# Understanding the combined influence of attitudes on Commuters' Travel Choice Behaviour in Developing Countries

School of Engineering

Newcastle University

By

Titayapa Meenapinunt

A thesis submitted for the degree of

Doctor of Philosophy in Transport at

Newcastle University

March 2024

# Declaration

This thesis is the original work of the author except where acknowledgement has been given. The material presented has never been submitted to Newcastle University or to any other educational establishment for purposes of obtaining a higher degree.

March 2024 Titayapa Meenapinunt

# Abstract

Climate change has emerged as one of the main environmental challenges facing the world in the 21st century. According to COP26, transport contributed 25% of worldwide carbon emissions from all sources. However, in the context of developing countries, specifically the Southeast Asia region, how environmental awareness influences travellers' choice of mode(s), whilst also considering the interplay of a wide range of other factors, is under-researched. This research aims to investigate the interrelationship between commuters' attitudes towards perceptions of the environment, accessibility, convenience, and safety and the effect they have on traveller behaviour and choice of mode(s).

A questionnaire was designed and piloted before posting on social media and operators' websites. Self-completed questionnaires were supplemented by direct interviews to provide a representative sample of the population of the Bangkok Metropolitan Region (BMR). In 2022, between April and May, 648 useful responses were collected. Descriptive analysis of the data led to basic understandings of the demographics and characteristics of the commuter. The descriptive analysis showed that was the most popular in BMR driving cars for commuting, followed by urban rail.

Four components were identified from the Principal Component Analysis, namely "*Pro-environment and health*", "*Pro-environmentally friendly cars*", "*Pro-safe*", and "*Pro-private vehicle*". The component scores were further investigated with attention to the respondents' gender, age, and self-identified mode of transport. Age and identity of transport mode strongly influenced the components, particularly active transport users. PCA components were fed into the regression model to study variable influences.

Six algorithms were developed by using Multinomial Logistic Regression each targeting a particular cohort of the population to inform mode shift from private vehicles and support government policy, public transport operation, and infrastructure investment decisions. The statistically significant variables that influenced mode choice of transport included travel cost, time, attitudes toward environmental and safety, and socio-demographics such as age and car ownership. Subsequently, the models were demonstrated to inform the potential to switch mode from the use of private cars and thus to inform policy. For example, a short-term policy may aim to increase cost of car ownership and use making bus alternatives more attractive.

This could be achieved by levying a tax for buying and/or use of car, by increasing fuel prices and/or parking charges. Long-term policies such as implantation of road user charging, regulation in purchasing a new car, improving infrastructure to make public transport systems more accessible should be introduced as part of a national development plan, perhaps as measures to meet carbon targets. The research demonstrated the importance of changing public attitudes through education and specifically raising awareness of the environmental benefits of the use of public transport. This research also revealed a much higher shift away from car to active transport mode or train depended on the distance travelled heightening the need for integrated transport policies that deliver sustainability in the long-term. The models whilst specifically providing scientific evidence that informs policies for travel in Bangkok, the methodological approach is transferable to other developing countries.

## Acknowledgements

To all individuals who have contributed to the successful completion of my thesis, I extend my sincere appreciation. Among the few cited key persons, my supervisors are the most remarkable. I have been incredibly privileged to have supervisors who consistently support me and enable me to pursue my ideas and interests, firstly by trusting me, and secondly, by sharing their valuable experiences and insights. Truly, I owe my sincere gratitude to my supervisors, Dr. Dilum Dissanayake and Prof. Margaret C Bell CBE because without their support this thesis would not have been possible. I was delighted to interact with both of my previous supervisors Dr. Gustav Bösehans and Dr. Kuldeep Kavta. Moreover, I extend my appreciation to all members of staff at the School of Engineering and Graduate School. I also am grateful to the Thai Government for the financial support and all the staff from the Office of Educational Affairs Royal Thai Embassy, without which I would not be able to even start my studies. In addition, I acknowledge the academic advice and emotional support of the lecturer team from the Mechanical Engineering Department, Kasetsart University, Assoc. Prof. Dr. Wichai Siwakosit, Asst. Prof. Dr. Prapot Kunthong, Assoc. Prof. Chawalit Kittichaikarn, Prof. John Robert, Dr. Sorawit Limthongkul and Asst. Prof. Tanet Aroonsrisopon.

Also, I would like to thank my friends in the Future Mobility research group for their technical support. Special thanks to the Thai community in Newcastle, they make me feel at home during my journey and time spent in Newcastle.

Lastly, I thank my family for their emotional support.

# Content

## Table of Figures

# List of Abbreviations

| | |
|---|---|
| AQI | Air quality index |
| $CO_2$ | Carbon dioxides |
| BMR | Bangkok Metropolitan Region |
| GHG | Greenhouse gas |
| DA | Descriptive analysis |
| LAs | Local authorities |
| HCA | Hierarchical cluster analysis |
| MC | Motorcycle |
| MLR | Multinomial logistic regression |
| MSP | Modal shift potential |
| PCA | Principal component analysis |
| PAF | Principal axis factoring |
| PM | Particle matter |
| RUC | Road user charges |
| SEI | Sustainable efficiency indicator |
| TCI | Traffic congestion index |

# Publications and Conferences

**Publication**

- Meenapinunt, T., Dissanayake, D., Bösehans, G. and Bell, M. (2025) 'Studying travel behaviour in the Bangkok Metropolitan Region: How attitudes towards the Environment, Accessibility, Convenience, and Safety, vary among commuters', *Transportation Research Procedia*, 82, pp. 2276-2293.

**In Preparation**

- Meenapinunt, T., Dissanayake, D., Bösehans, G, and Bell, M. 'Investigation of factors affecting mode choice decisions of commuters in the Bangkok Metropolitan region' *To be submitted to Journal of Advanced Transportation.*
- Meenapinunt, T., Dissanayake, D., Bösehans, G, and Bell, M. 'Understanding the combined influence of attitudes towards the Environment, Accessibility, Convenience, and Safety on Commuters' Travel by logistic model" *To be submitted to Transportation Planning and Technology.*

**Conference**

- 54th UTSG conference, Edinburgh, Scotland ,4th – 6th July 2022 – Oral presentation
- 55th UTSG conference, Cardiff, Wales, 10th – 12th July 2023– Poster presentation and prize winner of the Best Poster Award
- World Conference on Transport Research (WCTR) Conference 2023, Montreal, Canada, 17th – 21st July 2023 – Oral presentation (presented by Dr. Dilum Dissanayake)
- TRB meeting, Washington, DC, USA 7th – 11th Jan 2024 – Accepted as poster presentation.

Note: WCTR 2023 and TRB 2024 conference were not presented by myself due to the Visa situation.

# Chapter 1. Introduction

## 1.1. Background

Due to the increase in car ownership and use, carbon dioxide, $CO_2$ from the transport sector has multiplied rapidly over the recent decades, generating a number of negative impacts including global climate change (NASA, 2022; Varabuntoonvit *et al.*, 2023). The 26th United Nations Climate Change Conference in November 2021 set a milestone in an attempt to reverse this trend by encouraging countries across the world to set out plans to meet climate change targets (COP26, 2021). The World Health Organisation, WHO (2021) reported that rising levels of transport-related air pollution such as particulate matter (PM) are responsible for premature deaths. PM is a complex mixture of aerosols composed of particles of different sizes. The WHO recommends that the annual average concentration of PM2.5 (known as fine particulates with diameters of less than 2.5 microns is about 30 times smaller than the width of a human hair) should not exceed 5µg/m$^3$ and the 24-hour average exposure should not exceed 15µg/m$^3$ more than 3 to 4 days per year. For PM10 (particulates with diameters of 10 microns or less) the annual average concentration should not exceed 15µg/m$^3$ whilst the 24-hour average exposure should not exceed 45µg/m$^3$ for more than 3 to 4 days per year.

Particulate Matter is a mixture of tiny solid particles and liquid droplets which can have serious health impacts on people when exposed to levels above the thresholds set by governments. Health impacts include increasing the risk of heart attacks and strokes; developing diabetes and/or lung cancer, exacerbation of respiratory disease and can affect pregnancy and birth outcomes. The UK Regulations (2023) require that annual average PM2.5 should not exceed 10µg/m$^3$ at any monitoring station by 2040. Sources of PM in outdoor environments, included **traffic and transportation, industrial activities, power plants, construction sites, waste burning, fires or fields**. Whilst PM sources from road traffic are from the exhausts of diesel vehicles other sources including brake wear, tyre wear and road surface wear which currently constitute 60% and 73% (by mass), respectively, of primary PM2.5 and PM10 emissions from road transport. However, in the UK the National Atmospheric Emissions Inventory suggests that particles from non-exhaust sources will become more dominant in the future as more electric vehicles are introduced into the vehicle fleet. The environmental impact of traffic on

PM emphasises the need to facilitate shift from travelling by single occupancy cars to public transport modes. For example, under the umbrella of "sustainable urban transport" mode shift to bus, LRT, urban rail, and active travel (walking and cycling) should be prioritised, as well as investment in low-emission vehicle technologies. Modes can be categorised into three groups including private, public, and non-motorised (active) transport. Public transport comprises bus, rail, and mass transit systems, trams, and ferries. Non-motorised transport modes include walking and cycling.

A study by Wang *et al.* (2015) showed that the per-passenger emissions of $CO_2$, for public transport modes were significantly lower than those of private cars burning fossil fuels. Shiau (2013) developed a hierarchical approach for local government to deliver a sustainable transport city. The critical factor was the need to promote travel by public transport and active travel modes. Previous research in developed countries has focused on the evaluation of impacts on the environment and how this influences travellers' choice of mode(s) whilst also considering the interplay of a wide range of other factors including safety, accessibility, and convenience however, in the context of developing countries research is limited.

## 1.2. Motivation of Study

Previous case studies have demonstrated that public transport can be a popular transport mode in developed countries including Norway, Japan, and Singapore (Şimşekoğlu *et al.*, 2015; Engebretsen *et al.*, 2017; Wang *et al.*, 2019; Statistics Bureau of Japan, 2021). In addition, non-motorised transport modes have received considerable attention in recent years with the introduction of dedicated walking and cycling infrastructure and incentive campaigns (Rissel *et al.*, 2018; Transport for London, 2020). However, despite significant investment in sustainable transport systems, research has shown that private transport including cars and motorcycles continues to be the more popular mode in developing countries (Morikawa *et al.*; Wedagama and Dissanayake, 2010; Dissanayake *et al.*, 2012; Ashalatha *et al.*, 2013; Van *et al.*, 2014; Wijaya, 2019; Kumagai and Managi, 2020; Wedagama D *et al.*, 2020). For example, Bangkok Metropolitan Region invested in a Mass Transit System two decades ago but travellers continue to choose private vehicles over public transport (Office of Transport and Traffic Policy and Planning, 2018). Therefore, this suggests that user attitudes toward transport and the interplay of influencing factors on their mode choice decisions need to be researched to generate a fundamental understanding of why travellers continue to adopt unsustainable transport options. This in turn will provide evidence to inform sustainable transport policy in the future.

Previous research has studied factors that influence travel behaviour and shown that travellers are more likely to pay more attention to environmental concerns than they did in the past by opting to use cleaner modes or buying less-polluting cars (Atasoy *et al.*, 2013; Ali *et al.*, 2018; Bouscasse *et al.*, 2018). Accessibility and convenience-related variables in the use of public transport have been investigated and found that the layout of stations including the availability of lifts and/or escalators, the general environment, and walkability do impact perception and influence positive behaviour towards the uptake of public transport (Prasertsubpakij and Nitivattananon, 2012; Saw *et al.*, 2019; Majumdar *et al.*, 2020; Vichiensan and Nakamura, 2021). The studies of the influence of road infrastructure including pavements and cycle lanes, on active travel users' attitudes to safety have shown that both pedestrians and cyclists are believed to be safe when using routes segregated from cars (Mullan, 2013; Wedagama D *et al.*, 2020; Akgün-Tanbay *et al.*, 2022; Thibenda *et al.*, 2022). However, users of motorised modes of transport perceived that active transport was less safe (Mullan, 2013; Wedagama D *et al.*, 2020). Research focusing on integrated factors of travel behaviour can be found in case studies in developed countries (Anable, 2005; Handy *et al.*, 2005; Acker *et al.*, 2014; De Vos *et al.*, 2016; Molin *et al.*, 2016) but not in a developing country context where research has considered access, convenience, safety, and environment as individual factors rather than taking a holistic view of all factors in an integrated manner. In addition, there is a considerable lack of such studies in a Southeast Asian context. *Therefore, the novelty of this research is to explore how attitudes towards, and perceptions of, the factors of environment, accessibility, travel convenience, and safety together influence commuters' travel behaviour with regard to their selection of mode(s).* The case study selected was the Bangkok Metropolitan Region (BMR) in Thailand due to the complexity of its transport issues. In 2022, Bangkok was ranked the 19$^{th}$ highest traffic-congested city in the world (Bastea, 2023). The report further revealed that Bangkok's traffic congestion index (TCI) reached the highest point, 225.78, surpassing the TCI of developed cities such as London or Paris. Additionally, the sustainable efficiency indicator (SEI) of urban transport including public buses and urban trains in Bangkok was reported as being low (Varabuntoonvit *et al.*, 2023).

As above, in the setting of developing countries, the study that combined attitudes, considered environment and a wide range of other factors was limited. Therefore, this study aimed to replace this research gap by implementing designed a methodological approach that considers travel behaviours, background, and perceptions related to the environment, accessibility, travel convenience, and safety. The findings and recommendations from this study are expected to provide valuable decision-making processes for policymakers from the local sector until the government's approach to sustainability.

The Likert scale was employed in previous studies as a tool for examining attitudes. In order to develop an effective expression and model, continuous scale possesses the capability to offer a better level of precision in defining mode preference predictions, which is important for identifying the benefits of the outcomes.

## 1.3. Research Questions

Due to the knowledge gap, three research questions to be answered by this research can be presented as follows:

1. What are the attitudinal factors and the socio-demographic variables that characterise the use of transport in developing countries?
2. What is the main characteristic of the commuter that should be the target to shift to sustainable modes of transport?
3. Which influence can impact the target group to be more sustainable?

These questions were explored and answered by carrying out literature review and analysis.

## 1.4. Global Aim

The global aims of this study were to understand the attitudes and perceptions that influence mode choice to inform sustainable transport policy and maintain and grow the current use of public and active transport.

## 1.5. Research objectives

The specific objectives of the study were as follows:

1. to examine the overall travel behaviour and attitudes toward transport;
2. to identify the key significant attitudinal components that influence mode choice;
3. to identify groups based on their attitudes, mode identity and sociodemographic;

4. to investigate the relationships between mode preferences and the combination of travel behaviour, attitudes, and sociodemographic;
5. to provide scientific evidence to inform policymakers of how to reach the sustainable goal.

## 1.6. Research Tasks

The research objectives can be reached by the following tasks:

1. Conduct a literature review of methodological approaches and outputs of previous studies of transport, travel behaviour, and attitudes in different urban environments including developed and developing countries to identify the research gap.
2. Map out the methodological framework to achieve the research gap.
3. Identify the target group and requirements to ensure a sample representative of the population.
4. Develop the questionnaire addressing travel behaviour, perceptions, attitudes, and sociodemographic characteristics within the context of the case study.
5. Investigate the overall characteristics of the sample and identify attitudinal variables within four themes using descriptive statistics and identify the relationship between attitudinal components and demographics using descriptive analysis.
6. Group the responses to the questions using a clustering analytical method and identify the relationship between attitudinal variables and main characteristics of each cluster.
7. Explore scenarios that could influence mode shift of specific target groups.
8. Conclude with recommendations for further research to achieve the transport sustainability goal.

## 1.7. Thesis Outline

The outline of this thesis is structured to meet the objectives as follows:

Chapter 2 provides a critical review of research related to travel behaviour attitudes categorised by themes. Then, the methodological review and case study are presented in Chapter 3. The methodological approach with the flow diagram of this study is presented in Chapter 4. Chapter 5 explains the development of the questionnaire, sample target, and data-collecting process. Subsequently, in Chapter 6, an overview of the collected data is presented through descriptive analysis and dimension reduction techniques. Chapter 7 focuses on identifying clusters by cluster analysis and investigating the characteristics related to travel mode. Chapter 8 introduces a mathematical model aimed at identifying the trends in mode preference by multinomial logistic regression. Lastly, the conclusions and proposed further research are presented in Chapter 9.

# Chapter 2. Literature Review

## 2.1. Introduction

The previous chapter stated the research gap and set out the aim and objectives for the research for this thesis. This research aimed to study travel behaviour and attitudes toward environmental, accessibility, convenience, and safety. This chapter reviews previous research to develop the foundations of the research focusing on commuter travel behaviour and attitudes, to present the evidence to justify the research gap, and to investigate the key influence that impacts travel behaviour by themes with developing and developed countries.

Section 2.2 explains the transport challenges in delivering NetZero. Section 2.3 explains key attitudinal factors that impact travel behaviour including environmental, accessibility, convenience, safety, and sociodemographic characteristics. Section 2.4 details transport modes in the context of the Bangkok case study used in this research. Finally, in Section 2.5, the key findings are discussed, and a conclusion is drawn.

## 2.2. NetZero Challenge

The 26th United Nations Climate Change Conference in November 2021 was a significant step in the effort to reverse the trend of climate change. It urged governments worldwide to develop strategies to achieve their climate change goals in line with the global net zero by 2050 (COP26, 2021). Furthermore, there is the requirement to evaluate levels of air pollution that are responsible for premature deaths, as well as short- and long-term respiratory problems (WHO, 2021). However, the average global carbon dioxide from 1960 to 2021 has risen gradually (Statista, 2022b) and is still increasing.

The transport sector was accountable for the second largest amount of total carbon dioxide emissions by human activities, with 40% of carbon dioxide in this sector was from private transport (Statista, 2022a). Contributions from traffic congestion in the top Asia Pacific and APAC cities were reported as Mumbai (53%), Tokyo (43%), and Bangkok (31%) (Statista, 2021). Therefore, if these cities could resolve congestion problems significant reduction in carbon dioxide emissions and contribution to NetZero would be achieved.

## 2.3. Attitudes toward travel behaviour

Regards to research question 1, *What are the attitudinal factors and the socio-demographic variables that characterise the use of transport in developing countries?*, the attitude themes were pre-selected. Therefore, in this section, the role of attitudes on travel behaviour is discussed with five questions related to the main research questions;

1) Do attitudes to the environment impact on travel behaviour change? 2) Does accessibility and convenience influence mode selection? 3) Does security and safety have an effect on mode selection? 4) Did their socio demographic characteristics impact on mode preference? and finally 5) Did inter-relationships between themes play an important role in travel behaviour?

### 2.3.1. Do attitudes to the environment impact on travel behaviour change?

A number of research studies have focused on mode choice behaviour with specific attention to the **environmental theme** (Shen *et al.*, 2008; Kumagai and Managi, 2020; Tran *et al.*, 2020; Ryu, 2021). Tran *et al.* (2020) found that ecological policies in Japan had a positive impact on commuter mode choice with regard to railway and non-motorised options. The studies of Mullan (2013); Tyndall (2022) focused on cyclists in the UK and USA respectively, and showed that commuters selected cycling because their mode choice reduced environmental impact. *The weather in both case studies was dry therefore, in other climates such as tropical and rainy seasons or inclement weather such as ice and snow, commuters might be less inclined to choose cycling as a viable mode.* Some studies reported that environmental awareness influences an individual’s decisions related to the choice of transport mode (Shen *et al.*, 2008). This study focused on monorail, bus, and private car trips in Japan related to their attitude toward the environment. The simulation by multinomial logit model (MNL) predicted that environmental impact change affected the choice of transport. They tended to choose “cleaner” when they had the awareness of travel mode by shifting from private car to using bus or monorail. Similarly, the modelling of using MLR studied by Bouscasse *et al.* (2018) showed that environmental awareness influenced mode choice. However, Kumagai and Managi (2020) demonstrated that pro-environment attitudes do not always influence commuter mode choice in urban Asian cities such as city-state Singapore.

The influence of environmental policy and implementation more recently has been investigated by Ryu (2021), Xia *et al.* (2017), and Australasian Railway Association (2022). Ryu (2021) predicted the carbon dioxide impact of different green policies such as banning diesel cars. Xia *et al.* (2017) focused on sustainable transport in urban areas in Australia and showed that when people had environmental awareness, they were more likely to change their travel behaviour. A study by Australasian Railway Association (2022) found that in 2022, up to 66% of participants chose the railway for their transport due to the sustainability scheme. This study also specifically showed that preventing people from using their private cars through increases in the price of petrol is not an effective way to reduce car usage.

A common finding in all three studies was that a single policy designed to promote a shift to environmentally friendly modes was not strongly effective in delivering sustainable transport systems, instead, a mixture of policies tailored to the specific characteristics of the trip-making in the city was also required. Previous research relating to the influence of environmental awareness on mode choice has been conducted mainly in developed countries where climates, cultures, and access to sustainable transport alternatives to private cars are quite different in cities and urban areas of developing countries. This emerges as a gap in research given the need to better understand the factors that influence travel choices to inform policies that could change their behaviours.

### 2.3.2. Does accessibility and convenience influence mode selection?

The definition of **accessibility** adopted in the current study refers to the physical accessibility to public transport (Subeh *et al.*, 2016). Previous studies have found that **accessibility and travel convenience** are linked to mode choice behaviour. Sarkar and Mallikarjuna (2018) showed that personal mode choice was influenced by accessibility in a study of the choice of mode of transport among 561 samples in Agartala, India. The most popular mode was found to be private car due to ease of access whilst the lowest score was for bus and bicycle. In this city, bus was the only available public transport service. The sample size from this study resulted in the same direction therefore, private car was high accessibility in this context.

Prasertsubpakij and Nitivattananon (2012) conducted a study in Bangkok and found that accessibility to the urban train station itself depended heavily on the built environment and facilities available as well as age and physical condition. The score of accessibility to the rail services in this study was high due to the affordability for the elderly. However, this study was conducted in 2012, at the time the urban rail opened with only four lines and this public transport system in Bangkok was not previously available. Further investment in public transport services justifies further study of mode choice particularly in the context of barriers, particularly in the context of connectivity of transport services.

A number of studies have focused on the **convenience** of public transport including (Pongprasert and Kubota, 2017; Pongprasert and Kubota, 2018; Narupiti, 2019). Pongprasert and Kubota (2017)carried out a travel behaviour for residents who lived within a kilometre of an urban rail station in the Bangkok area in 2014 and found that the poor quality of pedestrian footways meant that walking to urban rail stations even a short distance presented challenges. A later paper by Pongprasert and Kubota (2018) highlighted factors of the impact on walking of people who lived near the urban train station in Bangkok. The education and income related to the perception of mode of transport.

Narupiti (2019) also carried out a study in Bangkok and confirmed that inconvenient payment systems in BMR were a barrier preventing public transport use, and therefore integrated ticketing increasingly is becoming an important feature in service provision to make public transport attractive and encourage use.

This study was an impactful case study in that it demonstrated that introducing a new technology or mode of public transport should not be implemented in isolation but in the context of improvements in access, ticketing, and considering existing public transport systems. *Currently, in 2024, urban rail services in BMR accept credit card payments in the MRT system but BTS and ARL require a specific ticket or advance payment. When the journey needs two or more types of transport, the commuter is required to buy two separate tickets. Bus or paratransit users still use cash when travelling.* Therefore, a question arises whether integrated ticketing could encourage multimodal travel and facilitate mode shift from private cars.

The European Environment Agency (2015) showed that on average, public transport modal share is lower than that of private transport in many countries. Amongst other reasons, this is because public transport does not tend to provide door-to-door services (i.e., direct services from origin to destination) therefore investment in first/last mile services such as shared e-mobility (Bösehans *et al.*, 2021) is important.

Fraszczyk *et al.* (2019) in a study in the BMR area showed that seamless connection between modes of transport was one of the criteria for using a new metro line consistent with the study by Vichiensan and Nakamura (2021) that focus existed Bangkok urban rail station. *Whilst both studies were based on questionnaires conducted by interviews in Bangkok, they did not cover the combined impact of environment, accessibility, convenience, security, and safety influence on multimodal travel when they anticipate the opening of a new line or when the new line opens.*

In addition, research by Townsend and Zacharias (2009) and Ozawa *et al.* (2021) showed that walking was not the most preferred mode choice for many due to poor facilities and environmental conditions. Van *et al.* (2014) in a study of six countries including Thailand, China, Vietnam, Indonesia, and Philippines between public transport car showed that people in developing countries had different attitudes toward not using public transport including social orderliness and convenience as important aspect of public transport, and therefore they preferred to use private transport. Interestingly, studies in developed countries did not consider accessibility as an influencing component on public transport system. *This implies that the policymaker has engineered public transport systems and services to meet the public need and therefore less attention was given to research in the accessibility theme. However, given the changes in trip making following COVID and the urgency presented by NetZero a better understanding of what motivates the public to use specific modes to inform sustainable policies and substantial improvements to better meet transport users' needs.*

### 2.3.3. Does security and safety effect on mode selection?

The **Safety** theme was a main focus in recent literature (Mullan, 2013; Kamargianni *et al.*, 2015; Sarkar and Mallikarjuna, 2018; Thibenda *et al.*, 2022). Mullan (2013) collected data through direct interviews of cyclists in Ireland and showed that roads were safer, active transport was considered as an option in commuter trip-making and yet public attitudes towards safety riding bikes overall were negative. Cyclists had the opinion on active transport, specifically riding to their workplace which was safe while other modes of transport users had negative feedback on bikes on the road. It can be seen from this study that the attitude toward safety is perceived differently by different users.

Research in Norway and Australia also illustrated that active travel use is popular in less car-dominated areas with better road safety (Şimşekoğlu *et al.*, 2015; Xia *et al.*, 2017). Şimşekoğlu *et al.* (2015) in a study in Norway showed that safety was a priority from both car user and non-car user group perspectives and interestingly, they were insignificantly different.

This result is consistent with that of the Hanoi case study by Thibenda *et al.* (2022), which revealed that people prefer to use their cars because they feel safe. However, public transport users were less impacted by this component compared to the private transport user group, and agreement with the safety component for active transport users was the least of all modes.

The study found that sociodemographic, specifically education and occupation influenced perception. From the study by Sarkar and Mallikarjuna (2018) studied in Agartala, India in 2012, the perception of safety from accidents had the highest score from car users while the lowest score was from bike users. It can be seen that the study in the area of developed countries and developing countries found similarities and dissimilarities. Safety was important in both types and based on their socio-demographics and their experiences. On the other hand, the perception of active transport related to safety in developed countries was more positive than the study from developing countries which preferred cars based on safety attitude.

It is clear that policymakers should understand travellers' needs from users of all modes because they have been shown both differently and similarly depending on demographics and other influencing factors in different ways.  It is wise for decision-makers to formulate policies that target specific segments of the population (Bösehans *et al.*, 2021) and where possible to co-create intervention measures to maximise the benefits of investment when a policy is released.

### 2.3.4. Did their socio demographic characteristics impact on mode preference?

Age and gender have been found to influence mode selection by numerous previous research studies including (Polk, 2004; Şimşekoğlu *et al.*, 2015; Ali *et al.*, 2018; Korzhenevych and Jain, 2018) and consistently, males stated a preference to drive more than females (Polk, 2004; Şimşekoğlu *et al.*, 2015; Ali *et al.*, 2018; Korzhenevych and Jain, 2018). Differences in mode choice emerged when considering the influence of age with the young generation more inclined to try out new technology compared to the older generation as found in a study by Fraszczyk *et al.* (2019). Similar to the study, a study in the UK by Bösehans and Walker (2020) was carried out by using the questionnaire filled out by 1249 students and staff of the University of Bath between 2014 and 2015. Student groups tend to switch more than staff groups. However, the age group in both studies was different. In the Asian context, the retirement age was 60 years old while in the Western 65 years old was retirement. Barbieri *et al.* (2021) showed that studies across the world particularly during the COVID-19 pandemic (N = 9394), not only found age and gender, affected travel behaviour but education level related.

### 2.3.5 Inter-relationships between themes

Previous studies have demonstrated there is a wide range of influencing factors that have been considered in the research presented in this thesis under five main themes, namely environment, accessibility, convenience, and safety. Most studies have considered attitudes in one or two of these themes, although evidence suggests that there is interplay between themes. Therefore, research should consider all themes together. For example, ease of physical access to public transport means that individuals also may consider that transport is safe and convenient. In addition to the attitudes in the context of these five themes demographic characteristics of travellers also have been found to influence mode choice. In order to consolidate the scholarship and identify, the research gap a summary of the research areas covered in previous studies along with details of the cities where the study has taken place and whether demographics were considered, are collated and presented in Table 2.1.

Research presented in Table 2.1 covered 40 publications of studies carried out in developing cities in Asia (14) including Thailand (9) India (3) China (1) and Indonesia and Vietnam (1), in developed cities 23 in the UK (4), USA (3), Canada (1), Australia (1), Europe (10), Japan (2), Brazil (1), Taiwan (1). Three studies in Asia considered both developed and developing countries. The modes considered were diverse, and whilst some studies focus on specific modes others on urban transport as a whole. Four themes of attitudes that influenced mode choice emerged from the review of literature along with evidence that demographic characteristics should not be neglected. Considering these four themes and demographics 8 studies covered at least 2 of the five, and 9 covered three. The study in California covered demographic influences along with attitudes regards accessibility, convenience, and safety but not the environment. A study of bikes in Ireland considered demographic influences along with attitudes to environment, accessibility, and safety but not convenience. Both these studies were in developed countries. A study in Ghent of all modes considered demographics alongside all four attitude themes as did a study in Bangkok however the latter focused on urban rail and walk as did all 9 publications available on mode choice influences in developing countries. Given that only one study has studied all modes, themes, and demographics in a developed city, and the Bangkok studies neglected modes other than rail and walk this state-of-the-art review reveals the research gap:

*The study in developing countries context that combined attitudes considering environment, accessibility, convenience, and safety was limited.*

which was addressed in this thesis.

Table 2.1 Summary of research papers in different research areas related to travel behaviour.

| Author's | Year | City, Country | Transport Mode | Research Areas | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Environment | Accessibility | Convenience | Safety | Demographic |
| **Developing Countries** | | | | | | | | |
| Townsend and Zacharias | 2009 | Bangkok, Thailand | Walk, Urban rail | | • | • | | |
| Prasertsubpakij and Nitivattananon | 2012 | Bangkok, Thailand | Walk, Urban rail | | • | • | | • |
| Ashalatha et al. | 2013 | Thiruvananthapuram City ,India | Bus , Car , Motorbike | | | | | • |
| Wang et al. | 2015 | Beijing, China | Car, Urban rail | • | | | | |
| Noichan and Dewancker | 2018 | Bangkok, Thailand | Walk, Urban rail | | • | • | | |
| Korzhenevych and Jain | 2018 | India | Urban transport | | | | | • |
| Pongprasert and Kubota | 2018 | Bangkok, Thailand | Walk, Urban rail | | | • | | • |
| Sarkar and Mallikarjuna | 2018 | Agartala, India | Walk, Urban rail | | • | • | | • |
| Fraszczyk et al. | 2019 | Bangkok, Thailand | Urban rail | • | • | • | • | • |
| Narupiti | 2019 | Bangkok, Thailand | Walk, Urban rail | | | • | | |
| Witchayaphong et al. | 2020 | Bangkok, Thailand | Walk, Urban rail | | • | | | • |
| Ozawa et al. | 2021 | Bangkok, Thailand | Walk, Urban rail | | • | • | | • |
| Ayaragarnchanakul and Creutzig | 2022 | Bangkok, Thailand | Walk, Urban rail | | | • | | |
| Thibenda et al. | 2022 | Indonesia & Vietnam | Motorised mode | | | | • | • |
| **Developed Countries** | | | | | | | | |
| Polk | 2004 | Sweden | Car | | | | | • |
| Handy et al. | 2005 | California, USA | All transport modes | | • | • | • | • |
| Anable | 2005 | UK | Car | • | | | | • |
| Shen et al. | 2008 | Osaka, Japan | Urban transport | • | | | | • |
| Shiau | 2013 | Taiwan | Urban transport | | • | • | | |
| Mullan | 2013 | Dublin, Ireland | Bike | • | • | | • | • |
| Acker et al. | 2014 | Ghent, Belgium | Private & Public transp. | • | | • | | • |
| Cao and Ettema | 2014 | Twin Cities, USA | Urban rail | | • | • | • | |
| Kamargianni et al. | 2015 | Cyprus | Walk , Bike, Shuttle bus | | | | • | |
| Chng et al. | 2015 | London, UK | Walk, Urban rail | | • | • | | • |
| Şimşekoğlu et al. | 2015 | Norway | Car | | | • | • | • |
| De Vos et al., | 2016 | Ghent, Belgium | All transport modes | • | • | • | • | • |
| Molin et al. | 2016 | Netherlands | All transport modes | • | | • | | • |
| Xia et al. | 2017 | Adelaide, Australia | Urban transport | • | | | • | • |
| Bouscasse et al. | 2018 | France | Urban transport | • | | | | |
| Bösehans and Massola | 2018 | São Paulo | Bike | | | | • | • |
| Ali et al. | 2018 | UK | Walk, Urban rail | • | | | | • |
| Saw et al. | 2019 | Tyne and Wear, UK | Urban rail | | • | • | | • |
| Bösehans and Walker | 2020 | UK | Urban transport | • | | • | | • |
| Tran et al. | 2020 | Nagoya, Japan | Urban transport | • | | | | |
| Ryu | 2021 | Winnipeg, Canada | Car, Bus | • | | | | • |
| Oña et al. | 2021 | Spain | Private and Public transport | | | • | | • |
| Tyndall | 2022 | USA | Bike | • | | | | • |
| **Developing and Developed Countries** | | | | | | | | |
| Van et al. | 2014 | Asia | Urban transport | • | | • | • | |
| Kumagai and Managi | 2020 | Asia | All transport modes | • | | | | • |
| Vichiensan and Nakamura | 2021 | Bangkok, Thailand and Nagoya, Japan | Walk , Urban rail | | • | • | • | • |
| Total **40 studies** | - | - | - | 17 | 15 | 22 | 12 | 29 |

## 2.4. Defining modes of transport

Urban transport plays a crucial role in connecting people within conurbations as well as surrounding towns and cities. Transport modes are categorised in many ways including public and private transport, fixed route, flexible route, and active or motorised transport. Firstly, private transport includes cars and motorcycles fulfilling the criteria that the vehicle is owned by the driver. Private cars include petrol, diesel, electric, and hybrid cars whilst motorcycles use petrol as a fuel source. The benefit of private transport is that it is available to drive anytime and anywhere for insured drivers. Secondly, public transport, owned mostly by the state/local governments but also privately, is a system available for use by everyone. However, access is governed by the routes, stop locations, frequencies, and times of day when services operate. Bus services share road space with private cars and therefore are subject to delays due to congestion. However, with frequent stopping and penetrating urban areas tend to be more accessible. Mass transit, such as heavy rail operates on dedicated track and therefore is safer and less prone to recurrent congestion delays. However, the distance between stops/stations is longer, therefore less accessible and the faster speeds mean they are more aligned with long-distance journeys for commuting. Light rapid transit, LRT, on dedicated tracks on existing roads in urban areas offers the benefits of transporting more people with less congestion delay as in heavy rail and the more frequent stopping and easy access afforded by the bus. Flexible route services or demand responsive transport, DRT, is relatively fast (very few stops) and more comfortable and allow the passenger to set the origin and destination of their trip. DRT provides passengers with a door-to-door service and the driver and passenger agree on the route and fare which depends on distance and time in advance. Paratransit mostly connects residential areas via alleys or villages to main roads, and local business areas including shopping malls or markets. Its function is similar to a bus, with specific routes and stops. Active transport including cycling and walking is the most environmentally friendly option and affords health benefits. Whilst providing the freedom of when and where trips take place they are limited to the speed of travel and the meteorological conditions.

In this thesis, for the purpose of the research employing choice modelling, the modes of transport are grouped as private transport, active transport, and public transport as presented in Figure 2.1.

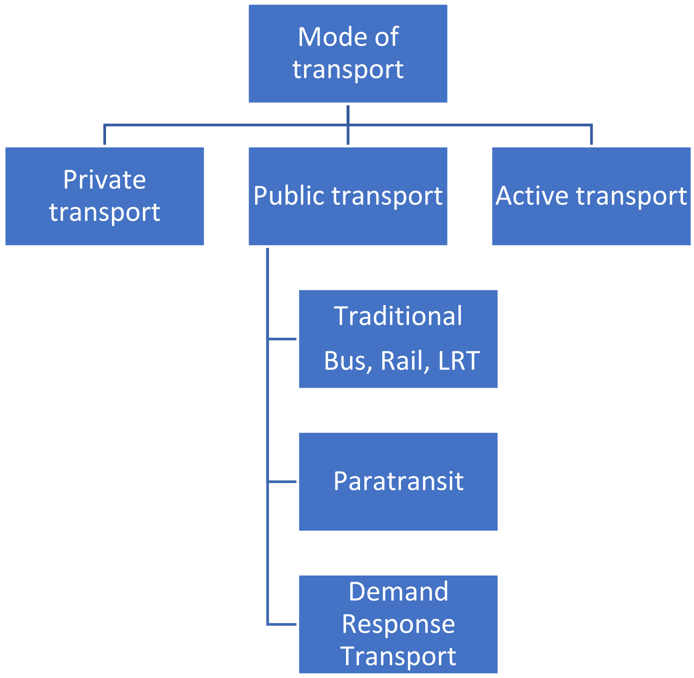



Figure 2.1 Summary of transport categories

The advantage of public transport systems is that they are more sustainable moving more passengers per kilometre travelled. de Oña *et al.* (2021) studied public transport from the private vehicle users' perspective in two cities in Spain in 2019 demonstrated the contribution of public transport to reducing traffic congestion, reliability as well as savings in cost and time. The study of public transport in large cities in China by Wang *et al.* (2015) showed that carbon dioxide emission per passenger was significantly less than that of private cars. Private cars, particularly fossil-fuelled cars, were the major contributor to carbon emissions and policies should focus on mode shift to more sustainable mode choices. Shiau (2013) developed the hierarchy for local government to deliver sustainable transport policy in the city, of Taipei. The critical factor was promoting travel by public transport which is widely known to have less impact on the environment. However, crucially an understanding of how the policies identified align with the attitudes and factors that influence travellers' choice of mode(s) would help to ensure successful implementation.

## 2.5 Case study: Bangkok transport modes

Bangkok is the capital city of Thailand and a province of the Bangkok Metropolitan Region (BMR) which also includes Nonthaburi, Samut Prakan, Pathum Thani, Nakhon Pathom, and Samut Sakhon. In 2019, the population of BMR was 10.8 million people (BMA, 2019), which was higher than Greater London with 9 million people (Statista, 2024b). Comparatively, the city of London has a higher population density than Bangkok province due to its smaller area. The retirement age in Thailand in 2019 was 60 years old, similar to other cities in Southeast Asia, whereas in the UK, it was set at 65 years old, whilst in 2024 it is 66 years due to rise to 67 years over the period 2026-2028.

Both cities operate in different economic context, the GDP of Thailand in 2022 according to the World Bank report was 495 billion USD whilst the GDP of the UK was significantly higher at 2.53 trillion USD (World Bank, 2022). The currency in the BMR was Thai Baht (THB) and in London British Pound Sterling (GBP). The exchange rate after the 1997 economic crisis, fluctuated based on the market condition with 1 GBP being approximately 40 – 55 THB (Statista, 2024a). Therefore, in this thesis, the exchange rate of 1 GBP to 40 THB was used. In 2022, the minimum wage of Bangkok was 300 THB compared to 7.5 GBP per day in London.

Transport systems are governed by many factors including topography, geography, climate, government, politics, economic status, and history, and therefore have different characteristics in cities within countries and between countries. Given this research is focusing on a study of Bangkok for completeness further details of the urban transport systems available are provided here. Therefore, the categories of transport modes were grouped differently. Narupiti (2019) suggested categorisation for modes of transport in the Bangkok Metropolitan region namely conventional, paratransit, and new mobility. Whilst *The Thailand Household Survey* study carried out by the Office of Transport and Traffic Policy and Planning (2018) and researched by Prasertsubpakij and Nitivattananon (2012) categorised modes in the BMR as private transport, public transport, and paratransit. For this study, public transport is grouped also into three sub-categories namely traditional public transport (bus, urban rail, ferry), paratransit (microbus, van), and demand response transport (DRT) as detailed below.

**Public Transport**

- Bus

The bus system served as a vital mode of transport for passengers in Bangkok. The network had 309 routes covered across the metropolitan area with affordable prices to travel around the city (BMTA, 2023). Two types of buses found in Bangkok were air-conditioned buses and non-air-conditioned buses, see Figure 2.2. The bus system faced several challenges including traffic congestion, and unreliability. During peak time, specifically evening peak, the significant issue is traffic congestion which causes delays and unreliable service. In addition, the lack of real-time information on the schedule such as the upcoming bus, location of the bus, and route could lead to the issue that was difficult to plan effectively. To address this problem, Bangkok Mass Transit Authority (BMTA) introduced GPS tracking and a mobile application for real-time information which launched in 2023 (BMTA, 2023) and expanded the fleet to meet the demand. In 2020, the ticket price for a non–air conditioned bus was fixed at 8 THB (0.2 GBP) per single leg while air-conditioned bus ticket ranged from 13 THB (0.35 GBP) to 25 THB (0.6 GBP) per single leg.


Figure 2.2 Buses operated in BMR area (source : Prachachat News (2022))

- Urban Rail

Urban rail or metro system includes Sky train (train on segregated track above road level) and the subway underground. There are three main operators in Bangkok namely Bangkok Skytrain (BTS) and Metropolitan Rapid Transit (MRT), see Figure 2.3 and Bangkok Airport Rail Link (ARL). The routes of the BTS, MRT, and urban rail lines are shown in Figure 2.4. The BTS has been in operation since 1999 and started only light green, green line (BTS, 2020). In 2004, MRT start operated in which started with the blue line. ARL connected the centre of Bangkok and Suvarnabhumi Airport commenced operation in 2010. While other routes have been under construction until 2030, full service of urban rail operation as the core of public transport will cover the BMR area. The benefits of urban rail include convenience and reliability, however, the ticket price is high and therefore not affordable for everyone (Ongkittikul and O-Charoen, 2021).

**(a)** **(b)**

Figure 2.3 Example of urban train in Bangkok such as (a) MRT (left) and (b) BTS (source : BTS (2020))

- Mainline train

The mainline train has operated since 1890 by the State Railway of Thailand (SRT). The mainline trains connected Bangkok with other provinces, offering both passenger and freight services. The Grand Central Station located in the north of Bangkok was the hub of mainline train network. The inexpensive ticket prices, started from 5 THB (0.10 GBP) and the good connectivity within the inner and northern regions of Bangkok result in high seasonal passenger occupancies. This is despite issues such as slow speeds, and poor accessibility leading to inconvenience and unreliability causing delays, all of which makes the system less attractive for commuters compared to other modes of transport. The lack of modernisation has resulted in a relatively small market share of mainline journeys, being only 5% compared to other rail systems in Bangkok (Department of Rail Transport, 2024). Fare prices are quoted in 2024 prices in all cases.

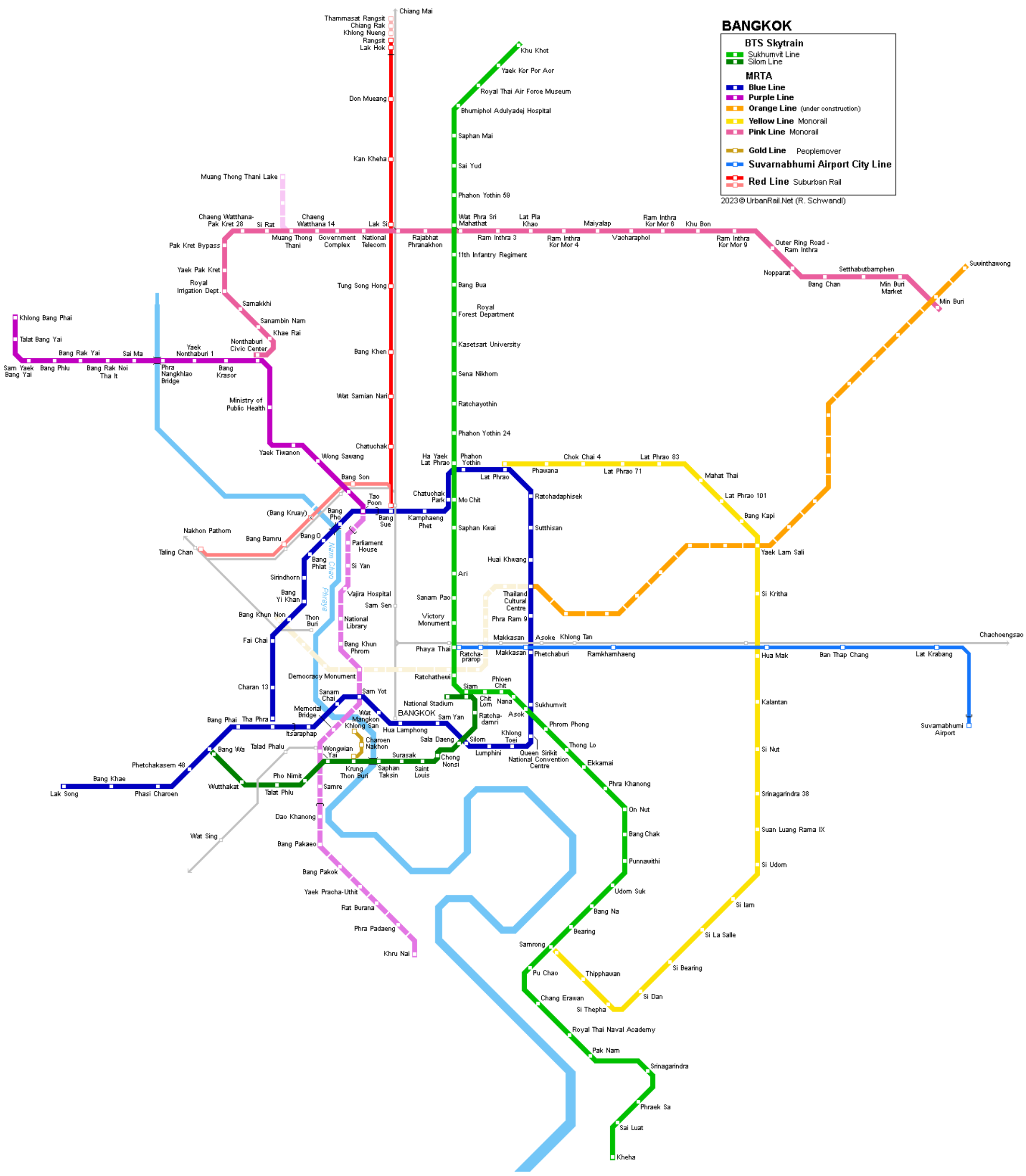


Figure 2.4 Bangkok rapid mass transit map 2023 (Source : Schwandi (2023))

- Ferry

Ferry or boat-bus are mostly found on the Chao Praya River which is the main river passing north to south through Bangkok. Ferry stops are located along the route. Some routes are operated by private companies. This is a faster way of travelling compared to a bus as travellers can avoid all traffic congestion and shorter distances are travelled, however, origins and destinations are constrained to those within acceptable access distance to the passenger terminals along the shores of the river. The ticket price is fixed depending on the type of ferry, for example the **express** service tickets start from 30 THB (0.85 GBP) whilst the **least expensive** ferry would cost 14 THB (0.35 GBP).

**Paratransit**

- Shuttle bus

Shuttle buses operated along the specific routes connecting key locations such as urban train stations to universities, and transport hubs. Buses often run at regular intervals to offer prediction for example, an internal shuttle bus provided by the university services all areas of the university connecting from the main gate (bus stop), and urban train station to a variety of faculties. This service was free of charge but limited the service area, as presented in Figure 2.5.


Figure 2.5 Internal shuttle bus travelling within Kasetsart University

- Microbus (van)

A popular mode of transport connecting the outskirts of Bangkok to other backbone public transport services is presented in Figure 2.6(a). Vehicles usually have 12 but up to 15 seats (Siangsuebchart *et al.*, 2021). Mostly, microbuses have only 2 or 3 main stops on each route and therefore are faster than buses. The ticket price was a flat rate of 25 THB (0.6 GBP) per leg.

- Song Taew

Song Taew and Ka Por are small trucks or pick-ups which have seating for up to 12 passengers and the vehicle is covered with canvas for shelter, as presented in Figure 2.6(b). The ticket price is set at 10 THB (0.25 GBP) per leg.

(a) (b)

Figure 2.6 Example of paratransit public transport in BMR ((a) van (b) Song Taew)

**DRT**

DRT modes found in Bangkok include conventional taxi, motorcycle taxi and three-wheel motorcycle taxi called, Tuk Tuk, presented in Figure 2.7. Taxis and motorcycle taxis are used for single trips and as feeder services into main public transport services. They play a crucial role in Bangkok and represent a fairly inexpensive personal travel option. Figure 2.7(c) is a shuttle bus which operates within Kasetsart University. Shuttle buses are free of charge at the expense of the university, but other employers provide shuttle buses to transport employees to and from home and the workplace. The cost of DRT varies with distance and typically is to 20 THB (0.5 GBP) per km.

The advantages and disadvantages of public transport types in Bangkok are presented in Table 2.2.


(a)

(b)


©

Figure 2.7 Example of DRT public transport in BMR ((a) motorcycle taxi and air-conditioned bus, (b) taxi , and (c) Tuk Tuk )

Public transport in Bangkok is diverse and offers alternatives to its citizens. However, accessibility to transport services is not equitable, being driven by affordability, availability, and accessibility amongst other factors. The ticket prices of public transport options presented above were per leg and per mode. The main public transport services included bus, urban train are mostly accessed as a second mode therefore passenger required to walk or use DRT or paratransit which they had to pay for the first/last mile services separately. In addition, the price is per mode per leg. Therefore, the total cost of transport from the origin to the destination is expensive. For example, if a passenger travelled by bus A, then transferred to bus B after that took a motorcycle taxi C to the destination, the passenger was required to pay a separate ticket for bus A, bus B, and motorcycle Taxi C. It is accepted worldwide that public transport is fundamental to sustainable travel in the future and since 2012 the Thailand government has increasingly invested in environmental protection in Thailand (Bank of Thailand,2022) as in developed countries such as the UK (Office for National Statistics (UK),2022) and Israel (Israel Central Bureau of Statistics,2023). Therefore, the research presented in this thesis seeks to better understand the factors that influence the mode choice of Bangkok citizens to help inform future policy.

Table 2.2 Advantage and disadvantage of public transport in BMR

| **Mode of transport** | **Advantage** | **Disadvantage** |
|---|---|---|
| **Traditional public transport** | | |
| Urban rail | - Fast<br>- High reliability<br>- Good safety record<br>- Convenient | - Expensive ticket price |
| Mainline train | - Reasonable ticket price | - Unreliable<br>- Uncomfortable |
| Bus | - Reasonable ticket price | - Poor safety record<br>- Unreliable due to road traffic |
| Ferry | - Fast<br>- Reasonable ticket price | - Inconvenient serving specific areas |
| **Paratransit** | | |
| Song Taew, Kapor | - Fast<br>- Convenient | - Poor safety record<br>- Operate in specific areas |
| Microbus (van) | - Fast | - Poor safety record |
| Shuttle bus | - Direct to the destination | - Fixed route<br>- Limited-service area |
| **Demand responsive transport** | | |
| Tuk Tuk | - Door to door travel | - Poor safety record<br>- Travelling area limit |
| Taxi | - Door to door travel<br>- Fast<br>- Convenient | - Fare depends on duration and distance |
| Motorcycle taxi | - Door to door travel<br>- Fast | - Poor safety record |

## 2.5. Conclusions of this chapter

Previous research, as explored in this chapter, has endeavoured to demonstrate the importance of mode shift from private vehicles to public transport as a necessary step towards NetZero. Furthermore, the need to not only understand the attitudes that influence the mode choices of citizens but also the interplay between them. Four themes namely environmental awareness, accessibility, convenience, and safety to categorise the attitudes that emerged from the previous research, and demographic characteristics were found to play an important role in travel behaviour.

Another interesting finding was that most research on mode choice behaviour embracing all modes of urban transport has been carried out only in developed countries and fewer studies in developing countries have focused on one or two themes and modes.

Therefore, the global aim of the research presented in this thesis is:.

*to understand the attitudes and perceptions that influence mode choice, to inform sustainable transport policy, and maintain and grow the current use of public and active transport.*

The research is conducted in Bangkok, Thailand considering demographic characteristics, all four attitude themes, and across all modes of transport including single and multi-modal journeys. Details of the range of transport options available in the Bangkok Metro Region (BMR) area have been presented which together offer a unique set of transport choices. The next chapter outlines the range of approaches to collecting and analysing mode choice data.

# Chapter 3. Methodological Review

## 3.1. Introduction

In the previous chapter critically reviewed previous literature related to challenging in the global problem and the future goal for sustainable transport, key influence on attitudes and travel behaviour with 4 themes and sociodemographic, and definition of mode of transport. This chapter will focus on a review of the methodologies that can be used to analyse attitudinal, travel behaviour, and their background. Attitudinal data in general is categorical data however, continuous data allowed more detail of additional data related to travel behaviour and demographic.

In this chapter, Section 3.2 discussed about the methodological that applied for dimension reduction analysis. Then, Section 3.3 explores methodological approaches for categorised data used in the previous research. Mathematical methods of modelling travel behaviour are then discussed in Section 3.4 Final section, Section 3.5 presents a conclusion of this chapter.

## 3.2. Research Design Approach

Research design in general can be divided into two main approaches, qualitative and quantitative. Qualitative approaches aim to capture and analyse data/information that is non-numerical to gain understanding of attitudes and social characteristics. Methods include interviews, focus groups, qualitative observation, and open-ended questionnaires. Notwithstanding, qualitative methods need to be structured, controlled and designed to meet research objectives. Qualitative analysis helps to not only understand what the issues are but also enhances deductive analysis methods based on Natural Language Processing (NPL), collating data into sentiments, word clouds, charts, cross tabulations. The summary or conclusion of qualitative study based on data then analysis with statistic (Johanna Zmud *et al.*, 2013). On the other hand, quantitative data collection and analysis methods by virtue of its label involves numerical data. Quantitative methods include structured surveys with closed questions with scaling including ordered or continuous, recordings to extract numerical data, direct observation counting. Data collected can be analysed with exploratory or more advanced statistical methods including factor analysis, principal component analysis, cluster analysis, and multiple logistic regression. The benefits of quantitative compared to qualitative research included they are based on more reliable numeric data to which statistical tests and mathematical distributions to derive models. Results can be applied to larger populations. Furthermore, as well as more precise outputs the data collection can be faster, more efficient and less labour intensive given the potential to use on-line platforms for circulation of the questionnaires. The number of samples available and their representativeness of the total population is fundamental to providing the quality of research. This tends to be achieved more effectively with quantitative compared to qualitative methods. In addition, ethical issues and sample bias can be a drawback of quantitative studies, however these can be minimised by checking representativeness against the total population using a Chi square test and being proactive in collecting further data from targeted populations. Ortúzar and Willumsen (2024) provided an algorithm to estimate sample size to achieve statistically significant results and examples of case studies that achieved statistical results by collecting sufficient numbers of samples (Ali *et al.*, 2018; Bösehans and Walker, 2020; Chonnipa *et al.*, 2022; Tyndall, 2022).

The popular technique for qualitative research included interviewing, unstructured questions, and opened end questions. The benefit of qualitative studies is that a smaller number of samples is required and provide the freedom to explore the answers to a set of pre-defined structured questions. However, the interviewer and researchers require a high level of knowledge for interpreting and understanding the data without bias. The qualitative study by Berg *et al.* (2015) which focused only on 24 newly retired car drivers in Swedish.

Mixed methods approach combines the benefits from both types of research. Either first conducting focus groups or direct interviews, which are often recorded, and subsequently analysed for example with NPL to explore the themes relevant to the subject area. The themes can then form the basis for the questions to be included in a questionnaire used subsequently in a quantitative study. Another approach would be to explore a high-level overview of the sample in a particular field using a quantitative questionnaire and then to carry out interviews, or carry out focus groups involving a smaller targeted sample to explore the "why" thus providing a better overall result (Mullan, 2013; Joachim *et al.*, 2024). However, mixed methods require more time and resources compared quantitative research study.

In this study, a quantitative approach using a comprehensive questionnaire based on a thorough literature review was adopted. The questionnaire included Likert scaling (ordinal data) to collect data on attitudes as well as demographic data to understand the characteristics of commuters with similar and different attitudes that influence their choice of travel mode. Interviews were carried out using the same questionnaire as that posted online to ensure that the sample was representative and of a size to ensure statistical significance of the results.

## 3.3. Method used for dimension reduction - Principal component analysis (PCA)

The first step of the main analysis was to conduct dimension reduction to reduce the number of attitudinal variables into a manageable number of components for subsequent use in cluster analysis. Common dimension reduction techniques include Factor Analysis (FA) and Principal Component Analysis (PCA) both are dimension reduction technique that applied with large dataset.

While the former assumes the existence of underlying latent factors that explain the data, PCA is primarily concerned with capturing as much of the variance in the data as possible without making any assumptions about underlying constructs. Therefore. PCA assumes the relationship between as linear (Jolliffe, 2002). The FA method, however, assumes that the factors cause the observed variables. In this respect, FA is used for data interpretation to capture the more complex relationships within the data. Examples of studies that used FA to reduce the attitudinal variables include (Bösehans and Walker, 2016; Ali et al., 2018; De Vos et al., 2019). The output of FA and PCA called “factor” and “component”, respectively.

In the present study, whilst focusing on the four themes that were chosen earlier in the research, for instance environment, accessibility, convenience, and safety, the authors made no assumptions about the structure of factors. This can be concluded that there were no underlying relationships, hence adopting a data-driven approach. Consequently, PCA was considered appropriate for the dimension reduction of the sample data and thus to combine those attitudinal variables with similar responses. Examples of studies that use PCA include Thibenda *et al.* (2022) who reduced the 60 variables to 5 components. Bösehans et al. (2021) applied CATPCA, Categorical Principal Component Analysis to attitudinal data collected with the data because the type of choice in the questionnaire that was categorical variable, **a 7-point** Likert scale. As the relationships between variables were non-linearly related, variables had different measurement levels, nominal, ordinal and numeric therefore CATPCA is a statistical method which can achieve both the reduction in dimensionality at the same time as quantifying categorical variables and therefore CATPCA was appropriate for this study. Therefore, PCA was proper for the data set that were continuous variable while CATPCA was suitable for categorical data set.

The interpretation of the outputs from the components can be improved by slightly moving the PCA axes relative to the original variable axes (rotation) whilst at the same time maintaining the *'lack of correlation'* referred to as the orthogonality. Therefore, rotation of the component solution was carried out to optimise factor loadings for easier interpretation. Two ways to rotate related data types are orthogonal and oblique (non-orthogonal) rotation. Orthogonal rotation produces uncorrelated factors while oblique rotation allows factors to be correlated. Orthogonal rotation methods include Varimax, Equamax and Quartimax, whilst oblique rotation methods include Promax and Direct Oblimin rotation. Thibenda et al. (2022) used the rotation for the case study to improve the interpreting data.

The suitability of the data for factor analysis was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity which assessed the strength of relationships between variables, while Bartlett's test verified the significant correlations among all relationships of variables. This approach ensured that the data possessed the necessary characteristics for component deduction.

Table 3.1 Examples of studies using dimension reduction.

| Authors | Years | Topics | Details of the research (Objectives) | PCA | FA | Statement → result |
|---|---|---|---|---|---|---|
| Ali et al. | 2018 | Cluster Analysis, MLR, environmental awareness, sociodemographic | This study explored car users' attitudes by using National Survey Data (2011 and 2014). The questions asked included attitudes toward transport. Cluster analysis was used to classify user type by transport modes, travel behaviour such as frequency of use public transport, and socio demographic such as gender, age, car ownership, working status. | | √ | 11 → 3 factors |
| Thibenda et al. | 2022 | MNL; Attitudes;<br><br>Safety; Jakarta; Hanoi; PCA; Economics;<br><br>Cluster Analysis; | Studied the relationship between young adults' and teenagers' perceptions towards vehicle type and driver behaviour influencing road safety.<br><br>In this study PCA was used to group variables generated from the questionnaire and MLR to examine the association between driver cluster and their road safety perception. Data was collected in surveys carried out in Jakarta and Hanoi. | √ | | 60 → 5 comp |
| De Vos et al | 2019 | Active transport, Cycling, walking, satisfaction | The result showed that measures taken to improve attitudes towards use of active transport have different outcomes for different travellers. Active transport travellers tend to continuous use their mode in the future. Additionally, built environment also improve their satisfaction, this highlighted the need of interventions to promote users' experience during the trip specifically active transport. | | √ | 9 → 3 factors |
| Bosehans and Walker | 2016 | Active transport, public transport,<br><br>student, attitude | The questionnaire explored the attitudes to public transport with 50 variables. FA was applied to reduce number of variables to 4 factors. Then clusters were identified from the characteristics within the factors and attitudes. The characteristics of the resulting clusters were used to inform policy. | | √ | 50 →4 factors |

## 3.4. Method used for data structures with socio-demographic attitudinal statement and travel behaviour- data clustering.

The Segmenting Method is a data analysis technique that is used to divide a dataset into smaller subgroups or "*segments*" based on common patterns or characteristics. The benefit of segmenting is to help the reader to identify specific characteristics of each cluster to improve understanding of the data holistically. The most common methods applied to the data include demographic, geographic and behavioural segmentation. Cluster Analysis is a technique used in segmentation as it groups data with similar characteristics. Cluster analysis methods include K-mean and Hierarchical Cluster Analysis, HCA. K–mean cluster analysis is suitable for a dataset with a known number of clusters while HCA has the advantage of estimating the number of clusters by identifying similarities within and differences between the groups of data identified. There are two types of HCA namely agglomerative and divisive. The agglomerative technique starts with each data stream as a cluster and merges data items into groups whilst divisive starts with a single group and splits the data into smaller clusters. HCA uses distance measures between objects and clusters and examples include Euclidean, Manhattan and Maximum distance. Different linking methods include single-linkage, complete-linkage, and Ward's method. Single linkage formed the cluster based on the closest neighbour. However, this technique is very sensitive regards outliers which form the new cluster. On the other hand, complete-linkage captures outliers effectively making it suitable for well-separated clusters. Ward's method lies between single-linkage and complete-linkage and minimises the variance within a cluster using the sum of the squared distance between the centre of gravity of the cluster and individual data streams. This method differs from the average-linkage method which calculates the average distance. Ward's method is effective in handling large datasets joining clusters with a similar number of observations and is sensitive to outliers. The agglomerative method of HCA is preferred because the computation is faster given that the divisive method considers $2^{n-1}$-1 iterations.

In this thesis agglomerative, HCA was conducted using SPSS which produces the table of the agglomerative coefficients which are plotted in a graph against the number of clusters. Defining the number of clusters to some extent is subjective but occurs at the point where the change in slope of the plot increases rapidly and is referred to as the elbow method.

Another method to identify number of clusters was using dendrogram. A dendrogram illustrates the collation of data items within, and the hierarchical structure between, the clusters. Similarly in divisive HCA the dendrogram shows diagrammatically how the total data has been separated into clusters. This method is quick as an overview analysis however this method can be ambiguous if the separation distance of the clusters is low. Another method to investigate the “optimal” number of clusters was the Silhouette measure. The Silhouette measure assesses how well a specific point fits into the allocated cluster and how distinct it is from the other clusters. In other words, it is a measure of the similarity within, and the separation between the clusters. The output of this method gives a score from -1 to 1 such that (-1 to 0) means poor, (0 to 0.5) fair and (0.5 to 1) good (IBM, 2024). However, this method required pre-screening of a range of number of clusters. Often, the number determined the Silhouette, dendrogram and the agglomerative table are considered together in defining the “optimal “number of clusters. Previous studies that have used Ward ‘s method are summarised in Table 3.2, where the sample size and the cluster number are given (Bösehans and Walker, 2016; Ali *et al.*, 2018; Crawford, 2020; Burke *et al.*, 2022; IQ Air, 2023). Some studies used the background and attitudinal component from dimension reduction as criteria for cluster identification (Bösehans and Walker, 2016)(Ali *et al.*, 2018). The studies with large population used two stage cluster analysis as pre-screening number of cluster, then the data were found the relation between distance and data by using the hierarchical to identify number of cluster (Crawford, 2020; Burke *et al.*, 2022).

Table 3.2 Example of study using cluster analysis.

| Authors | Years | Keywords | Details of the research (Objectives) | Number of Clusters | Number of Population |
|---|---|---|---|---|---|
| Crawford | 2020 | Segmentation, travel behaviour, commuting, pattern change | This paper analysed the change in the patterns of commuting over 19 years between 1998 and 2016 in England. The resulting clusters revealed types of commuter travellers namely *infrequent, spatially variable, temporally variable, and regular*. The number of regular travellers in 2016 was found to be lower than in 1998. Also, the research informed the decision making of the design and provision of policies and intervention measures to address transport problems such as traffic congestion by road user charging to reduce the volume of traffic during peak times. | 4 | 118,194 |
| Burke et al | 2022 | Segmentation, travel behaviour, cycling, pattern flow | This study focuses on the comparison of diurnal cycling flow profiles in the year pre- with post- COVID19 pandemic in the UK. The result showed the number of people cycling to work after pandemic was lower. Five clusters were identified from the pattern of diurnal cycling flow namely *evening only, midday steady, traditional commute, late morning peak, and mid-morning peak*. An outcome from this study was support for a policy to improve the cycling for leisure may realise more benefit compared to cycling for commuting. | 5 | 8741 |
| Bosehans and Walker | 2016 | Active transport, public transport, Travel Behaviour, Ward's method | This paper explored the motives and experiences of bus users at a UK university to identify subgroups that could be encouraged to adopt healthier, more sustainable travel modes. The analysis identified six distinct bus user types potentially open to active travel, while the more committed bus users could benefit from improvements to public transport services. The clusters are labelled depending on the characteristics including age, gender, transport modes, attitudes and were labelled *Mode Mixers, Wannabe walkers, All Fine on the Western Front, First Fan, Car Curtailed and Daily Drags*. The paper recommended that policies should be customised to align with the characteristics of the clusters to maximise the outcome of the policy. | 6 | 256 |

| Authors | Years | Keywords | Details of the research (Objectives) | Number of Clusters | Number of Population |
|---|---|---|---|---|---|
| Ali et al. | 2018 | Cluster Analysis, MLR, environmental awareness, sociodemographic | This study explored car users' attitudes by using data from the National Survey (2011 and 2014). Cluster analysis was used to classify user type by transport modes, travel behaviour such as frequency of use of public transport, and socio demographic including gender, age, car ownership, work status. The result showed that middle-aged full-time workers and retired males in 2014 tended to hold a more positive attitude towards climate change compared to 2011. The study recommended that interventions tailored for different age groups may encourage a shift away from private transport modes. | 7 | 5314 |

## 3.5. Method used for exploring the relationship of travel behaviour considered attitudinal data and sociodemographic.

Multinomial logistic regression (MLR) was a statistical model to clarify the relationships between dependent which is nominal and one or more continuous variables. Regards to Ben-Akiva and R. Lerman (1985), n referred to an individual related to every travel mode in the choice set. Level $j$ $(j \in 1, 2, \ldots, i-1, i+1, \ldots n)$ and $k$ $(k \in 1, 2, \ldots, i-1, i+1, \ldots, n)$ are two levels, $j$ is reference level. $\theta_j = P, y = \frac{j}{x}$ is the reference conditional probability that an individual chose alternative $j$. $\theta_k = P, y = \frac{k}{x}$ is the conditional probability that an individual chose alternative $k$.

The MLR model defined by Ben-Akiva and R. Lerman (1985) were applied

$$ln\left[\frac{\theta_k}{\theta_j}\right] = In\left[\frac{P\left(y = \frac{k}{x}\right)}{P\left(y = \frac{j}{x}\right)}\right] = \alpha_k + \beta_{k1}(x_1) + \beta_{k2}(x_2) + \cdots + \beta_{km}(x_n)$$

Equation 3.1

$$= \alpha_k + {}_{k=1}^{m}\beta_{kn}(x_n)$$

$$k \in 1, 2, \ldots, i-1, i+1, \ldots, n$$

$\theta_k$ is the conditional probability that an individual chose alternative $k$ ;
$\theta_j$ is the reference conditional probability that an individual chose alternative $j$ ;
$x_i$ is the independent variable $i$ ;
$n$ is the number of independent variables ;
$\alpha_k$ is the estimated intercept;
$\beta_{kn}$ is the estimated coefficient.

Ali et al. (2018) adopted MLR to capture the relationship between clusters and attitudinal variables comparing the changes from 2011 – 2014 presented in Table 3.2. However, this study considered two factors which emerged from the FA. Wedagama and Dissanayake (2010) developed an MLR model to show the relationships between attitudes and driver background linked to the type of accident. MLR model can be provided the probability of transport mode preference related to their background (Nutsugbodo et al., 2018). The example of study by using MLR presented in Table 3.3.

The collected data in this study were combined with attitudinal variables and sociodemographic data as independent variables and nominal choice set of mode of transport as in choice set therefore, MLR was suit for this study.

Table 3.3 Example of study using MLR

| Authors | Years | Topics | Details of the research (Objectives) | Dependent variables | Independent variables |
|---|---|---|---|---|---|
| Wedagama et al. | 2009 | Attitudes;<br><br>Safety;<br><br>Fatality;<br><br>Genders;<br><br>Motorcycle; | Studied the relationship between accident related factors on the motorcyclist's accident risk level by using MLR on data collected in Bali. The study applied 3 severity classes namely slight, serious, and fatal. The result showed more than half of sides-wipe accidents were likely to be serious injury to slight injury. A vehicle-vehicle collision was more likely to be slight injuries than other level. While side -swipe accidents with motorcyclists, failed to yield collisions and motorcycles at fault impacted severity of injury. | Probability of motorcyclist accidents (chance) | Accident Types<br><br>Collision Type;<br><br>Vehicle;<br><br>Accidents Cause;<br><br>Gender;<br><br>Locations;<br><br>Time of accident; |
| Nutsugbodo et al. | 2018 | Mode Preferences; Ghana; public transport; tourists; | Examines the mode preference of international tourists using public transport around the international airport in Ghana. The study showed sociodemographic had a strong relationship with mode preference. | Mode preference | Socio demographics |
| Thibenda et al. | 2022 | Attitudes;<br><br>Safety; Jakarta; Hanoi; Economics;<br><br>PCA; Cluster Analysis; | Study showed that young adults and teenagers perceived that vehicle type and driver behaviour influences road safety.<br><br>This study analysed data collected in Jakarta and Hanoi using MLR to examine the association between driver clusters by demographics their road safety perception. | Perception of road safety | Components of PCA as perception of road safety. |

Discrete choice modelling (DCM) is one of the most useful techniques to capture the decision-making processes of travellers presented with a set of alternatives. Some of the alternatives were not selected. DCM offers a more detailed approach to understanding the behaviour by explicitly modelling the utility function for each mode. This approach identified individual preferences allowing more complexity. The discrete choice included structural equations or nested models to account for correlation alternatives.

The benefit of DCM is in providing a deeper understanding of how different attributes of the option impact choice behaviour. However, the model requires is computationally demanding. Examples of nested discrete choice modelling applied to mode travel preference is the study in Bangkok by Dissanayake and Morikawa (2002) and in Flanders by Acker et al. (2014). The models were tested for goodness-of-fit and derived algorithms that informed choices depending on attitude and sociodemographic, tested by goodness of fit.

## 3.6. Conclusion of this chapter.

This chapter presented the methodologies that applied in the previous studies aimed to find the method to use for understanding the travel behaviour related to combined attitudes. The specific technique included dimension reduction, cluster analysis, and MLR model were presented.

Two techniques of dimension reduction analysis, namely PCA and FA are the most popular methods for large data set. However, PCA was proper with continued data.

Hierarchical cluster analysis was applied with unknown number of clusters. The benefit of Ward's method was an equal number of member clusters. MLR was the model that capture the relationship between nominal dependent variable and multiple independent variables would be any type of variable.

The next chapter will discuss the methodological framework which developed based on the method that discussed in this chapter.

# Chapter 4. Methodology

## 4.1 Introduction

A comprehensive methodology review outlined in the previous chapter identified suitable methods to be applied in this PhD. Descriptive analysis, factors analysis and cluster analysis, and logistic regression modelling have been popularly employed in previous research relating to travel behaviour analysis. However, previous research has tended not to combine all these techniques in studies of the combined influence of attitudes towards the environment, accessibility, convenience, and safety on the mode choices of cohorts of the population with different characteristics. This chapter outlines the methodological approach applied in this study.

First, the methodological framework of the research provided in an overview of all steps of the study in section 4.2 which is followed by more specific details of each analytical step. Section 4.3 details the questionnaire design and data collection including, data cleaning procedures and initial data analysis to inform sample size. This is followed in Section 4.4 by in-depth exploratory analysis of total data set and attitudinal variables for input to the principal Component Analysis (PCA). Section 4.5 explores the steps in the main data analysis that includes cluster analysis (CA) using hierarchical cluster analysis (HCA), Section 4.6 and Multiple Logistic Regression (MLR), Section 4.7. Finally, Section 4.8 draws the conclusion with a summary of key findings of this chapter.

## 4.2 Methodological framework

The methodological steps in this study include Data collection and Preparation, Preliminary Data Analysis, Main Data Analysis and Conclusions, as illustrated in Figure 4.1. Data collection and preparation embraces questionnaire design and pilot to test the understanding of the questions, followed by the 1st study survey and its preliminary analysis to ensure the data collected delivers the research questions before the main survey, 2nd study was launched online supplemented by face-to-face data capture to ensure a sample representative of the Bangkok population. This first step delivers Objective 1 and is described in Chapter 5. The next step of the research is to carry out using exploratory statistics including descriptive statistics of the data variables. Next Principal Component Analysis, PCA, is carried out to remove overlaps in the attitude questions by considering the scores assigned by the respondents to reduce the 20 variables to fewer factors or components. The results are reported in Chapter 6 and achieve Objective 2. The third step uses the attitude components from the PCA along with the demographics and trip characteristics for each respondent as input to cluster analysis to establish whether the mode choice of cohorts of the population are influenced in similar ways achieving Objective 3 and reported in Chapter 7. This knowledge and understanding are important to inform policies and intervention measures which may need to be tailored to specific population groups to maximise benefits from investment. The penultimate step of the analysis, independent of the Cluster Analysis, uses the travel behaviour data along with the components emerging from the PCA as input to Multinomial Logistical Regressions, MLR, to develop algorithms which allow the distribution of modes relative to a reference to be predicted for commuter trips in Bangkok. Finally, the algorithms are used to demonstrate their use to inform policy interventions. This achieves Objective 4 and 5 and results are reported in Chapter 8. In Chapter 9 the results of each step in the analysis are discussed before conclusions are drawn before the limitations of this research and ideas for the future are described. The following sections provide further explanation of each analytical step in the research reported in this thesis.

## 4.3 Questionnaire Design and Data Collection

Themes for questions to be included in the bespoke questionnaire were informed by the literature which also helped identify the variables needed to address the research questions. The questionnaire was designed in three parts namely self-reported travel behaviour, attitudinal statements, and socio-demographics. The first established details of variables including whether a car driver, which mode(s) including active transport, car, bus, rail, taxi, motorcycle, and shuttle, they used and their travel identity, whether their trip was a single or multimodal journey and details of their trip origin and destination postcodes. The second part consisted of 20 attitudinal questions concerned with the environment, accessibility, travel convenience, and safety which were rated by the responder on a continuous scale ranging from 0 (disagree) to 100 (agree). This scoring achieved granularity in attitude responses across a wider range than a more straightforward Likert scale with 5 or 7 alternatives. The final part of the questionnaire was to collect background information of each responder and included age, employment status, educational qualification, and household vehicle ownership. The variables from the questionnaire are detailed below.

Part 1: a) Travel behaviour variables

These included the mode of transport used in their most recent commuter journey, travel time, and cost. Also, the mode with which the traveller most strongly identified themselves for example as a user of a private car, private motorcycle, pedestrian, cyclist, public transport and whether single or multimodal user.

Main_Mode =Mode of travelling

Travel_Time = Travel time

Travel_Cost = Travel cost

Iden = Travel mode identification

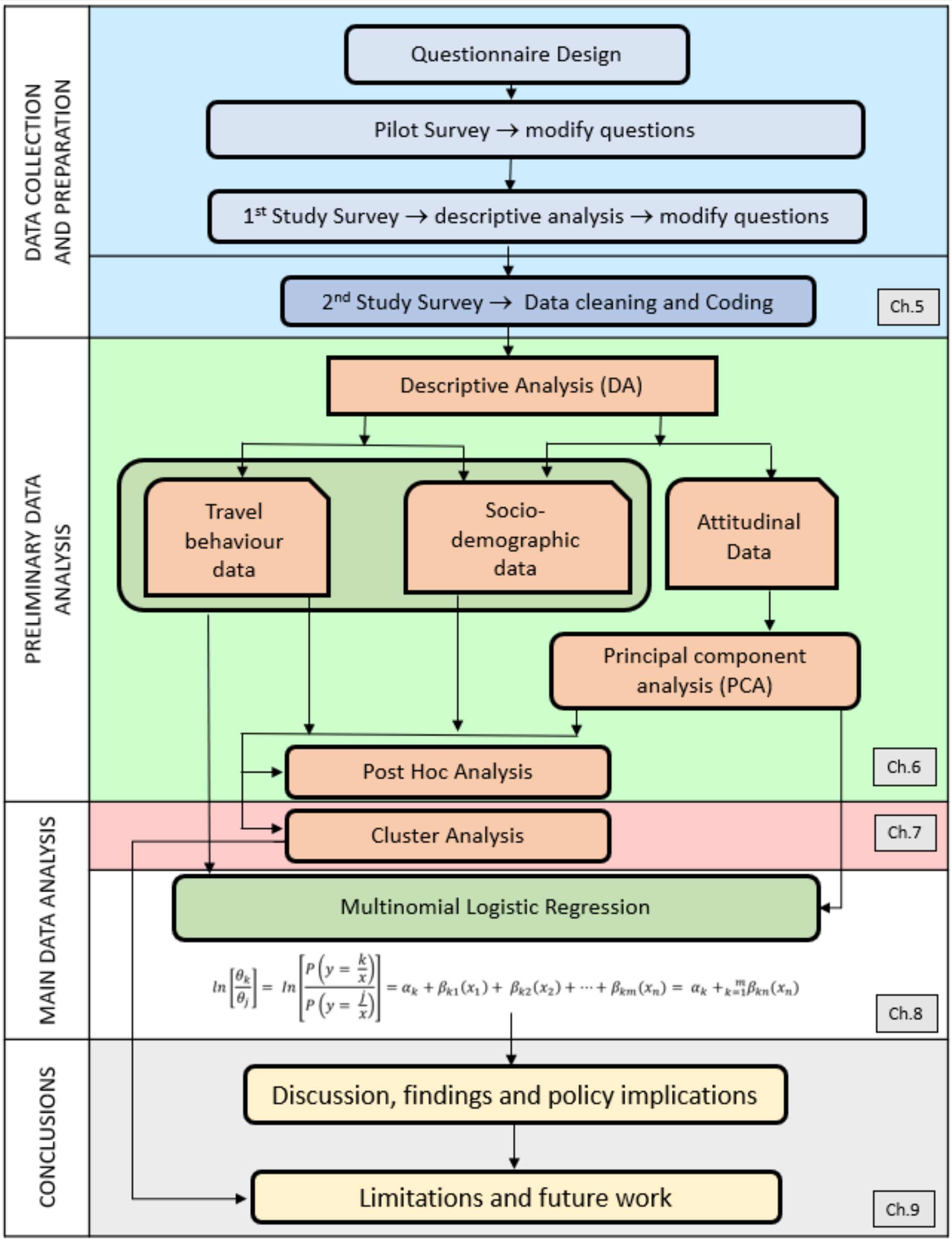



Figure 4.1 Methodology Framework.

Part 2: b) Attitudinal variables

Twenty variables were defined one each for the 20 attitudinal statements listed in Table 4.1. At the first column e.g. Q_2_x. The environment emerged from the literature as dominating policy initiatives worldwide namely those related to air quality and others to carbon reduction. In addition, the public's awareness as to whether the environmental impact of their mode choice influenced only their own health or that of others or both also emerged as an interesting aspect to research. As a result, 13 statements Q_2_1 to Q_1_3, were developed associated with the environment. Two statements each related respectively to accessibility and safety, Q_2_14 and Q_2_15, and Q_2_19 and Q_2_20, and finally three statements Q_2_16 to Q_2_18 focused on attitudes to the convenience of public transport services, see list of questions in Table 4.1.

| | |
|---|---|
| Literature Review on themes of Questionnaires | Identified four attitude themes and demonstrated that demographic characteristics had impact on travel behaviour. |
| Gathered example statements and questions to be considered for the questionnaire | Statements and questions based on the literature review were customised and collated to meet the aim of this research. |
| Designed and developed a draft questionnaire. | The questionnaire included 3 parts namely a record of recent travel, **34** attitudes statement, and demographics |
| Executed and analysed data from the pilot questionnaire. | The draft questionnaire was scrutinised for understanding and relevance to study aims by university staff and students |
| Developed the final questionnaire and used in the 1st study survey | The questionnaire was improved based on the pilot survey comments. The questionnaire included 3 parts namely a record of recent travel, **20** attitudes statement and demographics |
| Collected data as 1st study | The questionnaire was distributed through social media channels. |
| Modified the questionnaire for use in the 2nd study (main survey) | The questionnaire included 3 parts namely a record of recent travel, **20** attitudes statement, demographics. |
| Collected data as 2nd study | The questionnaire was posted on social media for self-completion. Members of the public were targeted and approached so that the sample according to the proportion of age and gender represented Bangkok population |
| Data Cleaning | Removed incomplete sets of data and replaced the missing value with median of the series as appropriate. |

Figure 4.2 Flow chart of questionnaire development

Table 4.1 Attitudinal statement section for questionnaire with their themes (Part 2)

| Statement number | Question | Themes: Environment | Accessibility | Convenience | Safety |
|---|---|---|---|---|---|
| Q_2_1 | My current travel behaviour impacts the health of others. | • | | | |
| Q_2_2 | My current travel behaviour impacts my health. | • | | | |
| Q_2_3 | I am willing to reduce the amount I travel to improve air quality and reduce the detrimental effect on the health of others. | • | | | |
| Q_2_4 | My current travel behaviour impacts climate change. | • | | | |
| Q_2_5 | Given an opportunity, I would be willing to buy a car with lower carbon emission to reduce the impact on climate change. | • | | | |
| Q_2_6 | People should be allowed to use their cars or motorcycles as much as they like, despite their impact on climate change. | • | | | |
| Q_2_7 | I find traffic congestion a serious problem in my town. | • | | | |
| Q_2_8 | I find exhaust fumes from traffic in town. | • | | | |
| Q_2_9 | I am willing to reduce the amount I travel to help reduce the impact of carbon on climate change. | • | | | |
| Q_2_10 | I am willing to leave the house earlier or later to avoid congestion and reduce my journey time. | • | | | |
| Q_2_11 | Given the opportunity I would purchase an electric or hybrid cars to reduce the impact on climate change. | • | | | |
| Q_2_12 | Given an opportunity, I would be willing to buy a less polluting car to improve air quality. | • | | | |
| Q_2_13 | People should be allowed to use their cars or motorcycles as much as they like, despite their contribution to pollution | • | | | |
| Q_2_14 | I feel cut off from public transport services due to heavy trafficked roads with no safe crossing. | | • | | |
| Q_2_15 | I feel cut off from public transport because of subways, footbridges. | | • | | |
| Q_2_16 | I would use public transport if the ticket I purchase could be used on different services and modes. | | | • | |
| Q_2_17 | I chose my current mode(s) because it is the quickest. | | | • | |
| Q_2_18 | I chose my current mode(s) because there are no alternative ways to reach my workplace. | | | • | |
| Q_2_19 | I chose my current mode(s) because there is less risk of accident. | | | | • |
| Q_2_20 | I chose my current mode(s) because I personally feel safe. | | | | • |

Part 3 c) Socio-demographic variables.

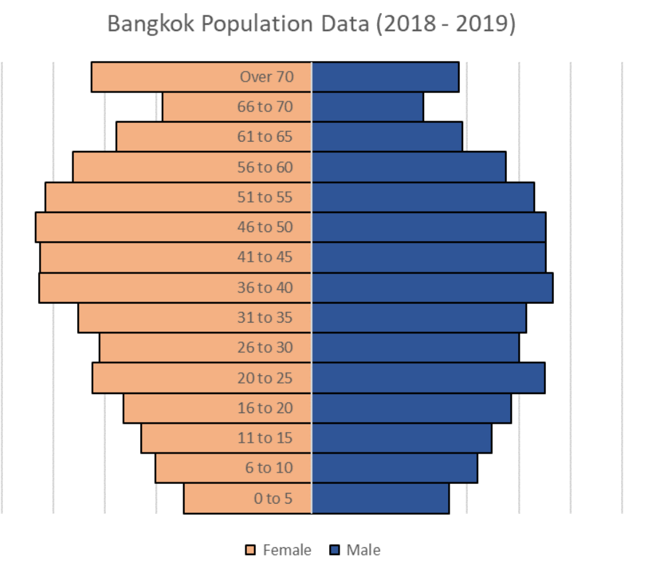
Given the literature demonstrated that demographic variables influenced mode choice the questionnaire captured the following characteristics of respondents:

- Age
- Gender
- location of residence
- location of workplace
- Number of people living in the household
- Number of children living in the house
- Education level
- Household income
- Number of vehicles in the household
- Disability

The travel behaviour collected mode of transport in each step and self-identify mode of transport user variable as an ordinal variable. In addition to this travel cost and travel time of each step were collected as continuous variables. The attitudinal variables from the attitudinal part were collected as continuous. The final part combined the variable type as ordinal variables and nominal variables. The socio-demographic data such as age, income, and educational level are ordinal, namely gender. The variables that were collected as nominal variables were gender, location of residence and workplace, number of household members (adult and children), car ownership, and disability status.

The data collection process involved three rounds: pilot, 1st Study, and 2nd Study. The initial design of the questionnaire was tested in a pilot, by circulating to at least 10 university staff and students. Feedback from peers was taken on board and the questionnaire was launched on social media as a 1st Study to capture at least 200 responses. This initial 1st Study data was analysed in full to check whether the data would meet the research gaps. Improvements in the questions were made before launching the main data collection survey labelled as 2nd Study Survey. The results of the 1st Study are reported in Section 5.4. The 2nd Study was launched online with the aim of capturing at least 500 completed questionnaires. The link to the survey was circulated via social media including Facebook and Instagram, webpages of the universities of Kasetsart University. Additionally, two students were trained to conduct the survey by voicing the questions and entering the respondent's answers by using a tablet. In this way, the response rate was increased and by targeting specific demographic groups, specifically the participants who were unfamiliar with technology devices or online platform, the final sample achieved was representative of the BMR. The demographic characteristics including age and gender of the sample responses were consolidated at regular intervals and compared with the population characteristics of Bangkok to ensure that the sample was representative by using the Census from BMA (2019). The population by age and gender are presented in Table 4.2 and the data over the age range were collated to match the age categories used in this study.

Table 4.2 Population in Bangkok 2018-2019 by age grouped in 5 year increments (Source: BMA (2019))




| **Age** | Male [%] | Female [%] |
|---|---|---|
| Over 70 | 2.8 | 4.3 |
| 66 to 70 | 2.2 | 2.9 |
| 61 to 65 | 2.9 | 3.8 |
| 56 to 60 | 3.8 | 4.6 |
| 51 to 55 | 4.3 | 5.2 |
| 46 to 50 | 4.5 | 5.3 |
| 41 to 45 | 4.5 | 5.2 |
| 36 to 40 | 4.7 | 5.3 |
| 31 to 35 | 4.1 | 4.5 |
| 26 to 30 | 4.0 | 4.1 |
| 20 to 25 | 4.5 | 4.2 |
| 16 to 20 | 3.8 | 3.6 |
| 11 to 15 | 3.5 | 3.3 |
| 6 to 10 | 3.2 | 3.0 |
| 0 to 5 | 2.6 | 2.5 |

This was achieved by collating the two consecutive 5-year to create 10-year bin widths. The proportion of males to females in Bangkok in 2018 was 47%:53%. Table 4.3 presents the collated numbers of Bangkok's population by age and gender. The expected data was 500 participants within the proportion of age and gender of participants to represent BMR population behaviour.

Table 4.3 Bangkok population data (2019) data by age and gender.

| Age | Bangkok Population | | | | | |
|---|---|---|---|---|---|---|
| | Male | | Female | | Total | |
| Under 20 | 100611 | 5.3% | 97466 | 4.6% | 198077 | 4.9% |
| 21 to 30 | 387582 | 20.5% | 377107 | 17.6% | 764689 | 19.0% |
| 31 to 40 | 392461 | 20.8% | 434779 | 20.3% | 827240 | 20.5% |
| 41 to 50 | 406768 | 21.5% | 476407 | 22.3% | 883175 | 21.9% |
| 51 to 60 | 367723 | 19.4% | 444653 | 20.8% | 812376 | 20.2% |
| Over 60 | 235611 | 12.5% | 309165 | 14.4% | 544776 | 13.5% |
| Total | 1890756 | 100% | 2139577 | 100% | 4030333 | 100% |

### 4.3.1 Data Cleaning and Missing Values

The feedback from the 1st Study mostly helped with the rewording of the questions and gave preliminary feedback on the duration of the survey. A compromise needed to be made between the number of questions asked and the motivation of the responders to complete the questionnaire. The data collected in the 1st Study survey was analysed in full. Incomplete records were deleted in this initial analysis however, the purpose of the 1st Study analysis was to test that the information captured would fulfil the research objectives and inform a strategy to deal with missing data and the size of the final sample. The data was tested sample size to test the statistical significance of the sample data using a chi-square (χ2) test.

## 4.4 Exploratory Statistical Analysis

The steps in the preliminary analysis are conceptualised in Figure 4.3. The raw questionnaire data was consolidated in an Excel spreadsheet (CSV file). The data was scrutinised registering missing data with the default 'Prefer not to say' if offered as an alternative. For other variables, namely car ownership, and household members, -99 was used as this was recognised as such by the SPSS software. The missing values in the attitudinal scores were substituted with the median or mean depending on whether the attitudinal scores were by using a distribution plot.

### 4.4.1 Descriptive statistical Analysis

Descriptive statistical analysis of the travel behaviour and socio-demographic data was carried out to provide an overview of the characteristics of the study sample and to provide general information before proceeding with an in-depth more advanced analysis.

### 4.4.2 Distributions of Attitudinal Variables.

Next, the distribution of attitudinal scores was generated for each of the 20 attitudinal statements with 10 bin width and compared to begin to understand differences and associations between the attitudes of the public within and across the environment, accessibility convenience and safety variables.

### 4.4.3 Principal Component Analysis of Attitudinal Variables.

The suitability of the 20 attitudinal data, with score from 0-100, for factor analysis was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity which assessed the strength of relationships between variables, while Bartlett's test verified the significant correlations among all relationships of variables. This approach ensured that the data possessed the necessary characteristics for component deduction.

The Components from the PCA are used as input to the main analyses as explained in the following sub-section.

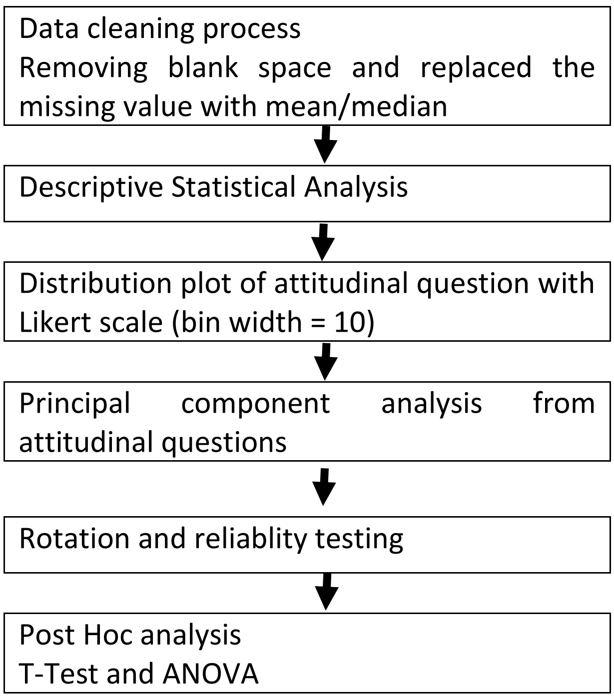



Figure 4.3 step for conduction descriptive analysis and PCA.

In the current study, the 20 attitudinal variables were coded with variable labels Q_2_1 to Q_2_20 and processed using PCA with Promax rotation as recommended by Brown (2009). The component correlation matrix was observed to understand the level of association among components before deciding whether to use Varimax rotation (in the case of low component correlations) or whether to remain with Promax rotation. At each step, by using the reliability statistic, each component was inspected (Cronbach's alpha) and if the reliability was high, the component was retained. The results of PCA were subsequently labelled according to the characteristics of the variables in each of the components.

Finally, the output from PCA was investigated in depth by post-hoc analysis (group comparisons) using the t-test for gender groups (male versus female), Analysis of Variance (ANOVA) for age groups (≤20, 21-30, 31-40, 41-50, 51-60, >60) and user self-identity categories (whether Public Transport, Private Transport and Active Transport).

In this study, all statistical tests were carried out at the 95% confidential level. The detailed results of PCA and Post Hoc analysis are presented in Chapter 6.

## 4.5 Main analysis

The main analysis consisted of two complementary statistical methods as follows:

- Data clustering using Hierarchical Cluster Analysis (HCA)

and

- Multinomial Logistic Regression (MLR) to explore the relationship between demographic data and key factors.

Each of these analytical methods is explained in the following sub-sections.

## 4.6 Data Clustering using Hierarchical Cluster Analysis (HCA)

Cluster analysis is a technique used for grouping data types with similar and different characteristics. HCA was chosen with Ward's method which seeks clusters of similar size, see Section 3.4 for justification. The HCA method was applied to the data using IBM SPSS statistics 28 and 29 and Figure 4.4 shows the steps in the clustering process.

The number of clusters at the beginning of this study is unknown and by consulting the outputs from the HCA, the dendrogram and the agglomerative coefficient the range of the number of clusters was defined. Next by systematically executing the HCA and fixing the number of clusters across the range, the 'optimal' number of clusters was defined. The next step was to calculate the median of the component scores. Cross-tabulation of the characteristics of the cluster membership and component scores allows appropriate labels to be assigned to each cluster. The detailed results of HCA are presented in Chapter 7.

| Travel characteristic, PCA Component and socio-demographic variables | |
|---|---|
| ↓ | |
| Hierarchical cluster analysis with Ward's method | The result from PCA were used as input to HCA processed in SPSS software. HCA was performed with unknown number of clusters. The ***range of cluster number*** was identified considering the dendrogram together with the agglomerative coefficient. |
| ↓ | |
| Systematically HCA repeated with cluster number specified across the range. | HCA with Ward's method was repeated with the range of number of clusters and the optimal cluster number identified, see Section 3.3. |
| ↓ | |
| Descriptive Analysis of characteristics of each Cluster. | Calculation of median of score for each component of each cluster |
| ↓ | |
| Labelling and analysis | Cross tabulation was used to identify the travel characteristics of the cluster membership and socio demographic data. |
| ↓ | |
| Policy suggestion | Recommendation of policy and intervention measures suggested from the travel behaviour and cluster characteristics. |

Figure 4.4 Steps in the execution of HCA.

## 4.7 Multinomial Logistic Regression (MLR) to explore the relationship between demographic data and key factors.

The MLR is an independent analysis which seeks statistically significant correlations between independent variables and components to create algorithms which describe the influence of attitudes on travel behaviour and choice of modes. The MLR analysis was carried out using IBM SPSS statistics 28 and 29. The equation from Section 3.5 was modified for this study.

Therefore, the MLR model in this study would be

$$In\left[\frac{P(user_i)}{P(user_j)}\right] = \alpha_i + {}_{i=1}^{n}\beta_i(travel\ behaviour_i) + {}_{i=1}^{n}\beta_i(component_i) \quad \ldots \quad \text{Equation 4.1}$$

$$+{}_{i=1}^{n}\beta_i(sociodemographic_i)$$

where:

$travel\ behaviour_i$ is the independent variable $i$ ;

$component_i$ is the independent variable $i$ ;

$sociodemographic_i$ is the independent variable $i$ ;

$user_i$ is the dependent variable $i$ ;

$user_j$ is the baseline variable $j$ ;

$\alpha_i$ is the estimated intercept;

$\beta_i$ is the estimated coefficient.

In SPSS, cluster analyses were used as the categorical dependent and attitudinal component scores were used as explanatory variables. One of the cluster variables was selected as a reference case (based line). Generally, the cluster with the lowest number of members was selected as a reference to prevent the error. The default of the software references group was the last group. However, in this study, the car user was selected as a reference group for comparison due to the aim of the study therefore Equation 4.1 user j was referred to the car user group. Therefore, the model combined 6 equations by mode relative to the car such as active transport mode compared to car.

### 4.7.1 Application of the MLR algorithms

Figure 4.5 shows the steps of MLR development. After the initial model includes time and cost, the independent variables included PCA components and sociodemographic were added one by one. However, if the variable had a significant level less than 0.05 in any mode, that variable would remain from the equation. Then, the equation was added to the next variables to test the significant level until the outcome of the final model was present. The details of the results of MNL are presented in Chapter 8.

### 4.7.2 Inform policy scenarios and interventions.

The final model was tested by example case study which is the biggest size from the cluster analysis. This can be presented as the most effective way to change travel behaviour. Time and cost were fixed while vary other variables. Then the result from changes would discuss the possible policies that can apply to the case study. The further policy discussions are presented in Chapter 9.

| | |
|---|---|
| Selected the reference case with travelling time and travelling cost | MLR was conducting using travel behaviour and socio demo graphic data with chosen variables. |
| ↓ | |
| Checking the significant level ↓ Adding attitudinal variables ↓ Adding sociodemographic variables | MLR was run by SPSS software by adding each variable one by one. If the significant level were less than 0.05 at least one mode, that variables would be remained in the MLR. |
| MLR Final model | The final model of MLR developed combined with the independent variables |
| ↓ | |
| Scenario valuing | Travelling time, cost, and attitudinal variable were vary for mode shifting situation |
| ↓ | |
| Policy suggestion | The policy recommendation from the vary scenario. |

Figure 4.5 Steps in the MLR analysis

## 4.8 Conclusions

This chapter explained the design and data collection tool and the analytical approaches applied in the research and mapped the steps of the methodology onto the objectives of this research. The techniques of data analysis used in this research were detailed and the flow of data between them was explained. The questionnaire captured data in three parts namely daily commuter travel behaviour, attitudinal statement, and socio-demographics. Exploratory statistical analysis set the foundations for the more advanced analysis, including, PCA, HCA and MLR.

The dimension reduction technique PCA was employed to reduce the attitudinal variables by grouping similar attitudinal variables into a smaller number of key components. Subsequently, the components along with the travel and socio-demographic variables were input to the HCA to identify population groups who have similar attitudes. MLR was used for the investigation of the relationship between the attitude components, sociodemographic data and the influence they have on travel behaviour variables. How the MLR models can be used to inform policy and intervention measures was explained.

In the next chapter, the experiences in questionnaire development and results of the pilot and 1$^{st}$ Study steps will be explained along with the exploratory and PCA analysis of the main data collection in 2$^{nd}$ Study.

# Chapter 5. Questionnaire Design and Data Collection

## 5.1. Introduction

In the previous Chapter 4 presented the methodology with reference to a conceptual methods diagram. This mapped out the steps of the method to match the objectives to fulfil the research gaps identified by the literature review.

In this chapter, the questionnaire design and initial screening are explained. The initial questionnaire was improved in the pilot and 1st Study steps before launching the main survey. The questionnaire was written in the English language first translated into the Thai language and posted online. The details of the questionnaire design and feedback from the pilot survey are described in Section 5.2. Section 5.3 presents the 1st Study survey and the steps taken to improve the questionnaire. Section 5.4 follows with the results of the descriptive analysis of the data collected in the 1st Study. Section 5.5 presents the modification of the questionnaire made before the launch of the 2nd Study survey. Section 0 derives the target for data collection to reach a representative sample of the Bangkok population and the statistical significance of the results. Section 5.7 describes the 2nd Study survey data collection before summarising the key findings of this chapter and concluding this chapter in Section 5.8.

## 5.2. Questionnaire design and 1st Study survey

A questionnaire was designed to investigate regular commuter trip and their attitudes toward the environment, convenience, accessibility, and safety. The survey questions were based on the National Travel Survey (UK NTS) combined with those from previous research addressing the similar topics (Prasertsubpakij and Nitivattananon, 2012), and more specifically questions from Bösehans *et al.* (2021).

The pilot study questionnaire was designed to comprise three sections, the first Section 1 aimed to study regular commuter trips by asking participants to self-report the modes used, cost, and duration of their regular commute journey. The second, Section 2 used a sliding scale from 0 to 100 to quantify the respondents' opinions of different attributes relevant to transport. The final Section 3 captured details of the demographics such as gender, age, number of people in a household, location of house, and workplace.

Section 1 collected details of each step/stage of respondents' regular commuter journey. The options of modes presented were from 3 groups as follows:

1) active transport (walking and cycling)
2) public transport
    a. public transport (air-conditioned bus, non-air-conditioned bus, train, ferry, urban railway system such as BTS, MRT, ARL)
    b. paratransit (minibus)
    c. demand responsive transport (taxi, motorcycle taxi, Tuk Tuk)
3) private vehicle (private car as a driver/ passenger, private motorcycle)

Other two-step/stage choices were "Waiting time" and "Transit time". Both steps/stages consume time and can influence the perception of travelling and accessibility to transport services. The next question *I consider myself a* _______ established respondent user identity and were given the following options: "Public transport user, Car user, Motorcycle user, Cyclist, Walker, Multi-modal user". A multi-modal user refers to a user not bound to any single mode of transport.

Section 2 was designed to gather the attitudes of passengers in all four areas of environment, safety, accessibility, and convenience by setting out 34 attitudinal statements. A sliding scale with scores from 0 to 100 (Extremely disagree to Extremely agree) was used in this research. The attitudinal statements are appended here:

1. Given an opportunity, I would be willing to buy a car with lower carbon emissions to reduce the impact of climate change.
2. Traffic congestion is a serious problem for me.
3. Exhaust fumes from traffic in the towns and cities are a problem for me.
4. I am willing to reduce the amount I travel by car to help reduce the impact of carbon on climate change.
5. I am willing to leave the house earlier or later to avoid congestion and reduce my journey time.
6. I am willing to leave the house earlier or later to avoid congestion and reduce the impact of my journey on the environment.
7. People should be allowed to use their cars as much as they like, despite their impact on climate change.
8. Given an opportunity, I would be willing to buy a less polluting car to improve air quality and impact the health of others.
9. Given the opportunity, I would buy an electric car to reduce the impact on the environment.
10. I am willing to reduce the amount I travel by car to improve air quality and reduce the impact on the health of others.
11. People should be allowed to use their cars as much as they like, despite their contribution to pollution and impact on health.
12. If I could, I would be willing to work from home.
13. I have good access to air-conditioned bus services.
14. I have good access to non-air-conditioned bus services.
15. I have good access to Microbus (Van) services.
16. I have good access to Minibus such as Song Taew, Ka Por.
17. I have good access to Urban railway (BTS).
18. I have good access to Urban railway (MRT).
19. I have good access to Urban railway (ARL).
20. I have good access to Mainline Train services.
21. I have good access to the Ferry.
22. I feel cut off from public transport services due to heavily trafficked roads.
23. I feel cut off from public transport because of subways, and footbridges.
24. I would use public transport if the ticket I purchase could be used on different services and modes.
25. I prefer the route that is less connected by different modes, even if it takes longer travelling time.
26. I feel acceptable to wait for the next bus or train if I miss that upcoming.
27. I fear for my personal safety when I travel by public transport.
28. I fear for my personal safety when I am driving.

29. I fear for my personal safety when I am using a motorbike.
30. I fear for my personal safety when I am walking.
31. I fear for my personal safety when I am cycling.
32. I am concerned about injury when walking.
33. I am concerned about the injury when travelling by public transport.
34. I am concerned about injury when cycling.

The third was designed to examine the demographic characteristics of participants. The questions were consistent with those used in the study by Bösehans *et al.* (2021). The objective of this part of the questionnaire was to understand how demographic characteristics influence the mode choices for the commuter trip assuming work-to-home is the reverse of home-to-work. The variables included age, gender, postcode of residence and workplace, number of people in the household, level of qualification or education, income, vehicle ownership, and disability.

Demographic questions were asked because previous research has demonstrated that age and different degree qualification influence the ticket type purchased, attitudes, and consequential mode selection. For example, urban rail system and buses have discounts on ticket prices for those over 60 years old. Thailand postcodes represented a large area and are non-specific to a particular location, therefore the name of the district and sub-district was requested. Bangkok area includes 50 districts and 171 subdistricts. A blank space was offered for the name of the district and the sub-district to be recorded. The location of the origin and destination of the journey was used as an estimate of the distance travelled. Moreover, in the 1st Study survey blank spaces were provided for respondents to add the details requested. This was found to be less confusing than drop-down choices offered in the pilot survey particularly when the survey was completed on the mobile phone. Also, the interviewers' feedback found entering the data into a blank space easier than drop-down menus when the questionnaires were completed on tablet or computer. The number of people in the household and car ownership were found in previous research to influence mode choice, particularly with families that have children, therefore questions to capture this information were included.

The pilot questionnaire was scrutinised by 15 university staff and PhD students via an online platform. This tested the technical aspects of the user interface, software platform, the duration of the survey as well as the comprehension of the set of questions posed. This online survey was carried out in English before it was translated into Thai for the 1st and 2nd Study surveys.

The feedback from the participants in the pilot indicated that the questionnaire was too long. Also, some questions were skipped towards the end of the questionnaire the reason given was that the length of the questionnaire was unacceptable. Therefore, it was decided to make Section 2 (attitudinal statements) of the questionnaire shorter by reducing the number of statements.

As a result and consistent with the study by Sharma (2022), the 34 attitudinal statements initially included were reduced to 20 which resulted in the majority of responders completing the questionnaire . The attitudinal statements aimed at receiving responses to what the current transport and related problems are, limitations to their selected mode, and what they are willing to do if they had the opportunity to purchase a new vehicle.

Therefore, the modified questions following the pilot questionnaire survey are presented in Table 5.1. Thirty-four questions were reduced to 20 attitude statements each with a sliding scale from 0 to 100 to provide a better-resolved response score than that achieved with a Likert scale of 5 to 7 increments commonly used in the literature. A number between 0 and 100 for each of the 20 attitude statements resulted from the questionnaire.

Statements 1 – 13 were included to explore attitudes to the environmental impact of their chosen transport mode on climate change and air quality and the extent to which their choice of mode impacts the health of the community or themselves. Statements 5 - 6 were particularly aimed at gathering respondents' awareness of environmental problems. Question 14 and Statement 15 were related to access to public transport. The assumptions made were that "fewer and shorter trips result in less emission" and "spreading the peak by commuters travelling earlier or later than the normal peak time" reduced associated congestion-related emissions (Australasian Transport Research, 2006; Jassmi and Ochieng, 2015).

Statement 16, Statement 17, and Statement 18 were added to examine the level of convenience of the current mode. The final two statements related to the attitude towards personal safety. It was decided to maintain the higher number of questions relating to the environment theme to explore attitudes towards the impact on health, air quality and climate change on the respondents themselves as well as on others. This was a unique component of this research given that previous research tended to investigate environmental impacts on either themselves or others, not both as in this research. This result in 13 statements in the environmental theme compared to 3 statements in the accessibility, 2 statements in convenience and 2 statements in safety. The next step was to carry out a 1st Study survey engaging a wider audience.

Table 5.1 List of questions in section 2, Attitude

| Statement number | Statement |
|---|---|
| Sec_2_Q1 | My current travel behaviour impacts the health of others. |
| Sec_2_Q2 | My current travel behaviour impacts climate change. |
| Sec_2_Q3 | My current travel behaviour impacts my health. |
| Sec_2_Q4 | Given an opportunity, I would be willing to buy a car with lower carbon emission to reduce the impact on climate change. |
| Sec_2_Q5 | I find traffic congestion a serious problem. |
| Sec_2_Q6 | I find exhaust fumes from traffic in towns and cities a problem. |
| Sec_2_Q7 | I am willing to reduce the amount I travel to help reduce the impact of carbon on climate change. |
| Sec_2_Q8 | I am willing to leave the house earlier or later to avoid congestion and reduce my journey time. |
| Sec_2_Q9 | People should be allowed to use their cars as much as they like, despite their impact on environment. |
| Sec_2_Q10 | Given an opportunity, I would be willing to buy a less polluting car to improve air quality. |
| Sec_2_Q11 | Given the opportunity I would purchase an electric car to reduce the impact the environment. |
| Sec_2_Q12 | I am willing to reduce the amount I travel to improve air quality and reduce the detrimental effect on the health of others. |
| Sec_2_Q13 | People should be allowed to use their cars as much as they like, despite their contribution to pollution and impact on health. |
| Sec_2_Q14 | I feel cut off from public transport services due to heavy trafficked roads with no safe crossing. |
| Sec_2_Q15 | I feel cut off from public transport because of subways, footbridges. |
| Sec_2_Q16 | I would use public transport if the ticket I purchase could be used on different services and modes. |
| Sec_2_Q17 | I chose my current mode(s) because it is the quickest. |
| Sec_2_Q18 | I chose my current mode(s) because there are no alternative ways to reach my workplace. |
| Sec_2_Q19 | I chose my current mode(s) because there is less risk of accident. |
| Sec_2_Q20 | I chose my current mode(s) because I personally feel safe. |

### 5.3. 1st Study survey and feedback

The 1st Study questionnaire was improved based on the pilot and translated into the Thai language. The questionnaire was released via online platforms including social media or website pages of universities and conducted from 1st to 10th February 2022, gathering an initial 274 valuable samples for further study.

Table 5.2 shows the number of respondents completing each question in turn throughout all sections. 39% of participants (108 participants) terminated the questionnaire at the end of the introduction section. This was maybe because the participants did not trust the questionnaire, or it may have been too long to complete. Only 19% (51 participants) answered all questionnaire. 35% of the questionnaires (96 responses) were not complete at least omitting one or two questions but did reach the end of the survey. Therefore, only a maximum of 153 answers were available for analysis from Section 2, the attitude part of the survey. Also, it is clear from Figure 5.1 that the two questions capturing the postcodes for origin and destination created a problem in achieving a significant number of respondents.

Table 5.2 Number of respondents answered each question.

| Question Number | Question | N |
|---|---|---|
| Sec_0 | Consent Form | 274 |
| Sec_1_Q1 | Please specify each step of your most regular commuter trip from home to workplace including all walk, wait and transfer times. | 166 |
| Sec_1_Q2 | I consider myself a ___________. | 166 |
| Sec_2_Q1 | My current travel behaviour impacts the health of others. | 151 |
| Sec_2_Q2 | My current travel behaviour impacts climate change. | 150 |
| Sec_2_Q3 | My current travel behaviour impacts my health. | 146 |
| Sec_2_Q4 | Given an opportunity, I would be willing to buy a car with lower carbon emission to reduce the impact on climate change. | 152 |
| Sec_2_Q5 | I find traffic congestion a serious problem. | 152 |

Table 5.2 Number of respondents answered each question. (Cont.)

| Question Number | Question | N |
|---|---|---|
| Sec_2_Q6 | I find exhaust fumes from traffic in towns and cities a problem. | 151 |
| Sec_2_Q7 | I am willing to reduce the amount I travel to help reduce the impact of carbon on climate change. | 152 |
| Sec_2_Q8 | I am willing to leave the house earlier or later to avoid congestion and reduce my journey time. | 151 |
| Sec_2_Q9 | People should be allowed to use their cars as much as they like, despite their impact on environment. | 144 |
| Sec_2_Q10 | Given an opportunity, I would be willing to buy a less polluting car to improve air quality. | 151 |
| Sec_2_Q11 | Given the opportunity I would purchase an electric car to reduce the impact the environment. | 151 |
| Sec_2_Q12 | I am willing to reduce the amount I travel to improve air quality and reduce the detrimental effect on the health of others. | 151 |
| Sec_2_Q13 | People should be allowed to use their cars as much as they like, despite their contribution to pollution and impact on health. | 143 |
| Sec_2_Q14 | I feel cut off from public transport services due to heavy trafficked roads with no safe crossing. | 145 |
| Sec_2_Q15 | I feel cut off from public transport because of subways, footbridges. | 140 |
| Sec_2_Q16 | I would use public transport if the ticket I purchase could be used on different services and modes. | 148 |
| Sec_2_Q17 | I chose my current mode(s) because it is the quickest. | 151 |
| Sec_2_Q18 | I chose my current mode(s) because there are no alternative ways to reach my workplace. | 147 |
| Sec_2_Q19 | I chose my current mode(s) because there is less risk of accident. | 149 |
| Sec_2_Q20 | I chose my current mode(s) because I personally feel safe. | 150 |
| Sec_3_Q1 | What is your gender? | 146 |
| Sec_3_Q2 | What is your age? | 147 |
| Sec_3_Q3 | Including yourself, how many people live in your household? | 145 |
| Sec_3_Q4 | What is the highest level of education that you have achieved? | 146 |
| Sec_3_Q5 | Approximately, what is the monthly income of your household before tax? (Baht) | 146 |
| Sec_3_Q6 | Where is your residence? | 131 |
| Sec_3_Q7 | Where is your workplace? | 131 |
| Sec_3_Q8 | How many vehicles are currently in use in your household? | 143 |
| Sec_3_Q9 | Do you have any physical disability that impacts your movement? | 140 |

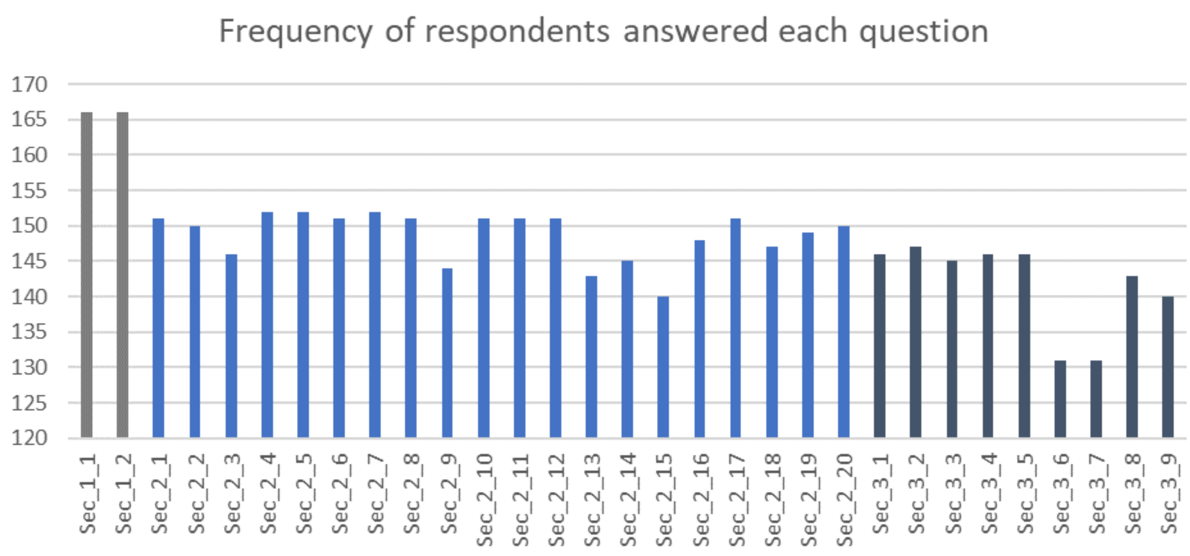



Figure 5.1 Frequency of respondents answered each question.

Table 5.3 Summary number of respondents on each section

| Status | Number of respondents | [%] |
|---|---|---|
| Finished the questionnaire at the end of introduction section (Consent form) | 108 | 39 |
| Finished the questionnaire at the end of Section 1 (Mode choice) | 7 | 3 |
| Finished the questionnaire during doing the questionnaire Section 2 (Attitude) | 6 | 2 |
| Finished the questionnaire at the end of Section 2 (Attitude) | 6 | 2 |
| Missing at least one answer across the entire survey | 96 | 35 |
| Answer all questions | 51 | 19 |
| Total | 274 | 100 |
| Number available for analysis | 153 | - |

The feedback received from participants was as follows:

- *The questionnaire does not seem to be authentic. Therefore, they did not continue to answer the questions.*
- Some over 60-year-old participants were retired and disqualified because they were not in employment and therefore ended the survey.
- Some participants were offered shuttle buses by their companies as an employee benefit. *They mentioned that there is no option in the Mode Choice section.*
- The cost options given in the Mode Choice section were too high.
- Respondents were confused between waiting time and transfer time.
- Some questions were considered complicated and similar to other questions. *More specifically the difference between pollution impact on health as opposed to carbon emissions contributing to climate change.*
- *The questionnaire was too long.*
- *Some questions in Section 2 were confusing and biased to agree to such question about no safe crossing.*

It can be concluded that Survey Monkey is not a familiar platform for Thai people. A Newcastle University logo was not included in the questionnaire. This might explain why many people opted not to continue the questionnaire after the initial consent. As a result of an analysis of this feedback, the questionnaire was adjusted to the 2$^{nd}$ Study version. The more specific changes made are dealt with in section 5.5.

## 5.4. Descriptive analysis of the 1st Study

Descriptive analysis of the 1$^{st}$ Study survey data provided the framework of the population which was considered useful to avoid errors in the 2$^{nd}$ Study survey. Before the analysis, the missing values from the 1$^{st}$ Study data were replaced by the median of all responses to each question. The median was used because the distribution of data across all samples was not normal. Additionally, the missing values in the demographic section was replaced by "preferred not to say". Initial statistics from Section 1 of the questionnaire are presented in Table 5.4. The total number of valid and complete questionnaires was 166. However, two respondents chose waiting times as the first Step 1 of the journey which was the mode of transport including the access by walking. Therefore, there were 164 useful answers. The most popular mode of transport in Bangkok was travelling by private car (46% of participants).

Interestingly, 2% reported driving a car as the second step in a journey, these are drivers who cannot park their car close to their home and therefore reported the *feeder* mode as walking. Why individuals use the car as step three or more is less clear. No one in the 1st Study survey chose the mainline train. The number of trips using the paratransit modes such as motorcycle taxi (6%) was high as the first step. Urban railway mode was highest in step 2 and step 3 (35% and 30% respectively). This may imply that public transport may not be convenient or easily accessible on foot at the start of the journey. At the end of the journey, paratransit appears not to be important. These results imply that places of work were easier to access on foot compared to access at the trip origin.

Table 5.4 Result of 1st survey with respect to mode of transport (section 1 of 1st study survey)

| | Step | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Modes of transport | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Walk | 34 | 4 | 7 | 10 | 3 | 6 | 1 | 1 |
| Cycle | 4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| Bus (Air conditioned) | 3 | 8 | 4 | 3 | 1 | 0 | 0 | 1 |
| Bus (Non-Air Conditioned) | 2 | 3 | 5 | 1 | 2 | 0 | 0 | 1 |
| Microbus (Van) | 3 | 2 | 2 | 0 | 2 | 1 | 0 | 0 |
| Minibus (Song Taew, Ka Por, Shuttle bus) | 2 | 2 | 6 | 2 | 1 | 0 | 2 | 1 |
| Urban railway (BTS, MRT, ARL) | 3 | 18 | 13 | 2 | 3 | 1 | 0 | 0 |
| Mainline Train | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ferry | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 |
| Taxi | 3 | 0 | 1 | 0 | 0 | 1 | 0 | 2 |
| Motorcycle Taxi | 10 | 3 | 2 | 2 | 2 | 1 | 2 | 0 |
| Tuk Tuk | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| Private Car as a Driver | 76 | 4 | 2 | 1 | 1 | 1 | 1 | 1 |
| Private Car as a Passenger | 18 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| Private Motorcycle | 6 | 3 | 1 | 0 | 0 | 1 | 0 | 0 |
| Total | 164 | 52 | 44 | 21 | 15 | 13 | 7 | 8 |

Table 5.5 shows the preliminary analysis of the cost and time data related to commuter travel. The average time spent travelling was 45 minutes with an average of 96 baht on a single leg of travel. However, the large differences in the mean median and mode particularly for the fare mean that the distribution is not normal. Therefore, medians should be used, and non-parametric testing is required.

Table 5.5 Descriptive analysis result on total time and cost of travelling for commuter trip in Bangkok of 1st Study survey.

| Statistical data | Total time (minutes) | Total cost (Baht) |
|---|---|---|
| Mean* | 45 | 96 |
| Median | 40 | 70 |
| Mode | 45 | 100 |
| Sample size (***N***) | 164 | 164 |
| Standard Deviation (S.D.) | 41.0 | 122.9 |
| Standard Error of the Mean (SEM) | 3.2 | 9.5 |

* Assuming a normal distribution

The initial analysis of data related to attitudinal statements is presented in Table 5.6. This shows that people are aware of the environmental impact of transport. Statement 7 and 9 answers suggest that the participants are aware that cars are a source of carbon dioxide and want society to limit car usage as a positive contribution to the mitigation of climate change.

They also confirm that problems in Bangkok include traffic congestion and that inconvenient public transport usage. Other issues include the lack of integrated ticketing as well as accessibility to public transport services. However, the result of Statement 18; *I chose my current mode(s) because there are no alternative ways to reach my workplace.* implies that public transport whether bus or train does not adequately serve all areas of Bangkok which forces people to choose DRT or private vehicles to reach their destination. Even in this preliminary sample the attitude questions have identified mode choice is limited in Bangkok and the use of separate tickets for services creates a barrier to public transport use. In addition, people were aware of the health and climate impacts due to transport and showed a willingness to take positive action to reduce the source of pollution.

Table 5.6 Basic statistic result of the attitudinal scale (Section 2) of 1st Study survey

| Question number | Statement | X | Med | Mode | N | S.D. | SEM |
|---|---|---|---|---|---|---|---|
| Sec_2_Q1 | My current travel behaviour impacts the health of others. | 37 | 40 | 0 | 151 | 29.9 | 5.5 |
| Sec_2_Q2 | My current travel behaviour impacts climate change. | 57 | 56 | 100 | 150 | 32.2 | 5.7 |
| Sec_2_Q3 | My current travel behaviour impacts my health. | 44 | 50 | 0 | 146 | 34.0 | 5.8 |
| Sec_2_Q4 | Given an opportunity, I would be willing to buy a car with lower carbon emission to reduce the impact on climate change. | 87 | 100 | 100 | 152 | 22.5 | 4.7 |
| Sec_2_Q5 | I find traffic congestion a serious problem. | 93 | 100 | 100 | 152 | 14.9 | 3.9 |
| Sec_2_Q6 | I find exhaust fumes from traffic in towns and cities a problem. | 91 | 100 | 100 | 151 | 16.9 | 4.1 |
| Sec_2_Q7 | I am willing to reduce the amount I travel to help reduce the impact of carbon on climate change. | 77 | 90 | 100 | 152 | 29.2 | 5.4 |
| Sec_2_Q8 | I am willing to leave the house earlier or later to avoid congestion and reduce my journey time. | 77 | 90 | 100 | 151 | 29.2 | 5.4 |
| Sec_2_Q9 | People should be allowed to use their cars as much as they like, despite their impact on environment. | 45 | 50 | 0 | 144 | 32.3 | 5.7 |
| Sec_2_Q10 | Given an opportunity, I would be willing to buy a less polluting car to improve air quality. | 89 | 100 | 100 | 151 | 19.9 | 4.5 |
| Sec_2_Q11 | Given the opportunity I would purchase an electric car to reduce the impact environment | 85 | 99 | 100 | 151 | 22.1 | 4.7 |
| Sec_2_Q12 | I am willing to reduce the amount I travel to improve air quality and reduce the detrimental effect on the health of others. | 76 | 90 | 100 | 151 | 27.8 | 5.3 |
| Sec_2_Q13 | People should be allowed to use their cars as much as they like, despite their contribution to pollution and impact on health. | 49 | 50 | 100 | 143 | 31.7 | 5.6 |
| Sec_2_Q14 | I feel cut off from public transport services due to heavy trafficked roads with no safe crossing. | 59 | 60 | 100 | 145 | 33.5 | 5.8 |
| Sec_2_Q15 | I feel cut off from public transport because of subways, footbridges. | 40 | 36 | 0 | 140 | 33.6 | 5.8 |
| Sec_2_Q16 | I would use public transport if the ticket I purchase could be used on different services and modes. | 79 | 91 | 100 | 148 | 26.7 | 5.2 |
| Sec_2_Q17 | I chose my current mode(s) because it is the quickest. | 82 | 100 | 100 | 151 | 26.1 | 5.1 |
| Sec_2_Q18 | I chose my current mode(s) because there are no alternative ways to reach my workplace. | 65 | 73 | 100 | 147 | 35.3 | 5.9 |
| Sec_2_Q19 | I chose my current mode(s) because there is less risk of accident. | 64 | 69 | 100 | 149 | 33.1 | 5.8 |
| Sec_2_Q20 | I chose my current mode(s) because I personally feel safe. | 74 | 80 | 100 | 150 | 29.2 | 5.4 |

#### 5.4.1 Attitude scores

The statements in Section 2 were grouped into themes (shaded with the same colour) and labelled health, climate change, traffic, air pollution, accessibility, convenience, and safety See Table 5.7.

Table 5.7 Aligning statements to themes.

| Theme | Statement numbers |
|---|---|
| Health | 1, 3, 12 |
| Climate change | 2, 4, 9 |
| Traffic | 5, 6, 7, 8 |
| Air Pollution | 10, 11, 13 |
| Accessibility | 14, 15 |
| Convenience | 16, 17, 18 |
| Safety | 19, 20 |

Given that the number of responses to each statement were different the distributions of attitude scores were normalised to percentages and plotted with 5-unit bin widths. Also, the distribution of attitudes for the different themes is plotted by grouping the statements that have a similar topic area (health, climate change, traffic-related, air pollution, accessibility, convenience and safety, and congestion) and plotted in Appendix A. The basic statistics are presented in Table 5.6. The overall distributions were not normal, and some revealed interesting features. The distributions will be discussed below in the context of each theme and then features emerging across themes will be highlighted.

The trend of the environment was different from another theme. The scores assigned to statements 1, 3, and 12 belong to the "health" theme and were quite different in shape when compared to each other. However, there was a strong attitude towards taking action to reduce travel to improve the health of others acknowledging that the public is aware that traffic is detrimental to the environment. From the air pollution theme, people were aware of problems that occurred in the town and willing to resolve the problem by choosing a low emission or electric vehicle to pollute less but no strong support to give up travelling to reduce pollution, suggesting that the public are relying on the technology. Notwithstanding, people strongly agree that traffic congestion is a problem in cities and are willing to leave earlier or later to spread the peak and reduce journey times suggests travellers are conscious that traffic is a contributor to pollution levels and willing to curb the amount of travel to reduce emissions. Whilst there is no strong evidence that the public understands that transport contributes to climate change gases, they seem willing to purchase a low-emission vehicle to reduce the impact of climate change and yet happy to allow people to travel as much as they like.

Interestingly, the shape of the distribution of scores assigned to statements in the accessibility theme was different from other themes. In the case of accessibility statements, scores have a wide range of options from strongly agree to strongly agree. This needs further investigation and combination with other factors such as age or mode to shed further understanding of the influence of accessibility on mode choice. Participants strongly agree to change the mode if alternatives become more convenient. Also, respondents agreed that their choices of mode were safe and had less risk of accident.

### 5.4.2 Demographic Influences

In the 1st Study survey round, more than half of the participants were female (64%) with 43% young adults (18-40 years), 56% middle-aged (41-65 years), and 1% of people found in the group of people over 65 years, see Table 5.8. Whilst 80% of participants were reported as having no child in their household 22% of participants lived alone. The majority of respondents had an education at least a bachelor's degree. The sample of participants in the 1st Study survey was found not to be representative of the commuter population in Bangkok

.

Table 5.8 Number of participants in different age range of 1st Study survey

| Age | Count | % | |
|---|---|---|---|
| 18 to 20 | 4 | 23 | |
| 20 to 25 | 10 | 7 | |
| 26 to 30 | 21 | 147 | Young adult 43 % |
| 31 to 35 | 13 | 9 | |
| 36 to 40 | 15 | 10 | |
| 41 to 45 | 18 | 12 | |
| 46 to 50 | 15 | 10 | |
| 51 to 55 | 17 | 12 | Middle age 56 % |
| 56 to 60 | 8 | 5 | |
| 61 to 65 | 25 | 17 | |
| 66 to 70 | 1 | 1 | Retired 1% |
| >70 | 0 | 0 | |
| Total | 147 | | |

Table 5.9 Number of people in household and number of children of 1st Study survey

| Number of adults in family | No child | % | One child | % | Two children | % | Three children | % |
|---|---|---|---|---|---|---|---|---|
| 1 | 26 | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 23 | 20 | 7 | 37 | 6 | 67 | 1 | 50 |
| 3 | 21 | 18 | 5 | 26 | 1 | 11 | 1 | 50 |
| 4 | 28 | 24 | 6 | 32 | 1 | 11 | 0 | 0 |
| =/> 5 | 17 | 15 | 1 | 5 | 1 | 11 | 0 | 0 |
| Total | 115 | 100 | 19 | 100 | 9 | 100 | 2 | 100 |

With reference to Table 5.9, the majority of households to which the respondents belonged had no child (79% of 145 respondents) and 47 % of no-child households were young adults, 52 % of which were middle-aged, and the rest were retired. While 19 respondents (13%) had one child in the household. There were no families with more than 3 dependants.

Private vehicle ownership in households was examined with 4 types of vehicles which included conventionally fuelled cars, electric cars, bikes and motorbikes as presented in Table 5.10. In the sample of respondents considered (N=147), 7% of participants had no vehicle, and 90% had at least one conventionally fuelled car in their household. Up to 80% of participants have one motorbike whilst only 3% of participants owned an electric car. This implies that the uptake of electric cars in Bangkok is low. Most people prefer to buy an electric car if the opportunity arose with up to 50% agreeing as shown in Statement 11. The aspiration to purchase electric vehicles is encouraging the few purchased, which could be for a variety of reasons including cost and lack of charging infrastructure. There was no clear relationship between the number of children in the household and the number of car users.

Table 5.10 shows that almost two-thirds (65%) of households own at least one or two diesel/petrol cars with 25% owning 3 or more diesel/petrol cars. Strikingly 4% of households owned five or more diesel/petrol cars. This demonstrates the dependency on the car for travel in Bangkok. Whilst only 8% of households do not own any type of private vehicle 97% of the 32.7 million UK licensed cars in 2020 were conventional fuel engines powered by petrol: diesel (58%:38%) (Office of National Statistics, 2021).

Table 5.10 Number of private vehicles in household of 1st Study survey

| Number of vehicles | Number of households belongs to private vehicle | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Petrol or diesel cars | | Electric cars | | Bikes | | Motorbikes | |
| | count | % | count | % | Count | % | count | % |
| 0 | 16 | 11 | 143 | 97 | 100 | 68 | 118 | 80 |
| 1 | 47 | 32 | 3 | 2 | 25 | 17 | 23 | 16 |
| 2 | 49 | 33 | 1 | 1 | 16 | 11 | 4 | 3 |
| 3 | 16 | 11 | 0 | 0 | 2 | 1 | 0 | 0 |
| 4 | 13 | 9 | 0 | 0 | 2 | 1 | 2 | 1 |
| ≥ 5 | 6 | 4 | 0 | 0 | 2 | 1 | 0 | 0 |
| Total | 147 | 100 | 147 | 100 | 147 | 100 | 147 | 100 |

## 5.5. Modifications made for the 2nd Study survey.

According to the previous section, it can be seen that a number of participants stopped answering the questionnaire. Therefore, it was decided to improve the next version of the survey by adding the University logo, email address, and footnote to encourage participants to continue completing the questionnaire and to gain their trust.

Table 5.6 shows the responses to the questions in section 2 (attitude statement). Total number of participants were 153. Many respondents failed to answer at least one or two questions. The percentage of replying to Statement 9 and Statement 13 were much lower. Some participants might not be aware that both questions asked for different outputs to environmental and health problems. Therefore, it was decided to reorder the questions in the final questionnaire change the wording for clarity and remove any ambiguity.

With reference to Table 5.6, Statement 14 *"I feel cut off from public transport services due to heavily trafficked roads with no safe crossing*" was answered by 145 respondents. Some people had no access to a safe crossing to access any mode of transport therefore the answer always would be true. Therefore, some people skipped this question. Statement 15; had fewer responses (140). The English words subways and footbridges in Thai have different meanings which led to misunderstanding. Therefore, from this point changes in the vocabulary will be made in the Thai version which might encourage more people to answer the questions.

Most people who reached the final section answered the demographic questions. However, Statement 5 *Including yourself*, *how many people live in your household* with a drop down for the number of children and Statement 8 *How many vehicles are currently in use in your household?* some participants left a blank space. Only 51 people out of 151 clicked to select "zero" on mode choice. This implies that the participants understand a no response means none because they continued with the next questions. Therefore, the default answer in both questions will be set to zero to prevent they skipped answering.

The improved version of the questionnaire will include both shuttle buses and school buses as options. A shuttle bus includes those provided by an employer. Participants will be provided with a blank space to insert the cost of the journey. An explanation and example of waiting time and transfer time will be added especially in the Thai version. In section 2, some statements might be reordered to prevent bias and vocabulary will be changed for clarification. In dropdown choices, as appropriate, the answer will be set to the default value of zero or none.

A summary of actions taken to deal with the issues raised in the 1st Study version of questionnaire is presented in Table 5.11.

Given the substantial changes made to the questionnaire following the 1st Study the data could not be combined with the data from the 2nd Study. Therefore, additional effort was needed in the 2nd Study to achieve statistical significance in the results.

Table 5.11 Summary issues raised in the 1st Study questionnaire and proposed action for 2nd Study questionnaire.

| Problem issues | Action |
|---|---|
| Lack of trust in authenticity of questionnaire | University logo, email address for contacting and footnote were added. |
| Some companies provide transport for employees, however there were no choice for bus provided by company. | Choices of mode of transport were added included shuttle bus and school bus as options. |
| High number of questions with no answer and/or misunderstanding for choosing answer | The default answer (0) will be applied in the drop-down menu for cost, number of people in household in both choices (adult, child), number of vehicles in the household for all vehicle type. |
| Skipped to add postcode of the origin and destination | Add the word "Please specify the sub district of your resident" and "Please specify the sub-district of your office". |
| Missed answering some questions in Thai version | Vocabulary will be changed to everyday language. |
| Waiting versus transfer time | An explanation will be included. This was a particular issue with the Thai version. |
| Confusion with regards to health, air quality and climate change. | The wording of the questions in Section 2 were clarified to remove misunderstanding. |

## 5.6. Bangkok population and data collecting target.

In the 2nd Study survey, care will be taken to ensure that the sample is representative and without bias. This was achieved by training students to use SurveyMonkey on a tablet or laptop computer to interview participants either face-to-face or on the phone. The Bangkok population data used to test for representativeness was from the Bangkok Metropolitan Administration and the proportion of target, presented in Chapter 4. The expected target is defined by gender and age group with a total number of 500 participants. The participants were asked about their commuter trips by using a questionnaire.

## 5.7. 2nd Study data collection

Based on the feedback from the respondents and the interviewers the questionnaire was further improved as the previous section. The version of the questionnaire obtained after making modifications is presented in Appendix A. The 2nd Study version questionnaire was released via online platforms including social media, university websites, and transport operators on 16 April and 16 May 2022. Two trained interviewers approached people at random who did not have access to a computer/laptop/tablet were not familiar with the technology to complete the survey online or were targeted specifically to achieve a representative sample. Altogether 858 questionnaires were collected.

The data was cleaned by removing entire questionnaires with incomplete answers and what were considered unreasonable answers to travel behaviour choices. In addition, "*Prefer not to say*" answers to the question asking about gender and age were filtered out. The sample overall was a random selection and representative by age and gender to the Bangkok population (47%: 53%, male: female) at the 95% level of confidence. The final sample size was 648 participants which were used in the analysis. Table 5.12 shows the sample data and Bangkok population.

Table 5.12 Collected sample data and Bangkok population data (2019) data by age and gender.

| | Collected Data | | | | | | BKK population | | |
|---|---|---|---|---|---|---|---|---|---|
| Age | Male | | Female | | Total | | Male | Female | Total |
| Under 20 | 16 | 5.2% | 11 | 3.2% | 27 | 4.2% | 5.3% | 4.6% | 4.9% |
| 21 to 30 | 54 | 17.6% | 51 | 14.9% | 105 | 16.2% | 20.5% | 17.6% | 19.0% |
| 31 to 40 | 47 | 15.4% | 62 | 18.1% | 109 | 16.8% | 20.8% | 20.3% | 20.5% |
| 41 to 50 | 70 | 22.9% | 73 | 21.3% | 143 | 22.1% | 21.5% | 22.3% | 21.9% |
| 51 to 60 | 70 | 22.9% | 86 | 25.1% | 156 | 24.1% | 19.4% | 20.8% | 20.2% |
| Over 60 | 49 | 16.0% | 59 | 17.3% | 108 | 16.7% | 12.5% | 14.4% | 13.5% |
| Total | 306 | 47% | 342 | 53% | 648 | 100% | | | |

Travel behaviour data included mode(s), travel time, and cost of each step of the reported journey. If respondents reported their trip as a multimodal commute trip, the mode with the longest duration was defined as their main mode. For single-mode trips, the stated mode was classified as the respondents' main mode. The results revealed that respondents did not include "waiting time" and "transfer time" are considered part of a multimodal journey. Note that walking to access public transport is ignored to define the main transport mode.

The set of attitudinal questions in the second part of the questionnaire was completed by 555 out of 648 respondents. SPSS software treats incomplete data points (i.e., respondents who missed one or more attitudinal statements) as missing data. Removal of missing records excluded a substantial proportion of the study sample (16.8%) questionnaires. Further investigation of the data revealed that missing data occurred in all 20 statements. However, 9 of the 20 statements had less than 2% (of the total 648) occurrence of missing values. Two statements in particular, Q_2_6 and Q_2_13 had the highest missing rate at 15.3% and 16.8% respectively. The remaining 10 questions had between 2.1% and 6.9% missing values. Therefore, before applying PCA, the missing values were substituted with the median of all responses, given the data of each variable was not normally distributed.

Both the distribution of total time and total cost were not distributed normally for more detain presents in the next chapter. Table 5.13 presents the questions along with the variable label used in the SPSS software.

Table 5.13 Questionnaire part 2, attitudinal questions

| Question number | Statement | Replacement | | | | |
|---|---|---|---|---|---|---|
| | | Before | | | After | |
| | | N | Missing | % | Median | S.D. |
| Q_2_1 | My current travel behaviour impacts the health of others. | 616 | 32 | 5.2 | 69 | 29.7 |
| Q_2_2 | My current travel behaviour impacts my health. | 623 | 25 | 4.0 | 70 | 28.8 |
| Q_2_3 | I am willing to reduce the amount I travel to improve air quality and reduce the detrimental effect on the health of others. | 609 | 39 | 6.4 | 72 | 28.9 |
| Q_2_4 | My current travel behaviour impacts climate change. | 615 | 33 | 5.4 | 73 | 29.7 |
| Q_2_5 | Given an opportunity, I would be willing to buy a car with lower carbon emission to reduce the impact on climate change. | 640 | 8 | 1.3 | 82 | 30.1 |
| Q_2_6 | People should be allowed to use their cars or motorcycles as much as they like, despite their impact on climate change. | 562 | 86 | 15.3 | 30 | 20.9 |
| Q_2_7 | I find traffic congestion a serious problem in my town. | 627 | 21 | 3.3 | 75 | 25.1 |
| Q_2_8 | I find exhaust fumes from traffic in town. | 647 | 1 | 0.2 | 80 | 14.9 |
| Q_2_9 | I am willing to reduce the amount I travel to help reduce the impact of carbon on climate change. | 619 | 29 | 4.7 | 70 | 26.5 |
| Q_2_10 | I am willing to leave the house earlier or later to avoid congestion and reduce my journey time. | 606 | 42 | 6.9 | 71 | 26.2 |
| Q_2_11 | Given the opportunity I would purchase an electric or hybrid cars to reduce the impact on climate change. | 640 | 8 | 1.3 | 81 | 30.0 |
| Q_2_12 | Given an opportunity, I would be willing to buy a less polluting car to improve air quality. | 640 | 8 | 1.3 | 83 | 29.7 |
| Q_2_13 | People should be allowed to use their cars or motorcycles as much as they like, despite their contribution to pollution | 555 | 93 | 16.8 | 27 | 21.0 |
| Q_2_14 | I feel cut off from public transport services due to heavy trafficked roads with no safe crossing. | 639 | 9 | 1.4 | 75 | 23.3 |
| Q_2_15 | I feel cut off from public transport because of subways, footbridges. | 627 | 21 | 3.3 | 71 | 28.8 |
| Q_2_16 | I would use public transport if the ticket I purchase could be used on different services and modes. | 623 | 25 | 4.0 | 76 | 30.2 |
| Q_2_17 | I chose my current mode(s) because it is the quickest. | 645 | 3 | 0.5 | 82 | 19.9 |
| Q_2_18 | I chose my current mode(s) because there are no alternative ways to reach my workplace. | 636 | 12 | 1.9 | 80 | 20.9 |
| Q_2_19 | I chose my current mode(s) because there is less risk of accident. | 645 | 3 | 0.5 | 80 | 20.5 |
| Q_2_20 | I chose my current mode(s) because I personally feel safe. | 644 | 4 | 0.6 | 82 | 18.1 |

The final part of the questionnaire is the socio-demographic data including household vehicle ownership, number of children, and any disabilities. Feedback from participants highlighted that when they did not have a car in their household, they did not enter zero instead left a blank therefore a zero was inserted. When there was a missing value in the questions that included an option *"Prefer not to say"* as an option, the missing value was treated as *"Prefer not to say"*. The main data set Chapter 6 will present the analysis, results, and interpretation of the main survey data collection. For the question about postcodes, the participants were asked to type-in the location for both their residence (origin) and their workplace (destination) and to specify the name of subdistrict. However, whilst the participants provided the postcode (number with five digits), many left the subdistrict name field blank. This created challenges in the analysis pinpointing the exact location due to the range of sizes of the subdistricts spatially. As a result, postcodes were used to categorise responses into two depending on whether the origin and destination postcodes were the "same" or "different". This was based on the assumption that having the same postcode indicated a short distance journey, referred to as "Intrazonal" whilst postcodes that were different represented long-distance travel, called "Interzonal" (Park *et al.*, 2020). This assumption has limitations given the wide range of size of districts and trips across the boundary could be short.

## 5.8. Conclusions of this chapter

This chapter has explained the questionnaire design and process of data collection. The questionnaire was tested in three rounds: pilot, 1st Study, and 2nd Study.

The questionnaire was developed in 3 sections: mode choices, attitudinal statements (to transport and environment, accessibility, convenience, and safety), and socio-demographic. A set of 34 attitudinal statements were collated based on the literature. A pilot survey was carried out in English to test the understanding and the time required to complete the survey. As a result, the number of attitudinal statements was reduced to 20 because the time taken to complete the original questionnaire was not acceptable. The language of the questionnaire was simplified into more everyday use to prevent misunderstanding. User interphase (UX) was improved to enable people to complete the questionnaire on mobile phones or tablets easily.

The modified questionnaire was translated into Thai and the 1st Study survey of 274 respondents was analysed in detail to ensure that the questionnaire will generate data that is free from bias and will address the research questions. Basic statistics were used to analyse the response rate for each question in each section, the trend of mode choice and attitudes. The response rate showed that the questionnaire had shortcomings in the Thai language which led to misunderstanding, the user interface required some adjustment and there was a need to add a logo and email address as 39% of respondents failed to embark on the questionnaire as they doubted its authenticity. SurveyMonkey is not a questionnaire platform known in Thailand. The direct feedback from and the 1st Study survey revealed details of several issues and steps have been taken to rectify these. Whilst the sample of respondents was not representative some interesting results emerged - people are aware of the environmental problem and supported suggested measures to reduce levels of pollution. The final version of the questionnaire addressed the issues raised which included modifications of the vocabulary, adding additional mode choices, and fine-tuning some of the questions.

Descriptive analysis showed differences between mean, median and mode because the distributions were not Normal therefore the median value was selected for the analysis.

2nd Study survey data was collected between April and May 2022. Due to the non-normal distribution of the answer, the missing values were replaced by medians of the series. The next chapter will investigate the overview of travel behaviour and their attitude by using descriptive analysis.

# Chapter 6. Descriptive Analysis

## 6.1. Introduction

The previous chapter presented the questionnaire development aimed at asking about commuter travel behaviour, their attitude toward the environment, accessibility, convenience, and safety. Additionally, the questionnaire asked about the sociodemographic of participants. The questionnaire was tested in the pilot and 1st Study rounds before being released via an online platform to collect the data in the BMR area. The data was collected between April and May 2022.

In this chapter, the descriptive analysis used to gain a fundamental understanding of the data collected by the questionnaire is presented. The data set's complexity was simplified using dimensionality reduction of the attitudinal variables to remove some of the features whilst maintaining the most important properties of the original data.

Section 6.2 presents the descriptive analysis of the data from each of the three parts of the questionnaire. The result of the component analysis is presented in Section 6.3, whilst Section 6.4 explains the results of cross-tabulation of demographic data with t-test and ANOVA. The final section, Section 6.5, presents a summary of the key findings of this chapter.

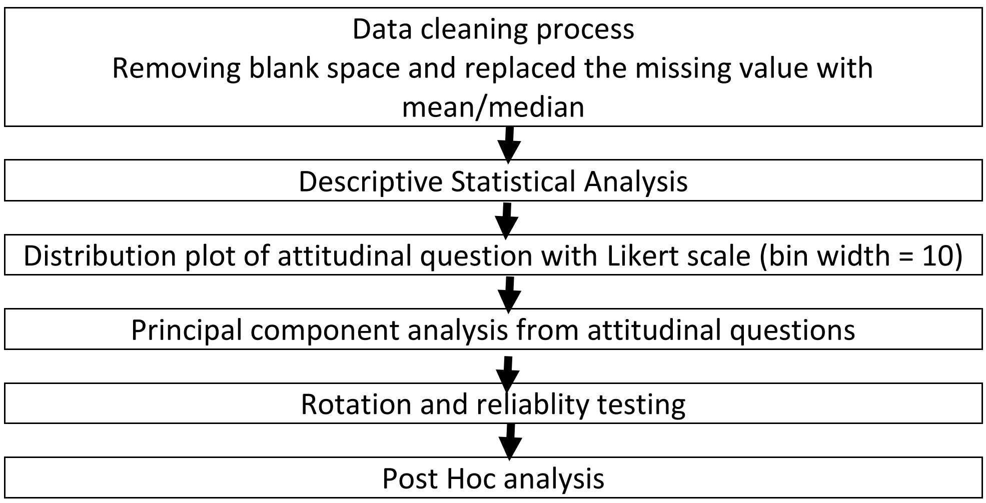


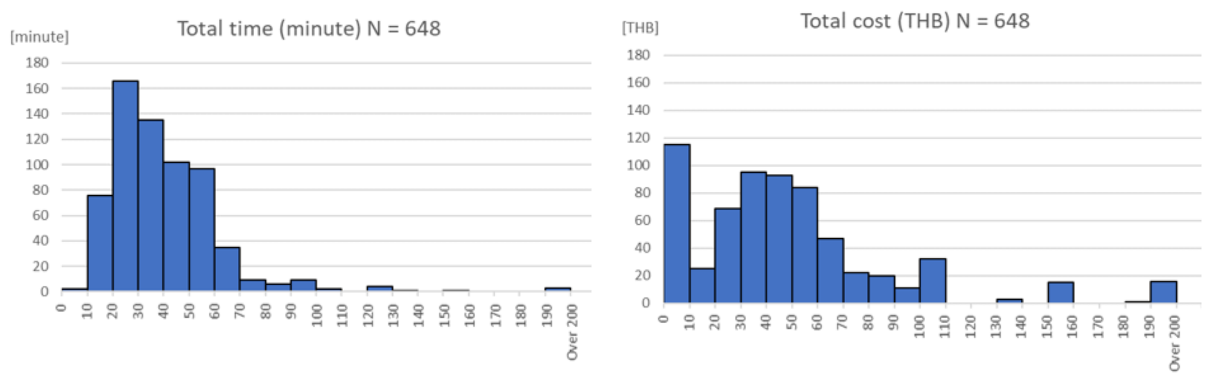

Figure 6.1 Methodology diagram focuses on chapter 6 descriptive analysis

## 6.2. Descriptive Analysis

This section presents the results of the exploratory statistics carried out to provide some initial insights into the data. This sets the foundations for more advanced statistical modelling, the results of which are presented in Chapter 7. First, the descriptive statistics of the demographics are presented. Next, a comparison of commuter trip characteristics according to the main mode of travel for single and multimodal journeys before synergy in the survey respondents' answers to the attitude statement questions.

### 6.2.1. Main Mode of Travel by Mode

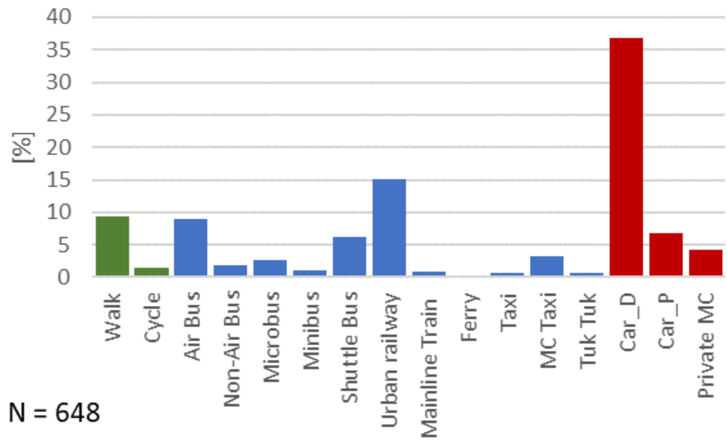
As mentioned in the previous chapter, if respondents reported their trip as a multimodal commute trip, the mode with the longest duration was identified as the main mode. The walk mode to access public transport is ignored. The frequency distribution of (a) total travel time (minutes) and (b) total travel cost (THB, Thai Baht) is presented. The distribution of main mode travel time and cost was right skewed with median values of 28 minutes and 40 THB per leg, respectively.




(a) (b)

Figure 6.2 Histogram of (a) total travel time (minute) and (b) total travel cost (THB) (N=648).

Overall, driving a car was the most popular main mode of choice for commuters to work (37%), followed by urban rail (15%). The latter was either used in combination with other modes (11%) or as a single mode (3%), as shown in Table 6.3. A further 9% of respondents chose to walk, while approximately 6% of respondents used shuttle buses provided by employers or school authorities.




| | Walk | Cycle | Air Bus | Non-Air Bus | Microbus | Minibus | Shuttle Bus | Urban | Mainline | Ferry | Taxi | MC Taxi | Tuk Tuk | Car Driver | Car Passen | Private MC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 9 | 1 | 9 | 2 | 3 | 1 | 6 | 15 | 1 | 0 | 1 | 3 | 1 | 37 | 7 | 4 |
| N | 61 | 9 | 58 | 12 | 17 | 7 | 40 | 98 | 6 | 0 | 4 | 21 | 4 | 239 | 44 | 28 |

Figure 6.3 Percentage of longest duration mode (main mode) of commute trips (N= 648).

The final question in section 1, the participants were asked to self-identify their mode of transport from six predefined options as described in section 2.4. However, the participants might identify themselves differently from the actual travel behaviour as asked to report their journey.

Figure 6.4 displays the proportion of participants according to their self-identification. Three categories were presented namely public transport users, private transport users, and active transport users. Firstly, public transport users included both public transport users and multi-modal users. The multimodal user group, represented in dark blue, indicates that 11% of the participants use more than one transport mode. Below that part, a light blue box indicates that 30% of users identify themselves as public transport users. The middle bar, the second group, contains private motorcycles and private car users as private transport group, at 7%

and 42%, respectively. The green bar, the third group, included cyclists (2%) and walkers (7%) of participants respectively.

Therefore, overall, private car users were the largest group (42%), followed by public transport users (30%) and active transport users (9%). Based on self-reported data, these three groups were used for further analysis to examine participants' perceptions of their chosen modes of transport.

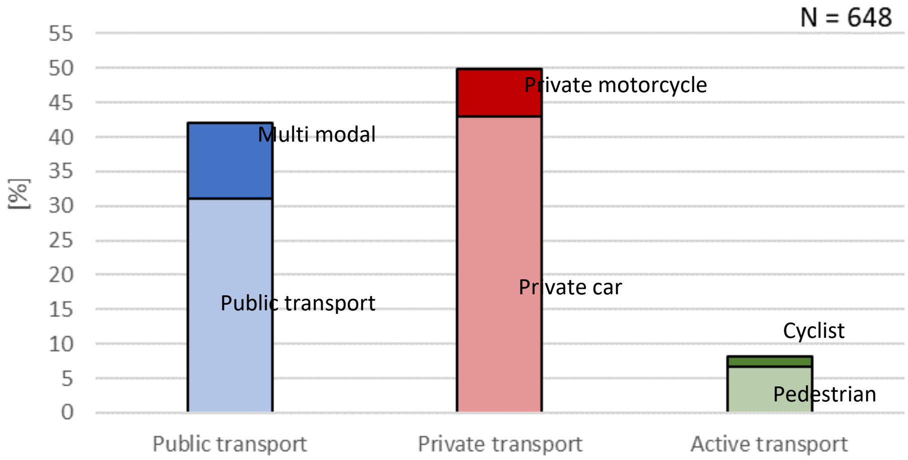



Figure 6.4 Percentage of self-defined mode categories (N =648).

### 6.2.1. Survey Respondents Attitudes

The second part of the questionnaire asked about attitudes towards the environment, accessibility, convenience, and safety. Figure 6.5 displays the distribution plots of the Likert scores for each of the twenty statements of missing values substituted with the median. Each graph title references the corresponding question number e.g. Q_2_8_MED indicates statement in Question 8 in Section 2 and substituted with medians. However, the following analysis will be called by a short name as *Q_2_x* e.g. *Q_2_8*.

Considering the shape of the graphs only, 4 groups emerged. Questions 1, 2, 3, 4, 9, and 10 display a small peak at the [below 20] with the highest frequency found in the range 70 to 90 and a relatively flat in between. Group 2, the distributions of Questions 5, 11, and 12 are similar with low frequency at low values that gradually increase to the higher score at 90-100. Group 3, Questions 6 and 13, are quite different with the highest number of participants found between the score range of 0-50 with a peak between 20 and 30, with few participants answering with high scores. Group 4, embracing Questions 17, 19, and 20 were of similar shape with the highest frequency can be found at scores between 80 and 90. Only a few participants answered with low scores. Questions 14, 15, 16, and Question 18 distribution were similar trends. However, Question 8 frequency distribution had a unique shape distribution, more than two to three of the participants answered. A small numbers of participants answered with low scores.

Based on the questions in the groups of the shapes of the distributions presented, the following observations can be made:

Group 1: the questions asked about environmental attitudes related to themselves and other people.

Group 2: the questions asked are aimed at themselves more specifically buying new eco-friendly fewer polluting cars.

Group 3: in contrast to Group 2, these questions refer to allowing others to freely purchase and use cars despite the impact on themselves or society.

Group 4: the questions asked about the perceived travelling time and safety which mixed between the topics.

Group 5: Question 14 – 16 and Question 18, covered a mix of topics from the question that asked about accessibility to the stations and ticketing. While the participants recognised the problem of pollution in their city from Question 8.

Whilst the above overview of the groups of the distributions of Likert scales is interesting and loosely categorises attitudes, there is a degree of overlap illustrating that the interrelationships between variables are by no means precise. Therefore, a more complex analysis to identify the key factors influencing travel behaviour is required.

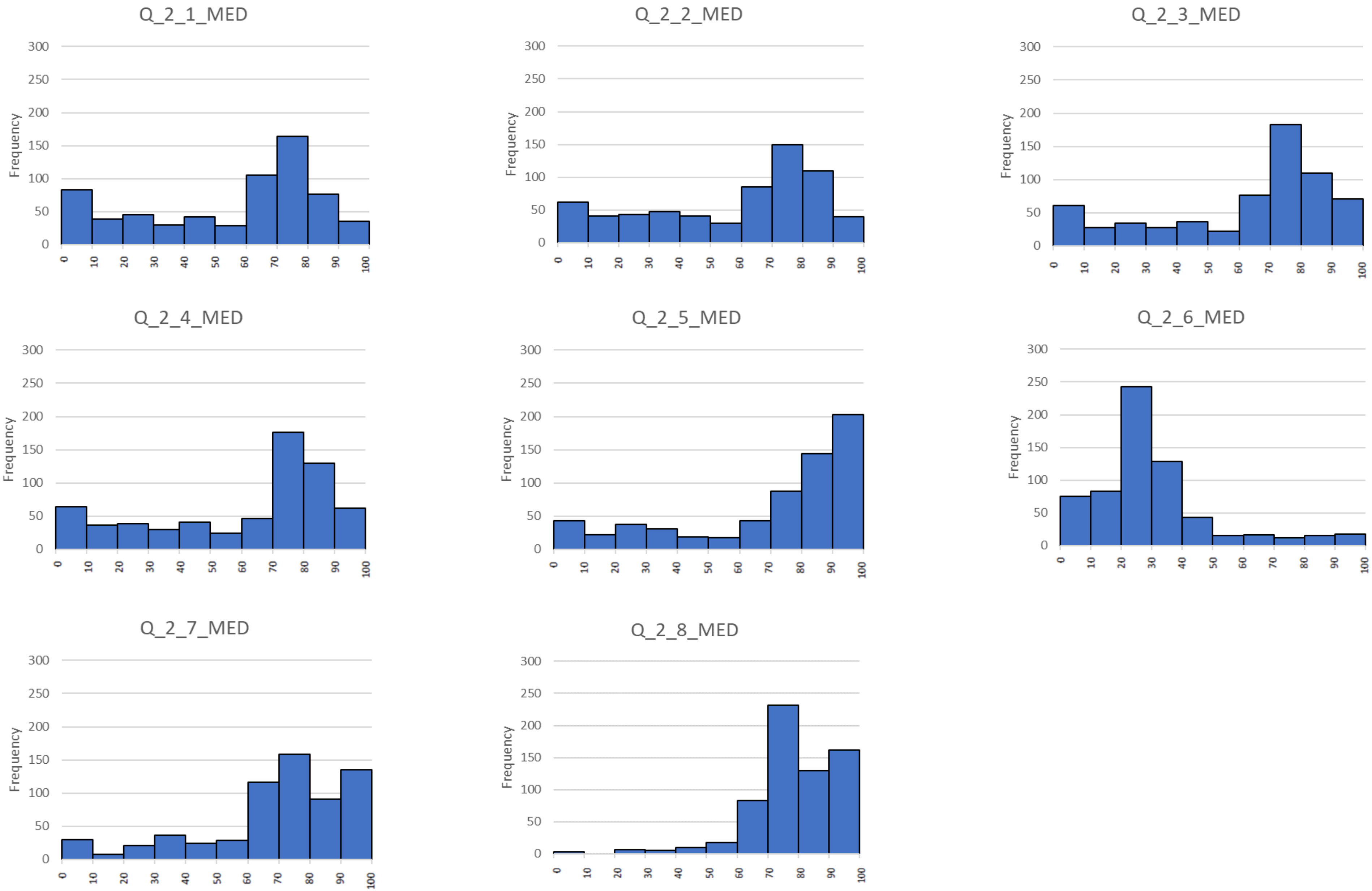



Figure 6.5 Distribution plot of attitudinal question (Part 2) substituted with medians of the series.

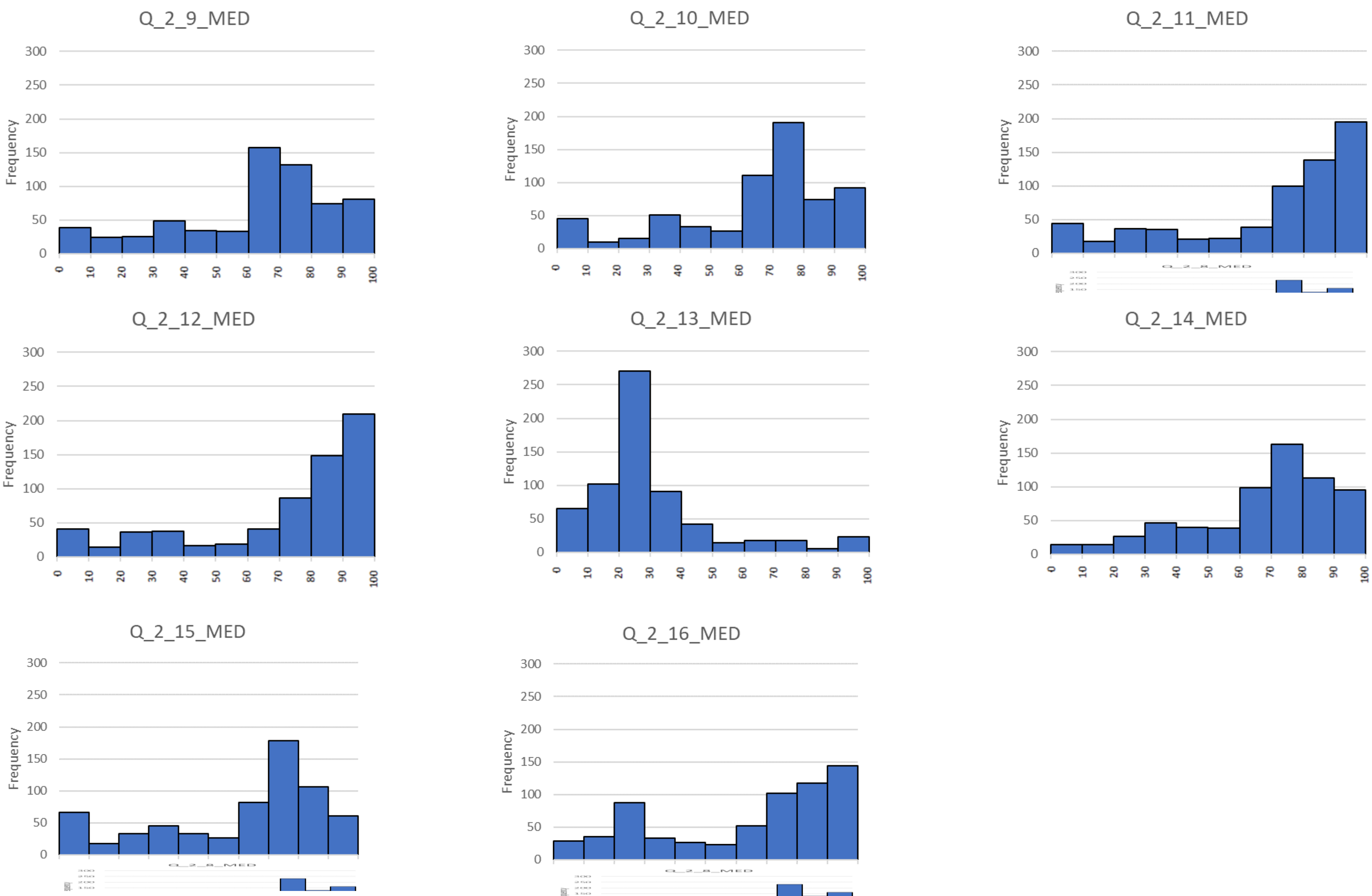



Figure 6.5 Distribution plot of attitudinal question (Part 2) substituted with medians of the series (Cont.).

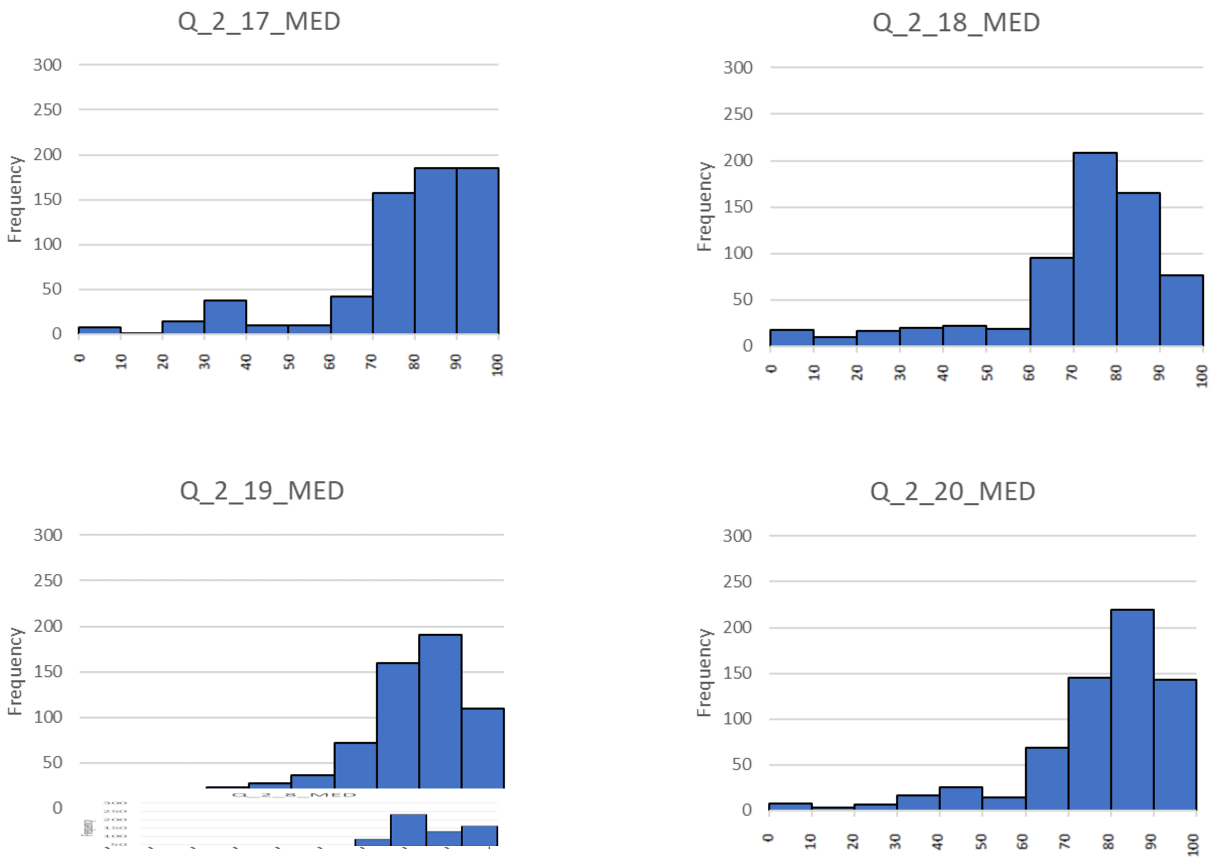



Figure 6.5 Distribution plot of attitudinal question (Part 2) substituted with medians of the series (Cont.).

### 6.2.2. Descriptive Analysis of Socio-Demographics

The final part of the questionnaire captured the socio-demographic data (gender, age, qualification, income) of participants and households and the statistics, frequency, and percentage, are presented in Table 6.1 along with the household vehicle ownership and their characteristics including fuel type (e.g. diesel, petrol, electric cars) and number of bikes. The frequency of postcodes was not presented in this table due to open answers.

The first two questions were about age and gender as discussed in the previous chapter. Then the next question asked about the highest qualification. Then the highest proportion was found in bachelor's degree, undergraduate level (54%), followed by master's degree (30%). It can be seen the highest proportion of members in the house were two adults (40%) and 45% of participants did not have children. The highest group of monthly household income was found more than 90,000 THB (30%) followed by a group that had income between 60,000 to 74,999 THB (19%).  80% of households had at least one car with petrol cars (69%) being the most popular choice of fuel diesel (30%) and electric (12%) least popular in Bangkok. Less than 20% owned a bike or motorbike in their household. Only 1% of all participants reported a disability.

The demographics of each self-reported traveller identity group are presented in Figure 6.6. Private transport was the most used, and active transport was the least used for both males and females. For each age group younger than 30 years old, public transport usage was up to 50%-60%. Car was a popular mode for the adult population of 31-60 years old.

Questionnaire respondents were asked for the postcode of their origin and destination. However, unlike the UK, BMR has only 50 districts, the postcode was not useful to estimate trip distances therefore in this study as discussed in section 5.7. Therefore each journey was classed as intra-zonal and inter-zonal (Park *et al.*, 2020). Intrazonal refers to the origin and destination within the same postcode area whilst inter-zonal refers to origin and destination with different postcodes.

Table 6.1 Frequency and percentage of sociodemographic questions (part3).

| | | | | | |
|---|---|---|---|---|---|
| **Age** | | **[%]** | **Number petrol cars** | | **[%]** |
| Under 20 | 27 | 4 | No cars | 203 | 31 |
| 21 to 30 | 105 | 16 | 1 | **234** | **36** |
| 31 to 40 | 109 | 17 | 2 | 171 | 26 |
| 41 to 50 | 143 | 22 | 3 | 36 | 6 |
| 51 to 60 | **156** | **24** | 4 or more | 4 | 1 |
| Over 60 | 108 | 17 | **Number diesel cars** | | **[%]** |
| **Gender** | | **[%]** | No cars | **454** | **70** |
| Male | 306 | 47 | 1 | 168 | 26 |
| Female | **342** | **53** | 2 or more | 26 | 4 |
| **Qualification level** | | **[%]** | **Number electric cars** | | **[%]** |
| Prefer not to say | 4 | 1 | No cars | **568** | **88** |
| Sec School | 40 | 6 | 1 | 65 | 10 |
| Vocational school | 19 | 3 | 2 or more | 15 | 2 |
| UG | **349** | **54** | **Number bike** | | **[%]** |
| PG MSc | 193 | 30 | No bikes | **562** | **87** |
| PhD | 43 | 7 | 1 | 61 | 9 |
| **Member (adult)** | | **[%]** | 2 | 18 | 3 |
| 1 | 103 | 16 | 3 | 6 | 1 |
| 2 | **258** | **40** | 4 or more | 1 | 0 |
| 3 | 171 | 26 | **Number motorbike** | | **[%]** |
| 4 or more | 116 | 18 | No motorbikes | **551** | **85** |
| **Member (kids)** | | **[%]** | 1 | 79 | 12 |
| No kids | **350** | **54** | 2 | 11 | 2 |
| 1 | 161 | 25 | 3 | 6 | 1 |
| 2 | 126 | 19 | 4 or more | 1 | 0 |
| 3 or more | 11 | 2 | **Number of cars** | | **[%]** |
| **Monthly income** | | **[%]** | No cars | 107 | 17 |
| Prefer not to say | 28 | 4 | 1 | **218** | **34** |
| < 15,000 | 8 | 1 | 2 | 208 | 32 |
| 15,000 to 29,999 | 49 | 8 | 3 | 82 | 13 |
| 30,000 to 44,999 | 71 | 11 | 4 or more | 33 | 6 |
| 45,000 to 59,999 | 81 | 13 | **Disability condition** | | **[%]** |
| 60,000 to 74,999 | 124 | 19 | Prefer not to say | 55 | 8 |
| 75,000 to 89,999 | 93 | 14 | No | **591** | **91** |
| > 90,000 | **194** | **30** | Yes | 2 | 1 |
| Total | 648 | 100 | Total | 648 | 100 |

Notes: Bold figures represent the highest proportion in the series.

Table 6.2 presents the frequency and percentage of travellers intra- and inter-zonal by main mode of their journey with single mode trips separated from multimode trips. For single-mode journeys, the car was most popular when travelling the zone trip (81%) whilst people tend to use active transport for within-the-zone trips (63%). However, multimode commuters preferred the train to travel to their out-of-zone workplaces (72%) and taxi mode was popular for intrazonal commutes (21%). No one reported the use of shuttle bus travelling within their area reflecting workplace and school policies for the provision of free public transport services.

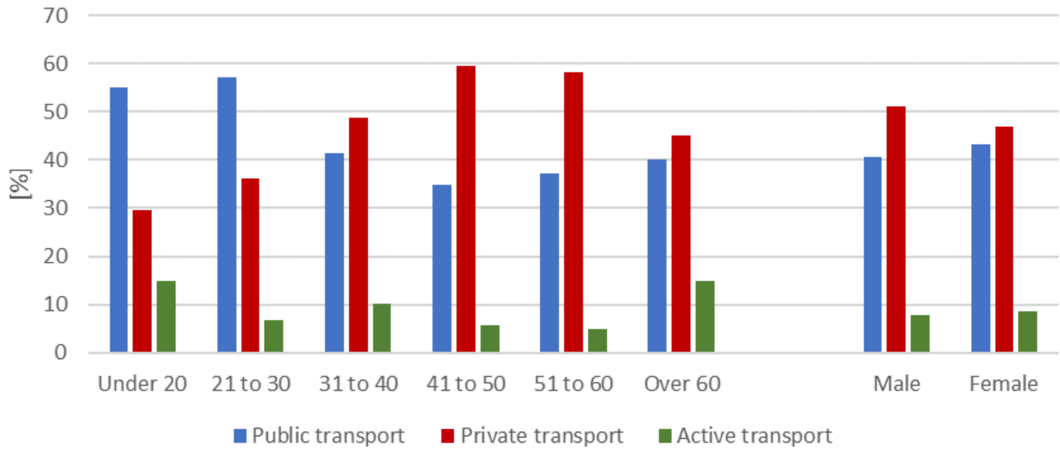



Figure 6.6 Percentage of self-categorised user of transport by age (in years) and gender (N=648)

Table 6.2 Number of commuters travelling to work/school within and outside of the residential zone by reported modes.

| Mode | | Single mode | | | | Multimode | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | In | [%] | Out | [%] | In | [%] | Out | [%] | Total |
| 1 | AT | 44 | **63** | 5 | 7 | 5 | 7 | 16 | 23 | 70 |
| 2 | Bus | 3 | 3 | 30 | 32 | 13 | 14 | 48 | **51** | 94 |
| 3 | Train | 4 | 4 | 19 | 18 | 6 | 6 | 75 | **72** | 104 |
| 4 | Taxi | 8 | 28 | 9 | **31** | 6 | 21 | 6 | 21 | 29 |
| 5 | Car | 36 | 13 | 228 | **81** | 4 | 1 | 15 | 5 | 283 |
| 6 | MC | 11 | 39 | 14 | **50** | 1 | 4 | 2 | 7 | 28 |
| 7 | Shuttle | 1 | 3 | 36 | **90** | 0 | 0 | 3 | 8 | 40 |
| Total | | 107 | 17 | 341 | 53 | 35 | 5 | 165 | 25 | 648 |

Notes: Bold figures represent the highest proportion for each mode across trip type.

Table 6.3 presents a cross-tabular between the mode of transport self-identified and their current main mode from the reported trip. For active transport, motorcycle, taxi and car users, the self-identified mode mapped extremely well onto the actual mode and for bus, train, and shuttle without exception. 16 out of 70 active travellers reported themselves as public transport users, and only 3 private vehicle users. This reflects a cohort of commuters that live close to their workplace and do not generally have access to a private vehicle.

Table 6.3 Cross tabulation data between main mode of transport (actual) and self-identified mode of transport (perception)

| Main mode | Self-identified mode of transport | | | Total |
|---|---|---|---|---|
| | Public transport | Private transport | Active transport | |
| Active transport (AT) | 16 | 3 | 51 | 70 |
| Bus | 94 | 0 | 0 | 94 |
| Train | 104 | 0 | 0 | 104 |
| Taxi | 10 | 19 | 0 | 29 |
| Car | 7 | 275 | 1 | 283 |
| Motorcycles (MC) | 1 | 26 | 1 | 28 |
| Shuttle | 40 | 0 | 0 | 40 |
| Total | 272 | 323 | 53 | 648 |

The participants identifying themselves as public transport users may also be multimodal users, for longer distance journeys, for example, walk-bus-train, even though time spent on a bus or train might be less than that spent on the walk.

Given that, 97% of car users identified themselves as private transport users and seven participants self-identified as public transport. In addition, one person defined themselves as active transport, even though their reported trip was by car. This may suggest that 3% of regular commuters are passengers and that they mostly use public transport or walk for all other trip purposes.

Reported taxi users self-identified themselves mostly as private (67%) or public transport (33%) users suggesting the casual use of taxis for convenience. In this research, the self-identified user was used in the cluster analysis because this informs people-focused actions for behavioural change whilst the actual reported modes reflect reality and are governed by the infrastructure and availability and use of public transport systems. Both inform policy and approaches from different perspectives.

## 6.3. Principal Component Analysis

The data was collected individually for each statement. However, the literature and distribution of each statement led to a combination of attitudes impacting travel behaviour. The principal component analysis techniques for the dimension from the attitudinal questions, as a small number of components, were applied.

In the current study, 20 attitudinal variables were used to examine the component. In the coding step, the statements were named Q_2_1 to Q_2_20, replaced by median. The attitudinal questions were suitably processed using PCA with Promax rotation as recommended by Brown (2009). The component correlation matrix was observed to understand the level of association among components before deciding whether to use Varimax rotation (in the case of low component correlations) or whether to remain with Promax rotation. At each step, by using the reliability statistic, each component was inspected (Cronbach's alpha), and if the reliability was high, the component was retained. The results of PCA were labelled to identify the characteristics of the component.

The result from PCA was finally investigated in depth by post-hoc analysis (group comparisons) using a t-test for gender groups (male versus female) and Analysis of Variance (ANOVA) for age groups (≤20, 21-30, 31-40, 41-50, 51-60, >60) and user self-identity categories (whether Public Transport, Private Transport and Active Transport). In this study, a 95% confidential level was the criterion.

The range of the KMO score was between 0.5 and 0.8 (see Table 6.4) demonstrating that the data set was suitable to apply the PCA technique The Bartlett's Test of Sphericity chi-square was 8642.9 with a statistically significant level of less than 0.001 and the anti-image test was statistically significant, presented in Appendix B ,endorses the suitability of the data to be processed with the PCA technique.

Table 6.4 KMO and Bartlett's test result

| KMO and Bartlett's Test | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .784 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 8642.947 |
| | df | 190 |
| | Sig. | <.001 |

Given that there were more than two factors, to simplify the interpretation, the attitudinal questions were processed using PCA with Promax rotation. Given that Components 1 and 2 were correlated with a value bigger than 0.32, see bold text Table 6.5. On the other hand, if the correlation from all components were less than 0.32. Varimax rotation would apply.

Table 6.5 Component correlation matrix

**Component Correlation Matrix**

| Component | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 1.000 | **0.358** | 0.063 | 0.071 | 0.108 | 0.062 |
| 2 | | 1.000 | 0.223 | 0.179 | -0.182 | -0.229 |
| 3 | | | 1.000 | 0.083 | 0.216 | 0.013 |
| 4 | | | | 1.000 | -0.020 | -0.196 |
| 5 | | | | | 1.000 | 0.286 |
| 6 | | | | | | 1.000 |

Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalization.

### 6.3.1. PCA with Six Components

The scree plot from PCA with Promax rotation was plotted (see Figure 6.1) and shows six components (highlighted in the blue oval) with Eigenvalues greater than 1, therefore was retained initially. However, upon examination of the scree plot, the curve flattens after the fifth component, Component 5 had a factor loading in the opposite direction. Cronbach's alpha was further examined to test the reliability of each component. The Cronbach's alpha scores for Component 1 – 6 were 0.891, 0.976, 0.748, 0.878, -0.869, and 0.45, respectively and weak reliability is prevented by only accepting Cronbach's alpha values equal to or above 0.7. Component 6 was omitted.

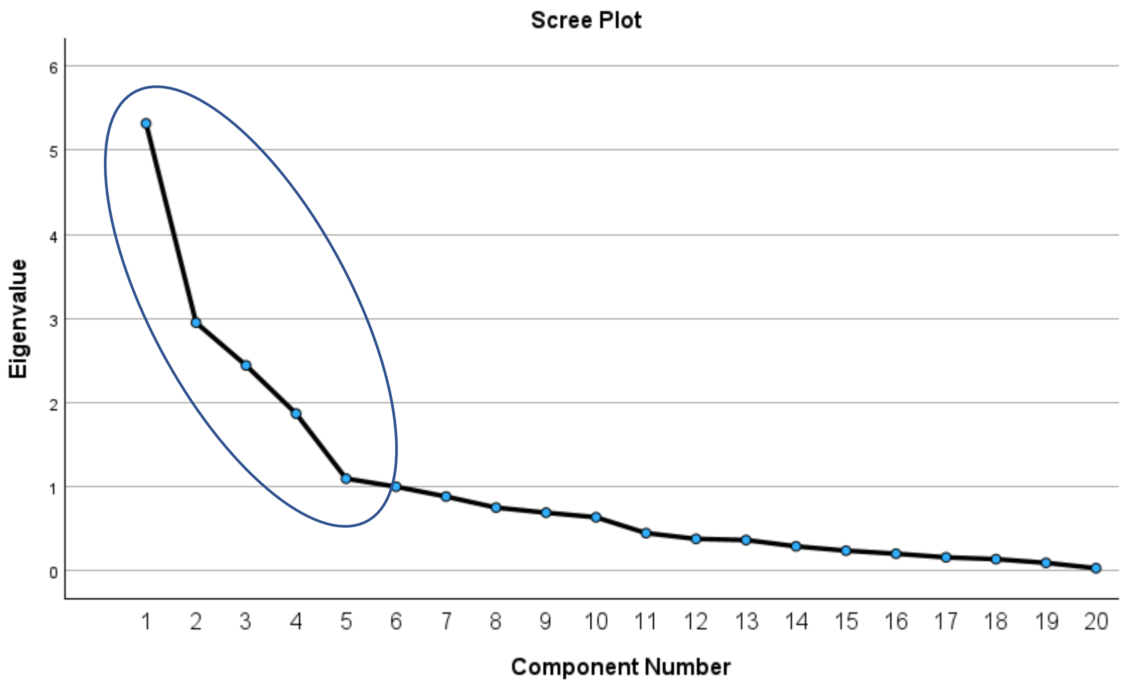



Figure 6.1Scree plot from PCA analysis with Promax rotation.

Focusing on the component loading matrix in Table 6.6 and applying the cutting point for this study of 0.5, Question 8, Q_2_8 I find exhaust fumes from traffic in town were removed due to low loading.

Another justification for removing this question is that the solution to this problem is not substantially addressed by behaviour change of one individual instead interventions are in the hands of the National and Local Governments. Similarly, in Questions Q_2_14 *I feel cut off* *from public transport services due to heavily trafficked roads with no safe crossing* and in Q_2_16 *I would use public transport if the ticket I purchase could be used on different services and modes* with low loadings were removed but also because they too require action to be taken by a third party. The former requires an infrastructure change which is the responsibility of Highway Divisions in Local Authorities, the Ministry of Transports, the Ministry of Digital Economy and Society, the Ministry of Finance, and private operators. The latter needs standardisation of ticket-issuing technologies and policies, which require action by operators in collaboration with local governments.

Table 6.6 Pattern matrix of component analysis with promax rotation

| | Component | | | | | |
|---|---|---|---|---|---|---|
| Statement | 1 | 2 | 3 | 4 | 5 | 6 |
| Q_2_1 | 0.813 | -0.086 | -0.110 | -0.040 | 0.115 | 0.261 |
| Q_2_2 | 0.678 | -0.078 | -0.217 | -0.082 | -0.068 | 0.398 |
| Q_2_3 | 0.888 | -0.030 | -0.005 | -0.005 | -0.054 | 0.011 |
| Q_2_4 | 0.878 | -0.077 | -0.060 | -0.123 | 0.071 | 0.114 |
| Q_2_5 | -0.011 | 0.984 | -0.054 | -0.033 | 0.040 | 0.005 |
| Q_2_6 | -0.016 | -0.068 | -0.010 | 0.957 | 0.012 | 0.151 |
| Q_2_7 | 0.631 | 0.204 | 0.085 | 0.119 | 0.074 | -0.162 |
| Q_2_8 | 0.315 | 0.234 | 0.299 | -0.207 | -0.117 | -0.177 |
| Q_2_9 | 0.795 | 0.034 | 0.127 | 0.065 | -0.117 | -0.112 |
| Q_2_10 | 0.668 | 0.133 | 0.071 | 0.196 | 0.061 | -0.203 |
| Q_2_11 | -0.029 | 0.998 | -0.036 | -0.043 | 0.003 | 0.070 |
| Q_2_12 | -0.014 | 1.007 | -0.051 | -0.022 | 0.028 | 0.037 |
| Q_2_13 | 0.026 | -0.047 | -0.024 | 0.947 | 0.010 | 0.079 |
| Q_2_14 | -0.011 | 0.259 | 0.066 | 0.069 | 0.841 | 0.110 |
| Q_2_15 | -0.022 | 0.063 | 0.083 | -0.028 | 0.446 | 0.586 |
| Q_2_16 | -0.065 | 0.370 | -0.011 | 0.060 | -0.729 | 0.340 |
| Q_2_17 | 0.002 | 0.066 | 0.628 | 0.077 | 0.087 | -0.074 |
| Q_2_18 | 0.073 | 0.059 | 0.189 | 0.179 | -0.178 | 0.746 |
| Q_2_19 | -0.043 | -0.102 | 0.817 | -0.061 | 0.007 | 0.370 |
| Q_2_20 | -0.016 | -0.101 | 0.893 | -0.046 | 0.018 | 0.134 |

Given that embraced issues relating to third-party responsibilities and not directly influencing travel behaviour, these five questions were not included in the next step of the analysis the results of which are presented in the next subsection. Worthy of note is that by removing the five Questions 8, 14, 15, 16, and 18 (See Table 6.7) the only question relating to convenience used in the PCA was *Q_2_17 I chose my current mode(s) because it was convenient.*

Table 6.7 Questions found not to be statistically significant.

| | Statement |
|---|---|
| Q_2_8 | I find exhaust fumes from traffic in town. |
| Q_2_14 | I feel cut off from public transport services due to heavy trafficked roads with no safe crossing. |
| Q_2_15 | I feel cut off from public transport because of subways, footbridges. |
| Q_2_16 | I would use public transport if the ticket I purchase could be used on different services and modes. |
| Q_2_18 | I chose my current mode(s) because there are no alternative ways to reach my workplace. |

### 6.3.2. PCA with Four Components

Table 6.8 shows the results of the PCA analysis, with the retained questions showing the components along with their respective labels, the grouped attitudes, and descriptive statistics (mean and standard deviation), along with the reliability measure (Cronbach's alpha).

Table 6.8 Result of PCA with Promax Rotation along with Component Labels and descriptive statistics.

| Statements | | Mean | S.D. | Loading |
|---|---|---|---|---|
| Component 1 (Com_1) Pro-environment and health (Alpha = 0.891) | | | | |
| Q_2_3 | I am willing to reduce the amount I travel to improve air quality and reduce the detrimental effect on the health of others. | 62.9 | 28.9 | 0.9 |
| Q_2_4 | My current travel behaviour impacts climate change. | 61.4 | 29.7 | 0.9 |
| Q_2_1 | My current travel behaviour impacts the health of others. | 55.9 | 29.7 | 0.8 |
| Q_2_9 | I am willing to reduce the amount I travel to help reduce the impact of carbon on climate change. | 63.9 | 26.5 | 0.8 |
| Q_2_2 | My current travel behaviour impacts my health. | 58.4 | 28.8 | 0.7 |
| Q_2_10 | I am willing to leave the house earlier or later to avoid congestion and reduce my journey time. | 65.8 | 26.2 | 0.7 |
| Q_2_7 | I find traffic congestion a serious problem in my town. | 70.6 | 25.1 | 0.6 |
| Component 2 (Com_2) Pro-environmentally friendly cars (Alpha = 0.976) | | | | |
| Q_2_12 | Given an opportunity, I would be willing to buy a less polluting car to improve air quality. | 72.6 | 29.7 | 1.0 |
| Q_2_11 | Given the opportunity, I would purchase an electric or hybrid cars to reduce the impact on climate change. | 70.9 | 30.0 | 1.0 |
| Q_2_5 | Given an opportunity, I would be willing to buy a car with lower carbon emission to reduce the impact on climate change. | 71.5 | 30.1 | 1.0 |
| Component 3 (Com_3) Pro-safe (Alpha = 0.748) | | | | |
| Q_2_20 | I chose my current mode(s) because I personally feel safe. | 79.3 | 18.1 | 0.9 |
| Q_2_19 | I chose my current mode(s) because there is less risk of accident. | 75.4 | 20.5 | 0.8 |
| Q_2_17 | I chose my current mode(s) because it is the quickest. | 80.0 | 19.9 | 0.6 |
| Component 4 (Com_4) Pro-private vehicle (Alpha = 0.878) | | | | |
| Q_2_6 | People should be allowed to use their cars or motorcycles as much as they like, despite their impact on climate change. | 32.2 | 20.9 | 1.0 |
| Q_2_13 | People should be allowed to use their cars or motorcycles as much as they like, despite their contribution to pollution. | 31.4 | 21.0 | 0.9 |

Component 1, Pro-environment and others' health (Com_1) are composed of statements from Question1-4, 7, 9, and 10, which include awareness of the environment and the impacts of transport on themselves as well as society. Component 2, Pro-environmentally friendly cars (Com_2) embrace statements concerned with buying new low-polluting cars related to climate change and air quality. Component 3, Pro-safe (Com _3), represents two groups of questions concerned with fast, convenient, and safe travel choices. The component loading was high in statements 19 and 20 (0.8 and 0.9, respectively) in the safety theme and the only question, Q_2_17 within the convenience theme had the lowest loading (0.6) in the factor. Therefore, component 3 is labelled as Pro-safe. The final Component 4, Pro-private vehicle (Com_4), embraces questions focusing on car use and lacking environmental awareness.

The characteristics of the four components will be studied in more detail in the next section before summarising the key findings emerging before moving on to the more advanced modelling.

## 6.4. Post Hoc Analysis

The relationship between the characteristics of the respondents, including their reported travel identity (private transport, public transport, and active transport), was investigated using statistical analysis for the four components emerging from the PCA. The average score and SD are based on the continuous scale (0 – 100) of all the questions collated in each component by gender, age, and self-defined user categories presented as descriptive and Inferential statistics, more specifically independent samples t-test and ANOVA along with post-hoc analysis involving multiple comparisons using the Scheffe procedure. The results are presented in the following subsections.

The mean score and S.D. of the components by gender, age, and self-defined user are presented in Table 6.9. Then, sub-categories had the statistic comparison among categories presented in Table 6.10, Table 6.11 and Table 6.12, respectively.

A paired sample t-test was performed to compare attitudes by gender for each component. The results are presented in Table 6.10. A statistically significant difference was found between male (score 73.9) and female (70.7); for C*omponent 2 (Pro-environmentally friendly cars)* with $t(646) = 1.334$, $p < 0.001$ and for *Component 4 (Pro-private vehicle)* and between male (33.0) and female (31.0) but with lower statistical confidence at 95%; t(646) = 1.102, p = 0.046.

Table 6.9 Mean score and S.D. of the components by gender, age, and self-defined user categories.

| Gender | N | Com_1 | | Com_2 | | Com_3 | | Com_4 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Male | 306 | 64.3 | 26.5 | 73.9 | 27.3 | 77.4 | 17.2 | 33.0 | 20.9 |
| Female | 342 | 63.5 | 26.0 | 70.7 | 31.6 | 79.3 | 19.1 | 31.0 | 18.6 |

| Age | N | Com_1 | | Com_2 | | Com_3 | | Com_4 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Under 20 | 27 | 71.9 | 20.7 | 91.1 | 13.3 | 61.6 | 31.9 | 32.2 | 24.3 |
| 21 to 30 | 105 | 71.6 | 21.4 | 87.1 | 17.3 | 75.1 | 20.4 | 34.8 | 22.2 |
| 31 to 40 | 109 | 64.9 | 27.7 | 87.9 | 15.3 | 82.4 | 19.0 | 32.6 | 23.9 |
| 41 to 50 | 143 | 63.1 | 26.4 | 81.9 | 18.9 | 78.0 | 18.8 | 30.5 | 20.7 |
| 51 to 60 | 156 | 64.2 | 24.0 | 66.1 | 27.8 | 80.4 | 14.8 | 31.8 | 16.7 |
| Over 60 | 108 | 54.1 | 30.1 | 33.3 | 29.9 | 79.6 | 10.1 | 29.6 | 13.1 |

| Identity | N | Com_1 | | Com_2 | | Com_3 | | Com_4 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Public Transport | 272 | 61.3 | 26.4 | 69.8 | 31.7 | 72.4 | 19.1 | 29.1 | 17.8 |
| Private Transport | 323 | 70.0 | 21.3 | 76.2 | 25.5 | 83.4 | 16.3 | 34.8 | 21.5 |
| Active Transport | 53 | 40.2 | 35.8 | 60.7 | 38.0 | 78.9 | 15.8 | 27.4 | 14.6 |
| Total | 648 | 63.9 | 26.2 | 72.2 | 29.7 | 78.4 | 18.2 | 31.8 | 19.7 |

Table 6.10 T-test result among components for gender

| By Gender | F | Sig |
|---|---|---|
| Com_1_Mean | 0.15 | 0.70 |
| Com_2_Mean | 12.26 | **0.00** |
| Com_3_Mean | 0.29 | 0.59 |
| Com_4_Mean | 4.00 | **0.05** |

Note: Significant level = 0.05 presented in bold text

An ANOVA was performed to compare the mean score of PCA components of five age groups, as presented in Table 6.11. The statistically significant difference between age group 21 to 30 and over 60 (p <0.001) was found in Component 1 *(Pro-environment and others' health)*. The mean scores for age groups over 51 years were statistically different (p <0.01) from other age groups in Component 2 *(Pro-environmentally friendly cars)*. Interestingly, the trend of *Component 2 (Pro-environmentally friendly cars)* was linearly associated with age, with younger generations (91.1) expressing a statistically significantly greater willingness to purchase alternative low-polluting cars, whilst the older age groups (33.3) prefer to stay with the conventional option. The youngest group had a statistically significantly lower mean score compared to other age groups, (p = <0.05) in Component 3 *(Pro-Safe)* with no statistically significant differences (p = 0.474) in the mean component score among the age group of Component 4 *(Pro-private vehicle).*

Table 6.11 ANOVA result among group of age

| ANOVA | Com_1 | | | | | | Com_2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Under 20 | 21 to 30 | 31 to 40 | 41 to 50 | 51 to 60 | Over 60 | Under 20 | 21 to 30 | 31 to 40 | 41 to 50 | 51 to 60 | Over 60 |
| Under 20 | | 1.00 | 0.90 | 0.75 | 0.84 | 0.07 | | 0.98 | 0.99 | 0.58 | **0.00** | **0.00** |
| 21 to 30 | 1.00 | | 0.60 | 0.25 | 0.38 | **0.00** | 0.98 | | 1.00 | 0.67 | **0.00** | **0.00** |
| 31 to 40 | 0.90 | 0.60 | | 1.00 | 1.00 | 0.09 | 0.99 | 1.00 | | 0.49 | **0.00** | **0.00** |
| 41 to 50 | 0.75 | 0.25 | 1.00 | | 1.00 | 0.18 | 0.58 | 0.67 | 0.49 | | **0.00** | **0.00** |
| 51 to 60 | 0.84 | 0.38 | 1.00 | 1.00 | | 0.08 | **0.00** | **0.00** | **0.00** | **0.00** | | **0.00** |
| Over 60 | 0.07 | **0.00** | 0.09 | 0.18 | 0.08 | | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | |
| | Com_3 | | | | | | Com_4 | | | | | |
| | Under 20 | 21 to 30 | 31 to 40 | 41 to 50 | 51 to 60 | Over 60 | Under 20 | 21 to 30 | 31 to 40 | 41 to 50 | 51 to 60 | Over 60 |
| Under 20 | | **0.03** | **0.00** | **0.00** | **0.00** | **0.00** | | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 21 to 30 | **0.03** | | 0.11 | 0.89 | 0.34 | 0.64 | 1.00 | | 0.98 | 0.72 | 0.92 | 0.60 |
| 31 to 40 | **0.00** | 0.11 | | 0.60 | 0.98 | 0.93 | 1.00 | 0.98 | | 0.99 | 1.00 | 0.95 |
| 41 to 50 | **0.00** | 0.89 | 0.60 | | 0.93 | 0.99 | 1.00 | 0.72 | 0.99 | | 1.00 | 1.00 |
| 51 to 60 | **0.00** | 0.34 | 0.98 | 0.93 | | 1.00 | 1.00 | 0.92 | 1.00 | 1.00 | | 0.98 |
| Over 60 | **0.00** | 0.64 | 0.93 | 0.99 | 1.00 | | 1.00 | 0.60 | 0.95 | 1.00 | 0.98 | |

Note: Significant level = 0.05 presented in bold text

Table 6.12 ANOVA result among identity group (private transport, public transport, active transport)

| ANOVA | Com_1 | | | Com_2 | | |
|---|---|---|---|---|---|---|
| | Public Transport | Private Transport | Active Transport | Public Transport | Private Transport | Active Transport |
| Public Transport | | **0.00** | **0.00** | | **0.03** | 0.12 |
| Private Transport | **0.00** | | **0.00** | **0.03** | | **0.00** |
| Active Transport | **0.00** | **0.00** | | 0.12 | **0.00** | |
| | Com_3 | | | Com_4 | | |
| | Public Transport | Private Transport | Active Transport | Public Transport | Private Transport | Active Transport |
| Public Transport | | **0.00** | 0.05 | | **0.00** | 0.74 |
| Private Transport | **0.00** | | 0.23 | **0.00** | | **0.04** |
| Active Transport | 0.05 | 0.23 | | 0.74 | **0.04** | |

Note: Significant level = 0.05 presented in bold text

Considering the mean score component among the three self-reported traveller identities of users (private transport, public transport, active transport), see Table 6.12, statistically significant differences in the mean score of components between user groups in Component 1 *(Pro-environmental and others' health)* were found. Active travellers' having the lowest mean score (40.2) tended to be aware that their mode did not cause environmental problems. For Component 2 *(Pro-environmentally friendly cars)*, the private transport mean score was statistically significantly different from that of public transport users (p=0.03) and active travellers (p ≤0.01, respectively). For Component 2, private transport users showed a statistically significantly greater intention to shift (76.2) to low-polluting cars than either active mode users (60.7) or public transport users (69.8). Similarly, in Component 4, private user attitudes were statistically significantly different from public transport and active travellers.

Active transport users were less agreeable to allowing people to freely use a private vehicle (27.4), while members of the private vehicle user group agreed to the use of motorised vehicles as much as they wished (34.8). With regards to respondents' Component 3 scores *(Pro-Safe),* the only statistically significant difference was found between private and public transport, ($p = <0.01$). Private transport users strongly agree that their mode is safe (83.4), which was statistically significantly higher than active (78.9) and public transport users (72.4). Component 4 *(Pro-private vehicle*), however, the attitude of active transport commuters was statistically indifferent to others.

In summary, age significantly impacts individuals' willingness to switch to a new vehicle with reduced emissions (Component 2). As expected, active travellers, walking and cycling, demonstrated a heightened awareness of the environmentally friendly nature of their travel choices (Component 1). In contrast, compared to other modes, car users indicated a preference for safety, highlighting its significance as a motivating factor in their mode selection. Component 4 was influenced by both demographic factors and the chosen mode of transportation.

## 6.5. Conclusions of this chapter

In this chapter, the data analysis was presented to gain a basic understanding of travel behaviour together with the influencing attitudinal variables towards the environment, ease of access, convenience, and safety in the context of demographic characteristics of commuters in the Bangkok Metropolitan Region (BMR). This chapter achieved the objective 2 which related to the research question 1 of the thesis. Descriptive statistical analysis led to a basic understanding of the characteristics of the commuter population. The data were analysed by using Principal Component Analysis to reduce the dimensionality of the data. The data also was analysed by self-defined traveller identity including private car users, public transport, and active transport users for single and main-mode multimodal users. The most popular mode of transport was the private car.

Age exerted a strong influence on travel behaviour choices, particularly with regard to respondents' willingness to shift to low-polluting cars. Younger generations are more willing to shift to lower-emission cars compared to the over-fifties who wish to continue using conventional carbon-based fuelled cars. This may reflect the aspirations of the younger generations who currently cannot afford to purchase a private car and the reality of the situation with the older generations who cannot afford to replace the car they currently own. This highlights the complexities of the interrelationships between the decisions made in the choice of mode and the underlying attitudes and self-identity of travellers. Respondents' traveller identity was strongly related to their awareness of environmental problems.

Gender exerted a significant impact on travel mode choice, but not all components. The results suggested that investment is needed to improve accessibility to extend the operation of public transport into areas not currently served. This research has provided decision-makers with scientific evidence to help inform policies and intervention measures which need to be tailored to specific segments of the population to deliver and incentivise the uptake of more sustainable transport options. However, the results also have revealed complexities in the relationships between demographics, mode identity and attitudes towards the environment, convenience, accessibility, and safety that together influence travel behaviour. Based on the review of the literature, cluster analysis has been identified as an analytical method which will allow the association between demographics, self-identity and the components identified in the PCA to be explored. Therefore, the next chapter will explore the cluster based on attitudes and socio-demographics to define the target group for the policy that can change their behaviour more sustainably.

# Chapter 7. Cluster Analysis

## 7.1. Introduction

The previous chapter studied responders’ travel behaviour, their attitudes, and sociodemographic data using descriptive analysis. Next, dimension reduction of 20 attitudinal questions was carried out using Principal Component Analysis, PCA. The result found that age and self-identity were key factors with some synergy with attitudes. In order to gain a deeper understanding of how the four components, namely *Pro-environment and other’s health* (Component 1), *Pro-environmentally friendly cars* (Component 2), *Pro-safe* (Component 3), and *Pro-private vehicles* (Component 4) influence the travel behaviour of cohorts of commuters was investigated by applying Hierarchical Cluster Analysis (HCA). The results will help to inform policies that may persuade car users to shift to a more sustainable mode. The objective of this chapter matches with Objective 3 of the research, presented in Chapter 1.

Section 7.2 details the data variables used as input to the HCA, Section 7.3 explains how the number of clusters is identified. The demographics of the responders in each cluster are discussed in Section 7.4. Section 7.5 considers the travel attitudes which together allow the clusters to be labelled. The outputs of the cluster analysis will be used to inform policy recommendations focused on specific cohorts of the population to maximise impacts. These will be discussed in Chapter 9. Finally, Section 7.6, concludes the chapter by summarising the key findings.

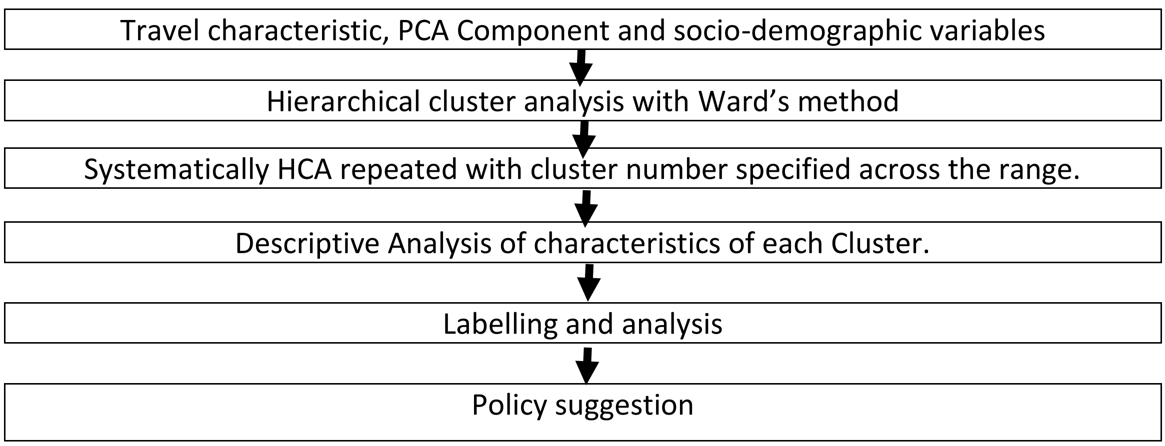



Figure 7. Methodology diagram focus on chapter 7 HCA

## 7.2. Collating the data for HCA

The data included component analysis and demographics such as age, gender, and self-identity were selected as input for HCA. Before feeding the input into the analysis, some modification was applied. Firstly, four components resulting from the dimension reduction analysis of attitudinal variables resulted from Chapter 6 Section 6.3. included namely *Pro-environment and health* (Component 1), *Pro-environmentally friendly cars* (Component 2), *Pro-safe* (Component 3), and *Pro-private vehicles* (Component 4) were called C1, C2, C3, and C4, respectively. Secondly, the questionnaire data for age was collected within 5 groups to match the census data as the variable "AGE_Group" from section 6.9. However, for the Cluster Analysis given the size of the under 20 years old group was small, it was combined with the under 30s to give four groups labelled as "Age_4G". Finally, to approximately balance the age ranges the two middle groups were joined resulting in 3 age ranges namely under 30, 31-50, and over 50 years old with a variable labelled as," Age_3G". The young, middle age and elder adults, respectively, contained 20.4%, 38.9% and 40.7% of participants, presented in Table 7.1.

Table 7.1 The proportion of participants classified by age group into three, four and five groups.

| All Age Groups AGE_Group | | | Four Age Groups AGE_4G | | | Three Age Groups Age_3G | | |
|---|---|---|---|---|---|---|---|---|
| **Age Range years old** | **Number** | **%** | **Age Range years old** | **Number** | **%** | **Age Range years old** | **Number** | **%** |
| Under 20 | 27 | 4.2 | | | | | | |
| 21 to 30 | 105 | 16.2 | Under 30 | 132 | 20.4 | Under 30 | 132 | 20.4 |
| 31 to 40 | 109 | 16.8 | 31 to 40 | 109 | 16.8 | 31 to 50 | 252 | 38.9 |
| 41 to 50 | 143 | 22.1 | 41 to 50 | 143 | 22.1 | Over 50 | 264 | 40.7 |
| 51 to 60 | 156 | 24.1 | Over 50 | 264 | 40.7 | | | |
| Over 60 | 108 | 16.7 | | | | | | |
| Total | 648 | 100 | | 648 | 100 | | 648 | 100 |

Gender was classified as male and female with the proportion at 47% and 53%, respectively. Finally, three types of self-identity were private (private car and private motorcycle users), public transport (multimodal and public transport users), and active transport (pedestrian and cyclist) can be found the detail in Section 6.2.

Therefore, in this analysis, the demographic data was using three age groups namely Age_3G, gender, and self-identity. The median value of the Likert scores of the number of questions, 7, 3, 2 and 3 in each component C1, C2, C3 and C4 respectively, as classified by the PCA, were used as input to the HCA.

## 7.3. Identifying Number of Clusters

Ward's method was used to determine the number of clusters. Ward's method was chosen because of less sensitivity with outliers. The dendrogram resulted from HCA, presented in Figure 7.1 which implies that the optimal number of clusters lies between 3 and 6 clusters. The five-cluster cut-off is indicated by the blue dashed line in Figure 7.1. Figure 7.2 presents the size of the cluster from 3 to 6 clusters. Five-cluster found that the largest cluster had 286 members followed by 130 members. While the six-cluster found the second largest was 79 members. The next step was to confirm the optimal number of clusters which was identified by repeating the Cluster Analysis and fixing the number of clusters systematically to three, four, five and six as well to derive the Silhouette value. The Silhouette value is a measure of how similar an object is to its cluster (cohesion) compared to other clusters (separation). The silhouette value for 5 clusters was nearly 0.5 which was a fair condition presented in Figure 7.3, while other Silhouette values and their condition and scree plot are presented in Appendix B. Therefore, in the analysis, five clusters were selected as the optimal size. The number of members of each of the five clusters, one, two, three, four ,and five, was 286, 70, 77, 85, and 130, respectively.

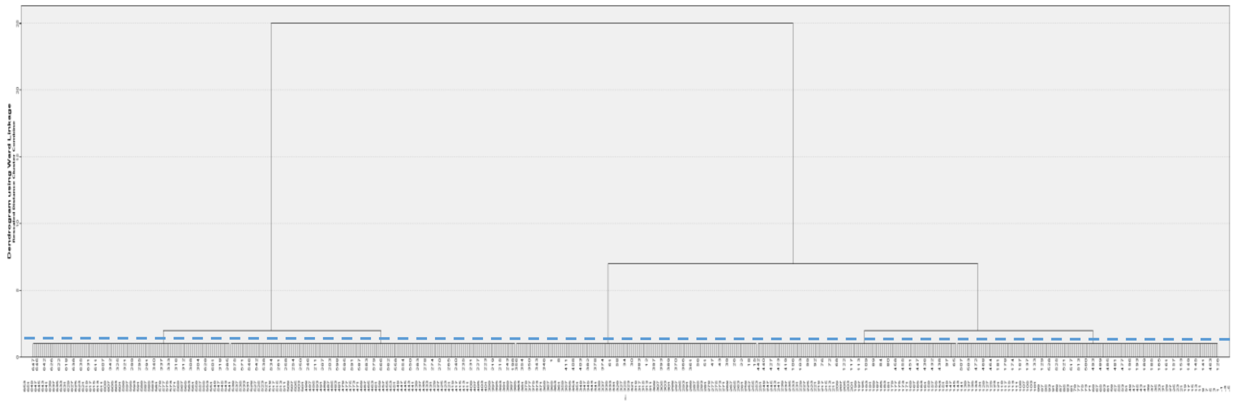


Figure 7.1 Dendrogram of attitudinal questions (n = 648)

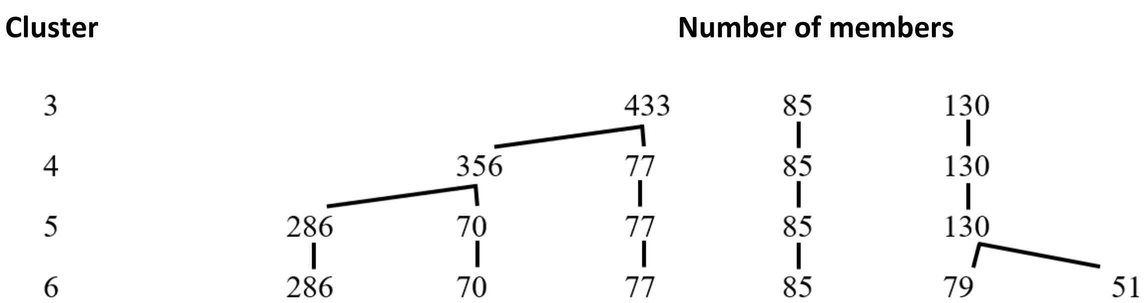



Figure 7.2 Number of members in each Cluster for each of 3 to 6-cluster (n = 648)

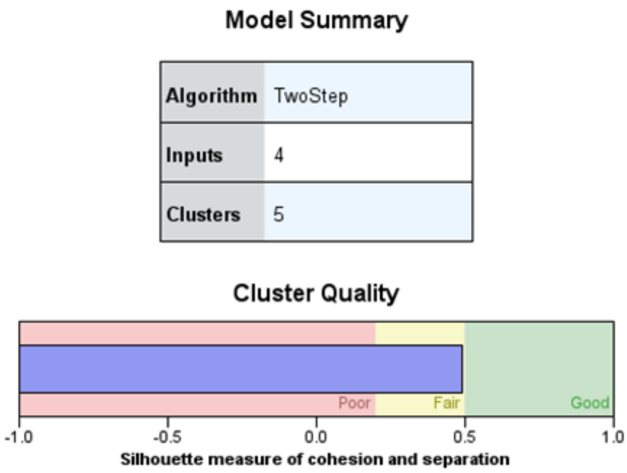



Figure 7.3 Silhouette measure of 5-cluster

## 7.4. Descriptive Statistics of the Clusters

In this section, the characteristics of the clusters will be explored and labelled to reflect the 'type' of person found to have similar attitudes towards the mode with which they identify themselves. Figure 7.4, Figure 7.5, and Figure 7.6 present the bar chart with the proportion of commuters by gender, age, and self-identity for each of the five clusters.

### 7.4.1. Overview of demographics across Clusters

The overview of demographics across each cluster found that genders classified as male and female were different, as presented in Figure 7.4. In Cluster 1, the proportion of males and females was equal. Cluster 2 found that the number of males were more than females, 56% and 44%, respectively. While Cluster 3, the proportions were insignificantly different, at 51% and 49%. The percentage of males in clusters 4 and 5 was less than their percentage of females at 38%:62% and 40%:60%, respectively. Figure 7.5 demonstrates the proportion of each cluster based on age. A large proportion in Clusters 1,2, and 4 were found in the middle-aged group. Cluster 3 the largest proportion was the younger group at 40%. The elder group was the largest proportion in Cluster 5 at 88%, and the youngest group became the smallest proportion in this cluster, only 2%.

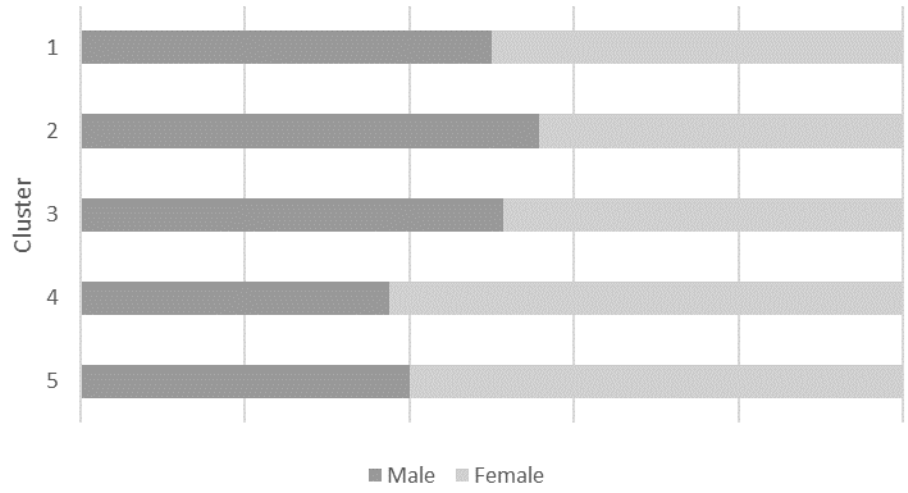



Figure 7.4 Percentage of travellers in each cluster by gender (n=648)

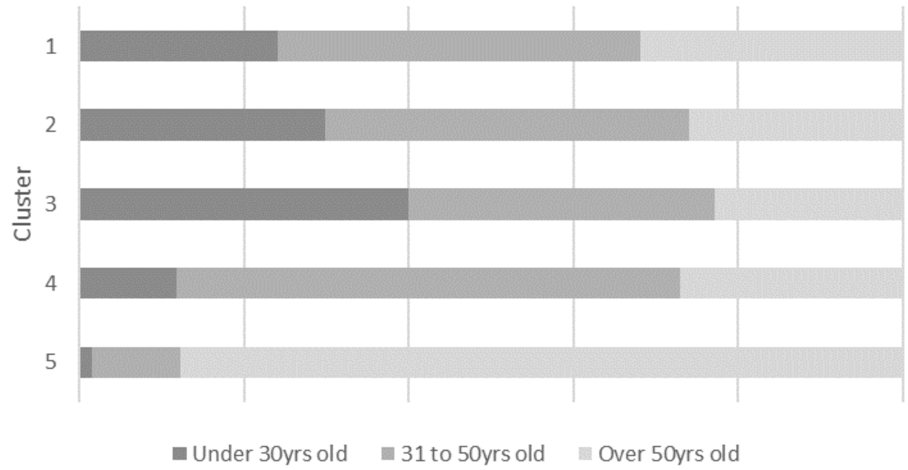



Figure 7.5 Percentage of travellers in each cluster by age (n=648)

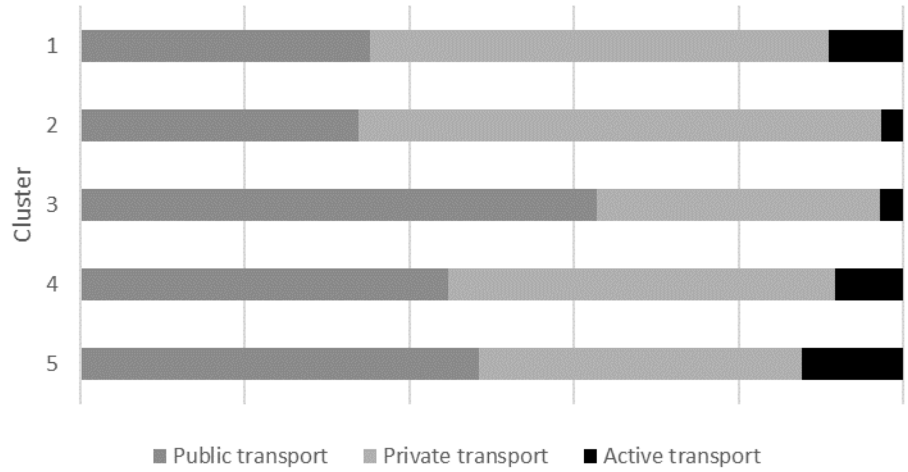



Figure 7.6 Percentage of travellers in each cluster by self-identity (n=648)

Figure 7.6 displays the proportion of mode identity. Cluster 1 and 2 mostly identified themselves as private transport users (56% and 64% respectively), whereas Cluster 3 mostly identified themselves as public transport users (63%). Cluster 4 has a similar percentage identifying themselves as public and private transport users (45% and 48% respectively). Although relatively small compared to other modes (private car, 39%, and public transport, 49%), the highest percentage the participant identifying themselves as active transport users is found in Cluster 5 (12%). This is compared to self-identify as active transport users in Cluster 1, 2, 3 and 4 with 9%, 3%, 3% and 8 %, respectively.

### 7.4.2. Characteristics of each Cluster

Before focusing on the attitudes of the respondents, this subsection explores the combined characteristics of each cluster according to agenda age and self-identity. Table 7.2 gives the characteristics of age, gender, and identity of each cluster. Further classification by age group and gender is illustrated visually with Sankey diagrams in Figure 7.7.

**Cluster 1** – Has the largest number of participants (n=286, 44%), with an equal number of males (n=143, 50%) and females, and the highest proportion of respondents belong to the middle-age group (n=126, 44%). More than half of its members identified themselves as private transport users (n=159, 56%).

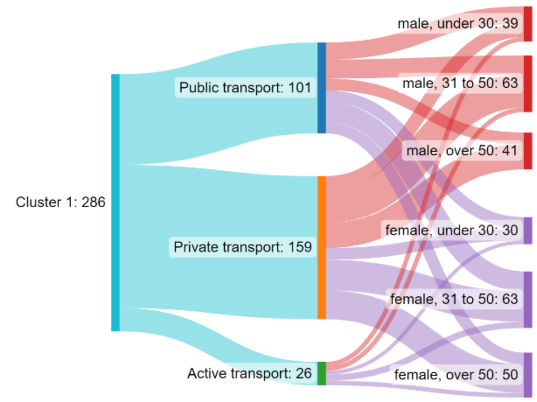
**Cluster 2** - The majority of 77 participants (12%) were male (n=43, 56%) aged between 31and 50 years old (n=34, 44%) with the highest number of males identifying themselves as private transport users (n=30, 70% of 49), representing 39% of the total membership of this cluster. Only 3% identified themselves as active transport users.

**Cluster 3** – Marginally having the smallest proportion of participants (n=70, 11%) had the largest proportion under 30 years old (n=28, 40%). No statistically significant difference was found between male and female participants (n=36, 51%: n=34, 49%) and most identified themselves as public transport users (n=44, 63%) and fewer as private transport users (n=24, 35%). Only two persons identified themselves as active transport users (n=2, 3%) both middle-aged commuters.

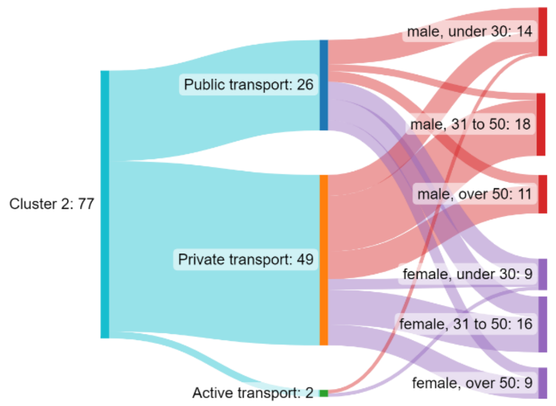
Table 7.2 Cluster characteristic by age, gender, and identity.

| Identity | Gender | Age | Cluster 1 | | Cluster 2 | | Cluster 3 | | Cluster 4 | | Cluster 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N | % | N | % | N | % | N | % | N | % |
| Public transport user | Male | Under 30 | 19 | 35.8 | 7 | 58.3 | 8 | 40.0 | 3 | 21.4 | 1 | 4.0 |
| | | 31 to 50 | 21 | 39.6 | 2 | 16.7 | 6 | 30.0 | 10 | 71.4 | 2 | 8.0 |
| | | Over 50 | 13 | 24.5 | 3 | 25.0 | 6 | 30.0 | 1 | 7.1 | 22 | 88.0 |
| | | Total | 53 | 100.0 | 12 | 100.0 | 20 | 100.0 | 14 | 100.0 | 25 | 100.0 |
| | Female | Under 30 | 13 | 27.1 | 5 | 35.7 | 11 | 45.8 | 7 | 29.2 | 1 | 2.6 |
| | | 31 to 50 | 22 | 45.8 | 6 | 42.9 | 8 | 33.3 | 14 | 58.3 | 4 | 10.5 |
| | | Over 50 | 13 | 27.1 | 3 | 21.4 | 5 | 20.8 | 3 | 12.5 | 33 | 86.8 |
| | | Total | 48 | 100.0 | 14 | 100.0 | 24 | 100.0 | 24 | 100.0 | 38 | 100.0 |
| | Total | | 101 | | 26 | | 44 | | 38 | | 63 | |
| Private transport user | Male | Under 30 | 15 | 18.8 | 6 | 20.0 | 5 | 33.3 | 0 | 0.0 | 0 | 0.0 |
| | | 31 to 50 | 37 | 46.3 | 16 | 53.3 | 5 | 33.3 | 7 | 50.0 | 2 | 10.5 |
| | | Over 50 | 28 | 35.0 | 8 | 26.7 | 5 | 33.3 | 7 | 50.0 | 17 | 89.5 |
| | | Total | 80 | 100.0 | 30 | 100.0 | 15 | 100.0 | 14 | 100.0 | 19 | 100.0 |
| | Female | Under 30 | 13 | 16.5 | 3 | 15.8 | 4 | 44.4 | 0 | 0.0 | 0 | 0.0 |
| | | 31 to 50 | 34 | 43.0 | 10 | 52.6 | 5 | 55.6 | 16 | 61.5 | 6 | 18.8 |
| | | Over 50 | 32 | 40.5 | 6 | 31.6 | 0 | 0.0 | 10 | 38.5 | 26 | 81.3 |
| | | Total | 79 | 100.0 | 19 | 100.0 | 9 | 100.0 | 26 | 100.0 | 32 | 100.0 |
| | Total | | 159 | | 49 | | 24 | | 40 | | 51 | |
| Active transport user | Male | Under 30 | 5 | 50.0 | 1 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| | | 31 to 50 | 5 | 50.0 | 0 | 0.0 | 1 | 100.0 | 3 | 75.0 | 0 | 0.0 |
| | | Over 50 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 25.0 | 8 | 100.0 |
| | | Total | 10 | 100.0 | 1 | 100.0 | 1 | 100.0 | 4 | 100.0 | 8 | 100.0 |
| | Female | Under 30 | 4 | 25.0 | 1 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| | | 31 to 50 | 7 | 43.8 | 0 | 0.0 | 1 | 100.0 | 2 | 66.7 | 0 | 0.0 |
| | | Over 50 | 5 | 31.3 | 0 | 0.0 | 0 | 0.0 | 1 | 33.3 | 8 | 100.0 |
| | | Total | 16 | 100.0 | 1 | 100.0 | 1 | 100.0 | 3 | 100.0 | 8 | 100.0 |
| | Total | | 26 | | 2 | | 2 | | 7 | | 16 | |
| Total | | | 286 | | 77 | | 70 | | 85 | | 130 | |

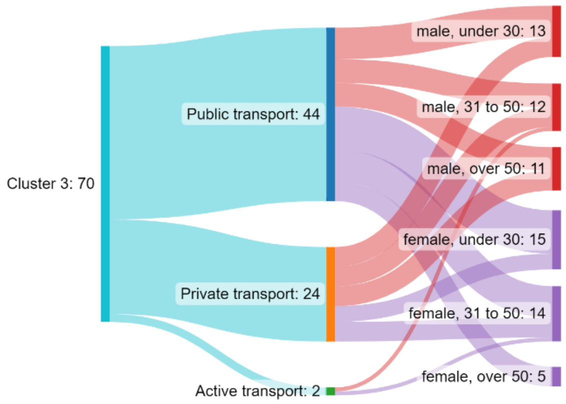
Usefully illustrates the gender and age split according to the transport self-identity to assist in describing the characteristics of the clusters which follows.



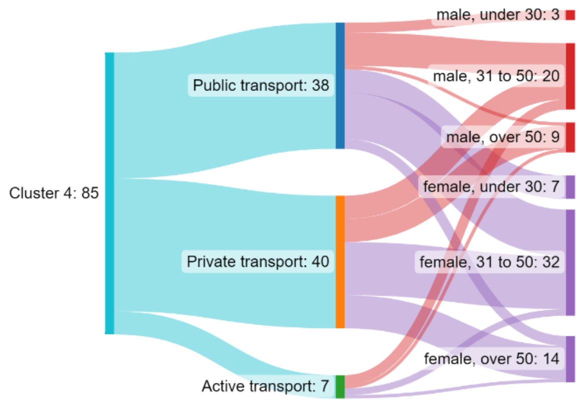

a) Cluster 1 Aspiring Environmentalists (n=286)



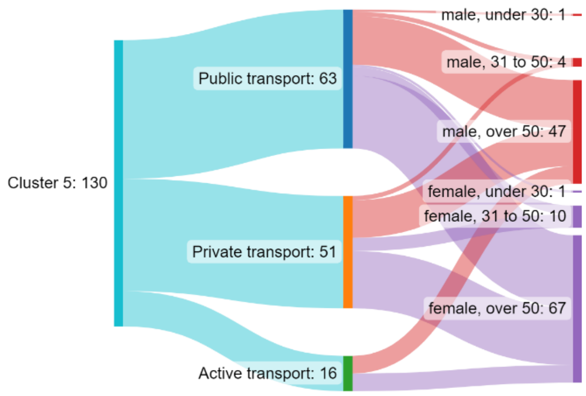

b) Cluster 2 Die Hard Drivers (n=77)




c) Cluster 3 Public transport passionate (n=70)




d) Cluster 4 Self-centred travellers (n=85)




e) Cluster 5 Pro sustainable transport (n=130)

Figure 7.7 Sankey's diagrams demonstrate the characteristics of each cluster. a) Cluster 1, b) Cluster 2, c) Cluster 3, d) Cluster 4, and e) Cluster 5.

**Cluster 4** – With 85 (13%) participants, the majority were female (n=53, 63%) and middle-aged (n=52, 61%). Participants identified themselves as either public (n=24, 45%) or private (n=26, 49%) transport users. No commuters identified themselves as private or active transport users and were of the younger ages.

**Cluster 5** – With the second largest number of participants (n=130, 20%) has the largest proportion from the older aged population (n=114, 88%). The percentage of females was statistically significantly higher than males (n=78, 60%:40%), with marginally more identifying themselves as public (n=63, 49%) rather than private (n=51, 40%) transport users. Interestingly these commuters who identified themselves as sustainable transport users (walk and cycle) were all over 50 age group (n=16, 12%).

Table 7.3 shows the proportions of each cluster by sociodemographic variables, including qualification level, number of adults and children in the household, household income, number of cars in the household, and the actual main mode of their journey. In addition, the number of cars in the household combined with the number of petrol, diesel and electric cars was presented in Table 6.1.

Overall, clusters a high proportion of responders had an undergraduate degree or higher compared to having a school education. The proportion of the highest qualification level in Cluster 4 was 96% with an undergraduate degree (46%), followed by a master's degree (44%) and PhD (96%), whilst Cluster 5 had 92% with higher degrees the distribution was a different undergraduate (67%), master's degree (20%) and PhD (5%). Cluster 5 has the largest proportion of family size of 3 adults (35%) or 4 (30%) and the highest proportion of children compared to other clusters. For the income, only Cluster 3 with the largest proportion was in the 60K – 75K THB per month (20%) whilst in other clusters the highest proportion was found to lie above 90K THB per month. Members of Cluster 3 had the lowest percentage of car ownership in their household, which reflected their reported main mode of transport used day to day, which was public transport mode (63%). The highest ratio of car users was found in Cluster 2, whilst shuttle bus users were found only in Cluster 1 and 5.

In the next sub-section, the attitudes of the commuters in each of the clusters will be explored.

Table 7.3 Details of sociodemographic data in each cluster.

| **Cluster** | **1** | | **2** | | **3** | | **4** | | **5** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | [%] | N | [%] | N | [%] | N | [%] | N | [%] |
| **Qualification level** | | | | | | | | | | |
| Prefer not to say | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Sec. School | 19 | 7 | 7 | 9 | 9 | 13 | 2 | 2 | 3 | 2 |
| Voc. school | 7 | 2 | 3 | 4 | 2 | 3 | 0 | 0 | 7 | 5 |
| UG | **153** | **53** | **31** | **40** | **39** | **56** | **39** | **46** | **87** | **67** |
| PG MSc | 85 | 30 | 28 | 36 | 17 | 24 | 37 | 44 | 26 | 20 |
| PhD | 20 | 7 | 8 | 10 | 3 | 4 | 5 | 6 | 7 | 5 |
| **Member (adult)** | | | | | | | | | | |
| 1 | 47 | 16 | 16 | 21 | 15 | 21 | 16 | 19 | 9 | 7 |
| 2 | **124** | **43** | **28** | **36** | **26** | **37** | **44** | **52** | 36 | 28 |
| 3 | 67 | 23 | 21 | 27 | 18 | 26 | 19 | 22 | **46** | **35** |
| 4 or more | 48 | 17 | 12 | 16 | 11 | 16 | 6 | 7 | 39 | 30 |
| **Member (child)** | | | | | | | | | | |
| No kids | **160** | **56** | **52** | **68** | **44** | **63** | **44** | **52** | **50** | **38** |
| 1 | 63 | 22 | 15 | 19 | 16 | 23 | 24 | 28 | 43 | 33 |
| 2 | 60 | 21 | 9 | 12 | 8 | 11 | 16 | 19 | 33 | 25 |
| 3 or more | 3 | 1 | 1 | 1 | 2 | 3 | 1 | 1 | 4 | 3 |
| **Income [THB]** | | | | | | | | | | |
| Prefer not to say | 9 | 3 | 5 | 6 | 8 | 11 | 4 | 5 | 2 | 2 |
| < 15,000 | 2 | 1 | 2 | 3 | 3 | 4 | 1 | 1 | 0 | 0 |
| 15,000 to 29,999 | 24 | 8 | 12 | 16 | 6 | 9 | 6 | 7 | 1 | 1 |
| 30,000 to 44,999 | 36 | 13 | 8 | 10 | 12 | 17 | 9 | 11 | 6 | 5 |
| 45,000 to 59,999 | 46 | 16 | 12 | 16 | 8 | 11 | 7 | 8 | 8 | 6 |
| 60,000 to 74,999 | 57 | 20 | 9 | 12 | **14** | **20** | 18 | 21 | 26 | 20 |
| 75,000 to 89,999 | 32 | 11 | 7 | 9 | 11 | 16 | 14 | 16 | 29 | 22 |
| > 90,000 | **80** | **28** | **22** | **29** | 8 | 11 | **26** | **31** | **58** | **45** |
| **Number of Cars** | | | | | | | | | | |
| No cars | 52 | 18 | 10 | 13 | 20 | 29 | 9 | 11 | 16 | 12 |
| 1 | 89 | 31 | **31** | **40** | **29** | **41** | **34** | **40** | 35 | 27 |
| 2 | **93** | **33** | 20 | 26 | 15 | 21 | 31 | 36 | **49** | **38** |
| 3 | 36 | 13 | 9 | 12 | 6 | 9 | 7 | 8 | 24 | 18 |
| 4 or more | 16 | 5 | 7 | 9 | 0 | 0 | 4 | 5 | 6 | 5 |
| **Main mode** | | | | | | | | | | |
| AT | 28 | 10 | 3 | 4 | 4 | 6 | 16 | 19 | 19 | 15 |
| Bus | 43 | 15 | 16 | 21 | **23** | **33** | 0 | 0 | 12 | 9 |
| Train | 27 | 9 | 5 | 6 | 17 | 24 | 25 | 29 | 30 | 23 |
| Taxi | 13 | 5 | 3 | 4 | 7 | 10 | 1 | 1 | 5 | 4 |
| Car | **137** | **48** | **47** | **61** | 11 | 16 | **42** | **49** | **46** | **35** |
| MC | 15 | 5 | 3 | 4 | 8 | 11 | 1 | 1 | 1 | 1 |
| Shuttle | 23 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 13 |
| **Total** | 286 | 100 | 77 | 100 | 70 | 100 | 85 | 100 | 130 | 100 |

Notes: Bold figures represent the highest proportion

### 7.4.3. Attitudes of commuters in each Cluster

The distribution of the scores across all questions in each component was not Normal/Gaussian therefore the median score for each Component was calculated for each cluster and presented in Table 7.4.

Table 7.4 Median score of components by clusters.

| Cluster | Comp_1 Pro-env and health | Comp_2 Pro env. friendly car | Comp_3 Pro-safe | Comp_4 Pro private vehicle |
|---|---|---|---|---|
| 1 | **79.0** | 87.0 | 83.5 | 28.5 |
| 2 | 71.0 | **90.0** | **86.0** | **74.0** |
| 3 | 66.0 | 84.0 | 48.5 | 28.5 |
| 4 | 24.0 | 89.0 | **86.0** | 25.0 |
| 5 | 70.0 | 24.0 | 80.0 | 27.5 |

Notes: Bold figures represent the highest value

The bold text highlights the highest median score of each component, and to assist in interpreting the data the background colour has been changed in increments of 10 ranging from red with a median score which lies between 0 and 10 (disagree with the component), through to yellow with median score >50 to 60 to green median score >90 to 100 (agree with the statement). For Component 1, Environmental Health, Cluster 4 was significantly lower (24) than all other Clusters which scored more than 66 with Cluster 1 with the highest score (79). This suggests that except for Cluster 4, 50% of respondents were all at least moderately aware of the environment. Component 2, Environmentally Friendly Car, resided in Cluster 2 with a score (of 90) which was the highest score overall components representing at least 50% were very interested in purchasing a no-emissions vehicle. Component 3 Pro safe scores were on the whole relatively high across all clusters as expected. The lowest score was in Cluster 3 (48) and the others for Cluster 1, 2, 4 and 5 were 83.5, 86, 86 and 80. A rather different distribution with only Cluster 2 with the highest score of 74 in Pro-Safe, Component 4 with all other clusters ranging from 25 to 28.5.

## 7.5. Labelling of Clusters

**Cluster 1 - *Aspiring Environmentalists***. The highest mean score in Component 1. Cluster 1 members acknowledged that their mode of identity impacted the environment and health but continued to use them. Interestingly, a similar mean score of Component 2 implies that Cluster 1 members with similar demographic characteristics also could be persuaded to be more environmentally friendly, an observation consistent with Bösehans and Walker (2020) and Webb (2010). The members of this cluster realised that their current mode of transport impacts others' health, but they would like to change if they have the opportunity.

**Cluster 2 - *Die-hard drivers***. With the highest median score of Component 4, this group is content for people to travel by private car as much as they wish. The proportion of private car users, Figure 7.5 confirmed that more than two out of three members in this cluster use a private transport mode. This attitude presents huge challenges to the government to persuade private car users to switch to sustainable alternatives. The median score of Component 1 was lower in Cluster 2 compared to Cluster 1 which suggests that members of Cluster 2 had less awareness of the impact on the environment of their mode of transport identity. However, the score of Component 2, willingness to change to greener cars, was higher in Cluster 2 compared to Cluster 1 suggesting a reluctance to change their mode identity for commuting. Cluster 2 exhibited similar demographics to the mostly male CAR group, '*the male loves driving'*, identified in the study by Molin *et al.* (2016).

**Cluster 3** - ***Public transport passionate***. Despite the highest proportion of respondents identifying themselves as public transport users with a similar proportion of young as middle-aged, Cluster 3 members were keen to aspire to purchase low emissions vehicles and the youngest population group identified themselves as private transport users. Cluster 3 profile was similar to the *Reluctant Rider* group from Webb (2010) with young and middle age with a preference for public transport. Cluster 3 even though identifying themselves more as users of public transport compared to other clusters did not agree (based on the Component 3 score) that their mode of choice was safe.

**Cluster 4** – ***Self-centred travellers***. The score of Component 3 was the highest and Component 2 was of a similar magnitude, suggesting this group feels safe as well as having awareness of environmental issues. However, they showed a selfish tendency not to want others to use their car freely and are not concerned with the impact the environment has on their health. This group was consistent with the *Convenience lover* cluster found in a study in developed countries in Europe which found respondents older than 30 years old consistently used vehicles day to day because of their convenience and had low environmental concern (Bösehans and Walker, 2020).

**Cluster 5** – ***Pro-sustainable transport.*** Respondents identifying themselves as public transport users were statistically significantly similar to those identifying themselves as Private transport users, and those identifying themselves as active transport users were entirely from the older generation. However, when mode identity was considered to actual reported mode of transport, the proportion of private transport mode users was smaller than the combination of active transport and public transport mode. The score for Component 2 *Pro environmentally friendly vehicle* was low compared to other clusters consistent with their mode identity and suggesting they perceived their modes of transport did not impact or cause environmental problems, similar to the study by Molin *et al.* (2016). This group is in sharp contrast with the *laggard group* from a study by Bösehans *et al.* (2021) and the *difficult shiftiness* to the metro in an area of BMR identified by Fraszczyk *et al.* (2019) whilst expecting others to move away from private vehicles.

From above, it can be seen across the cluster that Clusters 1, *Aspiring environmentalists* and Cluster 2 were similar in age group, namely middle-aged however, Component 3 was male dominant. Similarly, the scores in Components 1 to 3 were high and low in Component 4. This can be interpreted as females tending to care about society more than men and that males are passionate about driving. Components 1 and 2 in Cluster 3, *Public transport passionate*, and Cluster 2, *Die-hard drivers* were more inclined to change to an alternative lower emitting car. This is a positive sign and in sharp contrast with Cluster 2. Cluster 3 with similar pattern in behaviour and attitude to Cluster 5, *Pro-sustainable transport,* it is important to take steps to maintain loyalty to public transport and active transport by improving services and facilities, respectively.

Respondents from the younger generation were found to identify themselves as public transport users more than other age groups which is beneficial to the environment, in contrast, middle-aged adults preferred the convenience of private cars. Consistent with a study by Jan and Stewart (2011) measures aimed at changing attitudes toward the environment were important and could act as a trigger to influence commuter travel behaviour. Therefore, innovation on policies that consider a targeted and integrated approach addressing environment accessibility, safety and convenience together have much potential to incentivise and change the travel behaviour of the BMR population and deliver a transition to using public transport and active modes.

Given this research has demonstrated that there are cohorts of the commuter population that display similar characteristics (gender, age, education level, etc.) when identifying themselves as users of a particular transport mode because of their different attitudes. Therefore, it is clear that more success in delivering a mode shift from private to public and active transport will be achieved by tailoring intervention measures to align with the population groups identified by this research.

## 7.6. Conclusions of this chapter

The study was to investigate the Bangkok Metropolitan Region (BMR) population commuting behaviour and their attitudes toward the environment, accessibility, convenience, and safety. The questionnaire asked about their travel behaviour and attitudes, and explored the demographics of participants by using hierarchical cluster analysis.

Hierarchical cluster analysis based on the four components, demographics and self-identity revealed five clusters labelled as "*Aspiring Environmentalists*", *"Die-hard drivers"*, "*Public transport passionate", "Self-centred travellers*", *and "Pro sustainable transport*" considering component scores and characteristics of each cluster.

Most of the participants (90%) were aware that their modes of transport caused an environmental problem, and they care also about society. However, demographics were related to their attitude. Attitudes regarding environmental issues were key and shaped by both age and the self-identity mode of transport, which impact travel behaviour. The cluster with respondents with high environmental awareness and flexibility to change their behaviour indicated positiveness towards a transition to sustainable transport.

In this chapter, the policies were suggested for each cluster based on self-identified mode of transport. The recommendations on each cluster will be discussed in the discussion chapter. For further analysis, the next chapter will investigate the effect of each variable on the mode of transport and the impact of the policy that can shift people away from the car.

# Chapter 8 Multinomial Logistic Regression

## 8.1 Introduction

The previous chapter, Chapter 7, found that each cluster emerging from the Hierarchical Cluster Analysis (HCA) had a unique character in terms of each component. Five clusters were obtained from the HCA based on the four components of attitudes, demographics, and self-identity and labelled as “Aspiring Environmentalist”, “Die hard driver”, “Public transport passionate”, “Self-centred traveller”, and “Young at heart active traveller”.

In this chapter, the objective is to investigate independent variables that affect mode choices (dependent variable). The independent variables include travel time and cost, the four components identified by the PCA as well as age, car ownership, and travel-related variables including self-identity. The analysis used Multinomial Logistic Regression (MLR) to develop algorithms useful to explore sustainable policy options such as change in cost and travel time which generally influence behaviour. Examples are used to demonstrate the application of the outputs from this research.

First, the data preparation for the model is explained in Section 8.2, followed by model development in Section 8.3. Subsequently, the results of the MLR analysis are presented and examined in terms of travel time, cost, attitude components, and sociodemographic variables in Section 8.4. This is followed by applications of the outputs from the MLR model to evaluate the impact on travel choices of hypothetical situations of increased journey duration, cost, and attitudes in Section 8.5. The final section, Section 8.6, discusses the key messages and draws conclusions.

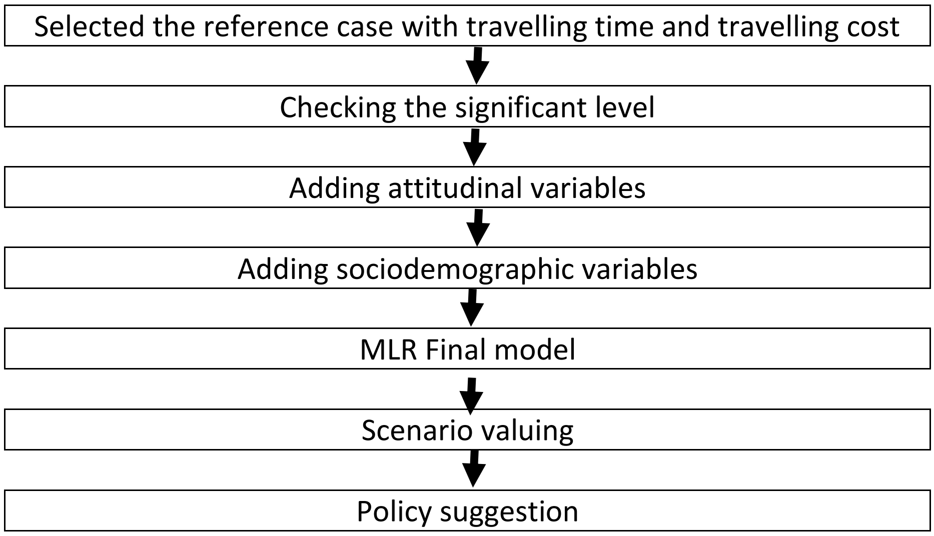



Figure 8.1 Methodology diagram focus on chapter 8 MLR analysis

## 8.2 Data Preparation for the Analysis

Variables in this analysis were categorised as dependent and independent variables. The dependent variable was a set of transport modes, whilst the independent variables included socio-demographic data, attitudinal components from the Principal Component Analysis, (PCA) and travel-related variables.

The respondents were requested to report their journey-related characteristics (transport mode, travel time, and travel cost). The longest time taken by a particular step of their journey was defined as the "main mode". No one reported using the ferry as their main mode, and therefore it was removed from the choice set. As explained in Section 6.2, the choice set (MAINMODE6G) contained 7 modes of transport considered as a dependent variable and included users of active transport (AT), bus (BUS), shuttle bus (SHUTTLE), train (TRAIN), on-demand public transport (TAXI), private car (CAR) and finally motorcycle (MC). The study incorporated socio-demographic data as ordinal variables, including age, income, and educational level, and nominal variables such as gender, and vehicle ownership. Moreover, PCA component scores were continuous independent variables.

The software selects the last category in the list as the reference group therefore some variables need to be modified before running the software. For example, the age group with the variable named “Age3G”, and “under 30 years old” would be used as the reference group therefore the name of the variable changes to “Age_3G_21Ref”. In addition, for the group of variables such as qualification level, household income, and disability that had the option of “Prefer not to say” the latter was used as the reference.

Other variables were transformed to a binary variable such as the number of cars in the household were transformed with two options i.e. “Have at least one car in their household” and “No cars in their household” creating the variable labelled “NumCar_All_HH”, and the number of children in the household with two options “Have children” or “No children” under the variable name “NumChild_HH”.

Table 8.1 Details of independent variables.

| Previous variable name | New variable name | |
|---|---|---|
| | | Options |
| Age_3G | Age_3G_21Ref | 31 to 50, over 50 , under 30yrs old |
| Income_code | income_H | < 15,000,15,000 to 29,999, 30,000 to 44,999, 45,000 to 59,999, 60,000 to 74,999, 75,000 to 89,999, > 90,000 (THB), Prefer not to say |
| edu_code | edu_H | Sec School, Vocational school, UG, PG, PhD, Prefer not to say |
| disable_code | disable_H | Yes, No, Prefer not to say |
| Num_All_car | NumCar_All_HH | Yes, No |
| Num_mem_child | NumChild_HH | Yes, No |

Note: The last option on each variable were used as reference.

The postcode of home (origin) and workplace (destination) were asked in the questionnaire and the number of combinations was too large to provide useful statistically significant results. Therefore, the data was redefined as discussed in Section 6.2.2 follows:

- The origin and destination postcodes were the same, the trip was within *the same area* which assumed a *short distance.* This trip was called “Intra-zonal” and labelled “Internal”.
- The origin and destination postcodes were different therefore the trip occurred *across the postcode area* which was assumed as *long-distance* trip. This trip was called “Inter-zonal” and labelled “External”.

Therefore, the variable named “TravelDistance” had two options “Internal” and “External” with External as the baseline. Whilst it is acknowledged that across adjacent postcode areas can be short and Internal trips at extreme opposite edges of postcode boundaries could be long, it was believed worth retaining a variable associated with distance rather than disregarding entirely this captured data. With reference to Table 6.2, the number and proportion of intra- and inter-zonal trips by modes of transport shows that 22% of participants travel within the same postcode area. Multimodal refers to a journey that combines more than one mode of transport alternatives. The main mode was referred to as that with the longest duration in that journey. as mentioned in Chapter 6 section 6.2.

## 8.3 Model set-up

There are two types of logistic regression, binary with two variables or multinomial with more than two. In this study, as the choice set has more than two options Multinomial Logistic Regression, MLR, method was selected. IBM SPSS Statistic 28 and 29 software provides powerful tools to process survey data with many variables and was employed. Selection of the required analysis function, “multinomial logistic regression” produces the set of options as shown in Table 8.1.

The data from the survey collated as explained in the previous section was converted and saved in *.sav* format, which is the file extension type used to store data for SPSS analysis. The descriptive statistics of the variables considered can be found in Section 6.2 and Table 6.1 according to the mode of transport, daily travel behaviour, age, gender, and number of vehicles in their household. These variables along with the components of attitudinal variables which were the result of PCA were used as input to the MLR.

Initially, exploratory research with MLR considered logistic regression analysis with “total time” and “total cost” as two independent variables, and travel behaviour (mode choice) as dependent variables using a motorcycle as the baseline. However, given that the aim of the research presented in this thesis is ***to explore policies and interventions to shift people away from cars to more sustainable modes,*** the car was used as the reference for the main analysis. The MLR model was developed by testing variables and the components in the model one by one. After checking statistical significance, at the level of better than 95% ($P<0.05$), variables, not reaching this threshold of statistical significance across all modes, were removed from the model. The analysis seeks to identify the relationships between independent variables, namely attitudinal PCA components, socio-demographics, and other factors influencing the choice of transport mode.

## 8.4 Model development.

First, only cost and time were considered to become familiarised with the modelling procedure. Subsequently, independent variables were considered systematically and the MLR was repeated to explore the influence each variable has on the coefficients and therefore the travel mode distribution. Variables that were statistically significant at 95% confidence were retained.

### 8.4.1 Time and Cost

This section provides the results of the MLR modelling. Initially selecting the time and cost variables the results for each mode were calculated with reference to the MC being the last in the list and was used as the default value from SPSS software, along with the taxi as the reference chosen because it had the fewest number of observations, see Appendix D.

Traditionally both travel time and cost are disutility (i.e. negative coefficients), however the positive and statistically significant coefficients for time for all modes except motorcycle imply that commuters in Bangkok recognise their time is spent as productive when travelling by bus and shuttle bus. Also, given the travel time coefficient is statistically significantly positive ($p<0.05$) for active travel users implies they also consider travel time as productive suggesting that active travellers enjoy the ride/walk or listen to music/communicate by mobile phone etc whilst travelling. Indeed, relevant to this finding is that a previous study has shown that Thailand has the fourth highest percentage of the population spending time using the internet on mobile phones in the world (Statista, 2023). The report also demonstrated that the Thai population were ranked third for the time spent per day on mobile phones seeking information, watching TV, social media etc. Also, Bangkok was reported to have the highest proportion of smartphone users in Thailand (National Statistical Office, 2023).

Interestingly, using MC as a reference all cost variables from all modes except for train were statistically significant whilst time coefficients were all positive. Similarly, using the taxi as a reference all except car and train were statistically significant. Only MC had the negative coefficient of total time, which is consistent with motorcycle riders, as well as car drivers, not able to engage in other activities when riding/driving and therefore find travel time as a disutility.

However, given that this research studies mode shift from car, the MLR model was repeated using the car as a reference, see Table 8.2. Using, a car as a reference, time was statistically significant in active transport, bus, MC, and shuttle bus. In addition, only MC had the negative sign of the coefficient. This suggests that people who use motorcycles spend time travelling less compared to by car, this indicates that motorcycles are more often used for shorter journeys and the time is a disutility unable to spend the time usefully by for example reading or playing games etc.

Table 8.2 MLR model considering total time and cost of the journey (Baseline: Car).

| Mode of transport | variables | β | Std. Error | Exp(β ) |
|---|---|---|---|---|
| AT | Total time | **0.03** | 0.01 | 1.03 |
| | Total cost | **-0.07** | 0.01 | 0.93 |
| Bus | Total time | **0.04** | 0.01 | 1.04 |
| | Total cost | **-0.06** | 0.01 | 0.95 |
| Train | Total time | 0.00 | 0.01 | 1.00 |
| | Total cost | 0.00 | 0.00 | 1.00 |
| Taxi | Total time | 0.00 | 0.01 | 1.00 |
| | Total cost | 0.00 | 0.00 | 1.00 |
| MC | Total time | **-0.08** | 0.03 | 0.92 |
| | Total cost | **-0.02** | 0.01 | 0.98 |
| Shuttle | Total time | **0.10** | 0.01 | 1.10 |
| | Total cost | **-0.36** | 0.10 | 0.70 |

Note: P<0.05 presented in bold. the references category is Car.

### 8.4.2 Attitudinal Components

In the next step of the analysis, the attitudinal components, namely *Pro-environment and others' health, Pro-environmentally friendly cars, Pro safe, and Pro-private vehicle* were included in the MLR model. The results are presented in Appendix D.

Pro-environment and others' health (Component 1) included in active transport choice was negative with an odd ratio of less than 1 (Exp(β) =0.23) suggesting that active transport users consider that their mode of transport did not impact other people's health compared to car user. This was true also for train users as the coefficient related to Component 1 is negative and statistically significant. Other modes of transport including bus, MC, and shuttle bus, had positive and statistically significant coefficients indicating that these groups of mode users are concerned that their mode selection impacts others' health compared to car users (baseline). This is encouraging because initiatives to heighten awareness of the detrimental impact of travel on the environment are worthwhile.

Pro-environmentally friendly cars, Component 2 for all modes except shuttle bus had a positive coefficient, although not statistically significant for any mode. This indicates that bus, train, and MC users are much keener that drivers consider purchasing environmentally friendly cars to benefit the environment compared to car users used as a reference. While the odds ratio of Pro-safe, Component 3, from all modes, was less than one it can be inferred that the car was considered more safe than other modes given the coefficient was positive. For Component 4, active transport, train, and shuttle bus had negative signs of the coefficient which was statistically significant relative to car suggesting there is consensus in not supporting "using private vehicle freely" and instead being keen to see restraint on car use.

A requirement of SPSS is that if one variable of a set is statistically significant then the variable is retained in the MLR. Also, given that the statistically significant level of Component 2 was close to 95% at this stage of the analysis a decision was made to retain Component 2 as a variable.

### 8.4.3 Gender, Age and other socio-demographic variables

The result of the MLR with the PCA components along with gender added to the model, presented in Appendix D. The results, considering the female as the reference group, were found not to be statistically significant (P>0.05) in all transport modes in this model. Therefore, the gender variable was removed from the model.

Next, the variables including education level attained, household income, disability, car ownership, number of children in their household, trip distance (internal/external), and single/multiple mode journey were considered. Some variables, namely qualification, household income, disability, and children in their household level were found not to be statistically significant in any mode therefore they were removed. The final model was found to include time, cost, and PCA components except Component 2 which did not reach the statistical significance criteria of $P<0.05$, age, car ownership and distance, single/multiple mode journey see Appendix D.

For the final MLR model, the pseudo-R square represented by Cox and Snell showed that 89.3% of data presented in this model was explained by the derived coefficients.

### 8.4.4 MLR Predictive Algorithms

The final coefficients (see Equation 4.1) provided the output of the MLR for each of the 6 mode preferences as a set of coefficients for each mode relative to the car. By way of example, the logit model for active transport preference relative to the car, $Logit\,(p\_AT)$, depended on the total time, total cost, attitude toward the environment, pro-safe, freedom of car use, age, vehicle(s) in their household, single mode, and distance in Equation 8.1 as follows:

$$
\begin{aligned}
Logit(p\_AT) = ln\left[\frac{p}{1-p}\right] \\
&= -4.35 + 0.04time - .06cost - 1.4C_1 \ - 0.46C_3 - 0.77C_4 \\
&- 0.5(Age30) - 1.44(Age50) - 0.35\ HaveCar \\
&- 2.31SingleMode + 1.96InZone
\end{aligned}
$$

Equation 8.1

The outputs from the MLR model, namely the constant and coefficients (β), for each mode preference relative to the car is given in the Table 8.3. Worthy of note is that the criteria for including a variable in the MLR model was that at least one variable for all modes was statistically significant at greater than 95% confidence. This is a limitation of the SPSS software. Other software packages, not available for use in this work, namely BIOGEME (Bierlaire, 2024) and GAUSS (*GAUSS Application - Discrete Choice Analysis Tools*, 2024), however, are able to develop an MLR algorithm which only considers the statistically significant variables. They allowed different and similar independent variables to be included in mode options.

Table 8.3 Constant and Coefficient **(β)** for each model, reference made car.

| | Mode of transport | | | | | |
|---|---|---|---|---|---|---|
| | **AT** | **BUS** | **Train** | **Taxi** | **MC** | **Shuttle** |
| Constant | 4.35 | 5.02 | 4.91 | 1.62 | 5.00 | 1.23 |
| **Variable** | **Coefficient (β)** | | | | | |
| Total time | **0.04** | **0.04** | 0.00 | 0.00 | **-0.07** | **0.11** |
| Total cost | **-0.06** | **-0.06** | -0.01 | 0.01 | -0.02 | **-0.36** |
| Pro-environment and others' health | **-1.40** | **1.32** | **-1.31** | **1.18** | 0.31 | 1.07 |
| Pro-safe | -0.46 | **-2.05** | **-0.97** | **-1.91** | **-1.10** | **-1.67** |
| Pro-private vehicle | **-0.77** | -0.23 | **-0.57** | -0.30 | -0.04 | -2.36 |
| 31 to 50yrs old | -0.50 | -1.01 | **-1.46** | -1.32 | -0.81 | 1.20 |
| over 50yrs old | **-1.44** | -0.62 | -0.46 | -0.42 | **-2.94** | 1.52 |
| Have Cars | **-3.84** | -3.33 | **-2.64** | **-3.24** | **-3.51** | **-4.30** |
| Single mode | **-2.31** | -3.41 | **-3.97** | **-2.14** | -1.05 | **-1.16** |
| In Zone | 1.96 | -0.48 | **-0.65** | **1.85** | 0.25 | **-3.43** |

Note coefficients statistically significant $P<0.05$ presented in bold.

These algorithms can be used to investigate how the distribution of trips across modes for different combinations of population demographics, male/female, age, internal/external trip type etc. and some examples are presented in the following section.

### 8.4.5 Defining the Base Case model for Active Travel

The reference case was calculated by using the median of all travel times (28 minutes) and costs (40 THBAHTS) irrespective of mode and overall participants, as presented in Section 6.2. The choice of the median, the fifty percentiles, is considered a typical distance against which to compare increases and decreases. The attitudinal Component values, $C_1$, $C_3$ and $C_4$ were set to neutral (C=0.5). Accordingly, the variable AGE_30 has 3 alternatives, and car ownership, trip type (single/multiple-mode), and distance (Internal/External) all have 2 options resulting in 24 types of participants in the base case.

Continuing with active travel by way of example, for the population group aged ***under 30 years,*** for internal trips with a travel time of 28 minutes (time = 28) and normalised travel cost of 40 THB (cost = 40/10), households have at least one car and have children, the transfer of trips from the car to active travel becomes:

$$Logit(p\_AT) = -4.35 + 0.04(28) - .06(4) - 1.4(0.5) \ - 0.46(0.5) - 0.77(0.5) - 0.5(0) - 1.44(0) - 0.35\ (1) - 2.31(1) + 1.96(1)$$

$$= -4.35 + 0.04(28) - .06(4) - 1.4(0.5) \ - 0.46(0.5) - 0.77(0.5) - 0.5(0) - 1.44(0) - 0.35\ (1) - 2.31(1) + 1.96(1)$$

$$= -0.3$$

Therefore, the mode preference for active travel is calculated as follows:

The probability ; $\boldsymbol{p(AT)} =$

$$\frac{\boldsymbol{e^{logit(p\_AT)}}}{\boldsymbol{1 + \ e^{logit(p\_AT)} + e^{logit(p\_BUS)} + e^{logit(p\_Train)} + e^{logit(p\_taxi)} + e^{logit(p\_MC)} + e^{logit(p\_Shuttle)}}}$$

$$= \ \frac{\boldsymbol{exp^{-0.3}}}{\boldsymbol{1 + \ e^{-0.3} + e^{-1.8} + e^{-3.8} + e^{-2.4} + e^{-1.8} + e^{-7.5}}}$$

= 0.344

The result suggests that the probability of choosing active transport is 34.4% when the journey time by car increases by 20%. The calculation was repeated, substituting an actual value for each variable in the appropriate algorithm for each mode to estimate the distribution of trips for each other mode relative to the car, see highlighted row in Table 8.4. Subsequently, the base case can be estimated for different sociodemographic values such as age. This results in the set of mode shift estimates for the different combinations of the 8 types of sociodemographic variables for the population group of age (see Table 8.4). It is clear that distance has a big influence on the younger travellers because, without access to a car, the higher proportions are seen to use the train and bus for both single and multi-modal trips for external trip making. Also evident is the use of shuttle buses mostly for long trips given that employers need to provide transport for employees who live a longer distance because they do not own a car. Another observation when respondents have at least one car in their household, they tend to be used. Whilst intrazonal journeys, the younger age group without cars tend to use single-mode active transport, 71.6% or combined with other modes (multi-mode), 64.8%. Worthy of note is that the sum of the distribution of trips across all modes adds up to 100%. This serves as a validation of the analysis. In this study, the analysis will be discussed with single mode as the case study only because the majority of car users were single mode.

Table 8.4 Logit and probability of each mode from based case with personality type for age group under 30 years old.

| Age under 30 years, no cars, single mode, travelling in zone | | | | | | | |
|---|---|---|---|---|---|---|---|
| | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Exp(Logit) | 5.0 | 7.5 | 0.6 | 0.4 | 4.5 | 1.3 | 0.0 |
| Prob [%] | 24.7 | 37.1 | 2.9 | 1.8 | 22.2 | 6.3 | 5.0 |
| Age under 30 years, have cars, multi-mode travelling out of zone | | | | | | | |
| | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Exp(Logit) | 1.1 | 8.1 | 2.2 | 0.1 | 0.4 | 0.1 | 0.0 |
| Prob [%] | 8.3 | 62.4 | 17.3 | 0.9 | 2.9 | 0.4 | 7.7 |
| Age under 30 years, have cars, single mode, travelling in zone | | | | | | | |
| | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Exp(Logit) | 0.8 | 0.2 | 0.0 | 0.1 | 0.2 | 0.0 | 0.0 |
| Prob [%] | 34.4 | 7.5 | 1.0 | 4.2 | 7.7 | 0.0 | 45.2 |
| Age under 30 years, have cars, multi-mode travelling in zone | | | | | | | |
| | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Exp(Logit) | 7.7 | 5.0 | 1.2 | 0.8 | 0.5 | 0.0 | 0.0 |
| Prob [%] | 47.5 | 31.1 | 7.3 | 4.9 | 3.0 | 0.0 | 6.2 |
| Age under 30 years, no cars, single mode, travelling out of zone | | | | | | | |
| | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Exp(Logit) | 1.2 | 4.0 | 0.4 | 0.2 | 0.2 | 5.8 | 0.0 |
| Prob [%] | 9.2 | 31.4 | 2.9 | 1.9 | 1.8 | 45.0 | 7.8 |
| Age under 30 years, have cars, multi-mode travelling out of zone | | | | | | | |
| | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Exp(Logit) | 50.1 | 225.9 | 31.3 | 3.1 | 12.7 | 4.0 | 0.0 |
| Prob [%] | 15.3 | 68.8 | 9.5 | 1.0 | 3.9 | 1.2 | 0.3 |
| Age under 30 years, no cars, single mode, travelling in zone | | | | | | | |
| | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Exp(Logit) | 35.3 | 4.6 | 0.3 | 2.4 | 5.7 | 0.0 | 0.0 |
| Prob [%] | 71.6 | 9.4 | 0.6 | 4.8 | 11.6 | 0.1 | 2.0 |
| Age under 30 years, no cars, multi-mode travelling in zone | | | | | | | |
| | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Exp(Logit) | 356.0 | 139.8 | 16.4 | 20.0 | 16.4 | 0.1 | 0.0 |
| Prob [%] | 64.8 | 25.4 | 3.0 | 3.6 | 3.0 | 0.0 | 0.2 |

## 8.5 Mode Preference for different scenarios to inform policy.

The model is used to calculate the transfer of trips from car use to alternative modes when specific situations arise or policy options are being considered. An example of a situation causing changes in travel behaviours could be traffic congestion worsening and car journey durations increasing the drivers may find public transport services more attractive and then switch modes. Another situation which may encourage a change in travel behaviour is if the cost of owning and/or using a car increases due to car parking charge increases or tax on fuel. On the other hand, policy responses can be modelled also in terms of facilitating journey time decreases and cost increases because they can be influenced by investment in infrastructure such as bus-only lanes, implementing road user charges, RUC, or through marketing, incentives to use public transport, to name a few.

In this section, the steps in the MLR to quantify the change in the distribution of trips across modes for travel time a) increasing and b) decreasing are described using as an example 20% decrease/increase in the median travel time compared to the base case study modelled in Section 8.4 which keeping the travel cost and all other variables fixed considering single mode journeys.

First, for each mode, the change in the proportion of trips by car is estimated increasing the median travel time from 28 minutes to 33.6 minutes (+20%) and second decreasing the median travel time from 28 minutes to 22.4 minutes (-20%). The results and percentage change are presented in Table 8.5. The highlighted column was the example of calculation presented as follows:

%Change = (Prob_Time20%Up - Prob_BaseCase)/ Prob_BaseCase * 100

Substituting values from the example to find the change when journey time increases by 20% can be found as follows:

%Change of probability of active transport when 20% increase in travel time

= (39.8-34.4)/34.4 *100

= 15.8%

Table 8.5 Example of calculation of mode preference of base and 20% increase travelling time.

| | AT | BUS | Train | Taxi | MC | Shuttle | CAR | Total |
|---|---|---|---|---|---|---|---|---|
| **Base Case** | | | | | | | | |
| Logit | -0.3 | -1.8 | -3.8 | -2.4 | -1.8 | -7.5 | 0.0 | - |
| exp(Logit) | 0.8 | 0.2 | 0.0 | 0.1 | 0.2 | 0.0 | 0.0 | - |
| Prob[%] | 34.4 | 7.5 | 1.0 | 4.2 | 7.7 | 0.0 | 45.2 | 100 |
| **Time_20%Up** | | | | | | | | |
| Logit | -0.1 | -1.6 | -3.8 | -2.4 | -2.2 | -6.9 | 0 | - |
| exp(Logit) | 1 | 0.2 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | - |
| Prob[%] | 39.8 | 8.7 | 0.9 | 3.9 | 4.8 | 0.0 | 41.9 | 100 |
| %Change | 15.8 | 15.8 | -7.4 | -7.4 | -37.4 | 71.4 | -7.4 | - |
| **%by Mode** | **5.4** | **1.2** | **-0.1** | **-0.3** | **-2.9** | **0** | **-3.3** | **0** |

Furthermore, the result showed that when the journey time by private car increases by 20%, perhaps due to an increase in congestion in BMR, an additional 5.4% and 1.2% of commuter trips shift to active travel and bus, respectively. Mode shift for train use was insignificant (0.1%) with no change found for shuttle bus use. This is expected as the shuttle services are provided free or paid less by businesses and institutions. However, a reduction of 0.3% and 2.9%, respectively for taxi, and motorcycle use emerged, also expected, given all road transport modes experience a 20% increase in journey time not just cars.

### 8.5.1 Decrease and increase travel time and car ownership, for external and internal travel.

In this section, the influence of change in travel time on mode shift for three age groups, under 30, 31 to 50, and over 50 years old is presented in Table 8.6, Table 8.7, and Table 8.8, respectively.

Table 8.6 presents the calculation of the probability mode shift to investigate the effect on mode shift of a decrease and increase in travel time by 20%, considering the case of commuters aged under 30 years and single mode trip, a) no car in their household, and b) car in the household and for travel external and internal zone. Bus has the highest probability, at P(bus) = 37% for the base case for external zone trips with no cars in their household. When decreasing travel time by 20%, an increase in motorcycle use of 12% and bus use decreases by 6%, whilst active travel reduces by 4%.

However, when the time increased by 20% members of this group preferred to choose the bus (increase by 4%), shuttle bus and active transport increased by 4% and 3%, respectively, whilst the probability of motorcycle use decreased by 9% compared with the base case. If commuters have at least one car in their household, they tend to use them however, the percentage of car use whether for a 20% increase or 20% decrease, the change was less than 3% from the base case use of car which was 63%. This result showed the possible emergence of suppressed demand or purchase of the less expensive motorcycle alternative to private vehicles when travel times decreased.

On the other hand, for intrazonal journeys, in the base case, the highest probability was found to be for active transport followed by motorcycle use, 72% and 12%, respectively (see Table 8.6). This group may typically include students or young professionals residing close to educational institutions or workplaces. When assessing the impact of increasing travelling time by 20%, a mode shift of 5% increases for active travel whilst a decrease of 5% for motorcycle use which suggests that the journey by walking/cycling is quicker than by motorcycle.

In general, notwithstanding the influence of travel time, policies should focus on ensuring this under-30 group, for both external and internal journeys, continues to adhere to their current mode of transport, as evidenced by their minimal preference for cars. On the contrary, in comparison, the similar personality-type group that owned at least one car in their family had the highest probability of using private transport and were more likely to use a car for intra-zonal commuting, at P(car) = 45%. When travel time decreased by 20%, the use of the motorcycle mode doubled the reference case, at P(MC)=12%. In contrast, when a 20% increase in travel time, this group preferred to choose a car less than 7% when compared with the reference case, whilst active transport and bus mode were higher than the reference case.

Table 8.6 Comparison of probability of mode preference in case of changing travel time for aged under 30 years old.

| Characteristic: age under 30yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.6 | 2.0 | -0.5 | -1.0 | 1.5 | 0.2 | 0.0 |
| | Prob [%] | 24.7 | 37.1 | 2.9 | 1.8 | 22.2 | 6.3 | 5.0 |
| Decrease | Logit | 1.4 | 1.8 | -0.5 | -1.0 | 1.9 | -0.4 | 0.0 |
| | Prob [%] | 20.7 | 31.1 | 3.1 | 1.9 | 34.4 | 3.5 | 5.2 |
| | %Change by mode | -4.0 | -6.0 | 0.1 | 0.1 | 12.2 | -2.7 | 0.2 |
| Increase | Logit | 1.8 | 2.2 | -0.5 | -1.0 | 1.1 | 0.8 | 0.0 |
| | Prob [%] | 27.2 | 40.8 | 2.6 | 1.6 | 13.2 | 10.2 | 4.4 |
| | %Change by mode | 2.5 | 3.7 | -0.4 | -0.2 | -9.0 | 3.9 | -0.6 |
| Characteristic: age under 30yrs old, have cars, single mode, external zone | | | | | | | | |
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.2 | -1.3 | -3.2 | -4.2 | -2.0 | -4.1 | 0.0 |
| | Prob [%] | 6.8 | 16.9 | 2.7 | 0.9 | 8.4 | 1.1 | 63.2 |
| Decrease | Logit | -2.5 | -1.5 | -3.2 | -4.2 | -1.6 | -4.7 | 0.0 |
| | Prob [%] | 5.5 | 13.7 | 2.7 | 0.9 | 12.6 | 0.6 | 64.0 |
| | %Change by mode | -1.3 | -3.2 | 0.0 | 0.0 | 4.2 | -0.5 | 0.8 |
| Increase | Logit | -2.0 | -1.1 | -3.2 | -4.2 | -2.4 | -3.5 | 0.0 |
| | Prob [%] | 8.1 | 20.3 | 2.6 | 0.9 | 5.5 | 1.9 | 60.7 |
| | %Change by mode | 1.4 | 3.4 | -0.1 | 0.0 | -3.0 | 0.8 | -2.5 |
| Characteristic: age under 30yrs old, no cars, single mode, internal zone | | | | | | | | |
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.6 | 1.5 | -1.2 | 0.9 | 1.7 | -3.2 | 0.0 |
| | Prob [%] | 71.6 | 9.4 | 0.6 | 4.8 | 11.6 | 0.1 | 2.0 |
| Decrease | Logit | 3.3 | 1.3 | -1.2 | 0.9 | 2.1 | -3.8 | 0.0 |
| | Prob [%] | 64.1 | 8.4 | 0.7 | 5.3 | 19.2 | 0.0 | 2.3 |
| | %Change by mode | -7.5 | -1.0 | 0.1 | 0.6 | 7.6 | 0.0 | 0.2 |
| Increase | Logit | 3.8 | 1.8 | -1.2 | 0.9 | 1.4 | -2.6 | 0.0 |
| | Prob [%] | 76.8 | 10.0 | 0.5 | 4.1 | 6.7 | 0.1 | 1.7 |
| | %Change by mode | 5.2 | 0.7 | -0.1 | -0.7 | -4.9 | 0.0 | -0.3 |
| Characteristic: age under 30yrs old, have cars, single mode, internal zone | | | | | | | | |
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.3 | -1.8 | -3.8 | -2.4 | -1.8 | -7.5 | 0.0 |
| | Prob [%] | 34.4 | 7.5 | 1.0 | 4.2 | 7.7 | 0.0 | 45.2 |
| Decrease | Logit | -0.5 | -2.0 | -3.8 | -2.4 | -1.4 | -8.1 | 0.0 |
| | Prob [%] | 28.8 | 6.3 | 1.0 | 4.4 | 12.0 | 0.0 | 47.5 |
| | %Change by mode | -5.5 | -1.2 | 0.0 | 0.2 | 4.3 | 0.0 | 2.2 |
| Increase | Logit | -0.1 | -1.6 | -3.8 | -2.4 | -2.2 | -6.9 | 0.0 |
| | Prob [%] | 39.8 | 8.7 | 0.9 | 3.9 | 4.8 | 0.0 | 41.9 |
| | %Change by mode | 5.4 | 1.2 | -0.1 | -0.3 | -2.9 | 0.0 | -3.4 |

The demographic of this group consisted of participants aged between 31 and 50 years who did not own a car in the household, interzonal travel trip in single mode, as shown in Table 8.7. Among this cohort, the shuttle bus was the most likely choice for commuting from household places to workplaces (32%), reflecting the skill set available amongst residents in the area for specific jobs valued by employers, followed by active transport and bus. However, when travel time was reduced by 20%, motorcycles experienced a notable shift, with the highest mode preference. However, when individuals spent more time on their journey, a shuttle bus was more likely to be selected up to 12% compared to the reference probability case. This is consistent with employers providing transport free of charge when needing to attract the skills required for specific industrial/commercial/educational activities. In the context of the increased cost of travelling by car, all other modes of transport increase in probability except shuttle bus.

Again, this is consistent with the disutility associated with price increases encouraging mode shift to less expensive options. On the other hand, the group that owned at least one car in their household had the highest likelihood of selecting a car for commuting, P(car) = 77%. This is consistent with the notion that people who own cars use them to maximise the value for money of car ownership. The percentage of probability change when travel time is decreased was found in a shuttle bus, dropping from 4% to 2%.

For active transport, P(AT) = 6% had a higher probability than that from the reference case when travel time increased by 20%. On the other hand, motorcycle and car use decreased by 2% and 4%, respectively.

For travel internally, active transport was more likely to be selected by people in households that did not own a car, P(AT) = 78% as expected. If travel time was longer, motorcycle mode was more likely to be used compared to the reference case, all be it at a lower value probability of 4%. This is consistent with this group owning and using the less expensive private vehicles.

For the group characteristic that people who owned at least one car in their household prefer to use a car for travel, P(CAR) = 61% followed by active transport (28%). However, for a 20% increase in travel time, the probability of car use decreased by 4%. For all distances, these were the highest probabilities found in car mode followed by active transport in all cases.

### 8.5.2 Decrease and increase travel time and car ownership, for external and internal travel for the over 50 years group.

Table 8.8 presents the demographic profile of the group that comprised of individuals aged over 50 years old who process no cars or at least a car in the household and travel by a single mode for external zone journey. The shuttle bus had the highest percentage of probability for mode preference with P(shuttle) = 45% followed by the bus, at P(bus) = 31%.

The group characteristic with people owning at least one car in their household, as expected, prefer to use a car for travel, P(CAR) = 78%. For longer travel times (+20%), this group did use the car less than the base case, but only by 6%. However, for travel single-mode journeys within the zone active transport was more likely to be selected by people who did not own a car in their household, at P(AT) = 59%. Whilst if they owned a car in their household, they tended to choose a car, at P(CAR) = 73.8%. However, even if they own a car or not, the elder people who travel with a single mode in their area, when the travelling time change, the probability of mode preference change less than 5% in all choices. It can be said that they tend to stick to their current mode.

Table 8.7 Comparison of probability of mode preference in case of changing travel time for age group between 31 and 50 years old

| Characteristic: age between 31 and 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.1 | 1.0 | -2.0 | -2.3 | 0.7 | 1.4 | 0.0 |
| | Prob [%] | 23.0 | 20.7 | 1.0 | 0.8 | 15.1 | 31.8 | 7.6 |
| Decrease | Logit | 0.9 | 0.8 | -2.0 | -2.3 | 1.1 | 0.8 | 0.0 |
| | Prob [%] | 21.9 | 19.7 | 1.2 | 0.9 | 26.7 | 20.5 | 9.1 |
| | %Change by mode | -1.1 | -1.0 | 0.2 | 0.1 | 11.6 | -11.3 | 1.5 |
| Increase | Logit | 1.3 | 1.2 | -2.0 | -2.3 | 0.3 | 2.0 | 0.0 |
| | Prob [%] | 21.6 | 19.4 | 0.8 | 0.6 | 7.7 | 44.2 | 5.7 |
| | %Change by mode | -1.4 | -1.3 | -0.3 | -0.2 | -7.4 | 12.4 | -1.9 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, external zone | | | | | | | | |
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.7 | -2.3 | -4.6 | -5.6 | -2.8 | -2.9 | 0.0 |
| | Prob [%] | 5.0 | 7.5 | 0.8 | 0.3 | 4.6 | 4.4 | 77.4 |
| Decrease | Logit | -3.0 | -2.6 | -4.6 | -5.6 | -2.4 | -3.5 | 0.0 |
| | Prob [%] | 4.1 | 6.2 | 0.8 | 0.3 | 7.0 | 2.4 | 79.3 |
| | %Change by mode | -0.9 | -1.4 | 0.0 | 0.0 | 2.4 | -2.0 | 1.9 |
| Increase | Logit | -2.5 | -2.1 | -4.6 | -5.6 | -3.2 | -2.3 | 0.0 |
| | Prob [%] | 6.0 | 8.9 | 0.7 | 0.3 | 2.9 | 7.7 | 73.4 |
| | %Change by mode | 0.9 | 1.4 | 0.0 | 0.0 | -1.6 | 3.3 | -4.0 |
| Characteristic: between 31 and 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.1 | 0.5 | -2.6 | -0.5 | 0.9 | -2.0 | 0.0 |
| | Prob [%] | 77.9 | 6.1 | 0.3 | 2.3 | 9.3 | 0.5 | 3.6 |
| Decrease | Logit | 2.8 | 0.3 | -2.6 | -0.5 | 1.3 | -2.6 | 0.0 |
| | Prob [%] | 71.3 | 5.6 | 0.3 | 2.6 | 15.7 | 0.3 | 4.2 |
| | %Change by mode | -6.6 | -0.5 | 0.0 | 0.3 | 6.4 | -0.2 | 0.5 |
| Increase | Logit | 3.3 | 0.7 | -2.6 | -0.5 | 0.5 | -1.4 | 0.0 |
| | Prob [%] | 82.3 | 6.5 | 0.2 | 1.9 | 5.3 | 0.8 | 3.1 |
| | %Change by mode | 4.3 | 0.3 | 0.0 | -0.4 | -4.0 | 0.3 | -0.6 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.8 | -2.8 | -5.3 | -3.7 | -2.6 | -6.3 | 0.0 |
| | Prob [%] | 28.3 | 3.7 | 0.3 | 1.5 | 4.7 | 0.1 | 61.4 |
| Decrease | Logit | -1.0 | -3.0 | -5.3 | -3.7 | -2.2 | -6.9 | 0.0 |
| | Prob [%] | 23.6 | 3.1 | 0.3 | 1.6 | 7.2 | 0.1 | 64.1 |
| | %Change by mode | -4.7 | -0.6 | 0.0 | 0.1 | 2.5 | 0.0 | 2.7 |
| Increase | Logit | -0.6 | -2.6 | -5.3 | -3.7 | -3.0 | -5.7 | 0.0 |
| | Prob [%] | 33.2 | 4.3 | 0.3 | 1.4 | 3.0 | 0.2 | 57.6 |
| | %Change by mode | 4.9 | 0.6 | 0.0 | -0.1 | -1.7 | 0.1 | -3.8 |

Table 8.8 Comparison of probability of mode preference in case of changing travel time for age group over 50 years old

| Characteristic: age over 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 0.2 | 1.4 | -1.0 | -1.4 | -1.4 | 1.8 | 0.0 |
| | Prob [%] | 9.2 | 31.4 | 2.9 | 1.9 | 1.8 | 45.0 | 7.8 |
| Decrease | Logit | -0.1 | 1.2 | -1.0 | -1.4 | -1.1 | 1.1 | 0.0 |
| | Prob [%] | 10.2 | 34.8 | 4.0 | 2.6 | 3.8 | 33.7 | 10.8 |
| | %Change by mode | 1.0 | 3.4 | 1.1 | 0.7 | 1.9 | -11.3 | 3.0 |
| Increase | Logit | 0.4 | 1.6 | -1.0 | -1.4 | -1.8 | 2.4 | 0.0 |
| | Prob [%] | 7.8 | 26.5 | 2.0 | 1.3 | 0.8 | 56.3 | 5.3 |
| | %Change by mode | -1.4 | -4.8 | -0.9 | -0.6 | -1.0 | 11.3 | -2.5 |
| Characteristic: age over 50yrs old, have cars, single mode, external zone | | | | | | | | |
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -3.7 | -1.9 | -3.6 | -4.7 | -5.0 | -2.6 | 0.0 |
| | Prob [%] | 2.0 | 11.1 | 2.1 | 0.7 | 0.5 | 6.1 | 77.5 |
| Decrease | Logit | -3.9 | -2.2 | -3.6 | -4.7 | -4.6 | -3.2 | 0.0 |
| | Prob [%] | 1.7 | 9.4 | 2.2 | 0.8 | 0.9 | 3.4 | 81.7 |
| | %Change by mode | -0.3 | -1.8 | 0.1 | 0.0 | 0.3 | -2.6 | 4.2 |
| Increase | Logit | -3.5 | -1.7 | -3.6 | -4.7 | -5.3 | -1.9 | 0.0 |
| | Prob [%] | 2.3 | 12.9 | 1.9 | 0.7 | 0.3 | 10.3 | 71.6 |
| | %Change by mode | 0.3 | 1.7 | -0.2 | -0.1 | -0.2 | 4.3 | -5.9 |
| Characteristic: age over 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 2.1 | 0.9 | -1.6 | 0.4 | -1.2 | -1.7 | 0.0 |
| | Prob [%] | 59.4 | 17.6 | 1.4 | 11.0 | 2.1 | 1.3 | 7.1 |
| Decrease | Logit | 1.9 | 0.7 | -1.6 | 0.4 | -0.8 | -2.3 | 0.0 |
| | Prob [%] | 55.9 | 16.6 | 1.6 | 12.9 | 3.7 | 0.8 | 8.4 |
| | %Change by mode | -3.5 | -1.0 | 0.2 | 1.9 | 1.6 | -0.5 | 1.3 |
| Increase | Logit | 2.3 | 1.1 | -1.6 | 0.4 | -1.6 | -1.1 | 0.0 |
| | Prob [%] | 62.1 | 18.4 | 1.2 | 9.2 | 1.2 | 2.0 | 5.9 |
| | %Change by mode | 62.1 | 18.4 | 1.2 | 9.2 | 1.2 | 2.0 | 5.9 |
| Characteristic: age over 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| time | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -1.7 | -2.4 | -4.3 | -2.8 | -4.7 | -6.0 | 0.0 |
| | Prob [%] | 13.3 | 6.6 | 1.0 | 4.5 | 0.7 | 0.2 | 73.8 |
| Decrease | Logit | -1.9 | -2.6 | -4.3 | -2.8 | -4.3 | -6.6 | 0.0 |
| | Prob [%] | 11.0 | 5.5 | 1.1 | 4.6 | 1.0 | 0.1 | 76.7 |
| | %Change by mode | -2.3 | -1.1 | 0.0 | 0.2 | 0.4 | -0.1 | 2.9 |
| Increase | Logit | -1.5 | -2.2 | -4.3 | -2.8 | -5.1 | -5.4 | 0.0 |
| | Prob [%] | 15.8 | 7.8 | 1.0 | 4.3 | 0.4 | 0.3 | 70.3 |
| | %Change by mode | 2.6 | 1.3 | 0.0 | -0.2 | -0.2 | 0.1 | -3.5 |

From the three examples above, changing travel time impacts preference mode significantly. When increasing travel time, the preference for car use drops. This is a good sign to develop the policy from this point.

### 8.5.3 Valuing the mode preference: 20% reduction and 20% increase of travelling cost.

Total cost varied by 20% decrease (22 THB) and increase (32 THB) across the different socio-demographics with three age groups.

The probability calculation in case that the commuter was age under 30 years old, had no cars and had at least one car in their household, external resident zone and internal resident zone, the table presented in Appendix D. The percentage of change in all cases was less than 2%.

Middle-group travellers who travelled Interzone and did not own cars in the household, the preference for shuttle bus increased by 6% when the travel cost was reduced. While the other middle-aged commuters had less than 2% preference change in all modes, see Appendix D.

Table 8.9 presented the mode preference of the older commuter group who travelled internal and external resident zones and had at least one car. It can be seen the change when the travel cost decreased by 20%, the bus was less interesting by 3% for the elder people while the shuttle bus became more attractive by 6% for the group that did not process the car in their household and travelled external their resident zone. In contrast, when increase in the travel cost by 20%, mode preference was changed by a 3% increase in bus and a 6% decrease in shuttle bus.

From the example of changing travel costs, travel behaviour was a different change among the age group. The participants who owned cars in their household still prefers using a car even travelling short or long distances. While short distance travelling, active transport was more attractive than long-distance travelling However, changing the cost in this example by 20% had an insignificant impact on shifting people away from cars.

Table 8.9 Comparison of probability of mode preference in case of changing travel cost

| Characteristic: age over 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 0.2 | 1.4 | -1.0 | -1.4 | -1.4 | 1.8 | 0.0 |
| | Prob [%] | 9.2 | 31.4 | 2.9 | 1.9 | 1.8 | 45.0 | 7.8 |
| Decrease | Logit | 0.2 | 1.4 | -1.0 | -1.4 | -1.4 | 2.0 | 0.0 |
| | Prob [%] | 8.3 | 28.1 | 2.5 | 1.6 | 1.6 | 51.2 | 6.7 |
| | %Change by mode | -1.0 | -3.2 | -0.4 | -0.3 | -0.2 | 6.3 | -1.1 |
| Increase | Logit | 0.1 | 1.3 | -1.0 | -1.4 | -1.5 | 1.5 | 0.0 |
| | Prob [%] | 10.1 | 34.4 | 3.3 | 2.2 | 2.1 | 38.8 | 9.0 |
| | %Change by mode | 0.9 | 3.1 | 0.4 | 0.3 | 0.2 | -6.1 | 1.2 |
| Characteristic: age over 50yrs old, have cars, single mode, external zone | | | | | | | | |
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -3.7 | -1.9 | -3.6 | -4.7 | -5.0 | -2.6 | 0.0 |
| | Prob [%] | 2.0 | 11.1 | 2.1 | 0.7 | 0.5 | 6.1 | 77.5 |
| Decrease | Logit | -3.6 | -1.9 | -3.6 | -4.7 | -4.9 | -2.3 | 0.0 |
| | Prob [%] | 2.0 | 11.4 | 2.0 | 0.7 | 0.5 | 7.9 | 75.5 |
| | %Change by mode | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 1.8 | -2.0 |
| Increase | Logit | -3.7 | -2.0 | -3.6 | -4.6 | -5.0 | -2.8 | 0.0 |
| | Prob [%] | 1.9 | 10.8 | 2.1 | 0.8 | 0.5 | 4.6 | 79.2 |
| | %Change by mode | -0.1 | -0.3 | 0.0 | 0.0 | 0.0 | -1.4 | 1.7 |
| Characteristic: age over 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 2.1 | 0.9 | -1.6 | 0.4 | -1.2 | -1.7 | 0.0 |
| | Prob [%] | 59.4 | 17.6 | 1.4 | 11.0 | 2.1 | 1.3 | 7.1 |
| Decrease | Logit | 2.2 | 1.0 | -1.6 | 0.4 | -1.2 | -1.4 | 0.0 |
| | Prob [%] | 59.9 | 17.8 | 1.3 | 10.4 | 2.1 | 1.7 | 6.8 |
| | %Change by mode | 0.4 | 0.1 | 0.0 | -0.5 | -0.1 | 0.4 | -0.3 |
| Increase | Logit | 2.1 | 0.9 | -1.6 | 0.4 | -1.2 | -2.0 | 0.0 |
| | Prob [%] | 59.0 | 17.5 | 1.4 | 11.5 | 2.2 | 1.0 | 7.4 |
| | %Change by mode | -0.5 | -0.1 | 0.0 | 0.5 | 0.1 | -0.3 | 0.3 |
| Characteristic: age over 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -1.7 | -2.4 | -4.3 | -2.8 | -4.7 | -6.0 | 0.0 |
| | Prob [%] | 13.3 | 6.6 | 1.0 | 4.5 | 0.7 | 0.2 | 73.8 |
| Decrease | Logit | -1.7 | -2.4 | -4.3 | -2.8 | -4.7 | -5.7 | 0.0 |
| | Prob [%] | 13.8 | 6.8 | 1.0 | 4.4 | 0.7 | 0.2 | 73.1 |
| | %Change by mode | 0.5 | 0.3 | 0.0 | -0.1 | 0.0 | 0.1 | -0.7 |
| Increase | Logit | -1.8 | -2.5 | -4.3 | -2.8 | -4.7 | -6.3 | 0.0 |
| | Prob [%] | 12.8 | 6.3 | 1.0 | 4.5 | 0.7 | 0.1 | 74.5 |
| | %Change by mode | -0.5 | -0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.7 |

### 8.5.4 Changing attitude by decreasing and increasing; C = 0 and 1

In this section, the travel cost and travel time were fixed at 28 minutes and 40 THB respectively whilst each component was changed to be C = 0 referred to as "disagree" and C = 1 referred to as "agree". The analysis was considering three different age groups, household no car/own car, and internal/external travel.

#### 8.5.4.1 Changing attitude component of pro-environment and others' health, C1

The results for active transport users, and the youngest group making external journeys are presented in Table 8.10. When C1=1, commuters strongly agree with Pro-environmental and others' health, the interesting outcome is that being aware of the environmental problem The younger residents of households that own cars and travel externally, tend to use cars less than the base case by 8%. Active transport tended to be selected by commuters with high environmental awareness in this socio-demographic group whether they lived in car-owning households. For no car-owning households and external trips, bus use increased by 18% and shuttle bus use by 2%, however, mode preference in train and motorcycle both reduced by 2%. For car-owning households and external trips, mode preference in bus increased by 12% and shuttle bus by 0.5%, train reduced by 1.5%, active travel by 4% and car by 8%. There is a suggestion here that for longer external journeys car users can be encouraged to shift to more sustainable modes.

However, if the younger group disagreed that travel impacts the environment and health of others, C1= 0, also used the bus less. For external trips, with-car households reduced bus use by 8%, increased car use by 0.6% and train 2.5% and without-car households bus use was reduced by 19% shifting to train which increased by 2.5% and active transport by 24%, motorcycles and shuttle reduced by 4% and 3% respectively. This finding is particularly interesting given there is a shift towards sustainable modes. This may be explained by the concept that the buses contribute substantially to the poor air quality in Bangkok and the train is considered a cleaner mode from the perspective of the impact it has on the health of others. Whilst this may explain the shift away from buses towards the train and the increase in active travel it does not reconcile with the fact that this response is when the pro-environment and health variable C = 0.

Single external trips with households with no car, the middle age group with high environmental awareness, C1= 1, shifted towards buses but with a smaller percentage (9% compared to 18% for the younger group). Active travel was reduced by 14%, motorcycles and cars by 2% each over the base case whilst shuttle buses increased by 9%.

Table 8.11 demonstrates the change in attitude towards pro-environment and recognising the impact of transport on others' health (C1) for older people and single-mode journeys, whether internal or external zone trips. In the base case commuters in households without a car travel out of the zone mostly by shuttle bus, P(shuttle) = 45% for external and active travel, P(AT) = 60%, whilst for car-owning households most commuters used car for both external and internal journeys, P(car)=77.5%, and P(car) = 74%. respectively.

If C1 = 0, members of the oldest age group, presented in Table 8.12 for external journeys without a car changed towards active travel and train which respectively increased by 15% and 4%. For internal journeys without a car changed substantially to active travel, 22%, with a marginal increase of less than 1% by train. This counterintuitive result to the more environmentally friend greener modes will be revisited in the discussion.

When C1 = 1, the members of this cluster, as expected, bus became more attractive but decreased in train compared to the base case. It can be implied that the perception people realise that trains and active transport impact others' health less than buses shuttle buses or taxis. In 2022, buses and shuttles in BMR were diesel therefore they could be changed to electric buses. They could have a more positive impact on attitude.

Table 8.10 Comparison of probability of mode preference in case of changing attitudinal component pro environmental and others' health (C1)

| Characteristic: age under 30yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.6 | 2.0 | -0.5 | -1.0 | 1.5 | 0.2 | 0.0 |
| | Prob [%] | 24.7 | 37.1 | 2.9 | 1.8 | 22.2 | 6.3 | 5.0 |
| 0 | Logit | 2.3 | 1.4 | 0.1 | -1.6 | 1.3 | -0.3 | 0.0 |
| | Prob [%] | 48.2 | 18.6 | 5.5 | 1.0 | 18.4 | 3.5 | 4.8 |
| | %Change by mode | 23.5 | -18.5 | 2.5 | -0.9 | -3.8 | -2.7 | -0.2 |
| 1 | Logit | 0.9 | 2.7 | -1.2 | -0.4 | 1.7 | 0.8 | 0.0 |
| | Prob [%] | 9.4 | 55.0 | 1.2 | 2.5 | 19.8 | 8.2 | 3.8 |
| | %Change by mode | -15.3 | 17.9 | -1.8 | 0.7 | -2.3 | 1.9 | -1.2 |
| Characteristic: age under 30yrs old, have cars, single mode, external zone | | | | | | | | |
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.2 | -1.3 | -3.2 | -4.2 | -2.0 | -4.1 | 0.0 |
| | Prob [%] | 6.8 | 16.9 | 2.7 | 0.9 | 8.4 | 1.1 | 63.2 |
| 0 | Logit | -1.5 | -2.0 | -2.5 | -4.8 | -2.2 | -4.6 | 0.0 |
| | Prob [%] | 13.7 | 8.8 | 5.2 | 0.5 | 7.3 | 0.6 | 63.8 |
| | %Change by mode | 7.0 | -8.1 | 2.5 | -0.4 | -1.1 | -0.4 | 0.6 |
| 1 | Logit | -2.9 | -0.7 | -3.8 | -3.6 | -1.9 | -3.5 | 0.0 |
| | Prob [%] | 2.9 | 28.7 | 1.2 | 1.4 | 8.6 | 1.6 | 55.5 |
| | %Change by mode | -3.8 | 11.8 | -1.5 | 0.5 | 0.2 | 0.5 | -7.8 |
| Characteristic: age under 30yrs old, no cars, single mode, internal zone | | | | | | | | |
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.6 | 1.5 | -1.2 | 0.9 | 1.7 | -3.2 | 0.0 |
| | Prob [%] | 71.6 | 9.4 | 0.6 | 4.8 | 11.6 | 0.1 | 2.0 |
| 0 | Logit | 4.3 | 0.9 | -0.5 | 0.3 | 1.6 | -3.7 | 0.0 |
| | Prob [%] | 87.5 | 2.9 | 0.7 | 1.6 | 6.0 | 0.0 | 1.2 |
| | %Change by mode | 15.9 | -6.4 | 0.1 | -3.2 | -5.6 | -0.1 | -0.8 |
| 1 | Logit | 2.9 | 2.2 | -1.8 | 1.4 | 1.9 | -2.7 | 0.0 |
| | Prob [%] | 45.4 | 23.1 | 0.4 | 11.0 | 17.3 | 0.2 | 2.6 |
| | %Change by mode | -26.1 | 13.8 | -0.2 | 6.2 | 5.7 | 0.1 | 0.6 |
| Characteristic: age under 30yrs old, have cars, single mode, internal zone | | | | | | | | |
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.3 | -1.8 | -3.8 | -2.4 | -1.8 | -7.5 | 0.0 |
| | Prob [%] | 34.4 | 7.5 | 1.0 | 4.2 | 7.7 | 0.0 | 45.2 |
| 0 | Logit | 0.4 | -2.5 | -3.2 | -3.0 | -1.9 | -8.0 | 0.0 |
| | Prob [%] | 53.6 | 3.0 | 1.5 | 1.8 | 5.1 | 0.0 | 35.0 |
| | %Change by mode | 19.2 | -4.5 | 0.5 | -2.4 | -2.6 | 0.0 | -10.2 |
| 1 | Logit | -1.0 | -1.1 | -4.5 | -1.8 | -1.6 | -7.0 | 0.0 |
| | Prob [%] | 18.2 | 15.4 | 0.6 | 8.0 | 9.6 | 0.0 | 48.2 |
| | %Change by mode | -16.2 | 7.9 | -0.4 | 3.8 | 1.9 | 0.0 | 2.9 |

Table 8.11 Comparison of probability of mode preference in case of changing attitudinal component pro environmental and others' health (C1)

| Characteristic: age between 31 and 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.1 | 1.0 | -2.0 | -2.3 | 0.7 | 1.4 | 0.0 |
| | Prob [%] | 23.0 | 20.7 | 1.0 | 0.8 | 15.1 | 31.8 | 7.6 |
| 0 | Logit | 1.8 | 0.3 | -1.3 | -2.9 | 0.5 | 0.9 | 0.0 |
| | Prob [%] | 46.9 | 10.8 | 2.0 | 0.4 | 13.1 | 18.9 | 7.7 |
| | %Change by mode | 24.0 | -9.8 | 1.0 | -0.3 | -2.0 | -12.9 | 0.1 |
| 1 | Logit | 0.4 | 1.7 | -2.6 | -1.7 | 0.8 | 2.0 | 0.0 |
| | Prob [%] | 8.6 | 30.1 | 0.4 | 1.0 | 13.3 | 40.9 | 5.7 |
| | %Change by mode | -14.4 | 9.4 | -0.6 | 0.3 | -1.8 | 9.1 | -1.9 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, external zone | | | | | | | | |
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.7 | -2.3 | -4.6 | -5.6 | -2.8 | -2.9 | 0.0 |
| | Prob [%] | 5.0 | 7.5 | 0.8 | 0.3 | 4.6 | 4.4 | 77.4 |
| 0 | Logit | -2.0 | -3.0 | -4.0 | -6.1 | -3.0 | -3.4 | 0.0 |
| | Prob [%] | 10.2 | 3.9 | 1.5 | 0.2 | 3.9 | 2.6 | 77.8 |
| | %Change by mode | 5.1 | -3.6 | 0.7 | -0.1 | -0.6 | -1.8 | 0.4 |
| 1 | Logit | -3.4 | -1.7 | -5.3 | -5.0 | -2.7 | -2.3 | 0.0 |
| | Prob [%] | 2.3 | 13.5 | 0.4 | 0.5 | 5.0 | 6.9 | 71.5 |
| | %Change by mode | -2.7 | 5.9 | -0.4 | 0.2 | 0.4 | 2.5 | -5.9 |
| Characteristic: between 31 and 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.1 | 0.5 | -2.6 | -0.5 | 0.9 | -2.0 | 0.0 |
| | Prob [%] | 77.9 | 6.1 | 0.3 | 2.3 | 9.3 | 0.5 | 3.6 |
| 0 | Logit | 3.8 | -0.1 | -2.0 | -1.1 | 0.8 | -2.5 | 0.0 |
| | Prob [%] | 90.3 | 1.8 | 0.3 | 0.7 | 4.6 | 0.2 | 2.1 |
| | %Change by mode | 12.4 | -4.3 | 0.0 | -1.6 | -4.7 | -0.3 | -1.5 |
| 1 | Logit | 2.4 | 1.2 | -3.3 | 0.1 | 1.1 | -1.5 | 0.0 |
| | Prob [%] | 55.2 | 16.9 | 0.2 | 5.9 | 15.4 | 1.2 | 5.2 |
| | %Change by mode | -22.7 | 10.8 | -0.1 | 3.6 | 6.2 | 0.7 | 1.6 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.8 | -2.8 | -5.3 | -3.7 | -2.6 | -6.3 | 0.0 |
| | Prob [%] | 28.3 | 3.7 | 0.3 | 1.5 | 4.7 | 0.1 | 61.4 |
| 0 | Logit | -0.1 | -3.5 | -4.6 | -4.3 | -2.7 | -6.8 | 0.0 |
| | Prob [%] | 45.3 | 1.5 | 0.5 | 0.7 | 3.2 | 0.1 | 48.8 |
| | %Change by mode | 17.0 | -2.2 | 0.2 | -0.8 | -1.5 | -0.1 | -12.6 |
| 1 | Logit | -1.5 | -2.2 | -5.9 | -3.1 | -2.4 | -5.8 | 0.0 |
| | Prob [%] | 15.4 | 7.8 | 0.2 | 3.0 | 6.0 | 0.2 | 67.4 |
| | %Change by mode | -12.9 | 4.2 | -0.1 | 1.5 | 1.3 | 0.1 | 6.0 |

Table 8.12 Comparison of probability of mode preference in case of changing attitudinal component pro environmental and others' health (C1)

| Characteristic: age over 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 0.2 | 1.4 | -1.0 | -1.4 | -1.4 | 1.8 | 0.0 |
| | Prob [%] | 9.2 | 31.4 | 2.9 | 1.9 | 1.8 | 45.0 | 7.8 |
| 0 | Logit | 0.9 | 0.7 | -0.3 | -2.0 | -1.6 | 1.2 | 0.0 |
| | Prob [%] | 24.0 | 21.0 | 7.3 | 1.4 | 2.0 | 34.1 | 10.1 |
| | %Change by mode | 14.8 | -10.4 | 4.4 | -0.5 | 0.2 | -10.8 | 2.3 |
| 1 | Logit | -0.5 | 2.1 | -1.6 | -0.8 | -1.3 | 2.3 | 0.0 |
| | Prob [%] | 2.9 | 38.7 | 1.0 | 2.2 | 1.4 | 48.9 | 5.0 |
| | %Change by mode | -6.3 | 7.3 | -2.0 | 0.3 | -0.5 | 4.0 | -2.8 |
| Characteristic: age over 50yrs old, have cars, single mode, external zone | | | | | | | | |
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -3.7 | -1.9 | -3.6 | -4.7 | -5.0 | -2.6 | 0.0 |
| | Prob [%] | 2.0 | 11.1 | 2.1 | 0.7 | 0.5 | 6.1 | 77.5 |
| 0 | Logit | -3.0 | -2.6 | -3.0 | -5.2 | -5.1 | -3.1 | 0.0 |
| | Prob [%] | 4.1 | 6.0 | 4.2 | 0.4 | 0.5 | 3.7 | 81.1 |
| | %Change by mode | 2.2 | -5.1 | 2.1 | -0.3 | -0.1 | -2.3 | 3.6 |
| 1 | Logit | -4.4 | -1.3 | -4.3 | -4.1 | -4.8 | -2.0 | 0.0 |
| | Prob [%] | 0.9 | 19.0 | 0.9 | 1.2 | 0.6 | 9.1 | 68.3 |
| | %Change by mode | -1.1 | 7.9 | -1.1 | 0.4 | 0.0 | 3.1 | -9.2 |
| Characteristic: age over 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 2.1 | 0.9 | -1.6 | 0.4 | -1.2 | -1.7 | 0.0 |
| | Prob [%] | 59.4 | 17.6 | 1.4 | 11.0 | 2.1 | 1.3 | 7.1 |
| 0 | Logit | 2.8 | 0.3 | -1.0 | -0.2 | -1.4 | -2.2 | 0.0 |
| | Prob [%] | 81.3 | 6.2 | 1.8 | 4.1 | 1.2 | 0.5 | 4.8 |
| | %Change by mode | 21.8 | -11.4 | 0.4 | -6.8 | -0.9 | -0.8 | -2.3 |
| 1 | Logit | 1.4 | 1.6 | -2.3 | 1.0 | -1.0 | -1.1 | 0.0 |
| | Prob [%] | 30.7 | 35.5 | 0.7 | 20.6 | 2.6 | 2.4 | 7.4 |
| | %Change by mode | -28.7 | 17.9 | -0.6 | 9.6 | 0.5 | 1.0 | 0.3 |
| Characteristic: age over 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| C1 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -1.7 | -2.4 | -4.3 | -2.8 | -4.7 | -6.0 | 0.0 |
| | Prob [%] | 13.3 | 6.6 | 1.0 | 4.5 | 0.7 | 0.2 | 73.8 |
| 0 | Logit | -1.0 | -3.1 | -3.6 | -3.4 | -4.9 | -6.5 | 0.0 |
| | Prob [%] | 24.5 | 3.1 | 1.8 | 2.3 | 0.5 | 0.1 | 67.7 |
| | %Change by mode | 11.2 | -3.5 | 0.8 | -2.2 | -0.1 | -0.1 | -6.1 |
| 1 | Logit | -2.4 | -1.8 | -4.9 | -2.2 | -4.6 | -5.4 | 0.0 |
| | Prob [%] | 6.4 | 12.4 | 0.5 | 7.8 | 0.8 | 0.3 | 71.8 |
| | %Change by mode | -6.9 | 5.8 | -0.5 | 3.4 | 0.1 | 0.1 | -2.0 |

#### 8.5.4.2 Changing attitude component of pro-safe, C3

In this section, travel cost and travel time were fixed at 28 minutes and 40 THB, respectively whilst each component was changed to be C3 = 0 (disagree) and C3 = 1 (agree), *Pro-safe* considering three different age groups, household no car/own car, and internal/external travel. All the result of comparison presented in Appendix D.

The youngest age group for long journeys found the change when C3 = 0 that they tend to use active transport and motorcycles less than the base case by 9% and 3%, respectively if they did not have a car in the household. However, if they had a car in the household, they tended to use a car less up to 19%. Both groups, tend to use buses up to 16% compared to their base case. On the other hand, they had positive change when C3 =1, if they own a car or not, they realised that the car was safe, particularly car owner they had a high percentage change (14% of change) more than those who did not own car (4% chance of change) relative to their base. Younger commuters think that buses tend to be unsafe due to the inverse of magnitude when decrease in C3. For the younger age group but travel short distances, if they did not own a car, C3=1 they tend to choose walking or cycling (+8%). Whilst the household had a car, they then selected the car up to 10%. However, from the younger age group even if C3 decrease, they may not affect the car owner group if they travel externally or internally.

The comparison probability of mode preference when changing C3 in the middle age group showed the change when C3=0 they tend to choose active transport compared to their base case, especially in a group that they have no car in their household when they travel external and internal their household is, at P(AT) = 33% and 83%, respectively. On the other hand, when C3 increased, the probability from all cases of middle-group bus use decreased in all cases, while the probability of car increased. This could be referred that the middle age group perceived that the car was safe.

The older age group also realised similar to both younger generations in the perspective of cars and buses related to safety components. If they own a car in their household, when C3=1, they then use the car increase by 11% when travelling externally and increase by 9% when travelling internally.

Interesting point on bus mode, the passenger had a bad attitude toward safety. An increase in C3 had less probability compared to their reference case. It can be inferred that the bus was not safe. Therefore, the participants might not prefer to use a bus for commuters. To increase the attractiveness of using a bus to go to work, the bus service should improve the appearance and the restricted driving style of the driver. It can inspire car users to select different modes of transport.

#### 8.5.4.3 Changing attitude component of pro-private vehicle, C4

The probability for the mode of transport selection related pro- private vehicles, C4, is presented in Appendix D. For all groups, if people agreed with this statement that allowed to use private vehicles freely (C4=1), the probability of private transport preference increased including car and motorcycle.

When their attitude disagreed (C4=0) with the statement, active transport was more likely to be chosen for the younger age group. In addition to this, if they have no cars and travel in different postcode areas, they tend to use shuttle bus by 9% increase in mode preference compared to a base case while less preferred in bus, motorcycles, and cars by 6%, 5%, and 1%, respectively. While the probability of shuttle buses and walking increased by 2% and cars decreased by 5%, they had at least one car in their household. However, when they agreed with the statement to use private vehicles freely (C4=1), the group that owned a car had a higher probability of choosing a car compared to a base car for external and external travel. If they did not own a car the probability of motorcycle preference increases.

For the middle age group, when C4=0, the group that had at least one car and travelled externally, the probability of choosing a car decreased by 9% while the probability of shuttle bus and active transport increased by 8% and 2%, respectively. On the other hand, if they travelled internally, the probability of choosing a car decreased by 8% while the probability of motorcycle and active transport increased by 1% and 8%, respectively.

As expected, the elderly group preferred using the shuttle bus (24% increase) when they travel long journeys with disagreed with using a car freely statement compared to their base case when they did not own a car in the household. The percentage change for MC in all scenarios of elder people is less than 1 percent.

From the variation of attitude change, it can be seen that the attitudes had a stronger influence than changing the cost and time of travelling. However, changing the attitude required more time for example education and realised that that their mode of transport caused how much amount of pollution. Travelling time was strongly influenced than travelling cost for this example case.  This study also found an interesting point regarding travel time coefficients in the model were positive in bus, train, and car modes. Hess *et al.* (2005) suggested that travel time should be a negative coefficient value.  However, this study found that the coefficient was positive on active transport, bus, train, and shuttle bus. It can be said that they perceived they spend time profitably. Compared to a study by Gadepalli *et al.* (2020) from India, travel time was one of the factors that people chose bus mode. On the other hand, up to 95% of participants in the Bangkok case study by Wilinski and Pathak (2022) accepted that public transport travel time was less than 2 hours. However, the study of acceptable travel time in Bangkok rarely found therefore this was a novel study proved on useful time.

Train commuters were highlighted on pro-environment and others' health and pro-safe and convenience variables. The latter variable had a much stronger influence on their mode selection than the environmental attitude. Time, cost, age, and vehicle ownership were not significant in the mode selection of train users. A similar finding to a study by Witchayaphong *et al.* (2020) that mass transit user was not affected by travelling time which was unique for Bangkok.

Car commuters were a notably attractive factor due to safety and convenience. Agustaniah and Wicaksono (2020) also showed that people in Indonesian chose cae commuter due to safety and convenience as demonstrated by the logit model. The younger group was less attracted to this mode similar result to the study from Jinit *et al.* (2022) that study on school trips in India. If the participants had at least one vehicle in their household, they tended to select a car for transport similar finding to Acker *et al.* (2014). However, cost and time did not significantly impact car selection.

The last mode of transport focus in this study, motorcycle users were influenced by cost, time, pro-safe, and age. They were also interested in this mode due to safety and convenience concerns.

Gender was not significant in this model. This result is similar to the result of the previous section that had no difference between genders in some clusters such as Cluster 2 *Die Hard*

*Driver*, Chapter 7. In contrast, the study by Wilinski and Pathak (2022) found that gender had a significant effect on public transport users' study by Kamargianni *et al.* (2015) because they focused only on school trips the participants were younger than this study.

Travel time and travel cost impact on travel behaviour, the result also confirms that people in Bangkok who have cars would like to use cars with a high odds ratio. In addition, the three attitudes had a high impact on mode preference. From the study, the policy should find a way to reduce the number of processed cars in their household, educate people about the disadvantages of the impact on each mode, and improve the appearance of public transport.

## 8.6 Conclusion of this chapter

This chapter has focused on investigating the variables that impact mode choice preference by using multinomial logistic regression. The independent variables in this study embraced three categories, travel behaviour, attitudinal PCA components and socio-demographic parameters. The result showed that travel time, travel cost, three attitudinal components namely *Pro-environment and others' health*, *Pro-safe*, and *Pro private vehicle*, and `sociodemographic variables including age and vehicle ownership for external and internal commuter journeys had statistically significant impacts on mode selection. The scenario results presented in Section 8.4 included a variation of 20% in travelling cost, 20% of travelling time, increase and decrease in 3 attitudinal scores (C=0 and 1). The example cases were for single-mode journeys with internal and external travelling zones, and car ownership by three age categories, younger, middle age and older group.

Key messages emerging from these results included:

20% increase in journey time by private car perhaps due to an increase in congestion in BMR results in 5.4% and 1.2% for *younger generation commuter trips* shift to active travel and bus respectively. Mode shift for train, shuttle bus, and bus was insignificant (less than 1%). However, a reduction of 0.3% and 2.9%, respectively for taxis, and motorcycles emerged given all road transport modes experienced a 20% increase in journey time not just cars.

The *middle age group who owned at least one car* in their household and acknowledged that their mode impacted others' health (C1=1) used their car less than 6% compared to the base case. In addition, if they disagreed with a *pro-private vehicle* (C4=0), the probability of using a car also was 10% lower. This investigation shows that attitudes can have a significant impact, but they are the most difficult to change and take much longer to deliver.

The study suggested that policies should focus on finding ways to reduce the number of cars purchased by households and/or delay purchase/incentivise younger generations not to purchase and use private cars. Educating people about the environmental impact, particularly of private car and motorcycle users and highlighting the benefits of sustainable options is imperative. In addition, improving public transport service frequency, convenience, and safety specifically for buses also is necessary given that it is important to make public transport use more attractive to attract car users. The finding was answers to the last research question 3, presented in Chapter 1

The next chapter will compare the findings of the different analysis methods, exploratory statistics, PCA, HCA and MLR used in this study and discuss the policy implications and recommendations.

# Chapter 9. Discussion and Conclusions

## 9.1. Introduction

The previous Chapter 8 presented the development of the Multinomial Logistic Regression, MLR, model for commuter mode preference and demonstrated its application using example scenarios exhibiting distinct characteristics. The variables that influenced mode preference included travel time, travel cost, three of the four attitudinal components i.e. pro-environment and others' health, a pro-safe and pro-private vehicle that emerged from the Principal Components Analysis, PCA, as well as socio-demographic factors including age, car ownership and commuter distance travelled. The research showed that attitudes towards the environment (Component 1 and Component 4) and safety (Component 3) appeared to influence mode preference more than travel cost and travel time.

This chapter provides an overview and discusses the analysis of the results obtained from all the statistical approaches used in this research, including descriptive analysis, principal component analysis, hierarchical cluster analysis, and multinomial logistic regression. An overview of the specific results of these techniques is presented in Section 9.2. The main, followed by the secondary finding are presented in Sections 9.3 and 9.4, respectively. The limitations, policy implications, and recommendations are addressed in Sections 9.5 and 1, respectively before future research directions are proposed in Section 9.7.

## 9.2. Overview of the Results

The study aimed to develop a fundamental understanding of the influence of, and interplay between, attitudes towards the environmental impact, travel convenience, accessibility, and safety on people's travel mode choices. Ultimately, this research seeks to identify strategies to encourage a shift away from private vehicle use, thereby reducing carbon emissions and contributing to a healthier environment.

This study investigated travel behaviour and attitudes towards environmental impact, travel convenience, accessibility, and safety specifically in a developing city region by using the Bangkok Metropolitan Region (BMR) as a case study. This represents an aspect of novelty in this research as previous research has considered factors in isolation, or combined with one or two factors for consideration, rather than taking a holistic view of the four factors and in the context of all modes available, as did the present study. Also, most manuscripts reviewed were of travel in developed countries rather than in developing countries. Furthermore, only one previous research study found that considered all of these attitude factors in Bangkok (Fraszczyk *et al.*, 2019) focused on urban rail travel and therefore did not consider mode choice between available mode options.

The questionnaire was developed and customised for Bangkok travel options within the pilot and 1st Study survey before launching the 2nd Study data collection online and by direct interview between April and May 2022. A representative sample was confirmed using a Chi-square test on the number of respondents compared to the population by age and gender. The questionnaire contained three parts and included travel behaviour and self-identification, attitudes with four main themes and socio-demographical data. The first part asked the participants to report their daily commuter journey from home of residence to the workplace including travel time, cost, and transport mode. The final question from this section asked the participants to identify themselves based on the mode of transport. The second part of the questionnaire asked the participants to rate their opinions related to their attitude towards the environment, accessibility, convenience, and safety with 20 statements and using a sliding scale from 0 (disagree) to 100 (agree). The last part captured sociodemographic data.

The overview of the data was investigated by descriptive analysis. Next, the principal component analysis is applied to attitudinal variables for data reduction to fewer dimensions. Four components emerged from the PCA and were labelled and investigated by post hoc analysis.

The post-hoc analysis provided an overview of the descriptive analysis. Component 2 Pro -low emissions vehicles, and Component 4, Pro-safe, were both found to have a higher proportion of males significantly. It can be concluded that compared to females, males are more inclined to choose to drive. Similar results were obtained in research by Ali *et al.* (2018); Korzhenevych and Jain (2018), which found that compared to females, males have a preference to drive. Component 4 also revealed that males tend to agree to allow people to freely travel by car.

Public and specifically active transport users feature strongly in Component 1, Pro-environment and health. This suggests that the younger generations are more aware of environmental issues compared to middle-aged groups. In turn, Component 2 commuters (i.e., those supporting the shift from conventional to alternative, less polluting cars), were found to be positively influenced by age suggesting that the younger generations are more aware of environmental problems and therefore keen to find ways to reduce environmental impact. This result is consistent with Fraszczyk *et al.* (2019), who found that students were more inclined to change their mode of transport compared to older people. On the other hand, convenience and safety do not emerge as the biggest challenge in changing the travel behaviour of the younger age group. This may reflect the agility of the younger generations and that they are less risk-averse compared to the older cohorts. In stark contrast, compared to other age groups, environmental awareness had less impact on the travel behaviour of the over 50-year-old group who were less concerned about how many times people use their private car, however, safety (Component 3) was important in their choice of mode across all ages. The youngest group had the lowest score for this component which was statistically different from other age groups. The majority of the sample had the score of this component very high. Moreover, car users had an attitude different from active and public transport users. Private transport users had a very high impact score of component 3his result is consistent with that of a case study in Hanoi by Thibenda *et al.* (2022), which showed that people prefer to use their cars because of feeling safe.

Although commuters that had a high score of Component 3, Pro-safe, showed some sensitivity towards the environment only in that they agreed to buy an environmentally friendly car. In the context of safety and convenience, using the private car far outweighed any environmental concerns.

On the other hand, active transport mode users did not cause environmental problems, and their lower score in agreement to switch to less-polluting cars may suggest they are not aware of the pollution from vehicles to which they are exposed as they walk or cycle. Based on the scores compared to private car users, public transport users felt less safe and active transport users were even less safe than public transport users. This result was endorsed by the research of Ozawa *et al.* (2021) who proposed policies that improved walkability in Bangkok to address safety issues. Commuters over the age of 30 tended to select private transport more than the younger generation indicating that convenience and accessibility were important and preferred to change to an environmentally friendly vehicle as their financial situation improved.

Hierarchical cluster analysis was conducted to identify the characteristics of each cluster related to self-mode of travel identity, age, gender, and their attitudes The component from PCA was fed in as an input. Ward's method was selected to classify the cluster. Finally, the mode preference and travel behaviour, attitudes that resulted from the PCA, and their background were investigated using multinomial logistic regression, allowing the recommendations and policy scenarios that targeted specific population groups to facilitate mode shift to more sustainable transport to be investigated.

### Novelty in this research

This research makes four contributions to the field of sustainable transport planning as follows:

1. Examined how a combination of attitudes and population's characteristics influence travel behaviour in the developing cities' context.
2. A detailed transferable online questionnaire that uses both direct and indirect (attitudes and identity) to analyse travel behaviour.
3. Complimentary analytical methods namely descriptive, principal component, hierarchical and cluster analysis, and multinomial logistic regression to identify those variables and attitudes that have a statistically significant influence on commuter's mode choice.
4. Developed algorithms that provide insights of a range of scenarios to inform recommendations, that help to target specific population groups to influence a shift to specific sustainable transport modes and maintain current levels of travel by public and active transport.

## 9.3. Main Findings

The research questions presented in Chapter 1 of this thesis were

1. What are the attitudinal factors and the socio-demographic variables that characterise the use of transport in developing countries?
2. Do attitudinal factors and socio-demographic characteristics lead to the need for an integrated approach to policies and interventions tailored to target specific commuter groups to deliver a shift to sustainable modes of transport?
3. Which attitudes and time, cost and other influences are most impactful on the target group considering the take up more sustainable options?

The primary contributions that addressed the research questions were as follows:

1. The descriptive analysis of collected data between April and May 2022, the results showed that driving the car to the workplace, whether internal or external to the post-code area of residence, was the most popular mode in BMR, followed by urban rail. When grouping respondents by self-identified mode of transport user, most respondents considered themselves as private transport users, followed by public transport and lastly active travel.
2. Descriptive analysis showed that most people in the age group of over 40 years old defined themselves as private transport user. This age group were in employment and could afford to buy a private vehicle whilst the younger age groups were more reliant on public transport. Compared to other modes active transport was less popular in the BMR area across all age groups and genders. Cycling was the smallest proportion in the self-identity grouping in this study which is consistent with publicly available data that bike users commuting in the BMR area represent only 1%.
3. Four attitudinal components emerged from PCA with ProMax rotation and were labelled as *Pro-environment and health* (Component 1), *Pro-environmentally friendly cars* (Component 2), *Pro-safe* (Component 3), and *Pro-private vehicle* (Component 4). The data was analysed by gender, age, and self-defined user mode of transport. There was a statistically significant influence of gender on Component 2 (i.e., buying a low-polluting car), and Component 4 (i.e., attitude towards using private vehicles freely). Variables including those related to severance, high traffic levels to cross, no through-ticketing, and exhaust fume problems were removed from the analysis. This was

justified as these variables were out of the control of the traveller and the responsibility of the Local Authority.

4. Hierarchical cluster analysis based on the four components, demographics and self-identity mode user revealed five clusters labelled as "*Aspiring Environmentalist*", *"Die hard driver"*, "*Public transport passionate", "Self-centred traveller*", *and "Young at heart active traveller".* The largest cluster was the *Aspiring Environmentalist cluster* (n =286,44% of total participants). The main characteristics of this cluster emerged as equally divided between male and female, and up to 56% of members identify themselves as a private transport user followed by public and active transport at 35% and 9%, respectively. The majority of members in this cluster were middle-aged.
5. The MLR analysis was carried out using the car as the reference given that the majority of commuters use cars, and it is these journeys that need to be influenced to have any chance to deliver net zero policies and interventions. The model revealed interesting and some counterintuitive results. The coefficient of total time in the logit model relative to the car, for active transport, train, and bus were positive signs. This can be interpreted as these commuters found their travel time as productive. This can be explained because they spend time on mobile phones, tablets and laptops working or engaging in other activities whilst the motorcycle users with negative coefficients were unable to do so.

## 9.4. Secondary Findings

1. Most previous studies conducted in developed countries found that people tend to use public transport which is inconsistent with this study found that the majority of commuter journeys were by private car. This is despite huge investment in urban rail and bus services and included in the national development plan.
2. Previous research focused generally on the mode of transport and considered only selected attitudinal themes when exploring influences on travel behaviour. This research clearly shows that there is an interplay between the attitudes which come together when decisions are made regarding mode choice. The strength of the influence of different attitudes (environment, accessibility, convenience, and safety) also differs depending on the socio-demographic variables of the commuter clearly showing that there is a need for a range of interventions and policies targeted to particular cohorts of the population. This addresses the research gap 2.

3. The distribution of scores for each attitude variable enabled questions to be grouped and whilst some distributions mapped well onto each other there were differences. Therefore, the more advanced analysis, PCA which identified 4 components was conducted. As expected, there was a similarity in the results from the grouping of questions from the simple descriptive statistics and each of the components. The questions grouped in the PCA Components 2, 3 and 4 were identical to those grouped in the descriptive analysis. Except for Statement 7 Component 1 mapped on Group 1 from simple statistics. Statement 7 related to "congestion is a serious problem in the city" which was associated with the Pro Environment Component 1 in the PCA despite the distribution not considered associated with Group 1 in the descriptive statistics. However, poor air quality in Bangkok is acknowledged by its citizens as being caused by congestion (Chavanaves *et al.*, 2021) and therefore association with Component 1 is reasonable. Both analytical approaches separated statements 14, 15, 16, 18, and 8 all of which were considered to be outside the control of citizens in the sense that they were associated with infrastructure, integration of bus and rail service operation through ticketing, which are the responsibility of BMR and operators. These variables were not included in further analyses.
4. The urban train was introduced in the early 2000s with the aspiration that people would facilitate a mode shift from cars. This research has provided clear evidence that the private car remains the preferred mode option and in some respects the problem has worsened such as traffic congestion.
5. Given that, 7% of car users' responses to the questionnaire in this study were that the "out-of-pocket cost" of travel by car was free. It can be inferred that there was no acknowledgement of such costs as fuel, tolls, maintenance fees, finance charges, tax, insurance, and depreciation.
6. The MLR demonstrated that reducing the costs of travelling by public transport encouraged commuters to give up their car. Therefore, efforts that enable annual travel cards, at reduced rates, to be purchased monthly through workplace schemes and local authority service charges such initiatives should be introduced at the same time. Car parking charges, fuel taxes etc are increased to incentivise drivers to switch to the much less expensive alternatives.
7. The MLR showed the strong influence of car ownership in the household. When they process at least one car in a household, they tend to use the car compared to the user

did not have a car. Therefore, the policy that can slow the new purchasing car may change their mode of preference significantly.

8. Increasing journey times by car in the MLR also was found to create a mode shift from car to public transport. Therefore, investment in more efficient and frequent public transport simultaneously with reducing the capacity of roads for traffic use for example signal control, narrowing lanes, introducing bus lanes, and a shift to public transport can be facilitated. Additional delay to traffic is inevitable in the short-term but co-creating strategies with citizens gives them ownership maximising the chance of success.

## 9.5. Limitations of the Study

1. The main limitation of this research was that data was collected during the period of COVID-19 pandemic restrictions and therefore to some extent reflects essential travelling.
2. The urban rail system was not fully opened with limited connections across the BMR area therefore the longer journeys with a transfer may be underrepresented.
3. Age exerted a strong influence on travel behaviour choices, particularly with regard to respondents' willingness to shift to low-polluting cars. Younger generations are more willing to shift to lower emission cars compared to the over 50 years old who wish to continue using conventional carbon-based fuelled cars. This may reflect the aspirations of the younger generations who currently cannot afford to purchase a private car and the reality of the situation with the older generations who cannot afford to replace the car they currently own.
4. The variables quantified in this study were chosen to reflect the research gap, which was to consider the interplay of attitudes to environment, accessibility, convenience, and safety with a focus on identifying sustainable interventions. Therefore, the factors affecting mode choice considered in this research were based on a selection of potential questions which were identified in the literature review due to constraints on the length of the survey. There are many more factors that could have been included vehicle comfort, provision of shelters, ticketing etc. that may affect travel behaviour and mode choice in Bangkok which were not considered in this study. The

length of the survey was optimised in the pilot and 1st Study stages of the methodological approach.

5. Norm or culture value and meteorological conditions also may influence mode choice but be neglected and considered outside the scope of the current study.
6. When considering the factors considered and subsequently included in the present study, in turn, influence the resulting cluster solution. Therefore, given that there is no independent mechanism to validate the resulting cluster solution the characteristics of these were scrutinised. The overlap of this study's findings with those of previous literature (see Chapter 2 Section 2.3) provides confidence in the extracted clusters.
7. Trip chain, waiting time and transfer time were neglected in this study due to lack of collected data. Most of the participants ignored spare time between modes of transport.
8. The postcode in Bangkok (used to collect the data of origin and destination) was too imprecise. The postcodes covered relatively large areas and therefore they could not be used to identify trip start and end when distances were short. Therefore, the assumption was made that travel within the same postcode area was labelled intrazonal or internal and when reported travel was to a different postcode area interzonal or external.
9. SPSS is a widely used and powerful statistical software package however; the software was unable to consider the removal of specific statistically insignificant coefficients of mode variables. Therefore, if only one coefficient in any of the 6 modes was statistically significant, the coefficient had to be included in the logit model irrespective of whether its magnitude was large or small. Other software such as BIOGEME (Biogeme 3.2.13 (epfl.ch)) and Gauss (Discrete Choice Analysis Tools - GAUSS Applications (aptech.com)) are available on the market but not accessible to this research.

## 9.6. Policy Implications of the Study

Whilst the results of the independent analytical steps, descriptive statistics, and MLR tend to reinforce findings, they also provide different perspectives bringing different insights in terms of informing policy. In this research given that the HCA embraced also the PCA components, the five clusters that from the analysis, emerged as the most powerful to inform sustainable schemes and policy interventions. These are discussed in this section.

Due to the score on environmental attitudes and their travel behaviour identity, ***Cluster 1: Aspiring Environmentalists*** could be persuaded to change to greener alternatives by reducing the purchase price or tax reductions on greener vehicles or through incentives to use public transport through service improvements making them more convenient to use. The characteristics of this cluster was similar to one of the clusters that emerged from the study by Anable (2005), which scored high in attitudes toward the environment and preference for using an alternative public transport. However, in the case study of Bangkok, the alternative transport solution such as public transport was not fully covered in all areas, unlike the case study in northwest UK, where individuals tend to shift to active transport mode. In Bangkok, even though there was the high awareness of environmental problem, the main mode of transport remained private vehicles. Therefore, this cluster highlights the need for practical and attractive sustainable alternative transport options to be developed to support the transition.

Due to their high scores across all components, it will be difficult to change the behaviour of ***Cluster 2: Die-hard drivers****.* They are aware of environmental issues and support the purchase of low emissions vehicles yet are willing to allow others to travel as much as they wish. They have strong attitudes towards safety and require short journey times, therefore, the convenience offered by the private car is likely to be considered paramount. This group should be indirectly persuaded to use their car less. This can be achieved by increasing taxes but also by raising car park charges and introducing incentives to use park and ride. From an ITS technology perspective, reducing the capacity of city roads for private vehicles by gradually reducing green signal durations, whilst at the same time giving priority to buses and active travel modes is an option but would require strong political backing. Also, taking initiatives such as inexpensive or free travel on public transport integrated with shared mobility could delay the purchase of the first and not require additional cars. In the longer term, it is necessary to encourage the purchase of lower-polluting vehicles by reducing purchase prices and taxes.

Given the important role of public transport in addressing environmental issues efforts to maintain and grow ***Cluster 3 - Public transport passionate*** by maintaining and improving the service quality, reducing journey times through bus priority and segregated bus lanes particularly improving connectivity (service integration, real-time information systems, integrated ticketing) and accessibility (shared e-mobility, priority pedestrian signal crossings with green waves for pedestrians at junctions and two way roads with central reservations) consistent with Webb (2010). However, worthy of note here is that this study was carried out during the COVID-19 pandemic when cross-city public transport was severely disrupted. Therefore, the score assigned by this group to some questions may have been affected.

Notwithstanding the mixed identity of transport mode of ***Cluster 4 – Self-centred traveller*** *there* was a lack of awareness of environmental issues therefore through targeted environmental awareness campaigns, this group should be educated to understand the importance of using more sustainable travel options and efforts to understand the barriers faced by these travellers would be valuable. The study by Bösehans and Walker (2020) indicated that the mode preference was influenced by its ease of use. This Cluster is to some extent consistent with this study, given that transport alternatives are not available and this lack of network coverage in Bangkok has led to people needing to use private transport.

***Cluster 5 – Pro-sustainable transport*** emerged as active travellers and public transport users and aligned with the sustainable goal of this paper. As in the labelling section in Chapter 7, the characteristic sociodemographic of this cluster was similar to the main characteristic of the *difficult shiftiness* to the metro in an area of BMR identified by Fraszczyk *et al.* (2019). However, the attitudes towards the environment were different, this study further found that their current modes of transport were active transport, and they realised that their mode of transport did not impact other people. Therefore, they might not want to change to other modes of transport or new technologies. Efforts should be to maintain their behaviour and nurture their attitudes towards the environment whilst expecting others to move away from private vehicles. Interventions similar to Cluster 3 are required to maintain and grow public transport use and active travel. In addition, investment to improve and increase facilities for active transport users including cycle paths, pedestrian crossings, signalised crossing with green waves for pedestrians and cyclists at junctions, and across dual carriageways reducing the capacity for vehicles to encourage mode shift from private to either public or active transport. Initiatives such as 'no car' days trialled with various degrees of success in Europe (Masiol *et al.*, 2014) should be considered in Bangkok.

A comparison of clusters and their characteristics with the component score in the MLR model found that Cluster1, *Aspiring Environmentalists,* and Cluster2 *Die-hard drivers* with the largest proportion of those aged between 31 to 50 years old and owned a car. Both clusters had a high score of Component 1 which indicates that they were aware of their mode of transport's impact on others. Interestingly, Cluster 1 and 2 were different in their score of Component 2. However, Component 2 did not appear in the model therefore the members of Cluster 1 and 2 can be interpreted in the same direction. The result from the MLR model depending on the specified characteristic showed that increased travel time generally shifted people away from car preference as the mode of commuter. If Component 1 had a higher score (close to 1), Cluster 2 may change in mode preference from car to more sustainable mode such as train mode due to that had the awareness of their mode.

Therefore, this research suggests that specifically targeting the middle-aged group, which is the age group with the highest proportion of the BMR population by age, for travel both internal and external of residential areas, with policies that increase the cost of travelling by car people will use their car less. LAs should consider making partnerships with employers to introduce mechanisms for employees to purchase discounted travel cards with cost deducted from pre-tax salary. Such subsidies from employers offering lower-cost tickets incentivise the use of public transport. These initiatives implemented simultaneously with gradual increases in parking fees in the city centre and abolition of free parking at the place of work will make commuters aware of “out of pocket” costs and encourage mode shift to public transport. Such policies could be part of a long-term policy to achieve car-free zones in parts of the city where footfall is high.

Alongside policies aimed to reduce private transport use, LA should provide frequent and efficient public transport extending network coverage to meet user needs. Also, infrastructure changes to make travel by public transport faster than by private car should be introduced. These include dedicated bus-only lanes, optimisation of traffic signal timings to give the priority to buses or trains at crossings. Public transport services should be improved making them more frequent, reliable, punctual, and comfortable avoiding overcrowding to encourage public transport use. In addition, conducting public awareness campaigns to address the lack of understanding of the actual costs of car ownership and use including maintenance and toll fees. By emphasising the financial and environment advantages of switching to sustainable transport will facilitate mode shift away from private car use. Active transport, currently only 1% for commuters, should be given priority by constructing protected bike lanes, introducing shared bike and scooter services, improving the size and condition of pathways with adequate lighting that can make active transport safer and more attractive.

Long term policies for sustainable transport based on the result of the study include introducing congestion pricing schemes, promoting sustainable urban development, regulating car ownership growth, investing in multimodal integration, adopting and scaling green technologies, and improving public awareness. Co-creation of intervention measures with the public will give travellers ownership which in turn increases success in the uptake of sustainable alternatives. Introducing pricing of congestion and to regulate exhaust emissions was shown in London (Transport of London, 2024) to effectively discourage car use and encouraged mode shift to more sustainable modes of transport. The finding of the research presented in this thesis indicated that increasing cost and time could significantly impact mode choice. Implementing a congestion charge in the inner business area of Bangkok is a practical approach, with the revenue return used to improve public transport infrastructure and services. Promoting sustainable urban development is important. Combining changes in land use and transport planning can significantly reduce the dependency on private vehicle use by bringing workplaces closer to residential areas. Mixed-use developments that offer seamless connectivity to public transport hubs should be prioritised. Such planning ensures reduced travel distances and reliance on private cars, contributing to a more sustainable and efficient urban environment in the longer term. Regulation can curb or slow down car ownership growth which emerged as a result of the MLR analysis. Also, reducing the current trend with policies aimed at discouraging a new or second car purchase is essential. Increasing registration taxes for new vehicles, offering incentives for car- and ride- sharing, and assigning an inner area of Bangkok as a car-free zone can facilitate a shift towards more sustainable modes.

Not only are operational improvements needed but investment in multimodal integration to enhance attractiveness of longer journeys. This will need simultaneous introduction of an integrated ticket system across all public transport modes and improved access to and facilities within multimodal hubs are critical in achieving a seamless-integrated and user-friendly network. The multimodal hub can be transformed into small green community area that includes EV station with access to Wi-Fi and coffee/tea facilities for drivers whilst waiting for vehicles to fast-charge thus meeting the support that emerged from this research for purchase low emission vehicles. Additionally, incentive to enable the replacement of high polluting cars is a crucial step to reduced emission and educating drivers to adopt more sustainable transport systems.

LAs and bus operators should keep records of incidents of accident and injury and take steps to promote a ‘drive safely’ culture awarding good drivers and thus influence a change in the perception of commuters. This study showed that attitude toward safety in public transport specifically buses. 9% of the middle age group who own a car and travel long distance may change their preference.

Engaging the population in the development of transport policies enhanced their acceptance and ensured alignment with community requirement. Top-down policy with co–creating policy strategies fosters a sense of ownership by reaching out to the green community is important therefore the need to establish community forums and by adopting a participatory planning process will allow people to contribute meaningfully.

From the above, short- and long-term policies, it can be concluded that travel behaviour and attitudes to the environment, accessibility, convenience, and safety greatly vary among BMR commuters of different characteristics and socio-demographics. The result from the study has shown that people in general are aware of environmental problems, willing to purchase low-emission cars, and acknowledge the effect of traffic-related congestion on their health however environmental effects appear not to be the main driver for mode choice but other factors such as safety and convenience also influence. Promoting sustainable modes as viable alternatives to private cars is an important step to delay or even prevent the purchase of a vehicle and reduce the vehicle kilometres travelled.

## 9.7. Future Research

1. Future research could focus on specific cohorts such as the younger generation, and car owners. As this was the first study of its kind in a developing country the findings relate to the city region of Bangkok it would be interesting to replicate the research in a different city in Thailand or in another developing country to explore transferability.
2. The future study could narrow down to focus only public transport group and identify the actual barrier of public transport mode for a more precise problem-solving solution not only for maintaining the current user but also for advertisement for mode shift from private transport users.
3. The factor of meteorological conditions could be included in further study within convenience because of the hot and humid weather in Bangkok with the average temperature around 30$^{o}$c.

4. The combination of changing more than one key important independent variable such as time and attitudinal components to develop the high-level analysis of change was more useful.
5. Due to the problem of postcodes in Thailand, precise location data, such as GIS or GPS technology collecting trip data by using tracking system could be included in the further studies.
6. In comparison with normal situations (without COVID-19 restrictions), travel behaviour might be different from this result.
7. The calculation of the MLR model could be made by using different software to allow the coefficient that had the statistically significant purely to play the influence on the mode preference.
8. Short term policies applied in small scale for example within the university could be introduced and monitored. Such policies could include increasing the cost of travelling by car such as levying a parking charge, charging an air-pollution tax (driving car passed in closed area) and improvements in the shuttle bus services through ticketing incentives. Methods of co-creation of policies could be researched, along with before and after surveys of attitudes, changes in travel behaviour, monitoring traffic flows, car park occupancies, passenger numbers following the introduction of real-world interventions. Much can be learned from small scale demonstrators over short periods of a year engaging high numbers of staff and students in the surveys. studies of intervention measures.

All in all, it can be concluded that the important outcome of this research has been to demonstrate that the interplay between environment, accessibility, convenience, and safety must be considered together to inform policy and support decision-making.

# References

Acker, V.V., Mokhtarian, P.L. and Witlox, F. (2014) 'Car availability explained by the structural relationships between lifestyles, residential location, and underlying residential and travel attitudes', *Transport Policy*, 35, pp. 88-99.

Agustaniah, R. and Wicaksono, A. (2020) 'Logit Model for Transportation Mode Choice in Berau Regency East Kalimantan', *Journal of physics. Conference series*, 1569(4).

Akgün-Tanbay, N., Campisi, T., Tanbay, T., Tesoriere, G. and Dissanayake, D. (2022) 'Modelling Road User Perceptions towards Safety, Comfort, and Chaos at Shared Space: The via Maqueda Case Study, Italy', *Journal of advanced transportation*, 2022, pp. 1-13.

Ali, F., Dissanayake, D., Bell, M. and Farrow, M. (2018) 'Investigating car users' attitudes to climate change using multiple correspondence analysis ,' *Journal of transport geography*, 72, pp. 237-247.

Anable, J. (2005) '‘Complacent Car Addicts’ or ‘Aspiring Environmentalists’? Identifying travel behaviour segments using attitude theory', *Transport policy*, 12(1), pp. 65--78.

Ashalatha, R., Manju, V.S. and Zacharia, A.B. (2013) 'Mode Choice Behavior of Commuters in Thiruvananthapuram City ,' *Journal of transportation engineering*, 139(5), pp. 494-502.

Atasoy, B., Glerum, A. and Bierlaire, M. (2013) 'Attitudes towards mode choice in Switzerland', *Disp*, 49(2), pp. 101-117.

Australasian Transport Research, F. (2006) 'Transport, making the most of it : 29th Australasian Transport Research Forum, Gold Coast Queensland, 27-29 September 2006'. //. [Gold Coast, Qld.?]: [The Forum?].

Barbieri, D.M., Lou, B., Passavanti, M., Hui, C., Hoff, I., Lessa, D.A., Sikka, G., Chang, K., Gupta, A., Fang, K., Banerjee, A., Maharaj, B., Lam, L., Ghasemi, N., Naik, B., Wang, F., Mirhosseini, A.F., Naseri, S., Liu, Z., Qiao, Y., Tucker, A., Wijayaratna, K., Peprah, P., Adomako, S., Yu, L., Goswami, S., Chen, H., Shu, B., Hessami, A., Abbas, M., Agarwal, N. and Rashidi, T.H. (2021) 'Impact of COVID-19 pandemic on mobility in ten countries and associated perceived risk for all transport modes', *PloS one*, 16(2), pp. e0245886--e0245886.

Bastea, T. (2023) 'Traffic Congestion Ranking - Annual Report 2023'. TrafficIndex. Available at: https://trafficindex.org/reports/annual-report-2023/.

Ben-Akiva, M.E. and R. Lerman, S. (1985) *Discrete choice analysis : theory and application to travel demand*. Cambridge, Mass.: MIT Press.

Berg, J., Levin, L., Abramsson, M. and Hagberg, J.-E. (2015) '“I want complete freedom”: car use and everyday mobility among the newly retired', *European transport research review*, 7(4), pp. 1--10.

Bierlaire, M. (2024) *Estimating discrete choice models with BIOGEME 3.2.13*. Available at: https://biogeme.epfl.ch/ (Accessed: Jan).

BMA (2019) *Bangkok population dataset 2018-2019 by age* Available at: https://opend-playground.gdcatalog.go.th/data.bangkok.go.th/ckan/207ef100-499e-4042-8ba1-fda2dc677a49 (Accessed: 1 Mar 2022).

BMTA (2023). Available at: http://www.bmta.co.th/th/services.

Bösehans, G., Bell, M., Thorpe, N., Liao, F., Homem de Almeida Correia, G. and Dissanayake, D. (2021) 'eHUBs—Identifying the potential early and late adopters of shared electric mobility hubs', *International journal of sustainable transportation*, pp. 1-20.

Bösehans, G. and Walker, I. (2016) '‘Daily Drags’ and ‘Wannabe Walkers’ – Identifying dissatisfied public transport users who might travel more actively and sustainably', *Journal of transport & health*, 3(3), pp. 395--403.

Bösehans, G. and Walker, I. (2020) 'Do supra-modal traveller types exist? A travel behaviour market segmentation using Goal framing theory', *Transportation (Dordrecht)*, 47(1), pp. 243--273.

Bouscasse, H., Joly, I. and Bonnel, P. (2018) 'How does environmental concern influence mode choice habits? A mediation analysis', *Transportation research. Part D, Transport and environment*, 59(en ligne), pp. 205-222.

Brown, J.D. (2009) *Principal components analysis and exploratory factor analysis Principal components analysis and exploratory factor analysis - Definitions Definitions , differences differences , and choices and choices*. Available at: https://hosted.jalt.org/test/bro_29.htm.

BTS (2020). Available at: https://www.bts.co.th/eng/info/info-history.html.

Burke, M., Dissanayake, D. and Bell, M. (2022) 'Cluster Analysis of Daily Cycling Flow Profiles during COVID-19 Lockdown in the UK', *Journal of advanced transportation*, 2022, pp. 1--16.

Chavanaves, S., Fantke, P., Limpaseni, W., Attavanich, W., Panyametheekul, S., Gheewala, S.H. and Prapaspongsa, T. (2021) 'Health impacts and costs of fine particulate matter formation from road transport in Bangkok Metropolitan Region', *Atmospheric pollution research*, 12(10), p. 101191.

Chonnipa, P., Kazushi, S. and Kiichiro, H. (2022) 'Effect of COVID-19 on Attitude and Travel Mode Based on Walking Distance—The Moderated Mediation Model', *Future Transportation*, 2(20), pp. 365--381.

COP26 (2021) *COP26 The Glasgow CLIMATE PACT*. Available at: https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf.

Crawford, F. (2020) 'Segmenting travellers based on day-to-day variability in work-related travel behaviour', *Journal of transport geography*, 86, pp. 102765--11.

de Oña, J., Estévez, E. and de Oña, R. (2021) 'Public transport users versus private vehicle users: Differences about quality of service, satisfaction and attitudes toward public transport in Madrid (Spain) ,' *Travel, behaviour & society*, 23, pp. 76-85.

De Vos, J., Mokhtarian, P.L., Schwanen, T., Van Acker, V. and Witlox, F. (2016) 'Travel mode choice and travel satisfaction: bridging the gap between decision utility and experienced utility', *Transportation (Dordrecht)*, 43(5), pp. 771--796.

De Vos, J., Schwanen, T., Van Acker, V. and Witlox, F. (2019) 'Do satisfying walking and cycling trips result in more future trips with active travel modes? An exploratory study', *International journal of sustainable transportation*, 13(3), pp. 180--196.

Department of Rail Transport (2024) *Number of rail passenger in Thailand 2023*. Available at: https://www.drt.go.th/public-relations/%e0%b8%9b%e0%b8%a3%e0%b8%b4%e0%b8%a1%e0%b8%b2%e0%b8%93%e0%b8%9c%e0%b8%b9%e0%b9%89%e0%b9%83%e0%b8%8a%e0%b9%89%e0%b8%9a%e0%b8%a3%e0%b8%b4%e0%b8%81%e0%b8%b2%e0%b8%a3%e0%b8%a3%e0%b8%96%e0%b9%84%e0%b8%9f.

Dissanayake, D., Kurauchi, S., Morikawa, T. and Ohashi, S. (2012) 'Inter-regional and inter-temporal analysis of travel behaviour for Asian metropolitan cities: Case studies of Bangkok, Kuala Lumpur, Manila, and Nagoya', *Transport policy*, 19(1), pp. 36-46.

Dissanayake, D. and Morikawa, T. (2002) 'Household travel behavior in developing countries: Nested logit model of vehicle ownership, mode choice, and trip chaining', *Transportation research record*, 1805(1805), pp. 45-52.

Engebretsen, Ø., Christiansen, P. and Strand, A. (2017) 'Bergen light rail – Effects on travel behaviour ,' *Journal of transport geography*, 62, pp. 111-121.

European Environment Agency (2015) *Passenger transport modal split*. Available at: https://www.eea.europa.eu/data-and-maps/daviz/passenger-transport-modal-split-2/#tab-chart_1.

Fraszczyk, A., Weerawat, W. and Kirawanich, P. (2019) 'Commuters' Willingness to Shift to Metro: a Case Study of Salaya, Thailand ,' *Urban rail transit.*, 5(4), pp. 240-253.

Gadepalli, R., Tiwari, G. and Bolia, N. (2020) 'Role of user's socio-economic and travel characteristics in mode choice between city bus and informal transit services: Lessons from household surveys in Visakhapatnam, India', *Journal of transport geography*, 88, p. 102307.

*GAUSS Application - Discrete Choice Analysis Tools* (2024). Available at: https://store.aptech.com/gauss-applications-category/discrete-choice.html (Accessed: March).

Handy, S., Cao, X. and Mokhtarian, P. (2005) 'Correlation or causality between the built environment and travel behavior? Evidence from Northern California', *Transportation research. Part D, Transport and environment*, 10(6), pp. 427--444.

Hess, S., Bierlaire, M. and Polak, J.W. (2005) 'Estimation of value of travel-time savings using mixed logit models', *Transportation research. Part A, Policy and practice*, 39(2), pp. 221--236.

IBM (2024) 'IBM SPSS Statistics 29 Core System User's Guide'.

IQ Air (2023). Available at: https://www.iqair.com/thailand.

Jan, P. and Stewart, B. (2011) 'Moving towards sustainability? Mobility styles, attitudes and individual travel behaviour', *Journal of Transport Geography*, 19(6), pp. 1590-1600.

Jassmi, A.A. and Ochieng, M. (2015) 'Quantifying The Benefits Of Peak Spreading As A Sustainable Solution To Addressing Traffic Congestion Within The Al Ain Private School Zone In Abu Dhabi, United Arab Emirates', *Urban Transport XXI*, 146, pp. 39-51.

Jinit, J.M.D.C., Anu, P.A. and Manju, V.S. (2022) 'Mode choice analysis of school trips using random forest technique', *Archives of Transport*, 62(2), pp. 39--48.

Joachim, S., Susanne, F., Verena, G., Oliver, H., Petter, N., Katja, S., Veronique and Annika, W. (2024) 'In search of causality in the relationship between the built environment and travel behaviour. On the challenges of planning and realising an ambitious mixed-methods panel travel survey among relocating households in Germany', *Progress in Planning*, 182, p. 100820.

Johanna Zmud, Martin Lee-Gosselin, Marcela Munizaga and Juan Antonio Carrasco (2013) *Transport survey methods best practice for decision making*. Bingley, U.K.: Emerald.

Jolliffe, I.T. (2002) *Principal Component Analysis*. 2nd 2002.. , edn.

Kamargianni, M., Dubey, S., Polydoropoulou, A. and Bhat, C. (2015) 'Investigating the subjective and objective factors influencing teenagers’ school travel mode choice – An integrated choice and latent variable model', *Transportation research. Part A, Policy and practice*, 78, pp. 473-488.

Korzhenevych, A. and Jain, M. (2018) 'Area- and gender-based commuting differentials in India’s largest urban-rural region', *Transportation research. Part D, Transport and environment*, 63, pp. 733-746.

Kumagai, J. and Managi, S. (2020) 'Environmental behaviour and choice of sustainable travel mode in urban areas: comparative evidence from commuters in Asian cities', *Production planning & control*, 31(11-12), pp. 920-931.

Majumdar, B.B., Dissanayake, D., Rajput, A.S., Saw, Y.Q. and Sahu, P.K. (2020) 'Prioritizing Metro Service Quality Attributes to Enhance Commuter Experience: TOPSIS Ranking and Importance Satisfaction Analysis Methods', *Transportation research record*, 2674(6), pp. 124--139.

Masiol, M., Agostinelli, C., Formenton, G., Tarabotti, E. and Pavoni, B. (2014) 'Thirteen years of air pollution hourly monitoring in a large city: Potential sources, trends, cycles and effects of car-free days', *The Science of the total environment*, 494-495, pp. 84--96.

Molin, E., Mokhtarian, P. and Kroesen, M. (2016) 'Multimodal travel groups and attitudes: A latent class cluster analysis of Dutch travelers,' *Transportation research. Part A, Policy and practice*, 83, pp. 14-29.

Morikawa, T., Yamamoto, T., Dissanayake, D., Sanko, N. and Kurauchi, S. 'Travel behavior analysis and its implication to urban transport planning for Asian cities: Case Studies of Bangkok, Kuala Lumpur, Manila, and Nagoya', *ICRA Project Report*.

Mullan, E. (2013) 'Exercise, Weather, Safety, and Public Attitudes: A Qualitative Exploration of Leisure Cyclists’ Views on Cycling for Transport', *SAGE open*, 3(3), pp. 1-9.

Narupiti, S. (2019) 'Exploring the possibility of MaaS service in Thailand, implications from the existing conditions and experts' opinions on “Who should be the MaaS provider in Bangkok?”', *IATSS research*, 43(4), pp. 226-234.

NASA (2022) *Carbon Dioxide*. Available at: https://climate.nasa.gov/vital-signs/carbon-dioxide/.

National Statistical Office (2023) 'The 2023 Household Survey on the Use of Information and Communication Technology (Quarter2)'.

Nutsugbodo, R.Y., Amenumey, E.K. and Mensah, C.A. (2018) 'Public transport mode preferences of international tourists in Ghana: Implications for transport planning', *Travel, behaviour & society*, 11, pp. 1--8.

Office of National Statistics (2021) *Over half of younger drivers likely to switch to electric in next decade*. Available at: https://www.ons.gov.uk/economy/environmentalaccounts/articles/overhalfofyoungerdriverslikelytoswitchtoelectricinnextdecade/2021-10-25 (Accessed: 2 Mar 2022).

Office of Transport and Traffic Policy and Planning (2018) *Travel Demand Freight Movement Survey for National Transport Planning*.

Ongkittikul, S. and O-Charoen, N. (2021) *Tackling BTS fares at root cause*. Available at: https://tdri.or.th/en/2021/04/tackling-bts-fares-at-root-cause/.

Ortúzar, J.d.D. and Willumsen, L.G. (2024) *Modelling transport*. Fifth . edn.

Ozawa, H., Fukuda, A., Malaitham, S., Vichiensan, V., Luathep, P. and Numa, H. (2021) 'Evaluation of walking environments around urban railway stations in Bangkok and consideration of improvement plans ,' *Asian transport studies*, 7, p. 100038.

Park, K., Sabouri, S., Lyons, T., Tian, G. and Ewing, R. (2020) 'Intrazonal or interzonal? Improving intrazonal travel forecast in a four-step travel demand model', *Transportation (Dordrecht)*, 47(5), pp. 2087--2108.

Polk, M. (2004) 'The influence of gender on daily car use and on willingness to reduce car use in Sweden', *Journal of transport geography*, 12(3), pp. 185-195.

Pongprasert, P. and Kubota, H. (2017) 'Factors Affecting Residents Living near Transit stations to Use Non-Motorized Access Mode: Case study about Daily Travel in Bangkok, Thailand', *Journal of the Eastern Asia Society for Transportation Studies*, 12, pp. 854--873.

Pongprasert, P. and Kubota, H. (2018) 'TOD residents' attitudes toward walking to transit station: a case study of transit-oriented developments (TODs) in Bangkok, Thailand', *Journal of modern transportation*, 27(1), pp. 39-51.

Prachachat News (2022). Available at: https://www.prachachat.net/general/news-1163789.

Prasertsubpakij, D. and Nitivattananon, V. (2012) 'Evaluating accessibility to Bangkok Metro Systems using multi-dimensional criteria across user groups', *IATSS Research*, 36(1), pp. 56-65.

Rissel, C., Crane, M., Standen, C., Wen, L.M., Ellison, R. and Greaves, S. (2018) 'Public support for bicycling and transport policies in inner Sydney, Australia: a cross-sectional survey', *Australian and New Zealand journal of public health*, 42(3), pp. 309-314.

Ryu, S. (2021) 'Mode choice change under environmental constraints in the combined modal split and traffic assignment model', *Sustainability (Basel, Switzerland)*, 13(7), p. 3780.

Sarkar, P.P. and Mallikarjuna, C. (2018) 'Effect of perception and attitudinal variables on mode choice behavior: A case study of Indian city, Agartala', *Travel, behaviour & society*, 12, pp. 108-114.

Saw, Y.Q., Dissanayake, D. and Ali, F. (2019) *World Conference on Transport Research - WCTR 2019*. Mumbai, 26-31 May 2019.

Schwandi, R. (2023) *BANGKOK*. Available at: https://www.urbanrail.net/as/bang/bangkok.htm (Accessed: 7 Mar 2024).

Sharma, H. (2022) 'How short or long should be a questionnaire for any research? Researchers dilemma in deciding the appropriate questionnaire length', *Saudi Journal of Anaesthesia*, 16(1).

Shen, J., Sakata, Y. and Hashimoto, Y. (2008) 'Is individual environmental consciousness one of the determinants in transport mode choice? ,' *Applied economics*, 40(10), pp. 1229-1239.

Shiau, T.-A. (2013) 'Evaluating sustainable transport strategies for the counties of Taiwan based on their degree of urbanization ,' *Transport policy*, 30, pp. 101-108.

Siangsuebchart, S., Ninsawat, S., Witayangkurn, A. and Pravinvongvuth, S. (2021) 'Public transport gps probe and rail gate data for assessing the pattern of human mobility in the bangkok metropolitan region, thailand ,' *Sustainability (Basel, Switzerland)*, 13(4), pp. 1-28.

Şimşekoğlu, Ö., Nordfjærn, T. and Rundmo, T. (2015) 'The role of attitudes, transport priorities, and car use habit for travel mode use and intentions to use public transportation in an urban Norwegian public', *Transport policy*, 42, pp. 113-120.

Statista (2022a) *Distribution of global carbon dioxide (CO2) emissions in 2020, by sector*. Available at: https://www.statista.com/statistics/1129656/global-share-of-co2-emissions-from-fossil-fuel-and-cement/.

Statista (2022b) *Transportation emissions worldwide*. Statista. Available at: https://www.statista.com/study/85839/global-transportation-emissions/.

Statista (2023) *Digital 2023: Thailand*. Available at: https://www.statista.com/statistics/1294961/thailand-share-of-reasons-to-use-the-internet/ (Accessed: 2 Sept 2023).

Statista (2024a) *Average exchange rate of British pound sterling (GBP) to Thai baht (THB) from 2014 to 2023*. Available at: https://www.statista.com/statistics/1535379/thailand-gbp-to-thb-exchange-rate/.

Statista (2024b) *Population of London from 1981 to 2023*. Available at: https://www.statista.com/statistics/910658/population-of-london/ (Accessed: July 2024).

Statistics Bureau of Japan (2021) *The Statistical Handbook of Japan 2021*.

Subeh, C., Kasey, Z. and Asif, K. (2016) 'The Effects of Access and Accessibility on Public Transport Users' Attitudes', *Journal of Public Transportation*, 19(1), pp. 97-113.

Thibenda, M., Wedagama, D.M.P. and Dissanayake, D. (2022) 'Drivers' attitudes to road safety in the South East Asian cities of Jakarta and Hanoi: Socio-economic and demographic characterisation by Multiple Correspondence Analysis', *Safety science*, 155.

Townsend, C. and Zacharias, J. (2009) 'Built environment and pedestrian behavior at rail rapid transit stations in Bangkok ,' *Transportation (Dordrecht)*, 37(2), pp. 317-330.

Tran, Y., Yamamoto, T. and Sato, H. (2020) 'The influences of environmentalism and attitude towards physical activity on mode choice: The new evidences', *Transportation research. Part A, Policy and practice*, 134, pp. 211-226.

Transport for London (2020) *Travel in London, report 13*.

Transport of London (2024) *Congestion Charge zone*. Available at: https://tfl.gov.uk/modes/driving/congestion-charge/congestion-charge-zone?intcmp=2055.

Tyndall, J. (2022) 'Cycling mode choice amongst US commuters: The role of climate and topography ,' *Urban studies (Edinburgh, Scotland)*, 59(1), pp. 97-119.

UK Regulations (2023) *The Environmental Targets (Fine Particulate Matter) (England) Regulations 2023*. Available at: https://www.legislation.gov.uk/uksi/2023/96/regulation/4/made.

Van, H.T., Choocharukul, K. and Fujii, S. (2014) 'The effect of attitudes toward cars and public transportation on behavioral intention in commuting mode choice-A comparison across six Asian countries', *Transportation research. Part A, Policy and practice*, 69, pp. 36-44.

Varabuntoonvit, V., Boonyarith, K., Pakornkarn, P., Pichetwanit, P. and Sittipong, W. (2023) 'Sustainable efficiency indicator for urban transportation: Case study of public bus and rapid transit systems in Bangkok', *Environmental progress & sustainable energy*, 42(4), p. n/a.

Vichiensan, V. and Nakamura, K. (2021) 'Walkability perception in asian cities: A comparative study in bangkok and nagoya ,' *Sustainability (Basel, Switzerland)*, 13(12), p. 6825.

Wang, Y., Wong, Y.D. and Goh, K. (2019) 'Perceived importance of inclusive street dimensions: a public questionnaire survey from a vision(ing) perspective', *Transportation (Dordrecht)*, 48(2), pp. 699-721.

Wang, Z., Chen, F. and Fujiyama, T. (2015) 'Carbon emission from urban passenger transportation in Beijing ,' *Transportation research. Part D, Transport and environment*, 41, pp. 217-227.

Webb, R. (2010) 'Public transport versus the private car: a study of attitudes towards transport modes in Plymouth', *The Plymouth Student Scientist*, 4(1), pp. 325-371.

Wedagama D, Bennett S and Dissanayake, D. (2020) 'Analyzing Pedestrian Perceptions towards Traffic Safety Using Discrete Choice Models', *International Journal on Advanced Science, Engineering and Information Technology 2020*, 10(6), pp. 2394-2401.

Wedagama, D.M.P. and Dissanayake, D. (2010) 'Analysing Motorcycle Injuries on Arterial Roads in Bali using a Multinomial Logit Model', *Journal of the Eastern Asia Society for Transportation Studies*, 8, pp. 1892-1904.

WHO (2021) *Ambient (outdoor) air pollution*. Available at: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health.

Wijaya, S.E. (2019) *Moving the Masses: Bus-Rapid Transit (BRT) Policies in Low Income Asian Cities Case Studies from Indonesia*.

Wilinski, K. and Pathak, S. (2022) 'Mobility in the Developing Country. The Case Study of Bangkok Metropolitan Region', *Komunikácie : vedecké listy Žilinskej univerzity = Communications : scientific letters of the University of Žilina*, 24(3), pp. A112--A122.

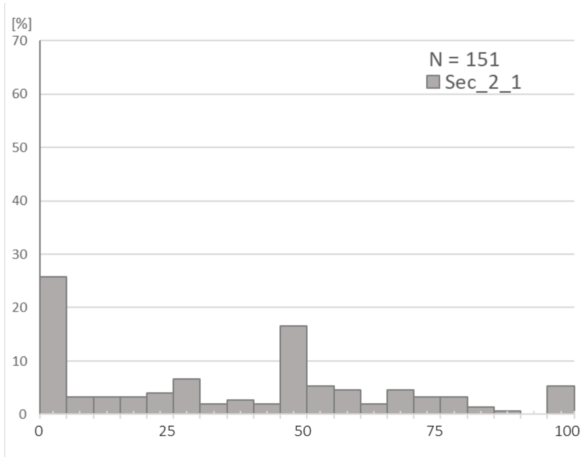
Witchayaphong, P., Pravinvongvuth, S., Kanitpong, K., Sano, K. and Horpibulsuk, S. (2020) 'Influential factors affecting travelers' mode choice behavior on mass transit in Bangkok, Thailand', *Sustainability (Basel, Switzerland)*, 12(22), pp. 1-18.

World Bank (2022) *Gross domestic product 2022*. Available at: https://databankfiles.worldbank.org/public/ddpext_download/GDP.pdf (Accessed: Jan 2022).

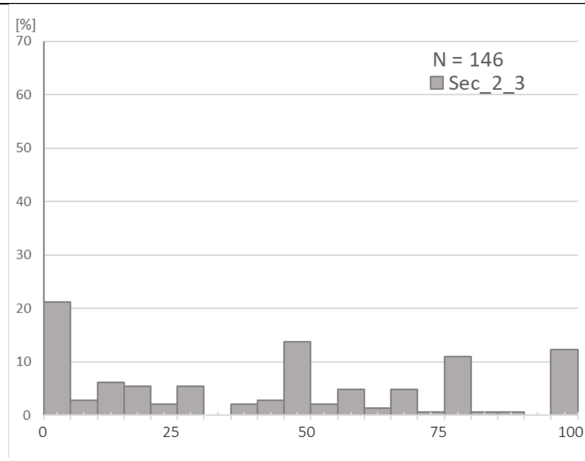
Xia, T., Zhang, Y., Braunack-Mayer, A. and Crabb, S. (2017) 'Public attitudes toward encouraging sustainable transportation: An Australian case study', *International journal of sustainable transportation*, 11(8), pp. 593-601.

# Appendix A.

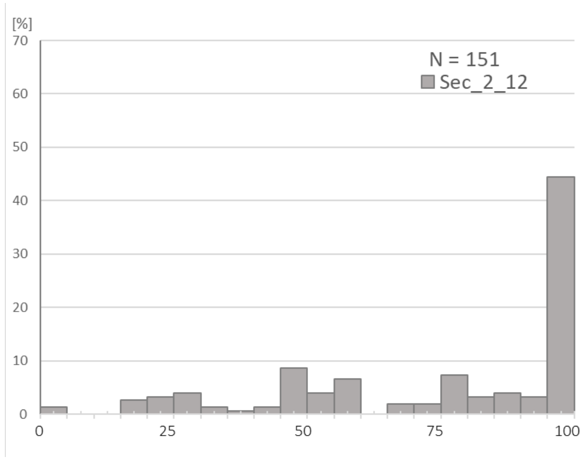
- Distribution plot of attitudinal statement answer from 1st Study questionnaire.
- Questionnaire for 2nd Study survey



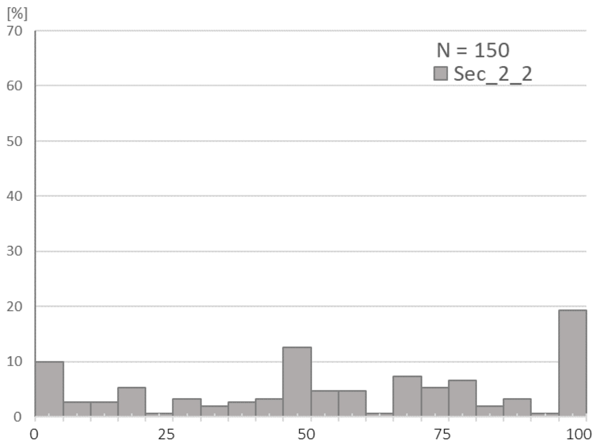

Sec_2_Q1 (N = 151)
“My current travel behaviour impacts the health of others.”



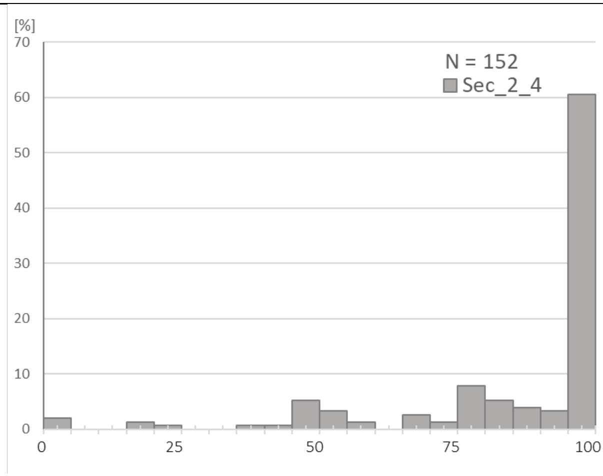

Sec_2_Q3 (N = 146 )
“My current travel behaviour impacts my health.”



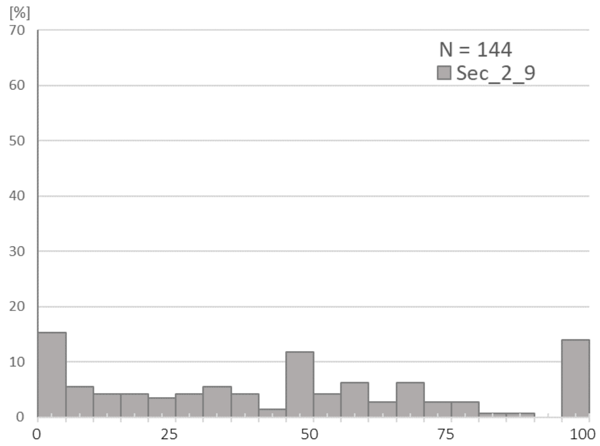

Sec_2_Q12 (N = 151 )
“I am willing to reduce the amount I travel to improve air quality and reduce the detrimental effect on the health of others.”




Sec_2_Q2 (N = 150)
“My current travel behaviour impacts climate change.”

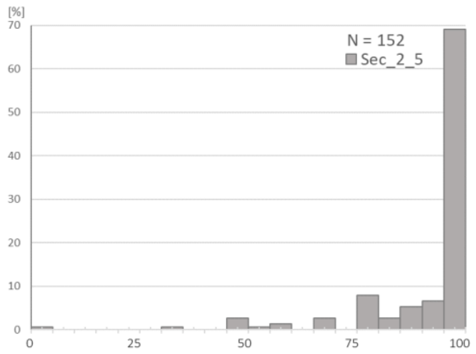



Sec_2_Q4 (N = 152)
“Given an opportunity, I would be willing to buy a car with lower carbon emission to reduce the impact on climate change.”

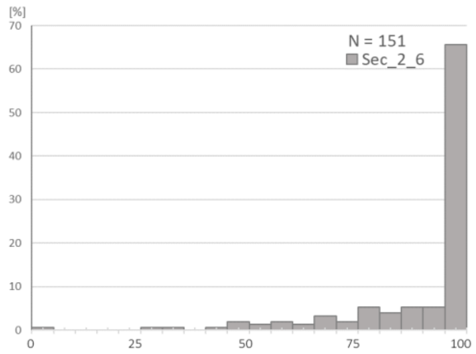



Sec_2_Q9 (N =144 )
“People should be allowed to use their cars as much as they like, despite their impact on environment.”

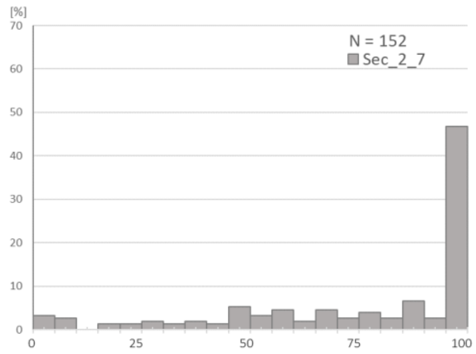
Figure A.1. Distribution Plot of result from questionnaire section 2 by health (top) and climate change theme (below)



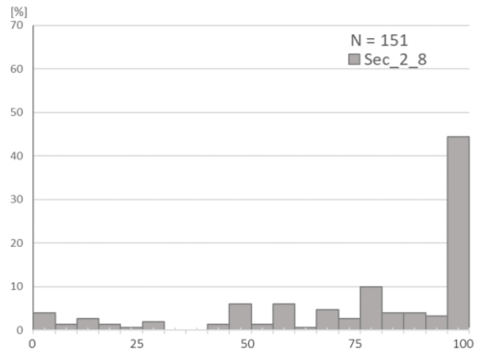

Sec_2_Q5 (N = 152 )
"I find traffic congestion a serious problem."



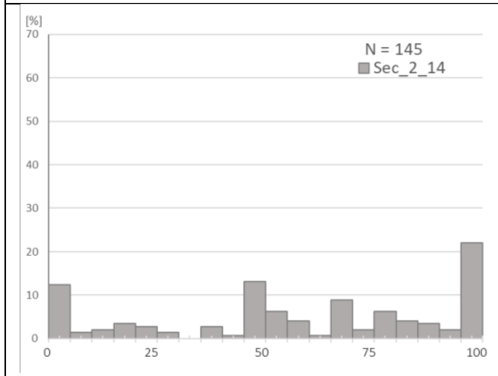

Sec_2_Q6 (N = 151)
"I find exhaust fumes from traffic in towns and cities a problem."



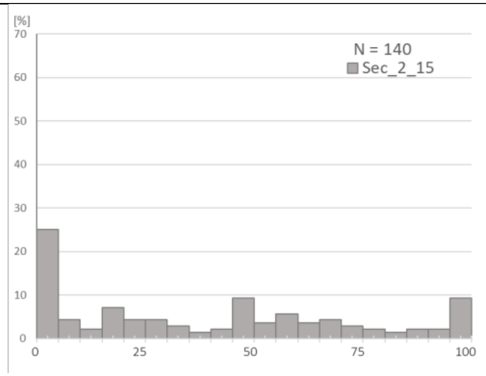

Sec_2_Q7 (N = 152 )
"I am willing to reduce the amount I travel to help reduce the impact of carbon on climate change."



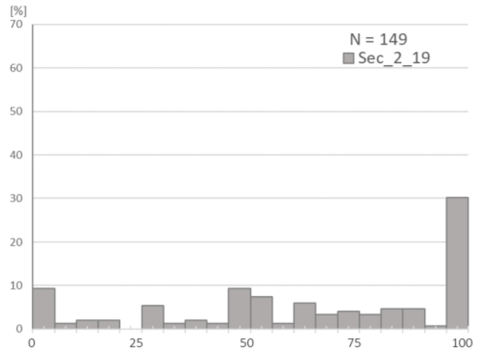

Sec_2_Q8 (N = 151 )
"I am willing to leave the house earlier or later to avoid congestion and reduce my journey time."



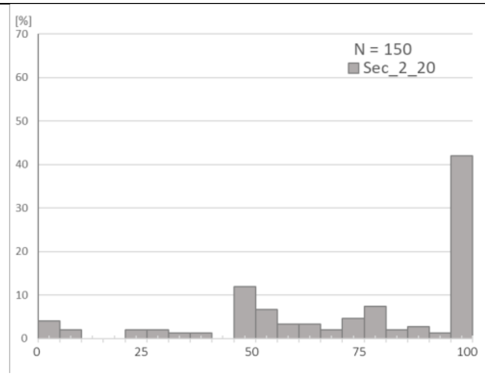

Sec_2_Q14 (N = 145 )
"I feel cut off from public transport services due to heavy trafficked roads with no safe crossing."




Sec_2_Q15 (N = 140 )
"I feel cut off from public transport because of subways, footbridges."

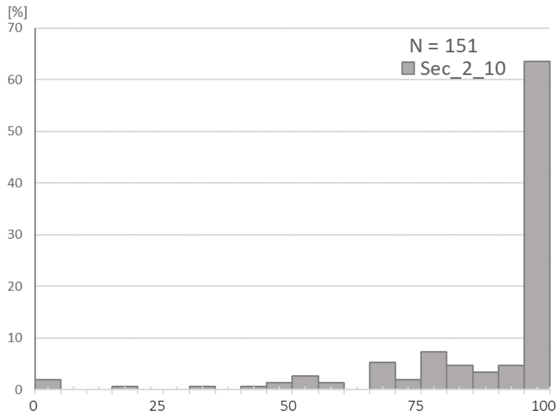



Sec_2_Q19 (N = 149 )
"I chose my current mode(s) because there is less risk of accident."

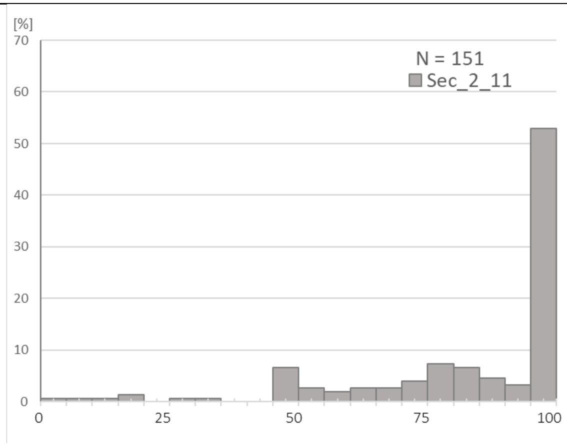



Sec_2_Q20 (N = 150 )
"I chose my current mode(s) because I personally feel safe."

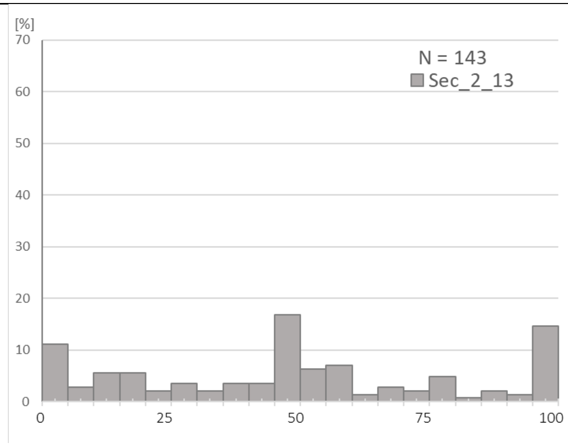
Figure A.1. Distribution Plot of result from questionnaire section 2 categorised by theme of questions (cont.) by traffic related (top) accessibility (left below) and safety theme (right below)



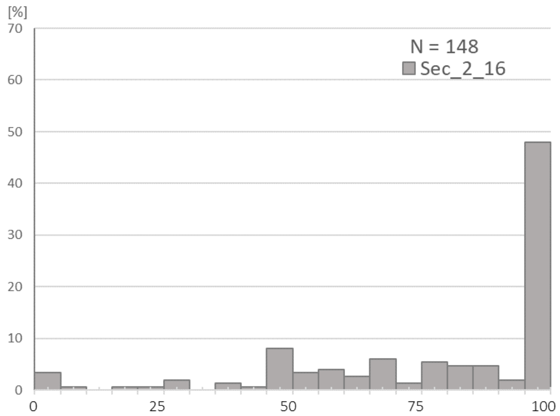

Sec_2_Q10 (N = 151 )
“Given an opportunity, I would be willing to buy a less polluting car to improve air quality”



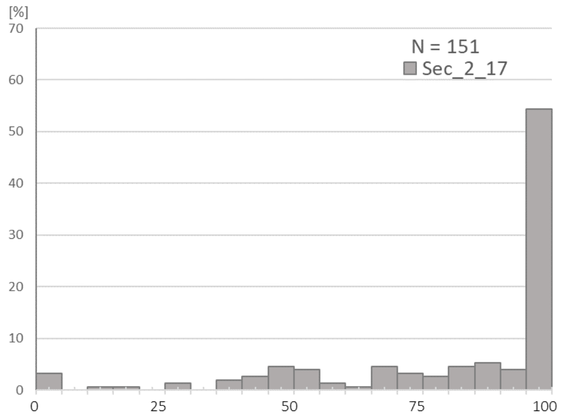

Sec_2_Q11 (N = 151 )
“Given the opportunity I would purchase an electric car to reduce the impact environment”



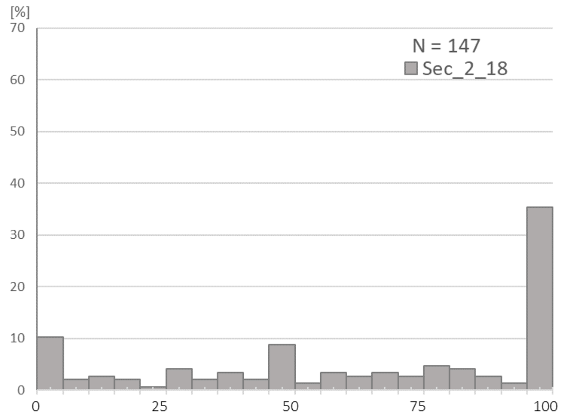

Sec_2_Q13 (N = 143)
“People should be allowed to use their cars as much as they like, despite their contribution to pollution and impact on health.”




Sec_2_Q16 (N =148 )
“I would use public transport if the ticket I purchase could be used on different services and modes.”




Sec_2_Q17 (N = 151 )
“I chose my current mode(s) because it is the quickest.”




Sec_2_Q18 (N = 147 )
“I chose my current mode(s) because there are no alternative ways to reach my workplace.”

Figure A.1. Distribution Plot of result from questionnaire section 2 categorised by theme of questions (cont.) by air pollution (top) and convenience theme (below)

**Questionnaire (English Version)**

Commuter Mode Choices in Bangkok Questionnaire

Questionnaire link: https://www.research.net/r/commute-choice?lang=en

ENGLISH

Newcastle University

**Commuter Mode Choices in Bangkok**

Introduction

**Thank you for taking the time to complete this questionnaire.**

This survey is being undertaken by a PhD student of the Future Mobility group at Newcastle University. The information you provide will be treated in strictest confidence and will be used for research purposes only.

The overall aim of this research is to study how passengers travel to work by all modes and how cost and time influence choices. In total, the survey should take about 15 minutes to complete. Once you have reached the end of the survey, you are welcome to take part in a prize draw for a chance of winning one of 5 x 200 baht Starbucks vouchers, and to sign up for future research related to this project (optional), by providing a valid email address.

If you have any concerns or queries while completing the survey, please email TravelChoice.BKK@newcastle.ac.uk

**What happens to the data I provide?**

All data is collected, processed and protected by online survey platform SurveyMonkey (surveymonkey.com). Your data will be stored on secure servers accessible only by authorised username and password. Any data you provide will be completely anonymised, stored and used for research and evaluation purposes only (e.g., in project reports or research papers) consistent with the General Data Protection Regulations and the Newcastle University data management policy. Your data will neither be used for marketing purposes nor given to any third parties.

We may, however, contact you if you have provided your email address/mobile phone if you have chosen to take part in future surveys. At any time, you have the right to request the survey administrators for copies of your personal data or to delete your personal data. If you make such a request, we have one month to respond to you.

## Commuter Mode Choices in Bangkok

### Consent

The questionnaire will ask for details about commuter trips, your opinions with regards travelling by more sustainable transport, and basic information about yourself.

* Statement of Consent (please tick the box of each statement below)

- ☐ I am over 18 years old
- ☐ I agree to take part in the study
- ☐ I understand that my participation is voluntary
- ☐ I understand, I am free to withdraw from study without giving any reason at any stage

ENGLISH

Newcastle University

## Commuter Mode Choices in Bangkok

### Commuter trip

In this section, we wish to learn more about your regular commuter trip from home to workplace including time and cost.

* Please specify each step of your most regular commuter trip from home to workplace including all walk, wait and transfer times. For all walk, wait, and transfer times, please put Cost = 0.

* If you are completing the questionnaire by phone or tablet please slide the screen to the left to view the cost column on the extreme right hand side.

a. Please identify the steps of your journey.

| | Travel Mode / waiting time / transfer time | Duration (in minutes) | Cost (in Baht) |
|---|---|---|---|
| Step 1 | | | |
| Step 2 | | | |
| Step 3 | | | |
| Step 4 | | | |
| Step 5 | | | |
| Step 6 | | | |
| Step 7 | | | |
| Step 8 | | | |

Please complete the following statement regarding your traveller identity:

I consider myself a...

- ◯ Public transport user
- ◯ Car user
- ◯ Motorcycle user
- ◯ Cyclist
- ◯ Walker
- ◯ Multi-modal user (not bound to any single mode of transport)

Prev Next

## Commuter Mode Choices in Bangkok

### Attitudes towards the Choice of main mode

This section of the survey focuses on attitudes of passengers to the environment, convenience, and safety.

Please use the provided slider scales to indicate your agreement with each statement. Please click or drag each slider until a score (0-100) appears in the box on the right hand side.

1. My current travel behaviour impacts the health of others.

Totally disagree — Totally agree

2. My current travel behaviour impacts my health.

Totally disagree — Totally agree

3. I am willing to reduce the amount I travel to improve air quality and reduce the detrimental effect on the health of others.

Totally disagree — Totally agree

4. My current travel behaviour impacts climate change.

Totally disagree — Totally agree

5. Given an opportunity, I would be willing to buy a car with lower carbon emission to reduce the impact on climate change.

Totally disagree — Totally agree

6. People should be allowed to use their cars or motorcycles as much as they like, despite their impact on climate change.

Totally disagree — Totally agree

7. I find traffic congestion a serious problem in my town.

Totally disagree — Totally agree

8. I find a problem of exhaust fumes from traffic in my town.

Totally disagree — Totally agree

9. I am willing to reduce the amount I travel to help reduce the impact of carbon on climate change.

Totally disagree — Totally agree

10. I am willing to leave the house earlier or later to avoid congestion and reduce my journey time.

Totally disagree — Totally agree

## Commuter Mode Choices in Bangkok

### Attitudes towards the Choice of main mode (continued)

This section of the survey focuses on attitudes of passengers to the environment, convenience, and safety.

Please use the provided slider scales to indicate your agreement with each statement. Please click or drag each slider until a score (0-100) appears in the box on the right hand side.

11. Given the opportunity, I would purchase an electric or hybrid car to reduce the impact on climate change.

Totally disagree — Totally agree

12. Given an opportunity, I would be willing to buy a less polluting car to improve air quality.

Totally disagree — Totally agree

13. People should be allowed to use their cars or motorcycles as much as they like, despite their contribution to pollution.

Totally disagree — Totally agree

14. I feel cut off from public transport services due to heavy trafficked roads with no safe crossing.

Totally disagree — Totally agree

15. I feel cut off from public transport because of subways, footbridges.

Totally disagree Totally agree

16. I would use public transport if the ticket I purchase could be used on different services and modes.

Totally disagree Totally agree

17. I chose my current mode(s) because it is the quickest.

Totally disagree Totally agree

18. I chose my current mode(s) because there are no alternative ways to reach my workplace.

Totally disagree Totally agree

19. I chose my current mode(s) because there is less risk of accident.

Totally disagree Totally agree

20. I chose my current mode(s) because I personally feel safe.

Totally disagree Totally agree

ENGLISH

Newcastle University

## Commuter Mode Choices in Bangkok

### Demographic part (for classification only)

This section helps us to learn more about you.

What is your gender?

- ◯ Male
- ◯ Female
- ◯ Prefer not to say

What is your age? (year old)

[ ]

What is the postcode of your residence?

| | |
|---|---|
| Postcode (e.g., 10XXX) | |
| Name of district | |
| Name of subdistrict | |

What is the postcode of your workplace?

| | |
|---|---|
| Postcode (e.g., 10XXX) | |
| Name of district | |
| Name of subdistrict | |

Including yourself, how many people live in your household?

| | Adults | Children |
|---|---|---|
| Number of | | |

What is the highest level of education that you have achieved?

Approximately, what is the monthly income of your household before tax? (Baht)

How many vehicles are currently in use in your household?

| | Number |
|---|---|
| Petrol cars | |
| Diesel cars | |
| Electric or hybrid cars | |
| Bikes | |
| Motorbikes | |

Other (please specify)

Do you have any physical disability that impacts your movement?

- ◯ Blind
- ◯ Other physical impairment
- ◯ None of the above
- ◯ Prefer not to say

**What happens to the data I provide?**

All data is collected, processed and protected by online survey platform SurveyMonkey (surveymonkey.com). Your data will be stored on protected secure servers accessible only by authorised username and password. Any data you provide will be completely anonymised, stored and used for research and evaluation purposes only (e.g., in project reports or research papers) consistent with the General Data Protection Regulations and the Newcastle University data management policy. Your data will neither be used for marketing purposes nor given to any third parties.

We may, however, contact you if you have provided your email address/mobile phone if you have chosen to take part in future surveys. At any time, you have the right to request the survey administrators for copies of your personal data or to delete your personal data. If you make such a request, we have one month to respond to you. If you would like to exercise any of these rights, please email TravelChoice.BKK@newcastle.ac.uk

Thank you very much for your participation. Please click the 'Submit' button below to save and submit your responses.

Prev Done

# Appendix B.

Table B.1 ANOVA result detail among group of age

| By age | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Com_1_Mean | Between Groups | 18645.776 | 5 | 3729.155 | 5.619 | **0.000** |
| | Within Groups | 426085.852 | 642 | 663.685 | | |
| | Total | 444731.628 | 647 | | | |
| Com_2_Mean | Between Groups | 242483.221 | 5 | 48496.644 | 95.232 | **0.000** |
| | Within Groups | 326938.235 | 642 | 509.250 | | |
| | Total | 569421.457 | 647 | | | |
| Com_3_Mean | Between Groups | 11306.134 | 5 | 2261.227 | 7.125 | **0.000** |
| | Within Groups | 203741.693 | 642 | 317.355 | | |
| | Total | 215047.827 | 647 | | | |
| Com_4_Mean | Between Groups | 1775.371 | 5 | 355.074 | 0.910 | 0.474 |
| | Within Groups | 250445.045 | 642 | 390.101 | | |
| | Total | 252220.416 | 647 | | | |

Note: Significant level = 0.05 presented in bold text

Table B.2 ANOVA result among identity group (private transport, public transport, active transport)

| By identity | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Com_1_Mean | Between Groups | 43843.938 | 2 | 21921.969 | 35.271 | **0.000** |
| | a | 400887.690 | 645 | 621.531 | | |
| | Total | 444731.628 | 647 | | | |
| Com_2_Mean | Between Groups | 13728.139 | 2 | 6864.070 | 7.967 | **0.000** |
| | Within Groups | 555693.317 | 645 | 861.540 | | |
| | Total | 569421.457 | 647 | | | |
| Com_3_Mean | Between Groups | 17887.999 | 2 | 8944.000 | 29.260 | **0.000** |
| | Within Groups | 197159.828 | 645 | 305.674 | | |
| | Total | 215047.827 | 647 | | | |
| Com_4_Mean | Between Groups | 6051.053 | 2 | 3025.527 | 7.927 | **0.000** |
| | Within Groups | 246169.363 | 645 | 381.658 | | |
| | Total | 252220.416 | 647 | | | |

Note: Significant level = 0.05 presented in bold text

Table B.3 Anti image testing

| | Q_1 | Q_2 | Q_3 | Q_4 | Q_5 | Q_6 | Q_7 | Q_8 | Q_9 | Q_10 | Q_11 | Q_12 | Q_13 | Q_14 | Q_15 | Q_16 | Q_17 | Q_18 | Q_19 | Q_20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Q_1 | .803[a] | -0.30 | -0.03 | -0.62 | 0.02 | -0.01 | -0.03 | 0.01 | -0.05 | 0.00 | -0.10 | 0.07 | -0.08 | 0.01 | -0.24 | 0.04 | 0.04 | 0.07 | -0.03 | 0.03 |
| Q_2 | -0.30 | .866[a] | -0.16 | -0.10 | 0.12 | -0.05 | -0.11 | 0.07 | 0.02 | 0.11 | 0.00 | -0.06 | 0.10 | 0.01 | -0.04 | -0.10 | 0.01 | -0.07 | -0.06 | 0.14 |
| Q_3 | -0.03 | -0.16 | .895[a] | -0.29 | -0.10 | -0.06 | -0.07 | 0.01 | -0.40 | -0.10 | 0.06 | 0.00 | 0.06 | 0.04 | 0.00 | 0.02 | 0.05 | -0.02 | 0.04 | -0.03 |
| Q_4 | -0.62 | -0.10 | -0.29 | .825[a] | -0.03 | 0.13 | -0.02 | -0.03 | 0.01 | -0.08 | 0.03 | 0.00 | -0.01 | -0.07 | 0.14 | 0.05 | -0.03 | -0.04 | 0.02 | -0.03 |
| Q_5 | 0.02 | 0.12 | -0.10 | -0.03 | .866[a] | -0.04 | -0.03 | -0.06 | 0.06 | -0.04 | -0.01 | -0.59 | 0.05 | -0.01 | -0.01 | -0.05 | 0.01 | 0.09 | -0.06 | 0.07 |
| Q_6 | -0.01 | -0.05 | -0.06 | 0.13 | -0.04 | .527[a] | -0.04 | 0.12 | -0.02 | -0.02 | 0.04 | 0.00 | -0.76 | -0.07 | -0.01 | -0.06 | -0.01 | 0.00 | -0.07 | 0.03 |
| Q_7 | -0.03 | -0.11 | -0.07 | -0.02 | -0.03 | -0.04 | .899[a] | -0.29 | -0.05 | -0.31 | -0.04 | 0.01 | -0.05 | -0.10 | 0.09 | 0.06 | 0.04 | -0.07 | 0.09 | -0.09 |
| Q_8 | 0.01 | 0.07 | 0.01 | -0.03 | -0.06 | 0.12 | -0.29 | .829[a] | -0.12 | 0.11 | -0.02 | 0.03 | 0.00 | -0.09 | 0.05 | -0.15 | -0.13 | -0.01 | -0.06 | 0.04 |
| Q_9 | -0.05 | 0.02 | -0.40 | 0.01 | 0.06 | -0.02 | -0.05 | -0.12 | .880[a] | -0.36 | 0.06 | -0.10 | 0.01 | 0.08 | 0.00 | -0.02 | 0.02 | -0.01 | -0.02 | -0.03 |
| Q_10 | 0.00 | 0.11 | -0.10 | -0.08 | -0.04 | -0.02 | -0.31 | 0.11 | -0.36 | .887[a] | 0.00 | -0.02 | -0.06 | -0.05 | -0.02 | 0.00 | -0.10 | 0.00 | 0.06 | 0.00 |
| Q_11 | -0.10 | 0.00 | 0.06 | 0.03 | -0.01 | 0.04 | -0.04 | -0.02 | 0.06 | 0.00 | .808[a] | -0.75 | -0.01 | 0.10 | -0.02 | -0.06 | -0.04 | 0.00 | -0.07 | 0.01 |
| Q_12 | 0.07 | -0.06 | 0.00 | 0.00 | -0.59 | 0.00 | 0.01 | 0.03 | -0.10 | -0.02 | -0.75 | .740[a] | -0.02 | -0.12 | 0.07 | -0.02 | 0.00 | -0.05 | 0.07 | -0.04 |
| Q_13 | -0.08 | 0.10 | 0.06 | -0.01 | 0.05 | -0.76 | -0.05 | 0.00 | 0.01 | -0.06 | -0.01 | -0.02 | .545[a] | -0.02 | 0.08 | 0.00 | -0.05 | -0.06 | 0.07 | -0.02 |
| Q_14 | 0.01 | 0.01 | 0.04 | -0.07 | -0.01 | -0.07 | -0.10 | -0.09 | 0.08 | -0.05 | 0.10 | -0.12 | -0.02 | .679[a] | -0.45 | 0.33 | -0.09 | 0.00 | 0.07 | -0.13 |
| Q_15 | -0.24 | -0.04 | 0.00 | 0.14 | -0.01 | -0.01 | 0.09 | 0.05 | 0.00 | -0.02 | -0.02 | 0.07 | 0.08 | -0.45 | .674[a] | -0.11 | 0.00 | -0.18 | -0.21 | 0.07 |
| Q_16 | 0.04 | -0.10 | 0.02 | 0.05 | -0.05 | -0.06 | 0.06 | -0.15 | -0.02 | 0.00 | -0.06 | -0.02 | 0.00 | 0.33 | -0.11 | .737[a] | 0.03 | -0.06 | 0.14 | -0.08 |
| Q_17 | 0.04 | 0.01 | 0.05 | -0.03 | 0.01 | -0.01 | 0.04 | -0.13 | 0.02 | -0.10 | -0.04 | 0.00 | -0.05 | -0.09 | 0.00 | 0.03 | .850[a] | -0.04 | 0.00 | -0.22 |
| Q_18 | 0.07 | -0.07 | -0.02 | -0.04 | 0.09 | 0.00 | -0.07 | -0.01 | -0.01 | 0.00 | 0.00 | -0.05 | -0.06 | 0.00 | -0.18 | -0.06 | -0.04 | .689[a] | -0.26 | 0.17 |
| Q_19 | -0.03 | -0.06 | 0.04 | 0.02 | -0.06 | -0.07 | 0.09 | -0.06 | -0.02 | 0.06 | -0.07 | 0.07 | 0.07 | 0.07 | -0.21 | 0.14 | 0.00 | -0.26 | .591[a] | -0.76 |
| Q_20 | 0.03 | 0.14 | -0.03 | -0.03 | 0.07 | 0.03 | -0.09 | 0.04 | -0.03 | 0.00 | 0.01 | -0.04 | -0.02 | -0.13 | 0.07 | -0.08 | -0.22 | 0.17 | -0.76 | .582[a] |

# Appendix C.

**Model Summary**

| | |
|---|---|
| **Algorithm** | TwoStep |
| **Inputs** | 4 |
| **Clusters** | 6 |


Figure C.1 Silhouette measure of 5-cluster

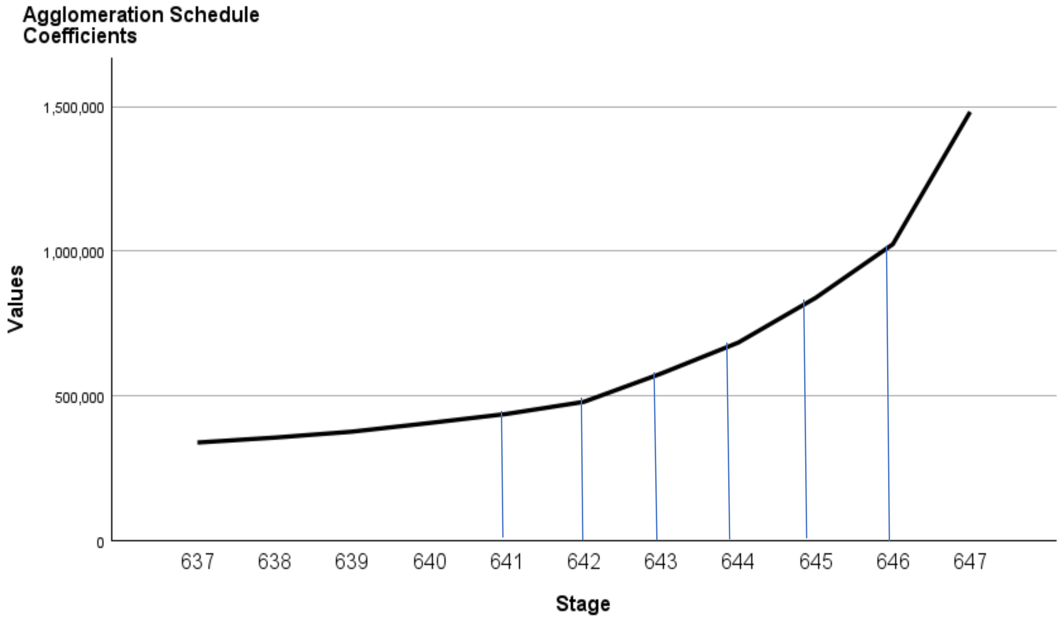



Figure C.2 Agglomeration Schedule coefficients plot

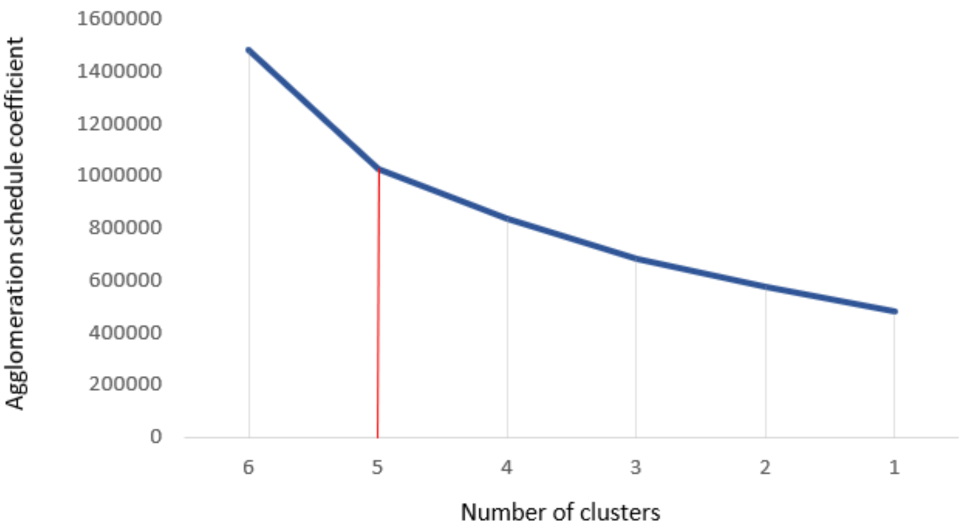



Figure C.3 Scree plot between number of clusters (range 1 – 6 cluster) and Agglomeration Schedule coefficients

# Appendix D.

Table D.1 Logistic regression model considering total journey time and cost (Baseline: MC)

| **Mode of transport** | **variables** | **β** | **Std. Error** | **Exp(β )** |
|---|---|---|---|---|
| AT | Total time | **0.11** | 0.03 | 1.12 |
| | Total cost | **-0.05** | 0.01 | 0.95 |
| Bus | Total time | **0.12** | 0.03 | 1.13 |
| | Total cost | **-0.03** | 0.01 | 0.97 |
| Train | Total time | **0.08** | 0.03 | 1.08 |
| | Total cost | 0.02 | 0.01 | 1.02 |
| Taxi | Total time | **0.08** | 0.03 | 1.08 |
| | Total cost | **0.03** | 0.01 | 1.03 |
| Car | Total time | **0.08** | 0.03 | 1.08 |
| | Total cost | **0.02** | 0.01 | 1.02 |
| Shuttle | Total time | **0.17** | 0.03 | 1.19 |
| | Total cost | **-0.34** | 0.10 | 0.71 |

Note: P<0.05 presented in bold. the references category is MC.

Table D.2 Logistic regression model considering total journey time and cost (Baseline: Taxi)

| **Mode of transport** | **variables** | **β** | **Std. Error** | **Exp(β )** |
|---|---|---|---|---|
| AT | Total time | **0.04** | 0.01 | 1.04 |
| | Total cost | **-0.08** | 0.01 | 0.92 |
| Bus | Total time | **0.04** | 0.01 | 1.04 |
| | Total cost | **-0.06** | 0.01 | 0.94 |
| Train | Total time | 0.00 | 0.01 | 1.00 |
| | Total cost | -0.01 | 0.00 | 0.99 |
| Car | Total time | 0.00 | 0.01 | 1.00 |
| | Total cost | 0.00 | 0.00 | 1.00 |
| MC | Total time | **-0.08** | 0.03 | 0.93 |
| | Total cost | **-0.03** | 0.01 | 0.97 |
| Shuttle | Total time | **0.10** | 0.02 | 1.10 |
| | Total cost | **-0.37** | 0.10 | 0.69 |

Note: P<0.05 presented in bold. the references category is Taxi.

Table D.3 Logistic regression model considering total time, cost, PCA components.

| Mode of transport | variables | β | Std. Error | Exp(β ) |
|---|---|---|---|---|
| AT | Total time | **0.04** | 0.01 | 1.04 |
| | Total cost | **-0.08** | 0.01 | 0.93 |
| | Pro-environment and others' health | **-1.48** | 0.19 | 0.23 |
| | Pro-environmentally friendly cars | **0.77** | 0.20 | 2.15 |
| | Pro-safe | **-0.96** | 0.23 | 0.38 |
| | Pro-private vehicle | **-0.75** | 0.20 | 0.47 |
| Bus | Total time | **0.04** | 0.01 | 1.04 |
| | Total cost | **-0.00** | 0.01 | 0.95 |
| | Pro-environment and others' health | **1.30** | 0.34 | 3.67 |
| | Pro-environmentally friendly cars | **0.42** | 0.20 | 1.52 |
| | Pro-safe | **-2.40** | 0.23 | 0.09 |
| | Pro-private vehicle | -0.19 | 0.18 | 0.83 |
| Train | Total time | 0.01 | 0.01 | 1.01 |
| | Total cost | 0.00 | 0.00 | 1.00 |
| | Pro-environment and others' health | **-1.27** | 0.16 | 0.28 |
| | Pro-environmentally friendly cars | **0.41** | 0.16 | 1.51 |
| | Pro-safe | **-1.41** | 0.20 | 0.24 |
| | Pro-private vehicle | **-0.53** | 0.16 | 0.59 |
| Taxi | Total time | -0.01 | 0.01 | 1.00 |
| | Total cost | 0.01 | 0.00 | 1.01 |
| | Pro-environment and others' health | **1.22** | 0.44 | 3.40 |
| | Pro-environmentally friendly cars | 0.26 | 0.27 | 1.30 |
| | Pro-safe | **-2.25** | 0.28 | 0.10 |
| | Pro-private vehicle | -0.19 | 0.24 | 0.83 |
| MC | Total time | **-0.09** | 0.03 | 0.92 |
| | Total cost | -0.02 | 0.01 | 0.98 |
| | Pro-environment and others' health | 0.26 | 0.34 | 1.30 |
| | Pro-environmentally friendly cars | **1.26** | 0.35 | 3.52 |
| | Pro-safe | **-1.44** | 0.25 | 0.24 |
| | Pro-private vehicle | 0.01 | 0.22 | 1.01 |
| Shuttle | Total time | **0.10** | 0.02 | 1.10 |
| | Total cost | **-0.34** | 0.10 | 0.71 |
| | Pro-environment and others' health | **1.26** | 0.58 | 3.51 |
| | Pro-environmentally friendly cars | -0.66 | 0.39 | 0.52 |
| | Pro-safe | **-1.50** | 0.53 | 0.22 |
| | Pro-private vehicle | **-1.64** | 0.59 | 0.19 |

Table D.4 Logistic regression model considering total time, cost, PCA components, and gender (reference Female) by transport mode.

| **Mode of transport** | **variables** | **β** | **Std. Error** | **Exp(β )** |
|---|---|---|---|---|
| AT | Total time | **0.04** | 0.01 | 1.04 |
| | Total cost | **-0.07** | 0.01 | 0.93 |
| | Pro-environment and others' health | **-1.47** | 0.19 | 0.23 |
| | Pro-environmentally friendly cars | **0.77** | 0.20 | 2.15 |
| | Pro-safe | **-0.96** | 0.23 | 0.38 |
| | Pro-private vehicle | **-0.76** | 0.20 | 0.47 |
| | Male | 0.02 | 0.34 | 1.02 |
| Bus | Total time | **0.04** | 0.01 | 1.04 |
| | Total cost | -0.05 | 0.01 | 0.95 |
| | Pro-environment and others' health | **1.30** | 0.34 | 3.67 |
| | Pro-environmentally friendly cars | **0.43** | 0.21 | 1.54 |
| | Pro-safe | -**2.40** | 0.23 | 0.09 |
| | Pro-private vehicle | -0.19 | 0.18 | 0.83 |
| | Male | -0.02 | 0.33 | 0.98 |
| Train | Total time | 0.01 | 0.01 | 1.01 |
| | Total cost | 0.00 | 0.00 | 1.00 |
| | Pro-environment and others' health | **-1.27** | 0.16 | 0.28 |
| | Pro-environmentally friendly cars | **0.42** | 0.16 | 1.52 |
| | Pro-safe | -1.42 | 0.2 | 0.24 |
| | Pro-private vehicle | -0.53 | 0.16 | 0.59 |
| | Male | -0.18 | 0.28 | 0.84 |
| Taxi | Total time | 0.00 | 0.01 | 1.00 |
| | Total cost | 0.01 | 0.00 | 1.01 |
| | Pro-environment and others' health | **1.23** | 0.45 | 3.44 |
| | Pro-environmentally friendly cars | 0.25 | 0.27 | 1.29 |
| | Pro-safe | -**2.26** | 0.28 | 0.10 |
| | Pro-private vehicle | -0.19 | 0.24 | 0.83 |
| | Male | 0.16 | 0.44 | 1.17 |

(cont.)

Table D.4 Logistic regression model considering total time, cost, PCA components, and gender by transport mode (cont.).

| **Mode of transport** | **variables** | **β** | **Std. Error** | **Exp(β )** |
|---|---|---|---|---|
| MC | Total time | **-0.09** | 0.03 | 0.92 |
| | Total cost | -0.02 | 0.01 | 0.98 |
| | Pro-environment and others' health | 0.25 | 0.35 | 1.28 |
| | Pro-environmentally friendly cars | **1.28** | 0.36 | 3.61 |
| | Pro-safe | **-1.44** | 0.26 | 0.24 |
| | Pro-private vehicle | -0.01 | 0.23 | 0.99 |
| | Male | 0.28 | 0.45 | 1.32 |
| Shuttle | Total time | **0.10** | 0.02 | 1.11 |
| | Total cost | **-0.36** | 0.11 | 0.70 |
| | Pro-environment and others' health | **1.41** | 0.63 | 4.08 |
| | Pro-environmentally friendly cars | -0.68 | 0.41 | 0.51 |
| | Pro-safe | **-1.47** | 0.56 | 0.23 |
| | Pro-private vehicle | **-1.68** | 0.58 | 0.19 |
| | Male | 1.38 | 0.71 | 3.99 |

Note: P<0.05 presented in bold. the references category is Car.

Table D.5 Logistic regression model considering total time, cost, PCA components, age, car ownership, distance, single mode journey by transport mode.

| **Mode of transport** | **variables** | **β** | **Std. Error** | **Exp (β)** |
|---|---|---|---|---|
| AT | Total time | **0.04** | 0.01 | 1.04 |
| | Total cost | **-0.06** | 0.01 | 0.94 |
| | Pro-environment and others' health | **-1.40** | 0.22 | 0.25 |
| | Pro-safe | -0.46 | 0.25 | 0.63 |
| | Pro-private vehicle | -0.77 | 0.24 | 0.46 |
| | 31 to 50yrs old | -0.50 | 0.57 | 0.61 |
| | over 50yrs old | **-1.44** | 0.63 | 0.24 |
| | Have Cars | **-3.84** | 0.69 | 0.02 |
| | Single mode | **-2.31** | 0.53 | 0.1 |
| | In Zone | **1.96** | 0.45 | 7.08 |
| Bus | Total time | **0.04** | 0.01 | 1.04 |
| | Total cost | **-0.06** | 0.01 | 0.95 |
| | Pro-environment and others' health | **1.32** | 0.36 | 3.75 |
| | Pro-safe | **-2.05** | 0.23 | 0.13 |
| | Pro-private vehicle | -0.23 | 0.21 | 0.8 |
| | 31 to 50yrs old | -1.01 | 0.52 | 0.36 |
| | over 50yrs old | -0.62 | 0.54 | 0.54 |
| | Have Cars | **-3.33** | 0.67 | 0.04 |
| | Single mode | **-3.41** | 0.48 | 0.03 |
| | In Zone | -0.48 | 0.51 | 0.62 |
| Train | Total time | 0.00 | 0.01 | 1.00 |
| | Total cost | -0.01 | 0.01 | 0.99 |
| | Pro-environment and others' health | **-1.31** | 0.21 | 0.27 |
| | Pro-safe | **-0.97** | 0.22 | 0.38 |
| | Pro-private vehicle | **-0.57** | 0.22 | 0.56 |
| | 31 to 50yrs old | **-1.46** | 0.54 | 0.23 |
| | over 50yrs old | -0.46 | 0.53 | 0.63 |
| | Have Cars | **-2.64** | 0.69 | 0.07 |
| | Single mode | **-3.97** | 0.45 | 0.02 |
| | In Zone | **-0.65** | 0.53 | 0.52 |

(cont.)

Table D.5 Logistic regression model considering total time, cost, PCA components, age, car ownership, distance, single mode journey by transport mode. (cont.).

| **Mode of transport** | **variables** | **β** | **Std. Error** | **Exp(β )** |
|---|---|---|---|---|
| Taxi | Total time | 0.00 | 0.01 | 1.00 |
| | Total cost | 0.01 | 0.00 | 1.01 |
| | Pro-environment and others' health | **1.18** | 0.48 | 3.25 |
| | Pro-safe | **-1.91** | 0.28 | 0.15 |
| | Pro-private vehicle | -0.3.0 | 0.28 | 0.74 |
| | 31 to 50yrs old | -1.32 | 0.67 | 0.27 |
| | over 50yrs old | -0.42 | 0.65 | 0.66 |
| | Have Cars | **-3.24** | 0.73 | 0.04 |
| | Single mode | **-2.14** | 0.58 | 0.12 |
| | In Zone | **1.85** | 0.53 | 6.34 |
| MC | Total time | **-0.07** | 0.03 | 0.93 |
| | Total cost | -0.02 | 0.01 | 0.98 |
| | Pro-environment and others' health | 0.31 | 0.37 | 1.36 |
| | Pro-safe | **-1.10** | 0.26 | 0.33 |
| | Pro-private vehicle | -0.04 | 0.24 | 0.96 |
| | 31 to 50yrs old | -0.81 | 0.55 | 0.45 |
| | over 50yrs old | **-2.94** | 0.87 | 0.05 |
| | Have Cars | **-3.51** | 0.7 | 0.03 |
| | Single mode | -1.05 | 0.77 | 0.35 |
| | In Zone | 0.25 | 0.54 | 1.28 |
| Shuttle | Total time | 0.11 | 0.02 | 1.11 |
| | Total cost | **-0.36** | 0.11 | 0.70 |
| | Pro-environment and others' health | 1.07 | 0.63 | 2.91 |
| | Pro-safe | **-1.67** | 0.67 | 0.19 |
| | Pro-private vehicle | **-2.36** | 0.72 | 0.09 |
| | 31 to 50yrs old | 1.20 | 1.32 | 3.33 |
| | over 50yrs old | 1.52 | 1.29 | 4.56 |
| | Have Cars | **-4.30** | 1.66 | 0.01 |
| | Single mode | **-1.16** | 1.32 | 0.31 |
| | In Zone | **-3.43** | 1.51 | 0.03 |

| Model Fitting Information | | | | |
|---|---|---|---|---|
| Model | -2 LL | Chi-Square | Df | Sig. |
| Final | 920.738 | 1182.122 | 60 | <.001 |

Note: P<0.05 presented in bold. the references category is Car.

Table D.6 Comparison of probability of mode preference in case of changing travel cost

| Characteristic: age under 30yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.6 | 2.0 | -0.5 | -1.0 | 1.5 | 0.2 | 0.0 |
| | Prob [%] | 24.7 | 37.1 | 2.9 | 1.8 | 22.2 | 6.3 | 5.0 |
| Decrease | Logit | 1.7 | 2.1 | -0.5 | -1.0 | 1.5 | 0.5 | 0.0 |
| | Prob [%] | 24.6 | 36.9 | 2.8 | 1.7 | 21.3 | 7.9 | 4.7 |
| | %Change by mode | -0.1 | -0.2 | -0.1 | -0.1 | -0.8 | 1.7 | -0.3 |
| Increase | Logit | 1.6 | 2.0 | -0.5 | -1.0 | 1.5 | -0.1 | 0.0 |
| | Prob [%] | 24.8 | 37.1 | 3.1 | 1.9 | 22.9 | 4.9 | 5.2 |
| | %Change by mode | 0.0 | 0.1 | 0.1 | 0.1 | 0.8 | -1.3 | 0.3 |
| Characteristic: age under 30yrs old, have cars, single mode, external zone | | | | | | | | |
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.2 | -1.3 | -3.2 | -4.2 | -2.0 | -4.1 | 0.0 |
| | Prob [%] | 6.8 | 16.9 | 2.7 | 0.9 | 8.4 | 1.1 | 63.2 |
| Decrease | Logit | -2.2 | -1.3 | -3.2 | -4.2 | -2.0 | -3.8 | 0.0 |
| | Prob [%] | 7.0 | 17.4 | 2.6 | 0.9 | 8.4 | 1.4 | 62.2 |
| | %Change by mode | 0.2 | 0.5 | 0.0 | 0.0 | 0.0 | 0.3 | -1.0 |
| Increase | Logit | -2.3 | -1.4 | -3.2 | -4.2 | -2.0 | -4.4 | 0.0 |
| | Prob [%] | 6.5 | 16.4 | 2.7 | 0.9 | 8.4 | 0.8 | 64.2 |
| | %Change by mode | -0.2 | -0.5 | 0.0 | 0.0 | 0.0 | -0.3 | 1.0 |
| Characteristic: age under 30yrs old, no cars, single mode, internal zone | | | | | | | | |
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.6 | 1.5 | -1.2 | 0.9 | 1.7 | -3.2 | 0.0 |
| | Prob [%] | 71.6 | 9.4 | 0.6 | 4.8 | 11.6 | 0.1 | 2.0 |
| Decrease | Logit | 3.6 | 1.6 | -1.2 | 0.8 | 1.8 | -2.9 | 0.0 |
| | Prob [%] | 72.1 | 9.4 | 0.6 | 4.5 | 11.3 | 0.1 | 1.9 |
| | %Change by mode | 0.5 | 0.1 | 0.0 | -0.2 | -0.3 | 0.0 | -0.1 |
| Increase | Logit | 3.5 | 1.5 | -1.2 | 0.9 | 1.7 | -3.5 | 0.0 |
| | Prob [%] | 71.0 | 9.3 | 0.6 | 5.0 | 11.9 | 0.1 | 2.1 |
| | %Change by mode | -0.5 | -0.1 | 0.0 | 0.2 | 0.3 | 0.0 | 0.1 |
| Characteristic: age under 30yrs old, have cars, single mode, internal zone | | | | | | | | |
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.3 | -1.8 | -3.8 | -2.4 | -1.8 | -7.5 | 0.0 |
| | Prob [%] | 34.4 | 7.5 | 1.0 | 4.2 | 7.7 | 0.0 | 45.2 |
| Decrease | Logit | -0.2 | -1.8 | -3.8 | -2.4 | -1.7 | -7.2 | 0.0 |
| | Prob [%] | 35.3 | 7.7 | 1.0 | 4.0 | 7.7 | 0.0 | 44.3 |
| | %Change by mode | 0.9 | 0.2 | 0.0 | -0.1 | 0.0 | 0.0 | -1.0 |
| Increase | Logit | -0.3 | -1.8 | -3.8 | -2.4 | -1.8 | -7.8 | 0.0 |
| | Prob [%] | 33.4 | 7.3 | 1.0 | 4.3 | 7.8 | 0.0 | 46.2 |
| | %Change by mode | -0.9 | -0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 1.0 |

Table D.7 Comparison of probability of mode preference in case of changing travel cost

| Characteristic: age between 31 and 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.1 | 1.0 | -2.0 | -2.3 | 0.7 | 1.4 | 0.0 |
| | Prob [%] | 23.0 | 20.7 | 1.0 | 0.8 | 15.1 | 31.8 | 7.6 |
| Decrease | Logit | 1.2 | 1.0 | -2.0 | -2.3 | 0.7 | 1.7 | 0.0 |
| | Prob [%] | 21.3 | 19.2 | 0.9 | 0.7 | 13.6 | 37.5 | 6.7 |
| | %Change by mode | -1.6 | -1.5 | -0.1 | -0.1 | -1.5 | 5.7 | -0.9 |
| Increase | Logit | 1.1 | 1.0 | -2.0 | -2.3 | 0.7 | 1.1 | 0.0 |
| | Prob [%] | 24.4 | 22.0 | 1.2 | 0.8 | 16.6 | 26.6 | 8.5 |
| | %Change by mode | 1.4 | 1.3 | 0.1 | 0.1 | 1.5 | -5.2 | 0.9 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, external zone | | | | | | | | |
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.7 | -2.3 | -4.6 | -5.6 | -2.8 | -2.9 | 0.0 |
| | Prob [%] | 5.0 | 7.5 | 0.8 | 0.3 | 4.6 | 4.4 | 77.4 |
| Decrease | Logit | -2.7 | -2.3 | -4.6 | -5.6 | -2.8 | -2.6 | 0.0 |
| | Prob [%] | 5.2 | 7.7 | 0.7 | 0.3 | 4.6 | 5.7 | 75.8 |
| | %Change by mode | 0.1 | 0.2 | 0.0 | 0.0 | 0.0 | 1.3 | -1.6 |
| Increase | Logit | -2.8 | -2.4 | -4.6 | -5.5 | -2.8 | -3.2 | 0.0 |
| | Prob [%] | 4.9 | 7.3 | 0.8 | 0.3 | 4.6 | 3.3 | 78.8 |
| | %Change by mode | -0.1 | -0.2 | 0.0 | 0.0 | 0.0 | -1.0 | 1.4 |
| Characteristic: between 31 and 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.1 | 0.5 | -2.6 | -0.5 | 0.9 | -2.0 | 0.0 |
| | Prob [%] | 77.9 | 6.1 | 0.3 | 2.3 | 9.3 | 0.5 | 3.6 |
| Decrease | Logit | 3.1 | 0.6 | -2.6 | -0.5 | 1.0 | -1.7 | 0.0 |
| | Prob [%] | 78.3 | 6.1 | 0.3 | 2.2 | 9.0 | 0.6 | 3.5 |
| | %Change by mode | 0.4 | 0.0 | 0.0 | -0.1 | -0.2 | 0.1 | -0.2 |
| Increase | Logit | 3.0 | 0.5 | -2.6 | -0.5 | 0.9 | -2.3 | 0.0 |
| | Prob [%] | 77.5 | 6.1 | 0.3 | 2.4 | 9.5 | 0.4 | 3.8 |
| | %Change by mode | -0.4 | 0.0 | 0.0 | 0.1 | 0.3 | -0.1 | 0.2 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| cost | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.8 | -2.8 | -5.3 | -3.7 | -2.6 | -6.3 | 0.0 |
| | Prob [%] | 28.3 | 3.7 | 0.3 | 1.5 | 4.7 | 0.1 | 61.4 |
| Decrease | Logit | -0.7 | -2.8 | -5.3 | -3.7 | -2.6 | -6.0 | 0.0 |
| | Prob [%] | 29.2 | 3.8 | 0.3 | 1.5 | 4.7 | 0.1 | 60.4 |
| | %Change by mode | 0.9 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -1.0 |
| Increase | Logit | -0.8 | -2.9 | -5.3 | -3.7 | -2.6 | -6.6 | 0.0 |
| | Prob [%] | 27.4 | 3.6 | 0.3 | 1.5 | 4.7 | 0.1 | 62.4 |
| | %Change by mode | -0.9 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |

Table D.8 Comparison of probability of mode preference with attitude component, pro safe (C3)

| Characteristic: age under 30yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.6 | 2.0 | -0.5 | -1.0 | 1.5 | 0.2 | 0.0 |
| | Prob [%] | 24.7 | 37.1 | 2.9 | 1.8 | 22.2 | 6.3 | 5.0 |
| 0 | Logit | 1.8 | 3.0 | 0.0 | 0.0 | 2.0 | 1.1 | 0.0 |
| | Prob [%] | 15.4 | 51.2 | 2.4 | 2.4 | 19.0 | 7.1 | 2.5 |
| | %Change by mode | -9.3 | 14.1 | -0.6 | 0.5 | -3.1 | 0.9 | -2.5 |
| 1 | Logit | 1.4 | 1.0 | -1.0 | -2.0 | 0.9 | -0.6 | 0.0 |
| | Prob [%] | 35.1 | 23.8 | 3.2 | 1.3 | 22.9 | 4.9 | 8.9 |
| | %Change by mode | 10.4 | -13.3 | 0.3 | -0.6 | 0.7 | -1.4 | 3.9 |
| Characteristic: age under 30yrs old, have cars, single mode, external zone | | | | | | | | |
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.2 | -1.3 | -3.2 | -4.2 | -2.0 | -4.1 | 0.0 |
| | Prob [%] | 6.8 | 16.9 | 2.7 | 0.9 | 8.4 | 1.1 | 63.2 |
| 0 | Logit | -2.0 | -0.3 | -2.7 | -3.3 | -1.5 | -3.2 | 0.0 |
| | Prob [%] | 6.0 | 33.0 | 3.0 | 1.7 | 10.2 | 1.7 | 44.3 |
| | %Change by mode | -0.8 | 16.1 | 0.4 | 0.8 | 1.8 | 0.7 | -18.9 |
| 1 | Logit | -2.5 | -2.3 | -3.7 | -5.2 | -2.6 | -4.9 | 0.0 |
| | Prob [%] | 6.6 | 7.4 | 2.0 | 0.4 | 5.9 | 0.6 | 77.1 |
| | %Change by mode | -0.2 | -9.5 | -0.7 | -0.5 | -2.5 | -0.5 | 13.9 |
| Characteristic: age under 30yrs old, no cars, single mode, internal zone | | | | | | | | |
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.6 | 1.5 | -1.2 | 0.9 | 1.7 | -3.2 | 0.0 |
| | Prob [%] | 71.6 | 9.4 | 0.6 | 4.8 | 11.6 | 0.1 | 2.0 |
| 0 | Logit | 3.8 | 2.6 | -0.7 | 1.8 | 2.3 | -2.4 | 0.0 |
| | Prob [%] | 59.3 | 17.2 | 0.7 | 8.1 | 13.2 | 0.1 | 1.3 |
| | %Change by mode | -12.2 | 7.8 | 0.0 | 3.4 | 1.6 | 0.0 | -0.7 |
| 1 | Logit | 3.3 | 0.5 | -1.7 | -0.1 | 1.2 | -4.0 | 0.0 |
| | Prob [%] | 79.9 | 4.7 | 0.5 | 2.6 | 9.4 | 0.1 | 2.8 |
| | %Change by mode | 8.3 | -4.6 | -0.1 | -2.2 | -2.2 | 0.0 | 0.8 |
| Characteristic: age under 30yrs old, have cars, single mode, internal zone | | | | | | | | |
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.3 | -1.8 | -3.8 | -2.4 | -1.8 | -7.5 | 0.0 |
| | Prob [%] | 34.4 | 7.5 | 1.0 | 4.2 | 7.7 | 0.0 | 45.2 |
| 0 | Logit | 0.0 | -0.8 | -3.3 | -1.4 | -1.2 | -6.7 | 0.0 |
| | Prob [%] | 32.0 | 15.4 | 1.2 | 8.0 | 9.9 | 0.0 | 33.4 |
| | %Change by mode | -2.4 | 7.9 | 0.2 | 3.8 | 2.2 | 0.0 | -11.8 |
| 1 | Logit | -0.5 | -2.8 | -4.3 | -3.3 | -2.3 | -8.3 | 0.0 |
| | Prob [%] | 33.3 | 3.3 | 0.7 | 2.0 | 5.5 | 0.0 | 55.2 |
| | %Change by mode | -1.0 | -4.2 | -0.2 | -2.2 | -2.3 | 0.0 | 10.0 |

Table D.9 Comparison of probability of mode preference with attitude component, pro safe (C3)

| Characteristic: age between 31 and 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.1 | 1.0 | -2.0 | -2.3 | 0.7 | 1.4 | 0.0 |
| | Prob [%] | 23.0 | 20.7 | 1.0 | 0.8 | 15.1 | 31.8 | 7.6 |
| 0 | Logit | 1.3 | 2.0 | -1.5 | -1.4 | 1.2 | 2.3 | 0.0 |
| | Prob [%] | 14.7 | 29.2 | 0.9 | 1.0 | 13.3 | 37.1 | 3.9 |
| | %Change by mode | -8.3 | 8.5 | -0.2 | 0.2 | -1.8 | 5.3 | -3.8 |
| 1 | Logit | 0.9 | 0.0 | -2.5 | -3.3 | 0.1 | 0.6 | 0.0 |
| | Prob [%] | 32.2 | 13.1 | 1.1 | 0.5 | 15.4 | 24.3 | 13.4 |
| | %Change by mode | 9.2 | -7.6 | 0.1 | -0.2 | 0.3 | -7.5 | 5.8 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, external zone | | | | | | | | |
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.7 | -2.3 | -4.6 | -5.6 | -2.8 | -2.9 | 0.0 |
| | Prob [%] | 5.0 | 7.5 | 0.8 | 0.3 | 4.6 | 4.4 | 77.4 |
| 0 | Logit | -2.5 | -1.3 | -4.1 | -4.6 | -2.3 | -2.0 | 0.0 |
| | Prob [%] | 5.1 | 16.8 | 1.0 | 0.6 | 6.4 | 8.1 | 62.0 |
| | %Change by mode | 0.0 | 9.3 | 0.2 | 0.3 | 1.8 | 3.7 | -15.4 |
| 1 | Logit | -3.0 | -3.4 | -5.1 | -6.5 | -3.4 | -3.7 | 0.0 |
| | Prob [%] | 4.5 | 3.0 | 0.5 | 0.1 | 3.0 | 2.1 | 86.7 |
| | %Change by mode | -0.6 | -4.5 | -0.2 | -0.2 | -1.6 | -2.3 | 9.3 |
| Characteristic: between 31 and 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.1 | 0.5 | -2.6 | -0.5 | 0.9 | -2.0 | 0.0 |
| | Prob [%] | 77.9 | 6.1 | 0.3 | 2.3 | 9.3 | 0.5 | 3.6 |
| 0 | Logit | 3.3 | 1.5 | -2.2 | 0.5 | 1.5 | -1.2 | 0.0 |
| | Prob [%] | 68.9 | 12.0 | 0.3 | 4.2 | 11.3 | 0.8 | 2.6 |
| | %Change by mode | -9.0 | 5.9 | 0.0 | 1.9 | 2.0 | 0.3 | -1.1 |
| 1 | Logit | 2.8 | -0.5 | -3.1 | -1.4 | 0.4 | -2.8 | 0.0 |
| | Prob [%] | 83.3 | 3.0 | 0.2 | 1.2 | 7.2 | 0.3 | 4.9 |
| | %Change by mode | 5.3 | -3.2 | 0.0 | -1.1 | -2.1 | -0.2 | 1.3 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.8 | -2.8 | -5.3 | -3.7 | -2.6 | -6.3 | 0.0 |
| | Prob [%] | 28.3 | 3.7 | 0.3 | 1.5 | 4.7 | 0.1 | 61.4 |
| 0 | Logit | -0.5 | -1.8 | -4.8 | -2.8 | -2.0 | -5.5 | 0.0 |
| | Prob [%] | 29.6 | 8.6 | 0.4 | 3.3 | 6.7 | 0.2 | 51.1 |
| | %Change by mode | 1.4 | 4.9 | 0.1 | 1.8 | 2.1 | 0.1 | -10.3 |
| 1 | Logit | -1.0 | -3.8 | -5.8 | -4.7 | -3.1 | -7.1 | 0.0 |
| | Prob [%] | 25.3 | 1.5 | 0.2 | 0.7 | 3.0 | 0.1 | 69.2 |
| | %Change by mode | -3.0 | -2.2 | -0.1 | -0.9 | -1.6 | -0.1 | 7.8 |

Table D.10 Comparison of probability of mode preference with varied attitudinal component, pro safe (C3)

| Characteristic: age over 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 0.2 | 1.4 | -1.0 | -1.4 | -1.4 | 1.8 | 0.0 |
| | Prob [%] | 9.2 | 31.4 | 2.9 | 1.9 | 1.8 | 45.0 | 7.8 |
| 0 | Logit | 0.4 | 2.4 | -0.5 | -0.5 | -0.9 | 2.6 | 0.0 |
| | Prob [%] | 5.2 | 39.1 | 2.1 | 2.2 | 1.4 | 46.4 | 3.5 |
| | %Change by mode | -4.0 | 7.8 | -0.8 | 0.3 | -0.4 | 1.4 | -4.3 |
| 1 | Logit | -0.1 | 0.4 | -1.5 | -2.4 | -2.0 | 0.9 | 0.0 |
| | Prob [%] | 14.8 | 22.7 | 3.6 | 1.5 | 2.1 | 39.4 | 15.8 |
| | %Change by mode | 5.6 | -8.6 | 0.7 | -0.4 | 0.3 | -5.5 | 8.0 |
| Characteristic: age over 50yrs old, have cars, single mode, external zone | | | | | | | | |
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -3.7 | -1.9 | -3.6 | -4.7 | -5.0 | -2.6 | 0.0 |
| | Prob [%] | 2.0 | 11.1 | 2.1 | 0.7 | 0.5 | 6.1 | 77.5 |
| 0 | Logit | -3.4 | -0.9 | -3.1 | -3.7 | -4.4 | -1.7 | 0.0 |
| | Prob [%] | 1.9 | 23.7 | 2.6 | 1.5 | 0.7 | 10.6 | 59.1 |
| | %Change by mode | -0.1 | 12.5 | 0.5 | 0.7 | 0.2 | 4.6 | -18.4 |
| 1 | Logit | -3.9 | -3.0 | -4.1 | -5.6 | -5.5 | -3.4 | 0.0 |
| | Prob [%] | 1.8 | 4.6 | 1.5 | 0.3 | 0.4 | 3.0 | 88.5 |
| | %Change by mode | -0.2 | -6.6 | -0.6 | -0.4 | -0.2 | -3.1 | 11.0 |
| Characteristic: age over 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 2.1 | 0.9 | -1.6 | 0.4 | -1.2 | -1.7 | 0.0 |
| | Prob [%] | 59.4 | 17.6 | 1.4 | 11.0 | 2.1 | 1.3 | 7.1 |
| 0 | Logit | 2.4 | 1.9 | -1.2 | 1.4 | -0.6 | -0.8 | 0.0 |
| | Prob [%] | 44.4 | 29.2 | 1.3 | 16.9 | 2.2 | 1.8 | 4.2 |
| | %Change by mode | -15.1 | 11.5 | -0.1 | 5.9 | 0.1 | 0.5 | -2.9 |
| 1 | Logit | 1.9 | -0.1 | -2.1 | -0.5 | -1.7 | -2.5 | 0.0 |
| | Prob [%] | 69.9 | 9.4 | 1.3 | 6.2 | 1.8 | 0.8 | 10.5 |
| | %Change by mode | 10.5 | -8.3 | -0.1 | -4.7 | -0.3 | -0.5 | 3.4 |
| Characteristic: age over 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| C3 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -1.7 | -2.4 | -4.3 | -2.8 | -4.7 | -6.0 | 0.0 |
| | Prob [%] | 13.3 | 6.6 | 1.0 | 4.5 | 0.7 | 0.2 | 73.8 |
| 0 | Logit | -1.5 | -1.4 | -3.8 | -1.9 | -4.2 | -5.1 | 0.0 |
| | Prob [%] | 13.5 | 14.8 | 1.3 | 9.4 | 0.9 | 0.3 | 59.7 |
| | %Change by mode | 0.2 | 8.2 | 0.3 | 4.9 | 0.3 | 0.2 | -14.1 |
| 1 | Logit | -1.9 | -3.4 | -4.8 | -3.8 | -5.3 | -6.8 | 0.0 |
| | Prob [%] | 11.8 | 2.6 | 0.7 | 1.9 | 0.4 | 0.1 | 82.4 |
| | %Change by mode | -1.5 | -3.9 | -0.3 | -2.5 | -0.2 | -0.1 | 8.6 |

Table D.11 Comparison of probability of mode preference with varied attitudinal component, pro private vehicle (C4)

| Characteristic: age under 30yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.6 | 2.0 | -0.5 | -1.0 | 1.5 | 0.2 | 0.0 |
| | Prob [%] | 24.7 | 37.1 | 2.9 | 1.8 | 22.2 | 6.3 | 5.0 |
| 0 | Logit | 2.0 | 2.1 | -0.2 | -0.8 | 1.5 | 1.4 | 0.0 |
| | Prob [%] | 27.6 | 31.5 | 3.0 | 1.6 | 17.1 | 15.4 | 3.8 |
| | %Change by mode | 2.8 | -5.6 | 0.0 | -0.2 | -5.0 | 9.2 | -1.2 |
| 1 | Logit | 1.2 | 1.9 | -0.8 | -1.1 | 1.5 | -1.0 | 0.0 |
| | Prob [%] | 20.5 | 40.2 | 2.7 | 1.9 | 26.4 | 2.3 | 6.0 |
| | %Change by mode | -4.3 | 3.1 | -0.3 | 0.1 | 4.2 | -3.9 | 1.1 |
| Characteristic: age under 30yrs old, have cars, single mode, external zone | | | | | | | | |
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.2 | -1.3 | -3.2 | -4.2 | -2.0 | -4.1 | 0.0 |
| | Prob [%] | 6.8 | 16.9 | 2.7 | 0.9 | 8.4 | 1.1 | 63.2 |
| 0 | Logit | -1.9 | -1.2 | -2.9 | -4.1 | -2.0 | -2.9 | 0.0 |
| | Prob [%] | 9.1 | 17.4 | 3.3 | 1.0 | 7.9 | 3.2 | 58.1 |
| | %Change by mode | 2.4 | 0.5 | 0.6 | 0.1 | -0.5 | 2.1 | -5.2 |
| 1 | Logit | -2.6 | -1.4 | -3.5 | -4.4 | -2.0 | -5.3 | 0.0 |
| | Prob [%] | 4.9 | 16.0 | 2.1 | 0.8 | 8.8 | 0.4 | 67.1 |
| | %Change by mode | -1.9 | -0.9 | -0.5 | -0.1 | 0.3 | -0.7 | 3.8 |
| Characteristic: age under 30yrs old, no cars, single mode, internal zone | | | | | | | | |
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.6 | 1.5 | -1.2 | 0.9 | 1.7 | -3.2 | 0.0 |
| | Prob [%] | 71.6 | 9.4 | 0.6 | 4.8 | 11.6 | 0.1 | 2.0 |
| 0 | Logit | 4.0 | 1.6 | -0.9 | 1.0 | 1.8 | -2.0 | 0.0 |
| | Prob [%] | 77.2 | 7.7 | 0.6 | 4.1 | 8.7 | 0.2 | 1.5 |
| | %Change by mode | 5.7 | -1.6 | 0.0 | -0.7 | -2.9 | 0.1 | -0.5 |
| 1 | Logit | 3.2 | 1.4 | -1.5 | 0.7 | 1.7 | -4.4 | 0.0 |
| | Prob [%] | 64.9 | 11.1 | 0.6 | 5.5 | 15.2 | 0.0 | 2.7 |
| | %Change by mode | 5.8 | 2.9 | 2.0 | 5.1 | 3.8 | 0.9 | 0.0 |
| Characteristic: age under 30yrs old, have cars, single mode, internal zone | | | | | | | | |
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.3 | -1.8 | -3.8 | -2.4 | -1.8 | -7.5 | 0.0 |
| | Prob [%] | 34.4 | 7.5 | 1.0 | 4.2 | 7.7 | 0.0 | 45.2 |
| 0 | Logit | 0.1 | -1.7 | -3.5 | -2.2 | -1.7 | -6.3 | 0.0 |
| | Prob [%] | 42.7 | 7.1 | 1.1 | 4.1 | 6.7 | 0.1 | 38.2 |
| | %Change by mode | 8.3 | -0.4 | 0.1 | -0.1 | -1.1 | 0.0 | -7.0 |
| 1 | Logit | -0.7 | -1.9 | -4.1 | -2.5 | -1.8 | -8.7 | 0.0 |
| | Prob [%] | 26.8 | 7.6 | 0.9 | 4.1 | 8.7 | 0.0 | 51.9 |
| | %Change by mode | -7.6 | 0.2 | -0.1 | -0.1 | 1.0 | 0.0 | 6.6 |

Table D.12 Comparison of probability of mode preference with varied attitudinal component, pro private vehicle (C4)

| Characteristic: age between 31 and 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 1.1 | 1.0 | -2.0 | -2.3 | 0.7 | 1.4 | 0.0 |
| | Prob [%] | 23.0 | 20.7 | 1.0 | 0.8 | 15.1 | 31.8 | 7.6 |
| 0 | Logit | 1.5 | 1.1 | -1.7 | -2.2 | 0.7 | 2.6 | 0.0 |
| | Prob [%] | 18.2 | 12.5 | 0.7 | 0.5 | 8.3 | 55.7 | 4.1 |
| | %Change by mode | -4.8 | -8.2 | -0.3 | -0.3 | -6.8 | 23.9 | -3.5 |
| 1 | Logit | 0.7 | 0.9 | -2.3 | -2.5 | 0.7 | 0.3 | 0.0 |
| | Prob [%] | 23.1 | 27.2 | 1.2 | 1.0 | 21.9 | 14.4 | 11.2 |
| | %Change by mode | 0.1 | 6.5 | 0.1 | 0.2 | 6.8 | -17.4 | 3.6 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, external zone | | | | | | | | |
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -2.7 | -2.3 | -4.6 | -5.6 | -2.8 | -2.9 | 0.0 |
| | Prob [%] | 5.0 | 7.5 | 0.8 | 0.3 | 4.6 | 4.4 | 77.4 |
| 0 | Logit | -2.4 | -2.2 | -4.3 | -5.4 | -2.8 | -1.7 | 0.0 |
| | Prob [%] | 6.5 | 7.4 | 0.9 | 0.3 | 4.1 | 12.6 | 68.2 |
| | %Change by mode | 1.5 | -0.1 | 0.1 | 0.0 | -0.5 | 8.2 | -9.2 |
| 1 | Logit | -3.1 | -2.4 | -4.9 | -5.7 | -2.8 | -4.1 | 0.0 |
| | Prob [%] | 3.6 | 7.1 | 0.6 | 0.3 | 4.8 | 1.4 | 82.2 |
| | %Change by mode | -1.4 | -0.4 | -0.2 | 0.0 | 0.2 | -3.0 | 4.8 |
| Characteristic: between 31 and 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 3.1 | 0.5 | -2.6 | -0.5 | 0.9 | -2.0 | 0.0 |
| | Prob [%] | 77.9 | 6.1 | 0.3 | 2.3 | 9.3 | 0.5 | 3.6 |
| 0 | Logit | 3.5 | 0.6 | -2.4 | -0.3 | 1.0 | -0.8 | 0.0 |
| | Prob [%] | 82.4 | 4.9 | 0.2 | 1.9 | 6.8 | 1.2 | 2.6 |
| | %Change by mode | 4.4 | -1.2 | 0.0 | -0.4 | -2.5 | 0.7 | -1.0 |
| 1 | Logit | 2.7 | 0.4 | -2.9 | -0.6 | 0.9 | -3.2 | 0.0 |
| | Prob [%] | 72.1 | 7.4 | 0.3 | 2.7 | 12.3 | 0.2 | 4.9 |
| | %Change by mode | -5.8 | 1.3 | 0.0 | 0.4 | 3.1 | -0.3 | 1.3 |
| Characteristic: between 31 and 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -0.8 | -2.8 | -5.3 | -3.7 | -2.6 | -6.3 | 0.0 |
| | Prob [%] | 28.3 | 3.7 | 0.3 | 1.5 | 4.7 | 0.1 | 61.4 |
| 0 | Logit | -0.4 | -2.7 | -5.0 | -3.6 | -2.6 | -5.1 | 0.0 |
| | Prob [%] | 36.3 | 3.6 | 0.4 | 1.5 | 4.2 | 0.3 | 53.7 |
| | %Change by mode | 8.0 | -0.1 | 0.1 | 0.0 | -0.5 | 0.2 | -7.7 |
| 1 | Logit | -1.2 | -2.9 | -5.6 | -3.9 | -2.6 | -7.5 | 0.0 |
| | Prob [%] | 21.4 | 3.7 | 0.3 | 1.4 | 5.1 | 0.0 | 68.1 |
| | %Change by mode | -6.9 | 0.0 | -0.1 | -0.1 | 0.4 | -0.1 | 6.7 |

Table D.13 Comparison of probability of mode preference with varied attitudinal component, pro private vehicle (C4)

| Characteristic: age over 50yrs old, no cars, single mode, external zone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 0.2 | 1.4 | -1.0 | -1.4 | -1.4 | 1.8 | 0.0 |
| | Prob [%] | 9.2 | 31.4 | 2.9 | 1.9 | 1.8 | 45.0 | 7.8 |
| 0 | Logit | 0.6 | 1.5 | -0.7 | -1.3 | -1.4 | 2.9 | 0.0 |
| | Prob [%] | 6.4 | 16.7 | 1.8 | 1.0 | 0.9 | 69.4 | 3.7 |
| | %Change by mode | -2.8 | -14.7 | -1.1 | -0.9 | -1.0 | 24.4 | -4.1 |
| 1 | Logit | -0.2 | 1.3 | -1.3 | -1.6 | -1.5 | 0.6 | 0.0 |
| | Prob [%] | 10.2 | 45.5 | 3.6 | 2.7 | 2.9 | 22.5 | 12.7 |
| | %Change by mode | 1.0 | 14.1 | 0.7 | 0.8 | 1.1 | -22.5 | 4.9 |
| Characteristic: age over 50yrs old, have cars, single mode, external zone | | | | | | | | |
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -3.7 | -1.9 | -3.6 | -4.7 | -5.0 | -2.6 | 0.0 |
| | Prob [%] | 2.0 | 11.1 | 2.1 | 0.7 | 0.5 | 6.1 | 77.5 |
| 0 | Logit | -3.3 | -1.8 | -3.3 | -4.5 | -4.9 | -1.4 | 0.0 |
| | Prob [%] | 2.5 | 10.7 | 2.4 | 0.7 | 0.5 | 16.9 | 66.4 |
| | %Change by mode | 0.5 | -0.4 | 0.3 | 0.0 | -0.1 | 10.8 | -11.1 |
| 1 | Logit | -4.1 | -2.1 | -3.9 | -4.8 | -5.0 | -3.7 | 0.0 |
| | Prob [%] | 1.4 | 10.6 | 1.7 | 0.7 | 0.6 | 2.0 | 83.0 |
| | %Change by mode | -0.5 | -0.5 | -0.4 | -0.1 | 0.0 | -4.1 | 5.5 |
| Characteristic: age over 50yrs old, no cars, single mode, internal zone | | | | | | | | |
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | 2.1 | 0.9 | -1.6 | 0.4 | -1.2 | -1.7 | 0.0 |
| | Prob [%] | 59.4 | 17.6 | 1.4 | 11.0 | 2.1 | 1.3 | 7.1 |
| 0 | Logit | 2.5 | 1.0 | -1.4 | 0.6 | -1.2 | -0.5 | 0.0 |
| | Prob [%] | 64.6 | 14.6 | 1.4 | 9.4 | 1.6 | 3.2 | 5.2 |
| | %Change by mode | 5.1 | -3.0 | 0.0 | -1.6 | -0.5 | 1.9 | -1.9 |
| 1 | Logit | 1.7 | 0.8 | -1.9 | 0.3 | -1.2 | -2.9 | 0.0 |
| | Prob [%] | 53.0 | 20.6 | 1.4 | 12.4 | 2.8 | 0.5 | 9.3 |
| | %Change by mode | -6.4 | 3.0 | 0.0 | 1.4 | 0.6 | -0.8 | 2.2 |
| Characteristic: age over 50yrs old, have cars, single mode, internal zone | | | | | | | | |
| C4 | | AT | BUS | Train | Taxi | MC | Shuttle | CAR |
| Base | Logit | -1.7 | -2.4 | -4.3 | -2.8 | -4.7 | -6.0 | 0.0 |
| | Prob [%] | 13.3 | 6.6 | 1.0 | 4.5 | 0.7 | 0.2 | 73.8 |
| 0 | Logit | -1.3 | -2.3 | -4.0 | -2.7 | -4.7 | -4.8 | 0.0 |
| | Prob [%] | 18.0 | 6.8 | 1.3 | 4.8 | 0.6 | 0.6 | 68.0 |
| | %Change by mode | 4.7 | 0.2 | 0.2 | 0.3 | 0.0 | 0.4 | -5.8 |
| 1 | Logit | -2.1 | -2.5 | -4.6 | -3.0 | -4.7 | -7.2 | 0.0 |
| | Prob [%] | 9.6 | 6.2 | 0.8 | 4.1 | 0.7 | 0.1 | 78.5 |
| | %Change by mode | -3.7 | -0.3 | -0.2 | -0.4 | 0.0 | -0.1 | 4.7 |