are the main barriers for local government/your department/your organization to promoting alternative transport/public transport/active transport use?

**Theme three**

*Implications for policy*

- From your perspective, what would encourage/assist the public with using alternative transport/public transport/active transport in Adelaide more often?
- From a governmental/organizational perspective, what kinds of policies are most effective to encourage the public to use alternative transport/public transport/active transport more often?
- How can local government, communities and businesses work together to promote alternative transport use?
- Do you have any further suggestions for other departments for better planning and building of networks for alternative transport/public transport/active transport?

## APPENDIX H: Journal Publications

### Review Article

# Cobenefits of Replacing Car Trips with Alternative Transportation: A Review of Evidence and Methodological Issues

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It has been reported that motor vehicle emissions contribute nearly a quarter of world energy-related greenhouse gases and cause nonnegligible air pollution primarily in urban areas. Reducing car use and increasing ecofriendly alternative transport, such as public and active transport, are efficient approaches to mitigate harmful environmental impacts caused by a large amount of vehicle use. Besides the environmental benefits of promoting alternative transport, it can also induce other health and economic benefits. At present, a number of studies have been conducted to evaluate cobenefits from greenhouse gas mitigation policies. However, relatively few have focused specifically on the transport sector. A comprehensive understanding of the multiple benefits of alternative transport could assist with policy making in the areas of transport, health, and environment. However, there is no straightforward method which could estimate cobenefits effect at one time. In this paper, the links between vehicle emissions and air quality, as well as the health and economic benefits from alternative transport use, are considered, and methodological issues relating to the modelling of these cobenefits are discussed.

## 1. Introduction

Over the last century, the number of motor vehicles built, purchased, and used on roads globally has dramatically increased to meet people's travel demands. Although alternative fuels have been developed, more than 95% motor vehicles are still dependent on fossil fuels, a dependency which does not seem to be abating [1, 2]. Because of the large consumption of fossil fuels, transportation is regarded as a major contributor of greenhouse gases (GHGs). According to research conducted by Kahn Ribeiro and colleagues [3], a quarter of world energy-related GHG emissions can be attributed to transportation and nearly 85% of transportation-related GHG is exhausted by land transportation. Furthermore, it is predicted that transport energy usage will continue to increase at a rate of about 2% per year worldwide, whilst total transport energy usage and carbon emissions will be 80% higher than their current levels by 2030 [3].

It is widely acknowledged that exhaust fumes from motor vehicles contain a variety of air pollutants such as nitrogen

dioxide (NO<sub>2</sub>), volatile organic compounds (VOCs), carbon monoxide (CO), and particulate matter (PM). Although the contribution of road transport to local pollution may vary depending on distinct local features, such as geographic and climatic features, the technology distribution of the national fleet, driving patterns and density [4], and vehicle emission is no doubt a significant source of air pollution, especially in highly car-dependent cities. The European Topic Centre on Air and Climate Change 2005 data [5] demonstrate that road transport accounts for about 42% of total NO<sub>x</sub> (NO and NO<sub>2</sub>), 47% of total CO, and 18.4% of total PM emissions at European Union of 15 member states.

To reduce the emissions from motor vehicles, mitigation strategies have been implemented in various countries. These mitigation strategies could be summarised as falling into three main approaches: (1) renovation of new vehicle technology, such as developing new energy sources for motor vehicles and elevating standards for emissions [6, 7]; (2) improvement of land use and urban planning, such as an establishment of bus rapid transit systems [8]; (3) travel

Xia, T., Nitschke, M., Zhang, Y., Shah, P., Crabb, S. & Hansen, A. (2015) Traffic-Related Air Pollution and Health Co-Benefits of Alternative Transport in Adelaide, South Australia, *Environmental International*.  
*Environment International*, v. 74, pp. 281-290

NOTE:

This publication is included on page 294 in the print copy of the thesis held in the University of Adelaide Library.

It is also available online to authorised users at:

<http://dx.doi.org/10.1016/j.envint.2014.10.004>