Impact of Ubiquitous Real-Time Information on Bus Passenger Route Choice

By

MD FAQHRUL ISLAM
B.Sc, M.Sc. (TUM)

A thesis submitted in partial fulfilment of the requirements of
Edinburgh Napier University, for the award of

Doctor of Philosophy

TRANSPORT RESEARCH INSTITUTE

OCTOBER 2018

If we knew what it was we were doing, it would not be called research, would it?

Albert Einstein

To Dad, Mum and Fatin

Acknowledgements

The journey to the completion of this PhD has been possible because of the continuous support and guidance of several people. First and foremost, I would like to express my sincere gratitude to Dr Achille Fonzone, my Director of Studies, for his invaluable advice, encouragement, and mentorship throughout the entire PhD.

I wish to thank my supervisors, Dr Andrew MacIver and Professor Keith Dickinson, for their useful critiques on this research work. Also, to Professor Tom Rye for being a supportive Independent Panel Chair and a wonderful ukulele mate.

There are a few people whose support cannot go unrecognised - Aisling, Ruth, Mel, and Clare, who have always been encouraging and caring. Special thanks to my panel of proof readers: Arek and Amaka. I must thank Niaz Gharavi for his technical support in writing with LaTeX. My friends Emine, Juan, Lara, Mengxiao, and Suzanne, who have been an important part of this journey.

Although 8000km apart, my family has always been a source of strength for me. My sincerest appreciation goes to my mum, Shimul, Hasnat, and Palash for always believing in me.

I would like to thank Edinburgh Napier University for offering me a 50th Anniversary scholarship to carry out this study. The support from the Transport Research Institute, especially Yvonne is gratefully acknowledged.

Declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. The entire work is the candidate's own work. Any views expressed in the dissertation are those of the author.

MD FAQHRUL ISLAM, B.SC., M.SC.(TUM)

APRIL 2018

ABSTRACT

Over the last decade, Ubiquitous Real-time Passenger Information (URTPI) has become popular among public transport passengers. The effectiveness of URTPI and hence the value of the investments into the necessary systems can be increased with a clear understanding of how URTPI influences passenger behaviour. However, such an understanding is still limited and fragmented. In particular, very little is known about the impact of URTPI on route choice. This study fills this gap evaluating the impact of URTPI on bus passengers' route choice.

A revealed preference survey methodology was adopted for data collection and two questionnaire surveys targeting bus users were carried out. Categorical Regression and discrete choice models, such as Binary Logit Model and Multinomial Logit Model, have been applied to analyse the survey data.

The study reveals that trip length, passenger age and profession are the main factors influencing the use of URTPI. Having access to URTPI, the frequency of its use is strongly influenced by the attributes of information and social norms. Bus arrival time and bus stop location are the two most important contents of information. Changing time of departure from the start and the boarding time are the two most popular actions taken by bus passengers after consulting URTPI. Passengers' decisions are influenced by information on bus arrival time, bus route, and walking distance. As a result of the impact of URTPI on passengers' choices, the demand distribution for bus runs could potentially be changed by 33% and for bus lines by 22%. The overall network demand distribution could be affected in 42% of cases as a result of consulting URTPI.

This study implicates that while investing in tailoring the sources of URTPI, passengers' preferred attributes and contents of information should be considered. Transport planners and operators should take the potential impact of URTPI into account to make better predictions of the PT demand distribution.

TABLE OF CONTENTS

List of Tables

List of Figures

List of Abbreviations

APTS Advanced Public Transport Systems. 15

ATIS Advanced Traveller Information Systems. xii, 4, 11, 15, 16, 17, 18, 19, 20, 21, 22, 31, 43, 45, 46, 47, 49, 50, 51, 52, 55, 56, 66, 67, 68, 70, 71, 72, 81, 83

ATMS Advanced Traffic Management Systems. 14, 15

AVL Automated Vehicle Location. 15, 23, 25

CATPCA Categorical Principle Component Analysis. 153, 154

CATREG Categorical Regression. v, viii, 115, 119, 123, 124, 125, 135, 142, 143, 154, 155, 161, 176, 177, 179, 180, 188, 189

DCM Discrete Choice Model. x, 115, 116, 118, 119

EMGB Extended Model of Goal-directed Behaviour. 41

ETA Expected Time of Arrival. 154, 155, 159, 160, 164, 171, 180, 184, 194, 197, 202, 208

EU European Union. 1, 13

GPS Global Positioning System. 19, 20, 72, 73

HAR Highway Advisory Radio. 18, 19, 20

ICT Information and Communication Technology. 4, 14, 19, 20, 57, 64, 75, 94, 202

ITS Intelligent Transport Systems. 3, 4, 14, 15

MaaS Mobility as a Service. 13, 23, 215

MNL Multinomial Logit Model. v, x, 119, 121, 135, 140, 142

PCA Principal Component Analysis. viii, x, xi, 115, 119, 121, 122, 125, 153, 154, 176, 178, 179, 288, 289

PT Public Transport. v, x, xii, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23, 24, 25, 26, 27, 28, 27, 29, 30, 32, 34, 35, 36, 42, 44, 45, 48, 49, 51, 52, 53, 54, 55, 56, 57, 58, 60, 61, 62, 63, 64, 65, 73, 74, 75, 77, 81, 83, 84, 91, 94, 95, 96, 98, 103, 105, 106, 116, 124, 126, 127, 133, 134, 142, 147, 149, 150, 151, 154, 163, 164, 165, 166, 169, 170, 180, 183, 184, 187, 188, 196, 197, 198, 200, 202, 204, 206, 208, 209, 210, 211, 214

RP Revealed Preference. 9, 67, 73, 79, 80, 81, 83, 84, 86, 113, 116, 119, 200

RTPI Real-time Passenger Information. x, 4, 5, 11, 15, 22, 23, 24, 25, 31, 30, 44, 49, 53, 54, 55, 56, 57, 58, 59, 60, 61, 63, 64, 65, 73, 74, 75, 77, 81, 202, 213, 214

RTTI Real-time Travel Information. 3, 4, 11, 15, 16, 19, 21, 22, 23, 24, 30, 32, 34, 43, 47, 50, 54, 56, 61, 62, 65, 66, 67, 68, 69, 70, 72, 73, 75, 77, 81, 83, 214

RUT Random Utility Theory. 116, 118

SP Stated Preference. 55, 57, 58, 61, 62, 64, 66, 67, 68, 69, 73, 75, 79, 80, 83, 116, 119

TfL Transport for London. 166, 197, 201

TIS Traveller Information System. 15, 17, 18, 19

TPB Theory of Planned Behaviour. 39, 41, 42, 43, 92, 115, 206

URTPI Ubiquitous Real-time Passenger Information. v, x, xi, xii, xiii, 1, 4, 5, 6, 7, 8, 9, 11, 15, 18, 20, 24, 25, 27, 30, 32, 33, 34, 35, 36, 38, 39, 40, 41, 46, 49, 53, 54, 55, 58, 59, 60, 61, 63, 64, 75, 77, 78, 79, 81, 84, 85, 86, 88, 91, 92, 94, 95, 96, 98, 99, 100, 101, 103, 104, 106, 107, 109, 110, 111, 112, 113, 115, 116, 119, 120, 121, 126, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 140, 142, 145, 147, 148, 149, 151, 152, 154, 155, 161, 162, 163, 164, 165, 167, 168, 169, 170, 171, 173, 174, 175, 176, 177, 178, 181, 184, 185, 184, 186, 187, 188, 189, 197, 198, 200, 201, 202, 203, 204, 206, 208, 209, 210, 211, 212, 213, 214, 249, 288

VMS Variable Message Signs. 18, 19, 20, 68, 69, 70, 71, 72, 73

CHAPTER 1

Introduction

This thesis investigates the impact of Ubiquitous Real-time Passenger Information (URTPI) on Public Transport (PT) users' choices, in particular on bus users. URTPI is available via different media and sources. This study focuses on the factors affecting the use of URTPI before discussing its impact on bus passengers' route choice. This chapter first discusses the study context, i.e. PT and real-time information. A brief motivation behind this study is presented to show the importance of this research. The research aim and research questions are presented. Finally, a structure of the thesis is presented.

1.1 Context

1.1.1 Public Transport

Over the last 70 years, the world has witnessed a continuous increase in population living in urban areas or cities. There is no evidence that this trend is reversing. The continuous growth in population is resulting in a considerable expansion of cities. Increased transport demand, car dependency, longer journeys and traffic congestion are the consequences of urban sprawl and the main challenges transport planners have to deal with. To overcome these ever-challenging issues in transport, sustainable mobility has been at the heart of transport strategies. Sustainable mobility strengthens the relationship between land use and transport. In the paradigm of sustainable mobility, PT plays a crucial role. In developed countries where over 50% of the journeys are made by PT, bike and on foot, urban transport journeys contribute to 5 to 7% of the the local community's GDP (UITP, 2002). The cost of urban journeys can reach 15% of GDP if the city mobility is dominated by cars. Such costs can be higher if population density is low and car ownership is high in respect to per capita income. In developing countries, these costs may exceed 25% of GDP. This demonstrates the importance of PT as a part of an urban transport system. In the European Union (EU) context, PT services contributes about €130 to 150bn per year (i.e. 1 to 1.2% of GDP). From an environmental point of view, the green-house gas emission per PT passenger is 3.5 times less than private cars. PT is therefore contributing to the EU targets of cutting CO_2 emissions to 20% below 1990 levels by 2020 (UITP, 2014b). Therefore, the contribution of PT as part of sustainable mobility is undeniable.

In the UK, a growing rate of market share held by PT has been observed. Out of the 793bn passenger kilometres recorded in 2015, 9% were travelled by PT (Department for Transport, 2016). However, outside London, a declination in PT use has been observed. In 2014, Edinburgh experienced a reduction in PT passenger journeys compared to 2006 data (PT journey index in 2006 =100, 2014 =94), albeit total vehicle kilometres travelled has increased by an index of 4 (Transport Scotland, 2016). In addition, the growing rate of car ownership threatens the use of PT as well. Every new car may potentially reduce 200-300 local bus trips per year (White, 2016). Hence, an efficient and attractive PT system should be offered to the passengers to increase the use of PT. The role of PT and necessity of improving the system has been addressed in Transport strategies. The European Commission (2011b, p. 12) white paper highlighted the importance of *"the quality, accessibility and reliability of transport services"* to promote PT. The paper also identified the importance of the availability of information in addition to the well developed PT services (i.e. frequencies, passenger comfort, easy access, etc.). In 2006, the Scottish Transport Strategy set a framework to be implemented by 2026 with five high level objectives. Two of the objectives are (Transport Scotland, 2016, p. 1):

- *To protect our environment and improve health by building and investing in PT and other types of efficient and sustainable transport which minimise emissions and consumption of resources and energy.*
- *To improve integration by making journey planning and ticketing easier and working to ensure smooth connection between different forms of transport.*

To compete with other modes of transport, PT should provide comparative travel time and reliability (Beirão and Cabral, 2007) and passengers should be informed regarding these attributes. Therefore, a well developed PT system would offer attractive services, efficient infrastructure and passenger information system. Provision of passenger information systems improve PT attractiveness by providing up to date travel information to the passengers.

1.1.2 Real Time Information

The term “Real-time" originated from computer science and refers to the phenomena of instant reaction to events with a near-zero delay. It is characterised by continuous data updating in response to real-world events. Use of real-time data is on the rise and being widely used in many aspects. Real-time data can be used by the law enforcement agency for security purposes, by environmentalists to monitor changes, such as air pollution, water level or seismic activity (Çelebi, 2006; Rolph et al., 2017). Currently even the sports teams are using real-time data to improve their on-field performance. Movement of football players are monitored in real-time and the changes or strategies are made accordingly during a particular match. In people's daily life, real-time information is widely used as well. For instance, real-time data on energy consumption allows citizens to increase their efforts for saving energy. Real-time data and information is even more important in a dynamic environment like transport. Transport systems are now being managed by collection and analysis of real-time data (Buana et al., 2016; Gavriilidou et al., 2017; Mirchandani and Head, 2001). This enables transport authorities to manage the systems efficiently. In addition, travellers are also provided with Real-time Travel Information (RTTI) for making journeys. As an integral part of a transport system, travel information helps travellers to plan and execute their journeys. At present, along with the information related to the trips, travel information is incorporated with additional information of travellers' interest, such as weather conditions, place of attraction, etc. The application of real-time data in transport, in particular the provision of RTTI became possible since the introduction of Intelligent Transport Systems (ITS).

ITS applies Information and Communication Technology (ICT) in transport to improve safety, mobility and efficiency. Addressing congestion was one of the initial motivations for the introduction of ITS (Figueiredo et al., 2001). Over the last decades, the emergence of ITS has opened the door of solutions to enhance mobility by reducing travel time, increasing safety and comfort. ITS contributed to travel information by introducing technology based information systems known as Advanced Traveller Information Systems (ATIS). ATIS have been defined by McQueen et al. (2002, p. 31) as "*The systematic application of information and communication technologies to the collection of travel-related data and the processing and delivery of information of value to the traveller*". Since its introduction, ATIS is found to be beneficial in reducing travel time for recurring congestion (Emmerink et al., 1995a). The value of ATIS for route choice is much realised if the information is provided in real-time for non-recurring congestion or incidents which cannot be anticipated easily (Emmerink et al., 1995b; Levinson, 2003). RTTI is now available to both private and PT users. RTTI is characterised by continuous data updating in response to real-world events. For PT users, RTTI is generally known as Real-time Passenger Information (RTPI).

In the context of PT systems, RTPI refers to the real-time information regarding PT services, such as remaining time until the arrival of the next vehicle, service disruptions, crowding conditions, etc. (Kim et al., 2009; Schweiger, 2003). It may include real-time data (e.g. location of the bus) and predicted information based on the real-time data (e.g. arrival of the next). Additionally, information about the nature and causes of disruptions may be provided. The information is updated in a very short span of time, for example Citymapper (2016) updates information every minute. The dissemination of the RTPI can be location-specific (local) or ubiquitous. As the term "ubiquitous" literally means existing or being everywhere especially at the same time, URTPI refers to the RTPI that can be accessed from anywhere at any time. Over the past decades, the provision of information for PT has become ubiquitous (Schweiger, 2011). URTPI is now available via different sources, such as mobile applications (hereafter referred as Mobile apps), travel websites, etc.

1.1.3 Motivation

The success or benefit of an effective travel demand management measure relies on its influence on traveller behaviour (Juhász, 2013; Meyer, 1999). Wockatz and Schartau (2015) highlighted four themes for the development of paths towards intelligent mobility (Figure 1.1). It is observed that influencing travellers' behaviour with information would be of high value for transport demand and supply.

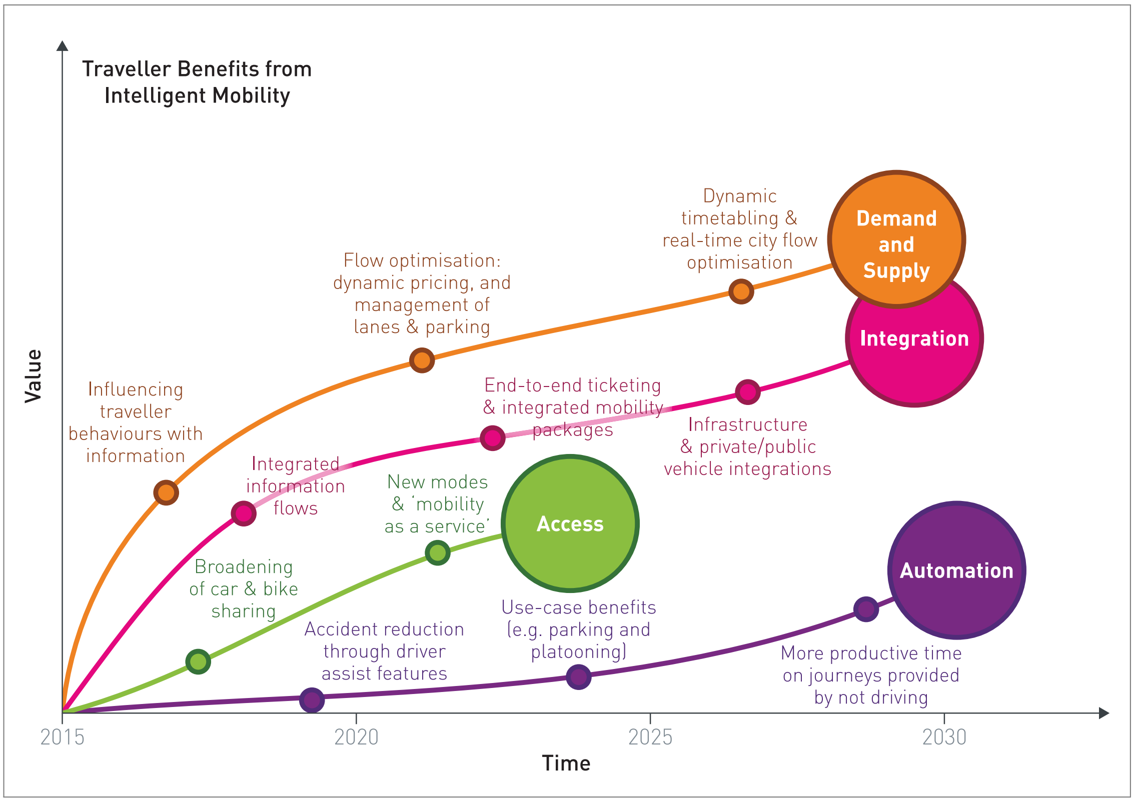


Figure 1.1 Influencing demand with information (Source: Wockatz and Schartau, 2015)

Previous studies on travel information indicate that an increasing number of methods of access to different information sources may instigate change in travel decisions (i.e. change route, time, or mode, or cancel trip) and internet-based information is associated with the highest propensity of changing any aspects of trips (Khattak et al., 2008). Simulation of PT network with RTPI show potential impact on network demand distribution (Cats et al., 2012). However, simulation studies are carried out based on behavioural assumptions which are not understood yet. The impact on the demand distribution may occur due to the influence of RTPI on passengers' decision-making. However, existing literature fails to reveal how passengers' decision-making is influenced by RTPI. Nowadays almost every person has access to the internet via different tools. Considerable investments and efforts are given to the development, dissemination and maintenance of passenger information. However, the use of URTPI and its impact on passengers' behaviour are not well understood yet. Our knowledge regarding the impact of URTPI on passenger route choice is limited and fragmented. This is important as it can affect passenger load and subsequently the performance of PT services. Understanding passenger behaviour under the influence of URTPI would lead to a better prediction of demand distribution over the PT network.

1.2 Research Aim and Approach

1.2.1 Research Aim

The aim of this study is to understand the factors influencing the use of URTPI as well as its impact on passengers' route choice. The study concerns bus passengers' behaviour under regular urban PT service condition. Regular PT service condition refers to the condition where the consultation of URTPI is not dominated by the service conditions (e.g. disruption). Passengers, however, might consider disruption or delay when making travel choices.

As this study aims to investigate the impact of URTPI on passenger route choice, it is necessary to define route choice in the context of this study. The following section discusses route choice before presenting the research questions.

Definition of Route Choice

Route choice refers to the route taken by passengers from their origin to destination. In this study, route choice includes passenger choices regarding time and space. Therefore, passengers' route choice can be influenced due to the changes in any of the following choice elements:

- ▻ Time of departure from start
- ▻ Boarding time
- ▻ Departure bus stop
- ▻ Alighting bus stop
- ▻ Bus route/line

Route choice has two dimensions: temporal dimension and spatial dimension, which are discussed below.

Temporal Dimension

The temporal dimension of route choice for a trip concerns time of departure from start and time of boarding bus. Hence, temporal route choice refers to passengers' choices concerning time and how it influences demand over time. Figure 1.2 shows two bus runs (Run A and Run B) available for passengers to make a trip. Passengers can adjust their time of departure from start. They may also decide to take a bus earlier or later on the same line and change their boarding time. If a passenger boards a bus at 08:38 instead of taking the bus at 08:23 which was initially planned, then the temporal dimension of route choice is influenced. Study of the impact of URTPI on the temporal dimension would help in understanding how information may affect PT load over time as well.

Spatial Dimension

In this study, spatial dimension of route choice refers to the complete path taken by the passengers to travel from origin to destination. Therefore, a route would comprise at least two modes of transport, i.e. walking and PT. Figure 1.3 shows an example of the spatial dimension of route choice with alternatives for a trip from origin (**O**) to destination (**D**). **A** and **B** are the bus stops near the origin and **E**, **F** and **G** near the destination. Solid lines represent bus route and dashed lines show walking paths to and from bus stops. Any changes in departure stop, alighting stop or bus lines would affect the spatial dimension of route choice.

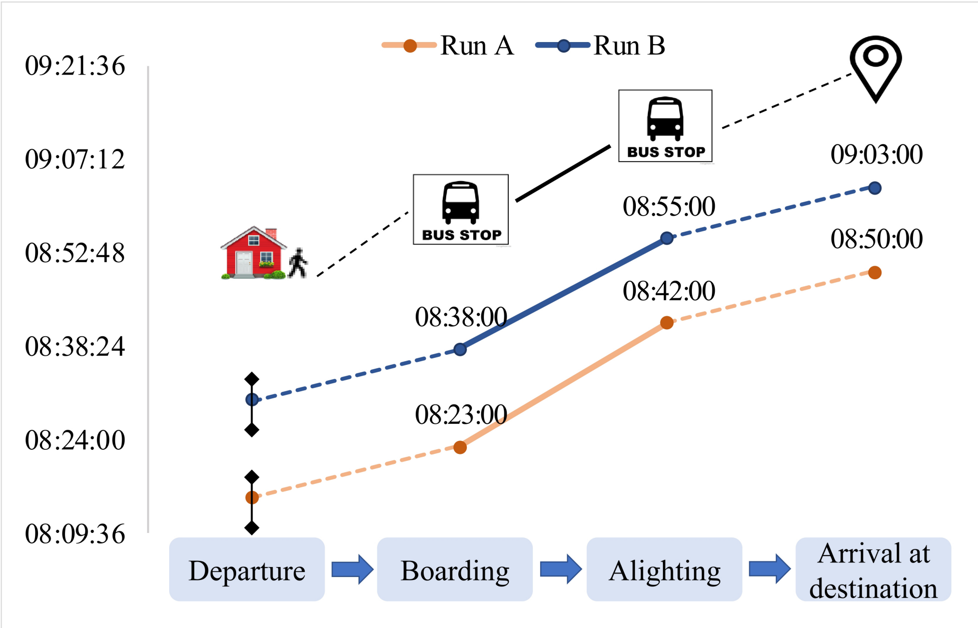


Figure 1.2 Temporal dimension of route choice

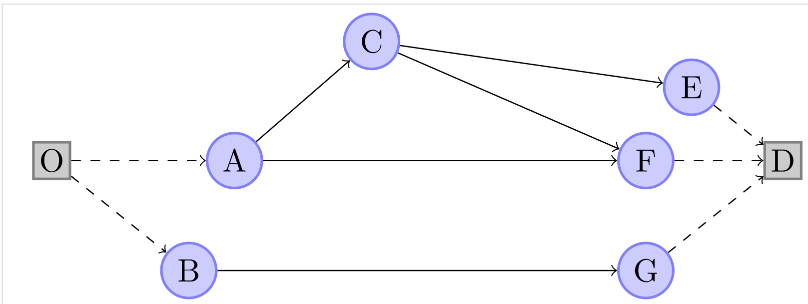


Figure 1.3 Spatial dimension of route choice

1.2.2 Research Questions

To accomplish the research aims the following set of research questions have been developed:

1. What drives the use of URTPI?
    a) What is the penetration of URTPI among PT passengers?
    b) Which URTPI sources are consulted by passengers?
    c) What contents of information are being sought by passengers?
    d) What factors influence the use of URTPI?

2. How is bus passenger route choice influenced by URTPI?

   a) What impact does URTPI have on user behaviour, especially in regards to temporal and spatial dimensions of route choice?

   b) What influence does URTPI have on PT demand distribution?

   c) How can cognitive aspects be used to explain passengers' use of URTPI, as well as their choices?

1.2.3 Research Methodology

This study adopts a Revealed Preference (RP) survey methodology to achieve the answers to the research questions. RP data reveals decision makers' choices in reality, which is appropriate to investigate the impact on passengers' route choice. Data is collected by surveys and analysed by means of statistical modelling.

1.3 Contributions

PT information assists passengers to plan and execute a seamless journey. A successful and effective provision of information is possible when information is served taking users' preferences and needs into account. This study reveals the drivers of and the barriers to the use of existing URTPI. Understanding passengers' preferences and needs are important for further investment on URTPI provision. This study then discusses passengers' choices after consulting URTPI and reveals the impact of URTPI on route choice. The study results contribute to the better understanding of demand distribution over the PT network.

Two academic papers have been published so far in conference proceedings during the course of this research. The bibliographic details are given below.

Islam, M. F., Fonzone, A., MacIver, A., Dickinson, K. (2017). Modelling factors affecting the use of ubiquitous real-time passenger information. In *5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems*, Napoli, Italy, 26-28 June 2017.

Islam, M. F., Fonzone, A., MacIver, A., Dickinson, K. (2017). Use of ubiquitous real-time passenger information. In *49th USTG Annual Conference*, Dublin, Ireland, 4-6 January 2017.

1.4 Structure of the Thesis

This thesis is composed of eight chapters. The remainder of the thesis presents the rest of the chapters to unfold the work undertaken and the findings required to answer the research questions. The chapters are as follows-

Chapter 2 discusses the background to this study. The subject area PT and travel information are discussed. The importance and the evolution of travel information are discussed. A discussion on the change of travel information research trend is also presented.

Chapter 3 presents the literature review on decision-making and real-time information. First, a review of the decision-making process is presented and how individual's decision can be influenced are discussed. The research gaps are identified by carrying out a comprehensive review of the studies related to travel information.

In *Chapter 4*, the development of the data collection methodology is discussed. At first, a review of the behavioural research approaches is presented in order to find the appropriate methodology for this study. A data collection framework is discussed; data collection by means of the adopted methods are then presented.

Chapter 5 discusses the data analysis methodology adopted in this study. A review of the data analysis techniques is presented and the appropriate techniques for this study are discussed.

Chapter 6 presents the bus stop survey results. Both descriptive and inferential statistical analyses are presented. The results are discussed in light of the research questions.

Chapter 7 presents the online survey results. Again both inferential and descriptive analyses of the data are carried out and the findings are discussed.

Chapter 8 summarises all the research findings from the bus stop and online surveys and discusses these in the context of the research questions. The implications of this research are then discussed. The limitations of this study and scope for further research are also presented.

Acronyms and Terminologies

RTTI refers to the Real-time Travel information for any mode as well as in context of car users. Existing studies have used the term ATIS and RTTI alternatively. When presenting the review of the studies, these terminologies are kept as it is mentioned in the respective studies. Hence, in this study, RTTI and ATIS are used alternatively, and both refer to real-time travel information systems. Real-time information for public transport users is termed as Real-time Passenger Information (RTPI) which refers to any real-time information sources, such as bus stop displays, websites, etc. As discussed in the research aim, this study focuses on the impact of ubiquitous sources only (i.e. apps, websites) which is refereed as URTPI.

The term ‘traveller’ is a generic term used to refer any mode users. PT users are referred as ‘Passengers’ in the following chapters.

CHAPTER 2

Public Transport and Traveller Information

This chapter presents the background to this study starting with a brief description of the subject area, i.e. Public Transport (PT). This is then followed by the role of information in PT. The evolution of travel information systems is discussed and a review of the state-of-the-art passenger information systems is presented. The chapter finishes with a discussion on how travel information research focus has changed over the time.

2.1 Public Transport and ITS

"Public Transport" is a common term refers to the transport modes provided by the government, private owners or corporations that could be used by the broader populace. The domain of PT has been found to vary according to the contexts of study. PT (also known as public transit, mass transit, and mass transportation) broadly refers to any mode of transport available to the general public. Hence, depending on the context, PT may be defined to include all the modes such as bus, coach, heavy rail (subway and elevated), light rail, tram, domestic air, and paratransit (also known as demand responsive mode such as taxi, car sharing, and bike sharing) (White, 2016). However, based on the operation of the modes, PT may also denote only the modes that run on fixed routes and with fixed schedules (Vuchic, 2002). The Oxford English Dictionary definition of PT includes the modes that are available to the public, charge set fares, and run on fixed routes, such as buses, trains, and other forms of transport. This excludes paratransit[1] from the PT domain. In this study, the term PT refers to the modes available for public use which operate on fixed routes with fixed schedules and charges (i.e. bus, light rail transit, metro and regional rail).

PT is an indispensable part of sustainable mobility. It is considered an effective solution to combat transport issues like increasing demand, congestion, and emissions (European Commission, 2011a). However, in Europe, the majority of trips are still made using cars. In 2015, 83% of the total journeys were made by car in Europe (Eurostat, 2017). The share of motor coaches, trolley buses and buses are 9.2%. In many cities, buses are the main mode of PT and cover the majority of local PT journeys. In Edinburgh, 77% of PT journeys were made by bus in 2015 (Transport Scotland, 2016). A study by the UITP[2] on urban public transport usage in the EU revealed that 57.6 billion trips were made by bus, metro and light rail in 2014. Figure 2.1 shows the percentage of journeys made by different modes of PT in 28 EU countries in 2014. 56% of the local PT journeys are made by buses, which emphasises the role of buses as a major PT mode within the sustainable mobility paradigm.

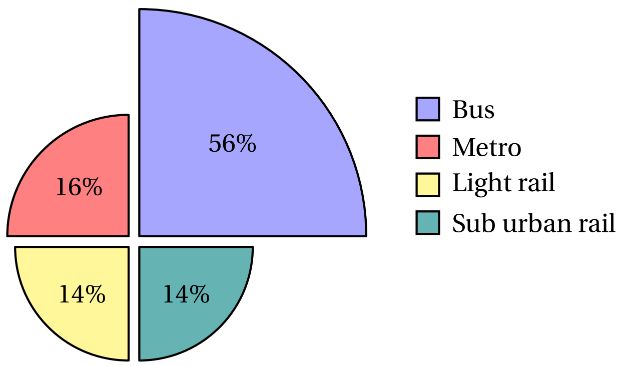


Figure 2.1 Local PT journeys in the EU in 2014 (UITP, 2014a)

[1] Paratransit or for-hire transportation is transportation provided by operators and available to parties which hire them for individual or multiple trips. Taxi, dial-a-bus and uber are the most common modes (Vuchic, 2002).

[2] *Union Internationale des Transports Publics (UITP)* is the International Association of Public Transport.

Traditionally, PT used to serve passengers as individual modes, such as buses, trains, etc., thus making passengers buy different tickets for making multi-modal trips. This inconveniences passengers if different operators of PT exist in cities. In addition to the PT modes, different shared modes, such as ridesharing and ride-hailing are now available in many cities; therefore, urban mobility is currently undergoing a paradigm shift as a result of the arrival of these new services. So far this change has been observed to be in favour of PT. The availability and growth of shared mobility services has been found to be complementary to PT services (Shared-Use Mobility Center, 2016). The latest addition to this transformation is the integrated mobility services, often referred as Mobility as a Service (MaaS). MaaS is a phenomenon for offering integrated transport services by bringing different transport providers together into a single mobile service (Jittrapirom et al., 2017). The first comprehensive definition of MaaS was given by Heitanen (2014, p. 27) as *"MaaS is a mobility distribution model where the transportation needs of individuals are satisfied by a service provider over a single interface"*. The provision of integrated mobility services by combining different modes, in particular PT with other modes, is also forecast to complement the traditional fixed route services, i.e. PT (UITP, 2011). Additionally, the successful implementation of an integrated service is also relied on by the available PT services (Li and Voege, 2017). Therefore, PT will continue to be at the heart of urban mobility.

To make PT more attractive and seamless for the passengers, travel information should be provided along with well developed services and infrastructures. As a key element of transport system, travel information has been improved over the time. The introduction of ITS brought significant improvement to travel information systems. ITS brings ICT and transport together to improve safety, efficiency of the service and traffic situation through transmitting real-time information. ICT uses computer hardware and software to convert, store, protect, process, transmit and retrieve information data (Monzón et al., 2016). ICT based measures, introduced by ITS, has made PT services more efficient as evidenced through the following literature review.

The concept of ITS was coined in the 1980s to deal with various traffic problems such as congestion. Major systems of ITS can be categorized into the following (Figueiredo et al., 2001):

- Advanced Traffic Management Systems (ATMS)
- Advanced Traveller Information Systems (ATIS)
- Commercial Vehicles Operation
- Advanced Public Transport Systems (APTS)
- Advanced Vehicles Control Systems

Among the above categories, commercial vehicle operation and advanced vehicle control are not discussed here. A description on these categories can be found in Figueiredo et al. (2001) and Stough and Yang (2009).

The initial motivation for the introduction of ITS was better traffic control and management by improving safety and reducing delay. Hence, Advanced Traffic Management Systems (ATMS) have been a fundamental part of ITS, which operate with different detectors (i.e. video, loop detectors) and incident control strategies to respond to traffic conditions. Data collected by ATMS is processed and disseminated through ATIS. The aim of ATIS is to provide real-time information to the travellers. Information provided through ATIS may enable the travellers to make choices (i.e. mode choice, route choice etc.) for a better journey. In recent times, ATIS is known as Real-time Travel Information (RTTI) (discussed in Section 2.2.4).

Advanced Public Transport Systems (APTS) is another system of ITS that was initially introduced to PT for better fleet management, such as using satellite technology for Automated Vehicle Location (AVL) and wireless communication or detectors for real-time tracking and monitoring of PT vehicles. Currently, ITS is applied to PT for various purposes, such as traffic control (e.g. PT priority), provision of RTPI, decision support systems for operators (i.e. headways, line suppression), e-ticketing and automatic passenger counting (Monzón et al., 2016). For passengers to make better use of PT systems, an updated Traveller Information System (TIS) was required. This led to the implementation of ATIS for PT passengers. The history of different ITS based information systems date back several decades and the current state-of-the-art includes URTPI, such as inter-modal journey planners, bus trackers (provides real-time location of buses) and on-board infotainment solutions with information about nearby points of interest. Apart from all these ATIS based information systems, crowd-sourced data such as big data, are getting popular day-by-day as potential sources of information on transport.

The following section discusses travel information systems and highlights the background and benefits of ATIS and RTTI.

2.2 Traveller Information Systems

2.2.1 Importance of Travel Information

Travel information is indispensable for the travellers to make any journey no matter what mode of transport they use or whatever the purpose of the trip. From a planners' as well as a researchers' point of view, travel information with alternatives is typically acknowledged as an effective travel demand management measure (Abdel-Aty and Abdalla, 2004; Gan et al., 2006; Khattak et al., 1996; Mahmassani and Srinivasan, 2004; Polydoropoulou and Ben-Akiva, 1998; Schofer et al., 1997). First of all, a traveller has to choose a mode along with a route. The information regarding the trip (i.e. mode and route choice) is not always known by the traveller, especially when making the trip for the first time. Even for an experienced traveller, the attributes of the known modes or routes are uncertain to a certain extent. Therefore, travel information is key to plan their journey or to make any changes. By having access to information regarding the trip, travellers are expected to make better travel choices, potentially leading to an efficient demand distribution over the network.

In general, travellers look for information about time, transfers (if needed) and price. Travel information helps them to manage time, modify trips, and reduce stress (Yim et al., 2002; Zhang et al., 2008). However, the way of using this information varies according to the type of traveller or journey. Deeter (2009) illustrates that a commuter performing local trips with a car uses travel information before departing from an origin. Their main concerns regarding information are traffic congestion on the route, impact of any incidents so that they can decide alternatives, and trip duration. On the other hand, a commuter travelling by PT has different needs for travel information. PT commuters need information on the services, such as bus or train arrival time, available alternatives services, ticketing systems, departure and alighting stops, etc. This shows the difference between the needs of two different mode users.

Again, inter-regional trip makers look for information regarding travel conditions at both the origin and the destination. Passengers travelling from one region to another expect uniform descriptions of traffic conditions for the whole route. In rural areas, response and clearance time is longer to any incident. Hence, rural travellers are interested in information on current and short-term weather forecasting as well as accidents or any other incidents. Planned or unplanned incidents, travel directions, and tourist information are also needed in rural areas. Therefore, travel information plays an important role in making travel choices. However, travel information may not resolve issues regarding service quality of any transport mode, neither can it change the perception of the passenger regarding those issues (Lyons, 1999). For example, if a particular PT service is delayed, information cannot minimize the delay; however, it may inform the passengers regarding the delay. Hence, information may highlight the disparity between different modes of transport to the passengers.

The benefits gained by travel information provision demonstrate their importance as an integral part of transport systems. For PT information, studies found the impact on passengers' satisfaction as well as on PT ridership. Reduction in passengers' perceived and actual time has also been observed (Dziekan and Kottenhoff, 2007; Watkins et al., 2011). In addition, an increase in PT ridership has been observed by Tang and Thakuriah (2012). Travel information for car users was also found to reduce travel time. A simulation study by Levinson et al. (1999) showed that an informed driver can minimize by nearly 100% an incident-induced delay by avoiding that route. The study found that travellers benefit is higher for non-recurrent congestion if they are willing to switch routes which may result in more effort and stress. A detailed discussion of the impact of information is presented in section 3.3.

Before discussing the state-of-the-art travel information, the evolution of travel information systems is presented in the following section.

2.2.2 From Traffic Information to Traveller Information

Following the last section on the importance of TIS, this section presents the evolution of TIS based on various studies carried out to date. Before the introduction of ATIS, TIS was available in static forms such as roadside signs, printed maps, timetables, etc. The necessity of changing these forms of information lies in the very well known problem of transport: the increase in transport demand due to urbanization. Increased traffic demand led to a more dynamic and complex transport network which requires integrated and updated information.

At the beginning of 20^{th}Century, car culture began to form in the UK and USA. A slow growth in car ownership was observed during World War II, though it recovered and began to rise sharply by 1950 (Auer et al., 2016). This continuous growth started to produce inevitable transport problems such as higher speed, congestion and safety related issues like accidents. Provision of state-of-the-art travel information has been an intrinsic part of dealing with these issues. To support this aim, research studies were dedicated to the development, implementation and impact assessment of this information.

Studies on TIS started back in the 1950s with driver information technologies. Since then, TIS can be categorized into two generations (Adler and Blue, 1998). Variable Message Signs (VMS) and Highway Advisory Radio (HAR) are recognized as first generation, whereas second generation refers to ATIS which provides dynamic route guidance, real-time traffic conditions and traveller service information. The information systems we use currently (such as URTPI systems or car navigation systems known as Sat Nav) are the improved version of second generation systems and can be termed as the third generation of TIS. Over the last six decades, traveller information has been improved as a part of greater interest and necessity in providing efficient transport systems.

The first generation of TIS was initially developed with one way communication systems to provide information on traffic conditions such as VMS and radio information. These systems were designed to inform travellers about non-recurring congestion such as special events or accidents. Therefore, information provided at that time mainly concerned the state of the road network. In the 1960s and early 1970s, large metropolitan cities in the USA started developing and testing technologies such as visual displays for traffic surveillance and real-time dissemination of information (Highway Research Board, 1971, 1973; Weinberg et al., 1966).

In addition to traffic information, the advancement of ICT made real-time monitoring of vehicles possible and information on vehicles such as position (i.e. location of buses), and route guidance were available for travellers. By the end of the 1980s centrally controlled, sophisticated VMS and HAR became common in many cities. However, VMS and HAR are one-way communication systems used to convey general traveller information to vehicles and the user had to search through the information to determine any particular action. To enhance the information services, in-vehicle route guidance systems were introduced in cars across the world. This enabled interactive communication where users could request information on routing. Some other features of second generation ATIS includes intelligent mapping, individualized path search, yellow pages directory, multi-modal information and dynamic route guidance (Adler and Blue, 1998). Yet, the information was typically based on historical data. Therefore, the information was not accurate in case of any unanticipated real-time events. Additionally, information was limited in terms of accessibility and content. In the following decades, the advent of the Internet made the information real-time and integrated. Information provided via Internet enabled the traveller to consult information for the whole journey and in real-time.

This introduction of the Internet along with Global Positioning System (GPS), led to a revolutionary change in TIS in the mid 1990s. In 1995, GPS achieved its full operational capability with 24 satellites, uniformly distributed in six orbital planes. Vehicle routing, vehicle location, transit locations at any position on this earth, became known with the implementation of GPS (Ochieng et al., 1999). Thereafter, both public and private internet-based ATIS have been expanded extensively. In the early 2000s, websites with travel information came into operation. The next significant change came into being with the availability of mobile devices, such as smartphones and tablets. Various mobile apps with respect to RTTI have been developed and are being widely used by travellers. Information is now available in real-time and can be accessed from anywhere and any time. Currently, social media platforms such as Twitter and Facebook are also being used by travellers as a potential source of travel information. The advancement of technologies has enabled us to get travel information at our fingertips. However, the main challenge for information providers is to provide suitable and accurate information so that travellers can easily use this information to make choices. Figure 2.2 shows the evolution of ATIS.

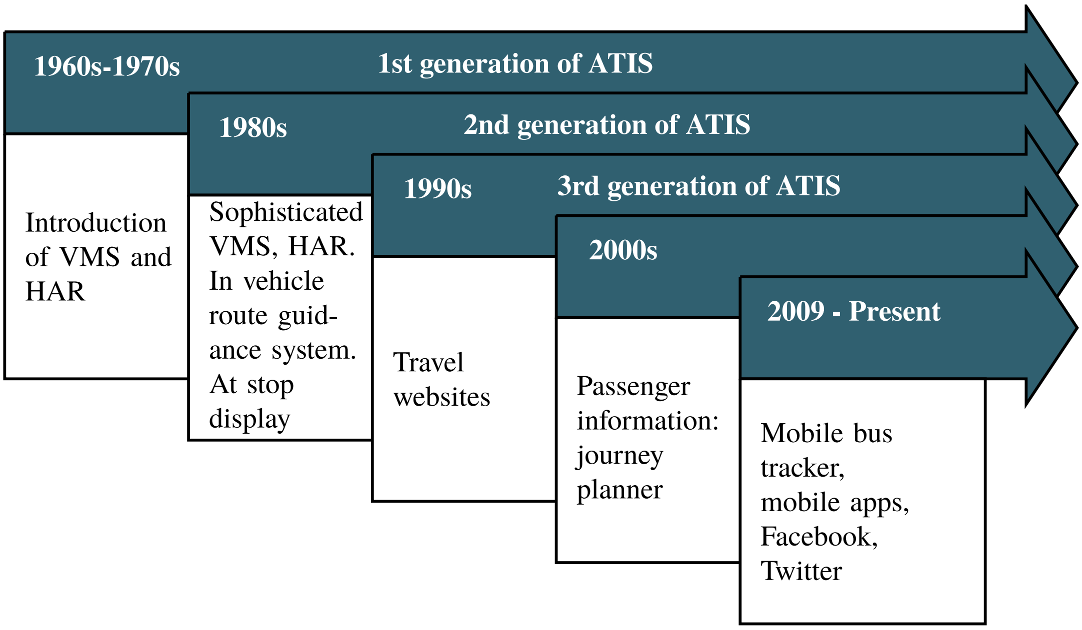


Figure 2.2 Evolution of ATIS

This study focuses on state-of-the-art passenger information which is remotely accessible, i.e. URTPI. Figure 2.3 shows the relationship of URTPI within traveller information systems for a better understanding of the terminologies. Section 2.2.3 discusses the introduction of ATIS and its benefits.

2.2.3 Advanced Traveller Information Systems

Following the last section, the introduction of technologies in information provision had given the name ATIS to travel information. ATIS is mainly used as the umbrella term referring to ICT based travel information systems. ATIS requires technological infrastructure for data collection, processing, and dissemination of the information. Different types of sensor technologies that monitor traffic conditions, such as inductive loops, video cameras, and laser detectors are used for data collection. GPS data is also used for locating vehicles. The data is then processed and analysed to extract the useful

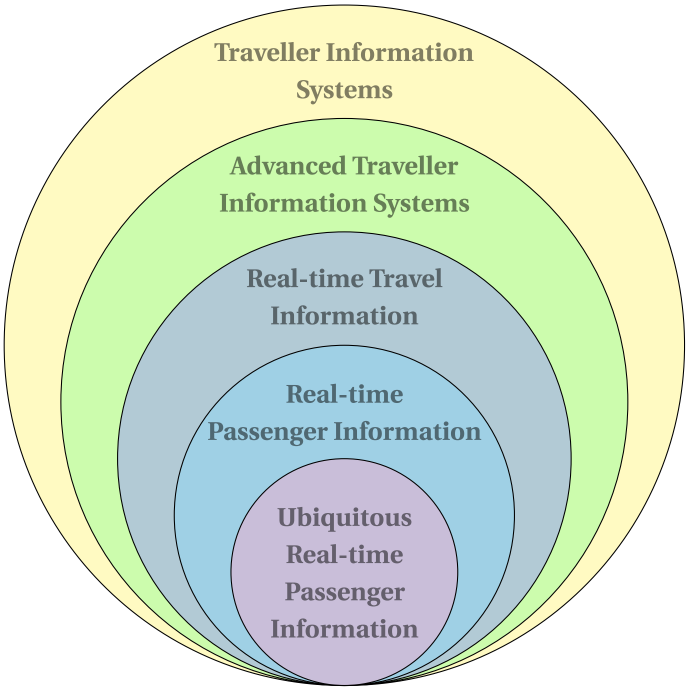


Figure 2.3 URTPI within Traveller Information Systems

information. Apart from data on route guidance or travel time, it may also include data on incidents, speed recommendations, or land use restrictions. The processed and analysed information are provided to the travellers through various platform such as HAR, VMS, telephone information services, Internet sites, kiosks with traveller information, personal data assistant-type devices, and in-vehicle devices.

Efforts have been made to find out the benefits of ATIS and information and navigation systems are found to have a positive impact on the travellers' journey. ATIS-based route guidance is found to reduce travel time both in simulation and field studies. Inman et al. (1995) carried out a field study with vehicles equipped with three different types of information. The first category of test vehicles was equipped with navigation with RTTI, the second category was equipped with navigation without RTTI and the third category had only printed maps with instructions. The study found 80% savings in planning time while the en route travel time reduction was modest. The study did not clearly identify the en route travel time reduction. Carter et al. (2000) reported the impact of ATIS as part of a project named San Antonio Metropolitan Model Deployment Initiative. The project studied the use of in-vehicle navigation deployed in 529 public agency-owned vehicles. The study illustrated that in-vehicle navigation could lead to an annual reduction of delays as a result of road incidents by 8.1%. Toledo and Beinhaker (2006) conducted a case study to quantify the travel time savings by ATIS. The study compared real-world travel time for different origins-destinations with computed shortest path (in terms of travel time) for those trips. The study results showed up to 14% reduction of travel time with the ATIS based routing. A simulation study by Florian (2004) showed up to 28% improvement in travel time for a low traffic demand scenario and 100% ATIS market penetration. For a high traffic demand scenario 50% ATIS market penetration works better and exhibited 12% reduction in travel time.

Since the introduction of ATIS, modelling and simulation studies have also been dedicated to the evaluation of the impact of information on traveller behaviour (Al Deek et al., 1998; Al Deek and Kanafani, 1993; Khattak et al., 1996). However, ATIS was available mostly for car drivers and much attention was given toward reduction in travel time and delay information during disruptions.

From the mid 1990s to mid 2000s, ATIS went through a transition due to the advent of the Internet. Therefore, the rising demand for travel information and the arrival of new technology signalled the inauguration of a next generation of ATIS, which was later termed as RTTI. In particular, RTPI started to become available for PT passengers. Nevertheless, the use of real-time information was found to be limited. In many cases, it was observed that available information sources were not being consulted by the travellers. Awareness of information services, travel contexts and individual characteristics were some of the factors behind the under utilization of information services (Lyons et al., 2008). In addition, the latter author highlighted that information may only be consulted for confirmatory purposes in case of familiar and predictable journeys.

The following section discusses the concept of RTTI and provides an insight into the available information sources.

2.2.4 Real-Time Travel Information

RTTI for Private Transport

RTTI may enable the private transport users to make informed route choice decision-making which could lead to reduction of travel time (Levinson, 2003). Private transport (i.e. cars) users may choose any of the available routes from origin to destination. On the other hand, PT passengers' route choice is constrained by the number of available alternative PT routes. Hence, private transport users have more flexibility to change routes during the trip compared to the PT users. On-board navigation systems serve private transport users with the most updated information on traffic situations. Other information sources such as mobile apps or websites are also available for the car users. The impact of this information on travel choices such as mode choice and route choice have been studied for years. Apart from the information, other factors related to the transport networks were also studied. Details of the studies are presented in the next chapter (sections 3.2 and 3.3).

RTTI for Public Transport

PT passengers receive information through different channels. RTPI got a new face with the arrival of smartphones. Information is available at our fingertips now. At stop displays, on-board displays, mobile apps, websites and radio information systems are the sources of RTPI. According to Dziekan and Kottenhoff (2007), the concept of real-time information systems for PT passengers started back in 1970s. One of the first AVL systems was installed by Chicago Transit Authority for providing passenger information (Forsyth and Silcock, 1985). Since 1977 and through the 1980s, Sweden was very active in this field. The first real-time information in Sweden was installed at a metro station in Stockholm in the 1980s. It used to provide estimated waiting time in minutes; indicates when a train was approaching and showed the destination of that particular train (Dziekan and Kottenhoff, 2007).

Over time, transport systems have become complex. Passengers need information to make more informed decisions when making PT journeys. Traditionally, travel time has been considered a major component of passenger information. However, Fonzone (2015) shows that expected arrival times at the destination are more important to the passengers. This implies that reducing travel time is not the only objective passengers intend to achieve when travelling by PT. The state-of-the-art passenger information enables passengers to accomplish their travel objectives by making choices with regard to the aspects of a journey (e.g. departure time, transfers, etc.).

RTTI for Integrated Transport Services

Travel information has been traditionally developed for mode-specific travellers. In recent times, multi-modal RTTI systems have become available. Although multi-modal RTTI services provide information on different modes (private or PT), the journeys with different modes are planned separately. With the arrival of new concepts of future mobility such as MaaS, traveller information services will have to be modified. The first integrated mobility app, "Whim", was introduced in Helsinki, Finland. An integrated platform of information is a prerequisite for the design of integrated mobility services (Jittrapirom et al., 2017). To design an integrated service and ensure the role of PT within the MaaS paradigm, it is important to understand passenger behaviour under the influence of RTPI.

This study concerns URTPI, therefore the following section presents and discusses the state-of-the-art URTPI sources.

State-of-the-art Passenger Information

Since the introduction of RTTI, researchers and developers strived to find the best possible ways to disseminate the information. Technological advancement has offered them the opportunity to make information available and easily accessible for passengers in several platforms. RTPI can be categorized into two types based on the location of access: location-specific and ubiquitous. Location-specific information refers to the sources available in specific places such as bus stop displays, travel shops and kiosks.

Providing displays in all the bus stops is costly and may not be justified for many transport authorities when considering the potential benefits and number of passengers (Čelan et al., 2017). Gammer et al. (2014) investigated the potential for providing information via QR codes located at the bus stops, where passengers can scan the QR code with a smartphone to consult information. They can then bookmark the web-link for the specific bus stop and revisit it when needed. To access this information passengers have to arrive at the bus stop at least for the first trip they are making from that stop. This way the information remains location-specific and provides limited information (i.e. information regarding that particular bus stop). Kiosks also provide RTTI for PT passengers and are considered an important source of information at transit hubs and tourist places (Kamga et al., 2013).

As mentioned above, the location-specific sources enable passengers to access information only on-site. On-site information is mostly descriptive, which refers to an account of the current or predicted conditions of network and services, such as arrival time of next bus, service disruptions, etc. To access location-specific information, passengers need to have prior knowledge about the point of access to information (i.e. bus stops, travel shops, etc.). In addition, consulting location-specific information enables making decisions only after reaching the point of access, hence, pre-trip planning is rather limited and solely depends on passengers prior knowledge. This warranted the necessity of implementing URTPI that can be accessed from any place at any time. To make RTPI ubiquitous, web-based PT information was developed and became available for passengers (Maclean and Dailey, 2001). AVL based prediction of departure time was available via web browsers and cell phones. However, the penetration rate of the Internet and devices (i.e. cell phones, computer) were very limited at that time. Hence, location-specific RTPI was available for all passengers. High growth of smartphone use and the Internet access made PT information accessible and gained popularity at the end of last decade. To date, URTPI is available on mobile apps and websites. URTPI is also available in social media pages (e.g. Facebook, Twitter).

PT information services are typically provided by the transport operators. Other sources of URTPI developed by private organizations (may be known as third party sources) are also available for the passengers. For example Google Maps, Citymapper are very well known URTPI services developed by third parties. Although these sources are developed by a third party organization, the data required for the development are typically obtained from local PT operators (i.e. AVL data). Hence, development of such URTPI requires data sharing which may also concern passenger user data. If AVL or user data is open to the public, the development of state-of-the-art URTPI by third party organizations would improve the information services for passengers. However, data sharing may raise issues regarding data privacy and security.

The URTPI sources not only enable travellers to access information remotely, but also provide both descriptive and prescriptive information (Parvaneh et al., 2012). Prescriptive information refers to the advice or alternatives suggested to the passengers based on computerised elaboration of descriptive information. For examples providing alternative routes based on travel time or number of transfers, etc. Personal features are also offered by URTPI, such as personalising the information service by bookmarking bus stops. This helps passengers to use URTPI more easily. Personalising information services is also considered to be crucial for providing URTPI (Schweiger, 2011). Additional information such as weather conditions or points of interest also inspire passengers to use information for PT. Information tailored with tools to search points of attraction, is believed to have potential to make passengers use PT if they have a flexible destination, such as going to a supermarket that has convenient PT connection (Watkins et al., 2010).

PT passenger information systems can be classified depending on the systems' characteristics. Figure 2.4 shows different characteristics to distinguish PT information systems.

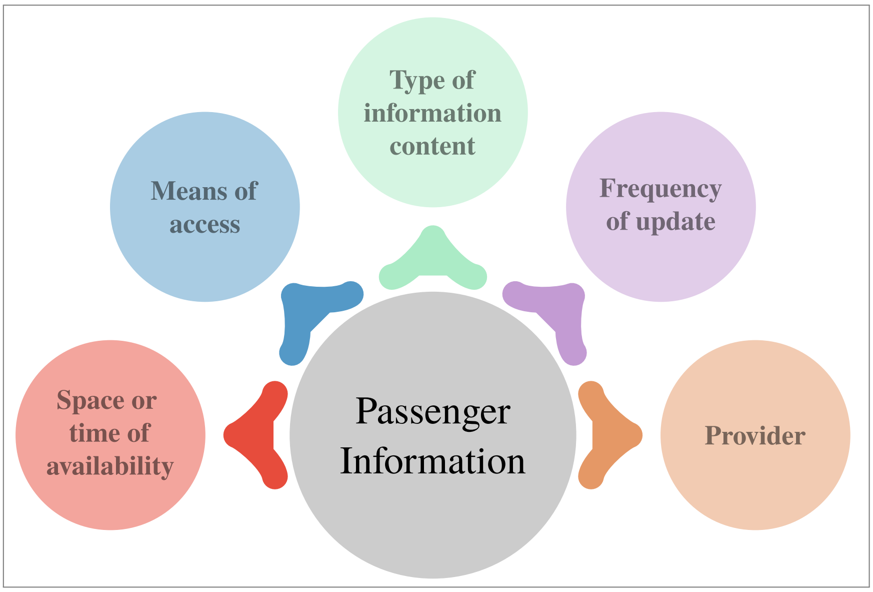


Figure 2.4 Passenger information attributes

Space or time of availability refers to places and time where passengers can consult information. For example, information from bus stop displays can be consulted when a passenger arrives at the bus stop. Based on the accessibility, information systems can be categorised into two groups: local and ubiquitous.

Means of access is the source where passengers consult information such as displays, websites, printed maps, etc.

Type of information content consulted by the passengers can be descriptive, such as arrival time of next bus or service disruptions and prescriptive information, such as providing alternative routes based on travel time or number of transfers, etc.

Frequency of update of information defines whether the information is static or real-time.

Provider of information indicates whether the information service is developed by an operator or a private organization. Based on these characteristics associated with PT information services, Table 2.1 presents a list of information services currently available for PT passengers.

This study concerns the use and impact of URTPI and some examples of different URTPI sources are presented here. Figure 2.5 shows an example of a mobile bus tracker app that provides only the arrival time of the next bus at a particular stop. Figure 2.6 displays a mobile journey planner which enables the passenger to get information on the arrival time of the next bus, plan a journey, and select a route from alternatives. Journey planners are available on websites as well, Figure 2.7 shows an example. Along with all the mobile apps and websites, Google Maps is popular among passengers as a source of travel information. Figure 2.8 shows the interface of Google Maps for planning a trip.

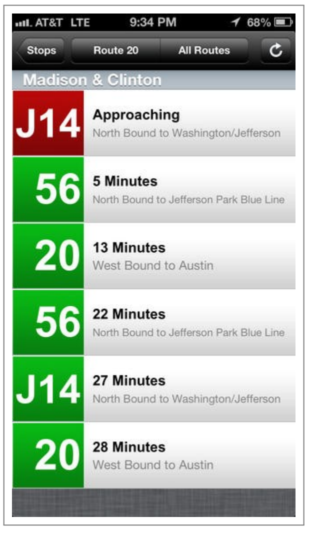


Figure 2.5 Example of a bus tracker app (Source: Chicago CTA Bus Tracker)

In many cities, multi-modal journey planners exist which enable the passengers to get integrated information of different PT systems such as bus, train trams or taxi

Table 2.1 Types of PT information systems

Name	Information content	Content type	Space or time of availability	Means/ Sources	Frequency of update	Provider
Printed timetables (at stop)	Bus departure time	Descriptive	Local	Document	Static	Bus operator/City council
Printed maps (at stop)	Bus route map	Descriptive	Local	Document	Static	
Online timetables	Bus departure time	Descriptive	Ubiquitous	Websites	Static	
Online maps	Bus route map	Descriptive	Ubiquitous	Websites	Static	
Electronic displays at stops, kiosks	Bus arrival time	Descriptive	Local	Display	Real-time	
Journey planner	Itinerary/journey planning	Prescriptive	Ubiquitous	Apps and Website	Real-time	Bus operator/City council/third party
Mobile bus tracker	Bus arrival time, location of bus stops	Descriptive	Ubiquitous	Apps and websites	Real-time	
Google Maps	Itinerary/journey planning	Prescriptive	Ubiquitous	Apps and Website	Real-time	Third party
Social media	Information on disruption	Descriptive	Ubiquitous	Apps and websites	Real-time	

services. Some journey planners also offer information integrated with private transport such as park and ride. In cities like London, Munich and Berlin, where different PT systems co-exist, integrated information systems are very much a prerequisite for a seamless journey.

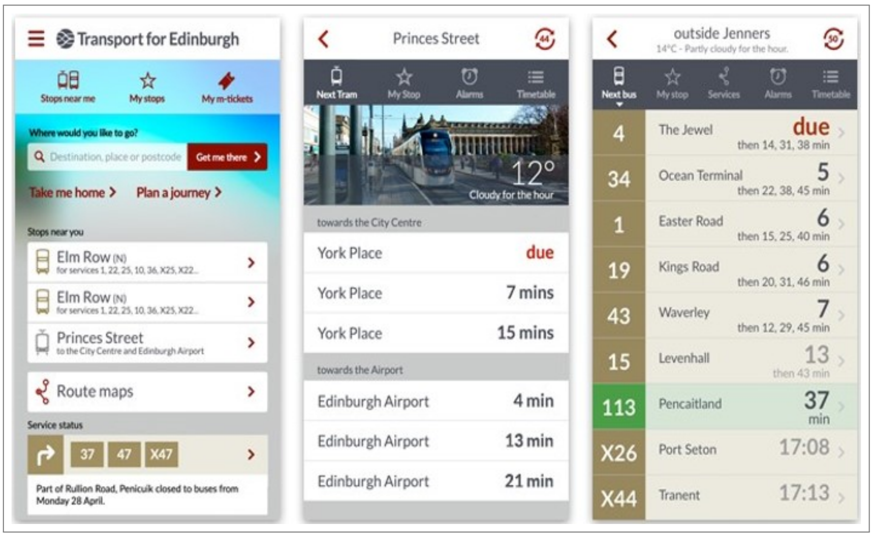


Figure 2.6 Example of a journey planner app (Source: lothianbuses.co.uk)

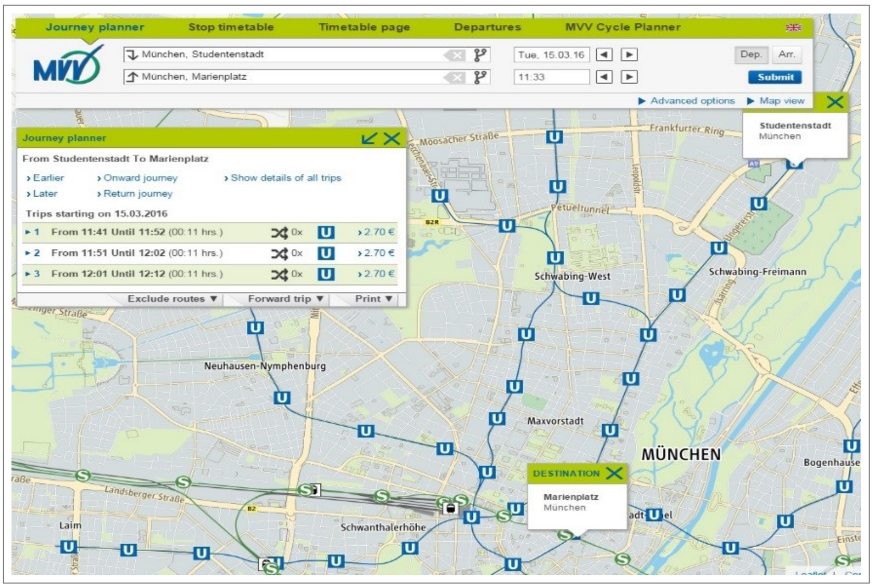


Figure 2.7 Example of a travel website (Source: mvv-muenchen.de)

Social media has occupied a huge room in modern day life. Apart from social networking, these platforms are being used for many other purposes (i.e. promotion, awareness, etc). Social media may also be used to search travel information and has been observed to be used for tourism (Chung and Koo, 2015; Xiang and Gretzel, 2010). Chung and Koo (2015) shows that information searches on social media are influenced

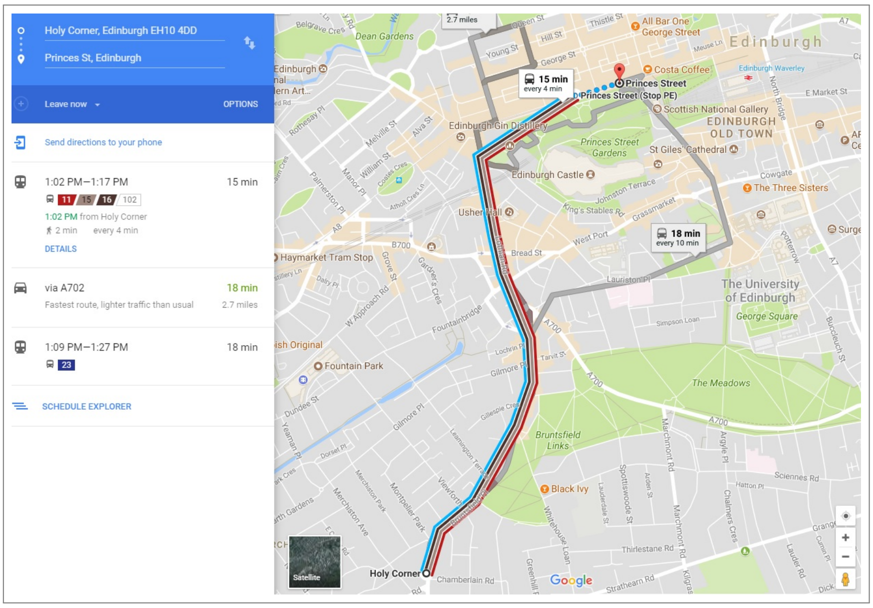


Figure 2.8 Google Maps journey planning interface

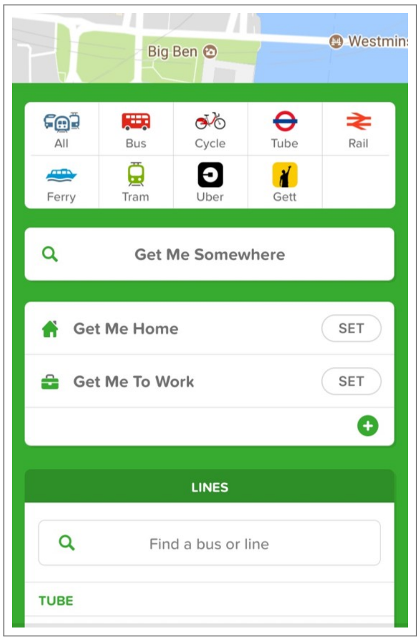


Figure 2.9 Example of a multimodal travel app (Source: citymapper.com)

by an individual's perceived value of social media, information reliability and level of enjoyment of the media. For PT information, the extent of consulting social media may be limited. In some cities, social media pages dedicated to travel information are available. If no designated social media page is available, travellers may get notified at least about any major disruptions as trending news.

This section illustrated how RTTI evolved for different modes and services over time. Studies dedicated to RTTI also changed over time. The following section presents the travel information research trend over time.

Table 2.2 Travel information research trend

Year	**Cars**			**PT**		
	Study aspects	Study method	Remarks	Study aspects	Study method	Remarks
1990s	Impact of ATIS penetration rate	Network modelling		Provision of information		
				Travel time savings	Path choice model	
1995	Route choice	Network modelling, behavioural studies with surveys		Need of information		
End 1990s	Route choice	Behavioural studies with surveys, Travel simulator experiments		Use of information		White paper in UK emphasised on the use of info
2000s	Mode choice	Behavioural studies with surveys, Travel simulator experiments	Introduction of multi-modal information	Use of information/need of information	Surveys	
2011	Route choice	Behavioural studies with surveys, Travel simulator experiments		Partial modal shift, impact on ridership and passenger experience	Surveys, Secondary data analysis	
				Impact of RTI on PT network	Network simulation	
2015	Route choice, travel time savings	Real-world/web-based experiments, surveys		Impact on RTPI PT passenger behaviour	Behavioural modelling	

2.3 Travel Information Research Trend

Studies dedicated to travel information, in particular RTTI discussed several aspects with respect to RTTI use and the impact of RTTI. Table 2.2 illustrates how research focus related to travel information has changed over time. It is observed that the use and impact of information has always been at the centre of research trends. Technological advancement such as the introduction of travel simulators made research possible under different traffic conditions, modes and users. For car users, route choice studies have been carried out since the mid 1990s. On the contrary, the earliest studies on PT information were focused on the provision of information. Few studies attempted to estimate travel time savings as a result of information provision. This may be because of limited sources as well as limited users of information available at that time. Due to increasing congestion levels in urban areas, UK transport policies (DETR, 1998) began to emphasise on the improvement of PT services and make it more attractive to the passengers. This led the studies to focus on PT information use in the late 1990s. In the early 2000s, this trend went on and studies discussed the use of information for different trip contexts. The arrival of new technologies led to the development of URTPI and the use of PT information increased considerably. Therefore, studies began to investigate the impact of information on PT ridership, and a potential modal shift. The impact of RTPI on a PT network has also been studied in simulation environments. The simulation studies found individual behaviour important in understanding the resulting impact of RTTI. Hence, research focus on the impact of RTTI on passenger behaviour came into being which is relatively new.

2.4 Summary

This chapter presented the background to this study. The role of buses as a major mode of PT has been discussed. The aim of this study is to understand PT passenger behaviour under the influence of URTPI. Therefore, a review of the different information systems was presented and URTPI sources were distinguished. Travel information was initially introduced to provide information on traffic conditions. Over time it went through changes and became traveller information which enables them to plan and execute journeys. This chapter also presented the existing RTTI sources for both private and PT users. Examples of PT information sources are presented and the information attributes were discussed to highlight the differences between the information services. Research trend on travel information shows that the impact of PT passenger behaviour with behavioural modelling is a relatively new area.

This study attempts to understand the impact of URTPI by means of investigating bus passengers' decision-making under the influence of URTPI. Hence, it is important to understand the role of information in decision-making. The following chapter discusses decision-making and reveals how individual's behaviour can be influenced. Literature review on travel information studies is also presented in the next chapter.

CHAPTER 3

Decision Making and Real-time Information

This chapter presents a review of the research carried out in relation to travel information and identifies the research gap regarding the impact of travel information on passengers' choices. The chapter starts with a discussion on decision-making process and emphasises the importance of real-time information for making decisions. The role of information in decision-making is highlighted as well as the aspects of passengers' decision-making that are influenced by information. Different decision-making theories related to this studies are then discussed. The chapter then reviews studies on the impact of real-time information and narrows down to the focus of this study, i.e. impact of information on passengers' choices.

3.1 Decision Making

Human life is inundated with decisions. In every step of life people have to make decisions, either big or small. Cognitive psychology analyses how people arrive at a decision (Anderson, 2015). Numerous efforts have been made to understand the decision-making process with theories and models being developed to support these efforts. This study deals with PT passengers' decision-making regarding route choice whilst utilising URTPI. Hence, decision-making theories could be useful to explain and understand passengers' choices. A review of the behavioural studies as well as decision-making theories is conducted to explore potential theories that could be applied in the context of PT passengers' route choice. This section presents an introduction on decision-making with information in general, and decision-making with RTTI in transport. A brief description is given on how individual's behaviour can be influenced and what the factors are that can influence behaviour. This review allowed the identification and decision-making theories that can be applied to understand passengers' behaviour under the influence of URTPI.

decision-making is typically categorized into two types: strategic and tactical decision-making. Strategic decision-making is also known as long-term decision-making, where the decision-maker takes steps that may not have an immediate effect, however will have an effect in longer term. For example, buying a car will affect the main mode of travel in the long-term. Tactical decision-making also known as short term decision-making, concerns an outcome that has immediate but short-term effects. The scope of this work is focused on passengers' choices when travelling with PT, which involves both strategic and tactical decision-making. Travel choices made by the PT passengers, such as departure time and transfers to other services may involve a tactical decision approach. A strategic approach is exhibited by the passengers when making route choice decisions (i.e. departure stops, bus lines) (Fonzone, 2015). In the context of this study, strategic and tactical decision-making are important to understand passengers' decisions when making PT trips after consulting URTPI.

3.1.1 Information and Decision Making

Impact of Information on Decision Making

In decision-making processes, information is considered as an important element of the decision support system. Hence, information helps individuals' to make better decisions. However, decision quality is bounded by the cognitive limitations of the decision makers. Existing literature on behavioural decision-making suggests that sometimes individuals are more concerned about conservation of effort than proving the decision quality. This implies that using decision aids such as information would improve the ease of making decisions by reducing their effort rather than maximising the decision quality (Todd and Benbasat, 1992). This phenomenon could be observed when a decision does not have a long-term significant effect on their life.

The role of information becomes more important when decisions are to be made in a dynamic environment (Gonzalez, 2004; Kerstholt and Raaijmakers, 1997). Transport network is a dynamic environment, hence, travel information plays a significant role in travellers' decision-making. Information assists travellers to make mode choice, route choice or to reduce their efforts (Lyons, 2006).

Information Search

The world is witnessing an ubiquitous and rapid change of technologies; in our societies as well as in business. New technologies enable people to access or receive information on literally any matter. The availability of information has made learning and decision-making much easier. People often make Internet searches about current news or events (Kruikemeier et al., 2014), health (Kammerer et al., 2013) and consumer goods (Darley et al., 2010). This information then influences their decision-making process as well. Either individual (Roscoe et al., 2016), entrepreneurial (Frishammar, 2003) or military (Ahituv et al., 1998) decision-making, information is vital.

Information search behaviour has been studied mostly in psychology and one of the key studies was carried out by Peterson and Merino (2003). The author proposes that the number of physical sources (i.e. newspaper, TV, radio, etc.) of information consulted by the consumer will decline over time. Therefore, the availability of multiple sources of information will not eventually increase the use of all sources by the passengers. In addition, the amount of information consulted by the passengers for decision-making is also limited by their cognitive abilities as well as the decision makers objectives (Todd, 2007). This suggests the necessity of understanding the extent of use of URTPI sources. Additionally, Peterson and Merino (2003) proposes that consumers search for information with a definite goal, will lead them to focus more on the attributes of information but less on the brand of information. Conversely, behavioural economics indicates that individuals generally put importance on the messenger (where information comes from) as well as the information content (Metcalfe and Dolan, 2012). In the context of travel information use, sources or provider of information (i.e. the developer or authority who provide the system) could therefore be an important factor. Maréchal (2016a) investigated the use of information by the PT passengers in London. The study reveals that passengers are more likely to use mobile apps if they put more importance on the provider of information than the content of the information. This may happen because passengers are ignorant about the quality of information from different sources or they have not found any substantial difference in the quality of information from different sources. However, it is not clear how much passengers are concerned regarding the providers, i.e. whether an app is developed by the local PT authority or a third party.

The following section discusses how real-time information affects decision-making from a psychological point of view.

3.1.2 Decision Making with Real-Time Information

The success or outcome of a decision depends on the information. Updated or real-time information is essential in such situations. The importance of real-time information is highly realized in dynamic and uncertain environments, where only real-time data can provide decision makers with such relevant knowledge (Delic et al., 2001). Hence, real-time information can be used in avoiding uncertainty and optimizing solutions. Decision-making in areas such as business, marketing, industrial production, economics and transport are exposed to dynamic and changing environment. For example, in air traffic control, large amounts of real-time information is needed for decision-making to ensure an efficient and safe operation (Allen, 2008). In the context of business, real-time information provides timely support to the decision makers. Real-time information is crucial for decision-making in a dynamic environment such as transport systems as traffic conditions changes both temporally and spatially. Hence, travellers have to be provided with the most updated information to allow them make safe, efficient and sustainable travel decisions.

The benefits of real-time information in transport would accrue in terms of economic, societal, personal/psychological, safety, and environmental benefits. For example, real-time parking information would help the drivers to find a parking space easily thus reducing their search time (Caicedo, 2010). This results in lower carbon emissions as well as improved parking management capabilities by the local authority. Use and provision of real-time information for the travellers is a significant method adopted by the transport providers to make services attractive and efficient (Cebon and Samson, 2011). The impact of this information has been found to be meaningful in several aspects including psychological, effects on ridership and travel behaviour (Lappin and Bottom, 2001; Skoglund, 2014). Travel behaviour is associated with decisions such as which mode, what time and which route passengers should choose. To make these decisions in the best possible way and outcome, real-time information is very significant. Real-time information for transport users is already in practice and has gained popularity in making trips. However, passenger's decision-making with information is influenced by several other factors. Some of the well-known factors are past experience of loss or gain (Juliusson et al., 2005), cognitive bias (Stanovich and West, 2008), age and individual differences, belief in personal relevance (Acevedo and Krueger, 2004) and escalation of commitment (Bazerman et al., 1984). The following section explores how an individual's behaviour can be influenced and singles out the factors relevant to travel information use.

3.1.3 How Individual's Behaviour Can be Influenced

Human's decision-making is shaped by their sub-concious mind as well as their concious one. Dolan et al. (2012) presents a synthesis of the different factors that influence an individual's decision. The study presents mnemonic MINDSPACE cues that affect individual's behaviour. These cues are reviewed to understand the relevant factors that can be used to explain the use of URTPI. However, given the time limitations and scope of this study, it is not possible to investigate all of the MINDSPACE cues in depth, but a review of the cues would provide an insight into the factors that are relevant to URTPI use (Table 3.1).

Table 3.1 Mnemonic MINDSPACE cue (Dolan et al., 2012)

MINDSPACE cue	Behaviour
Messenger	Individuals are strongly influenced by who communicates information to them
Incentives	People's response to incentives are shaped by predictable mental short-cuts such as strongly avoiding losses
Norms	Individuals are strongly influenced by other people's activities
Defaults	People 'go with the flow' of pre-set options
Salience	Individuals' attention is drawn to what is novel and seems relevant to them
Priming	Individuals' acts are often influenced by our sub conscious minds
Affect	The emotional associations can powerfully dominate individuals' actions
Commitments	People seek to be consistent with their public promises and reciprocate acts
Ego	Individuals act in ways that make them feel better about themselves

Messenger is the source of information. In the context of URTPI use, messengers are the provider of information. As of today, there are several media and other sources of information available. Hence, passengers preference for a particular app or website might be dictated by the provider (i.e. PT authority or third party).

Incentives inspire or motivate people thus influencing an individual's behaviour. The noted economist Landsburg (2007, p. 3) stated that - *"Most of economics can be summarised in four words: People respond to incentives." The rest is commentary*. In economics, incentives are any factors that motivate or inspire an individual to take an action (Ryan and Shinnick, 2010).

Norms represent the social and cultural rules or behavioural expectations upon an individual. Human behaviour is influenced by the surroundings, the environment we are in or the people we associate with shape our decisions as well. Behavioural theories also addressed this effect on individual behaviour, such as the Theory of Planned Behaviour (TPB) (Ajzen, 1985), which will be discussed in section 3.1.4. Therefore, opinions of other people might affect the use of URTPI sources. Gaker et al. (2010) find that car ownership is strongly influenced by social norms. In addition, passengers' perceived behavioural control may influence their choices after consulting URTPI. Hence, in the context of this study the effect of norms on the use of URTPI and its impact on passengers' choices will be considered.

Defaults sometimes make individuals opt for pre-set options or habitual behaviour. Hence, people who do not habitually use travel information may not consider using URTPI. Farag and Lyons (2008) and Verplanken et al. (1997) confirm that as habit strength (of non-use) increases the likelihood of consulting information decreases. This also happens in the case of mode choice and route choice as well (Aarts and Dijksterhuis, 2000).

Salience refers to the quality of being important or connected to what is happening around us. Individual's behaviour is also influenced by events or matter their attention is drawn to. People's affinity towards technology and technology-based solutions would be an example of salience. Lots of mobile applications or devices draw people's attention through promotions or other events. This would influence people's choices with regard to adopting those promoted solutions.

Priming shows that people's behaviour may be influenced by their previous exposure to certain experiences. For example, individuals cycle faster after they have watched a cycling race on TV (Dijksterhuis and Bargh, 2001). Hence, the sub-conscious mind shapes individual's behaviour.

Affect is the act of experiencing emotions which influence an individual's decision-making. Emotional responses start taking place automatically before cognitive evaluation takes over.

Commitments also shape an individual's behaviour. An individual tends to be consistent with public promises. For example, people who are more environmentally concerned would tend to travel less with cars. An experiment on route choice for recreational trips by Gaker et al. (2010) reveals that participants tend to choose the route with less environmental impact, albeit it may have higher travel time or cost. This suggests that information on environmental impact may influence people towards sustainable travel patterns.

Ego is what people think about themselves. People act in way that makes a positive impression to themselves. Hence, self-esteem or self-image would inspire people to give up smoking if they perceive it as an improvement of their image. In the context of travel information, use of information on smartphones may be perceived as positive to self-image. This may lead to a higher likelihood of using URTPI.

3.1.4 Decision Making Theories

Traditionally, decision-making is described with Rational Choice Theory. Rational decision-making suggests that consumers tend to maximise their utility by estimating and comparing the cost and benefits of all the available options (Adjei and Behrens, 2012; Doyle, 1999; Simon, 1955). However, complete rationality requires unlimited cognitive abilities which is rather unrealistic for human beings. Therefore, actual decision-making may not involve fully rational choices. To explain what the decision makers do in reality, descriptive decision-making theories are developed (Dillon, 1998).

Decision-making theories have been applied to understand travel behaviour and some of the most well known and widely used are TPB, Satisficing Theory, Image Theory and Prospect Theory. This study focuses on understanding the use of URTPI and its impact on passengers' choices. A review of the theories show that passenger behaviour is influenced by their attitude and intention, which is explained by the TPB. In addition, decision-making is influenced by the objectives of decision makers, i.e. the extent to which they would improve their decisions. Fonzone and Schmöcker (2014) find that decision-making objectives can lead the passengers to different route choice decisions. This study investigates the factors that influence passengers' attitude and intention with regard to the use of URTPI and route choice, being inspired by the TPB and Satisficing theory.

Theory of Planned Behaviour

The TPB is one of the most prominent and best-supported social psychological theories for predicting human behaviour. The theory postulates that behavioural decisions are the result of a reasoned process in which behaviour is influenced by attitudes, norms and perceived behaviour control (Ajzen, 1985). TPB is derived from the Theory of Reasoned Action because of limitations of the original model in dealing with behaviour over which people have incomplete volitional behavioural control (Ajzen, 1991). Perceived behavioural control refers to the perceived difficulty or ease of performing a specific task. TPB has been used to understand traveller behaviour and theories and models originating from this, such as Extended Model of Goal-directed Behaviour (EMGB) have been used in travel behaviour studies. A study by Farag and Lyons (2009a) applied EMGB to investigate the impact of people's intention, attitude and subjective norms on travel information use. The latter study analyses household survey data and finds that people's desire to consult information for an uncertain journey is affected by their attitude, subjective norms, past experience, and perceived behavioural control. A schematic representation of TPB is presented in Figure 3.1.

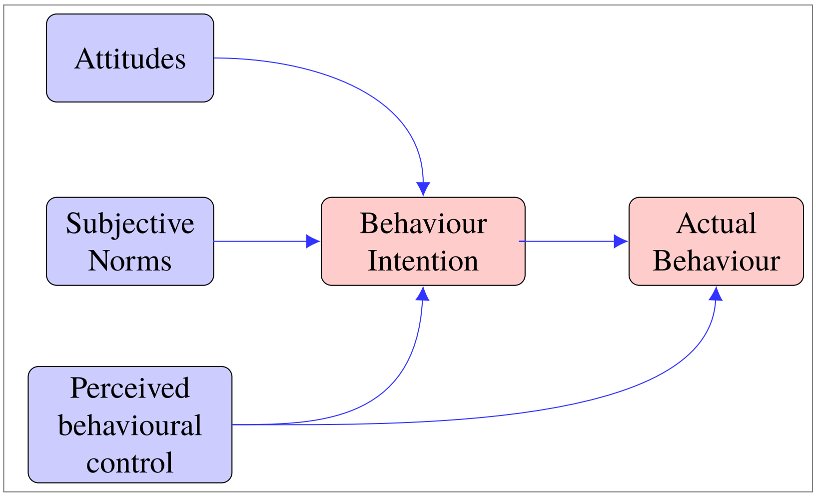


Figure 3.1 The Theory of Planned Behaviour (adapted from Ajzen, 1991)

The TPB has been widely used for understanding the use of information systems and technology adoption (Lu et al., 2009; Lynne et al., 1995; Mathieson, 1991) as well as travel behaviour (Thorhauge et al., 2016). Therefore, the TPB could also be used to investigate the use of travel information (Kempton, 2015). In the context of this study, TPB can be used to understand how passengers' attitude is influenced, which eventually influences their decisions.

Satisficing Theory

The first descriptive theory[1] on record is Satisficing Theory, which is linked to the idea of bounded rationality. This theory posits that the decision makers choose an alternative that exceeds some criterion or standard, they do not optimise in general. Therefore, Satisficing Theory is relevant to travel choice decision-making as passengers may not try to maximise in all the aspects of a trip and rather look for specific criteria to be

[1] Descriptive theory describes what people actually do in reality.

fulfilled. Travel information users might also exhibit this behaviour. Lyons (2006) states that PT passengers may look for information that meets their satisfaction rather than looking for the best alternative available. In this study, Satisficing Theory is adopted to investigate passengers' trip optimisation strategy (discussed in the next chapter, section 4.5).

This section has discussed the decision-making process with real-time information. In the context of this study, the factors that may influence passengers' behaviour were explored. A review of the decision-making theories is presented and in particular the TPB and satisficing theory have been discussed. The next section presents a review of the existing studies relevant to the use and impact of real-time information.

3.2 Use of Real-Time Travel Information

Since the introduction of RTTI, there has been a growing concern about the extent of use of information. The extent of use of RTTI refers to the number of travellers who have access to RTTI as well as who use information (either for confirmatory or planning purpose) for making trips. Lyons (2006) states that travel decisions could be made in three different ways. Firstly, 'unconscious' or habitual decisions that requires little or no travel information. Secondly, travel decisions could be confirmatory, e.g. double checking the bus arrival time before departing from an origin. Lastly, decisions could also be made by assessing the available alternatives. The latter study indicated that the demand for information is rather limited and mostly consulted by the passengers for confirmatory reasons. However, limited accessibility (i.e. location-specific), inadequate accuracy, and lack of awareness of information might limit the use of RTTI, especially in the last decade. To understand the use of information, studies have looked into different factors that influence the use of information.

Peirce and Lappin (2004) investigated six potentially influencing factors on the use of traveller information (both ATIS and conventional sources such as radio traffic report) by analysing self-completed travel diary data from Seattle, USA. The factors evaluated were: regional context (i.e. network conditions), awareness of sources, trip context, information quality, presence of delays and delay information, and availability of alternatives. The findings, related to trip context, socio-demographics and information characteristics, are presented in the following sections. In the context of ATIS, the latter study found no impact of traffic congestion or diffusion of technologies on the adoption rate. The study findings are limited however, as most of the trips were either off-peak or not time-sensitive (i.e. supposed to reach the destination in a certain time). Hence, for the findings regarding trip context, alternatives may not be valid because of the skewness of the data. In addition, the study could not confirm that the need for information as a result of increasing congestion and availability of new methods of access (advent of new technology) would inevitably raise the use of ATIS. A more recent study reveals that the frequency of using RTTI is higher when travellers face higher levels of road congestion (Petrella et al., 2014). This indicates that the use of travel information has changed over time. The developments of new methods of access to information as well as the rise in complexity in transport networks may have increased the necessity of consulting information.

In terms of mode choice, the need for travel information by car and PT users has been distinguished by Chorus et al. (2007b). The study presents the results of a web-based survey and reveals that car and PT users need for information are different depending on the type of information and familiarity of trips. Car users appear more resourceful (i.e. aware of alternative routes, confidence regarding the attributes of alternatives) than PT users when making familiar trips. In addition, they need more time-related information for making familiar trips compared to PT. Opposite results are observed for unfamiliar trips, i.e. PT users are more resourceful and need more time related information compared to car users. This demonstrates that the need for information varies depending on the travel mode. Hence, it is important to understand the user behaviour in the context of different modes as well. Studies began to focus on the use of RTPI for PT passengers in late 1990s, albeit, compared to car users less attention was given to study the use of PT information. In the initial stages of PT information research, researchers found that most of the passengers do not use information for making bus journeys in the UK (Balcombe and Vance, 1998) and only 7 to 11% of the passengers found information important (Vance and Balcombe, 1997). This emphasises the need of understanding the demand for information depending on the mode of travel (Lyons et al., 2001).

It is observed that the use of travel information varies depending on many factors associated with trips, modes or services and information. Existing literature highlights different factors that drive or hinder the use of travel information. The influencing factors can be categorized into three main groups:

- Socio-demographic characteristics: This concerns travellers' characteristics such as age, gender, income, profession, education, etc.
- Trip characteristics: This includes the characteristics of the trip for which travellers consult information. Trip characteristics concerns duration of trip, time of day, trip purpose, alternative modes or routes, etc.
- Information characteristics: This is a major concern for the growth in adoption rate of information and may include cost of information, ease of use, accuracy, etc.

The following sections discuss the studies on the factors affecting travel information use. Existing studies are categorised according to the context of study, i.e. car users and PT users to show that studies are biased towards car users and there is knowledge gap for PT.

3.2.1 Influence of Socio-demographics

Car users

Historically, studies on the use of travel information have been skewed to car users. Literature on travel information for car users highlighted lack of awareness, socio-economic characteristics, travel context and information characteristics as the influencing factors for ATIS use. One of the earliest studies by Polydoropoulou et al. (1997) used survey data to model the user adoption rate of ATIS. The study developed a statistical model to understand the effect of travellers' attitude and awareness of conventional information sources on ATIS adoption. The study found that travellers' awareness of the information services and willingness for trial use were drivers for higher adoption of ATIS. In addition, willingness for trial use was found to be dominated by perceived importance of information. In the initial era of ATIS, information was available via limited and specific channels and the acquisition of information was associated with mode and monetary cost. Hence, travellers' perceived importance of information would lead to trial use which would increase the adoption of ATIS. However, the latter study did not discuss travellers' socio-economic characteristics which might play a vital role in stimulating the use of ATIS.

Demographic characteristics of the traveller are mainly age, income, profession, gender, and education. Lack of awareness has been considered as a barrier to travel information use with awareness of information being shaped by individual and household characteristics (Peirce and Lappin, 2004). Goulias et al. (2004) studied awareness as an influencing factor for the use of ATIS by analysing data from a household travel diary. The study results show that decrease in car ownership leads to a lower likelihood of awareness. In addition, a decrease in number of driver's licenses in a household, increases the probability of awareness. The study also finds travellers' age inversely relates to awareness of information, i.e. older people are less aware of information.

Petrella and Lappin (2004) assessed the characteristics of the users of ATIS in two cities: Los Angeles and Seattle. An online self-completion survey data was analysed and the study results found gender, education and income are determinant for the users of ATIS. The study finds that male, highly educated, employed and younger participants are more likely to use ATIS.

On the other hand, Okazaki and Hirose (2009) observed that female participants are more interested in using mobile Internet when gathering tourist information. The study presents gender effects in tourist information searches by conducting an online panel survey in Japan. The study demonstrates affinity of female travellers towards active mobile Internet use as an indication of interest on a diverse range of information. Albeit, acquisition of travel information for local trips may be different than acquiring tourist information, this could be an indication of female travellers' inclination towards information available on smartphones. In addition, Okazaki (2004, 2007) demonstrates that female travellers are more inclined to use mobile Internet. This may lead to a potentially higher likelihood of using URTPI.

Studies by Wang et al. (2009) and Wang and Khattak (2013) with data from a household travel survey show the influence of income, age and car ownership on the access and acquisition of travel travel information. The studies observed that travel information acquisition is positively related to household income, younger residents and number of vehicles owned. The study findings on the factors are limited in the context of ATIS because the study area had less mature ATIS. Hence, the latter study would be valid for areas that are under-served by ATIS.

A study by Tsirimpa (2015) presents an analysis of stated and revealed preference data collected by a survey. The study modelled the acquisition of RTTI and their impact on travel choices for car users. The study findings illustrate that age, income, and profession of the traveller have an influence on information consulted from mobile devices. Age of passenger is negatively related to consultation of RTTI, whereas income is positively related to the likelihood of consulting information from mobile devices.

Familiarity of the information services is also an important factor for travel information acquisition (Peirce and Lappin, 2003) and travellers only access information which they are familiar with. Familiarity of information is dictated by individual characteristics such as willingness to consult information and age.

Travellers' knowledge of the network is also considered influential on the use of travel information. A literature review of ATIS studies by Chorus et al. (2006) mentioned that travellers are more likely to consult information regarding alternatives they are familiar with or used in the past (Polak and Jones, 1993; Srinivisan et al., 1999; Van der Horst and Ettema, 2005). Therefore, the number of known alternatives affects travellers use of information and choices. This might be a consequence of the availability of descriptive information only for any particular route (i.e. delay or travel time). Travellers needed prior knowledge about the available alternatives to search related information. A travel simulator experiment by Chorus et al. (2007a) reveals that knowing more alternatives deters travellers from accessing an ATIS service that generates alternatives. However, familiarity with the alternatives leads them to consult for information on the attributes of the alternatives. This indicates that familiarity of the alternatives relates to the consultation of descriptive information, whereas, unfamiliarity would lead travellers to consult prescriptive information.

Zhang et al. (2015) studied the demographics of the potential users of pre-trip travel information in Zhongshan Metropolitan Area, China. The study analysed data collected by a household survey and reveals that about three-quarters of the potential users are male. Income is also found to be positively related to the use of pre-trip information. Working groups of travellers show more interest whereas non-working groups, such as students and retired people, show less interest in consulting information. However, the study only looked into potential users and the actual users of pre-trip information are not identified.

PT users

The factors discussed for the car users are also found to be influential in the context to PT information use. A social-psychological theoretical framework was proposed by Farag and Lyons (2007) to address the barriers to PT information use. The study reported that barriers to the adoption include lack of awareness, inadequate quality of information, habit, and lack of reliability of information. The authors applied Attitude Theory to investigate the association of these factors in another study (Farag and Lyons, 2009a). The latter study carried out a postal household survey in Bristol and Manchester, UK, and captured participants' use of PT information for an uncertain journey. The structural equation model results reveal that factors related to information and socio-demographics do not have significant influence on PT information use. The study finds that preferred mode is a key driver for PT information use for planning an uncertain journey, i.e. if the preferred mode is PT then they are more likely to consult PT information. The study also observed the effect of positive attitude, subjective norms and past behaviour as drivers of PT information use.

Farag and Lyons (2008) also investigated the consultation of pre-trip information by conducting face-to-face interviews and focus groups in Bristol, UK. The study highlighted that social-psychological factors such as perceived behavioural control or past behaviour drive the consultation of pre-trip information. Demographics of the passengers shape these social-psychological factors. For example, younger people find it easy to obtain information from the Internet thus, passenger demographics is an important factor for the PT information use. However, the study only considered age and gender as demographic factor; other demographic factors such as education and profession might also be influential social-psychological factors.

Lack of awareness of information availability has been found to dictate the use of PT information, especially for a newly implemented system. A study on the use of real-time bus stop displays in London showed that even after one year of deployment about half of the passengers were unaware of the system (Hardy, 2012). Hence, lack of awareness of information hinders the growth in use of information.

Rahman et al. (2017) studied bus users' attitude toward a newly implemented real-time information system. The study focused on all available sources of access to real-time information (such as websites, apps, SMS, etc.) and carried out an online questionnaire survey. The survey reveals that male, high-income and infrequent commuters are more likely to be unaware of the current real-time information. In addition, females and low-income earners are found to be more likely to use RTPI. This demonstrates the influence of socio-demographic characteristics on the awareness of RTPI services. It was discussed in the previous section that for car users Petrella and Lappin (2004) found male, high income earners more likely to use ATIS. Therefore, contradictory results may indicate the difference between use of information by car and PT users or may show the change in use of information over time. Although, the latter study investigated factors affecting the frequency of use of RTPI, the author did not include trip characteristics in the model which is also one of the drivers of using RTPI.

Harmony and Gayah (2017) illustrate that demographic and socio-economic status might have influence on passenger's preference of PT information. The study conducted online surveys to investigate demand and supply of RTPI in the USA and observes that socio-economic and demographic factors influence the demand for information. In addition, the study finds that the evaluation of impact of RTPI by self-reported surveys may vary across different PT modes users (i.e. buses, trains, etc). However, it was not revealed which demographic characteristics influence the actual use of RTPI. Maréchal (2016b) collected PT information user data in London by means of a questionnaire survey. A discrete choice analysis shows that passengers' age, income and Internet use as influencing factors for choosing the type of media. The study reveals the impact of demographics on information acquisition under service disruption. Female passengers are less likely to gather information while commuters with higher education are more likely to look for travel information and change travel choices. A study on the same data set shows younger people and male commuters with an impatient attitude are likely to consult information during service disruption (Maréchal, 2016a). Both of the latter studies presented by Maréchal were carried out under disrupted service conditions. Hence, the influence of demographics on the consultation of URTPI in a regular service condition is not known yet.

3.2.2 Influence of Trip Characteristics

Car users

Factors associated with trip characteristics have been found to influence the use of RTTI by car users. Trip length has been found to be a dominating factor both for pre-trip and en route acquisition of ATIS (Emmerink et al., 1996; Lappin, 2000; Targa et al., 2003; Wang et al., 2009; Yim et al., 2002). In another study, Wang and Khattak (2013) find that when travel time is longer, the possibility of information acquisition is higher regardless of the trip purpose. Peirce and Lappin (2004) also observe that acquisition of information is tied to trip duration. For longer trips, higher levels of consultation of information were observed. The study also finds that time of day is an important factor for travellers to consult information. The purpose of the trip is another important trip characteristic. Time-sensitive trips are always in the lead position to drive the use of information. However, trips that are made regularly such as commute trips are found to inspire consultation of ATIS. Business trip makers are found to be likely to use travel information because of their higher value of time (Emmerink et al., 1996). In addition, Chorus et al. (2005) find that when making business trips, travellers place more importance on the travel time variability whereas for non-business trips the emphasis is on mean travel time. Familiarity with trips is found to dictate car users need for information (Chorus et al., 2007b). The latter study finds that car users exhibit a higher need for information when making trips to places they never visited before compared to frequently made trips. Therefore, familiarity with the trip and availability of alternatives, i.e. modes or routes, lead the travellers to consult information.

PT users

Caulfield and O'Mahony (2007) investigated PT passengers preferred information at different stages of a trip (i.e. pre-trip, at stops, on-board) in Dublin by conducting an online survey. The study demonstrated that about 60% of the participants used one source of travel information and methods of acquiring information (i.e. displays, printed maps) depends on the purpose of the trip. For example, for work to home pre-trip information passengers prefer the Internet for consulting information. The study also did not look into the drivers or barriers for each information service (such as the Internet, printed maps, etc.).

Trip characteristics have been identified as external factors that influence determinants (i.e. social-psychological factors) of pre-trip PT information use (Farag and Lyons, 2008). Again, Farag and Lyons (2009a) demonstrate that consultation of PT information depends on the trip characteristics for uncertain trips. However, in another study, the latter authors find that for unfamiliar trips and long distance business and leisure trips (more than 50 miles), trip purpose does not dictate the use of information (Farag and Lyons, 2009b). In addition, the study suspects that the use of PT information might be driven by individual's intention rather than trip characteristics. The study was carried out for long-distance trips, hence, it is not understood whether the trip purpose would affect the PT information use for local trips.

Typically, PT information studies focus on how the use of information may affect passengers' experience which would potentially encourage them to use PT services more frequently. However, Farag and Lyons (2012) argue that PT use affects the use of PT information more strongly than vice versa. This implies that passengers who already use PT would be more inclined to use PT information. This phenomenon was also verified in a study of the passengers who had a car available for making a trip (Farag and Lyons, 2010).

3.2.3 Influence of Information Characteristics

Characteristics of information services have also been considered as one of the influencing factors for the use of services. Information quality is one of the main characteristics of information that drives the use of ATIS. Quality of information typically refers to reliability, timeliness (update frequency), medium of access and coverage. Chorus (2007) finds that the success of travel information services is dependent on their ease of use and efforts needed to consult information. Therefore, characteristics of information may influence the use of information.

Car users

The introduction of ATIS brought a new medium of access to information. The availability of those information sources is subjected to monetary cost. Hence, the cost of information is important in driving the use of ATIS.

Information quality is acknowledged as an important factor for the use of information. Chorus et al. (2006) present previous studies where reliability, timeliness, and coverage of the information were highlighted; the following studies were included Fayish and Jovanis (2004), Hato et al. (1999), and Polydoropoulou and Ben-Akiva (1998). Hence, the availability of adequate information is crucial for consulting information services. Peirce and Lappin (2004) present a travel diary data analysis and find insufficient information quality to be the principal barrier to frequent use of information. About one-third of the participants in the latter study were not able to find any information regarding the trip. The authors also highlight the necessity of providing detailed information, such as causes of delay. In addition, with the availability of several information sources, multi-modal information services may encourage the use of PT information (Kenyon and Lyons, 2003). However, the preference of using a particular information source also depends on personal attitude towards the extent of consulting information.

These characteristics are even more important if the services require monetary cost (Polydoropoulou et al., 1997). As such the use of paid services depends on the users' perceived trade-off between the expected benefits, monetary cost and users' willingness to pay. However, few studies incorporated monetary and non-monetary cost, such as time consumption for travel information acquisition (e.g. Chorus et al., 2013). Lin et al. (2014) studied the effects of information characteristics on the adoption of web-based ATIS. The effect of information quality, response time, and system accessibility on the use of ATIS were modelled with an online survey data set. The study reveals that information quality influences the perceived ease of use and usefulness which lead to a greater intention to use ATIS. The study also highlighted the importance of mobile devices with Internet access for higher adoption of ATIS. If monetary cost-free information is available, the use of information services is also dependent on the cognitive cost of information i.e. time consumption, ease of use and understandability of information. Therefore, minimum search effort and user-friendly interface have been found important for the use of web-based information (e.g. Fayish and Jovanis, 2004).

Advancement in data collection and computing technologies improved the timeliness, coverage, and range of content of information. Eventually, these issues were minimised and the recent researches are mainly focussed on the effect of information attributes on travel decisions (Ben-Elia et al., 2013).

PT users

PT information characteristics are different than information for car users. Information for car users mainly concerns traffic conditions such as travel time or delays on a route, whereas information for PT passengers' focusses on the PT services, i.e. services available for a trip, departure, ticket price, etc.

Access to PT information sources are mostly free of cost; however, users might have to pay for Internet access for web-based information. Availability of free sources may also increase the usage of URTPI as PT passengers typically possess a low willingness to pay for information (Molin and Chorus, 2004; Neuherz et al., 2000; Vance and Balcombe, 1997).

The shift from static (i.e. printed timetables) to real-time information has greatly improved the timeliness of information. Hence, RTPI gained much attention and was observed to be preferred by the passengers. Molin and Timmermans (2006) administered a questionnaire survey in the Netherlands among the train passengers who travel for recreational purposes. The study found that the passengers had a preference towards real-time attributes of information. In addition, the option to look for alternatives to minimise transfers or fares are also important to the passengers. This indicates the rise in RTPI demand as well as alternative options to improve journey experience.

The previously discussed study by Farag and Lyons (2008) find perceived behavioural control, i.e. ease of obtaining and understanding information, and past behaviour, such as reliability as the drivers of PT information use. These social-psychological factors are strongly related to information characteristics as well. Therefore, the use of PT information services is also influenced by the quality of information, i.e. reliability, understandability and ease of use of the services.

Gooze et al. (2013) find that real-time data accuracy may produce real-time prediction error thus undermining the overall potential of information. A recent study on PT information demonstrates that the provision of accurate and timely information is expected by the passengers (Transport Focus UK, 2013). Real-time information does the work providing accurate and updated information to the passengers.

PT information has been found to be consulted for different stages of their trips, especially when passengers consult multi-modal information. A study by Grotenhuis et al. (2007) reveals that information search time and travel time savings are important to the passengers at the pre-trip stage. Wayside (i.e. bus stop displays or travel shop) consultation of information leads to travel time, as well as physical and affective effort[1] savings. On-board inter-modal information types are mainly related to travel time and affective effort savings.

Harmony and Gayah (2017) illustrate that information on vehicle location is most preferred while vehicle characteristics, such as seating availability are the least preferred by the passengers. Passengers preference of RTPI also differ for different modes of transport. This implies that passengers primary or pre-intended mode of travel dictates their RTPI preferences.

[1] Affective effort is the emotional energy. May occur by dealing with the uncertainty regarding the trip (Stradling et al., 2001).

Synthesis of literature on the use of RTTI

Early studies on the use of travel information are skewed towards the car users. The literature review shows that socio-demographic, trip characteristics, and information characteristics are influential on the use of travel information both for the car and PT users. Other factors such as the necessity of information and awareness are also found to be influential. However, the existing studies on PT information discuss the access to the location specific sources, such as bus stop displays. Hence, it is not understood what drives the PT passengers to use URTPI.

Since the introduction of ATIS, travel information systems have evolved over time. The evolution of information brought significant improvement to the information services in terms of quality, accessibility, price, etc. Alongside the advancement in technology, cheap, easy and widespread Internet access made the information available to travellers of all classes. Some barriers to information use, such as the cost of access and inadequate information accuracy have been minimised considerably. Whether a PT or private transport user, a fair amount of free-of-cost information is available for everyone. PT users are now privileged with access to mobile information, which offers freedom of consulting information for free (may have to pay Internet cost), any time, anywhere.

Studies on PT information use highlighted individual attitude as the drivers to adoption and trip context as the external factors for the use of passengers information. However, passenger demographics and trip characteristics that may shape their attitude have not been identified, especially in the context of the state-of-the-art URTPI under regular service conditions. Very few of the studies have looked into the usage of URTPI and they do not reveal the factors affecting their use. Traditionally, cost of information (i.e. cost of devices) and the income of travellers have been considered as influencing factors for PT information use. However, PT information is now free of cost. Although mobile devices and Internet access are the prerequisites for the use of such information, recent studies in the UK have shown that smartphone penetration would reach up to 81% by 2017 (Statista, 2016). Therefore, the use of URTPI could be dictated by their demographics and trip characteristics. In addition, studies on PT information use are mostly based on SP data which provides an estimation of the potential users of RTPI, who might not be actual users of information (Lyons et al., 2001).

3.3 Impact of Real-Time Travel Information

RTTI assists travellers to make informed decisions and so information poses an influence on the choices. Impact of RTTI can be categorized into three groups:

- Impact on travellers' experience, i.e. reduction in effort and stress for planning, waiting time, etc.
- Impact on mode choice and PT patronage.
- Impact on route choice.

A review of the studies investigating the impact of information on travel behaviour and the network is presented in the following sections.

3.3.1 Impact on Travellers' Experience

The impact of RTTI on travellers' experience is studied mainly in the context of PT passengers. On the other hand, the impact on car users behaviour is rather inclined towards route choice.

Car Users

Impacts of RTTI on car users' experience are observed as reducing stress and adjustment of departure time. Car drivers are also observed to be more satisfied after consulting RTTI. Chen and Mahmassani (1999) observe an increasing trend in satisfaction from day-to-day use of RTTI. In addition, the study finds that prescriptive information increases commuters satisfaction. Lappin (2000) reports that the use of ATIS helps drivers to reduce stress and avoid unsafe conditions. Car drivers' experience could also be improved by changing their departure time (Jou, 2001; Peirce and Lappin, 2004). Petrella et al. (2014) observe that frequent users of RTTI encounter relatively less congestion which makes them more satisfied with their travel experience.

PT users

The impact of RTPI has been investigated to assess PT passengers' experience when making a journey after consulting information. PT passengers' journey experience with regard to waiting time, satisfaction, and sense of security is found to be improved due to the provision of information.

One of the earliest studies on the impact of RTPI on passengers' travel time savings was carried out by means of network modelling (Hickman and Wilson, 1995). The authors presented a choice model developed to demonstrate the impact of real-time information on route choice decision in a simulated environment. The simulation results show that in spite of the various available paths, travel time reduction with RTPI was limited to 1 to 3%. The authors find that the variability in vehicle departure and running times (i.e. poor PT service quality) do not allow significant reduction in travel times. This demonstrates that the effectiveness of an RTPI system is also dependent on the PT service quality.

Many behavioural studies have been carried out to assess the impact of RTPI on passengers' experience. An SP online survey was conducted in Dublin city centre to investigate passengers' benefit gained from RTPI (Caulfield and O'Mahony, 2009). The study reveals that in 80% of cases, passengers experience frustration from being uncertain about the arrival time of buses. RTPI is found to reduce passengers' frustration by providing real-time bus arrival information. Nested logit model results show that among the existing RTPI systems, passengers benefit the most by consulting information from bus stop displays (note that some of the Internet based RTPI sources, such as mobile apps were not available at that time). In addition, Skoglund (2014) finds that passengers' perceived benefits of access to ICT based information are primarily related to comfort and convenience. The study reviewed the long term effect of ICT mediated information in Sweden by means of an online survey. It is observed that passengers' perceived benefit decreases over time. However, the study did not confirm whether the decrease in perceived benefits would lead to a lower likelihood to use information. On the other hand, Ramos et al. (2012) observe that car drivers tend to consult information more often as the time evolves in life. This may happen if they perceive increased benefits or they may get used to consulting information over time. This indicates the difference in perceptions between PT and car users.

Waiting time is considered as an important factor to maintain the quality of PT for the passengers (Beirão and Cabral, 2007; Dell'Olio et al., 2011). Therefore, PT trip satisfaction is greatly affected by waiting time (St-Louis et al., 2014) and a number of research studies are dedicated to understanding the impact information has on PT passengers' waiting time. Mascia (2003) studied the impact of pre-trip information on bus passengers' waiting time at the bus stop. The study conducted a bus stop survey in Turin, Italy. Survey results found that a very small number of passengers used the information system because of lack of awareness of information as well as high frequency of PT services deeming RTPI is less important. It is also found that bus stop displays would potentially reduce waiting time but only for low frequency of services. The bus stop displays could only reduce perceived waiting time by providing accurate bus arrival time, it cannot reduce actual waiting time as location-specific information requires passengers to arrive at the stop to consult information. Dziekan and Vermeulen (2006) studied the effect of real-time displays at tram stops in The Hague, The Netherlands. The study administered a before and after mail-back questionnaire and observed that passengers' perceived waiting time can be reduced by 20%. Again, Dziekan and Kottenhoff (2007) attempted to provide a framework for evaluation studies when implementing real-time information systems. The study discussed a few case studies highlighting the improvement in waiting time and the impact on passenger behaviour in the form of adjusted travel behaviour (i.e. walking speed). However, the study did not pay any attention to the travel plan changes.

Passengers' perceived and actual waiting time are very important and are often quite different. URTPI enables passengers to check information before leaving their origin. Therefore, the use of URTPI through smartphones helps passengers to improve their actual waiting time as well. Age of passenger, trip purpose and time of day are found to be important for passengers' perception of waiting time (Psarros et al., 2011). Chow et al. (2014) observed that RTPI displays influence passengers' perceived waiting time at train stations. The study presents in-station survey results and shows a significant reduction on perceived waiting time and suggested modest improvement in ridership.

The author also pointed to behavioural impact of RTPI as a further research area to measure whether people change their behaviour with respect to travel patterns (such as route choice, mode choice, rescheduling activities) as a result of real-time information. Improvement in passengers' waiting time was also studied by Chen (2012) in Taipei by means of an SP survey at the bus stops. As a result of consulting RTPI, passengers' perceived and tolerated waiting time was calculated and the author quantified the benefits gained in monetary value by assigning a monetary value to time.

A study with a bus stop survey on the passengers in Seattle, USA, found that URTPI users experienced 2 minutes less actual waiting time than traditional info user (Watkins et al., 2011). The reduction in actual waiting time accounts for a 31% improvement compared to traditional information users, whereas only modest changes in perceived waiting time is observed. Note that it is difficult to capture the difference between users' and non-users' perceived waiting time because, for passengers who access URTPI, perceived waiting time is equal to actual waiting time. Similar results are reported by Brakewood et al. (2014a) who conducted a behavioural experiment with before and after control groups[2]. URTPI was provided to only the experimental group to assess the impact of a particular URTPI system in Tampa, Florida. The study finds that the biggest impact of URTPI is observed in passengers' waiting time. Reduction in URTPI users' waiting time was nearly 2 minutes. In addition, access to information is observed to reduce passengers' anxiety level and frustration, eventually increasing the overall level of satisfaction.

The impact of RTPI on waiting time is mode specific. It was observed in the previous studies that bus passengers experience significant reduction in waiting time when using RTPI. On the other hand, Brakewood et al. (2014b) found the benefits gained by commuter train passengers after consulting RTPI to be limited. The latter study was carried out in Boston and data was collected by conducting an on-board survey. The study results reveal no evidence with regard to the correlation between RTPI use and lower waiting times. The punctual service of trains raises the relative predictability and

[2] In experimental designs, a control group refers to the "untreated" group with which an experimental group (or treatment group) is contrasted (Lavrakas, 2008).

reliability of the service which might result in a decline in the use of RTPI.

Politis et al. (2010) observed that bus passengers' satisfaction of using bus information is improved with RTPI by over 80% for both reliability and content of information. The study was carried out in Thessaloniki and an improvement of about 8% in passenger satisfaction index was observed as a result of using RTPI. Survey results in two other European cities (Madrid and Bremerhaven) show that passengers' perception of service quality was increased by 13% (Monzon et al., 2013). In addition, perception of PT image was also increased by 14%. The latter study also reports that the improvement in passengers' perception lead to a higher level of occupancy on buses and a corresponding reduction in car trips.

PT passengers' choices are often associated with transfers to other services. Passengers' choice of PT routes with transfers are influenced by several factors such as monetary cost (if another ticket is needed), physical and cognitive efforts, etc. Therefore, transfers influence passengers' route choice behaviour as well (Raveau et al., 2014). Passenger's attitude to use PT routes with transfers is influenced by their intention which is shaped by gender and frequency of PT use (Chowdhury and Ceder, 2013a). Chowdhury et al. (2014) observe that the quality of information on transfers is dependent on the integration of information and PT services (physical integration, i.e. walking distance and integration of bus lines). Integrated information is an important element for captive PT passengers to make transfers. The latter study conducted a survey among commuters in Auckland, New Zealand. Binary logit model results show the importance of integrated information for PT systems with 'unplanned' transfers. 'Unplanned' transfers refer to a lack of the following attributes: network integration, integrated timed-transfer, integrated physical connection of transfers, information integration, and fare and ticketing integration (Chowdhury and Ceder, 2013b). Therefore, integrated RTPI may be influential on passengers' route choice with transfers. In addition, integration of information is also crucial when passengers are making multi-destination trips as shown in the study conducted by Chowdhury and Giacaman (2015). The study involved a field trial to investigate the effectiveness of a smartphone app for planning multi-destination trips. For commuters and tourists, in 80% of the cases URTPI has been found to reduce planning efforts. This demonstrates the benefits of an integrated and personalised information tool. Parvaneh et al. (2014) studied the impact of personalised information on various types of activity-travel (i.e. trip purpose). A stated adaptation (see Parvaneh et al., 2013) survey data reveals that descriptive information increases the likelihood of changing departure time.

Another benefit of RTPI is that passengers feel a sense of security as a result of the availability of real-time bus arrival time (Zhang et al., 2008). Hence, the use of PT might increase the use of PT by passengers who perceive PT use risky at night. For example while waiting at the stops at night passengers feel a sense of security if they are aware of the arrival time of the next bus.

A review of the studies on the impact of RTTI on travellers' experience show that few studies dealt with car users' experience compared to PT passengers. The studies on PT passengers' experience put a heavy focus on waiting time reduction as a long waiting time is perceived negatively by the passengers. In addition, passengers' satisfaction, comfort and convenience regarding PT use has been explored.

3.3.2 Impact on Mode Choice and PT Patronage

Impact of RTTI on mode choice and PT ridership are discussed in this section. Studies on mode choice mainly investigate a travellers' complete or partial shift from cars to PT. A complete shift implies use of PT instead of a car for a trip and a partial shift refers to the use of PT to make a part the trip instead of a car only (i.e. switch to park and ride). These studies are therefore focused on car users. The increase in ridership is assessed to understand the impact of RTPI on PT patronage and this is done through a behavioural study as well analysing ridership data.

Mode Choice

Qualitative research discusses habitual behaviour of people with regard to travel choices in particular mode choice. Kenyon and Lyons (2003) studied the impact of multi-modal information on mode choice by means of focus groups. The study reveals that passengers normally have a primary or pre-defined mode of travel for a particular journey. Their pre-defined mode choice is strongly dictated by habit. This suggests that the demand for information to assist mode choice as well as the impact of information are limited. A reward experiment by Tseng et al. (2013) finds that information influences travel choices. The study shows that travellers' mode choice (i.e. shift from car to PT) and time of travel are affected by the consultation of information. Frei and Gan (2015) and Gan and Ye (2016) collected SP survey data to investigate commuters' en route mode choices regarding the switch from car to park and ride as a result of consulting multi-modal information. Both of the studies illustrate that multi-modal URTPI has a significant impact on this mode choice. Drivers' gender, age, income, education, and driving experience also influence mode choice. The latter studies find younger drivers (18 to 25) more likely and middle age drivers (25 to 61) least likely to switch mode. Female drivers are less inclined to choose “park and ride". Income and driving experience show a negative relationship with switching behaviour while participants' level of education positively affects mode switch.

A positive impact of information on mode choice is also observed in a disrupted network conditions where pre-trip information leads to a substantial shift to PT (Kattan et al., 2013). However, the shift was a combined effect of high frequency PT services with adequate alternatives and availability of pre-trip information. Skoglund (2014) observed a rise in PT use but no reduction in car use when multi-modal information is provided. A recent study by Ge et al. (2017) investigated the effect of multi-modal information displays on travel behaviour. The study conducted a before and after survey to understand the impact of real-time multi-modal information displays placed in office buildings located in Seattle, USA. The study found little evidence of change in modal shift after a six month study period, which demonstrates the limited impact of RTTI provision on modal shift. This is also supported by Veiga Simão (2014) in a behavioural experiment to assess the impact of a multi-modal real-time app named Smartmoov'. The author found that passengers' expectations of using apps were not fulfilled with regard to saving travel time.

Bai and Kattan (2014) modelled train passengers' en route decision in two scenarios related to delay in arrival time and service disruption. SP data analysis shows that if information on delay in arrival is provided, infrequent travellers and driver's licence holders are likely to change mode under cold weather conditions. In the case of service disruption with no information provided, primary mode of transport, age, household vehicle ownership, driver's license and weather are influencing factors. This indicates the influence of socio-demographics and trip characteristics as well as external factors (i.e. weather) on PT passengers' route choice. However, the assessment is done for a hypothetical scenario which needs to be validated in real scenarios.

The review of the studies shows that the impact of information on mode choice is limited. However, information may assist travellers' to change mode during disruptions or shift from drive only to park and ride. Multi-modal travel information serves travellers' with such information and nowadays multi-modal information sources are readily available. An increasing demand for multi-modal information may not be quantified as a potential increase in modal shift. Lyons et al. (2001) state that passengers may consult multi-modal information even if they have a pre-defined mode. Hence, the demand for multi-modal information services may not lead to a modal shift.

PT Patronage

RTPI has been found to be influential on PT ridership. Although RTPI is not acknowledged as the singular factor that instigates PT ridership, other service related factors play a vital role in increasing ridership, such as service frequency, available alternative PT lines, etc. In addition, other external factors such as employment level, gas prices, weather conditions, etc., are also associated with PT ridership.

For a well developed PT service, an increase in ridership is observed as a result of RTPI provision (Brakewood et al., 2015; Tang and Thakuriah, 2012). Ridership gain as a result of implementing a URTPI system in Chicago was studied by Tang and Thakuriah (2012). The study analysed weekly ridership data before and after the deployment of the URTPI system. The authors find a statistically significant increase in PT ridership on the bus routes where URTPI is available. However, the contribution of URTPI on the ridership gain is modest. Hence, information provision may help to achieve an increase in ridership. In addition, the study looked into the impact on bus ridership only, so there is a lack of evidence to verify any influence of URTPI on modal shift. This is important to understand whether PT ridership in the mentioned study area is a result of modal shift or increased number of PT trips made the passengers. A different study approach was adopted by Brakewood et al. (2015) to investigate PT ridership gain in New York. An on-board survey was conducted and analysed by means of regression modelling. The study observed that use of RTPI led to a higher ridership gain on the large routes (ridership increased by 2.3%) compared to small routes (ridership increased by 1 to 2%). This may happen if passengers are reluctant to use RTPI for short trips. The study also illustrates that the use of RTPI may attract passengers to make more infrequent trips using PT (i.e. shopping, leisure trips). Therefore, an increase in ridership is observed due to the increased number of trips made by the passengers who already use PT.

Bus passengers in Seattle were observed to make more trips on weekly basis after consulting URTPI in subsequent studies by Ferris et al. (2010, 2011). Both the latter studies present a self-reported survey and that study observes higher satisfaction with PT use and an increase in the number of non-commute trips per week made by the users of URTPI. In addition, 78% of the users reported that they are more likely to change their bus stop. However, the study only provides self-reported results to support their evaluation. Similar results were observed in Thessaloniki, where new trips were generated as a result of real-time bus stop displays (Politis et al., 2010). Tang and Thakuriah (2011) illustrate that a ridership gain can be achieved as a result of an influence of RTPI on commuters' attitudes towards travel time. The study analysed a small sample from an SP survey (99 respondents) and shows that additional PT trips as a result of RTPI provision are generated by the infrequent PT commuters.

Impact on ridership of a PT mode is also observed as a complementary effect of information provided for another mode. The implementation of a bus tracker in Chicago resulted in an increase of rail ridership. The study conducted by Tang et al. (2012) finds that the improvement in inter-modal transfer efficiency with bus tracker information is the potential reason for an increase in ridership. This suggests that the information on inter-modal transfers could be crucial for passengers' choices as well. Change in ridership may also be possible by instigating a modal shift with information. Mortazavi et al. (2011) found that a traveller would change to PT if the travel time savings are more than 15 minutes. Provision of such information would deter drivers from using cars and encourage them to use PT. However, as discussed previously, evidence of modal shift in reality has not been substantial. Skoglund (2014) also observed an increase in PT use as a result of increased number of trips by the passengers. The author investigated long-term effects of ICT mediated travel information services and finds that the use of ICT mediated services increases the use of PT. When multi-modal information is deployed, PT use is increased, although there is no sign of a reduction in car use. This resonates with the findings discussed before, i.e. an increase in PT ridership is a result of more trips made by the PT users, not due to a modal shift.

Information quality is observed to influence PT use as well. A survey carried out by Kaplan et al. (2017) within the university students in Brazil and Denmark also illustrates the effect of information quality on the use of PT. The study finds that information quality (i.e. reliability, clarity, completeness and efficiency) and availability of real-time information are positively related to the use of PT by young adults and high income passengers.

PT service unreliability influences ridership as well. Due to service variability, passengers waiting time might go up much higher than usual waiting time (Van Oort, 2011). In such circumstances, researchers suspect that RTPI may prove to be a 'double-edged sword'. A growth in the use of RTPI may intensify the unattractiveness of infrequent or unreliable services (Carrel et al., 2013). Therefore, RTPI may also have a negative impact on ridership.

Studies on the impact of PT patronage indicate that information influences PT ridership. Existing studies show that the increase in ridership is the outcome of passengers making more PT trips in the presence of RTPI. However, evidence for the influence of service related (i.e. frequency of buses) or external factors (i.e. gas prices, demographics) are also found. Therefore, it has not been possible to single out the sole contribution of RTPI.

3.3.3 Impact on Route Choice

The impact of RTTI on route choice has been one of the main areas of interest for researchers in this field. Depending on the methodology of the studies, route choice studies can be categorized into two groups: Network modelling and behavioural study.

Network modelling concerns modelling of a complete network to investigate impact of information on route choice. These studies are mainly carried out in simulated environments. On the other hand, behavioural modelling studies use traveller behaviour data by means of surveys or experiments (in the real world or with driving simulator). The studies can be divided according to mode of transport as well. The following sections present route choice studies and highlight their findings for car and PT users.

Car users

Route choice studies for car users date back more than 20 years. In fact, the majority of the route choice studies dealt with car users. In addition, many studies have been carried out through network modelling as well as behavioural research with a travel simulator.

In the early era of ATIS, access to information sources was limited, hence penetration rate of ATIS was a concern for impact assessment as well. Therefore, studies were dedicated to investigating the impact of the penetration rate of ATIS on drives' route choice. These studies were conducted with network modelling. Route choice behaviour under the influence of RTTI is expected to impact demand distribution. Complying with the information, if all the drivers choose the best alternative total network efficiency would decrease. A simulation study by Emmerink et al. (1995a) observes that benefits of information on recurrent congestion vary with market penetration rate. The study shows that in low penetration of information (<20%), network travel time savings can go up to 10%, whereas for high penetration (75%) travel time savings is 3 to 5%. The potential of ATIS is found more promising for non-recurrent congestion, however, the impact of market penetration shows similar results in this regard (Emmerink et al., 1995b). Another simulation study by Florian (2004) assessed the impact of ATIS penetration on the network efficiency, i.e. travel time. The study considered two demand scenario: low and high for an incident on a link of the network. Simulation results reveal that in low demand scenario maximum improvement in travel time (28%) is obtained at 100% ATIS penetration, whereas in high demand scenario maximum benefit (12% improvement in travel time) is obtained at 50% penetration.

Dia and Panwai (2007) developed a simulation model and observes that commuters' decisions to divert to alternate routes are influenced by their socio-economic characteristics, the familiarity of the network and the expectation of travel time improvement which are associated with individual characteristics. This indicates the importance of socio-demographic characteristics in shaping traveller behaviour under the influence of RTTI. The study also finds that drivers attitude such as aggression and delay tolerance thresholds have an influence on the route choice. The study was based on SP data and only looked at commute trips in a congested network. Hence, the impact of RTTI in other trip contexts and regular network conditions was not addressed.

In addition, the rate of compliance of the drivers' who have access to RTTI is also important for the network performance. Buscema et al. (2009) carried out an agent-based network modelling study and find that the network efficiency is dependent on the level of compliance with information. The network average travel time increases once the compliance rate is more than 50%. This indicates that information penetration rate is important for optimal network efficiency. Also the information accuracy is observed to be lower as the compliance rate increases.

Many route choice studies have been carried out by means of behavioural modelling. Srinivasan and Mahmassani (2000) studied the effect of inertia and compliance mechanism in route choice. The inertial mechanism represents the tendency of RTTI users to continue on their current paths and the compliance mechanism reflects the propensity of a user to comply with the information provided by RTTI. A laboratory simulation experiment was conducted and the study reveals that when traffic conditions fluctuate drastically from day to day, users are less likely to adjust their behaviour based on experience. However, for this study laboratory experiments with a driving simulator were conducted and the author considered commuters' route choice with only three alternatives, which may differ in the real world. The study also does not mention the impact of RTTI on these two mechanisms for other types of trips such as non-commute, recreational, etc. Moreover, simulated results have not been verified with any real world empirical data.

A behavioural study by Tsirimpa et al. (2005) finds that the biggest impact of ATIS is observed on drivers' departure time and route choice. The study carried out a household travel survey in Puget Sound Region, US. The impact of ATIS on route choice shows a potential redistribution of demand over the network. Model results reveal that time of information acquisition (i.e. pre-trip or en route) and the contents of information influence commuters' behaviour. A driving simulator study by Tian et al. (2011) shows that en route information is desired by the drivers; hence, route choice is not a fixed decision made at the pre-trip stage. Consultation of en route information leads to potential travel time savings (Lu et al., 2011). Impact of en route information is also presented by Tsirimpa (2015) with a combined SP and RP study. The author shows that en route information increases the probability of altering an aspect of their trip to over 90% if they are willing to acquire information from a mobile device. This demonstrates the impact of en route information specifically consulted from mobile information sources on drivers' route choice.

Content of information has been found to influence route choice as well. Wardman et al. (1997) conducted a household survey in Manchester, UK, with a SP questionnaire to understand the impact of VMS on route choice decisions. The study highlights that the contents of information and the nature of the delay, such as delay due to an accident are found to have a significant impact on route choice. Familiarity with the network also influences drivers' route choice. Hato et al. (1999) propose a route choice model based on a mail-back questionnaire survey in Tokyo, where multiple sources of roadside ATIS are available. The study considered the following sources of ATIS: a graphical map shows the level of traffic congestion, travel time to destination, and message sign on the length of congestion queues. The study found that information on a graphical map is influential on drivers' route choice. This might be associated with the impact of a visual presentation of congestion which may require less cognitive effort and provide better understandability of congestion level.

Information accuracy has been found to be important by Chen and Mahmassani (1999). The study investigated drives' decision-making, specifically on pre-trip route choice and departure time in the presence of ATIS. The study presents driving simulator experiment results and finds that high information accuracy and prescriptive information increase the likelihood of compliance with route choice. Drivers' past experience also influences their route choice; they are less compliant with route advice if they recently experienced significant congestion on a particular route. The impact of accuracy of RTTI on route choice is also observed by Ben-Elia et al. (2013) with a travel behaviour experiment. The study shows that the respondents shift from the riskier route (i.e. largest variance of travel time) to the reliable (i.e. lowest variance of travel time) one as the accuracy of information decreases which exhibits divers' risk aversion attitude. However, it was not discussed what impact the accuracy of information has on the acquisition of information.

Dia (2002) studied the drivers' route choice behaviour using a mail-back questionnaire survey conducted on a congested commuting corridor in Brisbane, Australia. The study finds that prescriptive (i.e. suggests alternatives), predictive (i.e. expected delay 15 minutes) and real-time delay information on alternative routes influence drivers' route change. The study developed a logit model to identify the factors that affect route choice under the influence of RTTI. The model results show that young drivers with flexible work schedules exhibit more propensity to change route and female drivers are likely to remain on their usual route. This resonates with the study findings by Emmerink et al. (1996). However, contradictory results were observed in a study carried out by Ma et al. (2014) in Beijing with an SP survey. The study investigated drivers' response to VMS and reveals that commuters and drivers familiar with the alternative routes are prone to divert to alternative routes. The study also demonstrates that female drivers are more likely to change their route in response to the information. This suggests that the impact of demographics may vary depending on the spatial heterogeneity of the study area. This is also supported by Wang and Khattak (2013). The latter study discussed the existence of spatial heterogeneity in travel decisions which indicates that the association between travel decisions and influencing variables (i.e. travel time, household income) varies over the study area. This suggests modelling the impact of RTTI may encounter spatial influence as well. In a prior study, Wang et al. (2009) developed a binary probit model to investigate the impact of information on travel behaviour changes. Consultation of travel information was found to influence the change of travel route in a majority of the cases (about 87%). The study reveals that participants who consult information from Internet sources exhibit a higher probability of changing travel plans. In addition, the frequency of access to information fosters a change in travel plans (change in departure time, mode or route, etc.).

Route choice behaviour was also studied by Mahmassani and Srinivasan (2004) with driving simulator experiments and the study discusses the impact of nature of information (i.e. descriptive and prescriptive). The results reveal that prescriptive information fosters drivers' route switching propensity. In addition, young male participants are more likely to be affected by the information inaccuracy. Users' departure time adjustments show an *anchoring effect*, i.e. users are likely to retain the previous day's departure time. The impact of ATIS on route switching propensity found in the latter study is not supported by the real-world experiments carried out by Essen et al. (2016) which presents car drivers' route choice study. The experiment was conducted in Virginia, USA, where 20 drivers were appointed in two phases. The drivers completed five trips per day with two alternative routes for each trip. The first phase of the experiment was conducted with no information provided and the second phase had given information on the routes. The study finds no significant impact of RTTI on route switching propensity. It is also observed that travel time information is influential if a similar travel time exists among the alternative routes. In that case, information representing the variation in travel time for a particular route may lead the driver switch to another route. The study contributed with real-world experiments, however, the results are limited as trip context was not considered which has been found to be influential for route choice.

Information and experience are found to have a combined effect on route choice behaviour in a study by Ben-Elia and Shiftan (2010). Non-informed participants are more likely to rely on their recent choices whereas informed participants have a longer perception horizon. The author also demonstrates that travel behaviour is influenced by the content of information to a large extent. For example, information on average travel time will result in a different traffic distribution than information on average travel time along with its variability. However, the study was limited to a certain range of travel times (high versus low). Again, their study did not incorporate revealed preference data in addition to the stated preference data, to provide the results with higher external validity.

The medium of consulted information is also found to be influential on travel plans. A study carried out in North Carolina by Khattak et al. (2008) discusses the impact of access to different information medium (i.e. Internet, radio, television, VMS) on travel behaviour. The study presents a statistical analysis of a household survey and the model results show that the frequency of information access increases the likelihood of making changes in travel plans such as a change in time or route. Consultation of information from Internet sources fosters a change in travel plans. Information via the Internet was available only in the pre-trip stage, hence the impact of information was limited to pre-trip planning. The study did not consider trip characteristics or demographics which have already been acknowledged as influencing factors.

Drivers' demographics and trip characteristics have been observed to influence route choice behaviour. Khattak et al. (1993) presented a study on the impact of ATIS on drivers' route diversion during an incident which induced congestion. Statistical model results of survey data reveal that familiarity of the alternative routes, longer trip length and longer delays foster en route diversion in the presence of ATIS. A similar study by Abdel-Aty et al. (1997) presents statistical analyses of telephone interview data and a mail survey data. The model results show that commuters route choice is affected by the trip length and roadway type when provided with travel time information on different routes. Drivers who commute longer distances are more likely to change route and alternatives that involve free-way are preferred by the driver. The study considered only age as the demographic characteristics and found a negative relation between driver's age and the propensity of changing the route.

Influence of VMS and radio information on travellers' route choice is studied by means of a survey among the road user in Amsterdam (Emmerink et al., 1996). The study observed that about 70% of motorway users are influenced by information. Discrete choice models show that demographics and trip characteristics dictate the user behaviour. Females and commuters are less likely to be influenced by information.

Lotan (1997) conducted a route choice study by means of driving simulator data collected for two types of driver: familiar and unfamiliar with the network. The study shows that the familiar groups have a clear preference among the alternatives and exhibits tendency to stick to their previous choice, whereas the unfamiliar group switches a lot from day-to-day. On the contrary, the familiar group demonstrated larger flexibility in their diversion behaviour en route than the unfamiliar group. However, both of the groups were unfamiliar with the information systems, therefore the study did not shed light on the effect of familiarity of information sources on route choice. Peirce and Lappin (2003) also confirmed that travellers' knowledge about the network is important for making changes in travel plans. However, at the initial phase of ATIS, travel information used to be descriptive, i.e. travel time on a particular route. Hence, even after consulting ATIS travellers may not be able to change if they are not aware of alternative modes, or routes.

Tseng et al. (2013) conducted a revealed preference study on drivers' route choice after consulting real-time information. The study finds that the drivers respond to the deviation of actual travel time from expected travel time when they are provided with RTTI. Expected travel time is the average travel time for a particular time of day. This indicates that the drivers' route choice may be influenced when they perceive a deviation in actual travel time from the average travel time after consulting RTTI. However, drivers' prior knowledge and experience regarding the trip and network are important to their perception of the travel time of a trip. For non-informed drivers, the findings are not significantly different and the reasons are not well understood. Hence, the behavioural impacts exhibited by RTTI are required for an insight into travellers responses.

Tsirimpa (2015) developed discrete choice models to understand the likelihood of changing mode, route or rescheduling activities after consulting RTTI. The study reveals the effects of socio-demographic characteristics, trip characteristics and individuals' technology characteristics (i.e. phone ownership, access to the Internet, etc.). The model results show that ownership of GPS devices increase the likelihood of changing the route. Among the trip characteristics, travellers are inclined to make changes when the trip purpose is work. In addition, when travelling by car they are likely to change the route.

Impact of ATIS is dependent on the traffic situation as well. The impact of information provided through VMS was studied in several European cities (London, Piraeus, Southampton, Toulouse, Turin, and Valencia) by Chatterjee and Mcdonald (2004). Survey data was collected in all the cities and the results reveal that incident messages induce drivers' route diversion up to 7% and route guidance increases the diversion rate up to 35%. Drivers' tend to use major roads unless any incident information is displayed.

Kattan et al. (2010) investigated the impact of incident information provision via VMS on drivers' choices. An SP survey among the commuters in Calgary, Canada reveals that about two-thirds of the drivers change their route after consulting information. However, 21% of the drivers who altered their route diverted to a route other than the suggested route. This indicates that a change in route choice does not solely infer compliance to information. Drivers' characteristics and their perception of information may influence the resulting impact of RTTI. Route choice in a congested network has also been studied by a RP experiment (Ramos et al., 2012). Participant drivers were appointed and provided with RTTI and GPS devices. The participants recorded their trip choices in a travel diary. The study reveals that the tendency to use information increases over time. RTTI assists drivers' decisions regarding route choice but are less likely to be used for deciding departure time.

Traditionally, route choice behaviour for car users only considers a singular travel objective e.g. minimise travel time. Venkatraman et al. (2014) conducted a web-application based experiment to investigate route choice behaviour with multiple travel objectives such as expected arrival time along with minimising travel time. The study finds that trip purpose and the available number of alternatives are influential in choosing routing policies such as optimal route, less congested route, etc.

PT users

Compared to cars users, less attention has been given to PT passengers' route choice. However, both behavioural and network modelling studies are found in existing literature.

Gentile et al. (2005) presented a mathematical route choice model to investigate the impact of RTPI available at bus stops. The study considered three available bus lines with different headways and travel time for a particular trip. The study finds that without consulting RTPI at stops, passengers tend to take the slowest but most frequent line (in 87% of cases). On the contrary, passengers' choice of the fastest but less frequent one rises to 51% (from 8.1%) after consulting RTPI. This indicates the potential of RTPI on the route choice and eventually on PT demand distribution.

RTPI inspires passengers to change their departure bus stops with 78% of the respondents reportedly willing to walk to a different stop based on the information, where the majority of them would then change to a different route (Ferris et al., 2011).

Fonzone (2015) investigated the impact of RTPI on PT passengers' decision-making. The study finds that descriptive information is largely sought by the passengers and getting to the destination and reducing waiting time are among their main objectives. The author also finds that in 85% cases information has a behavioural impact. 30% of the respondents changed their departure stop or bus lines. However, the study did not evaluate the factors affecting passengers' choices, in particular the impact information was not investigated. Among all the information systems, ubiquitous information sources are found to foster the adaptive behaviour.

One of the recent studies on the impact of PT information on travel behaviour has been carried out by Maréchal (2016b). The author looked into the use of information during disruption in London. The study found no influence of demographics on travel choices (i.e. mode choice, route choice). The only exception was observed for the passengers who were early adopters of technology; they are more likely to switch to walking during disruptions. Consulted sources of information and trip context are also influential on travel choices. The study shows that bus passengers are more likely to switch to another alternative than tube commuters. The use of RTPI during disruptions also influence passengers' choices. For longer delays, PT passengers are found to change their travel plans (see Maréchal, 2016a). It is worth noting that the latter study considers disrupted conditions, therefore, passengers' route choice behaviour in normal conditions is yet unexplored.

The above studies presented behavioural modelling of the impact of information on route choice. Studies have also been dedicated to assessing the impact of information on a PT network. A network simulation study by Cats and Jenelius (2014) finds a negative impact of RTPI during disruptions for some scenarios of a PT network in Stockholm, Sweden. The author concludes that customization of information depending on the local conditions is required to benefit from RTPI. Another study by Cats et al. (2011) investigated train passengers' path choice with a mesoscopic transit and traffic simulation model. The model shows that comprehensive provision of real-time information might lead to path choice shifts and time-savings. However, the model is not validated in the real-world to understand passengers' actual decision-making process under the influence of RTPI. Cats et al. (2012) also present the potential impact of RTPI on passenger load in PT lines due to the change in passengers choice (i.e. route choice, boarding time). Simulation results also reveal that RTPI provision leads to a fluctuation in distribution of passenger load compared to the baseline (no RTPI) scenario. Fonzone and Schmöcker (2014) also carried out a simulation study on travellers' strategy for using RTPI. The study exhibits that consultation of RTPI could reduce travel time by 20%. In addition, availability of information and passengers strategy would bring a significant change in the network loading. To quantify the impact on demand distribution over the network, it is very important to understand the impact of information on passengers' choices, particularly route choice.

The studies on the impact of RTPI have been carried out for different passenger information sources such as bus stop displays, websites, etc. Table 3.2 presents a list of the studies dedicated to the impact of RTPI.

The literature review on the use of RTTI as well as its impact highlights that when RTTI was made available for travellers, research streams started to flow towards following themes:

- Car users: acquisition of information, impact on route choice, travellers benefits.
- PT information: ridership effect, passenger benefits such as reduced perceived and actual waiting time, psychological effect, improvement in PT image to the passengers, acquisition of information.

Most of the RTPI impact studies discussed the effect of location-specific information services such as stop displays. On the other hand, URTPI sources enable passengers to access information at any place, at any time. Therefore, PT passengers are able to make pre-trip and en route choices when consulting URTPI. However, the impact of URTPI on passengers' choices in an urban environment under regular service conditions has not yet been studied. Hence, it is not known how information may influence

Table 3.2 Studies on modelling impact of RTPI

Sources of RTPI	Studies	Influenced aspects	Data collection
Bus stop displays	Nijkamp et al. (1996)	Change of mode (to walk), stop and bus line	At stop surveys
Tram stop displays	Dziekan and Kottenhoff (2007)	Mode choice, Adjusted walking speed to the stop	Questionnaire survey (postal)
Any ICT mediated service	Skoglund (2014)	Long term effect on user experience	Online surveys
Bus stop displays	Chen (2012) and Mascia (2003)	Impact on waiting time	At stop surveys
Train station displays	Chow et al. (2014)	Impact on waiting time	In-station surveys
Bus stop displays	Brakewood et al. (2014a)	Impact on waiting time	Behavioural experiment
Local and ubiquitous RTPI	Brakewood et al. (2014b)	Impact on waiting time	On-board survey
Bus stop displays	Politis et al. (2010)	PT user satisfaction	At stop survey
Local and ubiquitous RTPI	Monzon et al. (2013)	Perception of quality and punctuality of services, PT image	Surveys
URTPI	Chowdhury and Giacaman (2015)	Passengers' efforts for multi-destination trips	Field trial
URTPI	Parvaneh et al. (2014)	Change in departure time	Stated adaptation survey
URTPI	Zhang et al. (2008)	Passengers' sense of security	Online survey, On-board survey and travel diary
URTPI	Watkins et al. (2011)	Perceived and actual waiting time	At stop surveys
URTPI	Tang and Thakuriah (2012)	Ridership	Weekly ridership data
URTPI	Tang et al. (2012)	Ridership	Monthly weekday train ridership
URTPI	Brakewood and Watkins (2015)	Ridership	On-board survey
URTPI	Ferris (2011) and Ferris et al. (2010)	No. of weekly trips	Self-reported survey
URTPI	Ferris et al. (2011)	Wait time, No. of weekly trips	At stop surveys
URTPI	Maréchal (2016a,b)	Route and mode choice during disruption	Online Survey
URTPI	Mortazavi et al. (2011)	Modal shift	At station survey, Online survey and travel time data
Multi-modal URTPI	Frei and Gan (2015) and Gan and Ye (2016)	Modal shift	SP survey
Multi-modal URTPI	Kaplan et al. (2017)	Frequency of PT use	Online survey

passengers' decisions and what impact information may have on their route choice which eventually affects the PT demand distribution.

3.4 Summary

This chapter presented a literature review on decision-making and travel information research. Nowadays, several URTPI sources are available for PT passengers. However, this availability and accessibility of information does not guarantee the use of information. Existing literature on individual's behaviour towards using information for decision-making illustrates some limitation on the extent of information use. Psychological studies denote that information may not necessarily improve the quality of their decisions, it may rather reduce their efforts in decision-making. This implies that more information may not lead to a better decision. Therefore, the understanding of the extent of use of URTPI by PT passengers for decision-making is essential. In addition, travel information studies suspect that the use of information may be limited because travellers may not intend to maximise their experience, instead they may only try to find a satisfactory solution. URTPI enables passengers to access information remotely. Passengers may not always make a complete travel decision (i.e. planning the whole trip from origin to destination), however, they are enabled to make partial choices, such as only changing boarding time, or bus stops, which eventually affects their route choice as well as the demand distribution.

Two major gaps are identified from the presented literature review on the impact of RTTI. The first one is related to the use of state-of-the-art PT information, i.e. URTPI. Existing studies on PT information fail to understand the extent of the use of URTPI, i.e. who are the users, what are the preferred sources and content of information. Although Maréchal (2016b) studied the acquisition of a combination of information sources, the study considered the use of both traditional (i.e. printed maps) and RTPI in a disrupted service condition. Therefore, the use of URTPI in regular service conditions is not yet known. This is important to understand the need of information by the passengers. The understanding of the extent of use of URTPI leads to the next step of this investigation which contributes to the second identified gap in literature: PT passengers' route choice under the influence of URTPI. Impact assessments of PT information mainly focussed on passengers' experience (i.e. satisfaction, ease of use, waiting time, etc.), and impact on network patronage (i.e. ridership effect, modal shift). None of the studies looked into the impact of URTPI on passengers' route choice under a regular service condition. Hence, our understanding is limited with regard to the impact of URTPI on passengers' route choice and the resulting impact on the demand distribution over the PT network.

To contribute to the identified research gaps, this study investigates the extent of use of URTPI by the bus passengers and the impact of information on their choices. The research addresses these issues with a study of bus passengers' behaviour under the influence of state-of-the-art URTPI. A set of research questions has been developed to accomplish the research aim which was presented in section 1.2.2.

This chapter identified the gap in research practice and justified the importance of this study. The following chapter will discuss the data collection methodology used in this study.

CHAPTER 4

DATA COLLECTION METHODOLOGY

This chapter presents the methodology and data collection implemented in this study. This study investigates bus passengers' behaviour under the influence of URTPI. At first, a review of different data types that have been used in travel information research is presented and the data required for this study is discussed. After that, a review of different data collection methods is presented. Having reviewed the potential methods, two questionnaire surveys are chosen and discussed. The design of the survey questionnaires and data collection by carrying out the surveys are then presented.

4.1 Behavioural Research Approaches

Travel behaviour research requires data on travellers' responses under certain conditions. Behavioural data can be collected by Stated Preference (SP) and Revealed Preference (RP) methodology. Both of these types of data can be collected through surveys, interviews, focus groups, and laboratory experiments with simulators.

4.1.1 Stated Preference

SP experiments test what travellers, consumers or decision makers state they would do in a hypothetical scenario. The scenario might portray a situation at present or in the future. SP experiment was originally developed for marketing research in 1970s (Kroes and Sheldon, 1988). The commercial use of SP data increased in the early 1980s. Since then, SP experiments has been widely used to understand individual's preferences across all disciplines dealing with human behaviour including transport research. In the late 1970s, SP became a favourable method to collect data for transport research. Since then, the growing number of research studies with SP data demonstrated its popularity among researchers. In recent years, lab based experiments with travel simulators have been used for collecting SP data. SP experiments are sometimes criticized for the validity or confirmatory bias. Confirmatory bias refers to the tendency to look for information consistent to support a hypothesis or belief and ignores the inconsistent information that potentially contradicts the hypotheses (see Evans, 1989). Development of a hypothetical scenario is strongly influenced by the hypotheses it is built on. This may result in developing choices/options which may only provide information in favour of the hypotheses. However, the flexible, cheap and efficient nature of SP data has boosted its popularity and use for empirical research in transport. Numerous transport studies have been carried out with SP experiments. A Google Scholar search with *Stated preference "transport"* provides more than hundred pages of articles and books. A list of the SP studies related to travel information research that have already been discussed in Chapter 3 are presented in Table 4.1.

SP experiments are designed to examine participants' choices in a hypothetical scenario which is characterised by a set of attributes and attribute levels. An SP methodology enables studying the potential impact of any travel measures before implementation. Additionally, it is used to collect data which describes unobservable attributes related to travel behaviour, e.g. attitude or intention to use (Dia and Panwai, 2010). However, it is difficult to portray the real-world scenario in a hypothetical situation to obtain passengers' actual choices.

4.1.2 Revealed Preference

RP method was initially introduced as a theory by the noted economist Paul Samuelson (Samuelson, 1938). The theory was developed to understand consumer behaviour by observing their choices in reality. A decade later, RP method was considered as an approach to reveal consistent preference by the decision makers (Samuelson, 1948). In travel behaviour research, RP methods have been widely used. Since RP data reflects choices made by the respondents in reality, it possesses a higher validity in portraying real-world scenario. However, it is difficult to collect data relating to participants behaviour (unobservable attributes, such as attitude) with only RP methods. Some studies applied both RP and SP approach for data collection, where experiments are divided into different sections for each approach. Table 4.1 also presents a list of travel information studies carried out with RP.

This study aims to investigate the impact of the existing URTPI on passengers' choices as well as gain a better understanding of passengers' decision-making. Therefore, a RP methodology is adopted in this study. The following section discusses different data collection methods in the context of RP studies and selects the appropriate methods for this study.

4.2 Review of Data Collection Methods

RP data can be collected by means of observation or reporting mechanism. Data collection by observation can be carried out by means of simulations or from real-world data. On the other hand, reported data is collected by surveys.

Travel simulator-based data collection is very common is driver behaviour study to obtain RP data. Travellers' route choice under the influence of RTTI have been studied by simulator experiments (Ben-Elia et al., 2013; Chorus et al., 2007d; Mahmassani and Liu, 1999).

Real-world and web-based experiments are also found in travel information research. Real-world experiments are difficult to carry out because they are expensive and labour consuming. In travel information research, a limited number of studies are found

Table 4.1 Travel information studies with SP and RP data

Topic	SP	RP
Features of ATIS	Schofer et al. (1993),Caulfield and O'Mahony (2007)	
Acquisition of travel information	Chorus et al. (2007a, 2013), Polak and Jones (1993), Tsirimpa (2015), and Zhang et al. (2015)	Farag and Lyons (2008), Fujii and Kitamura (2000), Harmony and Gayah (2017), Hato et al. (1999), Maréchal (2016a), Peirce and Lappin (2003), and Peirce and Lappin (2004)
	Both SP & RP: Tsirimpa (2015)	
Departure time		Chen and Mahmassani (1999), Jou (2001), Peirce and Lappin (2004), Tseng et al. (2013), and Tsirimpa et al. (2005)
Route choice	Abdel-Aty et al. (1997), Bai and Kattan (2014), Ben-Elia et al. (2013, 2008), Chorus et al. (2013), Chorus (2007), Lu et al. (2011), Mahmassani et al. (2003), Mahmassani and Srinivasan (2004), Srinivasan and Mahmassani (2000), Tian et al. (2011), Venkatraman et al. (2014), and Zhang and Levinson (2008)	Chatterjee and Mcdonald (2004), Chen and Mahmassani (1999), Emmerink et al. (1996), Essen et al. (2016), Jou (2001), Kattan et al. (2010), Maréchal (2016b), Ramos et al. (2012), and Tsirimpa et al. (2005)
	Both SP & RP: Khattak et al. (1996), Lam and Xie (2002), and Tsirimpa (2015)	
Mode choice/ PT patronage	Bai and Kattan (2014), Chorus (2007), Frei and Gan (2015), Gan and Ye (2016), Kenyon and Lyons (2003), and Tang and Thakuriah (2011)	Brakewood et al. (2015), Ferris et al. (2010, 2011), Ge et al. (2017), Kattan et al. (2013), Maréchal (2016b), Politis et al. (2010), Tseng et al. (2013), and Veiga Simão (2014)
	Both SP & RP: Khattak et al. (1996) and Mahmoud et al. (2015)	
User benefits	Caulfield and O'Mahony (2009)	Brakewood et al. (2014a,b), Chen (2012), Chen and Mahmassani (1999), Chow et al. (2014), Dziekan and Vermeulen (2006), Mascia (2003), Monzon et al. (2013), Petrella et al. (2014), Politis et al. (2010), Skoglund (2014), Watkins et al. (2011), and Zhang et al. (2008)

to conduct real-world experiments. Additionally, with regard to real-world experiments, travellers' choices may be influenced if they realise that they are the subjects of an experiment. Reward experiments were carried out to study the impact of RTTI on drivers' departure time (Tseng et al., 2013) and route choice (Essen et al., 2016). Chorus et al.

(2007a) conducted an empirical analysis on mode choice by web-based experiments. The literature on the impact of RTPI on passengers' behaviour by means of real-world experiments is even scarcer. A behavioural experiment was carried out by Brakewood et al. (2014a) to assess PT passenger benefits as a result of using RTPI. A field trial was conducted by Chowdhury and Giacaman (2015) with university students. The study appointed undergraduate students to make multi-destination trips using an integrated URTPI source, which integrates information from different individual sources, such as Google maps, Google transit local operators, etc. The study compares the isolated use of sources with the integrated information source. However, the latter study was carried out on a pilot scale with 21 participants. Real-world experiments are difficult to carry out on a large scale which will cover all the demographics of PT passengers.

Surveys are one of the conventional data collection methods in transport research, especially in travel behaviour research. Both SP and RP data can be collected by means of surveys. In travel information research, surveys have been carried out to investigate the acquisition of information (Chung and Koo, 2015; Fonzone, 2015; Fujii and Kitamura, 2000; Harmony and Gayah, 2017; Kamga et al., 2013; Maréchal, 2016b; Seebauer et al., 2015), user benefits of RTTI (Brakewood et al., 2015, 2014b; Watkins et al., 2011) and travellers need or features of ATIS (Chorus et al., 2007b). The impact of RTTI on route choice (Dia and Panwai, 2007; Fonzone, 2015; Ma et al., 2014), mode choice (Maréchal, 2016b) and PT patronage (Brakewood et al., 2015; Ferris et al., 2010) have also been studied by means of surveys.

However, despite being used in practice, surveys may limit the validity of the research findings. The following issues regarding survey research should be considered by the researchers (Babbie, 2007; Bryman, 2008).

- Respondents might interpret the questions differently and end up having a different meaning than others.
- If the question refers to any incidents happened in the past, the answers would be highly dependent on how vividly respondents remember them.
- Some questions might steer them from the honest answer.
- The consistency between their stated and actual behaviour is always a concern.

To overcome these issues, surveys need to be chosen, designed and administered in a way that the data collection represents users' real behaviour.

RP data is required to investigate bus passengers' actual choices under the influence of URTPI. RP data collection with travel simulator are mainly in practice for car users and rather uncommon for behavioural studies on PT passengers. Travel simulator enables the researcher to create a hypothetical scenario to understand the sequential decision-making by the drivers (Chorus et al., 2007c). On the other hand, PT passengers' decision-making is not associated with complicated scenarios. Again, data on bus passengers' use of URTPI may be collected by the information providers; however, this data is not open to the public. In addition, real-world experiments are expensive to carry out and obtaining a representative sample of PT passengers is rather difficult. PT user data can be reported by the passengers by means of a travel diary (Allström et al., 2017; Greaves et al., 2015). Data collection by means of a travel diary requires a sampling frame so that passengers of different demographics could be appointed. Additionally, it is difficult to obtain a large sample because people are reluctant to report their everyday travel activities without incentives. Hence, data collection by means of travel diary would be expensive. After reviewing the aforementioned data collection methods, surveys are found to be the most suitable option for collecting RP data on bus passengers' behaviour. This study adopts a RP survey methodology to accomplish the research aim.

4.3 Survey Design

In general, the term survey refers to the examination of something. In social research, the survey is a means of obtaining information about a small group which represents a large population. The survey is defined by the Economic Commission for Europe of the United Nations (2000, p. 36) as *"An investigation about the characteristics of a given population by means of collecting data from a sample of that population and estimating their characteristics through the systematic use of statistical methodology"*. A sample is a subset of a population and survey data provide information on the units of the sample, which can be used to draw conclusions about the entire population. To learn about the entire population, a sample should be representative of the entire study population. Hence, the sampling method is one of the major concerns with regard to survey research. Survey sampling methods can be categorized into two main groups: probability and non-probability sampling. A brief review of these sampling techniques is presented below.

4.3.1 Sampling

Probability Sampling

Probability sampling is used to create a sample by random selection. Hence, all the participants have equal probabilities of being chosen and the sample would show the same variations that exist in the population, which limits the sample bias. Babbie (2007, p. 198) defined the principle of probability sampling as- "*A sample will be representative of the population from which it is selected if all the member of the population have an equal chance of being selected.*" Researchers tend to favour probability sampling because of its ability to provide more representative sample from a large population. In addition, the accuracy of representativeness can be estimated in the case of probability sampling. Different types of probability sampling techniques are briefly discussed below.

Simple Random Sampling is the most simple and completely random sampling technique where each unit of the population has an equal chance of being selected.

Stratified Random Sampling involves splitting the whole population into groups and then sampling randomly within each group.

Systematic Sampling is slightly different than simple random sampling, because it follows a systematic order. The surveyor can select participants from a random point with a systematic periodic interval from the sampling frame.

Cluster Random Sampling is applied when the population is too large to carry out a random sampling. The whole population is then clustered for a random sampling.

This study investigates the use of URTPI by bus passengers. Therefore, to apply probability sampling method, a sampling frame (i.e. a list of passengers) is needed. A sampling frame was not available for this research, hence probability sampling was not adopted in this study.

Non-probability Sampling

The non-probability sample does not involve random selection. It is applicable when participants are chosen according to specific properties of the sample, such as users of any particular service or groups with particular demographics. This type of sample cannot be collected by random sampling. Convenience sampling, purposive or judgemental sampling, snowball sampling, quota sampling, and self-selection are the main categories of non-probability sampling (Vehovar et al., 2016).

Convenience Sampling, also known as *haphazard* or *accidental sampling*, relies on the availability of subjects or by virtue of their accessibility to the survey, such as intercept survey on the street, recruitment during any event or other locations such as shopping mall, bus stops, etc. Convenience sampling is cheap, easy to conduct as participants are easily recruited. This type of sampling does not offer equal opportunities of being selected to all the qualified individual. Hence, convenience sampling is considered a risky method for social research as it does not permit control over the representativeness of the data (Babbie, 2007).

This study aims to collect RP data on passengers' actual choices regarding the use of URTPI. Therefore, convenience sampling was adopted to carry out the survey when passengers are making bus journeys. However, this method is associated with the risk of producing a biased sample, because the access to the survey would be limited to the passengers available at the survey locations and during the survey hours. To minimize the sample bias, the present study intended to cover as many survey locations as possible with the limited resources available. In addition, at the survey locations, participants were chosen randomly. Finally, the sample was checked for representativeness of the population by comparing with the bus passengers profile in terms of demographics and trip characteristics.

Purposive Sampling is carried out when research studies need to select a sample on the basis of some criteria of the subjects or the purpose of the study. A detailed discussion about this method can be found in Babbie (2007) and Tongco (2007). The surveyor decides to select the participants for the survey based on their characteristics. This method leads to a better understanding of a certain group of participants, however, the generalisability of the data would be lower (Etikan et al., 2016).

Snowball Sampling refers to a technique where researchers initially collect data on few of the subjects of the target population and then ask them to forward the survey invitation or to be introduced to other relevant participants. Although this sampling technique may provide questionable representativeness, it helps to collect data about the participants who are not easily reachable. In addition, this could be an effective or sometimes the only available option when participants are reluctant to take part in the survey. It has been illustrated that if administered properly snowball sampling is a potentially effective method in social research (Baltar and Brunet, 2012; Noy, 2008). In addition, some convenience sampling methods, such as web-based surveys may find it difficult to disseminate the questionnaire to certain groups and obtain an acceptable number of responses. In such cases, snowball sampling could be a better option to disseminate the survey to a wider audience. As this sampling technique does not have any sampling frame, it is subjected to bias. For, example people who have many friends are likely to be selected.

Quota Sampling begins with defining the properties of the sample size. If researchers need a sample size to meet certain criteria, such as the proportion of male and female in different age and ethnic groups, and the number of participants for each of the group is defined then researchers collect data from people who meet all those requirements (Moser and Stuart, 1953).

Self-selection Sampling refers to the technique where participants volunteer when asked or in response to an invitation or advert. Unsupervised surveys, such as a postal survey and web-based surveys provide self-selected samples. With the possibility of disseminating surveys to a larger population, self-selection sampling entirely depends on the willingness of the participants, which may lead to sample bias. Despite these limitations, self-selection sampling with web-based survey allows the dissemination of a longer questionnaire. In this study, a self-selection web-based survey was adopted to achieve an insight into passengers' behavioural aspects.

Sample Size

The reliability of the analysed results depends on the representativeness and sample size. Determining a minimum sample size is not straightforward. A large sample size will lead to more reliable results; however, obtaining a large sample is associated with higher costs, intensive labour and time. In some cases, participants' reluctance in participating in the survey is also a barrier to achieving a large sample size. On the other hand, if the sample size is small, a large variation in the analysis results and less reliable results will be observed. The minimum size of a survey sample depends on the objectives of the study which dictates the number of items to be investigated. Although some guidelines are found, defining the minimum sample size is not easy. Depending on the type of analysis to be carried out, studies have recommended minimum sample sizes. A factor analysis is advised to be carried out with a sample of minimum 300 responses (Pearson and Mundform, 2010; Tabachnick and Fidell, 2007). On the other hand, Comrey and Lee (1992) defined the adequacy of the sample size as: *50- very poor; 100- poor; 200- fair; 300- good; 500- very good; 1000 or more- excellent*. Bergtold et al. (2011) suggested that for a logistic regression analysis, the sample size is not the main concern; however, the study found improvement in sample bias for a sample greater than 250 observations compared to one with 100 only. For any statistical models, such as multiple regression, the ad hoc rules to determine the sample size is 'sample to variable ratio' of 10:1, i.e. 10 observations for each variable in the model (Roscoe, 1975; Tanaka, 1987). Lemeshow et al. (2013) and LeBlanc and Fitzgerald (2000) recommended 20 and 30 observations per independent variable respectively. This study adopts different data analysis techniques to answer the research questions. Defining sampling size with respect to the population is not possible. Hence, a rule of thumb approach with 30:1 sample to variable ratio was adopted to determine the minimum sample size in this study.

4.3.2 Survey Administration

To select the appropriate survey methods, a review of different survey administration techniques has been carried out. A list of different survey methods is presented in Figure 4.1.

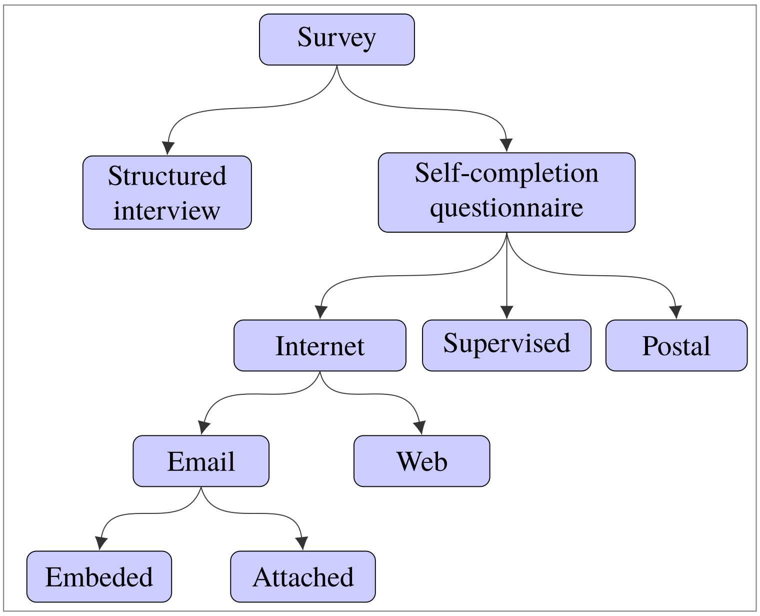


Figure 4.1 Different modes for administering a survey (adapted from Bryman, 2008)

A structured interview is used for collecting data by a formal conversation between the interviewer and respondents. It is normally carried out when the questions are subjective (also known as "open-ended") in nature and the targeted respondents are invited to a scheduled meeting. The structured interview requires a sampling frame to select and contact the participants for arranging the meetings. Additionally, structured interviews are expensive and time-consuming. On the other hand, the target population for this research is the bus passengers and no sampling frame is available. Hence, the structured interview is not an appropriate method for this study. A self-completion questionnaire survey method was adopted for this study as the time demand required from the respondents is short and can be completed without the intervention of a surveyor. The aim of this study is to understand bus passengers' choices after consulting URTPI. Therefore, a questionnaire survey focussed on a particular trip would reveal passengers' actual choices. This led to the adoption of a supervised intercept questionnaire survey as the participants were to be recruited when they are making a trip. An intercept survey on bus passengers can be carried out either on board or at the bus stops. Due to lack of permission from the bus operators, the survey was to be conducted at the bus stops. This survey is referred hereafter as the **Bus stop survey**. The survey was designed to intercept bus passengers when they were making a trip; hence, the passengers were able to state what they did for a particular trip after consulting URTPI. However, an intercept survey is suspected to produce bias, such as length bias. Length bias indicates that the survey sample may be biased as a result of the duration of participants' stay at the survey location (Nowell and Stanley, 1991). In the bus stop survey, participants were required for a certain amount of time at the location (3 to 4 minutes) to take part in the survey; therefore, their participation is dependent on their arrival at the stops before the bus arrives. People who arrive at the stops with time spared have more of a chance to be approached for this survey.

As previously mentioned, there was no defined sampling frame for the current bus passengers; therefore, a questionnaire survey could be disseminated by postal services or via the Internet. A postal survey is used to disseminate the questionnaire over a large area with an invitation to the bus users only. However, the response rate is very low, which may require the questionnaire to be sent several times to the same addresses. Postal surveys provide data on the use information in general, whereas the primary aim is to obtain data on a trip passengers are making. This justifies the adoption of an intercept questionnaire survey to be carried out at the bus stop.

A bus stop survey provides a limited time-frame to conduct the survey. Therefore, a second questionnaire was designed focussing on the behavioural aspects (i.e. cognitive aspects) of passengers' choices. A self-selection sampling technique for this survey was adopted. To disseminate this questionnaire, postal services or online platforms could be considered. However, postal surveys are expensive for disseminating the questionnaire over a large area. Given the limited resources and time for this study, online platforms were chosen to disseminate the second questionnaire. The self-selection questionnaire survey administered via online platforms is referred hereafter as the **Online survey**. Online platforms have become an increasingly popular medium for administering questionnaires over the last one and a half decades. Due to a higher penetration of the Internet (96% by 2016 in the UK Statista, 2017), it is now possible to disseminate questionnaires within a larger population. Online platforms enable dissemination of questionnaires to the masses at a lower cost (Couper, 2000). Compared to other traditional surveys methods, such as postal survey, online surveys are less expensive and less labour consuming. On the other hand, an online survey provides less response rate compared to postal surveys (Sepp, 2012). This is because of the significant number of online surveys in recent times, which results in a response fatigue. Therefore, the survey questionnaire needs to be disseminated over a large population to achieve the desired sample size. In addition, if the survey is not sent to particular groups of people and circulated with open invitation, the surveyors have less control over the sample size. Therefore, objections have been observed from researchers regarding the representativeness of the survey respondents (Babbie, 2007; Wright, 2005). Despite the limitations, online surveys have been adopted in previous transport research (see examples- Bai and Kattan, 2014; Brakewood, 2014; Lin et al., 2014; St-Louis et al., 2014; Lyu and Hwang, 2014; Mahmoud et al., 2015).

To obtain a representative sample size by means of an online survey, several sampling techniques were required. There is no database or list of bus users available for disseminating the online survey questionnaire. In such a situation, the population (i.e. the bus users) cannot be grouped or clustered to get only the bus users. Hence, the online survey questionnaire was disseminated by inviting only bus users to take part in the survey (i.e. self selection sampling). Moreover, if sufficient number participants are not found because of their reluctance in taking part in the survey, a snowball sampling can also be adopted. Table 4.2 shows how the data collected by means of the two surveys would answer the research questions.

Table 4.2 Data collection to answer the research questions

Research questions	Bus stop survey	Online survey
Q1. What drives the use of URTPI?		
Q1.1 What is the penetration of URTPI among PT passengers?	✓	
Q1.2 Which URTPI sources are consulted by passengers?	✓	
Q1.3 What contents of information are being sought by passengers?	✓	✓
Q1.4 What factors influence the use of URTPI?	✓	✓
Q2. How is bus passenger route choice influenced by URTPI?		
Q2.1 What impact does URTPI have on user behaviour, especially in regards to temporal and spatial dimensions of route choice?	✓	✓
Q2.2 What influence does URTPI have on PT demand distribution?	✓	✓
Q2.3 How can cognitive aspects be used to explain passengers' use of URTPI, as well as their choices?		✓

4.3.3 Piloting

A survey questionnaire needs to be validated by conducting a pilot survey before the final survey is administered. Piloting the questionnaire is a very important part of a survey methodology; however, often neglected by the surveyors. This can be a result of lack of time or cost associated with a pilot survey. A pilot survey can be useful even if all the assumptions of designing a survey are correct. In that case, a pilot survey will not reveal any caveats of the survey and the pilot survey results could be combined with the final survey sample. Alternatively, if any major issues arise in the pilot survey, the surveyor is able to amend it accordingly before the final survey. After designing the questionnaires for this study, pilot surveys were carried out. Any issues related to the questionnaires were dealt with before the commencement of the final surveys.

4.3.4 Survey Content Definition

Theoretical Framework

To design the survey questionnaires, at first, a theoretical framework was constructed which is inspired by TPB (discussed in section 3.1.4). Figures 4.2 and 4.3 present the factors investigated in this study that may influence passengers' behaviour. It is to be noted that this study does not measure individual's attitude directly by constructing questions on TPB. The design of the survey questionnaires was inspired by this theoretical framework (detailed discussions are presented in the survey design sections). Before designing the survey questionnaires, a focus group was carried out to minimize the confirmatory bias.

Focus Groups

Surveys are sometimes criticized for confirmatory bias, i.e. survey participants are pushed towards answers that are provided to them. Therefore, it is important to understand all the possible questions and options that passengers might come up with for a given situation. This can be done with a preliminary focus group discussion. A focus

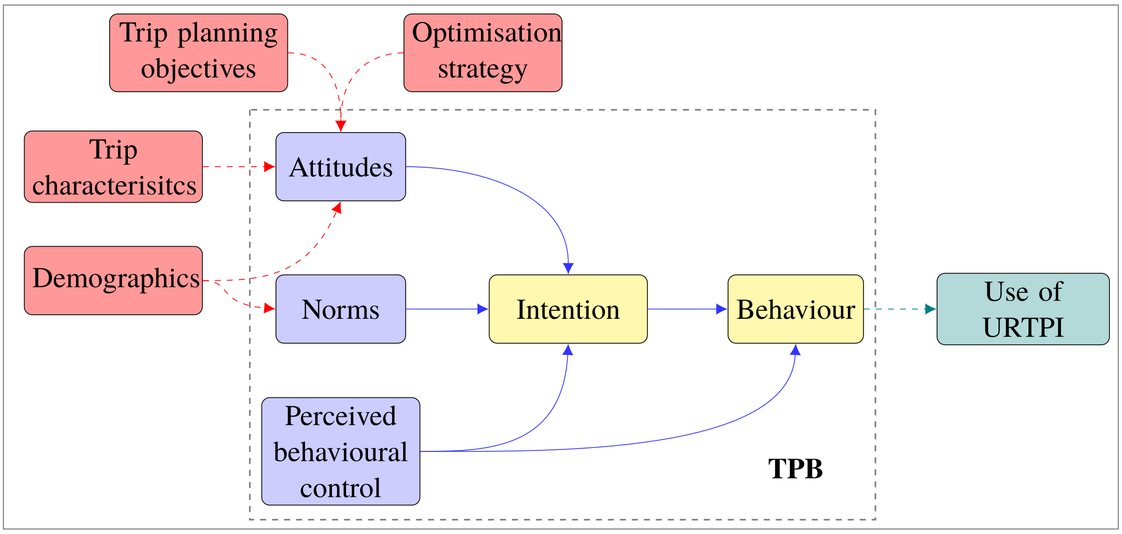


Figure 4.2 Framework for modelling factors affecting the use of URTPI

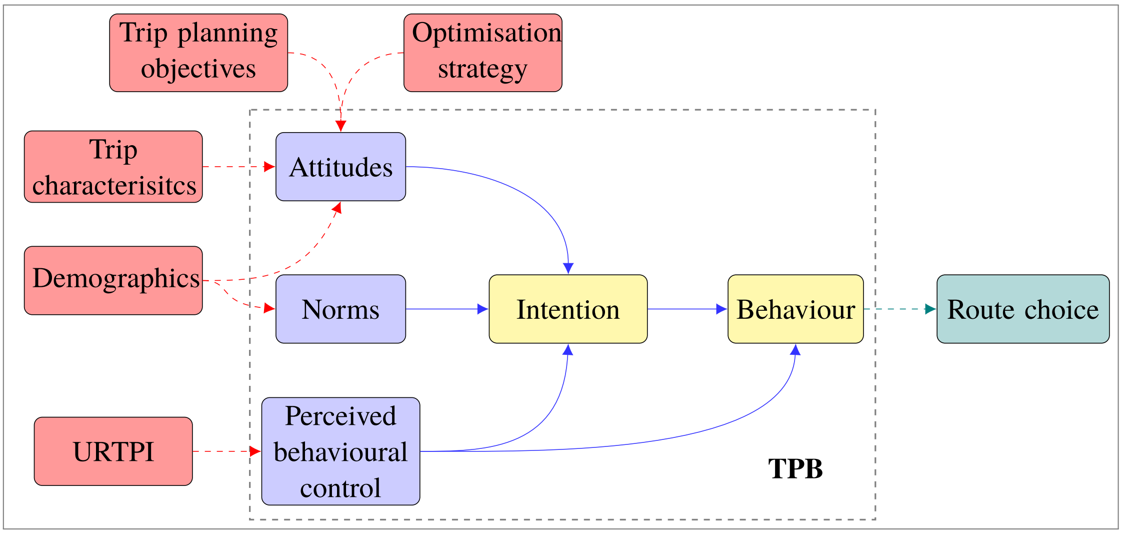


Figure 4.3 Framework for modelling factors affecting passengers' route choice

group method is a form of facilitated group discussion with several participants on a specific topic or issue (Kitzinger, 1995). It has been widely used for qualitative research in transport (e.g. Beirão and Cabral, 2007; Dell'Olio et al., 2011; Farag and Lyons, 2008; Gillam et al., 1999; Papangelis et al., 2013). Focus groups help to reduce the risk of confirmatory bias, as participants come up with their opinion without being pushed to any particular one. Focus groups allow the participants to agree or disagree with each other, which helps to understand their way of thinking. In addition, the interaction between the participants and facilitator stimulates the participants to reveal essential information relevant to the topic of the discussion. It also reveals how participants perceive different questions and how they tend to answer them. This would help to develop the aforementioned survey questionnaires.

In this study, the focus group was not the main method of data collection, it was used to get a preliminary idea of user perception regarding the use URTPI and to develop the choice options for the survey questionnaires. The focus group was conducted with seven participants where all the participants were students. It was designed and carried out to examine what passengers think about making journeys using URTPI. The total duration of the focus group was 1 hour and 45 minutes. The first part of the focus group was designed to collect information regarding participants' demographics, such as age, profession and gender as well as their PT usage (i.e. the frequency of PT use), type of ticket used and access to information services. The participants provided this information by filling out a form at the start of the session. Having access to the Internet on their phone, only one participant was found to be a non-user of URTPI. The main discussion began with the discussion on why they use (if they do) URTPI and the subsequent benefits gained by the travellers. The participants were then asked to propose any potential improvements in the information systems they would like to see in future. After that, participants were asked to explain how they make a journey and what changes they make. The focus groups transcription revealed several aspects regarding the use of information in Edinburgh. Participants who use URTPI stated why and when they use it. In addition, they described what actions they take after consulting URTPI. Examples of certain situations were also given by the participants to explain their actions. Although the focus group discussion revealed important information regarding the use of URTPI, the group of participants consisted of only students of age between 22 to 30 and the majority of them were female. Therefore, the sample cannot be considered representative of the bus passenger population. Use of a small and homogeneous sample may not provide all the important aspects of passenger behaviour as other user groups were missing, i.e. older passengers. On the other hand, the focus group participants were familiar with the ICT and so with mobile apps and websites. This led to a preliminary understanding of the use of URTPI. The focus group revealed that students and young passengers have higher propensity to use URTPI and perceived necessity plays an important role for not using it. Participants generally find information accurate and easy to use. Frequency of use of information and passenger choices are found to be influenced by trip characteristics such as trip length, time of day and trip purpose. In addition, the focus group also revealed some of the factors considered by the passengers when making trips. Although the findings relate to a particular group, it helped develop the survey questionnaires. Being aware of the focus groups sample limitations, the survey questionnaires were piloted to test whether all the aspects of different user groups were addressed. The list of focus group questions and transcriptions are provided in Appendix A.

4.4 Bus Stop Survey

4.4.1 Study Area

Before designing the questionnaire, a study area was defined. This study focuses on investigating the potential impact of URTPI on bus passengers' decision-making. Hence, it was important to collect data in a location where different URTPI sources are available for the passengers. In addition, passengers' decision-making is linked to the availability of alternative PT services. Therefore, a study area i.e. PT network was selected where bus services are well developed as well as the URTPI systems. Edinburgh, the capital city of Scotland (UK) has a population of 507,000 (Edinburgh City Council, 2017). 70% of the city population is of working age (16 to 64) and 51.3% of the population is female. The city has a well-developed and largely used PT system comprised of buses and trams. Trams offer services to limited destinations. Lothian Buses is the main transit option available to the passengers which handles about 0.35 million passenger journeys per day (Transport for Edinburgh, 2014). Compared to other Scottish cities, Edinburgh has a higher percentage of bus users and low car ownership. 40% of households do not own a car and 18.5% people use the bus as their main mode of transport. In addition, 89% of the adult passengers are satisfied with the PT services in Edinburgh (Edinburgh City Council, 2017).

Bus systems in Edinburgh offer frequent services to the passengers. The majority of bus lines offer bus headways of 5 to 10 minutes during the peak hours and 10 to 15 minutes during the off-peak hours. In addition, PT passengers in Edinburgh have access

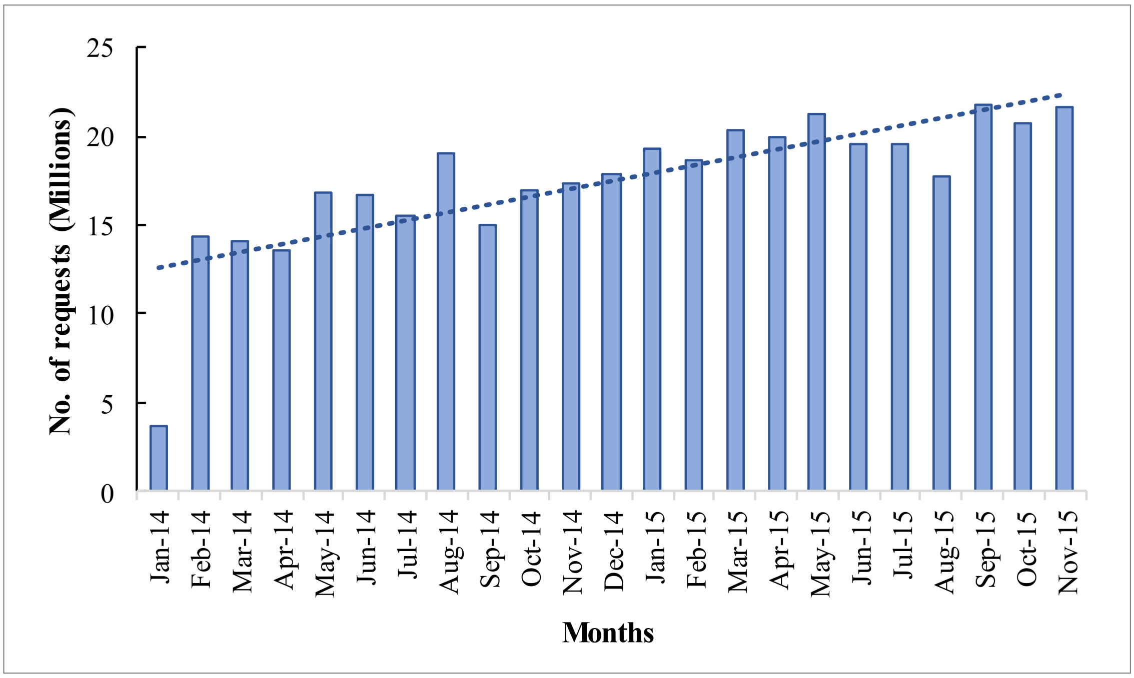


Figure 4.4 Number of user access to Edinburgh bus tracker

to different sources of information including URTPI sources, such as mobile apps and websites (see Table 2.1 for classification). Figure 4.4 shows the number of user requests received on the bus tracker service (Data source: SEStran[1]). Albeit, a local minimum (i.e. August 2015) is observed in the number of requests per month due to missing data, the user requests data demonstrates a mild increasing trend (trend line) in the use of URTPI. This may be a result of the increasing popularity of URTPI among PT passengers. The largely used bus services and the availability of different URTPI systems demonstrate the suitability of Edinburgh as the study area for the bus stop survey.

4.4.2 Survey Design

User and Trip Context

The bus stop survey was designed to collect data on PT passengers' behaviour as a result of using URTPI. The literature review revealed that demographics and trip characteristics influence traveller behaviour. Passengers were asked to answer considering the trips

[1] SEStran is the statutory Regional Transport Partnership for the South East of Scotland, which encompasses eight local authorities: City of Edinburgh, Clackmannanshire, East Lothian, Falkirk, Fife, Midlothian, Scottish Borders and West Lothian.

they were making. Questions on individual and trip characteristics were incorporated. This revealed passengers' behaviour with regard to trip contexts, such as purpose, length or familiarity of a trip. The trip characteristics and individual characteristics considered in this survey are listed in Table 4.3.

Table 4.3 Trip characteristics and demographics

Trip characteristics	Demographics
Trip length	Age
Trip purpose	Education
Time of day	Profession
Familiarity of trip	Gender
Availability of alternative bus lines	Residence
Availability of alternative modes	

Trip length is traditionally considered as one of the factors related to trip contexts that influence travel behaviour. Trip length could be estimated in terms of duration or distance of the trip. In the survey questionnaire, trip length is categorized into five groups: very short, short, medium, long, and very long. The classification is clearly fuzzy and influenced by the interpretation of the respondent. However, it was deemed that numeric evaluation of duration or distance would not be reliable enough. Furthermore, this study assumes that passenger choices are influenced by their perception of trip length, which depends on the context of the trip as opposed to the actual numeric duration or distance. For example, 'long' trips are different in London when compared to Edinburgh.

Trip purpose is typically linked with the time constraint of the trip and therefore expected to influence passenger behaviour. It is categorized as: trip to work or home, work travel, shopping, personal or family (p/f) business and leisure trips. The first category refers to commuting trips. Work travel means if the trip is being made as a part of their job, such as site visits, travelling to another office for a meeting. Shopping trips include any kind of shopping such as groceries. Personal or family business refers to meeting someone or picking up a parcel, etc.

Time of day is related to passengers' perception of the traffic or service conditions during the different times of a day. Hence, the time of day is expected to have an influence on passenger behaviour. No question was developed regarding the time of day as the survey hour provides the time of travelling. The survey was carried out during the day; therefore, depending on the survey hours, time of day was categorized into three groups: morning (before 10.30), midday (10.30 to 14.00) and evening (after 16.00).

Familiarity of trip revealed whether a passenger was making the trip for the first time or not. This may influence passenger behaviour as the planning and execution of a new trip requires more detailed information compared to a familiar trip. The passengers were asked whether they made the trip to the same destination before or not. This is related to passengers' awareness regarding different trip attributes, such as modes and bus lines available.

Alternative bus lines and mode of transport are also important for passengers to make choices. The availability of alternatives offers more choice options to passengers, which may also influence their consultation of information. Questions were developed to investigate whether passengers had any alternative modes (i.e. walking, cycling or other PT mode, etc.) or alternative bus lines available for the journey.

Demographic information was also collected regarding the levels or categories of the attributes such as individual's highest level of education, and their profession. Residence of the participants was also investigated to identify if they were local residents or visitors.

PT passengers get access to URTPI free of cost, albeit the required devices (i.e. smartphones and iPads, etc.), as well as access to the Internet, are associated with monetary costs. On the other hand, individual's value of time may depend on their income, which may influence their choices. However, it is difficult to obtain this information as participants are not commonly willing to disclose their income, especially in a supervised survey. Hence, income of the passengers was not included in the passenger demographics. UK transport networks have zone based flat fare system, so ticket types were not assumed to be affecting the choices. In addition, this study looks into the use of URTPI by existing bus users in the UK, hence other demographic information such as car ownership or driver's licence holding are not considered. These demographic information are mainly required for modal spilt study.

Passengers' Choices

To study bus passengers' behaviour under the influence of URTPI, a set of choice elements was defined. Passengers' decision-making can be classified into choice elements related to the route and mode.

Time of departure from start: This refers to the departure time from the origin, i.e. passengers may leave their origin earlier or later than they had intended.

Boarding time: This refers to the choice of boarding a bus at a certain time, i.e. a passenger may choose to board a bus at 09:45.

Departure stop: A bus stop where a passenger boards the bus.

Alighting stop: This is the bus stop where a passenger alights from the bus.

Bus lines: This refers to passengers' desired bus line for making a trip.

Mode choice: This is concerned with choosing a mode, i.e. bus, bike and walking, etc.

The aforementioned choice elements represent the aspects of a trip related to passengers' decision-making that can be influenced as a result of consulting URTPI. A list of the choice elements are presented in Table 4.4 along with different sources of information to show which sources enable passengers to make changes in the respective choice elements. It can be observed that URTPI offers more freedom of making changes to the passengers compared to the location-specific information systems (e.g. bus stop displays).

Questionnaire Design

Learning from the focus group discussion, the final survey was designed following the guidelines proposed in existing literature (Babbie, 2007; Bryman, 2008; Oppenheim, 2000; Richardson et al., 1995). The survey questionnaire comprised single choice, multiple choice, and Likert scale questions. No open-ended question[2] was asked except for participants' age. Open-ended questions are time-consuming and participants may skip them as they are reluctant to write. The final version of the bus stop survey ques-

[2] Open-ended questions refer to the ones that allow participants to give a free-form answer as opposed to providing them with options.

Table 4.4 Passengers' choice elements

		Sources of information					
		Printed maps and timetables		At stop display bus tracker	Mobile bus tracker	Bus Journey Planner	Multi-modal journey planner
		At stops	Online				
	Space and time of accessibility	Static local	Static ubiquitous	local RTPI	URTPI	URTPI	URTPI
Choice elements[1]	Time of departure from start		(✓)		✓	✓	✓
	Boarding time	(✓)	(✓)		✓	✓	✓
	Departure stop[2]	(✓)	(✓)	✓	✓	✓	✓
	Departure stop[3]		(✓)			✓	✓
	Alighting stop	(✓)	(✓)			✓	✓
	Bus lines	(✓)	(✓)	✓		✓	✓
	Change mode			✓[4]	✓	✓	✓

[1] Check marks in brackets show limited possibility to change without real-time info

[2] Walk to a different stop on the same bus line

[3] Walk to a different stop and choose a different bus line

[4] Offers limited choices, such as change to walking only after arriving at the stop

tionnaire consisted of 16 questions in total (attached in the Appendix B). Depending on the answers, participants who use URTPI have to answer a maximum 15 questions. Figure 4.5 presents the structure of the survey questionnaire followed by the sections discussing the structure and content of the survey questionnaire.

The survey questionnaire began with a question regarding the sources of information used by the passengers for the trip. Answering this question allowed the participants to be categorized as user or non-user of URTPI. If the participants select any of the URTPI sources, they had to answer questions regarding the use of URTPI.

Regardless of whether or not they use URTPI, all the participants were asked about their trip characteristics and demographics (mentioned in Table 4.3). Questions related to demographics were also included for all the participants. These questions were placed at the end of the questionnaire, because participants may get tired or bored as time progresses. Hence, providing questions at the end that require less cognitive efforts

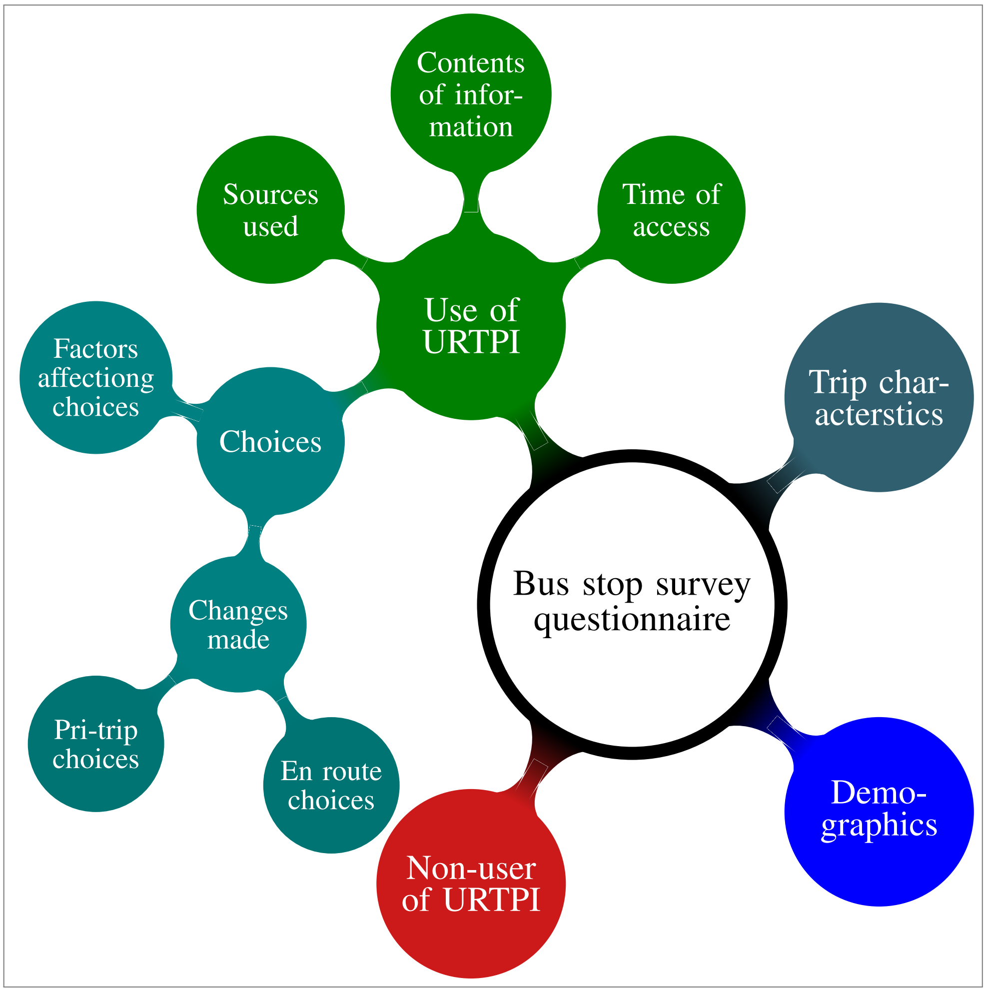


Figure 4.5 Structure of the bus stop survey questionnaire

would increase the possibility of getting more valid answers to questions related to the choices.

The questions on the use of URTPI only appeared to the participants if they had used at least one of the presented sources of URTPI for their trip. The use of information and passengers' choices were presented in this section of the questionnaire. Passengers' time of access to information (i.e. pre-trip or en route) and contents of information, such as bus arrival time, bus route map were the attributes of these questions. In addition, the participants were also asked about the changes they were making to that trip (Table 4.4). The factors affecting their choices were also considered in the questions. Passengers' choices as a result of pre-trip and en route access to URTPI were incorporated for the users of URTPI. Non-users of URTPI were asked to state the reason for not using URTPI, as well as answering questions regarding the trip and their demographics. Participants were offered little incentives[3] which was mentioned at the end of the questionnaire. The factors considered for modelling passengers' choices are trip characteristics, demographics, contents of information and the factors related to trip planning objectives. The total number of variables related to the aforementioned factors is 18. Hence, the bus stop survey sample was expected to contain at least 30*18=540 users of URTPI.

Survey Platform and Tools

The bus stop survey was a self-completion supervised survey. Therefore, the questionnaire was to be completed by the participants with the supervision (if needed) of the surveyors. This allowed the participants to ask the surveyors if they had any confusion or query about the questions. Supervised intercept surveys are commonly carried out by means of paper-based questionnaires. However, nowadays various web-based platforms are available, where the questions are uploaded and the survey can be carried out both online and off-line with mobile devices (i.e. phones, Tablets and laptops, etc.) This is a very convenient method for carrying out surveys as it reduces the effort of handling papers. When the survey is finished, the survey data can be uploaded to the server. Hence, the efforts and issues associated with transferring data from a paper based survey are avoided. Moreover, nowadays people are interested to use mobile devices which might encourage them to take part in the survey as well. For this study, the survey questionnaire was uploaded to an online survey platform named "Questionpro" (`www.questionpro.com`), which allows the survey to be carried out off-line. The bus stop survey was carried out with Android tablets.

Pilot Survey

A pilot survey was conducted at bus stops to test the passengers' understanding of the questionnaire and time required for the completion. A total of 33 participants took part in the pilot survey. The survey questionnaire was found quite understandable and a few

[3] Two £25 shopping voucher were given to two randomly selected participants who had provided their email address.

minor alterations in wording was made to the questions. No major concern regarding the content of the questionnaire was raised.

4.4.3 Survey Hours and Locations

The bus stop survey was designed to be conducted at bus stops in Edinburgh. The first step of data collection was to select the bus stops where the surveys were carried out. The bus stops were selected considering a few attributes related to PT services such as availability of bus lines and passenger information sources at the bus stops. To ensure that sufficient participants would be available, passenger demand at the bus stops was also considered. As no demand data for each of the bus stops in Edinburgh was available, the general crowdedness of the stops was observed during the pilot survey. The availability of multiple bus lines at the bus stops was also considered. Bus headways in Edinburgh are mostly 10 to 15 minutes during the day. Some of the bus lines have more frequent buses during morning peak hours (5 minute headways). This might not provide enough time to carry out the survey, therefore, when selecting a bus stop, the present study considered those that serviced bus lines of 10 to 15 minutes as well as 5 minutes headways in the selection process. This may produce a sample biased towards passengers using bus lines with 10 to 15 minutes headways. However, the effect was not expected to be significant as a few bus lines have short headways. Fifteen different bus stops were selected for the survey. Location-specific travel information sources such as bus stop displays, printed maps and timetables were available at all the selected bus stops. Figure 4.6 presents the location of the surveyed bus stops. The surveyed bus stop locations were mostly rather close to the city centre, which was a result of the criteria for selecting bus stops, i.e. available alternatives and sufficient passenger demand. This may produce biases regarding trip length, or availability of alternatives, because inbound trips to the city centre may be shorter and also have more alternatives than those outbound trips. To minimise the biases, both inward and outward directions were sampled. Outward surveys at stops in or near centre would pick up trips to outer suburbs, especially in the evening peak hours.

The survey was carried out at three different times of the day to cover the trips made

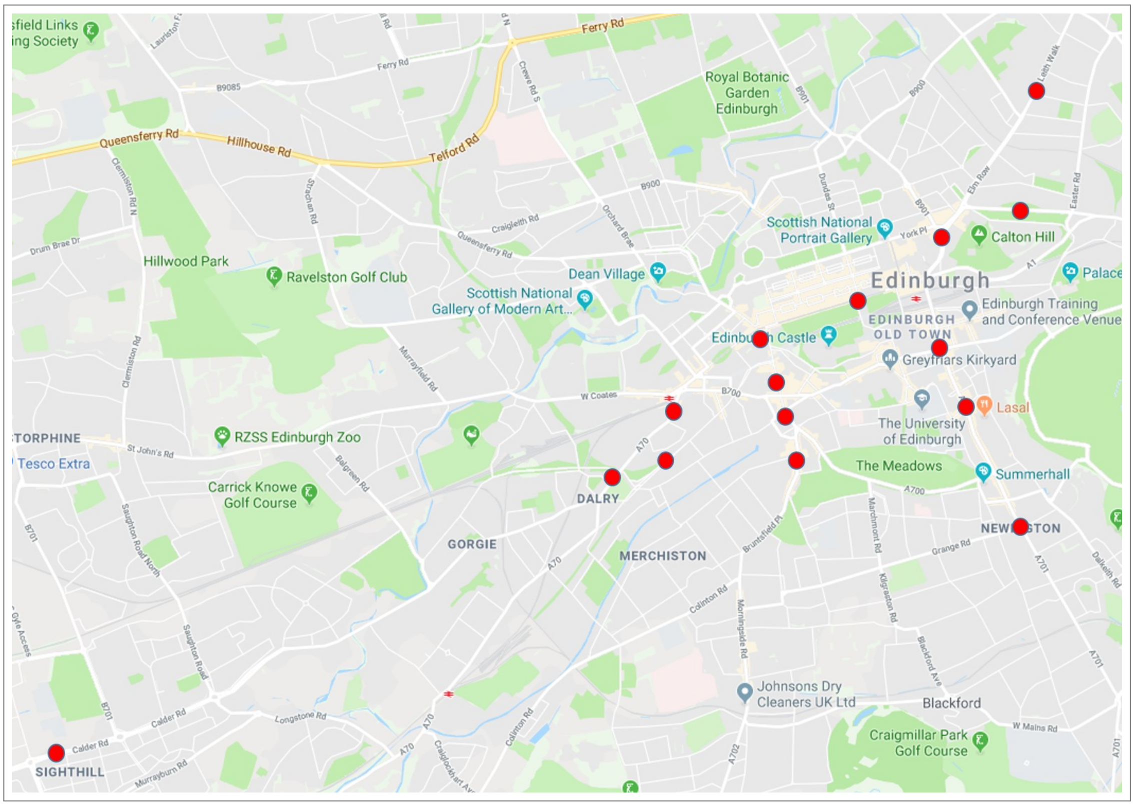


Figure 4.6 Location of the surveyed bus stops

on different days of the week and hours of a day. PT patronage data was not available to identify the hourly demand, hence an alternative data set on the number of user access to Edinburgh bus tracker (Mobile apps and websites that offer real-time bus arrival time) was used. This data was provided by SEStran, and the data is not open to the public. The user requests data indicates that URTPI is consulted most in the morning and evening peak hour of the weekdays (Figure 4.7).

Figure 4.7 shows that the peak demand for information in the morning is observed from 06:30 to 09:00 and the evening peak is from 15:30 to 18:00 (black dashed line). The weekday off peak is observed between 11:00 to 14:00 (red dashed line). In the weekend, the use of URTPI starts rising as the day progresses. Given the user demand for information, the morning hours from 07:30 to 10:30 and evening hours from 16:00 to 18:00 were selected to conduct the the survey. Although Figure 4.7 shows that morning peak demand for information begins at 06:30, it was assumed that the passengers would need some time to arrive at bus stops and passenger demand would be sufficient from 07:30 onwards. In addition, passengers in the morning were presumed to be less likely to take part in the survey, hence a three hour period for surveys in the morning was

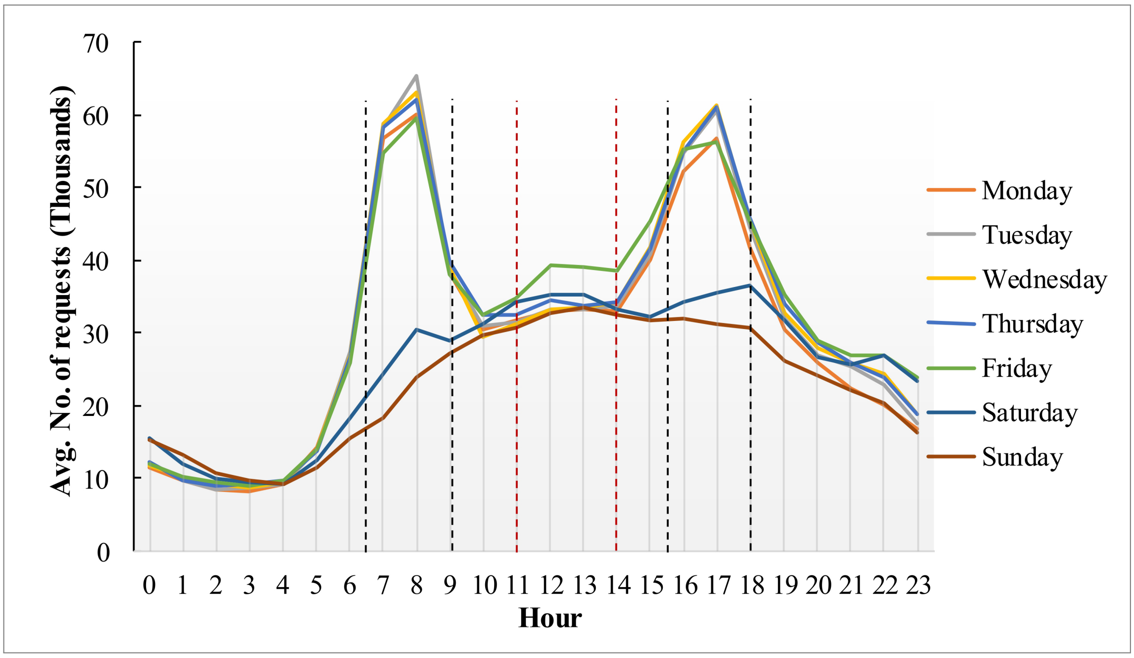


Figure 4.7 Number of access to Edinburgh bus tracker per hour

chosen. The following hours for each day was chosen to carry out the survey.

- ▻ Weekdays (Mon-Fri)
  - Morning (Peak): 07:30-10:30
  - Evening (Peak): 16:00-18:00
  - Midday (Off-peak): 11:00-13:00
- ▻ Weekend (Sat-Sun)
  - Midday : 10:30-13:30
  - Evening : 16:00-18:00

The data collection at peak and off-peak hour may limit the study results for PT users at other times of the day, such as passengers travel at night. Information for making trips at night may prove to be more important to the users. However, this survey was designed to collect a sample that is representative in terms of passenger demographics and trip characteristics. Different combinations of the above survey hours along with days of a week were chosen, which would provide data for different demographics and user contexts.

The bus stop survey was planned to be carried out in parallel at five different bus stops. Therefore, five surveyors were required to conduct the survey. To appoint the surveyors, an email was circulated to the students of the University and five students were contacted as per their expression of interest. All of them were briefed on the survey. They were given safety instructions as per the University regulations. In addition, each surveyor was provided with a T-shirt with University student ambassador logo to draw passengers' attention. As previously mentioned, the questionnaire was uploaded to an online platform (Questionpro), which allow to conduct the survey off-line as well. Five android tablets were installed with the "Questionpro" applications for this survey.

Human participation was involved in this data collection method. Therefore, as per the University research ethics, an "Ethical approval" for the survey was requested. All the details regarding the survey, data collection, data protection and privacy associated with the survey were provided to the University research ethics committee. The application was approved by the committee. Ethical approval form is attached in Appendix C.

4.4.4 Data Collection

The survey was not designed to assess the impact URTPI over a certain period. The URTPI sources have been available for several years and became popular due to a high level of smartphone and the Internet penetration. The aim of this study was to collect data on the extent of use of existing URTPI. Although temporal data may reflect the influence that the time of the year has on passenger behaviour, it was not considered given the aim of this study. Due to limited resources, the final survey was carried out in nine consecutive days from 4th July to 12th July 2016 including both weekdays and weekends. No special events were going on at that time; however, this period included school's summer break. Although the city may have had slightly smaller numbers of regular PT passengers due to the holidays, the bus stop survey would not have been affected much by school holidays, as the survey participants were at least 18 or older. The survey hours for each days are presented in the Table 4.5. A detailed survey schedule for all the bus stops is presented in Appendix D.

At first, the survey was carried out during two of the survey periods (4th to 7th July in Table 4.5). Due to a very low demand at the bus stops, survey hours were changed at some of the bus stops. Hence, on 8th, 11th and 12th July, surveys were conducted

Table 4.5 Bus stop survey schedule

Day type	Date	Survey hours [1]
Weekday	4th July	Midday and Evening
	5-7th July	Morning and Evening
	8th July	Morning, Midday and Evening
	11-12th July	Morning, Midday and Evening
Weekend	9-10th July	Midday and Evening

[1] Survey hours are defined in section 4.4.3

in different hours at each bus stop. Each of the surveyors spent the assigned hours of a day at one bus stop and changed the stop for the following day. This was done to make sure that the participants were not taking part in the survey more than once. In addition, participants were asked if they had already taken part in the survey. At the end of each day, the surveyors uploaded the survey data to the server. When approached at the bus stops, passengers were found to be willing to participate and, from surveyors' anecdotal accounts, approximately 80% people agreed to take part in the survey. A total of 1779 people started the survey, 1645 people completed it (completion rate of 92.5%). Average survey completion time was 4 minutes for the participants who used URTPI for their trip, whereas non-users of URTPI took on average of 3 minutes to complete the survey. Table 4.6 presents the number of respondents per bus stop. Figure 4.8 shows the percentage of passengers that participated in the survey at different time of days. 37% of the responses were collected during the morning survey periods. Midday and evening survey hours provided 28.8% and 34.2% of total responses respectively. It is noteworthy that the proportion of midday trips is not far short from peak hour trips. Typically, significantly higher number of trips are made during the peak hours. However, this study do not intend to find out the number of trips made at different hours of a day. Instead, it was deemed important to collect a number of responses for different time of day so that the statistical analysis reflects the effect of time of day on passenger choices. The survey was not designed to collect any observational data such as waiting time at the bus stops. The survey provides data based on what passengers stated in reply to the questions.

Table 4.6 Number of respondents in each bus stop

Bus stops	No. of respondents	Bus stops	No. of respondents
Brunton place	154	Scott Monument	202
Fountain Park	120	Salisbury road	37
Fountainbridge	31	Sighthill	39
Haymarket	177	South Bridge	32
Leith Street	103	Surgeons Hall	159
Lothian road (Pr. Str. west)	167	Tollcross	119
Orwell Place	142	Usher Hall	37
Pilrig	126		

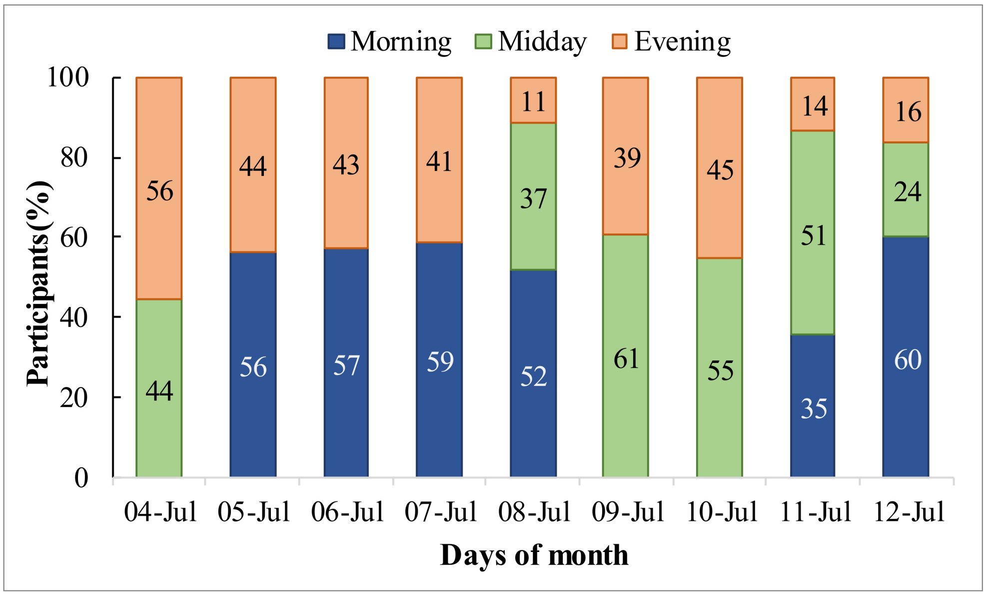


Figure 4.8 Bus stop survey responses at different times of days

Challenges of Bus Stop Survey

Few minor problems occurred during the bus stop survey data collection. Based on the pilot survey experience, the survey was expected to take a minimum of 4 to 4.5 minutes. Due to the widespread use of URTPI, passengers were found to arrive timely at the stops, i.e. with 2 to 3 minutes before the arrival of their bus. When requested to take part, passengers mentioned that their bus was arriving in 2 minutes or less; therefore, could not take part in the survey. Some of the passengers that started could not finish the survey due to time constraints. Thus, this method of data collection posed inconvenience to the willing participants for carrying out the survey. The bus passengers may have benefited from using URTPI and were able to arrive at the bus stop just before the arrival of the bus, which is also supported by Watkins et al. (2011).

The latter study found that URTPI users experience shorter waiting time at the bus stops in comparison to non-users. In addition, some of the bus stops were not being used by many passengers during the survey hours. This issue was resolved by adjusting the survey hours for the particular stops or changing the survey stops for a particular survey hour.

4.5 Online Survey

In this study, the bus stop survey was designed to collect data on passengers' actual behaviour. However, due to time limitations, the number of survey questions was limited. Few aspects of this study with regard to the research questions had not been accommodated in the bus stop survey, especially the impact of cognitive aspects on passengers' choices. Therefore, a longer survey questionnaire was developed to gain an insight into passengers behavioural aspects. This survey was planned to be administered via an online platforms. Unlike the bus stop survey, the online survey was designed considering passengers' behaviour in general when they travel by bus. To obtain answers on what participants typically do when travelling by bus, the questionnaire focused on passengers actions for the last six months from the time of taking part in the survey. In this kind of questionnaire survey, participants have to recall what they did in the past. Sometimes the responses reflect their very recent or worst experiences. The questions were developed with Likert scales to understand the frequency of any actions regarding the use of URTPI and their choices in different trip contexts. Unlike the bus stop survey questionnaire, the online survey questions were not limited to binary choices. This allows for a richer data set on passengers' behaviour to be obtained.

4.5.1 Study Area

As the online survey is disseminated through the Internet platforms, getting enough responses from one city is difficult. Therefore, to obtain a sample which is representative as well as large enough for statistical analysis, the survey was planned to be disseminated across the UK.

4.5.2 Survey Design

Questionnaire Design

The online survey questionnaire design was based on the previously discussed bus stop survey questionnaire. Hence, the survey format was similar to the bus stop survey. However, the online survey questionnaire was designed to investigate what passengers usually do and their usual behaviour was measured on Likert scales. Figure 4.9 illustrates the structure of the online survey questionnaire.

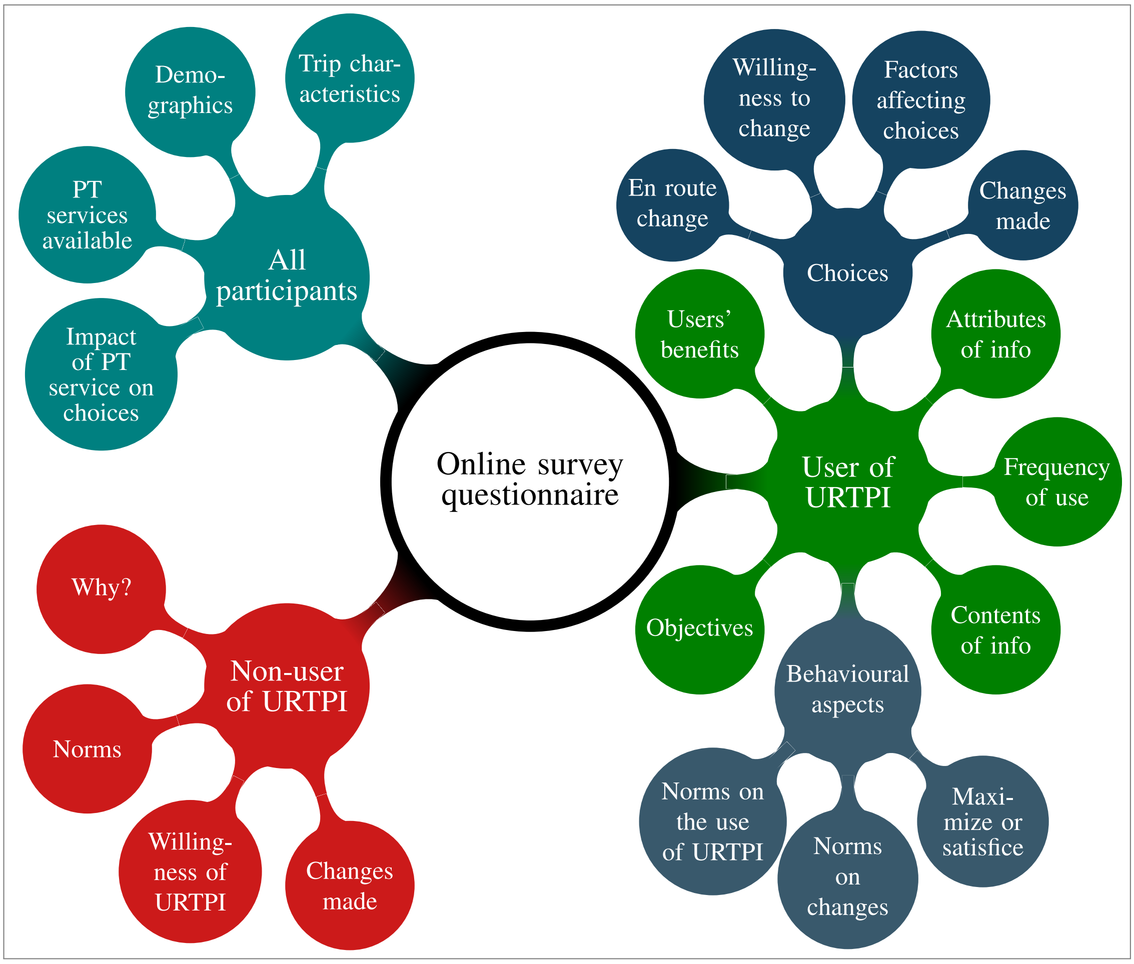


Figure 4.9 Structure of the online survey questionnaire

Similar to the bus stop survey, participants were asked about the sources of information they generally use when travelling by bus. To investigate the usage of URTPI, a question on the frequency of use of URTPI was also included. The URTPI users had to answer questions on the frequency of use of URTPI, perception regarding the attributes of information, benefits and factors affecting the use of URTPI and desired contents of information. To understand passengers' use of URTPI and their choices in light of behavioural theories, questions on norms and satisficing strategy were prepared. The impact of URTPI on passengers' route choice was to be assessed by investigating what changes respondents usually make after consulting URTPI. In addition, factors concerning their changes and passengers' intention to make changes were considered for designing the online survey questionnaire. En route information is one of the unique features offered by URTPI. This helps passengers to make choices en route as well as when making a trip chain[4]. Passengers' attitude towards en route information acquisition and choices were taken into account in this survey.

The design of questions for non-users began with the reason for passengers' indifference in using URTPI. Factors hindering the use of URTPI and any changes they make even without consulting information were studied.

Passengers' demographic information, frequency of travel by bus for different trip types were included. The online survey is a self-selected unsupervised survey, therefore it was important to gather information regarding any long standing disability that participant might have. This would help to understand whether their choices were influenced by any long standing disabilities.

Similar to the bus stop survey, "Questionpro" was also used for the online survey. The survey was uploaded to the online platform and disseminated via different Internet based media such as email, social and professional media, etc. A final version of the online survey questionnaire is presented in the Appendix E. Valid percentages (i.e. calculated based on the valid responses) of responses for each questions are also presented in the appendix.

Pilot Survey

A pilot survey is very crucial in the case of an unsupervised survey where the participants have to take part without any assistance. The length of the online survey questionnaire

[4] A trip chain, also known as multi destination trip, is a series of trips with short time activities (picking up a parcel or buy something from shops) in between trips.

was not limited as much in comparison to other surveys, such as intercept survey. However, the time for completion is important because participants may opt out if the questionnaire is too long. A face-to-face pilot survey was carried out with the online survey questionnaire to investigate participants' opinion regarding the survey. The time needed for completing the surveys was recorded. Participants feedback was noted for further refinement of the questionnaire. Main comments received from the pilot survey were: time consuming, and complicated language in some questions. Participation time varied from 15 to 20 minutes. The survey questionnaire was modified to resolve the language issues by consulting with both native and non-native English speakers. It was not possible to reduce the duration for completion, as reducing the number of questions would not provide all the data required. The online survey data analysis was expected to have more independent variables (about 20) than the bus stop survey. Therefore, the online survey questionnaire was disseminated to obtain a sample of 600 users of URTPI.

Before disseminating the questionnaire, the survey was Ethically approved by the University research ethics committee (see Appendix F). The survey was anonymous and participants consent were taken by presenting an option *"I want to participate"* at the beginning of the survey.

4.5.3 Data Collection

The online questionnaire was set in the online survey platform-"Questionpro". The questionnaire was comprised of 35 questions in total. However, a maximum of 27 questions were to be answered by any participants if they were users of URTPI. The dissemination of the survey questionnaire started in April 2017 and participants were offered a little incentive[5]. The invitation to take part in the survey was disseminated in different ways, using different tools. The survey was posted in professional and social media, such as Linkedin, Twitter, Facebook, etc. To get more attention, the posting was done with hash-tags. Different social and voluntary groups, such as cycling groups

[5] A £50 shopping voucher was given to one participant drawn from a lottery.

(Spokes), and Bus users UK, were contacted for disseminating the survey. The survey was shared by them on their respective Facebook and Twitter pages. However, even after two months, an insufficient number of responses was received. Hence, the survey was disseminated adopting snowball sampling. People who took part in the survey were requested to forward it to people they know. In addition, flyers with the survey link was distributed at bus stops and at events in Edinburgh (i.e. seminars and conferences). However, the response rate as a result of flyer distribution was less than 10%. After five months of dissemination, a total of 401 completed responses were collected. Although, the survey questionnaire was viewed by 2885 people, only 864 people started and 401 participants completed the survey. From the incomplete survey data, 351 partially completed responses were also obtained. Although a minimum of 600 responses was expected, it was not possible to meet the target.

Challenges of Online Survey

Existing literature highlights online survey as a potential technique to reach a large groups of people. Albeit, it is true that the use of the Internet enables researchers to disseminate survey within a large population, people's indifference to take part in this kind of voluntary survey was noticeable. The survey was viewed by a large amount of people, however, was disregarded by three-quarters of them. Therefore, getting a good sample of participants through online survey is quite challenging as people are not willing to spend time on taking part in surveys.

4.6 Summary

This chapter presented the methodology and data collection carried out in this study. To answer the research questions, a RP survey methodology was adopted. Two questionnaire surveys were designed and carried out. The first survey was carried out at the bus stops in Edinburgh, which focussed on in-situ data collection on passengers' choices, i.e. the trip they were making at the time of the survey. A total of 1645 responses were collected. Another RP questionnaire survey was carried out within the bus passengers in the UK via the Internet platforms. A sample of 401 responses was collected by means of the online survey. The latter survey incorporated questions regarding passengers' cognitive aspects along with the questions on the use of URTPI and choices. Both the survey data were then filtered and prepared for analysis.

The following chapter will discuss the data analysis techniques used in this study.

CHAPTER 5

DATA ANALYSIS METHODOLOGY

This chapter presents the methodology used in this study to analyse the data collected by two questionnaire surveys. At first, a review of different discrete choice models is presented and a logit model is discussed. The application of Principal Component Analysis (PCA) and Categorical Regression (CATREG) are also discussed in this chapter. The analysis tools used in this research are mentioned to conclude this chapter.

5.1 Discrete Choice Model

As stated in TPB (Section 3.1.4), an individual's behaviour is shaped by their attitude and intention. Existing literature supports the influence of attitude on the use of information, as well as on the choices made by the passengers. This study assumes that passengers' attitude to use information, as well as making choices are influenced by their demographics, trip characteristics and behavioural aspects (shown in Figure 4.2 and 4.3).

This study investigates the impact of trip characteristics and demographics on the use of URTPI by incorporating them as the independent variables in the models. The dependent variables for modelling the use of URTPI and the impact of information on passengers' choices are presented in Table 5.1 and 5.2 for the bus stop and online survey respectively. The dependent variables for modelling the survey data comprise a mix of binary, nominal, and ordinal types. The independent variables are the trip characteristics, demographics, contents of information and objectives of using URTPI. Hence, Discrete Choice Model (DCM) should be used for modelling passengers' choices regarding the use of URTPI and their choices. A review of DCM is presented in the following section and the theoretical background of the relevant models is reviewed.

Table 5.1 Variables in bus stop survey models

Aim	Model	Dependent variables	Variable type	Levels	Influencing factors[1]
To investigate the use of URTPI	Use of URTPI	User- of URTPI	Binary	0-No, 1- Yes	Trip characteristics and demographics (variables are nominal and ordinal)
	Preferred source of URTPI	Use of source(s)	Nominal	1-Mobile apps, 2-Google Maps, 3-Travel websites, 4-More than one sources	
	Importance of contents of information	Bus arrival time	Ordinal	Not at all important, slightly important, important, very important, extremely Important	
		Bus route map			
		Bus stop location			
		Journey plan			
		Transfer to other services			
To investigate the impact of information	Change in passenger choices	Time of departure	Binary	0-No, 1-Yes	Trip characteristics, demographics, contents of information and trip planning objectives (variables are nominal, ordinal, numeric)
		Boarding time			
		Departure stop			
		Alighting stop			
		Bus line			

[1] Variables and attributes are presented in the respective model analysis sections

Table 5.2 Variables in online survey models

Aim	Model	Dependent variables[1]	Variable type	Levels	Influencing factors[2]
To investigate the use of URTPI	Use of URTPI	Frequency of use of URTPI	Ordinal	Rarely, sometimes, often, always or very often	Trips per week, demographics, attributes of information, available PT services, benefits of using URTPI, trip planning objectives, optimisation strategies, Norms
	Importance of contents of information	Bus arrival time	Ordinal	Not at all important, slightly important, important, very important, extremely Important	Trips per week, demographics, available PT services, benefits of using URTPI, trip planning objectives, optimisation strategies, Norms
		Expected time of arrival (ETA)			
		Bus route map			
		Bus stop location			
		Walking distance			
		Journey plan			
		Transfer to other services			
To investigate the impact of information	Change in passenger choices	Time of departure	Ordinal	Never, rarely, sometimes, often, always/very often	Trips per week, demographics, available PT services, benefits of using URTPI, importance of information, trip planning objectives, optimisation strategies
		Boarding time			
		Departure stop			
		Alighting stop			
		Bus line			

[1] Models are developed for each dependent variables

[2] Variables and attributes are presented in the respective model analysis sections

5.1.1 Review of Discrete Choice Models

This section introduces and describes the DCM for data analysis used in Chapter 6 and 7. Behavioural research with SP/RP data have been carried out by different statistical analysis methods. Travel information research has also shown a great use of statistical methods, especially the application of DCM. McFadden (1978) developed the statistical estimation techniques for the application of DCM. In the context of Random Utility Theory (RUT), these techniques were improved and applied in transport research (Ben-Akiva and Lerman, 1985; Train, 1986).

The earliest travel demand and forecasting models, such as the gravity model (Bouchard and Pyers, 1965), consider aggregated data. Over time, the forecasting needs of the transport sector, has lead to a demand in modelling at disaggregated levels. The traditional four step model (Cascetta, 2009; Ortuzar and Willumsen, 2002) also requires modelling at disaggregated level, such as modelling mode choice. DCM was introduced in transport to model demand with disaggregated data. The theoretical approach of DCM lies in the RUT (McFadden, 1978), which takes both observed and unobserved effects into account. For example, in regards to mode choice, an individual's demographics and the trip characteristics can be observed; however, there are also underlying unobserved factors to be accounted for, such as perception of perceived quality and attitude towards a specific mode.

The formulation of basic DCM model starts with a simple linear function of co-variates that influence the discrete choice with an addition of an unobservable error or disturbance term (Hensher et al., 2015; Washington et al., 2011). The utility of a discrete outcome can be represented with an equation of U_{in} that determines the discrete outcome i for n observation can be formulated as-

$$\mathbf{U}_{in} = \mathbf{V}_{in} + \boldsymbol{\epsilon}_{in} \tag{5.1}$$

where,

$\mathbf{V}_i$= the deterministic component

$\boldsymbol{\epsilon}_{in}$= the random component known as disturbance term as well, which is assumed to be independent and identically distributed across all the observations n.

The deterministic part can be calculated from the observable parameter vector, hence the equation becomes-

$$\mathbf{U}_{in} = \sum \boldsymbol{\beta}_i \mathbf{X}_i + \boldsymbol{\epsilon}_{in} \tag{5.2}$$

where, β_i is a vector of observable parameters for the discrete outcome i X_i is a vector of the observable characteristics.

Based on this function, a discrete outcome i from a set of possible outcomes j for an n observation can be predicted with the following probability equation-

$$P_n(i) = P(\mathbf{U}_{in} \geq \mathbf{U}_{in}) \quad \forall j \neq i \tag{5.3}$$

$$P_n(i) = P(\boldsymbol{\beta}_i \mathbf{X}_{in} + \boldsymbol{\epsilon}_{in} \geq \boldsymbol{\beta}_j \mathbf{X}_{jn} + \boldsymbol{\epsilon}_{jn}) \quad \forall j \neq i \tag{5.4}$$

The structure of a DCM depends on the assumption of the distribution of disturbance term ϵ_{in} in Equation 5.4. When the disturbance term is assumed to be normally distributed, a *Probit model* is developed. On the other hand, a *Logit model* is developed assuming ϵ_{in} has a Gumbel distribution (Gumbel, 1958). SP and RP data have been analysed with DCM in numerous transport research studies. Table 5.3 presents a list of DCMs along with examples of travel information studies that have been carried out using the respective models.

Table 5.3 Travel information studies with DCM

DCM	Studies
Binary logit or probit model	Abdel-Aty et al. (1997), Chen (2012), Dia and Panwai (2010), Kim et al. (2009), Rahman et al. (2017), Tang and Thakuriah (2011), and Veiga Simão (2014)
Multinomial Logit Model (MNL)	Dia (2002), Emmerink et al. (1996), Kattan et al. (2013), Khattak et al. (1993), Ma et al. (2014), Maréchal (2016a), Tsirimpa et al. (2005), Venkatraman et al. (2014), and Zhang and Levinson (2008)
Mixed logit or probit Model	Ben-Elia et al. (2007), Ben-Elia and Shiftan (2010), Dantan et al. (2015), Gan and Ye (2016), Molin et al. (2009), and Tseng et al. (2013)
Ordinal logit or probit	Emmerink et al. (1996), Ge et al. (2017), Goulias et al. (2004), Rahman et al. (2017), and Zhang et al. (2008)
Nested logit model	Caulfield and O'Mahony (2009), Khattak et al. (1993), and Morfoulaki et al. (2015)
Multiple Discrete Continuous Extreme Value model	Maréchal (2016b)

Given the aim of this study, DCM will be applied for the bus stop data analysis. A binary logit model would be appropriate to identify the factors that influence passengers' use of URTPI. In addition, passengers' preferred choice of sources (single source or multiple sources) is a dependent variable with more than two levels. Hence, a Multinomial Logit Model (MNL) will be developed. Apart from the DCM, a Categorical Regression (CATREG) analysis will be performed to investigate the factors affecting the importance of contents of information (ordinal variable) and passengers' choices. CATREG has been preferred to other logit models (i.e. binary or ordinal logit) as the aim of this study is not to forecast, but to identify the significant factors that influence passengers' choices. Detailed descriptions in the following sections and the model development for each variable would justify the appropriateness of CATREG for this analysis. In addition, Principal Component Analysis (PCA) will also be performed to reduce the number of variables which are correlated. The analysis techniques for this study are described in the following sections.

5.1.2 Logit Model

As discussed earlier, a logit model is developed based on the assumption that the error term has a Gumble distribution (Hensher et al., 2015).

The following notations are generally used for logit model-

P	Probability of an outcome
$\boldsymbol{\epsilon}_{in}$	the random component known as disturbance term
$\boldsymbol{\beta}_0$	a constant or intercept
$\boldsymbol{\beta}_i$	a vector of regression co-efficient for a discrete outcome i
$\mathbf{X}_i$	a vector of observable characteristics (covariates) that determine discrete outcomes for observation n
j	set of choices

In this study, a binary logit model is developed to estimate the likelihood of a passenger to use URTPI or any particular source based on the predictor variables i.e. variables related to trip characteristics and demographics. If the probability of an outcome is P in a binary dependent variable, then the likelihood of that outcome can be expressed as: $Odds = \frac{P}{1-P}$, where P can be estimated by the Equations 5.2 and 5.3. The natural log (ln) of the odds represents the logit transformation, where logit is a function of covariates and can be expressed as:

$$logit(P) = ln\left(\frac{P}{1-P}\right) = \beta_0 + \sum \boldsymbol{\beta}_i \mathbf{X}_i \tag{5.5}$$

The probabilities of the event of interest can be computed from the logistic regression equation:

$$P = \frac{EXP\left(\beta_0 + \sum_{i=1}^{n} \boldsymbol{\beta}_i \mathbf{X}_i\right)}{1 + EXP\left(\beta_0 + \sum_{i=1}^{n} \boldsymbol{\beta}_i \mathbf{X}_i\right)} \tag{5.6}$$

Details of this model can be found in Ben-Akiva and Lerman (1985). In this study, a binary logit model is used to identify the factors that influence the use of URTPI as well as the use of individual sources of URTPI.

A MNL is developed when the dependent variable has more than two categories. The probability of choosing an alternative i from a choice set j by an individual k are expressed as:

$$P_k(i) = \frac{EXP(\boldsymbol{\beta_i X_{i,k}})}{\sum_{\forall j} EXP(\boldsymbol{\beta_j X_{j,k}})} \tag{5.7}$$

MNL is based on the following assumptions:

- The outcomes are not correlated
- Independence of Irrelevant Alternatives (IIA); odds ratio of one outcome versus another should be independent of other alternatives
- Error term has Gumble distribution

In this analysis, a MNL is applied to investigate passengers' exclusive choice of sources given the trip characteristics and demographics, i.e. which source of URTPI a passenger would use among the available ones.

5.2 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a mathematical procedure to reduce a large set of data by transforming the correlated variables into a number of uncorrelated variables. PCA is applied to reduce a large multivariate dataset and to the interpret data (Johnson and Wichern, 1992). The number of variables is reduced by explaining the variance-covariance structure using linear combinations of original variables (Washington et al., 2011). If a large proportion of the total variation of a dataset can be attributed to a few uncorrelated principal components, then these components can be used to replace the original variables without losing much information.

A dataset with p observations and n variables is expressed by a matrix **X**:

$$X_{P*n} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{P1} & x_{P2} & \dots & x_{Pn} \end{bmatrix} \tag{5.8}$$

The first principal component is calculated by the following equation:

$$Z_1 = a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \tag{5.9}$$

where,

Z_1=the first principal component, x_1, x_2 … x_n are the column vectors of original variables. a_{11}, a_{12} … a_{1n} are the coefficients of the linear model. VAR[Z_1] is maximized with the constraint:

$$a_{11}^2 + a_{12}^2 + \dots + a_{1n}^2 = 1 \tag{5.10}$$

The next principal component Z_2 is calculated with the same Equation 5.9 and subject to the constraint that $a_{21}^2 + a_{22}^2 + \dots + a_{2n}^2 = 1$ and $COR[Z_1, Z_2] = 0$ i.e. Z_1 and Z_2 are uncorrelated. Further principal components can be calculated in the same manner with the constraint that $COR[Z_1, Z_2, Z_3] = 0$

The eigenvalues of the sample covariance matrix **X** are the variances of principle components. The covariance matrix of the data set is defined as,

$$S^2[X] = \begin{bmatrix} s^2(x_1) & s(x_1, x_2) & \dots & s(x_1, x_n) \\ s(x_2, x_1) & s^2(x_2) & \dots & s(x_2, x_n) \\ \vdots & \vdots & \ddots & \vdots \\ s(x_n, x_1) & s(x_n, x_2) & \dots & s^2(x_n) \end{bmatrix} \tag{5.11}$$

The sum of the eigenvalues λ_n is equal to the diagonal elements of the matrix in Equation 5.11 or the sum of the variance of n variables in matrix **X**.

In this study, a factor analysis has been carried out based on the principle of PCA to understand the underlying relations between variables.

5.3 Categorical Regression (CATREG)

Categorical Regression, also known as CATREG, deals with categorical predictor variables and presents the relation between a change in a dependent variable with the categorical independent variables. CATREG quantifies the categorical variables by assigning numerical values to the categories using optimal scaling, resulting in an optimal linear regression for the transformed variable (Meulman and Heiser, 2005; SPSS, 2009). The optimal scaling is used to assign numerical quantifications to the categories of each variable, so that the quantifications reflect characteristics of the original categories (i.e. nominal or ordinal). In this method, the quantifications are obtained at the same time when the regression is carried out. A standardized coefficient is calculated for each predictor variable, which reflects how changes in the predictors affect responses (IBM Knowledge Center, 2014).

The following notations are used in CATREG mathematical algorithm.

n	Number of analysis cases (objects)
n_w	Weighted number of analysis cases: $\sum_{i=1}^{n} W_i$
n_{tot}	Total number of cases (analysis + supplementary)
w_i	Weight of object i ; w_i =1 if cases are unweighted; w_i = 0 if object i is supplementary
W	Diagonal $n_{tot} \times n_{tot}$ matrix, with w_i on the diagonal
r	Index of response variable

For variable j, $j = 1, ..., m$

G_j	Indicator matrix for variable j, of order $n_{tot} \times k_j$

The quantification matrices and parameter vectors are:

$\mathbf{y}_r$	Category quantifications for the response variable, of order k_r
$\mathbf{y}_j, j \epsilon J_p$	Category quantifications for predictor variable j, of order k_j
β	Regression coefficients for the predictor variables, of order p
$\mathbf{v}$	Accumulated contributions of predictor variables: $\sum_{j \epsilon J_p} \beta_j G_j y_j$

Objective function

The CATREG objective is to find the set of y_r (category quantifications for the response variable of order k_r), β (regression coefficients for the predictor variables of order p), and y_j , $j \epsilon J_p$ (category quantifications for predictor variable j of order k_j), so that the following function is minimal-

$$\sigma(\mathbf{y}_r; \boldsymbol{\beta}; \mathbf{y}_j) = \left(G_r y_r - \sum_{j\epsilon J_p} \beta_j G_j y_j\right)' W \left(G_r y_r - \sum_{j\epsilon J_p} \beta_j G_j y_j\right) \tag{5.12}$$

CATREG produces the relative importance of each of the predictor variables in the model, which is carried out using Pratt's measure of importance. Pratt's measure helps to understand the contributions of the predictor variables to the regression, yielding a sum of 1 for a model. Predictors with large individual relative importance to other variables indicates its significance to the regression. Pratt's measure also signals the suppressor[1] variables showing lower relative importance than a variable that has a co-efficient of similar size.

Pratt's measure of relative importance of predictor variable j is defined as (Pratt, 1987):

$$Imp_j = \frac{\beta_j r_{rj}}{R^2} \tag{5.13}$$

where,

β_j = regression co-efficient for the predictor variable

r_{rj} = Zero-order correlation, i.e. the correlation between the transformed predictor and the transformed response.

CATREG has not been used to a great extent in travel behaviour research in fact, very few studies used CATREG. In one of the few existing applications, Fonzone et al. (2010) applied CATREG to assess PT passengers' level of attitude to change travel path (i.e. change in departure stop, preferred lines, transfer points, etc.). The survey data obtained in this study contain categorical data. These techniques are appropriate for identifying the significant predictor variable (categorical). The model results provide a standardized regression co-efficient, and Pratt's importance for explaining the contribution of each

[1] A suppressor variable is a predictor variable that substantially improves the prediction of a criterion, however, it is uncorrelated or has relatively little correlation with the criterion but correlated to other sets of predictors (Thompson and Levine, 1997). The term was coined by Horst et al. (1941).

predictor variable. The transformation plots were obtained to show the quantifications for each variable. To interpret CATREG results, the β value of the predictor variable should firstly be considered. A positive or negative β value defines the relation of change in a dependent variable with regard to the independent variables. For example if the β value is positive and the plot shows a monotonously increasing trend, the likelihood of the dependent variable increases for the categories of predictor variables. On the contrary, if the β value is negative, then the change in likelihood is inversely proportional to the quantifications.

Analysis Tools

The statistical analyses in this study have been primarily conducted using the statistical software package SPSS version 23 (Wagner III, 2014). A part of the analysis has also been carried out using the open source tool R (Dalgaard, 2008). For example, conducting a factor analysis with binary data requires a specific algorithm which is available in R (Revelle, 2011).

5.4 Summary

This chapter presented the data analysis methodology adopted in this study. Given the data types and the aim of this study, logit model, PCA, and CATREG were chosen for analysing the survey data. These analysis techniques were then discussed. The following chapter presents the result of bus stop survey data analysis using all the aforementioned analysis techniques.

CHAPTER 6

Bus Stop Survey

This chapter presents analysis of the bus stop survey data. As stated in the aim of this study, this research intends to understand the extent of use of URTPI and its impact on passengers' route choice. The bus stop survey data analysis is carried out to investigate how trip characteristics and demographics affect passengers' propensity to use URTPI. In addition, the changes in route choice made by the passengers after consulting URTPI are also investigated. At first, the survey data is checked to validate the sample representativeness. The chapter then presents descriptive analyses of the data to reveal the extent of use of URTPI followed by modelling of the factors affecting the use of URTPI. Passengers' choices are modelled and discussed to reveal the impact of URTPI on route choice. The chapter concludes with a summary of the findings from bus stop survey analysis.

6.1 Sample Structure and Representativeness

The bus stop survey data was collected in the city of Edinburgh. Since no other sources of PT patronage or passenger data were available for Edinburgh, the survey data is checked and compared with historical bus user data from Transport Scotland (Transport Scotland, 2013) to make sure that the data is representative of the Edinburgh bus passengers. In this way, the demographics of the survey participants were compared. Among the trip characteristics defined in the bus stop survey questionnaire (Table 4.3), only trip purpose data was available in Transport Scotland user data. Figures 6.1 to 6.3 present the distribution of participants by age, gender, profession and trip purpose. One major difference found in the survey data is a higher percentage of employed and younger participants (Age 20 to 40) compared to the whole Scotland, which may be related to the survey hours. In addition, Edinburgh has a higher proportion of young workers and students as well (Edinburgh City Council, 2016).

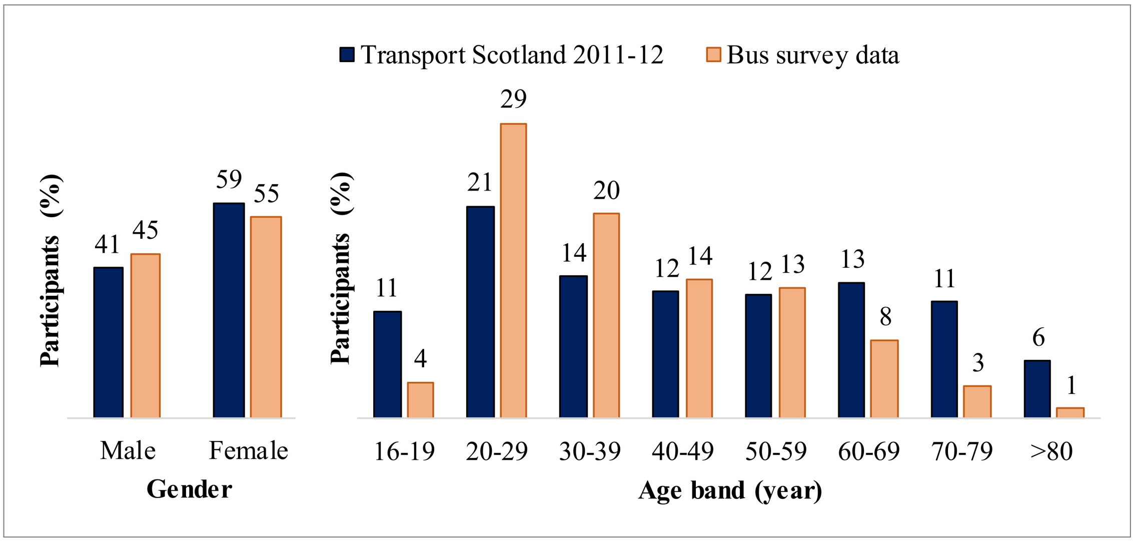


Figure 6.1 Representativeness of bus stop survey data: age and gender

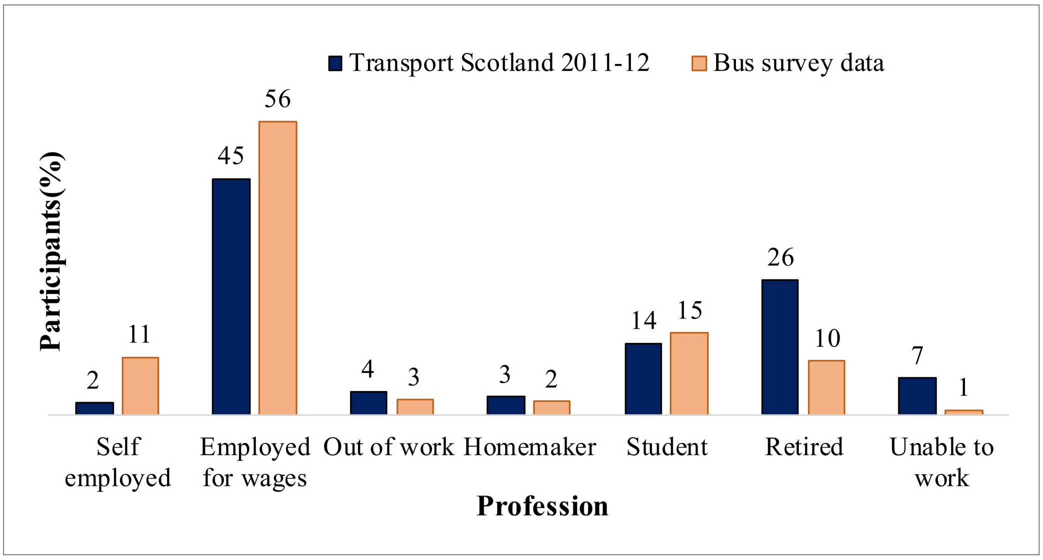


Figure 6.2 Representativeness of bus stop survey data: profession

The percentage of participants travelling to work or home was observed to be in line with Transport Scotland data (Figure 6.3). Nevertheless, the bus stop survey dataset includes an unexpectedly large number of trips (18%) made for work purposes (e.g. site visit, or business meeting). The bus stop survey was supervised and participants were instructed properly. Hence, the possibility of misinterpreting the question by the respondent is unlikely. The higher number of work trips can be explained by Edinburgh's well developed PT services and strict parking regulations. This may encourage people to travel with buses when making work trips. Moreover, comparatively smaller number of shopping trips was recorded (19% in Department for Transport statistics, 2014). This may be partly a result of the survey hours and days of week. Seven out of nine days of survey were weekdays and on only two hours of a day were off-peak. People tend to make more shopping trips in the weekends. In addition, Department for Transport statistics (2014) shows trips for all kinds of modes, whereas this survey only captures bus journeys for different trip purposes. The differences are compatible with Transport Scotland data given the profile of Edinburgh population, hence, it can be concluded that the overall survey sample is representative of Edinburgh PT passengers. The differences between the samples are not expected to affect the study results significantly.

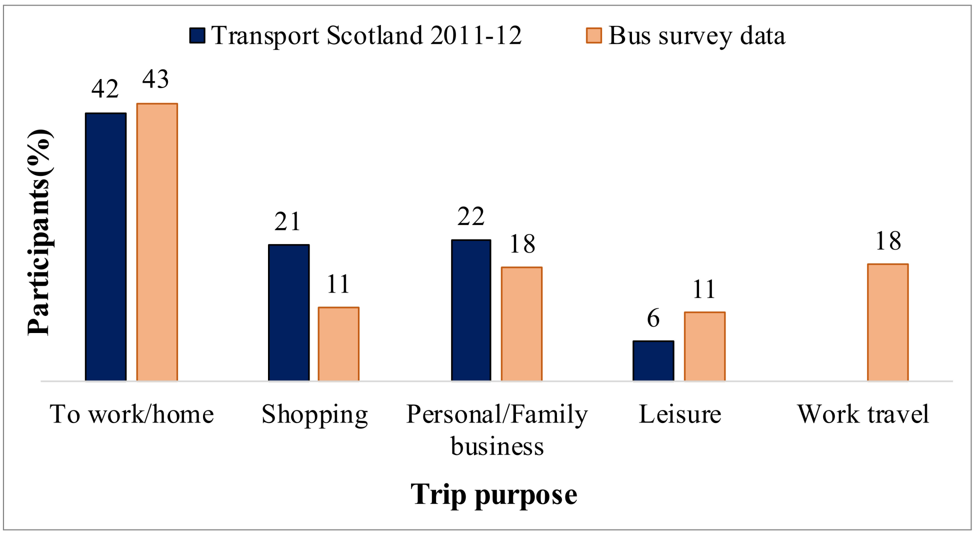


Figure 6.3 Representativeness of bus stop survey data: trip purpose

The aim of the survey was to capture all the principal trip characteristics, which are already described above. Other trip characteristics were not checked for representativeness due to the unavailability of data.

Figure 6.4 illustrates that more than half of the participants were making medium trips, followed by short and long trips. Only 2.4% of the participants were making very

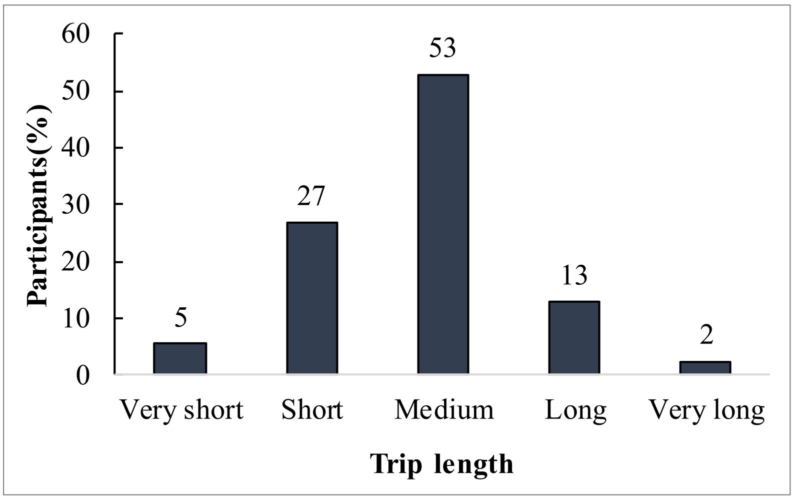


Figure 6.4 Distribution of participants in the bus stop survey by trip lengths

long trips. In regard to local trips, bus passengers are normally familiar with the trips. The survey sample shows that majority of the participants were familiar with their trips (Figure 6.5). In addition, two-thirds of the participants had an alternative bus line for that particular trip. Alternative mode of transport was available for 42% of the respondents. Although it was not possible to check the representativeness of the data in terms of all trip characteristics, the bus stop survey was able to capture data for trips made at different time of day, and with a possibility to use alternative routes (lines) or modes. In regards to trip length, sample (size) of participants making very short and very long trips are small. This may limit the effect of trip length on the use of URTPI. However, this could be a normal scenario for any urban network, where most of the "very short" trips (perceived by the passengers) are made by walking.

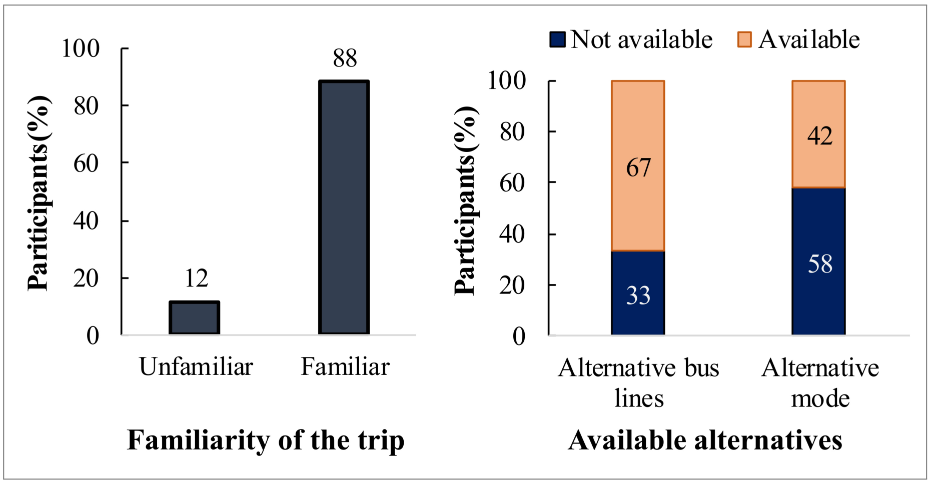


Figure 6.5 Participants' familiarity and available alternatives in the bus stop survey

6.2 Use of URTPI

The extent of use of URTPI is investigated by carrying out a descriptive and inferential statistical analysis. The inferential statistical analysis reveals the factors affecting the use of URTPI as well as passengers' preference of URTPI sources and the acquisition (choice of contents) of information. The available sources of information in Edinburgh have been presented in section 2.2.4 (Table 2.1). In this analysis, URTPI sources have been distinguished mainly in three categories. First, Mobile apps which refers to any apps such as journey planner, bus tracker, etc. (except Google Maps). Travel website refers to the websites passengers may access for travel information (including journey planner, bus tracker). Although Travel websites and Mobile apps may provide the same contents of information, in this study they are considered as different sources. URTPI was initially disseminated through websites. Further development and investments made it possible to make information accessible for travellers through Mobile apps. Hence, these two sources are treated separately to investigate whether there is any difference in use of the sources from the user point of view. Google Maps have been distinguished as a different source as it is traditionally known and used as a navigational and multi-modal information system to the passengers. Social media is also used as a source of URTPI.

6.2.1 Descriptive Analysis

Use of Passenger Information

The survey questionnaire mentioned all the available sources of information for bus passengers in Edinburgh (see questionnaire in Appendix B). Among the presented sources of information, URTPI sources were listed in Table 2.1. 85% of total respondents used at least one source of information for making trips, despite the fact that majority of the participants were familiar with their trips (Table 6.1).

Table 6.1 Use of information

		Familiar trip	
		Yes	No
Use of information	Yes	1180	177
	No	224	10
Use of URTPI	Yes	769	130
	No	643	57

Figure 6.6 presents the usage of different information sources in Edinburgh. For non-URTPI sources such as printed maps & timetables, and electronic (real-time) displays at stops, bars in orange colour present the proportion of participants who also used URTPI. Static local information, such as printed maps and timetables are still used by 10% of the participants, and only 2% of travel information users (85% of total population) do not use any real-time information. 56% of the participants used ubiquitous information for that particular trip.

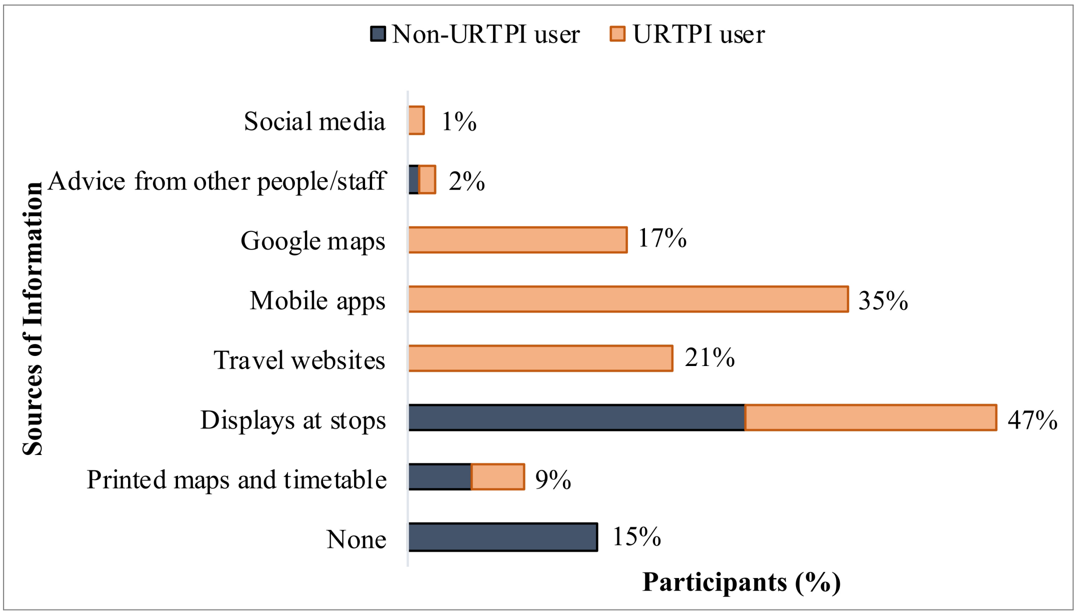


Figure 6.6 Use of different sources of passenger information (Q1 Appendix B)

Participants were allowed to choose all the information sources they had used. It is observed that displays at stops are the most used source of information among all the available options. This is expected given that the displays at stops are available for all at the bus stops and require no monetary costs. However, compared to a previous survey in Edinburgh (Fonzone, 2015), a decline in the use of displays at stops is observed in the present study. This may be associated with the cognitive cost required for consulting displays at stops. Maréchal (2016b) observes that the cognitive costs required for consulting information from displays at stops are greater than those required for consulting Mobile apps.

About half of the participants who use information from stop displays also consult URTPI sources. This suggests that participants consult URTPI sources for pre-trip information (at the start) as well as use displays once they arrive at the bus stop. Google Maps is one of the earliest and widely known navigation based source of multi-modal information. However, less than 20% of the participants used Google Maps. Analysis of the affecting factors will reveal passengers' tendency to consult any particular source of URTPI and specific contents of information.

A study carried out in 2013 in Edinburgh by Fonzone (2015) found a higher usage of non-URTPI sources, especially display at stops (75%) and printed maps and timetables (31%). On the contrary, this study finds less usage of non-URTPI sources (Figure 6.6), however, comparatively a higher usage of URTPI sources (Mobile apps, Websites, etc.). This indicates that passengers' preference of information is shifting from traditional to modern, state-of-the-art bus information systems. Hence, the demand for URTPI is displaying an uprising trend.

Total survey responses comprise 44% of non-users of URTPI. Figure 6.7 presents participants' reasons for not using URTPI.

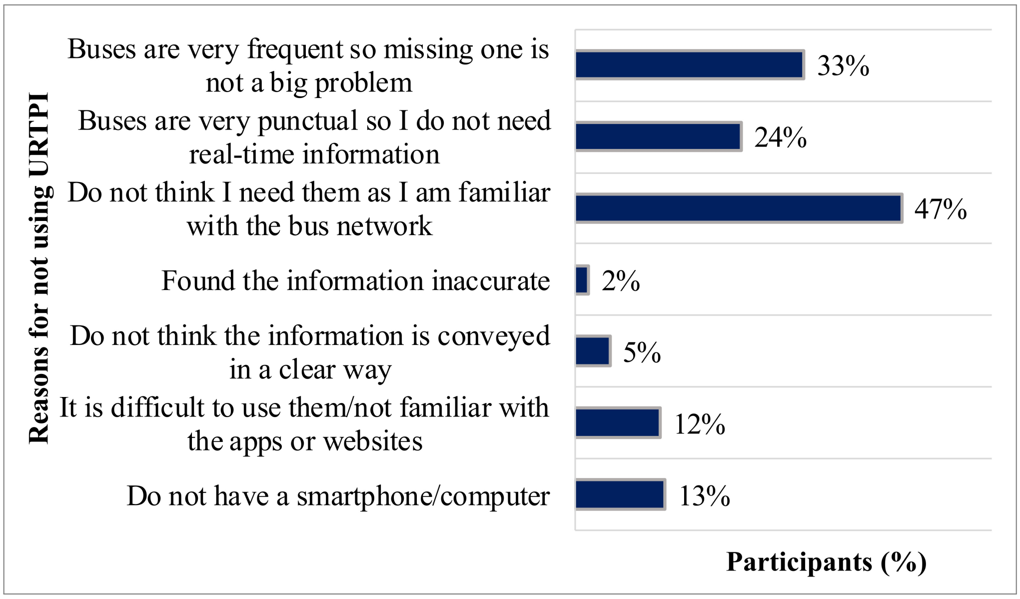


Figure 6.7 Reasons for not using URTPI (Q8 Appendix B)

Considerably a smaller amount of non-URTPI users find information inaccurate and unclear. A majority of the non-URTPI users highlighted that they do not perceive the necessity of using URTPI due to satisfactory bus service quality as well as the familiarity with the network.

Use of URTPI Sources

Nowadays, multiple sources of URTPI are available for passengers and information can be presented in different forms. This study assumes that passengers who use URTPI generally have access to multiple sources. Smartphone users have access to navigation maps (Google Maps, or iPhone maps), and additionally to other Mobile apps dedicated to particular modes of public transport or multiple modes including private transport as well.

Descriptive analysis reveals that Mobile apps are used by almost two-thirds of the passengers (Figure 6.8). Social media have not got much attention so far. This is because information on social media are generally descriptive information about the state of the network, such as disruption or diversion.

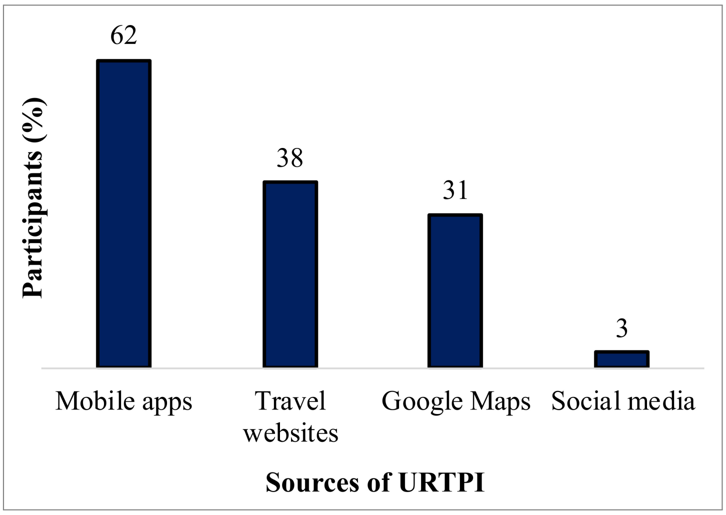


Figure 6.8 Use of URTPI sources (Q1 Appendix B)

72% of the URTPI users consult single source of information and 25% of them use two sources of URTPI. Table 6.2 presents a cross-tabulation of the percentage of users for each of the URTPI sources along with the combination of sources. The use of Mobile apps and Google Maps is the most popular combination. Travel websites are also accessed along with Mobile apps. It is observed that the use of other sources along with Mobile apps is rather complementary than substitutional. 20.5% of the passengers (in bold) use an additional source of URTPI with Mobile apps. Google Maps is used in conjunction with other sources by 15.3% (underlined) of the passengers, whereas 10.9% of the passengers used Google Maps as the only source of URTPI. Social media are accessed for PT information only in addition to Mobile apps. This may suggests that Google Maps and social media are used as additional sources with Mobile apps. On the other hand, travel websites seems to be preferred as an isolated source (21.6%). Therefore, passengers may use Mobile apps and travel websites as a primary source of URTPI which are mutually exclusive in majority of the cases. Google Maps is used as an additional source along with Mobile apps and Travel websites.

Table 6.2 Popular combination of sources used by the URTPI users

	Mobile apps	Google Maps	Travel website	Social media
Mobile apps	39.2%			
Google Maps	**11.2%**	10.9%		
Travel website	**6.7%**	4.1%	21.6%	
Social media	**2.6%**			

Contents of Information

Similar to the sources of PT information, contents of information available in URTPI sources can be classified as static and real-time information. Among the contents of information presented in Figure 6.9, *Bus route map* and *Bus stop location* are typically static information. On the other hand, *Bus arrival time*, *Journey plan* and *Transfer to other services* concern real-time information.

A vast majority of the passengers find *Bus arrival time* important, very important or extremely important. For making local trips, *Bus arrival time* may be the primary content of information consulted by the passengers. More than 60% of the passengers consider *Bus route map* and *Bus stop location* important, very or extremely important. Although these are static information, passengers may search for *Bus route map* and *Bus stop location* in conjunction with other real-time information to make choices, such as change of bus stops. Hence, being already familiar with the trips, passengers' interest in

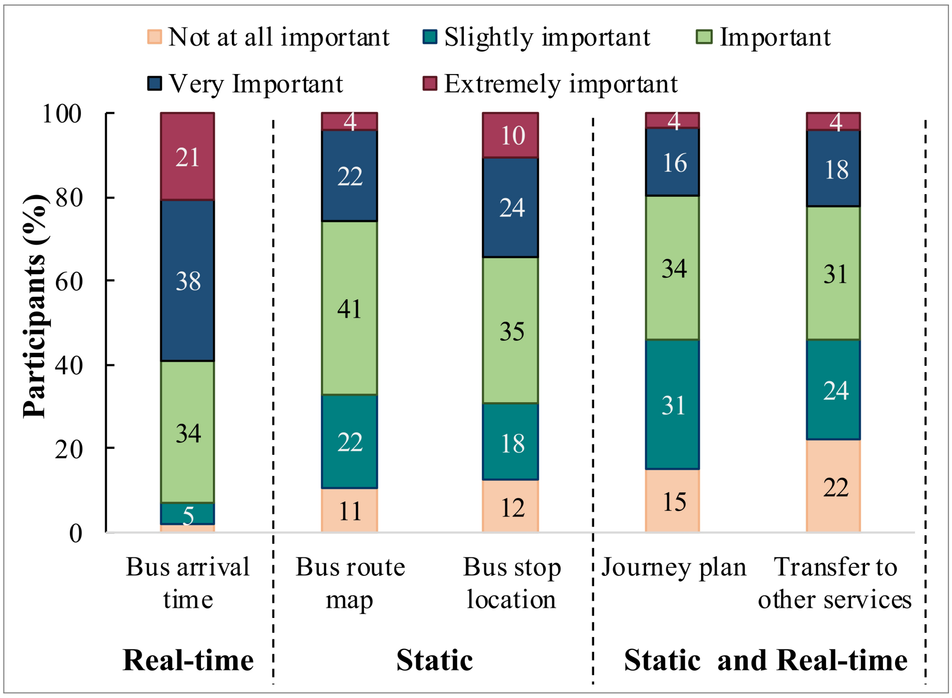


Figure 6.9 Importance of contents of information (Q3 Appendix B)

Bus route map and *Bus stop location* may indicate their tendency to look for alternatives to improve their journey experience. *Journey planning* and *Transfer* information are considered as important, very important or extremely important by half of the URTPI users; consultation of these contents of information may be associated with planning trips.

6.2.2 Factors Affecting the Use of URTPI

In the previous section, descriptive analyses of the use of URTPI, usage of different sources and contents of information were discussed. The descriptive analysis results show how many of the passengers access URTPI. Modelling of the bus passengers' use of URTPI would reveal the factors that affect their access to URTPI. The dependent variables for modelling the use of URTPI as well as its impact on passengers' route choice were previously introduced in section 5.1 (Table 5.1). Several models are developed to investigate the extent of use of URTPI. Table 6.3 presents the aim of each of the models presented in this section.

In the first part of this analysis passengers' access to URTPI regardless of the sources or contents of information is investigated. A binary logit model is developed to identify

Table 6.3 Models to explain the use of URTPI

Aim	Model	Table/Figure	Method
To identify the factors affecting the use of URTPI in general (i.e. any sources of URTPI)	Use of URTPI	Figure 6.10	Binary logit model
To identify the factors affecting passengers' preference of URTPI sources	Preferred sources of URTPI over others	Table 6.7	MNL
To identify the factors affecting the importance of contents of information	Importance of contents of information	Table 6.8	CATREG

the factors affecting bus passengers' access to URTPI. This would reveal the factors that define the user or non-user of URTPI. After identifying the factors affecting the use or non-use of URTPI, analysis is carried out to find passengers' use of URTPI sources and the contents of information. The use of different sources and contents of information is distinguished because it is impossible to say which of the two things caused the other one, i.e. whether the use of any particular source leads to the consultation of any particular contents of information or vice versa. A MNL model has been developed to investigate the factors that influence passengers' preference of any particular source over alternative sources, either as an isolated source or in combined use. The last model on the use of URTPI explores how the importance of the contents of information is influenced by the trip characteristics and demographics. CATREG model for each of the content of information has been developed.

Access to URTPI

In this analysis, user of URTPI refers to the passengers who use at least one source of URTPI (i.e. Mobile apps, Google Maps, travel websites or social media) regardless of the contents of information they consult. Therefore, the dependent variable is defined as the use of URTPI (binary) which is coded as 1-user of URTPI (56%) and 0-non-user of URTPI (44%).

A list of factors concerning participants' demographic information and trip characteristics has been defined (discussed in section 4.4.2), which are used as independent variables for developing the models. The independent variables along with the levels are presented in Table 6.4.

Table 6.4 Variables in the use of URTPI models

	Variables	Levels[1] (% response)
Trip characteristics	Trip length	*Very short* (5.4%), short (26.7%), medium(52.7%), long(12.8%), very long (2.4%)
	Time of day	*Midday*(28.8%), evening(34.2%), morning(37%)
	Trip purpose	*Commute*(43.2%), work travel[2] (17.5%), shopping(11.3%, p/f business(17.5%), leisure(10.5%)
	Familiarity of trip	*Familiar*(88.3%), unfamiliar(11.7%)
	Alternative mode	*No alternative available*(58.1%), alternative available(41.9%)
	Alternative bus line	*No alternative available*(33.4%), alternative available(66.6%)
Demographics	Age	18-25(24.3%), 26-35(25.3%), 36-45(18.4%), 46-55(14.7%), 56-65(10.2%), *>65*(7.2%)
	Profession	Employed for wages(56.5%), self employed(10.2%), out of work(4.5%), homeworker(2.4%), student(15.4%), *retired/unable to work*(11.0%)
	Gender	Female(55%), *male*(45%)
	Education	*Grammar school*(1.4%), high school or equivalent(16.7%), some college credit, no degree(26.2%), university degree(55.7%)
	Residence	*Edinburgh resident*(83.3%), frequent visitor(11.2%), infrequent visitor(2.8%), visiting for first time(2.8%)

[1] Levels in *Italic* are the reference for that variable in the following models

[2] Travel for work, such as site visit or business meeting

Model results show that some of the predictor variables are not individually significant, though they eventually have an impact on the whole model. Therefore, all these variables are included in the final model. The complete model results are presented in Appendix G. Table 6.5 shows the model fit measures of the final model. The Omnibus tests of model coefficient is significant ($p<0.05$), which suggests that the new model outperforms the null model (Burns and Burns, 2008). The null model is referred as "Beginning Block" in SPSS output, which shows the predictability of an outcome if no data on the predictor variables is considered. The Hosmer-Lemeshow test shows the model reasonably approximates the data as it is >0.05 (Hosmer and Lemeshow, 2000). The Nagelkarke R square represents the percentage of variation explained by the model.

Table 6.5 Factors affecting the use of URTPI: Goodness of fit

Number of observations	1645
Omnibus tests of model coefficients (p)	0.001
Nagelkerke R square	0.283
Hosmer and lemeshow test	0.477

The final model's average predictability rate is 70.4%.The model shows better predictability in identifying the URTPI users (85%) compared to non-URTPI users (53%). Therefore, it is difficult to predict when a passenger would not use URTPI considering their trip characteristics and demographics. Model results reveal seven statistically significant factors affecting the use of URTPI. *Trip Length, Trip Purpose, Availability of alternative mode* and *Familiarity of Trip* are the trip characteristics that essentially shape passengers' use of URTPI. *Time of day* and *Availability of alternative bus lines* are not observed to be influential. Since this study only captured the day trips, it is not understood whether night trips would have a different impact on the use of URTPI. Passengers' *Age, Profession* and *Residence* are the influencing demographic characteristics. *Education* and *Gender* have no impact on passengers' use of URTPI. The β coefficients are standardised; hence, the magnitude of β value indicates the level of influence on the dependent variable, i.e. the use of URTPI. The β values in the model results for use of URTPI (presented in Appendix G) show that *Trip length, Age* and *Profession* are the most significant factors affecting the URTPI. Figure 6.10 shows the binomial model results and illustrates the impact of the significant variables on the likelihood of using URTPI. Exp(β) represents the likelihood to use URTPI compared to the reference (reference levels presented in Table 6.4) and the error bars show the variability of the Exp(β) value. The likelihood to use URTPI is smaller if the lower value of Exp(β) is less than 1. Horizontal intercept lines at Exp(β)= 1 are plotted to demonstrate whether the lower value of Exp(β) is less than 1 or not. Bars in gray represent the statistically significant ($p<0.05$) levels of the predictor variables.

Model results show that trip length influences the use of URTPI significantly. Higher likelihood is observed for longer trips compared to very short trips. Albeit, it was expected that the likelihood of consulting URTPI might be increasing with the trip length, it is found to be true for short and medium trips only. A decline in the likelihood of

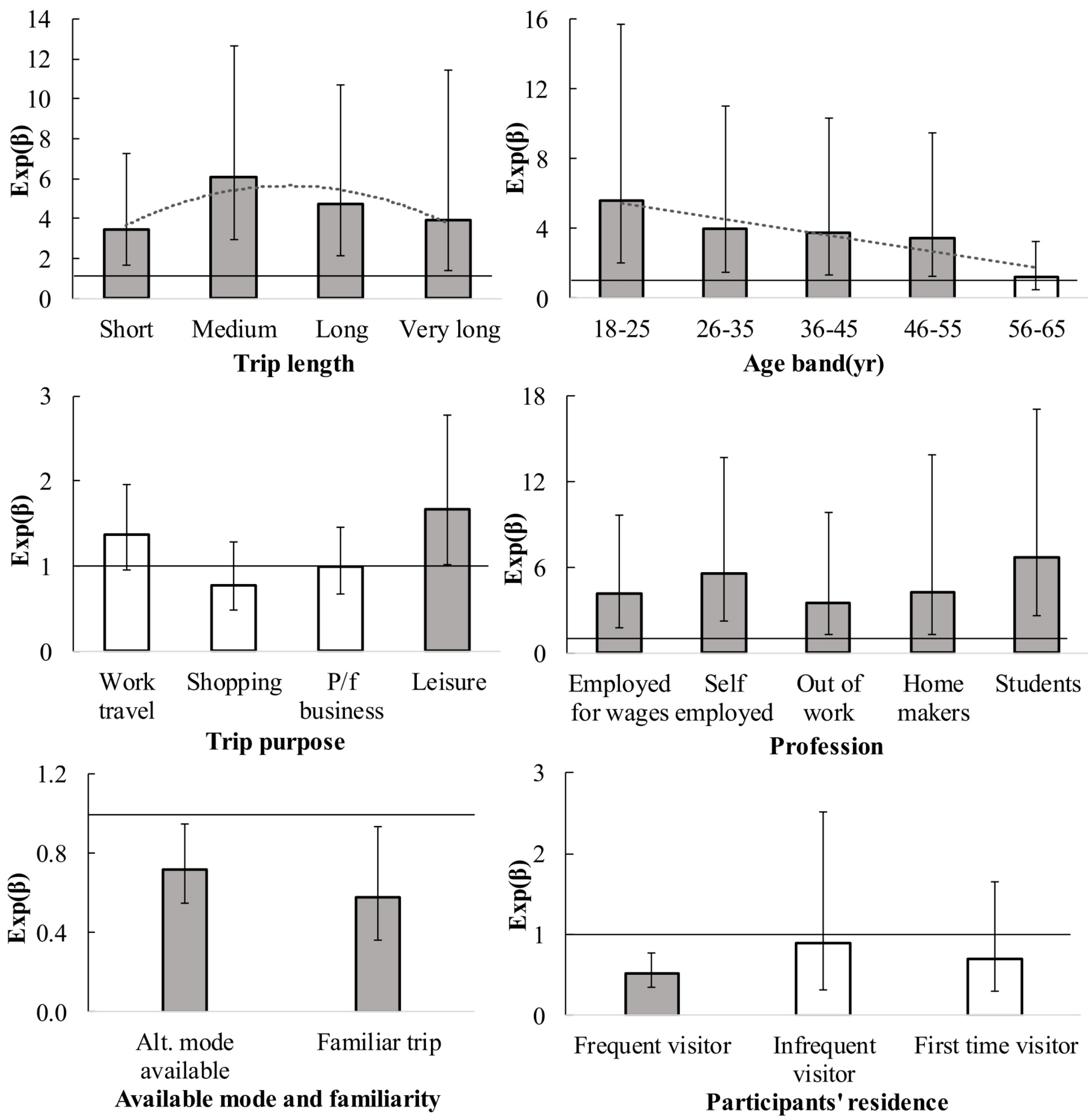


Figure 6.10 Factors affecting the use of URTPI

using URTPI is observed for long and very long trips. Additionally, the availability of alternative mode is inversely related to the use of URTPI, and for long and very long trips a smaller percentage of passengers had alternative modes available. Therefore, when making long and very long trips passenger should be more likely to use URTPI; however, the magnitude of likelihood was smaller compared to short and medium trip. One plausible reason for that could be passengers' risk aversion attitude. Passengers may prefer to be at the bus stop (perceived as safer) with enough spare time rather than consulting URTPI (Palma et al., 2012). In addition, the use of URTPI does not vary much according to trip purposes. Compared to commuting trips, only leisure trips illustrated significant impact on the use of URTPI. This may be due to the characteristics of leisure trips, which may include constraints of time (i.e. attending a show) or accompanying other people, etc. Compared to unfamiliar trips, passengers are more likely to use URTPI when making familiar trips. Use of URTPI is observed to be strongly dictated by age of the passenger. Younger passengers are more likely to use URTPI compared to aged participants (Ref: age>65), as their affinity towards technology is higher in general (known as Technophilia, see Seebauer et al., 2015). Passengers who work or study are more likely to use URTPI compared to those retired or unable to work. This may also be a result of being familiar with the up-to-date apps and websites. Frequent visitors are less likely to use the URTPI compared to the local residents.

Preferred Sources of URTPI

A MNL is developed to investigate passengers' preference of an individual URTPI source among the alternative ones considering their trip characteristics and demographics. The levels of the dependent variable are shown in Table 6.6. The reference category for the dependent variable is Mobile apps. Multiple sources refer to the use of any two of the three sources. The predictor variables remain the same as presented in Table 6.4. All the variables are included in the initial model. The model is then calibrated and the final model is developed excluding participants' age, profession, and education. The statistically significant result obtained by MNL are reported in Table 6.7. Complete MNL model results are included in Appendix G.

Table 6.6 Levels of the independent variable of MNL

Use of URTPI sources	% of responses
1-Mobile apps (reference)	41
2-Google Maps	12
3-Travel websites	23
4-Multiple sources	25

The MNL model results for preferred sources of URTPI show that passengers prefer Google Maps and Travel websites to Mobile apps for making unfamiliar and midday trips compared to familiar and morning trips. When making unfamiliar trips, passengers may not know the location of bus stops near the destination or may use an app that does not provide journey planning features, such as bus tracker. Google Maps is less

Table 6.7 Factors affecting the preference among URTPI sources

	Variables (*Reference categories*)		Source of URTPI (*Mobile apps*)		
			Google Maps	Travel websites	Multiple sources
	Predictors	Levels	Exp(β)	Exp(β)	Exp(β)
Trip characteristics	Trip length (*Very short*)	Short			
		Medium			
		Long			
		Very long			
	Time of day (*Morning*)	Midday	1.92*	2.02**	
		Evening			
	Purpose of trip (*Commute*)	Work travel		1.66*	
		Shopping			
		P/F business			
		Leisure			
	Familiarity of the trip (*Unfamiliar*)	Familiar	0.10***	0.42**	
	Availability of alternative bus line (*Not available*)	Available			
	Availability of alternative mode (*Not available*)	Available			
Demographics	Gender (*Male*)	Female	0.55**		
	Residence (*Edinburgh resident*)	Visiting first time	6.61**		
		Infrequent visitor			
		Frequent visitor	3.72**	2.81**	2.19*

Significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

preferred by female passengers compared to male passengers. First time visitors and frequent visitors prefer Google Maps to Mobile apps compared to Edinburgh residents. However, it is not understood why the obtained result is not significant for infrequent visitors.

Frequent visitors also prefer Travel websites as well as multiple sources (two sources) to Mobile apps only. Multiple sources may also include Mobile apps. In that case, frequent visitors may be familiar with the trip itinerary but do not remember all the locations (i.e. bus stops or names of destinations) they tend to travel. Hence, they cannot consult information regarding trip planning if they use a bus tracker app.

To sum up, Mobile apps are likely to be consulted mainly for morning trips and familiar trips. Google Maps and Travel websites are preferred by the visitors. Multiple sources (combination of two sources) are preferred by frequent visitors over Mobile apps only.

Contents of Information

The previous section revealed the factors affecting passengers' preference of URTPI sources. It is assumed that there may not be a biunivocal correspondence between the sources of URTPI and contents of information. Therefore, taking the analysis a step forward, this study now focuses on the contents of information that are likely to be consulted by passengers when they make PT trips.

The importance of information was measured on a 5-point Likert scale (presented in Figure 6.9). Ordinal logistics regression is generally used for modelling ordinal dependent variables. However, one of the key assumptions of ordinal logistic regression is that the effects of any explanatory variables are consistent (proportional) across the categories of the ordinal outcome variable. This assumption was not valid as *Test of parallel lines* showed statistically significant ($p<0.05$) results (UCLA: Statistical Consulting Group, 2011). Therefore, the ordinal logistic regression is not applicable in this case. A CATREG is preferred over traditional MNL model because CATREG allows to identify the significant interactions between the predictor variables and the dependent variable. The interactions are explained based on the quantification plots (see Appendix H). Hence, CATREG analysis is carried out to identify the relation between the changes in importance of information and the predictor variables. To investigate the impact of trip characteristics and demographics on the importance of contents of information, CATREG analyses are carried out by assigning the aforementioned contents of information as dependent variable. Independent variables for these models remain the same as presented in Table 6.4. The CATREG plots are attached in the Appendix H along with a description of plots' interpretation.

To develop a CATREG model, all the variables are included in the preliminary model and checked for the significance (p value). The insignificant variables are then taken out one by one depending on their relative importance in the model. This process continues until the model fit shows a stable situation and reaches the point where taking out more variables would reduce the model fit drastically and the final model is then interpreted. The SPSS CATREG has a default bootstrapping (1000 samples) options which provides slightly different p value for each run. To overcome this issue, CATREG were run with a larger bootstrap sample (10000 samples). Multiple runs were conducted to observe variations in significances. The final model is selected if the p value remains within 95% Confidence Interval for multiple runs.

Table 6.8 presents the CATREG standardized model coefficients with significance of the variables and Pratt's relative importance of the variables. The level of impact of the significant factors is categorised as low, medium and high, and presented in Table 6.9. The relative importance shows that passengers' search for information on *Bus arrival time* and *Transfer to other services* is equally influenced by trip characteristics and demographics. The importance of information on *Bus stop location* and *Journey plan* is dictated by demographics. On the contrary, passengers' preference of information on *Bus route map* depends on the characteristics of the trip they are making.

Trip characteristics: Trip length is found to be influential for consulting *Bus arrival time* and *Transfer to other services*. Both these contents of information concern arrival time of bus, either from the first stop or the transfer stop. Passengers are more likely to look for *Bus arrival time* when making long trips; however, its importance remains same for very short to medium length trips. Information on transfers is more likely to be consulted for medium and long trips.

Time of the day is observed to be significant in all the models except *Bus stop location*. However, the Pratt's relative importance of time of day is low in models for *Bus route map* and *Transfer to other services* (Table 6.8). It is observed that across all the models, contents of information are most important to passengers when making trips in the morning and least important around midday.

Trip purpose is observed to influence all contents of information except *Journey plan*. The relative importance of trip purpose is much higher for *Bus route map*. Analysis of the CATREG plots in conjunction with model coefficients in Table 6.8 shows that for commuting trips passengers give less importance on consulting *Bus route map*, which may indicate their limited flexibility to change bus line for commuting trips. Additionally, if commuters are habitual to any particular route, they would be reluctant

Table 6.8 Factors affecting the importance of contents of information

	Variables	Contents of information[1]														
		Bus arrival time			Bus route map			Bus stop location			Journey plan			Transfer to other services		
		β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.
Trip characteristics	Trip length	0.131	0.039	0.157										0.138	0.003	0.137
	Time of day	0.132	0.001	0.175	0.079	0.006	0.017				0.096	0.008	0.117	0.101	0.016	0.061
	Trip purpose	0.058	0.003	0.043	0.176	0.001	0.392	0.132	0.001	0.199				0.125	0.001	0.107
	Familiarity of trip				0.080	0.049	0.141									
	Alternative mode	0.100	0.010	0.097	0.085	0.033	0.055							0.116	0.020	0.063
	Alternative bus line													0.151	0.001	0.196
Demographics	Age	-0.155	0.001	0.321							-0.131	0.001	0.249	-0.153	0.001	0.191
	Profession	0.139	0.001	0.207	0.080	0.001	0.099	0.172	0.001	0.248	0.137	0.001	0.257	0.132	0.001	0.146
	Gender										0.101	0.023	0.139			
	Education										-0.155	0.029	0.240	-0.121	0.037	0.100
	Residence				0.148	0.001	0.296	0.264	0.001	0.553						

[1] negative Beta value shows inverse relation to the change in quantifications in Figure H.1 to H.5

to change bus line which would result in a less likelihood to consult *Bus route map*. For shopping and p/f business trips they would be more likely to consult *Bus route map*. In addition, *Bus stop location* is more important when making leisure trips. This may indicate that static contents of information are more likely to be consulted for making non-commuting trips, such as shopping, leisure and p/f business trips.

Familiarity with the trip is found influential for the consultation of *Bus route map*. It is observed that passengers are more likely to consult *Bus route map* if they are making an unfamiliar trip.

Availability of alternative mode of transport for making a particular trip might inspire passengers to consult *Bus arrival time*, *Bus route map* and *Transfer to other services*. However, the relative importance is rather small for *Bus route map*. Information on *Bus arrival time* and *Transfer to other services* could be consulted if they decide to change to another mode (i.e. walk instead of taking a bus) or change the bus line.

Availability of alternative bus lines is observed to influence information on *Transfer to other services*. Passengers are likely to consult this information if there are no alternative bus lines available. Again, this might be an indication of passengers' risk aversion attitude as missing the bus at a transfer stop would make the journey longer, especially when no alternative bus lines are available.

Demographics: Demographics are found to influence information on *Bus stop location* and *Journey plan* to a large extent. Among all the demographic factors, profession of the participants is observed to have an impact on the importance of all the contents of information. Participants' age, and residence are significant in some of the models with relatively high importance (Table 6.8).

The use of URTPI is observed to decline with the increase in participants' age. This trend continues for *Bus arrival time*, *Journey plan* and *Transfer to other services*. *Bus arrival time* is the most basic and popular content of information. The model results show that the importance of *Bus arrival time* to the passengers decreases for age groups up to 55 year old, albeit it is assumed that *Bus arrival time* is consulted by the URTPI users regardless of their demographics. *Transfer to other services* is consulted by comparatively younger participants (age <45). Following the same trend, the importance of *Journey planing* information is not found to vary much with the age; however, it is

Table 6.9 Level of impact of the factors affecting passengers' choices

	Variables	Contents of Information				
		Bus arrival time	Bus route map	Bus stop location	Journey plan	Transfer to other services
Trip characteristics	Trip length	Medium				Medium
	Time of day	Medium	Low		Medium	Low
	Trip purpose	Low	High	Medium		Medium
	Familiarity of trip		Medium			
	Alternative mode	Medium	Low			Low
	Alternative bus line					Medium
Demographics	Age	High			Medium	Medium
	Profession	Medium	Low	Medium	High	Medium
	Gender				Medium	
	Education				Medium	Low
	Residence		High	High		

Low: Pratt's importance 0 – 0.1
Medium: Pratt's importance 0.1 – 0.25
High: Pratt's importance > 0.25

more likely to be consulted by participants of age less than 65 year old. The use of URTPI and the importance of the aforementioned contents of information confirm an inverse relation with the age of passenger. A decrease in likelihood of using information may happen because of a decline in passengers' perceived necessity of using information with their age.

Participants' profession is found to influence the importance of all the contents of information. *Bus arrival time* is more likely to be consulted by homemakers. This may indicate their tendency to reduce their waiting time at the stops, as the effect of waiting time at the stops on riding buses is the greatest for homemakers (Kim et al., 2009). *Bus stop location*, *Journey plan* and *Transfer to other services* are important to passengers who are out of work, although it is not clear why this is the case. Information on *Transfer to other services* is important to people who are retired/unable to work. This may happen because transfers require physical and cognitive efforts, and additionally could be associated with monetary cost (i.e. additional tickets).

Female participants place higher importance on *Journey planing* information than male participants do. *Journey plan* refers to the information from the origin to destination. This supports female passengers' exhaustive and elaborative nature of information search (Kim et al., 2007; Meyers-Levy, 1988; Okazaki and Hirose, 2009).

Passengers' level of education is observed to be statistically significant for consulting information on *Journey plan* and *Transfer to other services*. The importance of this information contents declines with the increase in education level. Higher education may enable people to plan journey easily, which makes them reluctant to consult information on *Journey plan*. A contradictory result, however, was observed in the event of PT service disruptions by Maréchal (2016b). The study found that passengers' level of education is positively related to search for information. This demonstrates the effect of service conditions on passengers' use of information.

In the survey questionnaire participants were categorised as residents of the city and visitors, i.e. frequent, infrequent and first time visitor (Table 6.4). Model results show that residence of the participant is crucial for consulting *Bus route map* and *Bus stop location*. Both of these information are more likely to be consulted by relatively unfamiliar visitors (infrequent and first time visitor) than the residents of the city or frequent visitors.

Models for the use of URTPI sources and contents of information have the same independent variables and therefore, following conclusions can be drawn based on the model results.

- ▷ Younger participants may tend to look for information on *Bus arrival time* and transfers when consulting Mobile apps.
- ▷ When consulting *Bus arrival time* for making work trips, passengers may prefer Travel websites over Mobile apps.
- ▷ Google Maps is likely to be consulted when participants look for *Bus route map*, especially when making unfamiliar trips. In addition, passengers who are visitors, access Google Maps for *Bus stop location* and *Bus route map*.
- ▷ Commuting trip makers do not put much importance on any particular contents of information and are likely to use Mobile apps.
- ▷ Available PT services and alternative mode do not influence passengers' preference of sources; however influence the importance of contents of information.

Synthesis of Modelling the Use of URTPI

Trip Characteristics: Access to URTPI is influenced by trip length, trip purpose, familiarity of the trip and the availability of alternative mode. Longer trips inspire passengers to use URTPI especially by means of Mobile apps. Passengers making unfamiliar trips or leisure trips are more likely to use URTPI. Mobile apps are the most popular source of URTPI among the passengers and are likely to be consulted by the familiar trip makers. For unfamiliar and morning trips, Google Maps and Travel websites are preferred over Mobile apps.

Trip characteristics influence the importance of both real-time and static information. The significantly influenced contents of information are *Bus arrival time*, *Bus route map* and *Transfer to other services*. In the context of passengers' route choice, *Bus route map* is one of the important contents of information that could be used by the passengers to choose alternative bus lines. Trip purpose significantly influences the importance of *Bus route map* which may affect passengers' choice of bus lines.

Demographics: Among the demographics, participants' age, profession, and residence are influential. Younger participants show a higher inclination towards the URTPI access. In addition, working people, students and local residents of the city are more likely to use URTPI. Students are observed to be more inclined to use URTPI among all the professions; however, they did not exhibit tendency to place high importance on the contents of information. This suggests that they use URTPI because of their affinity towards technology, but not really concerned about the contents of information.

Information on *Transfer to other services* is found to be influenced by both trip characteristics and demographics. However, the need for consulting this information may be related to passengers' trip planning objectives.

Demographics shape passengers' knowledge and attitude; therefore, passengers' prior knowledge regarding the trip and information would be a relevant factor for consulting information on static location (i.e. *Bus stop location*). Demographics of the participants have significant impact on *Bus stop location* and *Journey plan*. Residence of the passengers is likely to influence the consultation of information related to geographical location, i.e. *Bus route map* and *Bus stop location*. Visitors in the city and non-commute trip makers (such as shopping trips) are more likely to search for *Bus route map*.

This section presented and discussed the model results for factors affecting the use of URTPI. The following section discusses the impact of URTPI on passengers' choices.

6.3 Passengers' Choices

6.3.1 Descriptive Analysis

The first part of this section presents the changes made by the passengers (i.e. in choice elements) after consulting the information . The choice elements have already been introduced in section 4.4. Figure 6.11 presents survey results of changes made by the passengers.

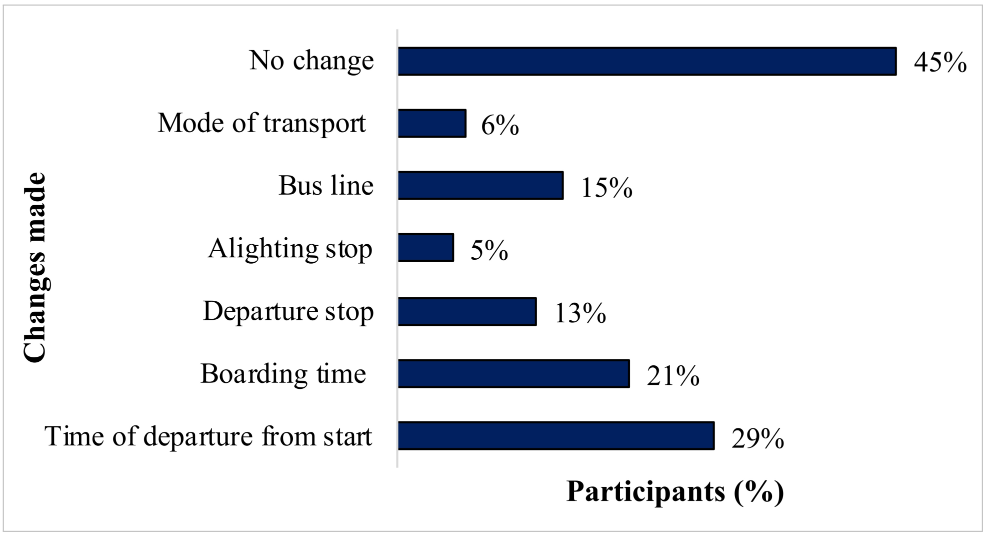


Figure 6.11 Changes made by the passengers after consulting URTPI (Q4 Appendix B)

Among the six choice elements, all but mode of transport are considered for assessing the impact of URTPI on route choice. Figure 6.11 shows that *Time of departure from start* is the most preferred choice made by the passengers after consulting URTPI. Change in *Time of departure from start* or *Boarding time* are considered as a change in temporal dimension of route. In addition, changes in *Departure stop*, *Alighting stop* or *Bus line* comprise a change in spatial dimension of route choice. Figure 6.12 presents how changes in different choice elements affect PT demand distribution. About 42%

of URTPI users make changes in their temporal dimension of route, whereas changes in spatial dimension are observed in 26% of cases. The impact of changes on PT demand distribution is estimated by combining the changes which occur in all the choice elements except *Time of departure from start*. For 39% of trips made by URTPI users, PT demand distribution is affected as a result of consulting information. Change of *Boarding time* is observed in 21% cases; however, a change in passenger distribution for bus runs occur only if passengers change their *Boarding time* without changing the *Bus line*. The demand distribution for bus runs is observed to be affected by 17% of the trips made by URTPI users.

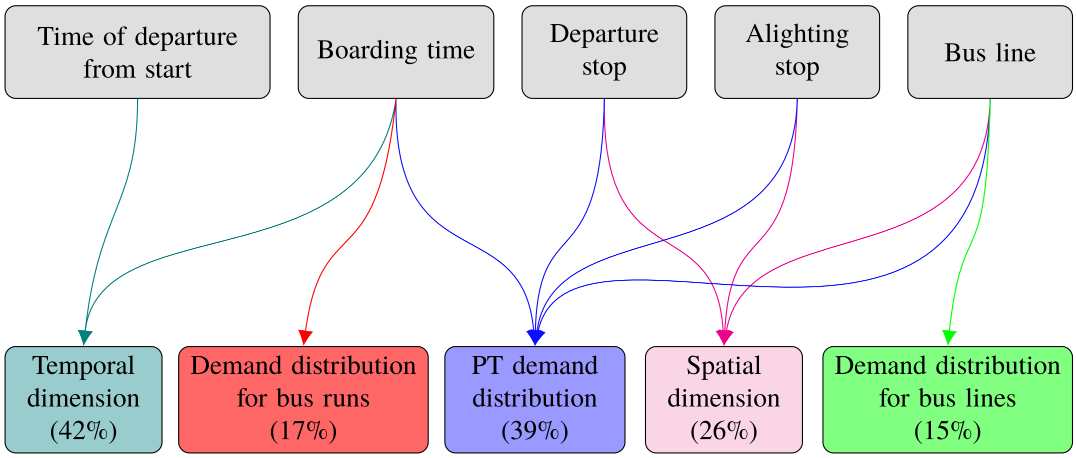


Figure 6.12 Potential impact of changes in choice elements on PT demand distribution

A factor analysis was conducted to examine if the choice elements are associated with any latent variable. Factor analysis helps to understand and explain the unobserved variables by collapsing all the variables into a few interpretable factors (Thompson, 2004). The association of each variable with the underlying factor is represented by component loadings. Factor analysis has been carried out with R "Psych" package (Beaumont, 2012) using varimax rotation. Rotation is applied in factor analysis to obtain a simplified structure. Rotations are typically two types: oblique rotation (correlated factors) and orthogonal rotation (uncorrelated factors) (Corner, 2009). No correlation was found between the factors, hence orthogonal rotation (varimax) has been used. The factor loadings are presented in Table 6.10.

Three components were extracted and the absolute value of the loading indicates

Table 6.10 Factor analysis for changes in choice elements

Variables	Component		
	1	2	3
Time of departure		0.93	
Boarding time			0.95
Departure stop	0.61		
Alighting stop	0.51		
Bus line	0.80		

the strength of association of a variable with the factor. Results show that the variables associated with spatial dimension of route are grouped in Factor (1), which could be labelled as 'spatial route flexibility'. Factor (2) and (3) are associated with the variables related to temporal dimension of PT route. Changes in departure stop, alighting stop and bus line are (i.e. spatial dimension of route) associated with each other, which indicates that these changes are likely to occur simultaneously. This implies that if passengers decide to change their original plan and take a different a bus line from a different bus stop, that leads them to alight at an alternative stop. Hence, changing all the elements of spatial dimension may be a part of their strategic decision.

Pre-trip Choices

Remote accessibility to real-time information enables passengers to access PT information prior to leaving their origin. Hence, pre-trip choices are enabled only by access to URTPI. Figure 6.13 illustrates passengers' actions after consulting pre-trip information. The number of valid responses for this question was 436. It is observed that about one-third of the participants changed their departure time only and 32% of the participants changed boarding time or bus line. This indicates that in one-third of the cases, consultation of pre-trip information leads to an impact on the PT demand distribution.

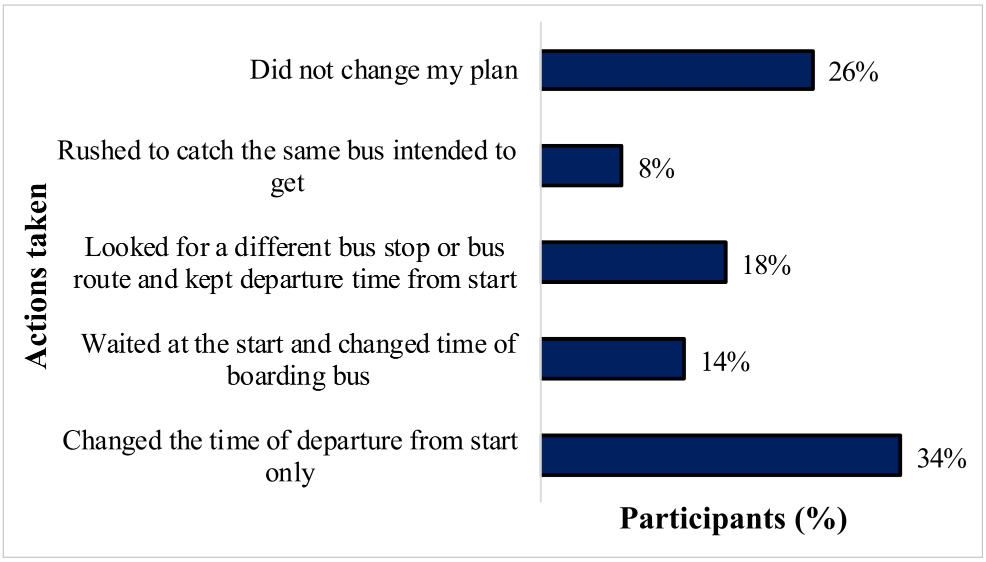


Figure 6.13 Actions taken after pre-trip information access (Q6 Appendix B)

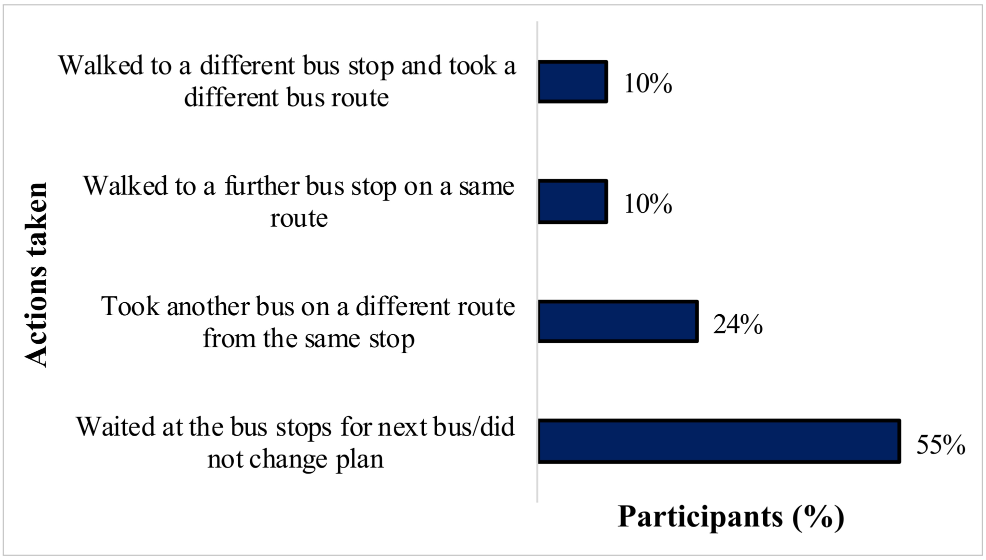


Figure 6.14 Actions taken after en route information access (Q7 Appendix B)

En route Choices

Changes made by the passengers after consulting URTPI en route are rather modest (Figure 6.14). Majority of the passengers do not take any action after consulting en route information. Hence, passengers may access URTPI en route to make sure that they are on time. This also leads them to waiting at the stops, which is the most frequent decision taken by the passengers. In such situation, passengers may just change their boarding time and take the next bus on the same line. Changing bus lines from the same stop is more frequent than changing from a different stop. In addition, frequencies of changing bus stops to take the same bus line and a different bus line are equal (10%).

Factors Affecting Passengers' Changes

In the previous section, choices made by the passengers as a result of consulting URTPI were presented and their pre-trip and en route choices were also highlighted. It is necessary to investigate whether the changes made by passengers (Figure 6.11) are affected by the factors related to their trip planning objectives. Figure 6.15 presents the objectives that shape passengers' choices.

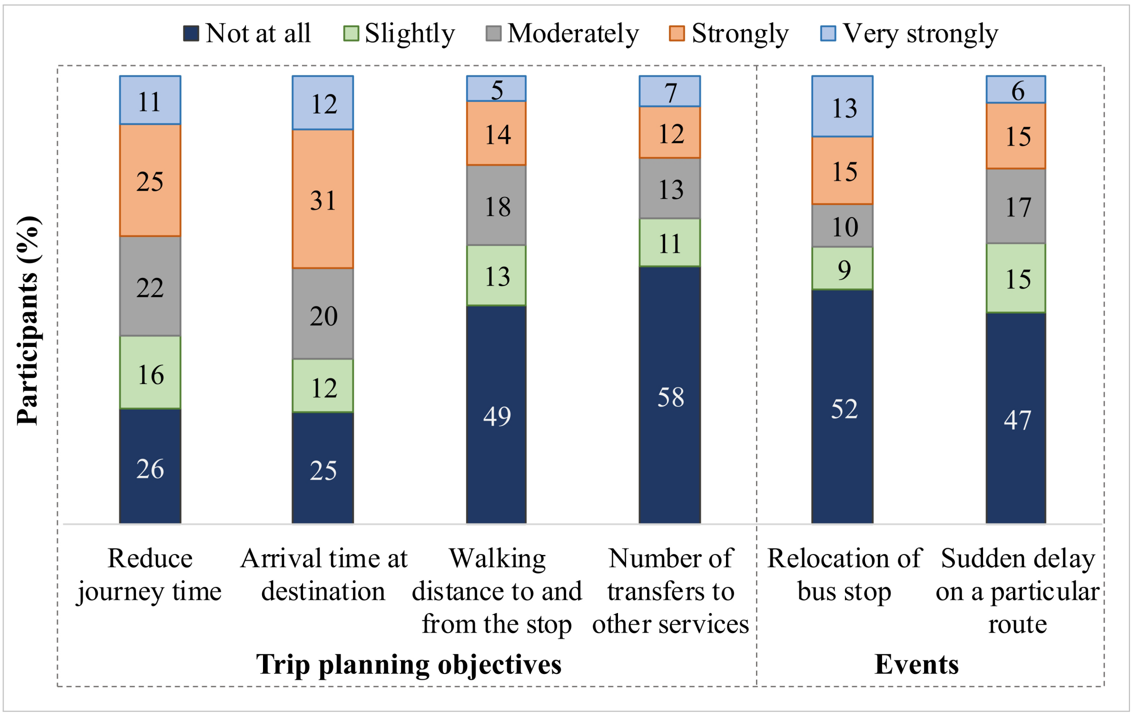


Figure 6.15 Factors affecting passengers' choices (Q5 Appendix B)

Arriving at the destination is perceived to be affecting the choices moderately, strongly or very strongly by about two-thirds of the passengers. More than half of passengers perceive reducing journey time as moderately, strongly or very strongly influential on the choices. On the other hand, walking distance, transfers, and change in bus stop location are perceived not at all influential by the majority of the passengers.

The factors associated with passengers' objectives will be used for modelling their choices. A PCA is carried out to check if there is any underlying association among the variables. PCA enables dimensional reduction of the variables. Standard PCA assumes a linear relationship between numerical variables. The aforementioned trip planning objectives that affect passengers' choices were measured on 5-point Likert scales. Therefore, a Categorical Principle Component Analysis (CATPCA) analysis is appropriate for these variables. CATPCA quantifies the categorical variables by reducing the dimensionality of the data, and therefore non-linear relationships between the variables can be modelled (Linting et al., 2007). The factor scores obtained from this analysis will be used for modelling passengers' choices.

CATPCA results show that these variables are associated with three underlying factors (Table 6.11). Reducing journey time and Expected Time of Arrival (ETA) are associated with Factor (1), whereas walking distance and transfers are grouped as Factor (2). Factors (1) and (2) can be named as "Journey time or ETA" and "Physical or cognitive efforts", and are associated with passengers' trip planning objectives. These two factors will be used as independent variables for modelling passengers' choices. Factor (3) indicates the events going on within the network.

Table 6.11 PCA analysis for factors affecting choices

Variables	Dimension		
	1	2	3
Reduce journey time	0.982		
Arrival time at the destination	0.982		
Sudden delay on a particular line		0.489	0.754
Walking distance to and from the stop		0.997	
Number of changes to other services		0.821	
Change in bus-stop location due to construction work			0.934
	Journey time or ETA	Physical and cognitive efforts	Service disruption

6.3.2 Factors Affecting Passengers' Choices

CATREG Results

Analysis conducted so far reveals that passengers' choices may lead to a change in PT demand distribution by 39%. Therefore, it is important to understand what triggers these changes and and how these are influenced by access to URTPI. CATREG has been carried out for modelling the changes passengers make after consulting URTPI. For each of the choice elements presented in Figure 6.12, a CATREG model has been developed. As previously discussed, passengers' intention and behaviour may be influenced by their trip characteristics, demographics and information (section 4.3.4), which eventually influence their route choice decisions. Therefore, independent variables for modelling the choices are related to trip characteristics, demographics, contents of information and the factors associated with trip planning objectives. Similar to the previous CATREG section, the standardized regression coefficients and Pratt's relative importance of the variables are presented in Tables 6.12 and 6.13. Based on the Pratt's relative importance of the variables, the level of impact of the factors on passenger choices is categorised as low, medium and high (Table 6.14). The plots of quantification are included in the Appendix H attached to this thesis.

Change in Time of Departure from Start

URTPI offers remote access to real-time information. Therefore, passengers are enabled to make changes in their *Time of departure from start* after consulting URTPI, which means passengers may leave earlier or later from their origin than they had intended. The CATREG model for *Time of departure from start* investigates how passengers' time of departure is influenced by the consultation of URTPI. As mentioned in the previous section, changing *Time of departure from start* is the most preferred action taken by the URTPI users. CATREG model for *Time of departure from start* shows that among the predictor variables, participants' age has the highest influence (Table 6.14). Therefore, the decision of changing departure time is strongly related to passenger demographics, which is also observed by Chen and Mahmassani (1999) in the context of car users. Trip characteristics and information have relatively smaller impact on the change of departure time.

Participants' age and profession are found significant in the model. Model results show that younger passengers are more likely to change their departure time than older passengers. It is observed that passengers who are out of work are the least likely, whereas retired passengers are the most likely to change departure time. Working people or students are more inclined to adjust their departure time than homemakers and unemployed passengers.

Time of day, familiarity of trip and availability of alternative mode of transport

Table 6.12 Factors affecting the choices related to temporal dimension

Factors	Variables	Time of departure from start			Boarding time		
		β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.
Demographics	Age	-0.228	0.001	0.518			
	Profession	0.105	0.001	0.009	0.055	0.015	0.032
	Gender				0.067	0.069	0.044
	Education						
	Residence						
Trip planning objectives	Journey time or ETA	0.113	0.012	0.140	0.218	0.001	0.407
	Physical or cognitive effort				-0.154	0.002	0.149
Trip characteristics	Trip length						
	Time of day	0.058	0.042	0.019	0.110	0.001	0.139
	Trip purpose				0.102	0.001	0.106
	Familiarity of trip	0.088	0.008	0.082			
	Alternative mode	0.091	0.011	0.144			
	Alternative bus line				0.085	0.021	0.089
Importance of contents of information	Bus arrival time	0.082	0.028	0.087			
	Bus route map						
	Bus stop location						
	Journey plan						
	Transfer to other services				0.082	0.008	0.035

Table 6.13 Factors affecting the choices related to spatial dimension

Factors	Variables	Departure stop			Alighting stop			Bus line		
		β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.
Demographics	Age									
	Profession	0.074	0.001	0.039	0.056	0.081	0.087	0.153	0.001	0.172
	Gender									
	Education							0.093	0.001	0.058
	Residence				-0.056	0.001	0.100			
Trip planning objectives	Journey time or ETA	0.137	0.004	0.269	0.070	0.149	0.129	0.116	0.013	0.135
	Physical or cognitive efforts	0.122	0.019	0.230				0.093	0.082	0.137
Trip characteristics	Trip length									
	Time of day									
	Trip purpose	0.130	0.001	0.136	0.084	0.001	0.201	0.108	0.001	0.092
	Familiarity of trip	0.092	0.012	0.059						
	Alternative mode				0.085	0.029	0.229			
	Alternative bus line[1]	0.104	0.003	0.089						
Importance of contents of information	Bus arrival time									
	Bus route map									
	Bus stop location							0.145	0.001	0.229
	Journey plan				0.098	0.001	0.253			
	Transfer to other services	0.121	0.007	0.179				0.115	0.001	0.177

[1] not included in the model for Bus line

are the trip characteristics that influence the change in *Time of departure from start*. Passengers are found to be less likely to change their departure time in the morning. This can be explained by the fact that morning trips mostly comprise commute trips. In addition, model results illustrate that journey time and ETA positively relate to the change in *Time of departure from start*. Hence, this is evident that passengers may change their departure time to reduce journey time or to maintain a ETA. This resonates with a simulation study carried out for car drivers by Toledo and Beinhaker (2006), where the authors observe the adjustments in drivers' departure time to avoid early or late arrival. In addition, they might consider alternative travel options, such as taking another bus line with the aim of reaching their destination as soon as possible. Hence, arriving at the destination may be more important than adjusting their departure time which is also supported by Fonzone (2015). In addition, Tsirimpa et al. (2005) found commuters more prone to change their departure time. However, this study does not find any impact of trip purpose on the change in *Time of departure from start*.

Information is also found to influence passengers' departure time. Consultation of bus arrival time leads to a higher likelihood of changing departure time. This is supported by Parvaneh et al. (2014) where the author demonstrated a higher likelihood of changing departure time after consulting descriptive information. The impact of information on the decision of changing departure time is rather modest (Table 6.14).

Change of Boarding Time

Model results for *Boarding time* indicate whether a passenger would keep their initial plan of taking a bus at a certain time, or would decide to change their boarding time by taking a bus earlier or later than the original plan. Unlike *Time of departure from start*, *Boarding time* is found to be influenced dominantly by passengers' objectives and trip characteristics (Table 6.14). Demographics and contents of information have little influence on the decision of changing the boarding time.

Passengers are more likely to change their boarding time during midday period and less likely in the morning period. This might happen because, trips in the morning are normally time bound (they need to reach the destination by certain time) and getting to

Table 6.14 Level of impact of the factors affecting passengers' choices

	Variables	Choices				
		Time of departure	Boarding time	Departure stop	Alighting stop	Bus line
Demographics	Age	High				
	Profession	Low	Low	Low		Medium
	Gender					
	Education					Low
	Residence				Low	
Obj. of trip planning	Journey time or ETA	Medium	High	High		Medium
	Physical or cognitive efforts		Medium	Medium		
Trip characteristics	Trip length					
	Time of day	Low	Medium			
	Trip purpose		Medium	Medium	Medium	Low
	Familiarity of trip	Low		Low		
	Alternative mode	Medium			Medium	
	Alternative bus line		Low	Low		
Imp. of contents of information	Bus arrival time	Low				
	Bus route map					
	Bus stop location					Medium
	Journey plan				High	
	Transfer to other services		Low	Medium		Medium

Low: Pratt's importance 0 – 0.1
Medium: Pratt's importance 0.1 – 0.25
High: Pratt's importance > 0.25

destination as soon as possible is very important for them. Shopping trips show higher likelihood for changing the boarding time. In addition, passengers are more likely to change their boarding time when alternative bus lines are available. This suggests that passengers may change their boarding time either by changing bus lines or getting an earlier or later bus on the same line.

Factors related to passengers' trip planning objectives are found to be significant on the decision of changing the *Boarding time*. Journey time and ETA are the most dominant factors. In addition, passengers tend to change the time of boarding when they are less concerned regarding the physical or cognitive efforts. This indicates that passengers who are not bothered by the transfers or walking distances are more likely to change their *Boarding time*.

The probability of changing the *Boarding time* depends on participants' profession. Homemakers show higher likelihood in changing their *Boarding time*.

Change of Departure Stop

Change of *Departure stop* refers to the situation where a passenger decides to board a bus from a different stop than according to their original trip plan (itinerary).

Model results show that passengers' decision of changing *Departure stop* is dominated by trip planning objectives, trip characteristics and contents of information. Passengers' objectives to reduce journey time, physical or cognitive efforts and maintaining their ETA are key factors that influence the change of *Departure stop*.

Higher likelihood of changing *Departure stop* is observed for shopping and leisure trips. This implies that passengers tend to change their *Departure stop* when making irregular or non-commuting trips. In addition, *Departure stop* is likely to be changed when making familiar trips. Passengers' familiarity with the network plays a key role here. Again, availability of alternative bus lines increases the likelihood of changing *Departure stop*. Passengers may change the bus stop to get a bus on an intended bus line, or they may consider an alternative bus stop because of available alternative lines. In this case, passengers' decision-making could be explained by two scenarios. Passengers may take the decision of changing *Departure stop* after consulting information because of getting a particular bus line among the alternatives. On the other hand, they may decide to go for a different bus stop due to availability of alternative lines, and a bus line could be chosen after arriving at the stop. It may also be deemed by passengers that missing one bus would not be a problem, which infers to their risk aversion attitude.

Contents of information are found to be of relevant influence in the decision of changing *Departure stop*. Consultation of information on transfer to other services leads to a higher likelihood of changing *Departure stop*. This may happen if departure stop is changed as a result of bus line choice.

Among the demographics, profession only is observed to have statistically significant influence on changing *Departure stop*. It is observed that working people and students are more likely change *Departure stop*, whereas Homemakers and passengers without work are less likely to change *Departure stop*.

Change of Alighting Stop

This section discusses the change of *Alighting stop* which refers to alighting from the bus at a different stop than according to an original trip plan. This may occur if they change to a different bus line which takes them to a different alighting stop. Survey results show that only 5% of the URTPI users changed their *Alighting stop*. CATREG results show that change in *Alighting stop* is strongly influenced by trip characteristics and the importance of contents of information (Table 6.14).

Highest likelihood is observed for changing *Alighting stop* when passengers make shopping trips, followed by work travel and personal or family business trips. Passengers are not likely to change *Alighting stop* for commuting and leisure trips. Shopping trips are not restrictive for passengers either in terms of time or location. In addition, availability of alternative mode relates positively with the decision to change *Alighting stop*. Hence, passengers may try to make connection between different modes by changing *Alighting stop*, i.e. change of *Alighting stop* to take a tram, or walk to the destination.

The importance of information contents is found to be most influential on the decision of changing *Alighting stop*. Passengers who journey planning information important are more likely to change their *Alighting stop*.

Change of Bus line

This model investigates the factors that influence passengers to change *Bus line* after consulting URTPI. This means that passengers may take a different bus line than the one they originally intend to as a result of consulting URTPI.

Passengers' decision of changing *Bus line* is related to the importance of contents of URTPI (Table 6.14). Passengers' objectives and demographics also influence the decision of changing *Bus line*. Trip characteristics possess the lowest impact on the change of *Bus line*.

Model result reveals that the likelihood to change *Bus line* increases when URTPI is consulted. Among the contents of information, the importance of bus stop location and transfers to other services is found significant. This indicates that changing *Bus line* requires a combination of static and real-time information. Bus stop location is important for passengers to choose a *Bus line*. This may be associated with reducing journey time which is also found significant in the model. In addition, information on transfers is important as it requires both physical and cognitive efforts as well as additional monetary cost if passengers have to pay for transfers.

Passengers' choice of *Bus line* is influenced by the purpose of trip. Shopping trips exhibit the highest likelihood for changing *Bus line*. This also indicates the flexibility to make changes as shopping trips are not typically time-bound.

Participants' demographics show that homemakers are in leading position for changing *Bus line*, among the profession groups. This shows their flexibility to make changes when making a journey. In the previously presented models, working people and students have been observed to be less likely to change time-related choice elements, i.e. *Time of departure from start* and *Boarding time*. Hence, passengers who belong to these groups of profession, may be strict about their journey plan including *Bus line*. However, they are likely to change *Departure stop* after consulting URTPI. This suggests that working people and students tend to keep their *Bus line* unchanged even if they change *Departure stop*. On the other hand, homemakers may take a tactical decision, which implies no rigorous planning or particular preference of *Bus line*. Educated passengers exhibit higher likelihood of changing *Bus line*.

Impact on Route Choice

In this study, the definition of route choice (presented in section 1.2.1) suggests that any changes in *Time of departure from start* or *Boarding time* lead to an impact on temporal dimension of route, whereas spatial dimension of route choice is influenced when there is a change in *Departure stop*, *Alighting stop* or *Bus line*. Therefore, the model results could lead to a conclusion that information has relatively minor influence on temporal dimension of route choice. Hence, the use of information regarding the elements of temporal dimension is rather confirmatory, i.e. passengers may consult URTPI to check if the bus is on time without making any changes in their original plan. On the contrary, spatial route choice is influenced by the importance of consulted URTPI.

In addition, changes associated with PT demand distribution (Figure 6.12) are influenced strongly by trip characteristics and information. Information consulted from URTPI has the highest influences upon the bus line choice. On the contrary, passengers' demographics influence their time adjustment after consulting URTPI.

6.4 Summary

This chapter presented analysis of the bus stop survey data. The descriptive analysis of the data reveals that 85% of the passengers consult some sort of information when travelling with buses, while more than half of the passengers use URTPI. Non-users of URTPI stated the perceived necessity as the main reason for not consulting URTPI. In addition, 38% of the URTPI users also use non-URTPI sources, i.e. printed maps, at stop displays and advice from other people/staff. Among the URTPI sources, Mobile apps are the most consulted and exclusive source. Travel websites and Google Maps are consulted by about one-third of the URTPI users. Google Maps is used in conjunction with other sources, while the use of Travel website is found to be exclusive in the majority of cases (Table 6.2). Passengers perceive bus arrival time as the most important content of information. Static information, such as bus route map and bus stop location, is also sought by about two-thirds of the passengers. Information on journey plan and transfers are perceived as important by half of the passengers.

The inferential analyses reveal that bus passengers' use of URTPI is influenced by four factors related to trip characteristics and three factors related to demographics (Figure 6.10). Trip length, participants' age and profession are found to be the most influential factors. Passengers' preference of URTPI sources is influenced by time of day, familiarity with the trip and their residence. Trip characteristics are observed to influence both static and real-time contents of information. Trip purpose is found to be significant for consulting bus route map. Demographics influence the search of bus stop location and journey planning information. Visitors in the city are likely to look for information related to geographic location , i.e. bus route map and bus stop location.

Passengers' choices after consulting URTPI influence PT demand distribution in 39% of revealed cases, which would lead to a change in demand distribution for bus runs and bus lines by 17% and 15% respectively. Information on bus stop location and transfer to other services are the two contents of information influencing the spatial dimension of route choice.

Passengers' choices after consulting URTPI have been modelled and factors influencing their decisions of making changes have been identified. It is observed that demographics have the highest influence on changing the time of departure. Changes of boarding time and departure stop are significantly influenced by passengers' trip planning objectives. Reducing journey time is the most important objective which influences their decision and exhibits significant impact on the change of boarding time and departure stop. Contents of information are observed to be the most influential on the decision of changing alighting stop or bus line. Information on transfers and bus stop location are crucial for changing bus line. Among the real-time information contents, transfers and bus arrival time have impact on passengers' decision-making, although bus arrival time did not reveal much relevance in the analysed model. Additionally, information on bus route map does not have any impact on the choices. This suggests that passengers may not be concerned about bus route and rather driven by other aspects of the trip, such as ETA or journey time.

This chapter sheds light on passengers' use of URTPI and the decision-making after consulting information. Due to limited time, bus stop survey questionnaire had a limited number of questions, which leaves room for further investigation on the impact of passengers' other trip planning objectives and optimisation strategies, as well as social norms on their decision-making. The following chapter presents analysis of the online survey data which will provide more insight into behavioural aspects of passengers' use of URTPI and its impact on their choices.

CHAPTER 7

ONLINE SURVEY

This chapter presents the results of the online survey data analysis. In the previous chapter, the bus stop survey results revealed passengers' choices for a particular trip under the influence of URTPI. However, the bus stop survey analysis did not discuss the underlying objectives of passengers' decision making. The online survey results discusses what bus passengers usually do after consulting URTPI. The aim of the online survey data analysis is to investigate the factors affecting the use of URTPI in general and the choices made by the passengers incorporating their cognitive aspects. This chapter begins with a description of the sample structure and the representativeness of the online survey data. A descriptive and inferential statistical analysis results is presented with regard to the use of URTPI. This is followed by the presentation of results in terms of the impact of URTPI on passengers' choices.

7.1 Sample Structure and Representativeness

The online survey questionnaire was disseminated via Internet platform with an invitation of participation to the UK bus users only. Hence, responses were expected to be received from bus users across the UK. A total of 752 responses were collected, of which 401 were fully completed. 371 participants provided their postcode; 24% of them were from England and the remaining 76% of participants were from Scotland. A more dispersed sample was expected because the questionnaire was shared through UK-wide Internet platforms. As previously discussed, online surveys do not allow control over the sample, i.e. the geographical locations of the respondents cannot be controlled. Hence, it is difficult to understand the survey participants' experience with PT and information systems in their cities, which may impact the use of URTPI and their choices as well. To minimise the potential impact of this issue, questions on the available PT services were included in the questionnaire.

The representativeness of the sample is one of the main concerns related to online survey. In the past, the main reason could be limited accessibility to Internet which would provide a sample skewed to the Internet users only. However, this issue has nowadays much smaller impact as the Internet penetration rate is as high as 90% in the UK (Office for National Statistics, 2017). Although a vast majority of the population have Internet access, this does not guarantee their participation in the survey. This implies that the participation in online survey depends on the Internet users' interests in PT and the use of information, which may provide a biased sample. To investigate the representativeness of the sample, the online survey data is compared with the Transport for London (TfL) 2014 bus user data (Transport for London, 2014) and Transport for Scotland 2012 bus user data. TfL data is related to bus users in an urban condition (City of London), whereas, Transport Scotland data presents both urban and rural passengers (whole Scotland). The data analysis for representativeness includes both partial and fully completed responses, i.e. 752 responses in total. Figure 7.1 shows that the survey sample has a higher share of male participants than the TfL data, which is not surprising as there is higher percentage of male internet users in the UK (Office for National Statistics, 2017).

A relatively smaller proportion of younger people (age 18 to 24) took part in the survey, whereas the proportion of participants aged 24 to 65 is higher compared to TfL data (Figure 7.2). Likewise a comparison of participants' age to Transport Scotland data shows a similar pattern. Participants of age less than 19 and greater than 60 year old are smaller in proportion in the survey sample. This is not surprising, as the online survey participants are 18 years or older. In addition, older people (age>64) may not be frequent users of the Internet. Figure 7.3 illustrates that in terms of profession, the online survey sample is more in line with the TfL data than the Transport Scotland data. Note that Transport Scotland data includes both urban and rural areas, whereas TfL data represents urban bus passengers, which is the context of this study.

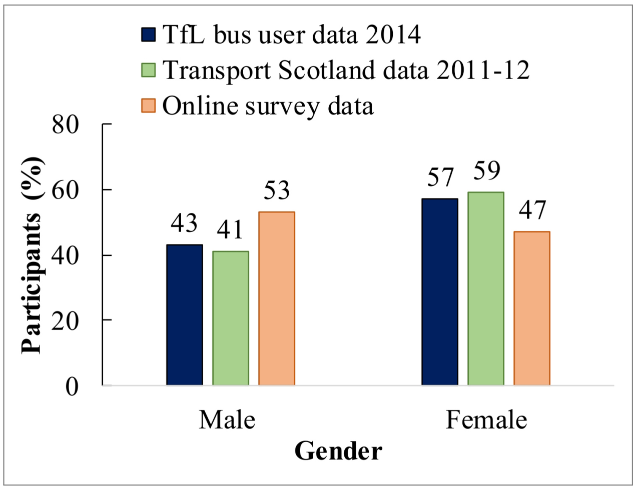


Figure 7.1 Representativeness of the online survey data: gender

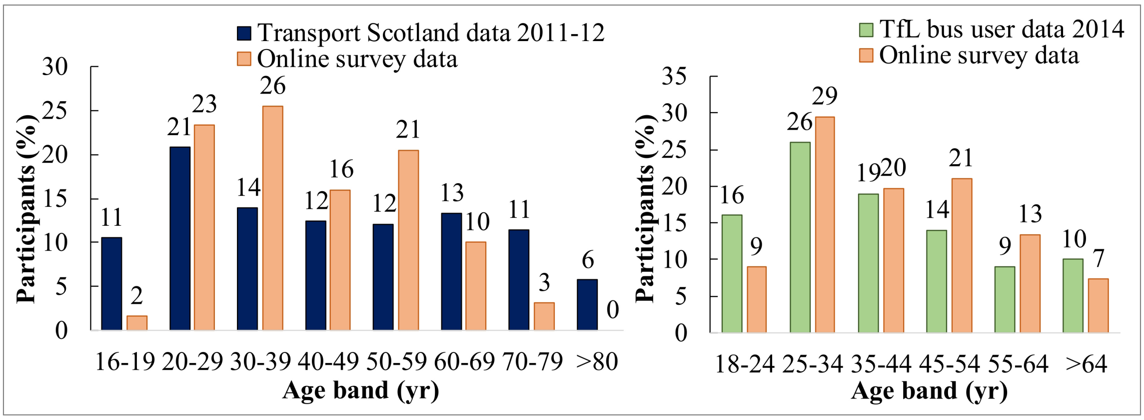


Figure 7.2 Representativeness of online survey data: age distribution

Majority of the online survey responses are from urban areas. The representativeness and descriptive analyses presented in the chapter consider all the responses (752 responses), i.e. both urban and suburban areas. However, the sample is filtered to obtain only the complete responses from urban areas for further modelling of the use of URTPI. In this study, cities with 100,000+ population were considered as urban areas. This reduced the sample size to 339 of which 315 are users of URTPI (93%). Smaller cities may have limited travel options in terms of alternative routes and bus frequency. This study aims to understand passenger behaviour when there is sufficient number of alternatives available, which is assumed to be true in urban areas as above defined. The

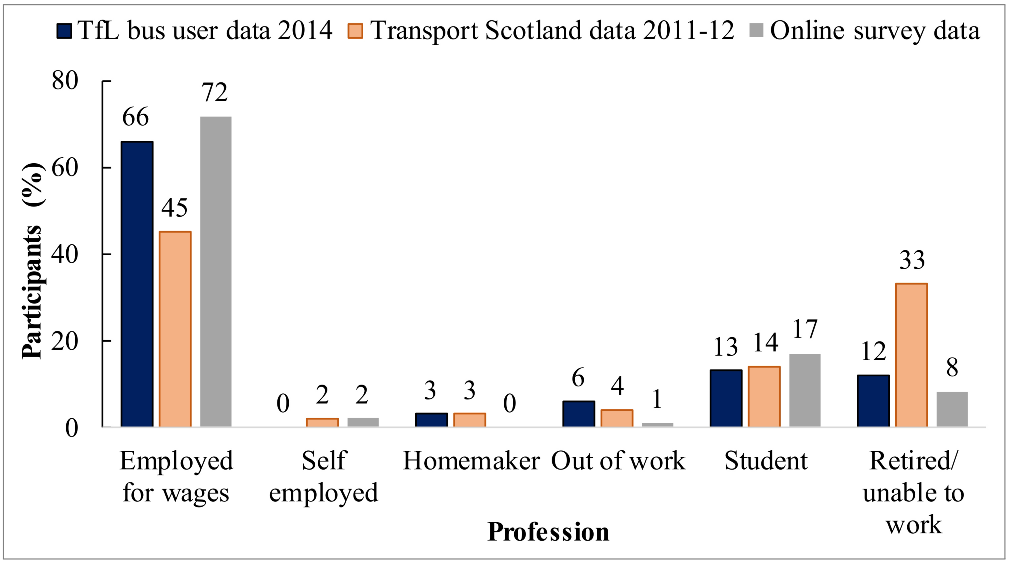


Figure 7.3 Representativeness of online survey data: profession

availability of alternative PT services may vary across the cities. Further breakdown of cities according to population may give a better indication of the alternative PT services. Given the small sample size it was not possible.

Although a relatively limited sample size was obtained through the online survey data collection, the sample is representative of urban bus passengers. Additionally, the sample is biased towards URTPI users (88%). This high proportion of URTPI users may be a result of collecting data through a web-based survey. Passengers who regularly access the Internet are more likely to use travel information. This is not an issue in context of the present study as the aim of this study is to understand the URTPI user behaviour.

7.2 Use of URTPI

The data analysis for the use of URTPI includes descriptive and inferential statistical analysis. This section presents the analysis of data to identify the factors affecting the use of URTPI in general, and the contents of information which are likely to be sought by the passengers. The data analysis techniques were previously discussed in Chapter 5.

7.2.1 Descriptive Analysis

Use of Passenger Information

The online survey questionnaire considered all the available sources of information for bus passengers in the UK (see questionnaire in Appendix E). The survey results show that 97% of total respondents use at least one source of information for making bus trips in their cities. Figure 7.4 presents the usage of different sources of information in the UK. Static local information, such as printed maps and timetables are still being used by 20% of the participants. Majority of the non-URTPI users (i.e. printed maps & timetables and displays at stops) also use URTPI. 88% of the participants use URTPI for making trips with buses.

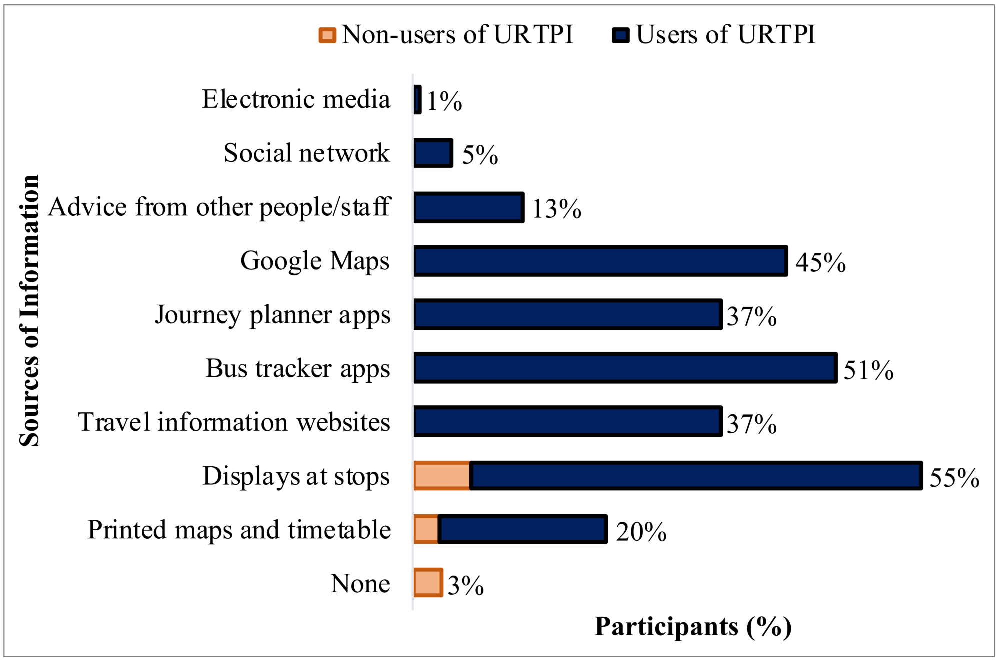


Figure 7.4 Use of different sources of passenger information (Q1 in Appendix E)

Compared to the bus stop survey data, the online survey participants show higher usage of the available passenger information sources. This is expected as online participants mentioned any sources of information they access, whereas bus stop survey participants selected only the sources they used for a particular trip. In addition, self-selection sampling techniques are also associated with bias, as passengers who are more concerned about PT services may be more interested to take part in the survey.

Familiarity with the network is the most commonly observed reason for not using

URTPI (Figure 7.5). Other important reasons include unfamiliarity with URTPI services and lack of willingness to use Internet on phone.

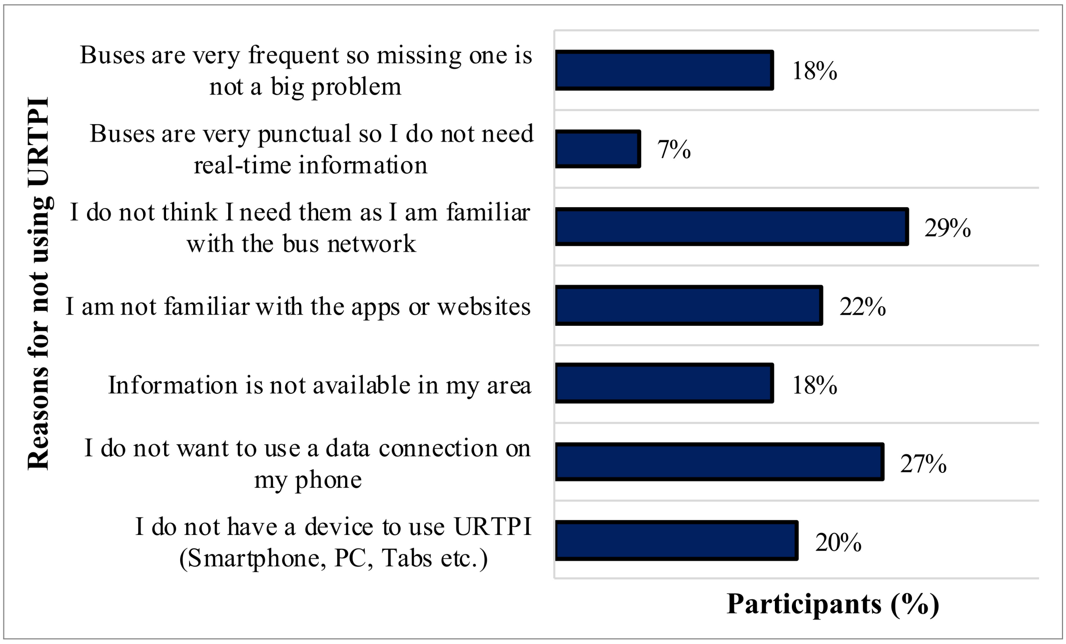


Figure 7.5 Reasons for not using URTPI (Q21 in Appendix E)

Use of URTPI Sources

As previously mentioned, 88% of the participants use at least one form of URTPI. Descriptive analysis reveals that Mobile apps are in the leading position in the online survey results as well. Among the URTPI users, 75% of the participants use Mobile apps (Figure 7.6). Half of the participants stated that they use Google Maps, which is much higher compared to the bus stop survey results. Travel websites are used by 42% of the passengers and Social media do not have many users (6%).

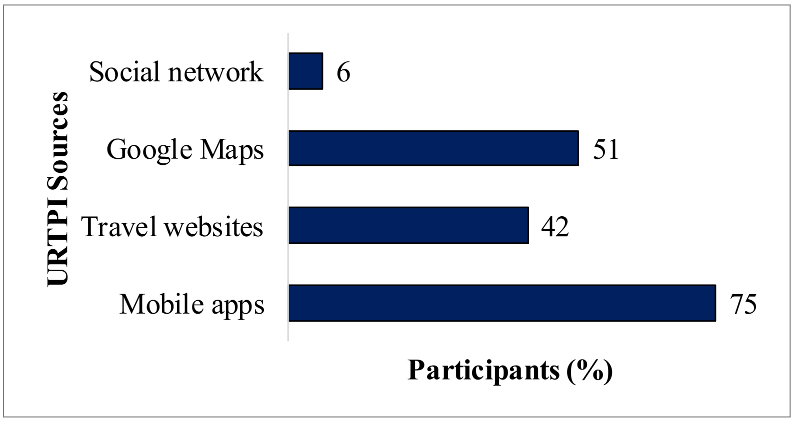


Figure 7.6 Use of URTPI sources

Frequency of URTPI Use

In the online survey questionnaire, participants were asked how frequently they use URTPI. The survey results show that 62% of the participants access URTPI often or very often and 20% of the participants use them rarely (Figure 7.7). PT service characteristics may have a relevant influence on the frequency of use of URTPI. Figure 7.8 shows the use of URTPI for different trips and service characteristics. 65% of the participants stated that they would use URTPI often if the trip duration is more than 15 minutes. Participants use URTPI for occasional or infrequent trips more often than for regular trips. The frequency of use of URTPI increases with the increase in bus headways. This demonstrates passengers' risk aversion attitude towards missing a bus as the bus service frequency becomes lower.

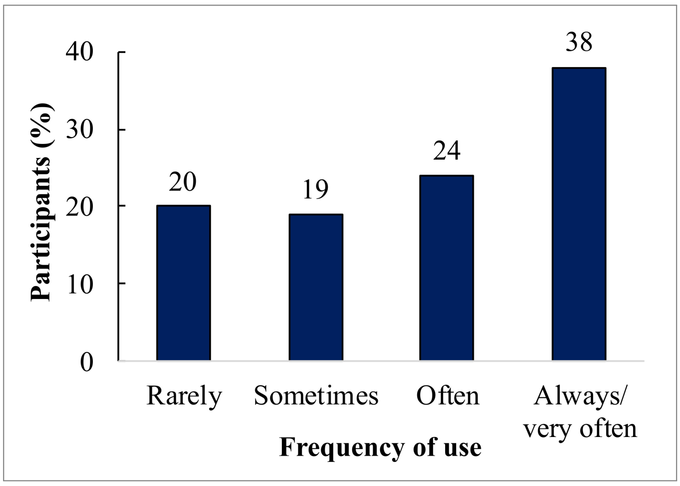


Figure 7.7 Frequency of use of URTPI (Q2 in Appendix E)

Passengers' perception of attributes of information may influence their use of URTPI. Figure 7.9 shows that more than half of the users do not perceive the consultation of URTPI as time-consuming (i.e. strongly disagree or disagree). Additionally, the majority of participants exhibit quite uniform attitudes in terms of the ease of use (i.e. user friendliness, understandability), reliability, and usefulness of URTPI. Chi-squared tests results show that there is a significant association between passengers' perception of information and frequency of the URTPI use (see Appendix I).

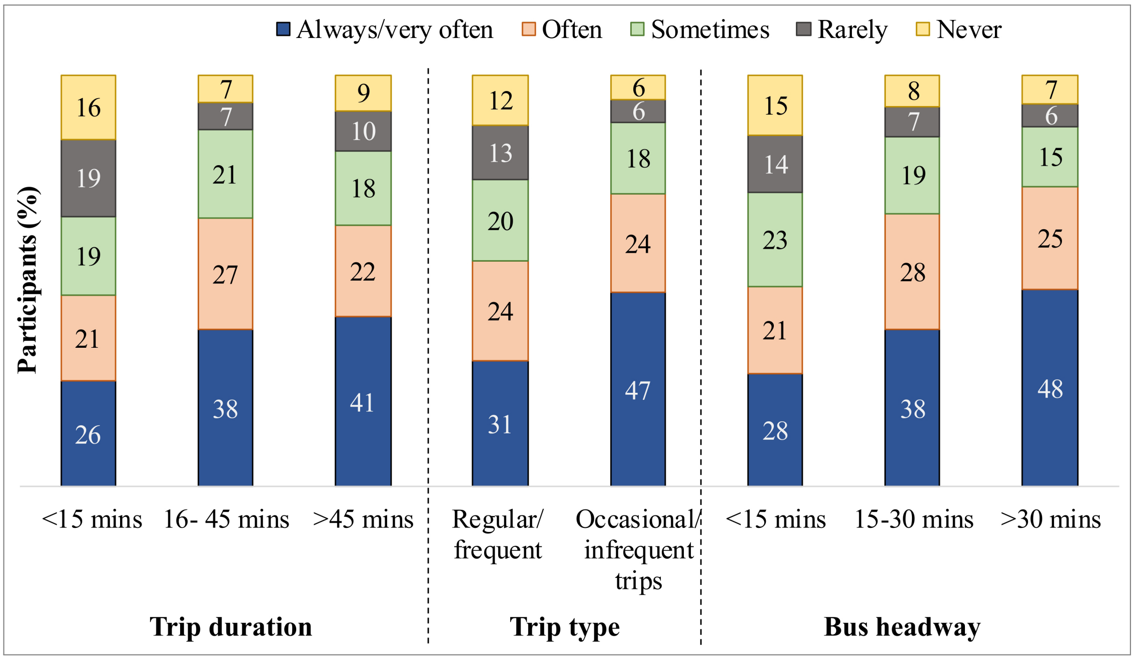


Figure 7.8 Frequency of use for trip and service characteristics (Q5-Q7 in Appendix E)

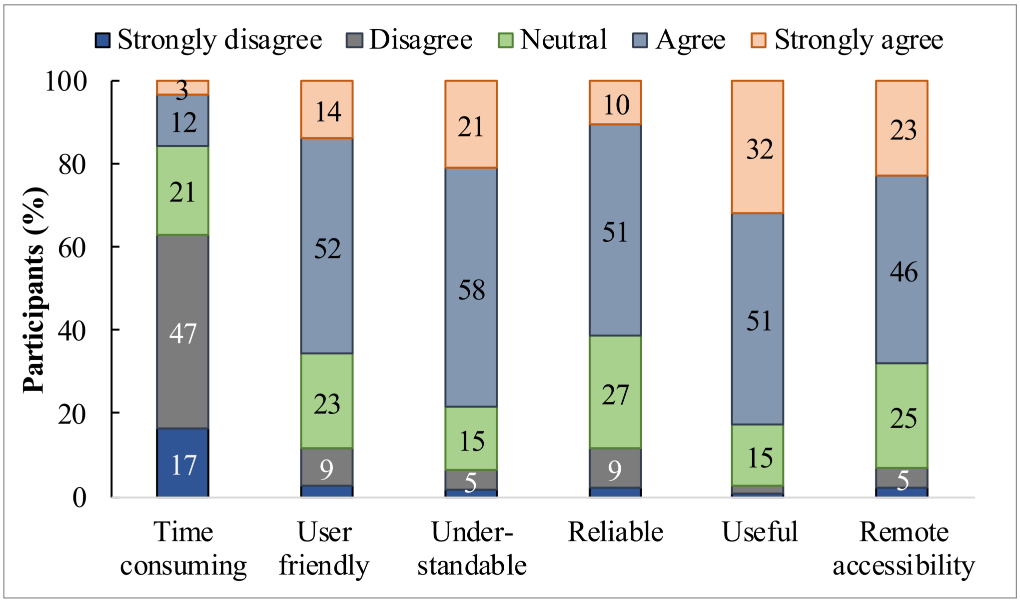


Figure 7.9 Perception of information attributes (Q3 & Q8 in Appendix E)

Contents of Information

Participant's interest in different contents of information is measured by the perceived importance of information. The importance of available information contents is presented in Figure 7.10. URTPI provides both real-time and static information. *Bus arrival time* and *Expected Time of Arrival (ETA)* are real-time (predictive) travel information contents available for the passengers. Information for *Journey plan* refers to information required for planning a trip from origin to destination, which provides both real-time information, such as arrival time of the next bus and travel time, as well as static contents, such as alternative bus lines and location of bus stops. Similarly, *Transfer to other services* consists of real-time (i.e. transfer time) as well as static contents (i.e. number of transfers and transfer stops). Information contents which are typically static (except for any temporary changes taking place, such as change in bus stop location due to construction works) are also available in URTPI sources. Static contents are *Bus route map*, *Bus stop location* and *Walking distance* to and from bus stops. The survey results show that *Bus arrival time* is important or very important to a majority of the URTPI users. This may be a result of high penetration rate of bus stop displays, which make passengers aware of bus arrival time. *ETA*, *Bus route map* and *Bus stop location* are important/very important to more than 80% participants. *Walking distance* to and from bus stops is a concern to the least percentage of participants. In summary, both real-time and static information are perceived as important by a substantial share of participants.

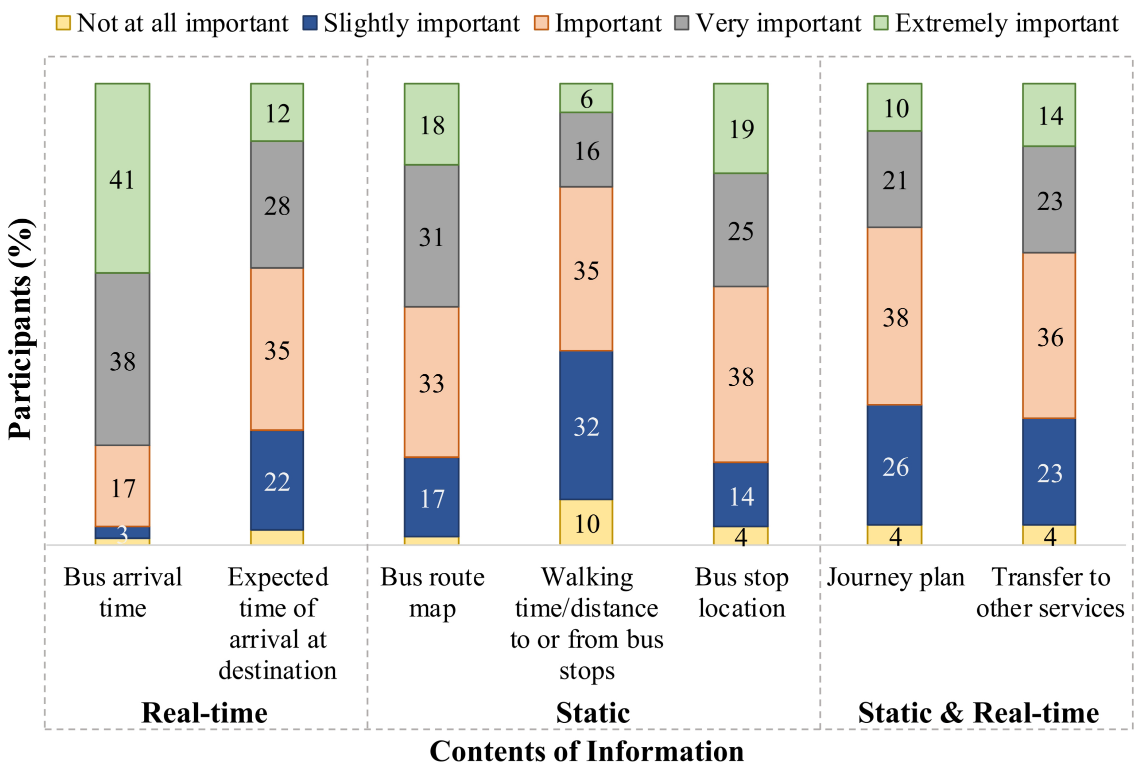


Figure 7.10 Importance of contents of information (Q10 in Appendix E)

Perceived Benefits of Using URTPI

The online survey investigates the passengers' perceived benefits of consulting URTPI. In the survey questionnaire, perceived benefits were measured on a 5-point Likert scale. Figure 7.11 shows that more than 80% of the users appreciate URTPI because it reduces travel uncertainty and helps with executing their trips. Reduction in efforts required for planning and scheduling the activities are also perceived as potential benefits by the majority of participants (more than 70%). It should be noted that a large number of participants consult information for planning and executing the trips, which again illustrates the significant potential of information to influence their decision-making process.

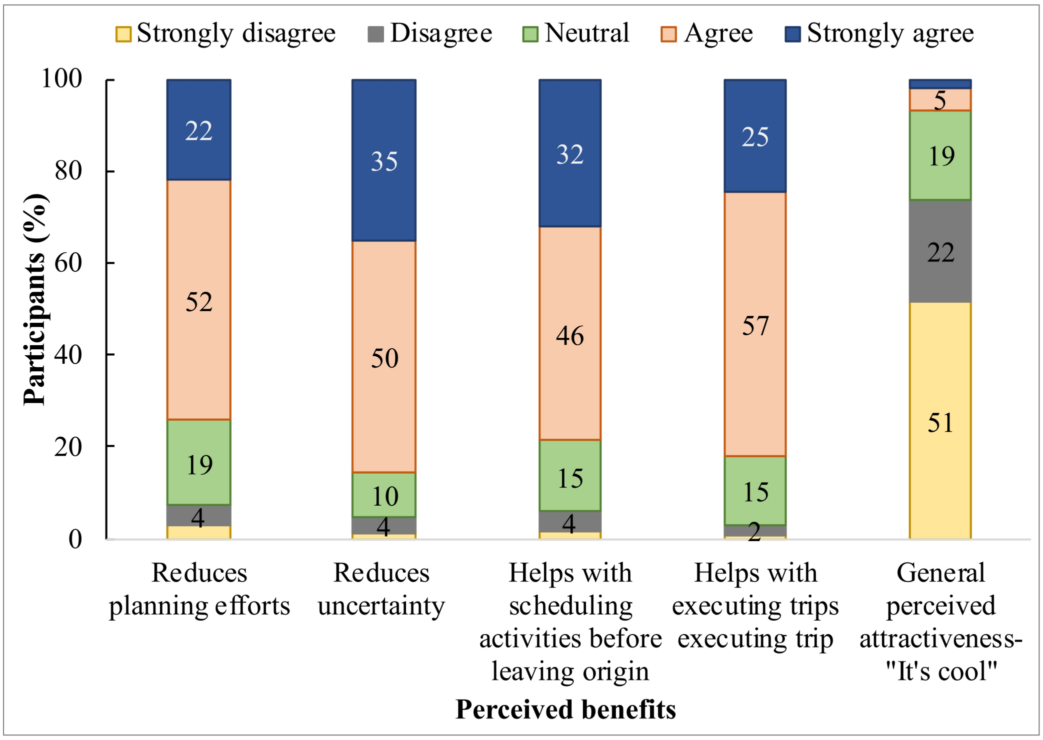


Figure 7.11 Perceived benefits of using URTPI (Q8 in Appendix E)

Trip planning objectives

Passengers' choices are shaped by the underlying trip planning objectives. In the online survey, participants stated their trip planning objectives when consulting URTPI. In addition, data on the extent to which they want to improve their journey experience is also collected. Figure 7.12 presents participants' trip planning objectives. It is observed that reducing waiting time (at the trip origin and the start bus stop) is the most important objective. In addition, reducing the number of transfers and transfer time is also important to the passengers. Passengers are found to be reluctant to reduce physical efforts (i.e. walking) after consulting URTPI.

In addition to the trip planning objectives, the extent to which participants aim to improve their experience should also be considered, i.e. whether they try to maximise or they are satisfied with their experience (Peng, 2013; Schwartz et al., 2002). This may also influence their decision-making process (discussed in the section 3.1.4). In the present study, the phenomenon of the extent of improvement is referred to as the *"Optimisation strategy"* in the following sections. Figure 7.13 shows that a majority of the passengers are maximisers with regard to waiting time. About 60% of the URTPI users tend to reduce their travel time and transfers. A majority of the passengers are reluctant to minimise their physical efforts.

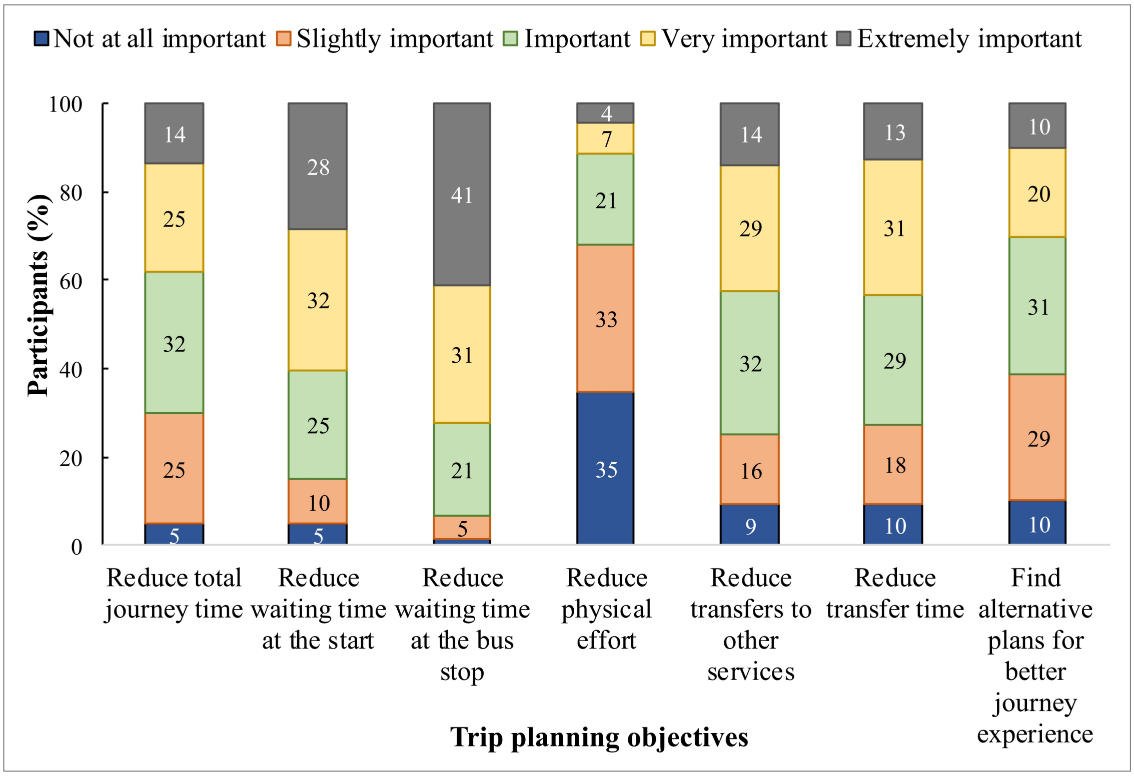


Figure 7.12 Trip planning objectives (Q14 in Appendix E)

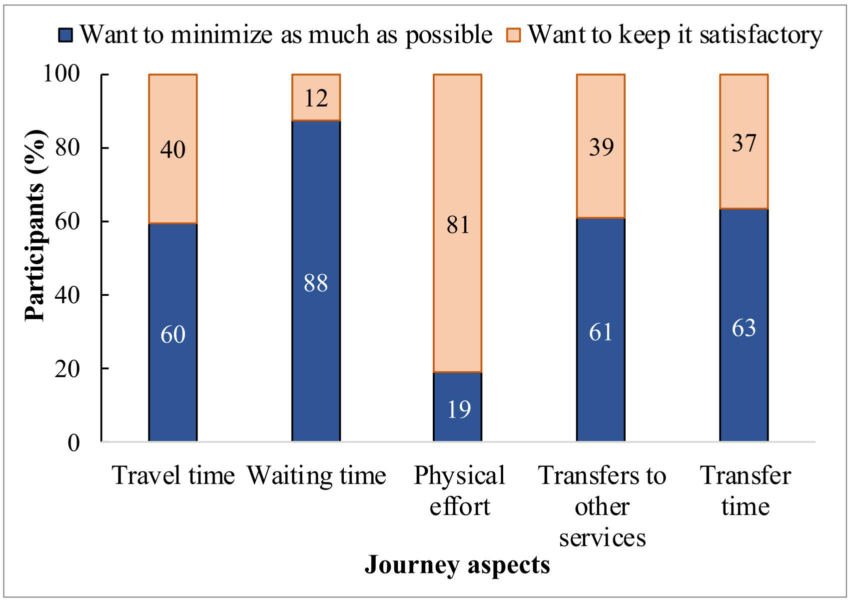


Figure 7.13 Optimisation of journey aspects (Q15 in Appendix E)

7.2.2 Factors Affecting the Use of URTPI

This section investigates the factors that influence passengers' use of URTPI. The use of URTPI is investigated through modelling of the frequency of use of URTPI and the contents of consulted information. Table 7.1 shows the models described in this section along with the aim of each models.

Table 7.1 Models to explain the use of URTPI

Aim	Model	Table	Method
To investigate the factors affecting the use of URTPI in general (i.e. any sources of URTPI)	Frequency of use of URTPI	Table 7.2	CATREG
To identify the factors affecting the contents of information that are likely to be consulted by passengers	Importance of contents of information	Table 7.4 and 7.5	

Frequency of URTPI use

Unlike the bus stop survey, the online survey focussed on the use of URTPI in general (passengers' use of information over the last six months). In the descriptive data analysis, it was observed that 88% of the participants use URTPI; hence, the data is skewed towards the users of URTPI. Instead of identifying the factors that affect passengers' decision of whether to use URTPI or not, a CATREG analysis is carried out to find out the factors that affect the frequency of use of URTPI. Therefore, the dependent variable is the frequency of use which was measured on a 4-point Likert scale (Figure 7.7). A list of independent variables is presented in Table 7.3. Since the sample size is smaller with respect to the number of variables, some predictor variables are combined by means of the PCA. The combined variables are used as predictor variables in the models. The PCA results are presented in the Appendix J. The CATREG model development technique remains the same as previously discussed in the bus stop survey analysis (see section 6.2.2)

The significant factors obtained from the CATREG results are presented in Table 7.2. The Pratt's measure shows the importance of each predictor variable in the model.

Table 7.2 Factors affecting the frequency of use of URTPI

Factors	Variables	β	Sig.	Pratt's Importance
Demographics	Age	-0.104	0.035	0.049
Benefits of using URTPI	Trip planning efforts	0.109	0.033	0.067
Optimisation strategy	Reduce physical effort	0.091	0.113	0.018
Norms	People you care about use URTPI	0.189	0.001	0.187
Attributes of information	Ease of use	0.395	0.001	0.576
	Remote accessibility	0.134	0.001	0.103

Model results show that the frequency of access to URTPI is strongly influenced by the attributes of information and social norms. Participants' perception of the ease of use of URTPI, i.e. understandability, user friendliness and remote accessibility are positively related to their access to URTPI. Additionally, passengers' perception of time required for consulting information is inversely related to the frequency of use of URTPI. Participants are likely to use URTPI if the people they care about (friends and family) use URTPI. Demographics has little impact on the frequency of use of URTPI. In addition, the age of participants is inversely related to the frequent access to URTPI, i.e. younger people are more likely to use URTPI on a frequent basis. The model results reveal that the main drivers of frequent use of URTPI are related to the information (i.e. attributes

Table 7.3 Factors affecting the use and importance of contents of URTPI: definition

System elements	Factors	Variables	Type	Levels[1,2]
Users	Demographics	Age	Ordinal	1-[18-25], 2-[26-35], 3-[36-45], 4-[46-55], 5-[56-65], 6-[>65]
		Education	Ordinal	1-Grammar school, 2-High school, 3-Some college degree, 4-University degree
		Profession	Nominal	1-Employed for wages, 2-Self-employed, 3-Out of work, 4-Student, 5-Retired/Unable to work
		Gender	Nominal	1-Female, 2-Male
	Frequency of trips per week	Commute or work trips	Numeric	Scores obtained from PCA
		Flexible trips (i.e. leisure trips, shopping trips and occasional trips)		
	Perceived benefits of using URTPI	Trip planning efforts	Numeric	Scores obtained from PCA
		Better execution of trips (i.e. reduced uncertainty, improved trip execution and scheduling of activities)		
		General attractiveness ("coolness")		
	Trip planning objectives (Importance)	Reduce transfers and find alternatives (i.e. no. of transfers, transfer time and find alternatives)	Numeric	Scores obtained from PCA
		Reduce waiting time (i.e. at start and at the stops)		
		Reduce physical effort		
		Reduce Journey time		
	Optimisation strategies (Maximise or satisfy)	Transfers	Numeric	Scores obtained from PCA
		Waiting time		
		Physical effort		

Continued on next page

Table 7.3 *Continued from previous page*

System elements	Factors	Variables	Type	Levels
	Social norms	People you care about use apps in general(any kind of app)	Ordinal	1-Strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree
		People you care about use URTPI		
PT Services	Availability of PT services	Bus frequency	Ordinal	1-Not at all, 2-Very few, 3-A few, 4-Quite a few, 5-Many
		Alternative bus lines		
Information	Perception of attributes of information	Ease of use (i.e. User friendliness, understandability and time consumption)	Numeric	Scores obtained from PCA
		Quality of info (i.e. Useful and reliable)		
		Remote accessibility		

[1] Category numbers are used for plotting CATREG quantifications graphs presented in Appendix K

[2] Combined variables obtained from PCA are presented in Appendix J

of information) and to the users (i.e. norms and demographics).

Contents of Information

In the bus stop survey, it was observed that the importance of contents of information is influenced by trip characteristics and demographics. Since the online survey is not focused on a particular trip, participants were asked about the frequency of different types of trips they make every week (Q27 in Appendix E) to identify PT demand. Available PT services for the participants are taken into account in modelling the importance of contents of information. In addition, passengers' trip planning objectives (Figure 7.12) and optimisation of journey aspects (Figure 7.13) may influence the important of contents of information. A CATREG model has been developed to explain the importance of each content of information presented in Figure 7.10, in which the dependent variables are the importance of each individual content of information. Independent variables are demographics, trips made per week, available PT services, trip planning objectives, optimisation strategies, and norms (presented in Table 7.3). Table 7.4 presents the CATREG results for contents of information that have real-time attributes. The CATREG results for static contents of information are presented in Table 7.5.

Model results show that the importance of both real-time and static contents of information is strongly influenced by passengers' trip planning objectives, optimisation strategies and demographics. Availability of PT services is also influential for some of the contents of information, such as *Bus arrival time*, *Journey plan* and *Bus route map*. The number of trips per week with different purposes is not significant in the models. The level of impact of the significant factors is categorised as low, medium and high and presented in Tables 7.6 and 7.7.

The most used information, *Bus arrival time*, is strongly influenced by participants' objective of reducing waiting time (at the trip origin and the start bus stop). Passengers are more likely to consult *Bus arrival time* if they aim to reduce their waiting time. In addition, the age of participants is negatively related to the importance of *Bus arrival time*. This result resonates with the bus stop survey analysis. The availability of PT services is not influential in terms of the importance of *Bus arrival time*.

Table 7.4 Factors affecting the importance of real-time information contents

Variables		**Real-time**						**Real-time and static**					
		Bus arrival time			ETA			Journey plan			Transfer to other services		
		β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.
Demo-graphics	Age	-0.188	0.001	0.138	-0.153	0.001	0.191						
	Profession							0.240	0.001	0.162	0.167	0.001	0.080
	Gender												
	Education												
Trip planning objectives	Reduce transfers and find alternatives				0.191	0.009	0.336	0.217	0.001	0.261	0.371	0.001	0.626
	Reduce waiting time	0.404	0.001	0.631	0.131	0.032	0.145						
	Reduce physical efforts							0.123	0.053	0.080			
	Reduce journey time				0.128	0.126	0.197	0.177	0.006	0.188	0.118	0.052	0.133
Optimisation strategies	Transfers	0.108	0.038	0.002									
	Waiting time												
	Physical efforts				-0.142	0.038	0.131	-0.157	0.026	0.160	-0.099	0.110	0.078
Norms	People you care about use URTPI	0.182	0.085	0.160									
Trips per week	Commute or work trips										0.135	0.020	0.082
	Flexible or irregular trips												
PT services	Buses frequency							0.183	0.016	0.036			
	Alternative bus lines	0.113	0.105	0.068				-0.211	0.011	0.113			

Table 7.5 Factors affecting the importance of static information contents

		Static								
	Variables	Bus route map			Bus stop location			Walking distance		
		β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.	β	Sig.	Pratt's Imp.
Demographics	Age	-0.210	0.036	0.397	-0.158	0.041	0.171			
	Profession				0.174	0.001	0.029	0.121	0.001	0.113
	Gender				0.100	0.090	0.085			
	Education	0.083	0.390	0.059						
Trip planning objectives	Reduce transfers and find alternatives				0.185	0.010	0.285	0.316	0.001	0.575
	Reduce waiting time				0.201	0.004	0.274			
	Reduce physical efforts	0.141	0.046	0.144						
	Reduce journey time									
Optimisation strategies	Transfers	-0.124	0.043	0.150						
	Waiting time									
	Physical efforts				-0.162	0.027	0.155	-0.109	0.123	0.076
Norms	People you care about use URTPI							0.183	0.064	0.235
Trips per week	Commute or work trips									
	Flexible or irregular trips									
PT services	Bus frequency									
	Alternative bus line	0.187	0.017	0.250						

ETA is also a real-time content of information which is important for a major share of passengers. Participants find *ETA* as important when they tend to look for better alternatives or to reduce transfers. The importance of *ETA* is inversely related to participants' age. Additionally, passengers' aim to optimise their physical efforts is found to be influential on the importance of *ETA*. Participants are likely to look for *ETA* when they want to minimise their physical efforts as much as possible.

Journey plan information refers to all the contents of information related to the trip from start to destination. It is comprised of both real-time and static information. The importance of information on *Journey plan* is mainly influenced by passengers' trip planning objectives, profession and optimisation strategies. It is perceived important when passengers look for alternatives and aim to reduce journey time. This suggests that even if passengers are aware of the alternatives, real-time information (i.e. *Journey plan*) is very important to maximise their journey experience. Among the professions, retired and employed for wages are the passenger groups who are most likely to consult *Journey plan* information. Passengers' tendency to minimise physical efforts leads them to assign higher importance for *Journey plan*.

Information on *Transfer to other services* is strongly associated with passengers' trip planning objectives of reducing transfers and journey time along with finding alternatives. In addition, participants who make more commuting or work trips per week are more likely to consult *Transfer to other services*.

Among the static contents of information, the importance of *Bus route map* is influenced by participants' age, available PT services, trip planning objectives and optimisation strategies. Participants' age is inversely related to the importance of *Bus route map*. In addition, the availability of alternative bus lines is also of high importance. This may indicate their propensity to consider different bus lines by consulting information if alternative PT services are available. *Bus route map* is also likely to be consulted when the objective is to reduce physical efforts and optimise trip experience by minimising transfers while travelling.

The importance of *Bus stop location* is strongly influenced by the trip planning objectives, demographics and optimisation strategies. Passengers perceive *Bus stop location* as important when they want to reduce transfers and waiting time. This may happen if passengers tend to look for multiple bus stops along with real-time bus arrival time and choose the stop to minimise their waiting time. Additionally, finding alternative routes exhibits a positive correlation with the importance of *Bus stop location*. Furthermore, passengers who intend to minimise transfers as much as possible assign relatively high importance to the *Bus stop location*.

Information on *Walking distance* is found to be influenced by trip planning objectives and participants' profession. The model results show that passengers assign importance to walking when they intend to improve the journey experience by choosing between alternative routes and reducing transfers. Walking distance is more important to students than to any other profession.

Model results for the importance of contents of information show that younger participants are more interested in real-time contents i.e. *Bus arrival time* and *ETA*. Available PT services mainly influence *Bus arrival time* and *Bus route map*. Both static and real-time contents are important to accomplish passengers' trip planning objectives. Information on *Journey plan* and *Bus stop location* are important for maximising passengers' journey experience.

Synthesis of the Use of URTPI

The presented model results on the use of URTPI reveal the factors affecting passengers' frequency of access to URTPI and the contents of information they are primarily interested in. It is observed that the frequency of use of URTPI is affected by the attributes of information. This highlights the importance of understanding how information should be presented and justifies the study of the sources of URTPI desired by the passengers in the bus stop survey analysis. Social norms are also significantly influential with regard to the frequency of use of URTPI. Therefore, the growing use of smartphone-based apps can be expected to increase the use of URTPI as well.

The importance of contents of information is found to be strongly influenced by the trip planning objectives (Tables 7.6 and 7.7). Reducing transfers and waiting time as well as finding alternatives are the main trip planning objectives that influence the importance of information contents. Passengers' demographics, i.e. age and profession,

Table 7.6 Level of impact of the factors affecting the importance of real-time contents

	Variables	Real-time		Real-time and Static	
		Bus arrival time	ETA	Journey plan	Transfer to other services
Demographics	Age	[Medium]	[Medium]		
	Profession			[Medium]	[Low]
	Gender				
	Education				
Trip planning objectives	Reduce transfers and find alternatives		[High]	[High]	[High]
	Reduce waiting time	[High]	[Medium]		
	Reduce physical efforts				
	Reduce journey time			[Medium]	
Optimisation strategies	Transfers	[Low]			
	Waiting time				
	Physical efforts		[Medium]	[Medium]	
Norms	People you care about use URTPI				
Trips per week	Commute or work trips				[Low]
	Flexible or irregular trips				
PT services	Bus frequency			[Low]	
	Alternative bus line			[Medium]	

Low: Pratt's importance 0 – 0.1
Medium: Pratt's importance 0.1 – 0.25
High: Pratt's importance > 0.25

also affect the importance of contents of information.

The bus stop survey results indicate the impact of trip characteristics and demographics on the use (or non-use) of URTPI, whereas the online survey results reveal the impact of information attributes on the frequency of use of URTPI. This implies that passengers may choose to use source of information, i.e. URTPI or non-URTPI, based on the trip or personal characteristics; however, the frequency of use of the information source is highly dependent on the attributes of information. Additionally, bus stop survey found both trip characteristics and demographics as highly influential in terms of the importance of contents of information. Given the online survey results, it can be concluded that passengers' trip planning objectives and optimisation strategies are

Table 7.7 Level of impact of the factors affecting the importance of static contents

	Variables	Static: Bus route map	Static: Bus stop location	Static: Walking distance
Demographics	Age	High	Medium	
	Profession		Low	Medium
	Gender			
	Education			
Trip planning objectives	Reduce transfers and find alternatives		High	High
	Reduce waiting time		High	
	Reduce physical efforts	Medium		
	Reduce journey time			
Optimisation strategies	Transfers	Medium		
	Waiting time			
	Physical efforts		Medium	
Norms	People you care about use URTPI			
Trips per week	Commute or work trips			
	Flexible or irregular trips			
PT services	Bus frequency			
	Alternative bus line	Medium		

Low: Pratt's importance 0 – 0.1
Medium: Pratt's importance 0.1 – 0.25
High: Pratt's importance > 0.25

principally dominated by trip characteristics, which leads them to consulting particular contents of passenger information.

7.3 Passengers' Choices

7.3.1 Descriptive Analysis

The online survey was developed focusing on passengers' behaviour in general after consulting URTPI. Hence, the survey questionnaire measured the frequency of changes in the choice elements, which are presented in Figure 7.14.

Changing *Time of departure from start* and *Boarding time* are the most frequent

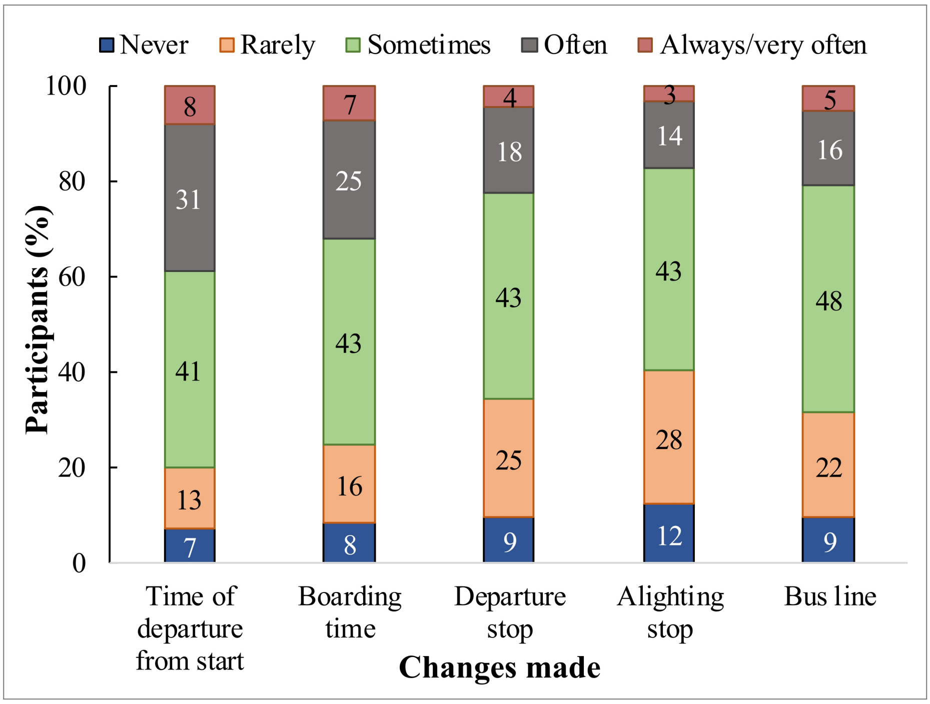


Figure 7.14 Frequency of changes made by passengers (Q11 in Appendix E)

choices made by passengers and these changes are observed to be made often or very often by 39% and 32% of the participants respectively. *Alighting stop* is changed rarely or never by about 40% of the participants.

In the bus stop survey analysis, the impact of changes in choice elements on route choice dimensions and PT demand distribution was estimated based on passengers' action for a particular trip (i.e. changes they made in their trip itinerary). In the online survey, participants stated how frequently they make changes in the choice elements after consulting URTPI. Hence, to calculate the impact of changes on route choice (spatial and temporal dimensions), participants' statement of making changes *often* or *very often* are considered as the potential change in the respective choice elements. Participants who chose *sometimes*, *rarely* and *never* are considered as those who make no changes in the respective choice elements. Figure 7.15 presents the potential impact of the changes in choices elements on PT demand distribution. The impacts are similar to those presented in the bus stop survey analysis (Figure 6.12). It is observed that for 42% of trips, PT demand distribution could potentially be affected as a result of consulting URTPI. In the bus stop survey analysis, the impact on demand distribution for bus runs was considered when passengers changed *Boarding time* without changing their *Bus line*. However, in the online survey analysis, it is not possible to estimate when the passengers would change *Boarding time* only. Hence, it can be concluded that up to 33% of change in demand distribution for bus runs may occur as a result of consulting URTPI.

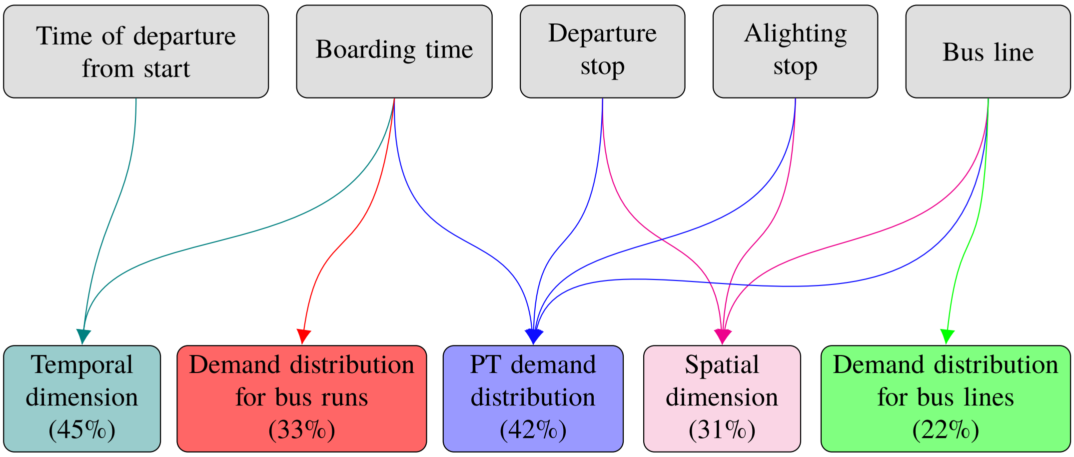


Figure 7.15 Potential impact of changes in choice elements on PT demand distribution

7.3.2 Factors Affecting Passengers' Choices

This section presents the analysis of the online survey data to investigate the impact of URTPI on passengers' choices. As previously mentioned, passengers' choices are modelled based on the completed responses for urban PT trips (315 users of URTPI).

CATREG analyses have been carried out to model passengers' choices. Passengers' choices were measured by the frequency of change on a 5-point Likert scale (Figure 7.14). To investigate the influence of different factors on passengers' choices, frequencies of making changes in different choice elements are used as the dependent variables. A CATREG analysis is carried out for each of the choice elements. Similar to the bus stop survey analysis, demographics are taken into account to explain passengers' choices. However, owing to time constraints, in the bus stop survey it was not possible to investigate how passengers' trip planning objectives affect their decisions. Although two factors related to the trip planning objectives were included in the bus stop survey analysis, the objectives were not measured directly. This has been done in the online survey data analysis.

Decision making is also influenced by decision makers' optimisation strategies (discussed in section 3.1.4). Therefore, passengers' optimisation strategies for different journey attributes are included as independent variables. A list of the independent variables is presented in Table 7.8. CATREG model results for each of the choice elements (shown in Figure 7.14) are presented in Tables 7.9 and 7.10.

Table 7.11 presents the level of impact of the significant factors. The temporal dimension of route choice is strongly influenced by the trip planning objectives and the importance of contents of information. On the other hand, spatial dimension of route is influenced by passengers' demographics, trip planning objectives, optimisation strategies and contents of information. The plots of CATREG quantifications are attached to this thesis as Appendix K.

Change in Time of Departure from Start

Model results illustrate that the change in *Time of departure from start* is mainly driven by passengers' trip planning objectives, frequency of available bus services and the importance of contents of information. *Time of departure from start* is positively influenced by passengers' objective of reducing journey time. Additionally, the availability of frequent bus service increases the likelihood of changing departure time. Real-time information is required by passengers to change their departure time; hence, the frequency of change in *Time of departure from start* is likely to be increased with the increase in importance of *Bus arrival time*. In addition, passengers who make more flexible trips (i.e. shopping, leisure trips) are more likely to change departure time as a result of consulting URTPI. They can adjust their departure time as these trips are not typically time-bound.

Change of Boarding Time

Similar to the departure time, trip planning objectives, frequency of available bus services and the importance of contents of information are the most significant factors influencing the decision of *Boarding Time* (Table 7.11). Passengers are likely to change *Boarding Time* when they want to reduce their journey time. Information on *Bus arrival*

Table 7.8 Factors affecting passengers' choices: definition

System elements	Factors	Variables	Type	Levels[1,2]
Users	Demographics	Age	Ordinal	1-[18-25], 2-[26-35], 3-[36-45], 4-[46-55], 5-[56-65], 6-[>65]
		Education	Ordinal	1-Grammar school, 2-High school, 3-Some college degree, 4-University degree
		Profession	Nominal	1-Employed for wages, 2-Self-employed, 3-Out of work, 4-Student, 5-Retired/Unable to work
		Gender	Nominal	1-Female, 2-Male
	Frequency of trips per week	Commute or work trips	Numeric	Scores obtained from PCA
		Flexible trips (i.e. leisure trips, shopping trips and occasional trips)		
	Trip planning objectives (Importance)	Reduce transfers and find alternatives (i.e. no. of transfers, transfer time and find alternatives)	Numeric	Scores obtained from PCA
		Reduce waiting time (i.e. at start and at the stops)		
		Reduce physical effort		
		Reduce Journey time		
	Optimisation strategies (Maximise or satisfice)	Transfers	Numeric	Scores obtained from PCA
		Waiting time		
		Physical effort		

Continued on next page

Table 7.8 *Continued from previous page*

System elements	Factors	Variables	Type	Levels
PT Services	Availability of services	Bus frequency	Ordinal	1-Not at all, 2-Very few, 3-A few, 4-Quite a few, 5-Many
		Alternative bus lines[3]		
Information	Importance of contents of information	Bus arrival time	Ordinal	1- Not at all important, 2- Slightly important, 3- Important, 4- Very Important, 5- Extremely important
		ETA		
		Bus route map		
		Bus stop location		
		Walking distance		
		Journey plan		
		Transfer to other services		

[1] Category numbers are used for plotting CATREG quantifications graphs presented in Appendix K

[2] Combined variables by PCA and factor analysis are presented in Appendix J

[3] Not included in the model for change of *Bus line*

Table 7.9 Factors affecting passengers' choices related to temporal dimension

Factors	Variables	Time of departure from start			Boarding time		
		β	Sig.	Pratt's Importance	β	Sig.	Pratt's Importance
Demographics	Age						
	Profession				0.115	0.020	0.088
	Gender	0.065	0.157	0.029			
	Education						
Trip planning objectives	Reduce transfers and find alternatives						
	Reduce waiting time	0.101	0.177	0.124	0.106	0.084	0.122
	Reduce physical efforts						
	Reduce journey time	0.216	0.001	0.336	0.237	0.001	0.337
Optimisation strategies	Transfers						
	Waiting time						
	Physical efforts						
Trips per week	Commute or work trip						
	Flexible or irregular trips	0.097	0.048	0.060			
PT services	Bus frequency	0.174	0.001	0.227	0.143	0.001	0.130
	Alternative bus lines						
Importance of contents of information	Bus arrival time	0.160	0.006	0.223	0.203	0.001	0.257
	ETA						
	Journey plan						
	Transfers to other services						
	Bus route map						
	Bus stop location				-0.164	0.026	0.066
	Walking distance to or from bus stops						

Table 7.10 Factors affecting passengers' choices related to spatial dimension

Factors	Variables	Departure stop			Alighting stop			Bus line		
		β	Sig.	Pratt's Importance	β	Sig.	Pratt's Importance	β	Sig.	Pratt's Importance
Demographics	Age	-0.219	0.001	0.199	-0.264	0.001	0.248	-0.228	0.001	0.238
	Profession				0.237	0.001	0.081			
	Gender									
	Education	0.108	0.367	0.059				0.163	0.001	0.095
Trip planning objectives	Reduce transfers and find alternatives									
	Reduce waiting time									
	Reduce physical efforts				0.212	0.004	0.139			
	Reduce journey time	0.158	0.028	0.155				0.140	0.032	0.116
Optimisation strategies	Transfers									
	Waiting time	-0.204	0.001	0.185	-0.172	0.001	0.113			
	Physical efforts									
Trips per week	Commute or work trip	-0.081	0.160	0.004	-0.165	0.015	0.043			
	Flexible or irregular trips	0.150	0.010	0.095						
PT services	Bus frequency				0.247	0.001	0.220	0.272	0.001	0.301
	Alternative bus lines	0.227	0.001	0.225						
Importance of contents of information	Bus arrival time									
	ETA							-0.162	0.013	0.004
	Journey plan									
	Transfers to other services	0.127	0.038	0.077				0.188	0.146	0.099
	Bus route map							0.169	0.014	0.147
	Bus stop location									
	Walking distance to or from bus stops				0.198	0.001	0.157			

time positively influences the change of *Boarding Time*. On the other hand, information on *Bus stop location* decreases the likelihood to change the time of boarding. This may happen when passengers look for a different bus stop to keep their boarding time intact.

Table 7.11 Level of impact of the factors affecting passengers' choices

	Variables	Choices: Time of departure	Boarding time	Departure stop	Alighting stop	Bus line
Demographics	Age			Medium	Medium	Medium
	Profession		Low		Low	
	Gender					
	Education					Low
Trip planning objectives	Reduce transfers and find alternatives					
	Reduce waiting time					
	Reduce physical efforts				Medium	
	Reduce journey time	High	High	Medium		Medium
Optimisation strategies	Transfers					
	Waiting time			Medium	Medium	
	Physical efforts					
Trips per week	Commute or work trips				Low	
	Flexible or irregular trips	Low		Low		
PT services	Bus frequency	Medium	Medium		Medium	High
	Alternative bus line			Medium		
Importance of contents of information	Bus arrival time	Medium	High			
	ETA					Low
	Journey plan					
	Transfer to other services			Low		
	Bus route map					Medium
	Bus stop location		Low			
	Walking distance to stops				Medium	

Low: Pratt's importance 0 – 0.1
Medium: Pratt's importance 0.1 – 0.25
High: Pratt's importance > 0.25

Change of Departure Stop

The frequency of change of *Departure stop* is influenced by the availability of alternative bus lines, participants' demographics, trip planning objectives and optimisation strategies. An increase in the number of (available) alternative bus lines leads to a higher likelihood of changing the *Departure stop*. Participants' age is negatively related to propensity of changing the *Departure stop*. It is observed that participants tend to change the *Departure stop* more frequently if they want to minimise the waiting time as much as possible. Importance of information on transfers is found to be influential on the frequency of change of *Departure stop*. This suggests that passengers tend to change *Departure stop* mainly if they aim to avoid transfers.

Change of Alighting Stop

The descriptive analysis reveals that the change of *Alighting Stop* is the least influenced choice element in passengers' trip itinerary (Figure 7.14). Participants' age, objective of reducing physical efforts, frequency of available bus services and information on walking distance are the most influential factors. Passengers' age is negatively related to the frequency of change of *Alighting stop*. *Alighting stop* is likely to be changed when passengers aim to reduce physical effort. This is also supported by the impact of importance of information on walking distance, which is positively related to the frequency of changing *Alighting stop*. Additionally, passengers' trip optimisation strategy of minimising waiting time encourages them to change *Alighting stop*.

Change of Bus Line

The change of *Bus line* is influenced by passenger demographics, contents of information and trip planning objectives. Younger participants show higher propensity to change *Bus line* compared to the older participants. Furthermore, an increase in the frequency of *Bus Line* change is correlated with an increase of bus service frequency. *Bus line* is likely to be changed when passengers' objective is to reduce journey time and they consult *Bus route map* with high importance. It is noteworthy that the frequency of changing *Bus line* is not observed to be significantly associated with any real-time contents of information.

Impact on Route Choice

Model results show that the temporal dimension of route choice is strongly influenced by passengers' trip planning objectives, frequency of available bus services and the importance of *Bus arrival time*. On the other hand, the spatial dimension of route choice is influenced by a wide range of factors (Table 7.11) including availability of PT services (i.e. frequency and alternative lines), passenger demographics, and contents of consulted information. *Bus route map* and *Walking distance* to stops are the two most influential contents of information. Spatial dimension of route choice is also influenced by passengers' trip planning objectives and optimisation strategy.

Participants' demographics show little impact on the temporal dimension of route choice. Passengers who are self-employed, are three to five times more likely to change boarding time compared any other profession. On the other hand, participants' demographics, and in particular their age, is found to strongly influence all the choice elements related to the spatial dimension of route choice, i.e departure stop, alighting stop and bus line. Younger passengers are two to four times more likely to change these choice elements. Additionally, working people are 1.5 to 6 times more likely to change alighting stop than any other professions. A higher educational level seems to be correlated with a higher likelihood of changing bus line.

Passengers' objective of reducing journey time significantly influences their decision of making changes in all of the choice elements except *Alighting stop*. The resultant impact is higher on the temporal dimension of route choice, i.e. departure and boarding time. The objective of reducing physical efforts influences the change of alighting stop.

Optimisation strategies adopted by passengers are not influential on temporal route choice dimensions. Among the choice elements related to the spatial dimensions, departure and alighting stop are likely to be changed when passengers want to minimise their waiting time. The "minimisers" of waiting time are three times more likely to change departure or alighting stop compared to the "satisficers". Passengers may go to a different bus stop to get a bus of the same line to reduce their waiting time. However, it is not clearly understood how they would minimise waiting time by changing alighting stop only. This may happen if a trip is associated with transfers and the passengers may decide to get off at an earlier or further bus stop to reduce the waiting time.

The number of trips made per week for different purposes shows little impact on the changes. Although bus stop survey found a significant association between trip purposes and passengers' decisions, the online survey could not capture this aspect because passengers may not be able to make an accurate average of the frequency of changes in the choice elements, and neither could they explicitly state the number of different types of trips.

Passengers' experience of PT services is associated with the frequency of changes made during their trips. A higher freedom of choices in terms of bus frequency and bus line makes them more likely towards making changes in their trip itinerary.

With regard to the impact of information, *Bus arrival time*, *Bus route map* and *Walking distance* are the most significant contents of information. It can be highlighted that the temporal dimension of route choice is mainly influence by real-time content of information (i.e. *Bus arrival time*), whereas the spatial dimension is influenced mainly by static contents of information (i.e. *Bus route map* and *Walking distance*).

7.4 Summary

This chapter has presented the analysis of the online survey data. The survey sample is characterised by a somewhat higher percentage of male and younger people compared to the TfL and Transport Scotland bus user data. Hence, the models results could be biased towards the younger and male participants.

The descriptive analysis shows that 97% of participants use passenger information when making bus trips, while 88% of them use at least one source of URTPI. A majority of the participants (62%) use URTPI sources on a regular basis (i.e. quite often). Participants are mainly interested in *Bus arrival time*, *Bus stop location* and ETA.

When consulting the contents of URTPI, reducing waiting time and transfers are the most important trip planning objectives. Passengers tend to minimise their waiting time as much as possible. On the other hand, reducing physical effort is of minor importance to them and they want to keep it at a (relatively) satisfactory level. This might be an effect of the sample bias as the online survey respondents are a more enthusiastic and active group who would show higher optimisation approach in the later mentioned aspects.

Model results show that the frequency of URTPI use is strongly influenced by the attributes of information and social norms. Information attributes related to ease of use, such as user friendliness, understandability and smaller time consumption are likely to foster the frequency of use of URTPI. In addition, people who are in contact with URTPI users are more likely to use URTPI frequently. On the other hand, the importance of contents of information is influenced by passengers' trip planning objectives and demographics. Reducing transfers, finding alternatives and reducing waiting time are the main trip planning objectives that influence the search for travel information, which is also influenced by the passenger demographics (i.e. age and profession).

Changing *Time of departure from start* and *Boarding time* are found to be the most popular choices made by the passengers after consulting URTPI. On the other hand, changing *Alighting stop* is clearly the least popular option. Changes in the choice elements show a potential impact on passenger demand distribution for bus runs, PT and bus lines of as much as 33%, 42% and 22% respectively (Figure 7.15). Reducing journey time and physical efforts are the main trip planning objectives that strongly influence passengers' route choice. In addition, minimising waiting time is the main optimisation strategy adopted by the passengers that significantly influences the decision related to changing departure and alighting stop. Bus arrival time, bus route map and walking distance are the most influential information contents with regard to passengers' route choice. It should be noted that among the real-time contents of information, bus arrival time is the only content with significant influence over passengers' decisions. Static contents of information available in URTPI are largely consulted, which are also found to be of relevant impact upon passengers' decisions.

The online survey analysis reveals the importance of providing information with passengers' favourable attributes. This is crucial to foster the use of URTPI. Passengers' choices are strongly driven by their trip planning objectives, which are assumed to be shaped by the trip context as well. Information influences their choices, though it is difficult to single out its impact on decision-making process from other factors. Albeit a small sample size was used for analysing passenger behaviour, the sample considered only urban responses. Hence, the results presented in this chapter are expected to be valid in urban bus passengers' context.

The next and the final chapter presents a synthesis of the research findings and conclusions based on both bus stop and online survey results.

CHAPTER 8

Conclusions

The aim of this research was to investigate the impact of URTPI on PT passenger route choice. The present study was carried out in the context of bus users in urban areas under normal service conditions. This chapter presents an overall view of the work undertaken in this thesis by highlighting the main findings, contributions to knowledge, limitations and scope for further study. At first a synthesis of the bus stop and online survey results is presented. Based on the discussion of the survey results, the research questions are answered. This is followed by the presentation of contributions to knowledge and practical implications of this study. The chapter then discusses the limitations and highlights scope for further research. Finally, concluding remarks are presented in the research epilogue section.

8.1 Summary of the Findings

This study adopted a RP survey methodology and carried out two questionnaire surveys. The bus stop survey focussed on passengers' behaviour for a particular trip, whereas the online survey collected data on what passengers usually do. Therefore, bus stop survey data are more reliable, however, limited in terms of the scope of questions. On the other hand, participants in the online survey had to answer the questions by reporting their normal behaviour in different situations. Passengers' action in different situations are difficult to capture with Likert scale questions, because participants cannot easily do that. This may be because they remember their most recent experiences or the worst ones, which would influence their choices when answering the questions. Additionally, participants' statements may not represent what they actually do in reality. Hence, an online survey is comparatively less reliable, however, it offers a wider scope of questions. When analysing the survey data, this study used qualitative variables for both descriptive and inferential statistical analyses. In most cases the variables were inherently qualitative as this study focussed on passenger behaviour. Nevertheless, on some occasions the variables were deliberately measured as qualitative, such as trip length, which provides a better understanding of individual's perception.

8.1.1 Sample Size and Representativeness

The survey design was aimed at obtaining samples with a minimum of 540 and 600 users of URTPI for the bus stop and online survey respectively (discussed in sections 4.4.2 and 4.5.2). As previously discussed in Chapter 6, the bus stop survey sample has 920 users of URTPI; hence, the sample was appropriate for this study. On the other hand, the online survey sample contains 752 responses in total, 401 responses of which were fully completed. The sample was then filtered to obtain responses only from urban areas. Finally the filtered sample provided 315 users of URTPI which was smaller than the expected sample. Given this limitation, final models were developed with fewer variables.

The bus stop survey data was found to be in line with Transport Scotland bus user data in terms of gender. As previously discussed, Edinburgh has more younger and working people compared to whole Scotland which is also reflected in the distribution of sample according to trip purposes, i.e. more working trips. Distributions of the sample obtained from the online survey in terms of demographics are found to be different from the bus stop survey. Unlike the bus stop survey sample, the online survey sample has a higher proportion of male participants which may have an influence on the models if gender is found to be significant. Similar to the bus stop survey, the online survey has more younger participants. Distribution of the sample by participants is in line with TfL bus user data. The online survey sample does not have any “homemaker" participants, which covers a small percentage of the bus passenger. The samples should be valid for urban bus passengers where the majority of the passengers are familiar with URTPI. Nevertheless, the impact on passenger behaviour may vary across urban bus networks due to the influence of other service related factors, such as fare systems.

8.1.2 Use of URTPI

The bus stop survey results reveal that 15% of passengers do not use any information, whereas only 3% of the online survey participants are found to be non-users of information. This demonstrates that the Internet users are more prone to use travel information. The bus stop survey reveals that 56% of passengers use URTPI and 47% of the passengers use local RTPI. The online survey sample provides a higher proportion of URTPI users (88%). This is because of the Internet users' familiarity with ICT-based information services. In addition, local RTPI is found to be used by a very small portion of respondents compared to the bus stop survey, which is a limitation of the online survey responses. This was not an issue as the present study is focussed on existing URTPI users' route choice as a result of consulting information.

The frequency of use of URTPI is related to the availability of PT services. Less frequent buses and lack of alternative bus lines may increase the frequency of access to URTPI; however, passengers are able to use it for confirmatory purposes only. On the other hand, the availability of frequent buses and alternative bus lines offer more freedom to the passengers to make travel choices. This may reduce their frequency of access to URTPI, notwithstanding it would enable them to make better travel choices by consulting URTPI.

The perceived importance of contents of information was found to be relatively higher in online survey results than the bus stop survey. The bus stop survey found bus arrival time as the most important content of information. Bus route maps and bus stop locations are also perceived as important by the passengers. The online survey shows that bus arrival time, bus stop location and ETA are the most important contents of information to the passengers. Information on walking distance is the least important among all the available contents.

Modelling of the bus stop survey data shows that demographics and trip characteristics influence the use of URTPI. On the other hand, the online survey results show that information attributes, i.e. ease of use, and norms are the main drivers of the frequency of use of URTPI. Passengers who find URTPI user friendly, understandable and less time consuming are four times more likely to access URTPI frequently than those who do not perceive URTPI easy to use. Additionally, social norms positively influence the frequency of access to URTPI.

Peterson and Merino (2003) proposed that the number of physical sources (i.e. newspaper, TV, radio, etc.) of information consulted by the consumer will decline over time. Therefore, a potential increase in the use of URTPI sources may lead to a decrease in the use of traditional (i.e. printed maps) and non-URTPI sources (i.e. displays at stops). In addition, the number of sources of URTPI used by the passengers may decline over time, which emphasises the need of understanding passengers' preference of URTPI sources. The present study modelled passengers' preference of URTPI sources using the bus stop survey data. The analysis reveals that passengers' preference of URTPI sources are influenced by the trip characteristics and demographics. The residence of participants, trip familiarity and time of day are the most influential factors. For unfamiliar and midday trips, passengers are more likely to use Google Maps than Mobile apps. The importance of contents of information is also found to be influenced by both trip characteristics and demographics. Bus arrival time, the most consulted content of information is influenced strongly by participants age, and profession. Younger participants (18 to 35) find bus arrival time two times more important than participants who are older than 35 year old. Homemakers find bus arrival time four times more important than retired passengers. Bus stop location are five times more important to the infrequent and first time visitors in the city compared to the local residences. Participants' age and level of education are inversely related to the importance of journey plan. The online survey results show that the importance of contents of information is strongly influenced by passengers' trip planning objectives. Finding alternatives, and reducing transfers, journey time and waiting time are the main objectives that positively influence the importance of contents of information.

The bus stop survey reveals that 44% of the passengers do not use any URTPI sources when making a journey. The vast majority of the non-users of URTPI do not perceive the necessity of using it as they are familiar with the bus network and PT services are frequent. Passengers in a large PT network may be less familiar with the network which may inspire them to use URTPI. In addition, 13 to 20% of the participants do not use URTPI because they do not own a device. It is noteworthy that a vast majority of the non-users of URTPI perceive information accurate. Hence, the lack of information accuracy is no longer a barrier to the use of URTPI. Furthermore, 13 to 22% participants stated that they are not familiar with the URTPI sources or they find it difficult to use them. As previously discussed in section 7.2.2, attributes of information influence the frequency of use of URTPI. Therefore, the ease of use of URTPI should be improved to foster their use.

8.1.3 Impact on Passengers' Choices

The impact of URTPI has been studied in both survey data analyses. The samples represent urban bus passenger; therefore, the survey results would be valid for the passengers in a well developed urban bus network where URTPI sources are available.

The bus stop survey analysis presented in Chapter 6 illustrates that passengers' choices (explained in section 1.2.1) are influenced by the trips characteristics and their trip planning objectives. The importance of contents of information is found to be strongly influential on the spatial dimension of route choice, in particular journey planning and transfer information have significant impact on the choices.

Based on the changes made by the passengers, the maximum impact that may occur on PT demand distribution has been estimated which was referred as the potential impact. The temporal dimension of route is observed to be affected the most (for 42% trips) as a consequence of changes in *Time of departure from start* and *Boarding time* after consulting URTPI. This leads to a potential change in PT demand distribution for bus runs by 17%. The spatial dimension of route choice is influenced in 26% of cases. The impact on the temporal and spatial dimensions results in a potential change

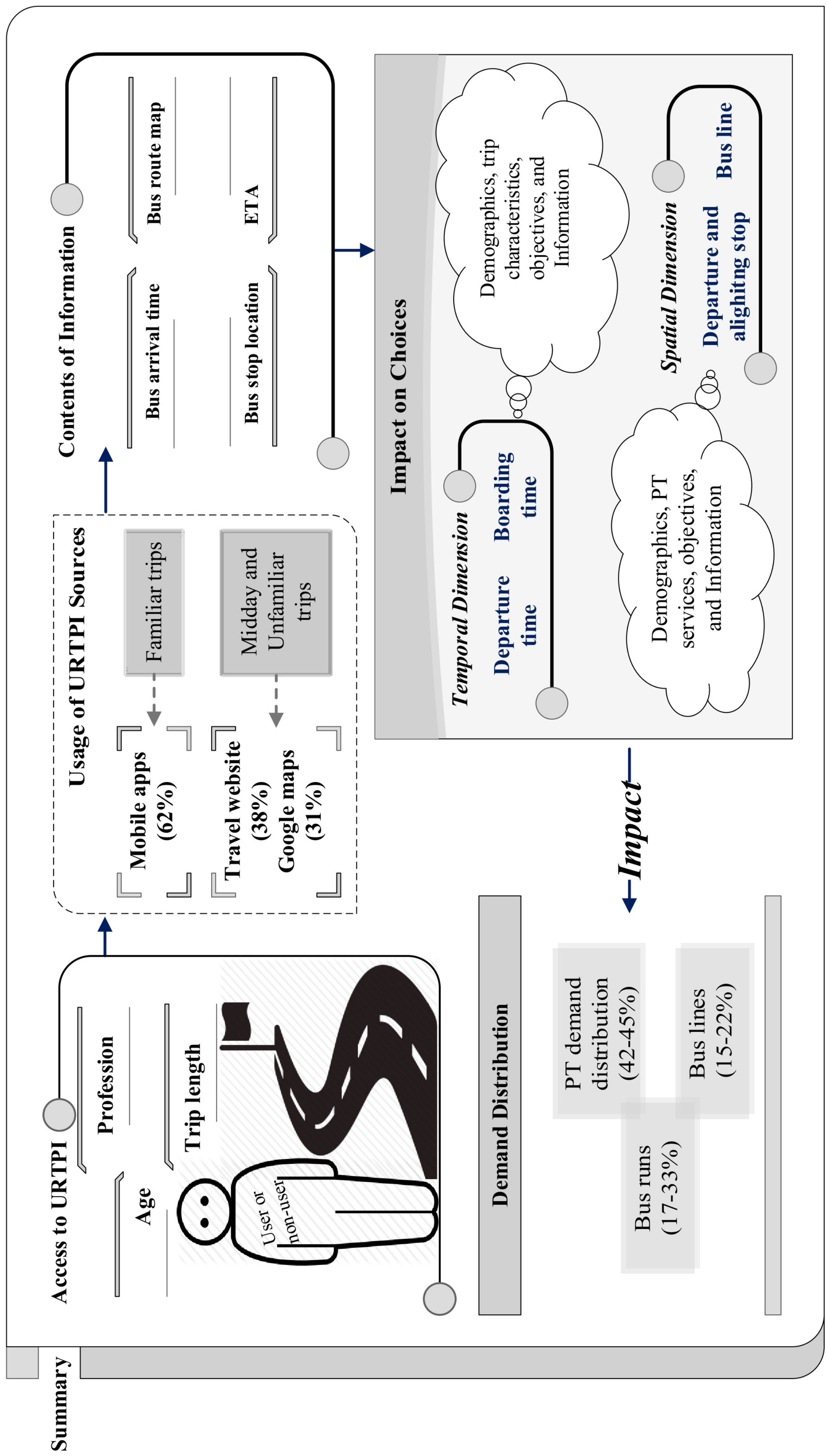


Figure 8.1 Summary of the findings

in overall PT demand distribution by 39%. Demand distribution for bus lines would potentially be influenced in 15% cases.

The online survey analysis presented in Chapter 7 reveals that passengers' decision related to temporal dimension is strongly influenced by their trip planning objectives, available bus frequency and information on bus arrival time. On the other hand, spatial route dimension is affected by available PT services, passenger demographics and information on bus route. The online survey shows an impact of the changes in choice elements as a result of consulting URTPI on route choice which is similar to the bus stop survey results. This is surprising, given the differences between the survey techniques. The temporal and spatial dimensions are influenced in 43% and 29% cases respectively. This leads to a potential change in demand distribution by 42% over the bus network. The demand distribution for alternative bus lines may be affected in the case of 21% of trips. Combining both the survey results a summary of the key findings is illustrated in Figure 8.1.

8.2 Answers to the Research Questions

It is appropriate to recall the research aim and show how answers to the research questions were achieved in this thesis prior to answering the research questions in light of the synthesis of the survey results. The aim of this study was to investigate *the impact of URTPI on passengers' route choice*. The impact of URTPI was studied by taking only the existing users of URTPI into account; therefore, the study findings are valid for passengers who use URTPI when travelling by bus. To achieve the research aim, a set of research questions was developed and data was collected by means of two questionnaire surveys administered at the bus stops and via online platforms. Table 8.1 presents the methods for achieving answers to the research questions. The answers to all the research questions are presented below.

Q1. What drives the use of URTPI?

Q1.1 What is the penetration of URTPI among PT passengers?

Farag and Lyons (2008) mentioned that passengers tend to consult at least one form of information for travelling with PT unless the trip has no time constraint or the services

Table 8.1 Achievement of answers to the research questions

Research questions	Methods of achievements	Related chapters in the thesis
Q1. What drives the use of URTPI?		
Q1.1 What is the penetration of URTPI among PT passengers?	Descriptive analysis of bus stop survey data	Chapter 6
Q1.2 Which URTPI sources are consulted by passengers?	Descriptive analysis of bus stop survey data	Chapter 6
Q1.3 What contents of information are being sought by passengers?	Descriptive analysis of bus stop and online survey data	Chapter 6 and 7
Q1.4 What factors influence the use of URTPI?	Modelling factors affecting the use of URTPI (any source), preference of sources and contents of information.	Chapter 6 and 7
Q2. How is bus passenger route choice influenced by URTPI?		
Q2.1 What impact does URTPI have on user behaviour, especially in regards to temporal and spatial dimensions of route choice?	Modelling passengers choices after consulting URTPI	Chapter 6 and 7
Q2.2 What influence does URTPI have on PT demand distribution?	Impact of changes on route dimensions	Chapter 6 and 7
Q2.3 How can cognitive aspects be used to explain passengers' use of URTPI, as well as their choices?	Incorporated norms, trip planning objectives and optimisation strategies to model passengers choices	Chapter 7

are frequent or local trips. This study demonstrates that although a vast majority of the passengers was familiar with their trips in the bus stop survey, 85% of the total respondents used PT information for travelling by bus. This implies that PT information is largely sought by the passengers for making trips in urban conditions either for confirmatory or planning purposes. However, despite the high penetration of smartphones (81% in Scotland, see Ofcom, 2017), only 56% of the passengers were found to use URTPI in the bus stop survey. Previously discussed barriers to travel information use, such as inadequate quality of information, lack of awareness and trusts (Farag and Lyons, 2007) have diminished considerably in recent days. The present study assumed that the use of URTPI is shaped by passengers' intention and attitude as stated in TPB; therefore, several factors that may influence passengers' intention and attitude were studied.

Q1.2 Which URTPI sources are consulted by passengers?

Existing studies demonstrated a higher likelihood of access to Internet-based information (Farag and Lyons, 2008). However, the extent of use of the information sources available via Internet was not known. This study finds that Mobile apps and Travel websites are the most popular sources of URTPI, which are consulted by 62% and 38% of the URTPI users respectively when travelling by bus. Google Maps is consulted by 31% of passengers. Mobile apps are typically dedicated to PT only (in Edinburgh). Hence, the use of Mobile apps by a vast majority of the URTPI users shows that PT passengers are less interested in multi-modal information sources.

Q1.3 What contents of information are being sought by passengers?

Bus arrival time is the most important content of information. Bus stop location and bus route maps are also considered important by more than 60% of the URTPI users. ETA is also important to 40% of passengers. Journey plan and transfer information are not perceived important by majority of the URTPI users; however, they are found significant in the models. Hence, the latter contents of information are also crucial for decision-making, especially regarding the choices related to spatial dimension of route choice (Table 6.14).

Q1.4 What factors influence the use of URTPI?

This study identifies trip length, age and profession as the main factors influencing the use of URTPI. Passengers making medium length trips are six times more likely to use URTPI than those who make very short trips. The use of URTPI is not linearly related to trip length. For long and very long trips passengers show less likelihood compared to medium trips. Students and employed people are four to six times more likely to use URTPI compared to retired or unable to work passengers. Additionally, younger people (up to age 55) are three to five times more likely to use URTPI compared to passengers of age greater than 65 year old. Among the trip purposes, only leisure trip is found significant in the model; however, the reason is not very clear. In addition, attributes of information and social norms help to explain the frequency of access to URTPI.

Passengers' preference of URTPI sources are influenced by trip characteristics and demographics. This may be a result of passengers' perception regarding the utility of URTPI sources in the context of a trip. For example, passengers are observed to be ten times more likely to prefer Google Maps and 2.5 times more likely to choose travel websites over Mobile apps when making unfamiliar trips. This may occur because of the availability of multi-modal information in Google Maps, which would help them to choose a mode. In addition, this may be a result of passengers' habit of using Google Maps for searching new places.

Information on bus route map and transfers are strongly related to the trip characteristics. On the other hand, the importance of bus stop location and journey plan are dominated by demographics. Contents of information are also influenced by passengers' trip planning objectives.

Q2. How is bus passenger route choice influenced by URTPI?

Q2.1 What impact does URTPI have on user behaviour, especially in regards to temporal and spatial dimensions of route choice?

Both survey results demonstrate an impact on passengers' choices as a result of consulting URTPI, which leads to a potential impact on PT demand distribution. This study finds temporal dimension of route choice to be potentially influenced for 42 to 45% of the trips made by the URTPI users. The spatial dimension of route choice is found to be affected for 26 to 31% of the trips.

Q2.2 What influence does URTPI have on PT demand distribution?

It is observed that the changes in passengers' choices for 39 to 42% of the trips are associated with the passenger demand distribution for the whole network. This shows the potential impact on PT demand distribution due to the changes in passengers' choices after consulting URTPI. For a particular origin-destination, PT demand distribution for bus runs could potentially be changed by 17 to 33% and for different bus lines by 15 to 22%.

Q2.3 How can cognitive aspects be used to explain passengers' use of URTPI, as well as their choices?

This study considered cognitive aspects to understand passengers' decision-making. The study results show that the use of URTPI is strongly influenced by social norms. Passengers' optimisation strategy, i.e. minimising waiting time is found influential on their decision of changing departure and alighting stop. Hence, in regards to other choice elements there is no significant difference between the choices made by maximisers or satistifcers. Passengers' decisions are significantly influenced by their trip planning objectives. Reducing waiting time, transfer as well as overall journey time are the influential trip planning objectives.

8.3 Implications

The contribution of this study lies in the scope of research, i.e. actual use of the state-of-the-art information (URTPI) by PT passengers in an urban regular service condition. This study looked into passenger behaviour regarding the use of URTPI taking different sources (including multi-modal) of URTPI into account, which would be difficult to assess by analysing real-world observed data (if accessible), because the sources are owned by different authorities. The key contributions of this study fall into two categories which are presented below.

Despite the large body of literature that exists on travel information research, the factors influencing the use of URTPI and its impact on PT passengers' decision-making were not discussed before. This study investigated passenger behaviour under regular service condition, which contributes to the knowledge of passenger behaviour in the presence of information.

The value of the investments into the necessary systems for information provision can be increased by a clear understanding of how URTPI influences passenger behaviour. This study demonstrates a substantial use of URTPI by bus passengers and investigates the impact on their decision-making. The study findings can provide valuable implications to transport planners and researchers. The implications of this study are listed below.

- Influencing passengers' behaviour with information is one of the effective measures to benefit from intelligent mobility (Wockatz and Schartau, 2015). A change in route choice shows an impact on demand distribution. The present study shows that up to 22% of the passengers who use URTPI may change their bus routes, which is almost consistent throughout different time of day (in bus stop survey). This suggests that consultation of information may change the demand distribution over the available alternatives by 22%. This may produce an additional passenger load for a bus line. If a vast majority of passengers makes changes after consulting URTPI, a significant change in PT demand distribution will be observed. The effect of this change could be managed by the provision of real-time information on crowding, which would help passengers to make decisions considering the vehicle condition as well, such as seat availability. In addition, midday trips show higher likelihood to change departure and boarding time; therefore, consultation of information for making trips in the off peak period may lead to a change in demand distribution for bus runs. Transport operators should take the potential impact of URTPI into account when making demand prediction.

- The study investigated the use of existing URTPI and found that Mobile apps are the most preferred sources. Along with individual characteristics, social norms influence the use of URTPI. The increasing popularity of Mobile apps for different purposes indicates a potential increase in use of Mobile apps as a source of passenger information. This justifies further investments on the development of Mobile apps. Other sources of URTPI, such as Google Maps and Travel websites are preferred for making unfamiliar trips. This demonstrates that passengers' perception regarding the utility of the sources may vary according to the type of trips and individual characteristics. This may be because of multimodal options and ease of finding unknown places. In addition, Mobile apps dedicated to PT only provides PT options even though the trip could be made on foot only. Therefore, when providing integrated information, the features passengers consider for making different type of trips should be taken into account. In addition, Google Maps allows people to look for places of attraction, which may lead passenger to use it for planning trips as well, in particular for unfamiliar trips. Hence, this attribute could be introduced in URTPI, which is also supported by Watkins et al. (2010). Attributes of information, i.e. user friendliness, understandability and time consumption are also found important to foster the frequency of use of URTPI. Fayish and Jovanis (2004) also support the importance of information attribute, which they observed in the context of car users information use. Personalised features, such as bookmarking and alarm on bus arrival are available in some apps; these should be introduced when providing an integrated information service.

- Information is not found to be consulted for a whole trip. This indicates the demand for descriptive information and the consultation of descriptive information leads to the tactical decision-making. On the other hand, prescriptive information is necessary for strategic decision-making. Therefore, both descriptive and prescriptive information should be provided. The study results show that passengers change the aspects of route choice considering information on transfers, bus stop location and journey plan. Hence, information should be crafted considering these contents and the alternatives should be prescribed accordingly.

- URTPI shows potential impacts on the passenger demand distribution. Transport planners and operators should take the impact of URTPI into account when developing demand prediction models. This would help them to make a better prediction of demand distribution under the influence of URTPI. The understanding of the changes on bus runs as well as bus lines at different time of day can help the bus operators to maintain efficient services by adjusting service frequencies. In addition, operators may provide information to influence traveller behaviour and instigate changes if required.

8.4 Limitations and Further Study

Despite the valuable contributions that have been made, this study is not exempt from limitations. The following are the identified limitations to the study findings.

- This study focused on bus passengers decision-making under the influence of URTPI; hence, decision-making by the non-users of URTPI was not studied. Local RTPI, i.e. displays at stops enable passengers to make changes in some of the choice elements, such as decision of taking a bus in an alternative line after arriving at the stop. However, making changes without consulting URTPI would not be effective in terms of achieving a particular trip planning objectives, such as reducing transfer time. Additionally, some changes are not even possible to make without consulting URTPI, i.e. change in departure time. Given the study aim, it is not possible to single out the impact of URTPI only.

- As discussed in this study, passengers' trip optimisation strategies influence their decisions. In the bus stop survey, passengers who are optimisers may have arrived at the bus stops (at the survey locations) with insufficient time to take part in the survey. Although passengers' optimisation strategies were not investigated in the bus stop survey, the survey sample may be biased because of this issue.

- The present study was carried out with cross sectional data. Therefore, the impact of URTPI on decision-making at different times of a year is not studied.

- The impact of URTPI was studied considering the availability of alternatives, such as frequent buses and alternative lines. Although URTPI may be more important to the passengers when alternatives are not available, this was not captured in the bus stop survey. In addition, bus stop survey provides data on bus journeys made during the day only. Therefore, the study results would be valid for day trips in a medium to medium-large cities.

- Due to time limitations, the sample size for online survey was smaller than expected, which led to a reduced number of independent variables for modelling the use of URTPI and its impact on passengers' choices.

- This study quantifies the impact of changes in passengers' choices on PT demand as a result of consulting URTPI. However, the changes in choice elements discussed in this study are not exclusive and may be substitutional. For example, passengers of two bus lines can be interchanged when individuals change their bus line. Therefore, the impact of changes in choice elements made by a passenger may be compensated by the changes made by other passengers, which will lead to a smaller resultant impact on PT demand distribution.

In light of the aim, scope and limitations of this study, future research avenues have been identified and presented below.

- As mentioned in the limitations of the study, behavioural studies could be carried out between the URTPI users and non-users decision investigating how real-time information may improve the quality of decision-making compared to the non-URTPI users.

- This study identified the significant factors that influence passenger behaviour. Hence, further simulation models can be developed to predict the changes made by passengers taking these factors into account.

- This study only considered bus passenger behaviour under the influence of information; therefore, a study on passenger behaviour in a multi-modal network could provide a better understanding of the impact of URTPI. In addition, Wang and Khattak (2013) discussed the existence of spatial heterogeneity in travel decisions, which indicates that the association between travel decisions and influencing variables (i.e. travel time, household income) varies over the study area. Therefore, studies in different PT networks could be carried out to validate the results in terms of spatial heterogeneity.

8.5 Epilogue

Travel information, in particular RTTI has evolved immensely over the last three decades. The growth in use of RTPI was observed to be slower than the use of RTTI for car users. Even when location-specific RTPI followed by the Internet-based information became available, the level of information use was not found satisfactory (Farag and Lyons, 2009b). A rapid rise in smartphone uptake and Internet penetration changed the face of information provision and boosted the development of new information services. Traditionally, transport operators were responsible for providing information to the passengers. Nowadays several sources of information developed by third party organisations are available for passengers and the access to these sources are free of monetary cost. In addition, some sources of URTPI provide information for different cities. The availability of several sources and medium of access have made PT information popular to the passengers. As stated by Harmony and Gayah (2017), bus passengers find RTPI most significant for improving their journey among all the modes of transport. Therefore, the impact of use of URTPI on bus passengers' decision-making is expected to be the most dynamic one. This makes the impact of URTPI for making travel choices a concern of transport planning.

Travel information is expected to face the next phase of change with the arrival of new services, such as MaaS, which would require a high degree of integration of information (Jittrapirom et al., 2017). This may lead to an information overflow making it too complicated for the passengers to consult information for making decisions because of bounded rationality (Selten, 1990; Simon, 1972). This highlights the importance as well as the challenges of information provision and understanding traveller behaviour.

With the rise in information use, the risk of privacy and data protection have been brought forward. Although a massive amount of user data is being collected by transport operators and information providers, very little of it is accessible to researchers. Real-world observed data could be very helpful for understanding passenger behaviour. Therefore, a safe and secure use of such information will be a major step forward in travel behaviour research.

References

Aarts, Henk and AP Dijksterhuis (2000). "The automatic activation of goal-directed behaviour: The case of travel habit". In: *Journal of Environmental Psychology* 20.1, pp. 75–82.

Abdel-Aty, Mohamed A, Ryuichi Kitamura, and Paul P Jovanis (1997). "Using stated preference data for studying the effect of advanced traffic information on drivers' route choice". In: *Transportation Research Part C: Emerging Technologies* 5.1, pp. 39–50.

Abdel-Aty, Mohamed and M Fathy Abdalla (2004). "Modeling drivers' diversion from normal routes under ATIS using generalized estimating equations and binomial probit link function". In: *Transportation* 31.3, pp. 327–348.

Acevedo, Melissa and Joachim I Krueger (2004). "Two egocentric sources of the decision to vote: The voter's illusion and the belief in personal relevance". In: *Political Psychology* 25.1, pp. 115–134.

Adjei, E and Roger Behrens (2012). "Travel behaviour change theories and experiments: a review and synthesis". In: *31st Southern African Transport Conference (SATC 2012), 9-12 July, Pretoria, South Africa.*

Adler, Jeffrey L and Victor J Blue (1998). "Toward the design of intelligent traveler information systems". In: *Transportation Research Part C: Emerging Technologies* 6.3, pp. 157–172.

Ahituv, Niv, Magid Igbaria, and A Viem Sella (1998). "The effects of time pressure and completeness of information on decision making". In: *Journal of Management Information Systems* 15.2, pp. 153–172.

Ajzen, Icek (1985). "From intentions to actions: A theory of planned behavior". In: *Action Control.* Springer, pp. 11–39.

Ajzen, Icek (1991). “The theory of planned behavior”. In: *Organizational Behavior and Human Decision Processes* 50.2, pp. 179–211.

Al Deek, Haitham M, Asad J Khattak, and Paramsothy Thananjeyan (1998). “A combined traveler behavior and system performance model with advanced traveler information systems”. In: *Transportation Research Part A: Policy and Practice* 32.7, pp. 479–493.

Al Deek, Haitham and Adib Kanafani (1993). “Modeling the benefits of advanced traveler information systems in corridors with incidents”. In: *Transportation Research Part C: Emerging Technologies* 1.4, pp. 303–324.

Allen, David (2008). “Electronic flight bag: Real-time information across an airline’s enterprise”. In: *Boeing Aero Magazine*.

Allström, Andreas, Ida Kristoffersson, and Yusak Susilo (2017). “Smartphone based travel diary collection: experiences from a field trial in Stockholm”. In: *Transportation Research Procedia* 26, pp. 32–38.

Anderson, John R (2015). *Cognitive psychology and implications*. New York Worth Publishers.

Auer, Ashley, Shelley Feese, and Stephen Lockwood (2016). *History of intelligent transportation systems*. Tech. rep. Booz Allen Hamilton.

Babbie, Earl (2007). *The practice of social research*. Wadsworth, Cengage Learning.

Bai, Yuan and Lina Kattan (2014). “Modeling riders’ behavioral responses to real-time information at light rail transit stations”. In: *Transportation Research Record: Journal of the Transportation Research Board* 2412, pp. 82–92.

Balcombe, RJ and CE Vance (1998). “Information for bus passengers: A study of needs and priorities”. In: *TRL Report 330*. Cited in Lyons, G., Harman, R., Austin, J. and Duff, A. (2001) Traveller information systems research: A review and recommendations for transport direct. Technical Report. DTLR: Transport Local Govern- ment Regions. Available from: http://eprints.uwe.ac.uk/10197.

Baltar, Fabiola and Ignasi Brunet (2012). “Social research 2.0: virtual snowball sampling method using Facebook”. In: *Internet Research* 22.1, pp. 57–74.

Bazerman, Max H, Toni Giuliano, and Alan Appelman (1984). “Escalation of commitment in individual and group decision making”. In: *Organizational Behavior and Human Performance* 33.2, pp. 141–152.

Beaumont, Robin (2012). “An introduction to principal component analysis & factor analysis using SPSS 19 and R (psych package)”. In: *Factor Analysis and Principal Component Analysis (PCA)* 24.8-9.

Beirão, Gabriela and JA Sarsfield Cabral (2007). “Understanding attitudes towards public transport and private car: A qualitative study”. In: *Transport Policy* 14.6, pp. 478–489.

Ben-Akiva, Moshe E and Steven R Lerman (1985). *Discrete choice analysis: theory and application to travel demand*. Vol. 9. MIT press.

Ben-Elia, E, Y Shiftan, and I Erev (2007). “A behavioral approach to modeling route choice decisions with real time information”. In: *Proceedings of the European Transport Conference, 17-19 October, Leiden, The Netherlands*.

Ben-Elia, Eran, Roberta Di Pace, Gennaro N Bifulco, and Yoram Shiftan (2013). “The impact of travel information’s accuracy on route-choice”. In: *Transportation Research Part C: Emerging Technologies* 26, pp. 146–159.

Ben-Elia, Eran, Ido Erev, and Yoram Shiftan (2008). “The combined effect of information and experience on drivers’ route-choice behavior”. In: *Transportation* 35.2, pp. 165–177.

Ben-Elia, Eran and Yoram Shiftan (2010). “Which road do I take? A learning-based model of route-choice behavior with real-time information”. In: *Transportation Research Part A: Policy and Practice* 44.4, pp. 249–264.

Bergtold, Jason S, Elizabeth A Yeager, Allen Featherstone, et al. (2011). “Sample size and robustness of inferences from logistic regression in the presence of nonlinearity and multicollinearity”. In: *The Annual Meeting of Agricultural and Applied Economics Association*.

Bouchard, Richard J and Clyde E Pyers (1965). “Use of gravity model for describing urban travel”. In: *Highway Research Record* 88, pp. 1–43.

Brakewood, Candace Elizabeth (2014). “Quantifying the impact of real-time information on transit ridership”. PhD thesis. Georgia Institute of Technology.

Brakewood, Candace, Sean Barbeau, and Kari Watkins (2014a). "An experiment evaluating the impacts of real-time transit information on bus riders in Tampa, Florida". In: *Transportation Research Part A: Policy and Practice* 69.1, pp. 409–422. ISSN: 09658564. DOI: 10.1016/j.tra.2014.09.003.

Brakewood, Candace, Gregory S. Macfarlane, and Kari Watkins (2015). "The impact of real-time information on bus ridership in New York City". In: *Transportation Research Part C: Emerging Technologies* 53, pp. 59–75. ISSN: 0968090X. DOI: 10.1016/j.trc.2015.01.021.

Brakewood, Candace, Francisca Rojas, P. Christopher Zegras, Kari Watkins, Joshua K. Robin, Jake Sion, and Sam Joran (2014b). "An analysis of real-time commuter rail information in Boston". In: *Proceedings of the 2014 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Brakewood, Candace and Kari Watkins (2015). "Quantifying the impact of real-time information on transit ridership". In: *Conference on Advanced Systems in Public Transport.* Rotterdam, The Netherlands.

Bryman, Alan (2008). *Social research methods.* pg. 167. Oxford university press.

Buana, Putu Wira, I Made Sukarsa, Ida Bagus Gede Purwania, and I Gusti Bagus Yoga Prasetya (2016). "Real time trans bus tracking and passenger information system using hybrid application technology". In: *International Journal of Software Engineering and ITS Applications* 10.9, pp. 35–50.

Burns, Robert P and Richard Burns (2008). *Business research methods and statistics using SPSS.* Sage.

Buscema, Daniele, Matteo Ignaccolo, Giuseppe Inturri, Alessandro Pluchino, Andrea Rapisarda, Corrado Santoro, and Salvatore Tudisco (2009). "The impact of real time information on transport network routing through Intelligent Agent-Based Simulation". In: *Science and Technology for Humanity (TIC-STH), IEEE Toronto International Conference*, pp. 72–77. ISBN: 9781424438785.

Caicedo, Felix (2010). "Real-time parking information management to reduce search time, vehicle displacement and emissions". In: *Transportation Research Part D: Transport and Environment* 15.4, pp. 228–234.

Carrel, Andre, Anne Halvorsen, and Joan Walker (2013). “Passengers’ perception of and behavioral adaptation to unreliability in public transportation”. In: *Transportation Research Record: Journal of the Transportation Research Board* 2351, pp. 153–162.

Carter, Mark et al. (2000). *Metropolitan model deployment initiative San Antonio evaluation report*. Tech. rep. Science Applications International Corporation.

Cascetta, Ennio (2009). *Transportation systems analysis: models and applications*. Vol. 29. Springer Science & Business Media.

Cats, Oded, Wilco Burghout, Tomer Toledo, and Haris N Koutsopoulos (2012). “Modeling real-time transit information and its impacts on travelers’ decisions”. In: *Proceedings of the 2012 Annual Meeting of the Transportation Research Board, Washington, D.C.* Pp. 1–8.

Cats, Oded and Erik Jenelius (2014). “Dynamic vulnerability analysis of public transport networks: mitigation effects of real-time information”. In: *Networks and Spatial Economics* 14.3-4, pp. 435–463.

Cats, Oded, Haris Koutsopoulos, Wilco Burghout, and Tomer Toledo (2011). “Effect of real-time transit information on dynamic path choice of passengers”. In: *Transportation Research Record: Journal of the Transportation Research Board* 2217, pp. 46–54.

Caulfield, Brian and Margaret O’Mahony (2007). “An examination of the public transport information requirements of users”. In: *IEEE Transactions on Intelligent Transportation Systems* 8.1, pp. 21–30.

Caulfield, Brian and Margaret O’Mahony (2009). “A stated preference analysis of real-time public transit stop information”. In: *Journal of Public Transportation* 12.3, p. 1.

Cebon, Peter and Danny Samson (2011). “Using real time information for transport effectiveness in cities”. In: *City, Culture and Society* 2.4, pp. 201–210.

Čelan, Marko, Mitja Klemenčič, Anamarija L Mrgole, and Marjan Lep (2017). “Bus-stop based real time passenger information system-case study Maribor”. In: *IOP Conference Series: Materials Science and Engineering*. Vol. 245. 4. IOP Publishing, p. 042008.

Çelebi, Mehmet (2006). “Real-time seismic monitoring of the New Cape Girardeau Bridge and preliminary analyses of recorded data: an overview”. In: *Earthquake Spectra* 22.3, pp. 609–630.

Chatterjee, Kiron and Mike Mcdonald (2004). “Effectiveness of using variable message signs to disseminate dynamic traffic information: Evidence from field trails in European cities”. In: *Transport Reviews* 24.5, pp. 559–585.

Chen, Dun-Ji (2012). “Measuring the passenger’s benefit of providing the real time information system of the bus transit”. In: *Proceedings of the 2012 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Chen, Peter S. T. and Hani S. Mahmassani (1999). *Dynamics of urban commuter behavior under real-time traffic information*. Tech. rep. Center for Transportation Research The University of Texas at Austin, 271–271 p.

Chorus, Caspar G, Theo A Arentze, Eric JE Molin, Harry JP Timmermans, and Bert Van Wee (2005). “The value of travel information: Decision strategy-specific conceptualizations and numerical examples”. In: *Transportation Research Part B: Methodological* 40.6, pp. 504–519.

Chorus, Caspar G, Theo A Arentze, and Harry JP Timmermans (2007a). “Information impact on quality of multimodal travel choices: conceptualizations and empirical analyses”. In: *Transportation* 34.6, pp. 625–645.

Chorus, Caspar G, Theo A Arentze, Harry JP Timmermans, Eric JE Molin, and Bert Van Wee (2007b). “Travelers’ need for information in traffic and transit: Results from a web survey”. In: *Journal of Intelligent Transportation Systems* 11.2, pp. 57–67.

Chorus, Caspar G, Eric JE Molin, Theo A Arentze, Serge P Hoogendoorn, Harry JP Timmermans, and Bert Van Wee (2007c). “Validation of a multimodal travel simulator with travel information provision”. In: *Transportation Research Part C: Emerging Technologies* 15.3, pp. 191–207.

Chorus, Caspar G, Eric JE Molin, and Bert Van Wee (2006). “Use and effects of Advanced Traveller Information Services (ATIS): a review of the literature”. In: *Transport Reviews* 26.2, pp. 127–149.

Chorus, Caspar G, Joan L Walker, and Moshe Ben-Akiva (2013). "A joint model of travel information acquisition and response to received messages". In: *Transportation Research Part C: Emerging Technologies* 26, pp. 61–77.

Chorus, Caspar Gerard (2007). "Traveler response to information". PhD thesis.

Chorus, Casper, T Arentze, H Timmermans, Z Sun, E Molin, and B Van Wee (2007d). "Behavioral aspects of travel information: models and experiments". In: *Proceedings of the European Transport Conference (ETC) 2007 held 17-19 October 2007, Leiden, the Netherlands.*

Chow, William, David Block-Schachter, and Samuel Hickey (2014). "Impacts of real-time passenger information signs in rail stations at the Massachusetts Bay Transportation authority". In: *Transportation Research Record: Journal of the Transportation Research Board* 2419, pp. 1–10.

Chowdhury, Subeh and Avishai Ceder (2013a). "A psychological investigation on public-transport users' intention to use routes with transfers". In: *International Journal of Transportation* 1.1, pp. 1–20.

Chowdhury, Subeh and Avishai Ceder (2013b). "Definition of planned and unplanned transfer of public transport service and user decisions to use routes with transfers". In: *Journal of Public Transportation* 16.2, p. 1.

Chowdhury, Subeh, Avishai Ceder, and Ripul Sachdeva (2014). "The effects of planned and unplanned transfers on public transport users' perception of transfer routes". In: *Transportation Planning and Technology* 37.2, pp. 154–168.

Chowdhury, Subeh and Nasser Giacaman (2015). "En-route planning of multi-destination public-transport trips using smartphones". In: *Journal of Public Transportation* 18.4.

Chung, Namho and Chulmo Koo (2015). "The use of social media in travel information search". In: *Telematics and Informatics* 32.2, pp. 215–229.

Citymapper (2016). *Realtime Travel Times*. URL: https://citymapper.com/news/1151/realtime-travel-times.

Comrey, Andrew L and Howard B Lee (1992). *A first course in factor analysis*. pg. 217. Psychology Press.

Corner, Statistics (2009). “Choosing the right type of rotation in PCA and EFA”. In: *JALT Testing & Evaluation SIG Newsletter* 13.3, pp. 20–25.

Couper, Mick P (2000). “Web surveys: A review of issues and approaches”. In: *The Public Opinion Quarterly* 64.4, pp. 464–494.

Dalgaard, Peter (2008). *Introductory statistics with R*. Springer Science & Business Media.

Dantan, Sophie, Julie Bulteau, and Isabelle Nicolaï (2015). “Potential demand for multimodal information. Evidence from the Plateau-de-Saclay”. In: *22nd ITS World Congress, Bordeaux, France, 5-9 October*.

Darley, William K, Charles Blankson, and Denise J Luethge (2010). “Toward an integrated framework for online consumer behavior and decision making process: A review”. In: *Psychology & Marketing* 27.2, pp. 94–116.

Deeter, Dean (2009). “Real-time traveler information systems: A synthesis of highway practice”. In: *NCHRP Synthesis* 399.

Delic, Kemal A, Laurent Douillet, and Umeshwar Dayal (2001). “Towards an architecture for real-time decision support systems: challenges and solutions”. In: *Database Engineering and Applications, 2001 International Symposium on*. IEEE, pp. 303–311.

Dell’Olio, Luigi, Angel Ibeas, and Patricia Cecin (2011). “The quality of service desired by public transport users”. In: *Transport Policy* 18.1, pp. 217–227.

Department for Transport (2016). *Transport statistics Great Britain 2016*. Tech. rep. URL: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/576095/tsgb-2016-report-summaries.pdf.

Department for Transport statistics (2014). *National Travel Survey*. Tech. rep. Department for Transport. URL: https://www.gov.uk/government/statistics/national-travel-survey-2014.

DETR (1998). *A new deal for transport: Better for everyone*. London: Transport White Paper, Department of the Environment, Transport and the Regions.

Dia, Hussein (2002). “An agent-based approach to modelling driver route choice behaviour under the influence of real-time information”. In: *Transportation Research Part C: Emerging Technologies* 10.5, pp. 331–349.

Dia, Hussein and Sakda Panwai (2007). “Modelling drivers’ compliance and route choice behaviour in response to travel information”. In: *Nonlinear Dynamics* 49.4, pp. 493–509.

Dia, Hussein and Sakda Panwai (2010). “Evaluation of discrete choice and neural network approaches for modelling driver compliance with traffic information”. In: *Transportmetrica* 6.4, pp. 249–270.

Dijksterhuis, Ap and John A Bargh (2001). “The perception-behavior expressway: Automatic effects of social perception on social behavior”. In: *Advances in Experimental Social Psychology* 33, pp. 1–40.

Dillon, Stuart M (1998). “Descriptive decision making: Comparing theory with practice”. In: *Proceedings of 33rd ORSNZ Conference, University of Auckland, New Zealand.*

Dolan, Paul, Michael Hallsworth, David Halpern, Dominic King, Robert Metcalfe, and Ivo Vlaev (2012). “Influencing behaviour: The mindspace way”. In: *Journal of Economic Psychology* 33.1, pp. 264–277.

Doyle, Jon (1999). “Rational decision making”. In: *MIT Encyclopedia of the Cognitive Sciences*, pp. 701–703.

Dziekan, Katrin and Karl Kottenhoff (2007). “Dynamic at-stop real-time information displays for public transport: effects on customers”. In: *Transportation Research Part A: Policy and Practice* 41.6, pp. 489–501.

Dziekan, Katrin and Arjan Vermeulen (2006). “Psychological effects of and design preferences for real-time information displays”. In: *Journal of Public Transportation* 9.1, p. 1.

Economic Commission for Europe of the United Nations (2000). “Terminology on statistical metadata”. In: *Conference of European Statisticians Statistical Standards and Studies, No. 53, Geneva.*

Edinburgh City Council (2016). *Edinburgh by numbers 2016.* Tech. rep. Edinburgh, pp. 1–35.

Edinburgh City Council (2017). *Edinburgh by numbers 2017.* Tech. rep. Edinburgh, pp. 1–35.

Emmerink, Richard HM, Kay W Axhausen, Peter Nijkamp, and Piet Rietveld (1995a). "Effects of information in road transport networks with recurrent congestion". In: *Transportation* 22.1, pp. 21–53.

Emmerink, Richard HM., Kay W. Axhausen, Peter Nijkamp, and Piet Rietveld (1995b). "The potential of information provision in a simulated road transport network with non-recurrent congestion". In: *Transportation Research Part C: Emerging Technologies* 3.5, pp. 293–309.

Emmerink, Richard HM, Peter Nijkamp, Piet Rietveld, and Jos N Van Ommeren (1996). "Variable message signs and radio traffic information: An integrated empirical analysis of drivers' route choice behaviour". In: *Transportation Research Part A: Policy and Practice* 30.2, pp. 135–153.

Essen, Mariska van, Tom Thomas, Caspar Chorus, and Eric Van Berkum (2016). "Role of travel time information on day-to-day route choice behavior based on real-world experiments". In: *Proceedings of the 2016 Annual Meeting of the Transportation Research Board, Washington, D.C.* 16-0806.

Etikan, Ilker, Sulaiman Abubakar Musa, and Rukayya Sunusi Alkassim (2016). "Comparison of convenience sampling and purposive sampling". In: *American Journal of Theoretical and Applied Statistics* 5.1, pp. 1–4.

European Commission (2011a). *Roadmap to a Single European Transport Area-Towards a competitive and resource efficient transport system*. Tech. rep.

European Commission (2011b). *White paper on transport: Roadmap to a single European transport area: Towards a competitive and resource-efficient transport system*. Publications Office of the European Union.

Eurostat (2017). *Modal split of passenger transport*. URL: http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tsdtr210&language=en (visited on 09/19/2017).

Evans, Jonathan St BT (1989). *Bias in human reasoning: Causes and consequences*. Lawrence Erlbaum Associates, Inc.

Farag, Sendy and Glenn Lyons (2007). "Conceptualising barriers to travel information use". In: *39th Annual Universities Transport Study Group Conference*.

Farag, Sendy and Glenn Lyons (2008). "What affects use of pretrip public transport information?: Empirical results of a qualitative study". In: *Transportation Research Record: Journal of the Transportation Research Board* 2069, pp. 85–92.

Farag, Sendy and Glenn Lyons (2009a). "Explaining public transport information use through attitude theory". In: *41st Annual Universities Transport Study Group Conference*.

Farag, Sendy and Glenn Lyons (2009b). "Public transport information (non-) use empirically investigated for different trip types". In: *Proceedings of the 2009 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Farag, Sendy and Glenn Lyons (2010). "Explaining public transport information use when a car is available: attitude theory empirically investigated". In: *Transportation* 37.6, pp. 897–913.

Farag, Sendy and Glenn Lyons (2012). "To use or not to use? An empirical study of pre-trip public transport information for business and leisure trips and comparison with car travel". In: *Transport Policy* 20, pp. 82–92.

Fayish, Aaron and Paul Jovanis (2004). "Usability of statewide web-based roadway weather information system". In: *Transportation Research Record: Journal of the Transportation Research Board* 1899, pp. 44–54.

Ferris, Brian (2011). "OneBusAway: Improving the usability of public transit". PhD thesis. University of Washington.

Ferris, Brian, Kari Watkins, and Alan Borning (2010). "OneBusAway: results from providing real-time arrival information for public transit". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, pp. 1807–1816.

Ferris, Brian, Kari Watkins, and Alan Borning (2011). "OneBusAway: Behavioral and satisfaction changes resulting from providing real-time arrival information for public transit". In: *Proceedings of the 2011 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Figueiredo, Lino, Isabel Jesus, JA Tenreiro Machado, Jose Rui Ferreira, and JL Martins De Carvalho (2001). "Towards the development of intelligent transportation systems". In: *ITSC 2001. 2001 IEEE Intelligent Transportation Systems. Proceedings (Cat. No.01TH8585)*, pp. 1206–1211. DOI: 10.1109/ITSC.2001.948835.

Florian, Daniel George (2004). "Simulation-based evaluation of advanced traveler information services (atis)". PhD thesis. Massachusetts Institute of Technology.

Fonzone, Achille (2015). "What Do You Do with Your App? Study of bus rider decision making with real-time passenger information". In: *Transportation Research Record: Journal of the Transportation Research Board* 2535, pp. 15–24.

Fonzone, Achille and Jan-Dirk Schmöcker (2014). "Effects of transit real-time information usage strategies". In: *Transportation Research Record: Journal of the Transportation Research Board* 2417, pp. 121–129.

Fonzone, Achille, Jan-Dirk Schmöcker, Michael GH Bell, Guido Gentile, Fumitaka Kurauchi, Klaus NÖKEL, and Nigel HM Wilson (2010). "Do"hyper-travellers" exist?–Initial results of an international survey on public transport user behaviour'". In: *12th World Conference on Transport Research, Lisbon, Portugal*.

Forsyth, E and DT Silcock (1985). "Evaluation of real-time information on the arrival of urban public transport services". In: *Seminar on Public Transport Operations Research*. Cited in Dziekan, K., and Kottenhoff, K. (2007). Dynamic at-stop real-time information displays for public transport: effects on customers. Transportation Research Part A: Policy and Practice, 41(6), 489-501.

Frei, Andreas and Hong-cheng Gan (2015). "Mode switching behavior with the provision of real-time multi-modal traveler information". In: *Proceedings of the 2015 Annual Meeting of the Transportation Research Board, Washington, D.C.* Pp. 1–18.

Frishammar, Johan (2003). "Information use in strategic decision making". In: *Management Decision* 41.4, pp. 318–326.

Fujii, Satoshi and Ryuichi Kitamura (2000). "Anticipated travel time, information acquisition, and actual experience: Hanshin expressway route closure, Osaka-Sakai, Japan". In: *Transportation Research Record: Journal of the Transportation Research Board* 1725, pp. 79–85.

Gaker, David, Yanding Zheng, and Joan Walker (2010). "Experimental economics in transportation: focus on social influences and provision of information". In: *Transportation Research Record: Journal of the Transportation Research Board* 2156, pp. 47–55.

Gammer, Nick, Tom Cherrett, and Christopher Gutteridge (2014). “Disseminating real-time bus arrival information via QRcode tagged bus stops: a case study of user take-up and reaction in Southampton, UK”. In: *Journal of Transport Geography* 34, pp. 254–261.

Gan, HongCheng, LiJun Sun, JianYang Chen, and WenPing Yuan (2006). “Advanced traveler information system for metropolitan expressways in Shanghai, China”. In: *Transportation Research Record: Journal of the Transportation Research Board* 1944, pp. 35–40.

Gan, Hongcheng and Xin Ye (2016). “Investigation of impacts of smartphone delivered real-time multi-modal information on commuting drivers’ mode switch decisions”. In: *Proceedings of the 2016 Annual Meeting of the Transportation Research Board, Washington, D.C.* 16-5305.

Gavriilidou, Alexandra, Oded Cats, David Leffler, Francesco Corman, and Serge Hoogendoorn (2017). “Real-time transfer synchronization of public transport services using passenger data”. In: *Proceedings of the 2017 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Ge, Yanbo, Parastoo Jabbari, Don MacKenzie, and Jiarui Tao (2017). “Effects of a public real-time multi-modal transportation information display on travel behavior and attitudes”. In: *Journal of Public Transportation* 20.2, p. 3.

Gentile, Guido, Sang Nguyen, and Stefano Pallottino (2005). “Route choice on transit networks with online information at stops”. In: *Transportation Science* 39.3, pp. 289–297.

Gillam, Theodore, Glenn Lyons, and Mike McDonald (1999). “Traveller information systems: What do end-users really want?” In: *Proceedings of the European Transport Conference on Traffic Management, Safety & Intelligent Transport Systems, Cambridge, UK, 27th - 29th September*, pp. 329–341.

Gonzalez, Cleotilde (2004). “Learning to make decisions in dynamic environments: Effects of time constraints and cognitive abilities”. In: *Human Factors* 46.3, pp. 449–460.

Gooze, Aaron, Kari Watkins, and Alan Borning (2013). "Benefits of real-time transit information and impacts of data accuracy on rider experience". In: *Transportation Research Record: Journal of the Transportation Research Board* 2351, pp. 95–103.

Goulias, Konstadinos G, Tae-Gyu Kim, and Ondrej Pribyl (2004). "A longitudinal analysis of awareness and use for advanced traveler information systems". In: *Intelligent transportation systems*. Vol. 8. 1. Taylor & Francis, pp. 3–17.

Greaves, Stephen, Adrian Ellison, Richard Ellison, Dean Rance, Chris Standen, Chris Rissel, and Melanie Crane (2015). "A web-based diary and companion smartphone app for travel/activity surveys". In: *Transportation Research Procedia* 11, pp. 297–310.

Grotenhuis, Jan-Willem, Bart W Wiegmans, and Piet Rietveld (2007). "The desired quality of integrated multimodal travel information in public transport: Customer needs for time and effort savings". In: *Transport Policy* 14.1, pp. 27–38.

Gumbel, EJ (1958). "Statistics of extremes". In: *Columbia Univ. Press, New York*.

Hardy, Nigel (2012). "Provision of bus real time information to all bus stops in London". In: *19th ITS World Congress, Vienna, Austria, 22-26 October 2012*, pp. 1–20.

Harmony, Xavier J and Vikash V Gayah (2017). "Evaluation of real-time transit information systems: An information demand and supply approach". In: *International Journal of Transportation Science and Technology*.

Hato, E, M Taniguchi, Y Sugie, M Kuwahara, and H Morita (1999). "Incorporating an information acquisition process into a route choice model with multiple information sources". In: *Transportation Research Part C: Emerging Technologies* 7.2, pp. 109–129.

Heitanen, Sampo (2014). "'Mobility as a Service'-the new transport model?" In: *Euro-Transport* 12.2, pp. 2–4.

Hensher, David A, John M Rose, and William H Greene (2015). *Applied choice analysis*. Cambridge University Press.

Hickman, Mark D and Nigel HM Wilson (1995). "Passenger travel time and path choice implications of real-time transit information". In: *Transportation Research Part C: Emerging Technologies* 3.4, pp. 211–226.

Highway Research Board (1971). *The changeable message concept of traffic control.* Tech. rep. Cited in Adler, J. L. and Blue, V. J. (1998), 'Toward the design of intelligent traveler information systems', Transportation Research Part C: Emerging Technologies 6(3), 157-172. University of Zurich, Department of Informatics.

Highway Research Board (1973). *Changeable message signs-a state-of-the-art report.* Tech. rep. Cited in Adler, J. L. and Blue, V. J. (1998), 'Toward the design of intelligent traveler information systems', Transportation Research Part C: Emerging Technologies 6(3), 157-172. Highway Research Board.

Horst, Paul et al. (1941). *The prediction of personal adjustment.* New York.

Hosmer, David W and Stanley Lemeshow (2000). *Applied logistic regression.* John Wiley & Sons.

IBM Knowledge Center (2014). *Categorical Regression (CATREG).* URL: https://www.ibm.com/support/knowledgecenter/en/SSLVMB_22.0.0/com.ibm.spss.statistics.help/spss/categories/idh_catr.htm.

Inman, V, R Sanchez, C Porter, and L Bernstein (1995). *Travtek evaluation yoked driver study.* Tech. rep. Science Applications International Corporation.

Jittrapirom, P, V Caiati, A Feneri, S Ebrahimigharehbaghi, MJ Alonso-González, and J Narayan (2017). "Mobility as a service". In: *Urban Planning* 2.2, pp. 13–25.

Johnson, Richard and Dean Wichern (1992). *Applied multivariate statistical analysis.*

Jou, Rong-Chang (2001). "Modeling the impact of pre-trip information on commuter departure time and route choice". In: *Transportation Research Part B: Methodological* 35.10, pp. 887–902.

Juhász, Mattias (2013). "Travel Demand Management-Possibilities of influencing travel behaviour". In: *Periodica Polytechnica. Transportation Engineering* 41.1, p. 45.

Juliusson, E Ásgeir, Niklas Karlsson, and Tommy Gärling (2005). "Weighing the past and the future in decision making". In: *European Journal of Cognitive Psychology* 17.4, pp. 561–575.

Kamga, Camille, M Anıl Yazıcı, and Abhishek Singhal (2013). "Implementation of interactive transit information kiosks at New York City transit facilities: Analysis of user utilization and lessons learned". In: *Transportation Research Part C: Emerging Technologies* 35, pp. 218–231.

Kammerer, Yvonne, Ivar Bråten, Peter Gerjets, and Helge I Strømsø (2013). “The role of Internet-specific epistemic beliefs in laypersons’ source evaluations and decisions during Web search on a medical issue”. In: *Computers in Human Behavior* 29.3, pp. 1193–1203.

Kaplan, Sigal, Mayara Moraes Monteiro, Marie Karen Anderson, Otto Anker Nielsen, and Enilson Medeiros Dos Santos (2017). “The role of information systems in non-routine transit use of university students: Evidence from Brazil and Denmark”. In: *Transportation Research Part A: Policy and Practice* 95, pp. 34–48.

Kattan, Lina, Alexandre G de Barros, and Hina Saleemi (2013). “Travel behavior changes and responses to advanced traveler information in prolonged and large-scale network disruptions: A case study of west LRT line construction in the city of Calgary”. In: *Transportation Research Part F: Traffic Psychology and Behaviour* 21, pp. 90–102.

Kattan, Lina, Khandker Habib, Shahid Nadeem, and Tazul Islam (2010). “Modeling travelers’ responses to incident information provided by variable message signs in Calgary, Canada”. In: *Transportation Research Record: Journal of the Transportation Research Board* 2185, pp. 71–80.

Kempton, Calum James (2015). “Behavioural econometric modelling of real-time passenger information usage: inside the mind of traveller”. Thesis. Edibnburgh Napier University: The school Engineering and the Built Environment.

Kenyon, Susan and Glenn Lyons (2003). “The value of integrated multimodal traveller information and its potential contribution to modal change”. In: *Transportation Research Part F: Traffic Psychology and Behaviour* 6.1, pp. 1–21.

Kerstholt, José H and Jeroen GW Raaijmakers (1997). “Decision making in dynamic task environments”. In: *Decision making: Cognitive models and explanations*, pp. 205–217.

Khattak, Asad J, Xiaohong Pan, Billy Williams, Nagui Rouphail, and Yingling Fan (2008). “Traveler information delivery mechanisms impact on consumer behavior”. In: *Journal of the Transportation Research Board* 2069, pp. 7–11. DOI: 10.3141/2069-10.

Khattak, Asad J, Joseph L Schofer, and Frank S Koppelman (1993). “Commuters’ enroute diversion and return decisions: analysis and implications for advanced traveler information systems". In: *Transportation Research Part A: Policy and Practice* 27.2, pp. 101–111.

Khattak, Asad, Amalia Polydoropoulou, and Moshe Ben-Akiva (1996). "Modeling revealed and stated pretrip travel response to advanced traveler information systems". In: *Transportation Research Record: Journal of the Transportation Research Board* 1537, pp. 46–54.

Kim, Dae-Young, Xinran Y Lehto, and Alastair M Morrison (2007). "Gender differences in online travel information search: Implications for marketing communications on the internet". In: *Tourism Management* 28.2, pp. 423–433.

Kim, Joon-Ki, Backjin Lee, and Sungho Oh (2009). "Passenger choice models for analysis of impacts of real-time bus information on crowdedness". In: *Transportation Research Record: Journal of the Transportation Research Board* 2112, pp. 119–126.

Kitzinger, Jenny (1995). "Qualitative research. Introducing focus groups". In: *British Medical Journal* 311.7000, p. 299.

Kroes, EP and RJ Sheldon (1988). "Stated preference methods: an introduction". In: *Journal of Transport Economics and Policy* 5.

Kruikemeier, Sanne, Guda van Noort, Rens Vliegenthart, and Claes H de Vreese (2014). "Unraveling the effects of active and passive forms of political Internet use: Does it affect citizens' political involvement?" In: *New Media & Society* 16.6, pp. 903–920.

Lam, Soi-Hoi and Feng Xie (2002). "Transit path-choice models that use revealed preference and stated preference data". In: *Transportation Research Record: Journal of the Transportation Research Board* 1799, pp. 58–65.

Landsburg, Steven E (2007). *The Armchair Economist: Economics & Everyday Life*. pg. 3. Simon and Schuster.

Lappin, Jane (2000). *Advanced traveler information service (ATIS): What do ATIS customers want?* Tech. rep. John A. Volpe National Transportation Systems Center.

Lappin, Jane and Jon Bottom (2001). *Understanding and predicting traveler response to information: a literature review*. John A. Volpe National Transportation Systems Center.

Lavrakas, Paul J (2008). *Encyclopedia of survey research methods*. Sage Publications.

LeBlanc, Michael and Shawn Fitzgerald (2000). "Logistic regression for school psychologists." In: *School Psychology Quarterly* 15.3, p. 344.

Lemeshow, Stanley, Rodney X Sturdivant, and David W Hosmer (2013). *Applied logistic regression (Wiley Series in probability and statistics)*. Wiley.

Levinson, David (2003). "The value of advanced traveler information systems for route choice". In: *Transportation Research Part C: Emerging Technologies* 11.1, pp. 75–87.

Levinson, David, David Gillen, and Elva Chang (1999). "Assessing the benefits and costs of intelligent transportation systems: The value of advanced traveler information systems". In: *California Partners for Advanced Transit and Highways (PATH)*.

Li, Yanying and Tom Voege (2017). "Mobility as a Service (MaaS): challenges of implementation and policy required". In: *Journal of Transportation Technologies* 7.02, p. 95.

Lin, Ting-Wei, Chia-Yen Lin, and Wen-Ho Hsu (2014). "Effects of system characteristics on adopting web-based advanced traveller information system: evidence from Taiwan". In: *PROMET-Traffic&Transportation* 26.1, pp. 53–63.

Linting, Marielle, Jacqueline J Meulman, Patrick JF Groenen, and Anita J van der Koojj (2007). "Nonlinear principal components analysis: introduction and application." In: *Psychological Methods* 12.3, p. 336.

Lotan, Tsippy (1997). "Effects of familiarity on route choice behavior in the presence of information". In: *Transportation Research Part C: Emerging Technologies* 5.3, pp. 225–243.

St-Louis, Evelyne, Kevin Manaugh, Dea van Lierop, and Ahmed El-Geneidy (2014). "The happy commuter: A comparison of commuter satisfaction across modes". In: *Transportation Research Part F: Traffic Psychology and Behaviour* 26, pp. 160–170.

Lu, Xuan, Song Gao, and Eran Ben-Elia (2011). "Information impacts on route choice and learning behavior in a congested network: Experimental approach". In: *Transportation Research Record: Journal of the Transportation Research Board* 2243, pp. 89–98.

Lu, Yaobin, Tao Zhou, and Bin Wang (2009). "Exploring Chinese users' acceptance of instant messaging using the theory of planned behavior, the technology acceptance model, and the flow theory". In: *Computers in Human Behavior* 25.1, pp. 29–39.

Lynne, Gary D, C Franklin Casey, Alan Hodges, and Mohammed Rahmani (1995). "Conservation technology adoption decisions and the theory of planned behavior". In: *Journal of economic psychology* 16.4, pp. 581–598.

Lyons, Glenn (1999). "UK passenger transport information on the internet: Promoting best practice through accreditation". In: *Proceedings of the European Transport Conference on Public Transport Planning and Management, Cambridge, UK.*

Lyons, Glenn (2006). "The role of information in decision-making with regard to travel". In: *IEE Proceedings-Intelligent Transport Systems.* Vol. 153. 3. IET, pp. 199–212.

Lyons, Glenn, Erel Avineri, and Sendy Farag (2008). "Assessing the demand for travel information: Do we really want to know?" In: *European Transport Conference, Leeuwenhorst Conference Centre, The Netherlands, 6th-8th October 2008.*

Lyons, Glenn, Reg Harman, John Austin, and Alastair Duff (2001). *Traveller snformation systems research: A review and recommendations for Transport Direct.* Tech. rep. DTLR: Transport Local Government Regions.

Lyu, Seong Ok and Jinsoo Hwang (2014). "Are the days of tourist information centers gone? Effects of the ubiquitous information environment". In: *Tourism Management* 48, pp. 54–63.

Ma, Zhuanglin, Chunfu Shao, Yang Song, and Jun Chen (2014). "Driver response to information provided by variable message signs in Beijing". In: *Transportation Research Part F: Traffic Psychology and Behaviour* 26, pp. 199–209.

Maclean, Stuart D and Daniel J Dailey (2001). "MyBus: helping bus riders make informed decisions". In: *IEEE Intelligent Systems* 16.1, pp. 84–87.

Mahmassani, Hani S, Nathan N Huynh, Karthik Srinivasan, and Mariette Kraan (2003). "Tripmaker choice behavior for shopping trips under real-time information: model formulation and results of stated-preference internet-based interactive experiments". In: *Journal of Retailing and Consumer Services* 10.6, pp. 311–321.

Mahmassani, Hani S and Yu-Hsin Liu (1999). "Dynamics of commuting decision behaviour under advanced traveller information systems". In: *Transportation Research Part C: Emerging Technologies* 7.2, pp. 91–107.

Mahmassani, Hani S and Karthik K Srinivasan (2004). "Experiments with route and departure time choices of commuters under real-time information: heuristics and adjustment processes". In: *Human Behaviour and Traffic Networks*. Springer, pp. 97–131.

Mahmoud, Mohamed S, Khandker M Nurul Habib, and Amer Shalaby (2015). "Survey of cross-regional intermodal passenger travel: Joint revealed preference-stated preference survey integrated with a multimodal trip planner tool". In: *Transportation Research Record: Journal of the Transportation Research Board* 2526, pp. 108–118.

Maréchal, Séverine (2016a). "Modelling the acquisition and use of information sources during travel disruption". In: *UTSG Conference, Bristol*. January, pp. 1–12.

Maréchal, Séverine (2016b). "Modelling the acquisition of travel information and its influence on travel behaviour". PhD thesis. Imperial College London.

Mascia, Margherita (2003). "Effects of traveller information systems on modal choice". In: *EIRASS workshop Behavioural response to ITS, Eindhoven, The Netherlands*. July.

Mathieson, Kieran (1991). "Predicting user intentions: Comparing the technology acceptance model with the theory of planned behavior". In: *Information Systems Research* 2.3, pp. 173–191.

McFadden, Daniel (1978). "Modeling the choice of residential location". In: *Transportation Research Record* 673.

McQueen, Bob, Rick Schuman, and Kan Chen (2002). *Advanced traveler information systems*. Artech House.

Metcalfe, Robert and Paul Dolan (2012). "Behavioural economics and its implications for transport". In: *Journal of transport geography* 24, pp. 503–511.

Meulman, Jacqueline J and Willem J Heiser (2005). *SPSS Categories 14.0*. Chicago, IL: SPSS Inc. Available via SPSS at http://www. spss. com/SPSS Categories.

Meyer, Michael D (1999). "Demand management as an element of transportation policy: using carrots and sticks to influence travel behavior". In: *Transportation Research Part A: Policy and Practice* 33.7-8, pp. 575–599.

Meyers-Levy, Joan (1988). "The influence of sex roles on judgment". In: *Journal of Consumer Research* 14.4, pp. 522–530.

Mirchandani, Pitu and Larry Head (2001). "A real-time traffic signal control system: architecture, algorithms, and analysis". In: *Transportation Research Part C: Emerging Technologies* 9.6, pp. 415–432.

Molin, EJE and CG Chorus (2004). “Willingness to pay for personalized public transport information services”. In: *Proceedings of the 2004 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Molin, Eric JE and Harry JP Timmermans (2006). “Traveler expectations and willingness-to-pay for Web-enabled public transport information services”. In: *Transportation Research Part C: Emerging Technologies* 14.2, pp. 57–67.

Molin, Eric, Caspar Chorus, and Ruud Van Sloten (2009). “The need for advanced public transport information services when making transfers”. In: *European Journal of Transport and Infrastructure Research (EJTIR)* 9.4.

Monzon, Andres, Sara Hernandez, and Rocio Cascajo (2013). “Quality of bus services performance: benefits of real time passenger information systems”. In: *Transport and Telecommunication* 14.2, pp. 155–166.

Monzón, Andrés, Sara Hernandez, Andrés G. Martínez, Ioannis Kaparias, and Francesco Viti (2016). “Modelling public transport passenger flows in the era of intelligent transport systems”. In: ed. by Guido Gentile and Klaus Noekel. Switzerland: Springer Tracts on Transportation and Traffic.–Springer International Publishing. Chap. Public Transport in the Era of ITS: ITS Technologies for Public Transport, pp. 85–128. ISBN: 978-3-319-25080-9.

Morfoulaki, Maria, Glikeria Myrovali, and Kornilia Kotoula (2015). “Increasing the attractiveness of public transport by investing in soft ICT based measures: Going from words to actions under an austerity backdrop–Thessaloniki’s case, Greece”. In: *Research in Transportation Economics* 51, pp. 40–48.

Mortazavi, Ali, Krute Singa, Xiaohong Pan, Tia McDonald, Eui Jae Jin, and Marin Odioso (2011). “Effect of real time information on commuter travel mode”. In: *Proceedings of the 2011 Annual Meeting of the Transportation Research Board, Washington, D.C.* 11-3097.

Moser, Claus Adolf and Alan Stuart (1953). “An experimental study of quota sampling”. In: *Journal of the Royal Statistical Society. Series A (General)* 116.4, pp. 349–405.

Neuherz, Martina, Verena Patz, Thomas Pischner, and Hartmut Keller (2000). “User acceptance and impacts of new multimodal traffic information services in BAYERN-INFO”. In: *7th ITS World Congress, Torino, Italy.*

Nijkamp, P, G Pepping, and D Banister (1996). "Telematics and transport behaviour". In: Springer. Chap. 7: Public transit information systems: An English case study.

Nowell, Clifford and Linda R Stanley (1991). "Length-biased sampling in mall intercept surveys". In: *Journal of Marketing Research*, pp. 475–479.

Noy, Chaim (2008). "Sampling knowledge: The hermeneutics of snowball sampling in qualitative research". In: *International Journal of social research methodology* 11.4, pp. 327–344.

Ochieng, WY, PJ Shardlow, and Gordon Johnston (1999). "Advanced transport telematics positioning requirements: An assessment of GPS performance in greater London". In: *The Journal of Navigation* 52.3, pp. 342–355.

Ofcom (2017). *Communications Market Report*. Tech. rep. URL: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/104933/cmr-2017-scotland.pdf.

Office for National Statistics (2017). *Internet users in the UK: 2017*. Tech. rep.

Okazaki, Shintaro (2004). "How do Japanese consumers perceive wireless ads? A multivariate analysis". In: *International Journal of Advertising* 23.4, pp. 429–454.

Okazaki, Shintaro (2007). "Exploring gender effects in a mobile advertising context: on the evaluation of trust, attitudes, and recall". In: *Sex Roles* 57.11-12, pp. 897–908.

Okazaki, Shintaro and Morikazu Hirose (2009). "Does gender affect media choice in travel information search? On the use of mobile Internet". In: *Tourism Management* 30.6, pp. 794–804.

Oppenheim, Abraham Naftali (2000). *Questionnaire design, interviewing and attitude measurement*. Bloomsbury Publishing.

Ortuzar, Juan de Dios and Luis G Willumsen (2002). *Modelling transport*. Vol. 3.

Palma, André de, Robin Lindsey, and Nathalie Picard (2012). "Risk aversion, the value of information, and traffic equilibrium". In: *Transportation Science* 46.1, pp. 1–26.

Papangelis, Konstantinos, Nagendra R Velaga, Somayajulu Sripada, Mark Beecroft, John D Nelson, Jillian Anable, and John H Farrington (2013). "Supporting rural public transport users during disruptions: The role of real time information". In: *Proceedings of the 2013 Annual Meeting of the Transportation Research Board, Washington, D.C.* 13-2964.

Parvaneh, Zahra, Theo Arentze, and Harry Timmermans (2012). "Understanding travelers' behavior in provision of travel information: a Bayesian belief approach". In: *Procedia-Social and Behavioral Sciences* 54, pp. 251–260.

Parvaneh, Zahra, Theo Arentze, and Harry Timmermans (2013). "Evaluation of changes in individuals' activity-travel behavior induced by advanced travel information: design of a stated adaptation approach". In: *Proceedings of World Conference on Transport Research (WCTR), Rio de Janeiro, Brazil.*

Parvaneh, Zahra, Theo Arentze, and Harry Timmermans (2014). "A stated adaptation approach to assess changes in individuals' activity-travel behavior in presence of personalized travel information". In: *Transportation Research Procedia* 3, pp. 21–30.

Pearson, Robert Henry and Daniel J. Mundform (2010). "Recommended sample size for conducting exploratory factor analysis on dichotomous data". In: *Journal of Modern Applied Statistical Methods* 9.2, pp. 359–368. DOI: 10.22237/jmasm/1288584240.

Peirce, Sean and Jane Lappin (2003). "Acquisition of traveler information and its effects on travel choices: evidence from a Seattle-area travel diary survey". In:

Peirce, Sean and Jane E Lappin (2004). "Why don't more people use advanced traveler information? Evidence from the Seattle area". In: *Proceedings of the 2004 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Peng, Starry (2013). "Maximizing and Satisficing in Decision-Making Dyads". University of Pennsylvania ScholarlyCommons.

Peterson, Robert A and Maria C Merino (2003). "Consumer information search behavior and the Internet". In: *Psychology & Marketing* 20.2, pp. 99–121.

Petrella, Margaret and Jane Lappin (2004). "Comparative analysis of customer response to online traffic information in two cities: Los Angeles, California, and Seattle, Washington". In: *Transportation Research Record: Journal of the Transportation Research Board* 1886, pp. 10–17.

Petrella, Margaret, Paul Minnice, and Jane Lappin (2014). "Traveler use of and response to real-time traffic and traveler information: Evidence from integrated corridor management traveler surveys in Dallas, Texas, and San Diego, California". In: *Transporta-*

tion Research Record: Journal of the Transportation Research Board 2423, pp. 44–51.

Polak, John and Peter Jones (1993). "The acquisition of pre-trip information: a stated preference approach". In: *Transportation* 20.2, pp. 179–198.

Politis, Ioannis, Panagiotis Papaioannou, Socrates Basbas, and Nikolaos Dimitriadis (2010). "Evaluation of a bus passenger information system from the users' point of view in the city of Thessaloniki, Greece". In: *Research in Transportation Economics* 29.1, pp. 249–255.

Polydoropoulou, Amalia and Moshe Ben-Akiva (1998). *The effect of Advanced Traveler Information Systems (ATIS) on travelers behavior*. Transportation Research Board.

Polydoropoulou, Amalia, Moshe Ben-Akiva, and Dinesh Gopinath (1997). "Modeling user adoption of advanced traveler information systems (ATIS)". In: *IFAC Proceedings Volumes* 30.8, pp. 1357–1362.

Pratt, John W (1987). "Dividing the indivisible: Using simple symmetry to partition variance explained". In: *Proceedings of the Second International Conference in Statistics*. Tampere, Finland: University of Tampere, pp. 245–260.

Psarros, Ioannis, Konstantinos Kepaptsoglou, Matthew G Karlaftis, and Stelios Efstathiadis (2011). "Wait time at bus stops: An empirical investigation of passenger perceptions". In: *Proceedings of the 2011 Annual Meeting of the Transportation Research Board, Washington, D.C.* 11-0195.

Rahman, Md Matiur, Lina Kattan, and SC Wirasinghe (2017). "Bus users' attitudes toward a newly implemented real-time bus information system". In: *Proceedings of the 2017 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Ramos, Moraes G, Emma Frejinger, Winnie Daamen, and SP Hoogendoorn (2012). "A revealed preference study on route choices in a congested network with real-time information". In: *13th International Conference on Travel Behaviour Research, Toronto, Canada, 15-20 July*. University of Toronto.

Raveau, Sebastián, Zhan Guo, Juan Carlos Muñoz, and Nigel HM Wilson (2014). "A behavioural comparison of route choice on metro networks: Time, transfers, crowding, topology and socio-demographics". In: *Transportation Research Part A: Policy and Practice* 66, pp. 185–195.

Revelle, William (2011). “An overview of the psych package”. In: *Department of Psychology Northwestern University* 3, p. 2012.

Richardson, Anthony J, Elizabeth S Ampt, and Arnim H Meyburg (1995). *Survey methods for transport planning*. Eucalyptus Press Melbourne.

Rolph, Glenn, Ariel Stein, and Barbara Stunder (2017). “Real-time environmental applications and display system: Ready”. In: *Environmental Modelling & Software* 95, pp. 210–228.

Roscoe, John T (1975). *Fundamental research statistics for the behavioral sciences*. Holt, Rinehart and Winston, New York.

Roscoe, Rod D, Carola Grebitus, Joseph O’Brian, Adam C Johnson, and Irfan Kula (2016). “Online information search and decision making: Effects of web search stance”. In: *Computers in Human Behavior* 56, pp. 103–118.

Ryan, Geraldine and Edward Shinnick (2010). “The power of incentives in decision making”. In: *IT Outsourcing: Concepts, Methodologies, Tools, and Applications*. IGI Global, pp. 1829–1838.

Samuelson, Paul A (1938). “A note on the pure theory of consumer’s behaviour”. In: *Economica* 5.17, pp. 61–71.

Samuelson, Paul A (1948). “Consumption theory in terms of revealed preference”. In: *Economica* 15.60, pp. 243–253.

Schofer, Joseph L, Asad Khattak, and Frank S Koppelman (1993). “Behavioral issues in the design and evaluation of advanced traveler information systems”. In: *Transportation Research Part C: Emerging Technologies* 1.2, pp. 107–117.

Schofer, Joseph, Frank Koppelman, and William Charlton (1997). “Perspectives on driver preferences for dynamic route guidance systems”. In: *Transportation Research Record: Journal of the Transportation Research Board* 1588, pp. 26–31.

Schwartz, Barry, Andrew Ward, John Monterosso, Sonja Lyubomirsky, Katherine White, and Darrin R Lehman (2002). “Maximizing versus satisficing: Happiness is a matter of choice.” In: *Journal of Personality and Social Psychology* 83.5, p. 1178.

Schweiger, Carol L (2003). *Real-time bus arrival information systems*. TCRP Synthesis 48. Transportation Research Board.

Schweiger, Carol L (2011). *Use and deployment of mobile device technology for real-time transit information.* TCRP Synthesis 91. Transportation Research Board.

Seebauer, Sebastian, Regina Stolz, and Martin Berger (2015). "Technophilia as a driver for using advanced traveler information systems". In: *Transportation Research Part C: Emerging Technologies* 60, pp. 498–510.

Selten, Reinhard (1990). "Bounded rationality". In: *Journal of Institutional and Theoretical Economics (JITE)/Zeitschrift für die gesamte Staatswissenschaft* 146.4, pp. 649–658.

Sepp, Alar (2012). "Online versus postal questionnaires: a comparison between two data collection methods". In: *8th Pharmacy Academic Conference.* Instituto Politécnico do Porto. Escola Superior de Tecnologia da Saúde do Porto, pp. 101–112.

Shared-Use Mobility Center (2016). *Shared mobility and the transformation of public transit.* Tech. rep. Shared-Use Mobility Center.

Simon, Herbert A (1955). "A behavioral model of rational choice". In: *The Quarterly Journal of Economics* 69.1, pp. 99–118.

Simon, Herbert A (1972). "Theories of bounded rationality". In: *Decision and Organization* 1.1, pp. 161–176.

Skoglund, Tor (2014). "Effects of long-term access to ICT-mediated travel information services-Users' assessments and reported behavioural changes". PhD thesis. Chalmers University of Technology.

SPSS (2009). "SPSS Statistics 17.0 - Algorithms". In: *SPSS Inc., Chicago, Illinois.*

Srinivasan, Karthik and Hani Mahmassani (2000). "Modeling inertia and compliance mechanisms in route choice behavior under real-time information". In: *Transportation Research Record: Journal of the Transportation Research Board* 1725, pp. 45–53.

Srinivisan, K, Iris Chen, PDVG Reddy, and PP Jovanis (1999). "Pre-trip information systems: an investigation into users' information acquisition process". In: *Proceedings of the 1999 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Stanovich, Keith E and Richard F West (2008). "On the relative independence of thinking biases and cognitive ability." In: *Journal of Personality and Social Psychology* 94.4, p. 672.

Statista (2016). *Share of mobile phone users that use a smartphone in the United Kingdom from 2010 to 2017*. URL: https://www.statista.com/statistics/257051/smartphone-user-penetration-in-the-uk/.

Statista (2017). *UK internet penetration: percentage of population using the internet in the United Kingdom from 2000 to 2016*. URL: https://www.statista.com/statistics/468663/uk-internet-penetration/.

Stough, Roger R. and Guang Yang (2009). "Transportation Engineering and Planning-vol. II". In: ed. by Tschango. J Kim. Oxford, UK: Eolss Publisher Co. Ltd. Chap. Intelligent transportation systems, pp. 87–108. ISBN: 978-1-84826-981-1.

Stradling, S, J Hine, and M Wardman (2001). "Physical, cognitive and affective effort in travel mode choices". In: *International Conference on Traffic and Transport Psychology*. Berne, Switzerland.

Tabachnick, Barbara G and Linda S Fidell (2007). *Using multivariate statistics*. Allyn & Bacon/Pearson Education.

Tanaka, Jeffrey S (1987). ""How big is big enough?": Sample size and goodness of fit in structural equation models with latent variables". In: *Child Development*, pp. 134–146.

Tang, Lei, H Ross, and X Han (2012). "Substitution or complementarity: An examination of the ridership effects of real-time bus information on transit rail in the city of Chicago". In: *Proceedings of the 2012 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Tang, Lei and Piyushimita Thakuriah (2011). "Will psychological effects of real-time transit information systems lead to ridership gain?" In: *Transportation Research Record: Journal of the Transportation Research Board* 2216, pp. 67–74.

Tang, Lei and Piyushimita Vonu Thakuriah (2012). "Ridership effects of real-time bus information system: A case study in the City of Chicago". In: *Transportation Research Part C: Emerging Technologies* 22, pp. 146–161. ISSN: 0968090X. DOI: 10.1016/j.trc.2012.01.001.

Targa, Felipe, Asad J Khattak, and Youngbin Yim (2003). "Understanding access and use of dynamic travel information". In: *Proceedings of the 2003 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Thompson, Bruce (2004). *Exploratory and confirmatory factor analysis: Understanding concepts and applications.* American Psychological Association.

Thompson, Franklin T and Daniel U Levine (1997). “Examples of easily explainable suppressor variables in multiple regression research”. In: *Multiple Linear Regression Viewpoints* 24.1, pp. 11–13.

Thorhauge, Mikkel, Sonja Haustein, and Elisabetta Cherchi (2016). “Accounting for the Theory of Planned Behaviour in departure time choice”. In: *Transportation Research Part F: Traffic Psychology and Behaviour* 38, pp. 94–105.

Tian, Hengliang, Song Gao, Donald L Fisher, and Brian Post (2011). “Route choice behavior in a driving simulator with real-time information”. In: *Proceedings of the 2011 Annual Meeting of the Transportation Research Board, Washington, D.C.* 11-1474.

Todd, Peter M (2007). “How much information do we need?” In: *European Journal of Operational Research* 177.3, pp. 1317–1332.

Todd, Peter and Izak Benbasat (1992). “The use of information in decision making: an experimental investigation of the impact of computer-based decision aids”. In: *MIS Quarterly*, pp. 373–393.

Toledo, Tomer and Ross Beinhaker (2006). “Evaluation of the potential benefits of advanced traveler information systems”. In: *Journal of Intelligent Transportation Systems* 10.4, pp. 173–183.

Tongco, Ma Dolores C (2007). “Purposive sampling as a tool for informant selection”. In: *Ethnobotany Research and Applications* 5, pp. 147–158.

Train, Kenneth (1986). *Qualitative choice analysis: Theory, econometrics, and an application to automobile demand.* Vol. 10. MIT press.

Transport Focus UK (2013). *Bus passengers’ experience of delays and disruption.* Tech. rep. April.

Transport for Edinburgh (2014). *One city ... many journeys.* Tech. rep. December.

Transport for London (2014). *TfL bus user survey 2014.* Tech. rep. URL: http://content.tfl.gov.uk/tfl-bus-users-survey.pdf.

Transport Scotland (2013). *Bus and coach statistics 2011-12.* Tech. rep. URL: https://www.transport.gov.scot/media/10673/buscoach2011_12.pdf.

Transport Scotland (2016). *National transport strategy*. Tech. rep. URL: https://www.transport.gov.scot/media/10310/transport-scotland-national-transport-strategy-january-2016-final-online.pdf.

Tseng, Yin Yen, Jasper Knockaert, and Erik T. Verhoef (2013). "A revealed-preference study of behavioural impacts of real-time traffic information". In: *Transportation Research Part C: Emerging Technologies* 30, pp. 196–209. ISSN: 0968090X. DOI: 10.1016/j.trc.2011.11.006.

Tsirimpa, Athena (2015). "Modeling the impact of traffic information acquisition from mobile devices during the primary tour of the day". In: *Journal of Intelligent Transportation Systems* 19.2, pp. 125–133.

Tsirimpa, Athena, Amalia Polydoropoulou, and Constantinos Antoniou (2005). "Modelling the impact of advanced traveller information systems on travellers' behavior: Puget sound region case study". In: *European Transport Conference*.

UCLA: Statistical Consulting Group (2011). *Ordered logistic regression| SPSS annotated output*. URL: https://stats.idre.ucla.edu/spss/output/ordered-logistic-regression/.

UITP (2002). *A UITP position paper: Public transport for sustainable mobility*. Tech. rep. July. The International Association of Public Transport.

UITP (2011). *Becoming a real mobility provider combined mobility: public transport in synergy with other modes like car-sharing, taxi and cycling*. Tech. rep. April. The International Association of Public Transport. URL: http://www.uitp.org/sites/default/files/cck-focus-papers-files/FPComMob-en.pdf.

UITP (2014a). *Local public transport in the European Union*. URL: http://www.uitp.org/sites/default/files/cck-focus-papers-files/UITP_Statistics_PT_in_EU_DEF_0.pdf (visited on 09/19/2017).

UITP (2014b). *Public transport: driving Europe forward in 2014-2019*. Tech. rep. The International Association of Public Transport. URL: http://www.uitp.org/sites/default/files/cck-focus-papers-files/UITP_EN_Driving%20Europe%20Forward%20in%202014-2019.pdf.

Van der Horst, RSN and D Ettema (2005). “Use of travel information and effects on mode choice for recreational trips”. In: *Proceedings of the 2005 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Van Oort, Niels (2011). “Service reliability and urban public transport design”. PhD thesis.

Vance, CE and RJ Balcombe (1997). “How to tell bus passengers what they need to know”. In: *Public transport planning and operations. Proceedings of seminar held at PTRC European transport forum.* Cited in Lyons, G., Harman, R., Austin, J. and Duff, A. (2001) Traveller information systems research: A review and recommendations for transport direct. Technical Report. DTLR: Transport Local Govern- ment Regions. Available from: http://eprints.uwe.ac.uk/10197.

Vehovar, Vasja, Vera Toepoel, and S Steinmetz (2016). “Non-probability Sampling”. In: *The SAGE Handbook of Survey Methodology*, p. 329.

Veiga Simão, José Pedro Ramalho (2014). “Impacts of advanced travel information systems on travel behaviour: Smartmoov’ case study”. PhD thesis. Politecnico di Torino, Italy.

Venkatraman, Ravi, Stephen D. Boyles, Rachel James, and Avinash Unnikrishnan (2014). “Adaptive routing behavior with real time information under multiple travel objectives”. In: *Proceedings of the 2014 Annual Meeting of the Transportation Research Board, Washington, D.C.*

Verplanken, Bas, Henk Aarts, Ad Van Knippenberg, et al. (1997). “Habit, information acquisition, and the process of making travel mode choices”. In: *European Journal of Social Psychology* 27.5, pp. 539–560.

Vuchic, Vukan R (2002). “Urban public transportation systems”. In: *University of Pennsylvania, Philadelphia, PA, USA* 5, pp. 2532–2558.

Wagner III, William E (2014). *Using IBM® SPSS® statistics for research methods and social science statistics.* Sage Publications.

Wang, Xin and Asad Khattak (2013). “Role of travel information in supporting travel decision adaption: exploring spatial patterns”. In: *Transportmetrica A: Transport Science* 9.4, pp. 316–334.

Wang, Xin, Asad Khattak, and Yingling Fan (2009). "Role of dynamic information in supporting changes in travel behavior: two-stage process of travel decision". In: *Transportation Research Record: Journal of the Transportation Research Board* 2138, pp. 85–93.

Wardman, M, PW Bonsall, and JD Shires (1997). "Driver response to variable message signs: a stated preference investigation". In: *Transportation Research Part C: Emerging Technologies* 5.6, pp. 389–405.

Washington, Simon P, Matthew G Karlaftis, and Fred Mannering (2011). *Statistical and econometric methods for transportation data analysis*. CRC press.

Watkins, Kari Edison, Brian Ferris, Alan Borning, G. Scott Rutherford, and David Layton (2011). "Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders". In: *Transportation Research Part A: Policy and Practice* 45.8, pp. 839–848. ISSN: 09658564. DOI: 10.1016/j.tra.2011.06.010.

Watkins, Kari Edison, Brian Ferris, and G Scott Rutherford (2010). "Explore: An attraction search tool for transit trip planning". In: *Journal of Public Transportation* 13.4, p. 6.

Weinberg, Morton I, Norman J Deleys, and Richard F Schneeberger (1966). *Surveillance methods and ways and means of communicating with drivers*. Tech. rep.

White, Peter (2016). *Public transport: its planning, management and operation*. Taylor & Francis.

Wockatz, Philip and Philipp Schartau (2015). *Traveller needs and UK capability study*. Tech. rep. October. Transport systems CATAPULT.

Wright, Kevin B (2005). "Researching Internet-based populations: Advantages and disadvantages of online survey research, online questionnaire authoring software packages, and web survey services". In: *Journal of Computer-Mediated Communication* 10.3, pp. 00–00.

Xiang, Zheng and Ulrike Gretzel (2010). "Role of social media in online travel information search". In: *Tourism Management* 31.2, pp. 179–188.

Yim, Youngbin, Asad Khattak, and Jeremy Raw (2002). "Traveler response to new dynamic information sources: Analyzing corridor and areawide behavioral surveys".

In: *Transportation Research Record: Journal of the Transportation Research Board* 1803, pp. 66–75.

Zhang, Feng, Qing Shen, and Kelly Clifton (2008). “Examination of traveler responses to real-time information about bus arrivals using panel data”. In: *Transportation Research Record: Journal of the Transportation Research Board* 2082, pp. 107–115.

Zhang, Lei and David Levinson (2008). “Determinants of route choice and value of traveler information: A field experiment”. In: *Journal of Transport Research Board* 2086, pp. 81–92. DOI: 10.3141/2086-10.

Zhang, Yi, Xiaoguang Yang, Qixing Liu, and Chaoyang Li (2015). “Who will use pre-trip traveler information and how will they respond? Insights from Zhongshan metropolitan area, China”. In: *Sustainability* 7.5, pp. 5857–5874.

Appendices

APPENDIX A

FOCUS GROUP

Table A.1 Focus group transcription

Basic info	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Summary
Profession	Research student	Research student	Research student	Research student	Research student	Research student	Research student	
Age	22	27	26	28	27	30	23	
Sex	Female	Female	Female	Female	Female	Female	Male	
PT use	Frequent user	Frequent user	In-frequent user	Frequent user	Infrequent user	Infrequent user	In-frequent user	
Ticket	Bus card	Bus card	Daily or single ticket	Bus card	Bus card	Bus card	Daily or single ticket	
Smartphone user	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Available travel information	Apps, websites, radio, Facebook, twitter	Apps	Apps, websites	Apps, websites	Apps	Apps, twitter	Apps, websites	All the participants have access to URTPI
Do you use URTPI?	Yes	No	Yes	Yes	Yes	Yes	Yes	Majority of the participants use URTPI

What do you like about it?	Accurate info, helps planning journey. Migrated from bus tracker to journey planner, found it much better	Time of Arrival of the bus, maps	Time of arrival of the bus, maps	Reliable and accurate. Tells where to get off in planning journey	Google Maps for stops and bus lines. Apps for arrival of the bus, travel time.	Easy to use, planning O-D.	Stops, Arrival of the bus stops. Journey planning, route	Accurate information. Used for planning, different sources for different contents of informaiton
What are the benefits of using it?	To be exactly on time to catch the bus. For new places it is very important. Quicker and easier to look into the apps.	Do not use the apps often. Just go there and wait for bus. Have several options to reach my destination. Would not use even if there would be less options.	Weather dependent. I do not mind waiting for the bus if it is sunny. Sometimes makes me stressed if the bus is arriving in 5 min.	Agree with others. Hate to wait and miss a bus. Would rather wait there. Adjust walking speed according to the time info.	Hate to run for the bus. Purpose of the trip matters for the time of arrival at the destination.	I take the bus from Princes street. So high frequency	-	Easy to use. Familiarity, PT services influence the use.

Dislikes and room for improvements	Delay information is not explicitly mentioned, the remaining time goes back and forth. Would prefer to get a bus with longer travel time, rather than wait for the one with unknown delay time. Experienced discrepancy (bus did not show up)	Do not really know. Bus stop displays are not accurate.	-	Would prefer more alternative routes to choose. Displays at stops are found to be accurate	I prefer walking than waiting at the stops. 5 min doesn't mean 300 sec. It is not reliable.	Apps and bus tracker displays are not synchronized. Displays at stops are found to be accurate	Not so much updated. Few alternative routes are provided. More options should be offered.	Not always reliable, discrepancies among the sources, want more alternatives options-modes, routes
Information you would like to get	Do not really know. Some information in advance on a particular bus line such as road works in 2 days. Personalized apps.	Nothing	Information on crowdedness would be nice if we have more options.	How many seats left would be beneficial for travelling with company	I would like to have all the options, such as with walking and taxi. Information on congestion for any particular line.	Exactly how many minutes a bus will be delayed? Would be nice if my walking pace can be incorporated in the apps or Google Maps.	Information on crowdedness in weekends night	Personalized apps, information on Crowdedness and delay

How do you plan and execute a journey? Description	Typically see the app 2-3 min before leaving the house. It depends on the purpose of the journey. Look at the apps for arrival time to meet the appointment. In the weekends, once to organize my trip. Once before leaving the house and again at the bus stop. But if the weather is not good, then keep refreshing. Weekdays- I leave house just 2 min before the arrival of the bus. Do not have to check again.	I do not look into the app, just go to the stop, and wait for the bus.	An hour before I leave. I organize my schedule. (arrive the stop 2 min before the departure) Normally in the weekends (not a frequent user). Once to organize my trip. Once before leaving the house and again at the bus stop. But if the weather is not good, then keep refreshing.	I check before leaving house and while walking to bus stop. For journeys to catch a particular train, check it early to make sure I do not miss the train. Generally I check it 1-2 times before leaving and once on the way to the stop.	Depends on the purpose of the journey. In case of an appointment I check in the night before, which bus, what time. Google Maps for making a journey for the first time to know where to start. Then go the app before leaving and keep	I check the timetable as soon as the train enters the Waverly station. So approximately 5-6 min before leaving the station. 2 times before the journey	It depends on the journey. For trip from home to uni would not take much time to plan. But for longer trip I would see bit early couple of times.	Both pre-trip en route access. Access several times to catch a particular service or for longer trips. Trip characteristics are very important

How do you make choices after consulting info?	If the bus I would take, is arriving in 15 min then would look for another line. *Had to reach Craiglockhart for an appointment and left 4 min before the bus arrival. Could not catch the bus so had to take a taxi. Was annoyed as I did not look for any other route available before.*		It is situational. *Was coming from airport once at night and the bus just left a minutes ago. So had to wait 25 min for next one. So took a taxi.* If making the trip from home then I would check Facebook or stay bit longer at home.	Adjust my walking speed or just relax and take time in doing my tasks slowly (eating..) If I am going to town for shopping, I do not really check. Depends on the time of day. To take bus I had to walk on a lonely road at night. So I preferred to take a taxi.	Depends on the time of arrival. If I have to be there on time then would look for other options like taxi or I can wait or walking. I hate to wait for the bus outside. I may do something. Yesterday I realized I cant take the next bus so I waited at home for 5 min and left. The distance to the stop is important, would prefer one bus rather than two as do not have any bus card. Also how much have to walk after taking the bus.	Do not have many choices. If I miss, one but I need it for the next one. From school to home I would stay at the office longer and leave on time.	If the bus is delayed or coming after a while I would look for any other options like bus, tram, or taxi or walking to another bus stop depending on the length of the journey. Search for another mode choice	Choices depend on trip context. Adjust walking speed, change departure time, mode. Walking distance, transfers are important factors.

What factors do you consider when making trip choices?	I am familiar with the network. Do not mind taking a route with transfers if the route is faster. But cannot really think of an example for such situation. For example, *I take a bus to city centre and then 100 to airport instead of 35.*	I have two options. Both of them have same route until I reach uni. So does not make any difference. I would take tram to airport which takes longer time than taking a bus from princess street, because it saves walking. 35 or 100 to airport, I would choose the cheaper one. *For situation like, bus lines 11/16 in holy corner or 45 from Napier, I would go for the holy corner as I do not use URTPI there is more chance of getting a bus.*	Limited bus services from my stop. It is about fares as I do not have bus pass.	Depends on how energetic I am. Some days I am lazy to walk so I would take the changes rather than walking. Sometimes I would walk. Travel time is important sometimes if I am in hurry.	Taking one bus is preferable. Distance to departure stop and from arrival stop. Changes normally takes longer time. Do not really like to change the bus.	Always think about the comfort first. Would avoid, changes. Prefer train or tram to bus as it is comfortable. Would take the faster route from Waverly to school or school to Waverly.	Time and cost both. 100 or tram to airport-I would choose 100, as it is faster. Would go for the cheaper one (avoid interchanges)	Reduce journey time and transfers. Go to stops where alternative bus lines available

Delay information before and after arrival at the stop	If I am at the stop it does not say how much of delay, I would be annoyed. If I am informed about the delay before leaving home, I will look for another route even with transfers.	I would walk to the next bus stop but same line.	I will keep the same route stay there and wait. It depends on the trip context.			Depends on how much delay. If it is long, I will look for other alternatives. If the delay is short I will wait.	For delay like 10-15 min I will change to another route in both cases. If the delay is considerable I would change after arriving the stop as well.	Change bus lines with pre-trip delay information, change bus stop, or just wait for shorter delay.
What benefits of using URTPI over at stop displays	I started using app ever since I am in Edinburgh	I prefer the displays rather than looking into tiny letters in the app.	Sometimes my neck gets strained looking at the stop displays. I prefer to look at the app as I have to get out of the shade to look at the displays.	Have always been using URTPI in Edinburgh, never used the at stops displays only.	I found the stops with displays more secure than the one without displays.	We are able to save time, plan journey. Make me informed when the bus is coming. We are sometimes stressed for planning and checking the time.	Easy to use, being informed before leaving origin.	

APPENDIX B

BUS STOP SURVEY QUESTIONNAIRE

This questionnaire is part of a study carried out by Edinburgh Napier University to understand the use of real-time information on public transport in the city of Edinburgh. Your collaboration can help us improve the bus service in Edinburgh. All information is treated as confidential. Thank you for your participation!!

Please answer the following questions. In the following, by“start” we mean the place where you were before going to the bus stop. The “destination” is the final place you are going to. A place can be your home, work, school, a shop, or other. The term “route” means the complete path travelled from start to final destination.

Questions	Options (% of responses)
Q1. Which sources of information are you using for this journey? Please select all that apply.	☐ None (15.0%) ☐ Printed maps and timetable (9.2%) ☐ Displays at stops (46.6%) ☐ Lothian Buses or other websites on phone (16.5%) ☐ Lothian Buses or other websites on computer (6.1%) ☐ Mobile apps (34.8%) ☐ Google Maps (17.3%) ☐ Other people’s advice (2.2%) ☐ Facebook (1.2%) ☐ Twitter (0.5%)
If no URTPI sources selected, please go to Q8	
Q2. When have you used these sources of information for this journey?	☐ Once before starting journey (32.2%) ☐ More than once before starting journey (19.6%) ☐ Once during the journey (En-route) (9.8%) ☐ More than once during the journey (En-route) (8%)

Q3. Please rate the importance of these information to you.

	Not at all important	Slightly important	Important	Very important	Extremely important
Bus arrival time	☐(0.9%)	☐(2.7%)	☐(18.5%)	☐(20.6%)	☐(11.2%)
Bus route map	☐(5.1%)	☐(10.8%)	☐(19.9%)	☐(10.7%)	☐(1.9%)
Bus stop location	☐(5.9%)	☐(8.9%)	☐(16.9%)	☐(11.6%)	☐(5%)
Entire journey	☐(6.3%)	☐(12.8%)	☐(14.3%)	☐(6.7%)	☐(1.5%)
Transfers to other services	☐(8.8%)	☐(9.7%)	☐(12.6%)	☐(7.4%)	☐(1.7%)

Q4.	Have you made any changes to the following once you got the information?	☐ Time of departure from start (16.0%) ☐ Time of boarding bus (11.7%) ☐ Departure stop (7.0%) ☐ Alighting stop (2.9%) ☐ Bus route/line (8.3%) ☐ Means of transport (Bus instead of car, taxi, walking, biking etc.) (3.4%) ☐ No change (25.4%)

If no URTPI sources selected, please go to Q8

Q5. How much did these factors affect your decision to change once you got the information? Please select from the drop down list.

	Not at all	Slightly	Moderately	Strongly	Very strongly
Overall journey time	☐(7.8%)	☐(4.9%)	☐(6.8%)	☐(7.5%)	☐(3.2%)
Arrival time of the next bus	☐(4.8%)	☐(3.2%)	☐(5.9%)	☐(12.4%)	☐(4.0%)
Arrival time at the destination	☐(7.5%)	☐(3.6%)	☐(6.1%)	☐(9.5%)	☐(3.5%)
Sudden delay on a particular route	☐(14.3%)	☐(4.7%)	☐(5.0%)	☐(4.5%)	☐(1.7%)
Walking distance to and from the stop	☐(14.8%)	☐(4.1%)	☐(5.3%)	☐(4.4%)	☐(1.6%)
Number of changes to other services	☐(17.4%)	☐(3.3%)	☐(2.9%)	☐(3.5%)	☐(2.0%)
Change in bus-stop location due to construction work	☐(15.9%)	☐(2.9%)	☐(3.0%)	☐(4.5%)	☐(4.1%)

Q6.	Which of the following statements describe your action, once you got the information at the start?	☐ I changed the time of departure from my start only (9.1%) ☐ I waited at the start and changed the time of boarding the bus (3.6%) ☐ I looked for a different bus stop or bus route and kept my departure time from start (4.7%) ☐ I rushed to catch the same bus I intended to get (2.1%) ☐ I used the spare time for other activities (1.8%) ☐ I did not change my plan (5.2%)
Q7.	Which of the following statements describes your action, once you got the information en route (at the bus stop or while walking to stop) ?	☐ I waited at the bus stop for the next bus (3.7%) ☐ I took another bus on a different route from the same stop (3.0%) ☐ I walked to a further bus stop of the same route (1.6%) ☐ I walked to a different bus stop and took a different bus route (1.8%) ☐ I did not change my plan (2.1%)

Please go to Q9.

Q8.	Why did you not use mobile apps or websites for this journey as a source of information?	☐ I do not have a smartphone/computer (5.7%) ☐ I think it is difficult to use them/not familiar with the apps or websites (5.4%) ☐ I do not think the information is conveyed in a clear way (2.4%)

	☐ I found the information inaccurate (0.9%) ☐ I do not think I need them as I am familiar with the bus network (20.5%) ☐ Buses are very punctual so I do not need real-time information (10.6%) ☐ Buses are very frequent so missing one is not a big problem (14.5%)
Q9. How would you categorize your journey?	*Trip Length* ☐Very short(5.3%) ☐Short(26.6%) ☐Medium(52.4%) ☐Long(12.7%) ☐Very long(2.4%) *Familiarity of the trip* ☐ Familiar with the route(85.8%) ☐ Unfamiliar with the route(11.4%)
Q10. For this journey, could you have used-	*Different bus routes* ☐ Yes(66.1%) ☐ No(33.2%) *Different alternative modes (walking, cycling etc.)* ☐ Yes(41.0%) ☐ No(56.8%)
Q11. What is the purpose of this journey?	☐ Travelling to or from home, work(42.7%) ☐ Work travel(17.3%) ☐ Shopping(11.2%) ☐ Personal/Family business(17.3%) ☐ Leisure(10.4%)
Q12. How would you classify yourself?	☐ Edinburgh resident(82.8%) ☐ Frequent visitor(11.1%) ☐ Infrequent visitor(2.7%) ☐ Visiting Edinburgh for first time(2.7%)
Q13. What is your educational level?	☐ Grammar school(1.3%) ☐ High School or equivalent(15.1%) ☐ Some college credit, no degree(23.8%) ☐ University degree(50.5%) ☐ Other(6.4%)
Q14. What is your profession	☐ Employed for wages(55.6%) ☐ Self-employed(10.0%) ☐ Some college credit, no degree(2.8%) ☐ Out of work and looking for work(1.6%) ☐ Out of work but not currently looking for work(2.4%) ☐ Homemaker(2.4%) ☐ Student(15.2%) ☐ Retired(10.0%) ☐ Unable to work(0.9%)
Q15. Your gender	☐ Female(54.3%) ☐ Male(44.4%)
Q16. Your age	....

Please provide your Email Address if you are interested in participating in future transport surveys. You have a chance to win one of the two £25 Amazon vouchers!!!!

APPENDIX C

ETHICAL APPROVAL: BUS STOP SURVEY

SEBE RESEARCH & KNOWLEDGE TRANSFER ETHICS AND GOVERNANCE APPROVAL FORM
Section 1 – Research details
Name/s of researcher/s Staff members: MD FAQHRUL ISLAM
Title of project: Impact of Ubiquitous Real Time Passenger Information
Aim of Research The aim of this research is to study the factors that encourage public transport travellers in using URTPI for trip making and to assess the impact of using URTPI on travel choices in particular route choice.
Details of the research methods to be used, please consider all of the following in your response: a. The data will be collected by at stop survey questionnaire. Surveyor will be asking passengers to take part in the survey at the stop. b. Data will be collected using an offline survey tool on Tablets. c. The data will be gathered at the bus stops of Edinburgh d. Students will be appointed as a casual staff to collect the data e. how the data sample will be selected (e.g. random/cluster/sequential/network sampling) f. People who use public transport in Edinburgh are the participant for this survey g. The survey data will be tasted in terms of completion of questions h. if applicable, please attach a copy of the questionnaire/interview questions (for student researchers, please include notification of approval of the questionnaire from your supervisor) A questionnaire along with the supervisors' approval have been attached

Section 2 – Research Subject Details

Will participants be free NOT to take part if they choose?

Yes, they will be free to choose whether to take part or not.

Explain how informed consent will be achieved.

N/A

Will any individual be identifiable in the findings?

The survey will be anonymous; therefore, the participants will not be identifiable.

How will the findings be disseminated?

The findings will be used for writing academic articles.

Is there any possibility of any harm (social, psychological, professional, economic etc) to participants who take part or do not take part? Give details.

There is no potential harm if anyone takes or does not take part in the survey.

How / where will data be stored? Who will have access to it? Will it be secure? How long will the data be kept? What will be done with the data at the end of the project?

The data will be stored on online as well as in the computer. The supervisors will have online access as well. The data will be kept until PhD project is finished.

Any other information in support of your application

Continue to section 3

Section 3 – School Advisors Approval

Delete as appropriate:

I approve this research / I ~~refer this research~~ to the School Research Committee (give reason for referral)

Name of School Advisor

Achille Fonzone

Signature of School Advisor

Date

Signature of researcher/s to confirm understanding and acceptance of Advisor's decision

Date 21.08.2016

Section 4 – School Research Committee Approval

SRC decision APPROVED

Tom Hyde (acting Ethics Officer, SEBE).

Does this issue need to be referred to the UREGC? NO

If YES Secretary to forward to UREGC Secretary for referral with any appropriate paperwork

Date actioned

Reason for referral

Signature of Convener of SRC

Date

Date researcher/s informed of SRC's decision – include copy of email to researcher/s

APPENDIX D

BUS STOP SURVEY SCHEDULE

Table D.1 Bus stop survey schedule

Dates	Survey hours	Bus stops
4th July	11.00-13.00 & 16.00-18.00	Pilrig, Fountain Park, Salisbury road, Lothian road (Pr. Str. west), Princes Str. (Scott Monument)
5th July	07.30-10.30 & 16.00-18.00	Leith Street, Surgeons Hall, Tollcross, Brunton Place, Orwell Place
6th July	07.30-10.30 & 16.00-18.00	Pilrig, Fountain Park, Haymarket, Lothian road (Pr. Str. west), Princes Str. (Scott Monument)
7th July	07.30-10.30 & 16.00-18.00	Leith Street, Surgeons Hall, Tollcross, Brunton Place, Orwell Place
8th July	07.30-10.30 & 11.00-13.00	Pilrig, Fountain Park, Haymarket, Lothian road (Pr. Str. west), Princes Str. (Scott Monument)[1]
9th July	10.30-13.30 & 16.00-18.00	Pilrig, Fountain Park, Haymarket, Lothian road (Pr. Str. west), Princes Str. (Scott Monument)
10th July	10.30-13.30 & 16.00-18.00	Haymarket, Surgeons Hall, Tollcross, Brunton Place, Orwell Place
11th July	07.30-10.30 & 11.00-13.00	Leith Street [1], Princes Str. (Scott Monument), Sighthill, Brunton Place, Orwell Place
12th July	07.30-10.30 & 11.00-13.00	Fountainbridge [1], Surgeons Hall, Usher Hall, Haymarket [1], South Bridge

[1] midday hour was replaced by evening hour (16.00-18.00)

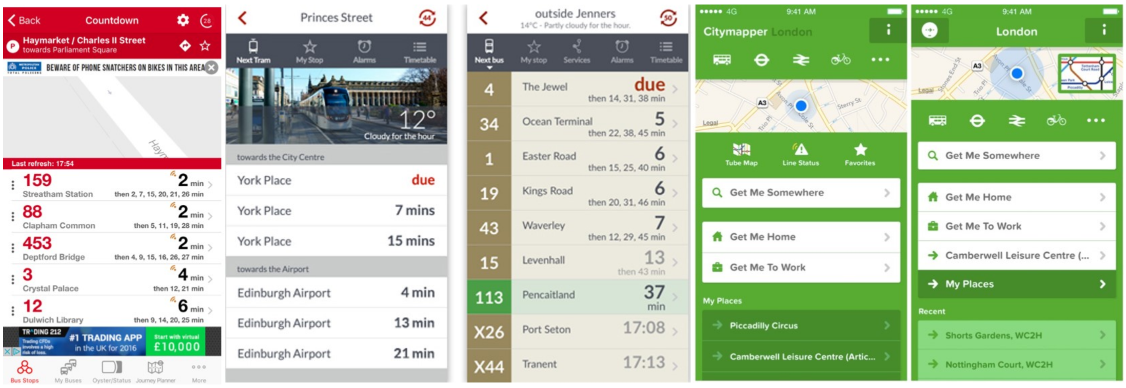
APPENDIX E

ONLINE SURVEY QUESTIONNAIRE

Hello, at Edinburgh Napier University, we are studying the impact of real-time bus passenger information. If you live in the UK and use buses in your city, you are cordially invited to take part in this survey. It will take approximately 12-15 minutes to complete the questionnaire. Your participation in this study is completely voluntary. If you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important for us to learn your opinions. Your collaboration can help us improve the bus services and information provision for passengers. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate form. This survey is completely anonymous and your personal information will be coded and will remain confidential. To appreciate your participation, we will put your name on a raffle draw and you may win one of the two £50 shopping vouchers!!!.

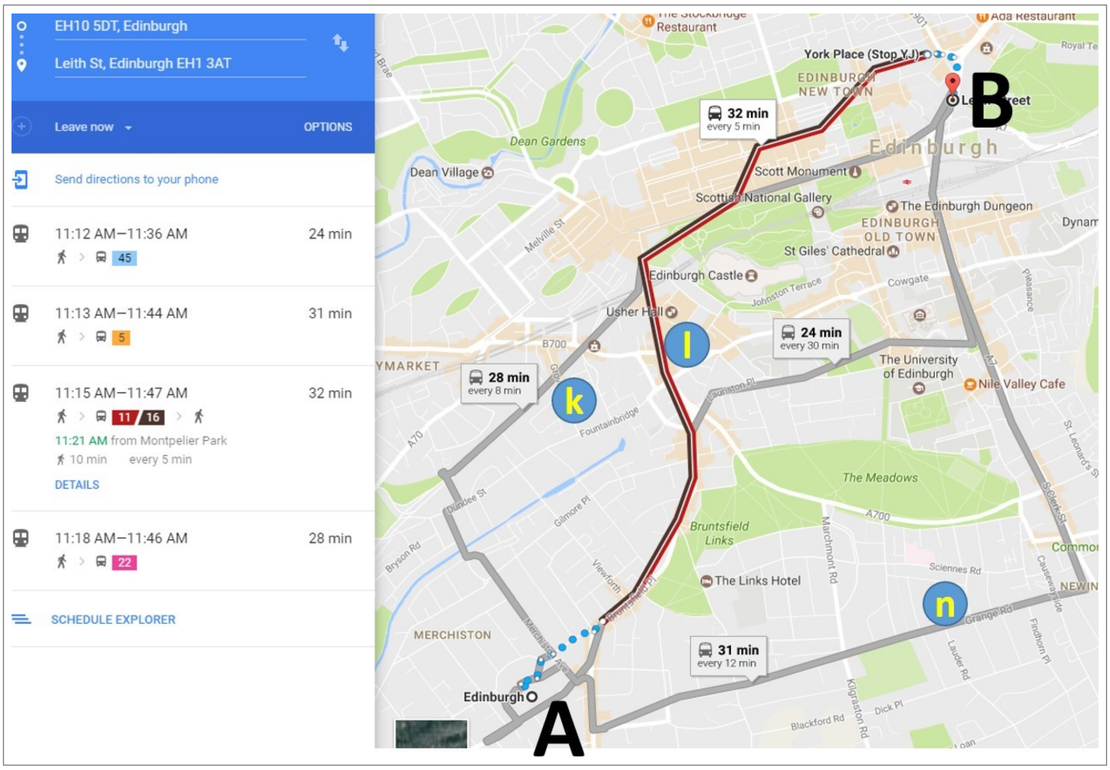
If you have questions at any time about the survey or the procedures, you may contact [Faqhrul Islam] by email [f.islam@napier.ac.uk]. Thank you very much for your time and support. Please answer the questions considering your trips with buses in the last 6 months within your city.

Let us explain some of the terms mentioned in this questionnaire.
URTPI: Ubiquitous real-time passenger information is information you get from apps, websites, or any other mobile sources that provide real-time bus information. The figure below shows examples of URTPI sources.



Start (A): The place* where you were before going to the bus stop.
Destination (B): The final place* you are going to.
*A place can be your home, work, school, a shop, park, garden etc.

Route: The complete path travelled by you from the Start (A) to Destination (B). The figure below shows some examples of available routes. In this figure, available routes are k, l, m, and n. We consider walking as part of the route.



Questions	Options (% responses)
Q1. What sources of information do/did you use for making trips with the buses in your city? Select all that apply. (Valid responses: 752)	☐ None(2.5%) ☐ Printed maps and timetable(23.3%) ☐ Displays at stops(61.4%) ☐ Travel information websites (E.g. TfL website https://tfl.gov.uk/)(37.1%) ☐ Bus tracker apps (provides only arrival time of the next bus)(51.2%) ☐ Journey planner (provides information on the whole journey including alternative routes & modes)(37.1%) ☐ Google maps(45.1%) ☐ Other people's advice(13.3%) ☐ Social networking media (Facebook, Twitter)(4.5%) ☐ Electronic media (Radio, TV)(0.7%) ☐ Other.........
Q2. When travelling by bus in your city, did you access ubiquitous real- time passenger information (URTPI)? URTPI sources are mobile apps, websites, etc. (Valid responses: 639)	☐ Always/very often(36.2%) ☐ Often(22.3%) ☐ Sometimes(17.7%) ☐ Rarely(18.7%) ☐ Never(5.2%)
If 'never' is selected then go to question Q20	
Q3. Please state your opinion regarding the use of information from URTPI sources? (Valid responses: 560)	
	Strongly disagree | Disagree | Neutral | Agree | Strongly agree

	Accessing info is very time-consuming	□(16.5%)	□(46.6%)	□(21.4%)	□(12.1%)	□(3.4%)
	Sources are user-friendly	□(2.0%)	□(6.6%)	□(16.9%)	□(38.7%)	□(10.2%)
	Information is easy to understand	□(2.7%)	□(8.9%)	□(22.7%)	□(52.0%)	□(13..6%)
	Information is reliable	□(2.3%)	□(9.1%)	□(27.4%)	□(50.7%)	□(10.4%)
	Information is useful	□(0.9%)	□(1.6%)	□(15.0%)	□(50.8%)	□(31.7%)

Q4. How often do you access the URTPI sources? (Valid responses: 560)

	Always/ very often	Often	Some-times	Rarely	Never
I access before the trip	□(40.5%)	□(28.3%)	□(19.3%)	□(6.6%)	□(5.3%)
I access en route	□(12.9%)	□(18.9%)	□(32.1%)	□(20.8%)	□(15.3%)

Q5. How often do you use URTPI if the duration of your trips are as follows? (Valid responses: 503)

	Always/ very often	Often	Some-times	Rarely	Never
Trip duration: less than 15 mins	□(25.6%)	□(20.9%)	□(19.1%)	□(18.9%)	□(15.5%)
Trip duration: 16-45 mins	□(38.1%)	□(27.1%)	□(21.4%)	□(6.7%)	□(6.7%)
Trip duration: more than 45 mins	□(41.2%)	□(22.4%)	□(18.0%)	□(9.8%)	□(8.6%)

Q6. Do you use URTPI for the following type of trips? (Valid responses: 501)

	Always/ very often	Often	Some-times	Rarely	Never
Regular or frequent trips	□(30.7%)	□(24.1%)	□(19.7%)	□(13.3%)	□(12.2%)
Occasional or infrequent trips	□(47.1%)	□(24.0%)	□(17.6%)	□(5.6%)	□(5.8%)

Q7. Do you use URTPI, if the bus frequency for your trip is as follows? (Valid responses: 495)

	Always/ very often	Often	Some-times	Rarely	Never
Less than 15 mins	□(27.6%)	□(21.1%)	□(22.7%)	□(13.9%)	□(14.7%)
15-30 Mins	□(38.1%)	□(28.2%)	□(18.9%)	□(7.3%)	□(7.5%)
More than 30 mins	□(47.9%)	□(25.1%)	□(14.5%)	□(5.7%)	□(**6.9**%)

Q8. What makes you use URTPI? Select all that apply. (Valid responses: 473)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Helps to reduce my efforts in planning trips	□(2.7%)	□(4.4%)	□(18.6%)	□(52.2%)	□(22.0%)
Reduces uncertainty about the trip	□(1.3%)	□(3.5%)	□(9.8%)	□(50.1%)	□(35.3%)
Helps me to schedule my activities before leaving my place	□(1.5%)	□(4.4%)	□(15.5%)	□(46.4%)	□(32.2%)
Helps me to execute my trip plan	□(0.8%)	□(2.3%)	□(14.9%)	□(57.3%)	□(24.6%)

	Possible to access info at any place	□(2.3%)	□(5.7%)	□(23.9%)	□(43.9%)	□(24.2%)
	Just because "It is cool"	□(51.4%)	□(22.5%)	□(19.3%)	□(4.9%)	□(1.9%)

Q9. If you have alternative bus routes or modes of transport (walking, cycling or any other), how often do you use URTPI? (Valid responses: 471)

	Always/ very often	Often	Some-times	Rarely	Never
If alternative bus routes are available, I use URTPI	□(22.3%)	□(29.9%)	□(29.0%)	□(9.6%)	□(9.2%)
If alternative modes of transport are available, I use URTPI	□(12.7%)	□(21.7%)	□(30.4%)	□(19.7%)	□(15.5%)

Q10. Please rate the importance of the following forms of information to you (Valid responses: 480):

	Not at all impor-tant	Slightly impor-tant	Important	Very im-portant	Extremely impor-tant
Arrival time of the next bus	□(1.2%)	□(2.7%)	□(17.4%)	□(37.5%)	□(41.2%)
Bus route map	□(3.1%)	□(21.8%)	□(35.1%)	□(27.6%)	□(12.4%)
Expected arrival time at the destination	□(1.7%)	□(17.4%)	□(32.5%)	□(30.8%)	□(17.6%)
Walking time/distance to or from bus stops	□(9.8%)	□(32.2%)	□(35.5%)	□(16.4%)	□(16.4%)
Location of the bus stops	□(3.9%)	□(13.7%)	□(38.2%)	□(24.9%)	□(19.3%)
Entire journey from start to final destination	□(4.2%)	□(26.2%)	□(38.5%)	□(20.9%)	□(10.3%)
Transfers to other bus routes	□(4.2%)	□(23.3%)	□(35.6%)	□(23.3%)	□(13.5%)

Q11. When URTPI provides alternatives to improve your journey experience, how often do you make any change to the following? (Valid responses: 475)

	Always/ very often	Often	Some-times	Rarely	Never
Time of departure from start	□(7.8%)	□(30.3%)	□(42.1%)	□(12.4%)	□(7.4%)
Time of boarding the bus	□(6.5%)	□(24.8%)	□(44.0%)	□(15.8%)	□(8.8%)
Departure bus stop	□(4.8%)	□(17.9%)	□(41.5%)	□(24.2%)	□(11.6%)
Alighting bus stop	□(3.6%)	□(13.9%)	□(41.1%)	□(27.4%)	□(14.1%)
Bus route/line	□(5.3%)	□(15.6%)	□(47.4%)	□(20.4%)	□(11.4%)
Mode of transport	□(3.6%)	□(13.5%)	□(33.1%)	□(31.6%)	□(18.3%)

Q12. How much do these factors influence your choice to improve your journey experience using URTPI? (Valid responses: 392)

	Not at all	Slightly	Mode-rately	Strongly	Very strongly
Frequency of buses in different routes	□(9.1%)	□(12.1%)	□(31.6%)	□(36.4%)	□(10.9%)
Alternative modes of transport	□(18.9%)	□(25.3%)	□(34.2%)	□(15.6%)	□(6.1%)

Q13. If you never change your route choice (departure stop, alighting point, bus routes/line, mode of transport) after obtaining information from URTPI, how well do the following statements describe your action? (Valid responses: 18)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Improvement with the alternatives is not significant	□(0%)	□(5.6%)	□(50.0%)	□(38.9%)	□(5.6%)
Habit/dislike changing	□(5.6%)	□(0.0%)	□(61.1%)	□(16.7%)	□(16.7%)
Do not trust info	□(16.7%)	□(22.2%)	□(61.1%)	□(0.0%)	□(0.0%)

Q14. What do you want to achieve when consulting information from URTPI sources? Please select all that apply from the following (Valid responses: 391)-

	Not at all important	Slightly important	Important	Very important	Extremely important
To reduce total journey time	□(5.1%)	□(24.2%)	□(33.1%)	□(23.5%)	□(14.1%)
To reduce my waiting time at the start (start: where you were before going to the bus stop)	□(4.8%)	□(10.6%)	□(24.4%)	□(33.7%)	□(26.6%)
To reduce my waiting time at the bus stop	□(1.3%)	□(5.0%)	□(21.4%)	□(32.7%)	□(26.6%)
To reduce my physical effort (e.g. walking)	□(36.6%)	□(33.0%)	□(19.1%)	□(7.6%)	□(4.0%)
To reduce the number of changes to other services (e.g. bus, train, etc.)	□(9.4%)	□(15.7%)	□(33.4%)	□(28.1%)	□(13.4%)
To reduce transfer time	□(9.2%)	□(17.1%)	□(30.9%)	□(29.7%)	□(13.0%)
To reduce ticket fares	□(33.2%)	□(18.7%)	□(20.2%)	□(15.1%)	□(12.8%)
To find an alternative plan that offers better journey experience than my original plan	□(10.5%)	□(27.9%)	□(30.8%)	□(20.8%)	□(10.0%)

Q15. What do you want to achieve for each of the followings in order to improve your journey experience using URTPI? Please select all that apply. (Valid responses: 375)

	want to minimize as much as possible	want to keep it satisfactory
Travel time	□(59.6%)	□(40.4%)
Waiting time	□(86.9%)	□(13.1%)
Physical effort	□(18.4%)	□(81.6%)
Delay	□(88.6%)	□(11.4%)
Changes to other services	□(60.6%)	□(39.4%)
Transfer time	□(62.9%)	□(37.1%)
Ticket fares	□(46.8%)	□(53.2%)

Q16. How often do you make changes in the following if you access URTPI en-route and find a better alternative than your original plan? (Valid responses: 328)

	Always/very often	Often	Sometimes	Rarely	Never
I change departure stop	□(4.3%)	□(14.9%)	□(44.2%)	□(28.4%)	□(8.2%)
I change bus route	□(4.3%)	□(19.1%)	□(46.8%)	□(23.4%)	□(6.4%)
I change alighting point	□(3.4%)	□(14.0%)	□(47.0%)	□(29.0%)	□(6.7%)

I change mode of transport	□(3.4%)	□(10.4%)	□(30.6%)	□(37.6%)	□(18.0%)

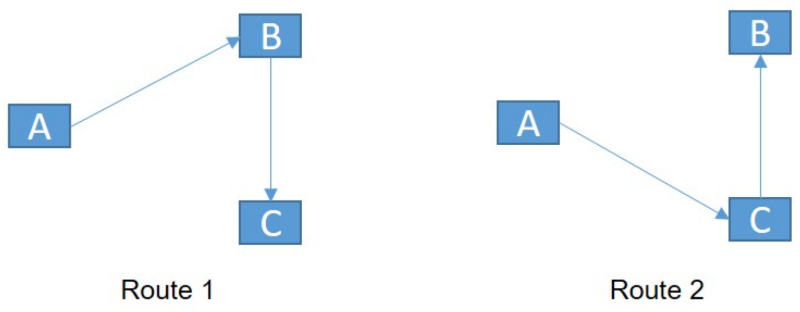
Q17. I prefer information gathered from URTPI to other sources (non-mobile sources, e.g. display at stops, printed timetables, etc.) for the following trips (Valid responses: 375):

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Commute trips	□(4.5%)	□(10.4%)	□(31.2%)	□(33.6%)	□(20.3%)
Work trips (travelling for work, e.g. site visit)	□(4.0%)	□(6.4%)	□(29.8%)	□(39.1%)	□(20.7%)
Leisure trips	□(3.5%)	□(9.0%)	□(31.6%)	□(39.1%)	□(16.8%)
Shopping	□(4.1%)	□(11.4%)	□(39.2%)	□(32.7%)	□(12.7%)
Occasional trips (personal of family business)	□(3.2%)	□(10.7%)	□(33.6%)	□(37.3%)	□(15.2%)

Q18. Please state your level of agreement with the following (Valid responses: 378):

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
People who are most important to me (friends and family), generally use apps (any kind of app) on their phone -	□(5.3%)	□(11.4%)	□(23.0%)	□(43.1%)	□(17.2%)
People who are most important to me (friends and family), use URTPI when travelling by bus-	□(5.0%)	□(15.0%)	□(37.2%)	□(32.5%)	□(10.3%)
URTPI improves my knowledge to make changes for a better journey experience -	□(3.3%)	□(2.5%)	□(18.1%)	□(53.5%)	□(22.6%)
I intend to use URTPI and make changes accordingly if possible when travelling by bus-	□(3.6%)	□(6.4%)	□(19.3%)	□(49.2%)	□(21.5%)

Q19. Imagine you need to travel from A to B and C (figure below) with no preference to go to B or C first. Assuming Route1 was your original plan but URTPI shows a better journey experience for Route 2, how likely would you be to change from Route 1 to Route 2 consulting URTPI? (Valid responses: 375)



	Definitely	Probably	Possibly	Probably not	Definitely not
I would change	□(18.1%)	□(42.9%)	□(30.9%)	□(6.1%)	□(1.9%)

Q20. Generally, when you travel by bus, do you have alternatives in terms of the followings? (Valid responses: 416)

	Not at all	Very few	A few	Quite a few	Many
Bus line/routes	☐(8.7%)	☐(29.8%)	☐(38.7%)	☐(16.8%)	☐(6.0%)
Frequent buses	☐(7.0%)	☐(24.8%)	☐(34.6%)	☐(24.5%)	☐(9.1%)

For users of URTPI, go to question Q26., for non users go to Q21

Q21. Why do you not use ubiquitous sources of information when making trips with buses? (Valid responses: 47)

- ☐ I do not have a device to use URTPI (Smartphone, PC, iPads, Tabs, etc.)(21.3%)
- ☐ I do not want to use a data connection on my phone(25.5%)
- ☐ Information is not available in my area(17.0%)
- ☐ I am not familiar with the apps or websites(21.3%)
- ☐ I do not think I need them as I am familiar with the bus network(31.9%)
- ☐ Buses are very punctual so I do not need real-time information(6.5%)
- ☐ Buses are very frequent so missing one is not a big problem(17.0%)

Q22. Please state your level of agreement with the following (Valid responses: 43):

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
People who are most important to me (friends and family), generally use apps (any kind of app) on their phone -	☐(11.6%)	☐(11.6%)	☐(27.9%)	☐(37.2%)	☐(11.6%)
People who are most important to me (friends and family), use URTPI when travelling by bus-	☐(27.3%)	☐(31.8%)	☐(27.3%)	☐(9.1%)	☐(4.5%)

Q23. Which of the following statements describe your willingness to use ubiquitous sources of information (if possible for you) for making trips with buses? (Valid responses: 45)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I am likely to use-	☐(15.6%)	☐(20.0%)	☐(31.1%)	☐(31.1%)	☐(2.2%)

Q24. Would you consider using URTPI if you have alternative bus routes or modes of transport to make a trip? (Valid responses: 45)

	Definitely	Probably	Possibly	Probably not	Definitely not
I would use URTPI if alternative bus are routes available	☐(4.3%)	☐(30.4%)	☐(32.6%)	☐(21.7%)	☐(10.9%)
I would use URTPI if alternative modes are available	☐(6.8%)	☐(20.5%)	☐(34.1%)	☐(22.7%)	☐(15.9%)

Q25. When you travel by bus, how often do you make any change to the following? (Valid responses: 47)

	Always	Very Often	Sometimes	Rarely	Never
Time of departure from start	☐(2.1%)	☐(29.8%)	☐(44.7%)	☐(23.4%)	☐(0.0%)
Boarding time of bus	☐(4.3%)	☐(29.8%)	☐(48.9%)	☐(17.0%)	☐(0.0%)
Departure bus stop	☐(4.3%)	☐(14.9%)	☐(40.4%)	☐(34.0%)	☐(6.4%)
Alighting bus stop	☐(2.2%)	☐(8.7%)	☐(45.7%)	☐(34.8%)	☐(8.7%)
Bus route/line	☐(2.1%)	☐(10.6%)	☐(25.5%)	☐(56.8%)	☐(14.9%)
Mode of transport	☐(6.3%)	☐(18.8%)	☐(31.3%)	☐(37.5%)	☐(6.3%)

Q26. If you are making a trip with a combination of modes along with buses (apart from walking) such as train, tram, park and ride, etc., are you more interested in using URTPI? (Valid responses: 368)

	Definitely	Probably	Possibly	Probably not	Definitely not
I use URTPI	☐(29.1%)	☐(30.2%)	☐(27.7%)	☐(9.0%)	☐(4.1%)

Q27. How many trips (approximately) do you make every week with buses for the following purposes? (Valid responses: 401)

	Less than 2	2-4	5-7	8-10	More than 10
Commute trips	☐(49.4%)	☐(16.0%)	☐(14.7%)	☐(13.7%)	☐(6.2%)
Work trips (travelling for work, e.g. site visit)	☐(69.8%)	☐(12.3%)	☐(8.6%)	☐(4.4%)	☐(4.9%)
Leisure trips	☐(54.8%)	☐(33.6%)	☐(7.2%)	☐(2.5%)	☐(2.0%)
Shopping	☐(72.7%)	☐(21.1%)	☐(4.0%)	☐(1.3%)	☐(1.0%)
Occasional trips (personal of family business)	☐(70.5%)	☐(22.8%)	☐(3.8%)	☐(1.5%)	☐(1.5%)

Q28. Your gender? (Valid responses: 403)

☐ Female(46.4%)
☐ Male(53.1%)
☐ Other(0.5%)

Q29. What is your highest educational qualification? (Valid responses: 405)

☐ Grammar school(0.5%)
☐ High School or equivalent(7.4%)
☐ Some college credit, no degree(11.6%)
☐ University degree(73.8%)
☐ Other(6.7%)

Q30. What is your profession? (Valid responses: 406)

☐ Employed for wages(74.0%)
☐ Self-employed(2.2%)
☐ Out of work and looking for work(1.0%)
☐ Out of work but not currently looking for work(0.5%)
☐ Homemaker(0.5%)
☐ Student(17.2%)
☐ Retired(7.4%)
☐ Unable to work(0.7%)

Q31. Your age? (Valid responses: 383) ......

Q32. Please state if you have any long standing disability. (Valid responses: 16) ......

Q33.	Please state the first part of your postcode (Valid responses: 385):	......
Q34.	If you have any other comments/suggestions, please state below:	......
Q35.	Please provide your email address and you have a chance to win one of the two £50 shopping vouchers!!!!	......

APPENDIX F

ETHICAL APPROVAL: ONLINE SURVEY

SEBE RESEARCH INTEGRITY PROCEDURE ETHICS APPROVAL FORM FOR STUDENT USE	
Please complete sections 1 and 2 and sign in section 3, confirming whether you are self-certifying (in which case simply retain a copy of this form with your research materials) or referring the matter to the school academic lead on Research Integrity.	
Section 1 – Research details	
Student name and number	MD FAQHRUL ISLAM 40200070
Supervisor	
Module leader	Dr Achille Fonzone
Module number and name	PhD project
Title of project Impact of Ubiquitous Real Time Passenger Information	
Aim of research The aim of this research is to study the factors that encourage public transport travellers in using URTPI for trip making and to assess the impact of using URTPI on travel choices, in particular route choice.	
Details of the research methods to be used. Please consider all of the following in your response: a. The data will be collected by an online survey. b. Data will be collected using an online survey platform. c. People who live in the UK and use bus within their city, are the targeted participant for this survey d. The survey data will be tested in terms of completion of questions e. A questionnaire along with the supervisors' approval have been attached	

Who/what will be the research subjects in the research? a. Staff/Students of Edinburgh Napier (please give details) UK bus passengers will be the research subjects. b. Vulnerable individuals (please give details e.g. school children, elderly, disabled) N/A c. All other research subjects (please give details). N/A

Section 2 – Research Subject Details
Will participants be free NOT to take part if they choose? Yes, they will be free to choose whether to take part or not.
Explain how informed consent will be achieved. Participants will be informed about the aim and type of research in the beginning of the survey. They have to click "I want to participate" for taking part in the survey.
If you plan to use assumed consent rather than informed consent please outline why this is necessary. N/A
Will any individual be identifiable in the findings? The survey will be anonymous; therefore, the participants will not be identifiable. However, if they want to participate in the prize draw, they have to provide their email address.
How will the findings be disseminated? The findings will be used for writing academic articles.
Is there any possibility of any harm (social, psychological, professional, economic, etc.) to participants who take part or do not take part? If so, give details of the potential harm and the mitigation strategies you have adopted. Participation in this survey is voluntary. There is no potential harm if anyone takes or does not take part in the survey.
How / where will data be stored? Who will have access to it? Will it be secure? How long will the data be kept? What will be done with the data at the end of the project? The data will be stored online as well as in the computer. The supervisors will have online access as well. The data will be kept for the next few years as long as it requires to achieve the research objectives. Some aggregated data will be kept for future use as well.
If payment or reward will be made to participants please justify that the amount and type are appropriate.

Approved Oct 2016 p2 of 4

Any other information in support of your application.

Section 3 – Self-certification (to be signed by both student and module leader or dissertation supervisor)
Delete as appropriate: I confirm that I have completed the self-certification checklist and have not identified any ethical issues requiring approval. OR I ~~refer this research to the school lead on Research Integrity (give reason).~~

	Student	Module leader or dissertation supervisor
Signature	[signature]	
Name	MD FAQHRUL ISLAM	Dr Achille Fonzone [signature]
Date	27.03.17.	29.03.17

If you have self-certified that best practice has been followed and no ethical issues have been identified, please sign the form and retain with your research materials.

If you need to refer the matter to the school lead on Research Integrity, please sign and email to Dr Jason Monios: j.monios@napier.ac.uk. In most cases Jason will be able to provide guidance and approve the research, but in some cases he may need to take the matter to the next meeting of the school Research and Innovation Committee. Exceptionally, the matter may be referred to the University Research Integrity Committee.

Approved Oct 2016 p3 of 4

Section 4 – Approval by school lead on Research Integrity (if applicable)	
Delete as appropriate: I approve this research OR I refer this research to the School Research and Innovation Committee (give reason)	
Signature	
Name	
Date	

Section 5 – School Research and Innovation Committee Approval (if applicable)
SRIC decision
Does this issue need to be referred to the URIC? If YES Secretary to forward to URIC Secretary for referral with any appropriate paperwork Date actioned
Reason for referral
Signature of Convener of SRIC Name Date
Date researcher informed of SRIC's decision

Approved Oct 2016 p4 of 4

APPENDIX G

BUS STOP SURVEY: MODEL RESULTS

Table G.1 Factors affecting the use of URTPI: Binomial logit model results

Variables	Levels	β	S.E.	Sig. (P)	Exp(β)	95% C.I.for EXP(B)	
						Lower	Upper
Trip length (reference: very short)	Short	1.233	0.380	0.001	3.432	1.628	7.232
	Medium	1.808	0.374	0.001	6.096	2.931	12.679
	Long	1.558	0.414	0.001	4.752	2.111	10.696
	Very long	1.374	0.543	0.011	3.953	1.364	11.456
Time of day (reference: midday)	Morning peak	-0.163	0.168	0.333	0.850	0.611	1.182
	Evening peak	-0.056	0.168	0.739	0.946	0.680	1.315
Trip purpose (reference: commute trips)	Work travel	0.312	0.184	0.089	1.366	0.953	1.958
	Shopping	-0.244	0.252	0.331	0.783	0.478	1.282
	P/F business	-0.012	0.199	0.953	0.988	0.669	1.459
	Leisure	0.516	0.258	0.045	1.676	1.012	2.777
Familiarity of trip (reference: familiar)	Unfamiliar	-0.546	0.243	0.025	0.579	0.360	0.933
Alternative bus route (reference: not available)	Available	0.185	0.138	0.180	1.204	0.918	1.578
Alternative mode (reference: not available)	Available	-0.329	0.141	0.020	0.720	0.546	0.949
Age (Reference: (>65)	18-25	1.726	0.525	0.001	5.619	2.008	15.725
	26-35	1.389	0.517	0.007	4.011	1.455	11.052
	36-45	1.316	0.519	0.011	3.729	1.349	10.305
	46-55	1.229	0.521	0.018	3.417	1.231	9.485
	56-65	0.206	0.502	0.682	1.229	.459	3.290
Profession (reference: Retired/unable to work)	Employed for wages	1.423	0.433	0.001	4.148	1.774	9.696
	Self employed	1.718	0.458	0.001	5.574	2.273	13.666
	Out of Work	1.259	0.523	0.016	3.523	1.265	9.813
	Homeworker	1.455	0.600	0.015	4.285	1.322	13.894
	Student	1.907	0.476	0.001	6.735	2.652	17.103
Gender (reference: female)	Male	0.114	0.129	0.377	1.121	0.870	1.445

Continued on next page

Table G.1 *Continued from previous page*

Variables	Levels	β	S.E.	Sig. (P)	Exp(β)	95% C.I.for Exp(β)	
						Lower	Upper
Education (reference: grammar school	High school	0.352	0.842	0.676	1.421	0.273	7.398
	Some college degree	0.772	0.835	0.355	2.164	0.421	11.128
	University degree	1.028	0.831	0.216	2.795	0.548	14.252
Residence (reference: Edinburgh resident	Frequent visitor	-0.668	0.207	0.001	0.513	0.341	0.770
	Infrequent visitor	-0.114	0.528	0.828	0.892	0.317	2.509
	First time visitor	-0.353	0.434	0.415	0.702	0.300	1.644

Table G.2 Factors affecting passenger preference of URTPI sources: MNL model results

Dependent variable reference: Mobile apps

	Variables	Levels	β	S.E.	Sig. (P)	Exp(β)	95% C.I.for EXP(B)	
							Lower	Upper
Google Maps	Trip length (reference: very short)	Short	0.058	0.777	0.940	1.060	0.231	4.862
		Medium	-0.313	0.758	0.680	0.731	0.166	3.229
		Long	-1.032	0.847	0.223	0.356	0.068	1.873
		Very long	-0.607	1.100	0.582	0.545	0.063	4.470
	Time of day (reference: Morning)	Midday	0.656	0.322	0.042	1.926	1.025	3.622
		Evening peak	-0.466	0.337	0.167	0.628	0.324	1.215
	Trip purpose (reference: commute trips)	Work travel	0.433	0.343	0.207	1.542	0.787	3.021
		Shopping	-0.228	0.521	0.662	0.796	0.287	2.211
		P/F business	-0.549	0.470	0.242	0.578	0.230	1.450
		Leisure	0.039	0.451	0.931	1.040	0.429	2.518
	Familiarity of trip (reference: familiar)	Unfamiliar	-2.279	0.360	0.000	0.102	0.051	0.207
	Alternative bus line(reference: not available)	Available	-0.111	0.296	0.707	0.895	0.500	1.599
	Alternative mode (reference: not available)	Available	0.083	0.282	0.769	1.086	0.625	1.887
	Gender (reference: female)	Male	-0.591	0.267	0.027	0.554	0.328	0.934
	Residence (reference: Edinburgh resident)	Frequent visitor	1.312	0.443	0.003	3.715	1.560	8.847
		Infrequent visitor	1.074	0.705	0.128	2.928	0.735	11.667
		First time visitor	1.888	0.599	0.002	6.609	2.041	21.394

Continued on next page

Table G.2 *Continued from previous page*

	Variables	Levels	β	S.E.	Sig. (P)	Exp(β)	95% C.I.for EXP(B)	
							Lower	Upper
Travel websites	Trip length (reference: very short)	Short	-0.475	0.498	0.340	0.622	0.235	1.650
		Medium	-0.677	0.479	0.158	0.508	0.199	1.300
		Long	-0.164	0.531	0.758	0.849	0.300	2.404
		Very long	-1.117	0.745	0.134	0.327	0.076	1.410
	Time of day (reference: Morning)	Midday	0.703	0.247	0.005	2.019	1.243	3.280
		Evening peak	0.266	0.223	0.233	1.305	0.843	2.020
	Trip purpose (reference: commute trips)	Work travel	0.507	0.246	0.039	1.660	1.026	2.686
		Shopping	-0.295	0.361	0.413	0.744	0.367	1.510
		P/F business	0.036	0.288	0.900	1.037	0.590	1.824
		Leisure	-0.123	0.362	0.733	0.884	0.435	1.797
	Familiarity of trip (reference: familiar)	Unfamiliar	-0.877	0.327	0.007	0.416	0.219	0.790
	Alternative bus line (reference: not available)	Available	0.318	0.198	0.109	1.375	0.932	2.028
	Alternative mode (reference: not available)	Available	-0.137	0.196	0.485	0.872	0.593	1.281
	Gender (reference: female)	Male	0.062	0.188	0.742	1.064	0.736	1.538
	Residence (reference: Edinburgh resident)	Frequent visitor	1.032	0.343	0.003	2.806	1.432	5.496
		Infrequent visitor	0.019	0.753	0.979	1.020	0.233	4.458
		First time visitor	-0.690	0.872	0.429	0.501	0.091	2.772
Multiple sources	Trip length (reference: very short)	Short	0.848	0.802	0.290	2.336	0.485	11.25
		Medium	1.296	0.784	0.098	3.656	0.787	16.98
		Long	1.349	0.820	0.100	3.854	0.773	19.21
		Very long	0.351	1.027	0.732	1.421	0.190	10.63
	Time of day (reference: Morning)	Midday	0.451	0.238	0.058	1.571	0.984	2.506
		Evening peak	-0.097	0.221	0.659	0.907	0.588	1.399
	Trip purpose (reference: commute trips)	Work travel	0.163	0.263	0.535	1.177	0.703	1.970
		Shopping	0.200	0.337	0.553	1.221	0.631	2.365
		P/F business	0.381	0.270	0.158	1.464	0.862	2.484
		Leisure	0.556	0.316	0.078	1.744	0.939	3.237
	Familiarity of trip (reference: familiar)	Unfamiliar	-0.502	0.336	0.135	0.605	0.313	1.169
	Alternative bus route (reference: not available)	Available	-0.344	0.209	0.099	0.709	0.471	1.067

Continued on next page

Table G.2 *Continued from previous page*

Variables	Levels	β	S.E.	Sig. (P)	Exp(β)	95% C.I.for EXP(B) Lower	95% C.I.for EXP(B) Upper
Alternative mode (reference: not available)	Available	0.116	0.193	0.548	1.123	0.769	1.641
Gender (reference: female)	Male	0.105	0.184	0.567	1.111	0.775	1.593
Residence (reference: Edinburgh resident)	Frequent visitor	0.785	0.362	0.030	2.192	1.079	4.451
	Infrequent visitor	0.990	0.639	0.121	2.692	0.769	9.418
	First time visitor	0.060	0.704	0.932	1.062	0.267	4.222

APPENDIX H

BUS STOP SURVEY: CATREG PLOTS

Table H.1 Categories of levels of independent variables in CATREG plots

	Variables[1]	Levels
Trip characteristics	Trip length	1- very short, 2- short, 3- medium, 4- long, 5- very long
	Time of day	1- midday, 2- evening, 3- morning
	Trip purpose	1- commute, 2- work travel, 3- shopping, 4- p/f business, 5- leisure
	Familiarity of trip	1- familiar, 2- unfamiliar
	Alternative mode	1- no alternative available, 2-alternative available
	Alternative route	1- no alternative available, 2-alternative available
Demographics	Age	1- [18-25], 2- [26-35], 3- [36-45], 4- [46-55], 5- [56-65], 6- [>65]
	Profession	1- employed for wages, 2- self employed, 3- out of work, 4- homeworker, 5- student, 6- retired/unable to work
	Gender	1- female, 2- male
	Education	1-grammar school, 2- high school or equivalent, 3- some college credit, no degree, 4- university degree
	Residence	1- Edinburgh resident, 2- frequent visitor, 3- infrequent visitor, 4- visiting for first time
Imp. of contents of Information	Bus arrival time	1- not important, 2- slightly important, 3- important, 4- very important, 5- extremely Important
	Bus route map	
	Bus stop location	
	Journey plan	
	Transfers to other services	
Trip planning objectives	Journey time or ETA	Scores obtained from PCA
	Physical or cognitive efforts	

[1] All variables are used to model passengers' choices. Models for contents of information are developed with only trip characteristics and demographics

CATREG Plot Interpretation: Taking the beta value into account, Figures presented below are investigated to examine the changes in quantifications for different categories of the factors. If the beta value is positive, then the importance of information changes proportionally to the quantifications. On the other hand, negative beta value implies that the change is inversely related to the quantifications.

Factors Affecting the Importance of Contents of Information

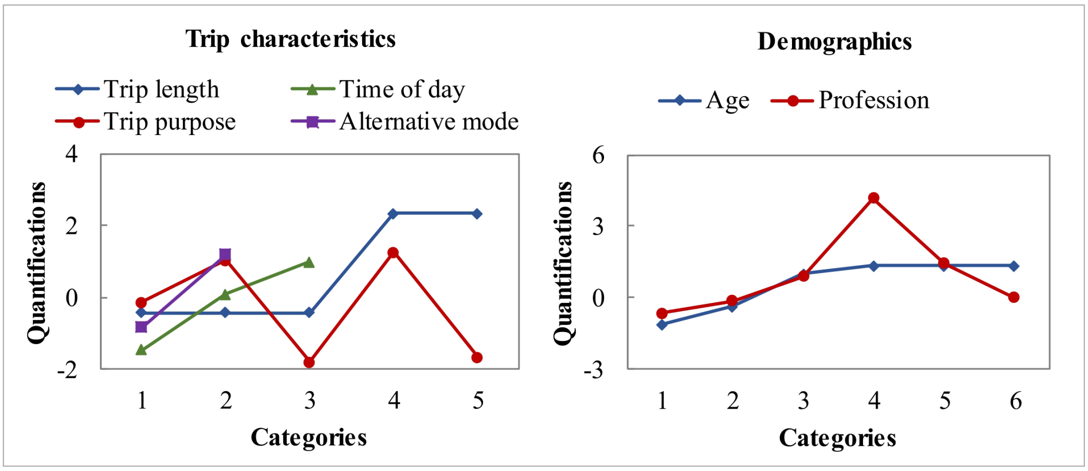


Figure H.1 Factors affecting the importance of *Bus arrival time*: CATREG plots

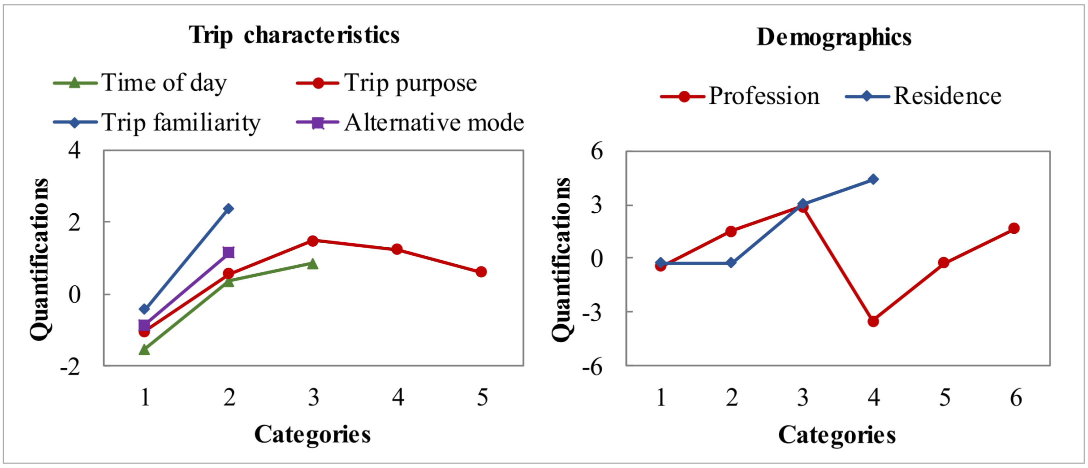


Figure H.2 Factors affecting the importance of *Bus route map*: CATREG plots

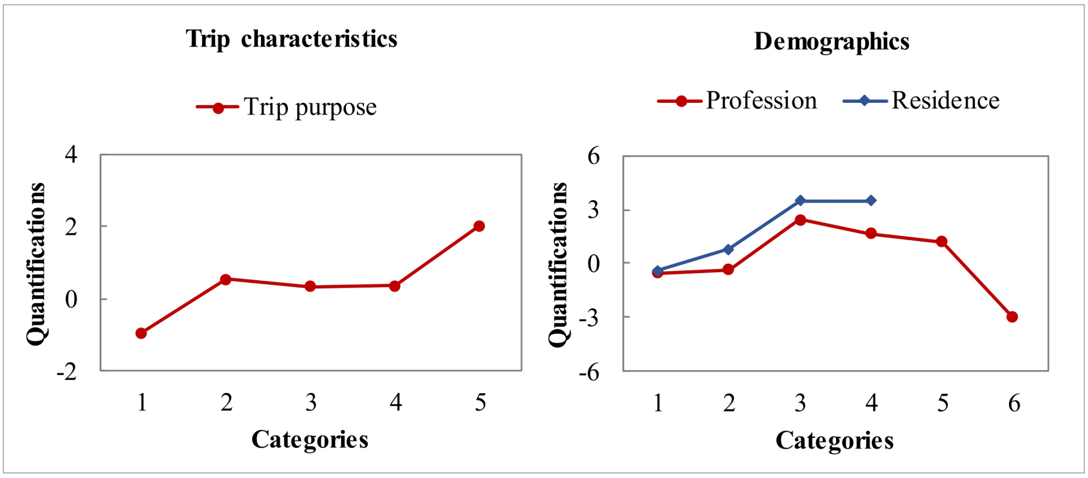


Figure H.3 Factors affecting the importance of *Bus stop location*: CATREG plots

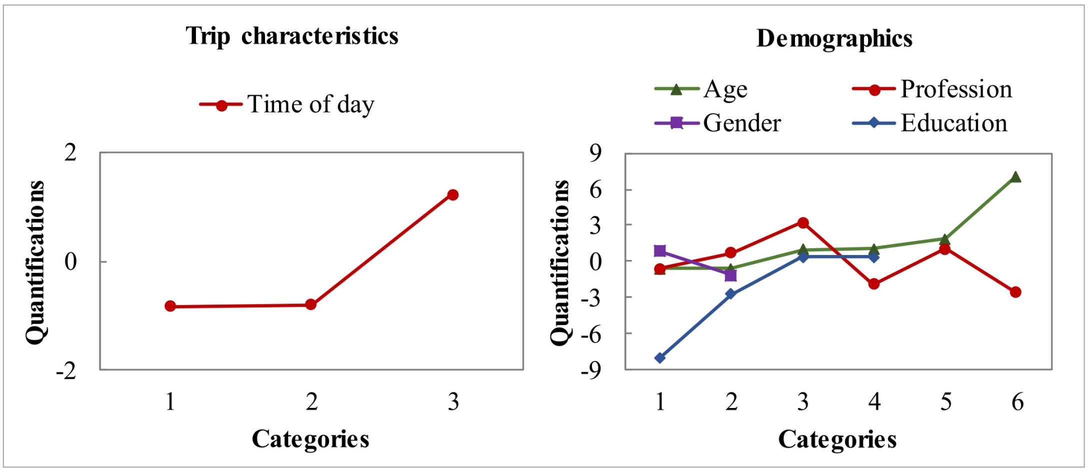


Figure H.4 Factors affecting the importance of *Journey planning*: CATREG plots

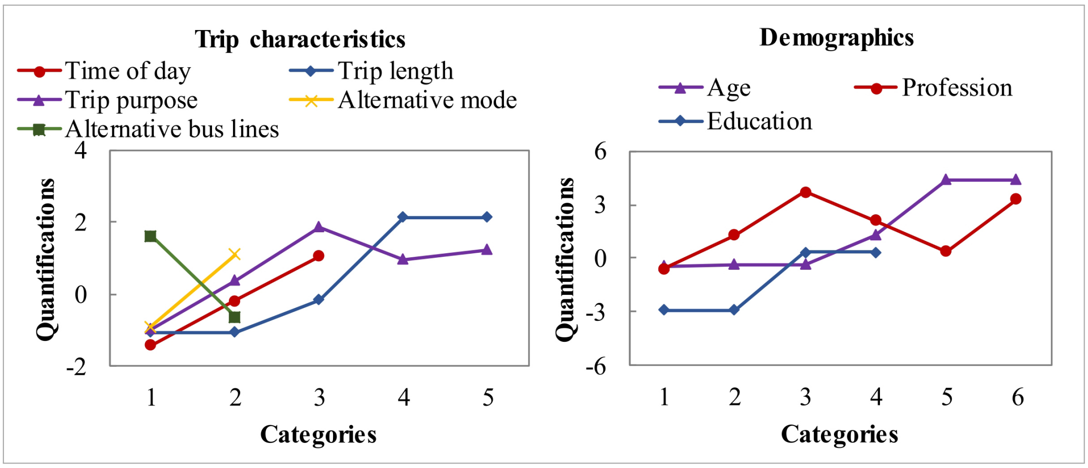


Figure H.5 Factors affecting the importance of *Transfer to other services*: CATREG plots

Factors affecting passengers' choices

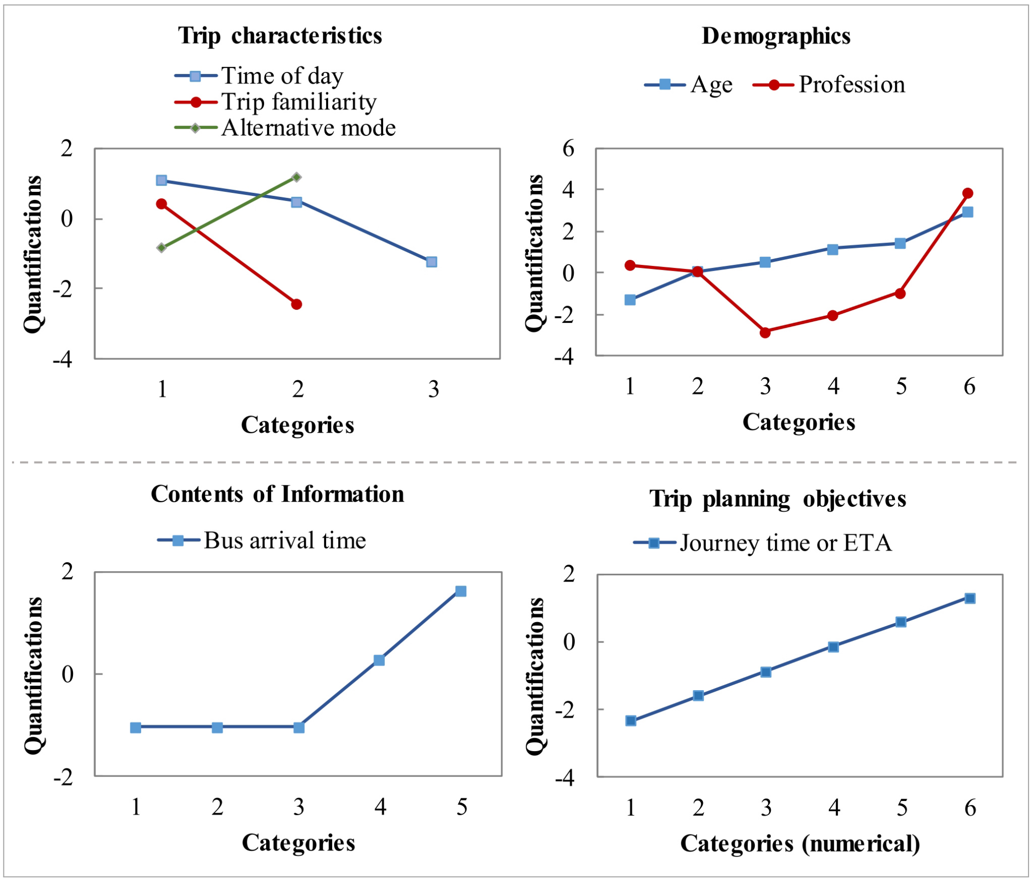


Figure H.6 Factors affecting the change in *Time of departure*: CATREG plots

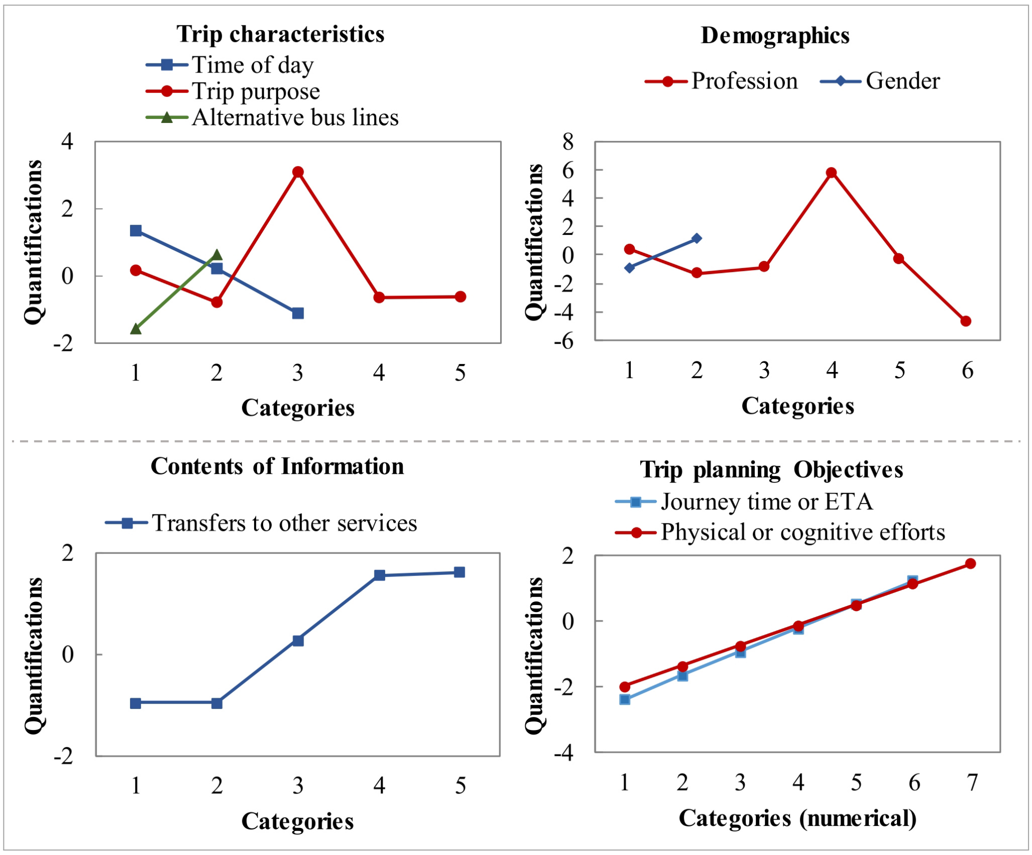


Figure H.7 Factors affecting the change of *Boarding time*: CATREG plots

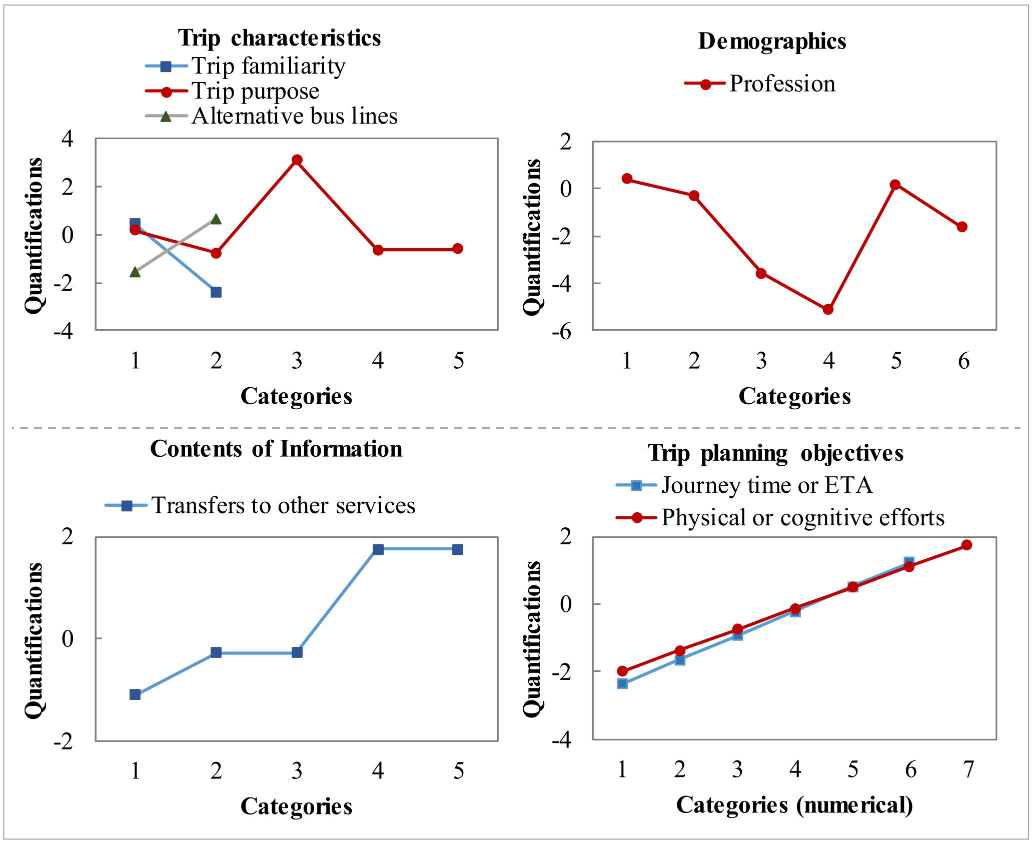


Figure H.8 Factors affecting the change of *Departure stop*: CATREG plots

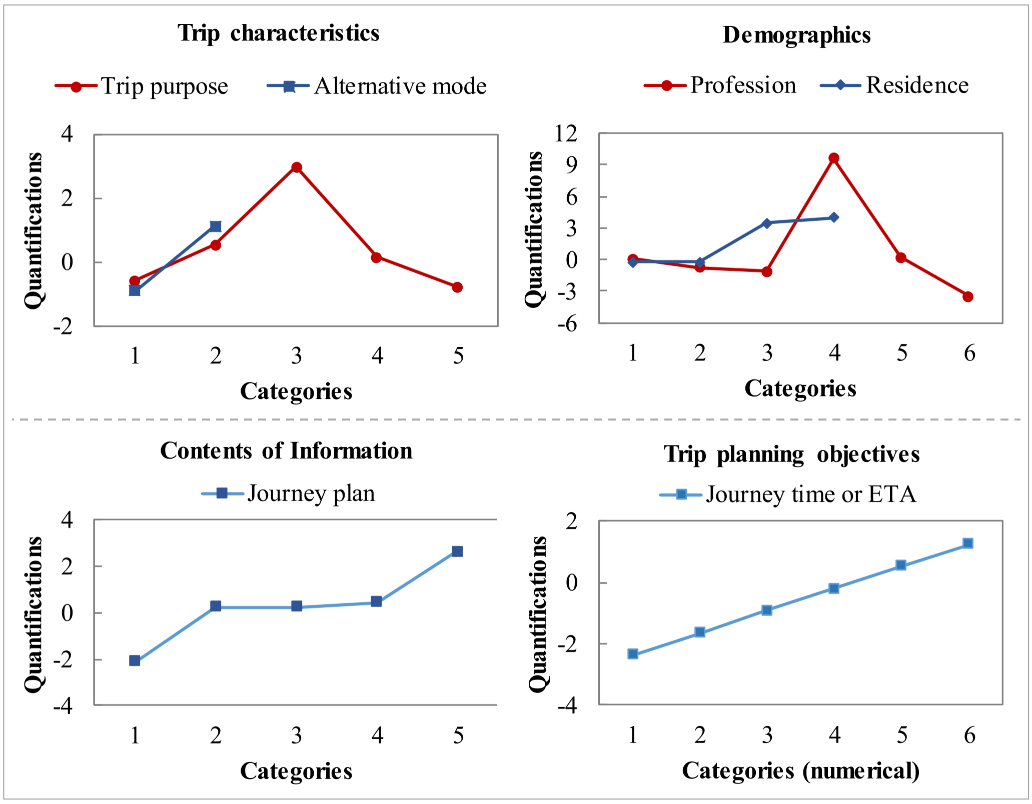


Figure H.9 Factors affecting the change of *Alighting stop*: CATREG plots

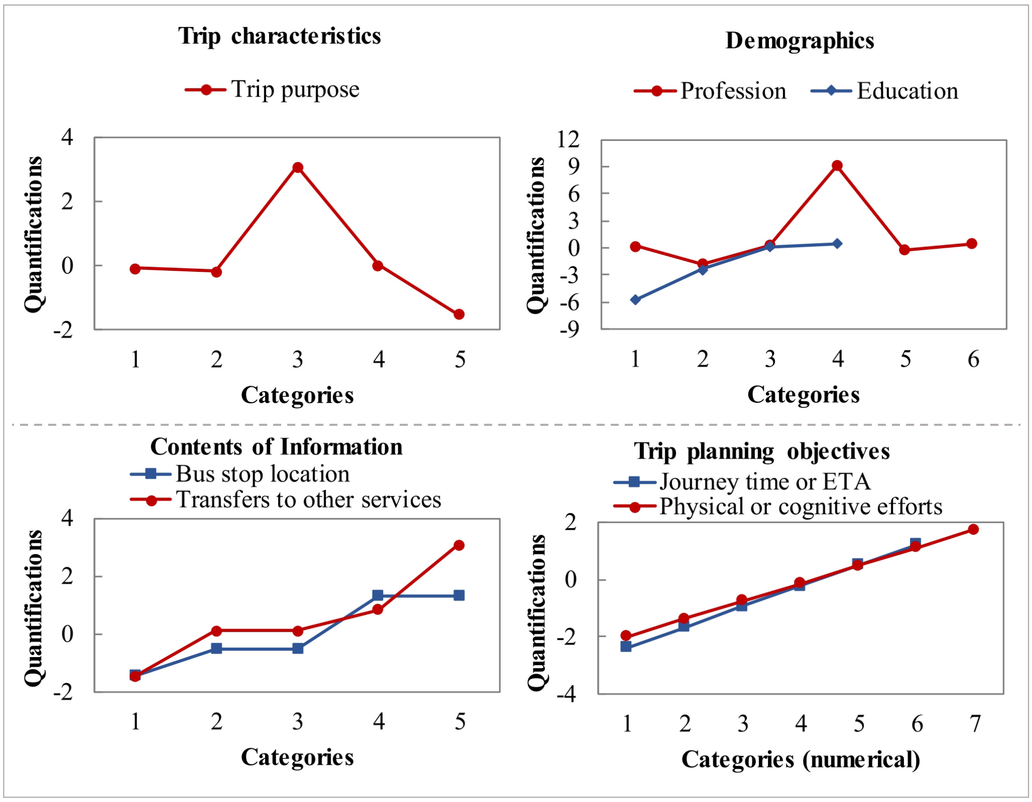
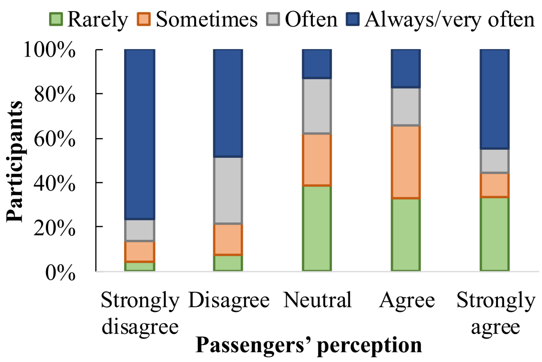
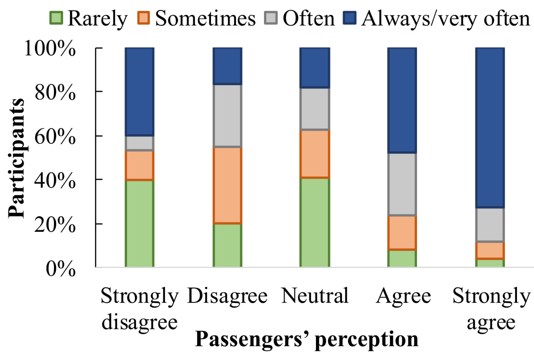


Figure H.10 Factors affecting the change of *Bus line*: CATREG plots

APPENDIX **I**

FREQUENCY OF USE VS ATTRIBUTES OF INFORMATION

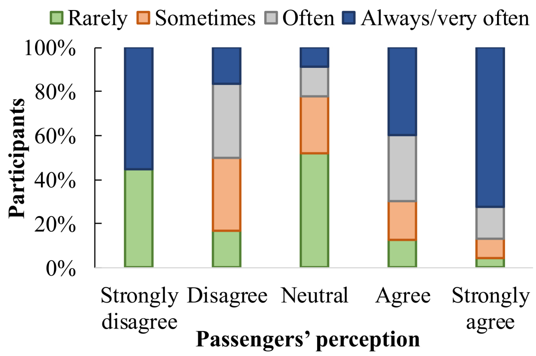


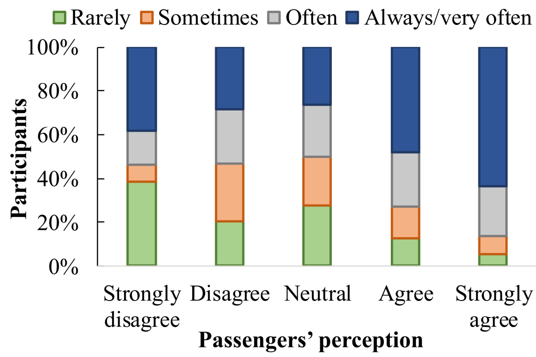


Chi squared test: x^2=159.31, p=0.001 **Chi squared test: x^2=134.83, p=0.001**

(a) Time consuming vs frequency of use (b) User friendly vs frequency of use

Figure I.1 Cross-tab: Frequency of use Vs time consumption and user friendliness

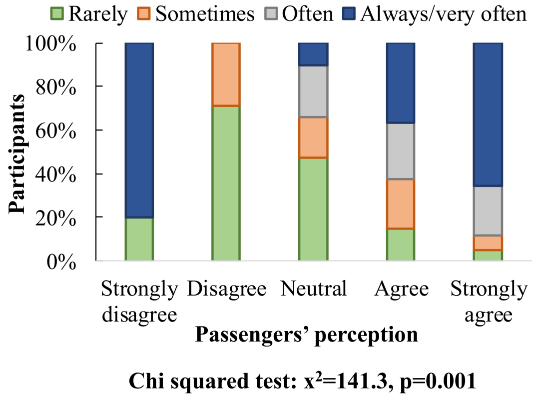




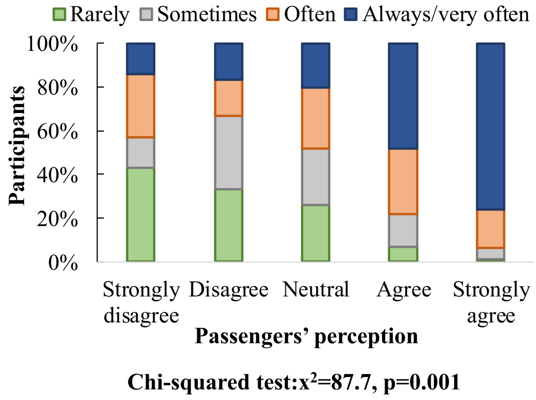
Chi squared test: x^2=158.2, p=0.001 **Chi squared test: x^2=51.6, p=0.001**

(a) Understandability vs frequency of use (b) Reliability vs frequency of use

Figure I.2 Cross-tab: Frequency of use Vs understandability and reliability



(a) Usefulness vs frequency of use



(b) Remote accessibility vs frequency of use

Figure I.3 Cross-tab: Frequency of use Vs usefulness and remote accessibility

APPENDIX J

COMBINING VARIABLES

Table J.1 Combining variables related to attributes of information by PCA

Factor loadings: Pattern matrix with promax rotation

Variables (Appendix E- Q3 & Q8)	Dimension		
	1	2	3
Time consuming	-0.807		
User friendly	0.901		
Understandability	0.882		
Usefulness		0.769	
Reliability		1.014	
Remote accessibility			0.945
	Ease of use	Quality of info	Remote accessibility

Table J.2 Combining variables related to benefits of using URTPI by PCA

Factor loadings: Pattern matrix with oblimin rotation

Variables (Appendix E- Q8)	Dimension		
	1	2	3
Helps to reduce my trip planning efforts			0.995
Reduces uncertainty about the trip	0.825		
Helps me to schedule my activities before leaving my place	0.928		
Helps me to execute my trip plan	0.988		
Just because“It is cool”		1.012	
	Executing trips	General attractiveness “Coolness”	Trip planning efforts

Table J.3 Combining variables related to trip planning objectives by PCA

Factor loadings: Pattern matrix with promax rotation

Variables (Appendix E- Q14)	Dimension			
	1	2	3	4
Reduce total journey time			0.938	
Reduce waiting time at the start		0.876		
Reduce waiting time at the bus stop		0.912		
Reduce physical effort (eg. walking)				0.949
Reduce transfers to other services	0.893			
Reduce transfer time	0.820			
Find alternative plans for better journey experience	0.712			
	Transfers and alter-natives	Reduce waiting time	Reduce Journey time	Reduce physical effort

Table J.4 Combining variables related to optimisation strategies by PCA

Factor loadings: Rotated component matrix with varimax rotation

Variables (Appendix E - Q15)	Dimension		
	1	2	3
Travel time			
Waiting time		0.932	
Physical effort			0.969
Transfers to other services	0.847		
Transfer time	0.800		
	Transfers	Waiting time	Physical effort

Table J.5 Combining variables related to trips per week by PCA

Factor loadings: Pattern matrix with Promax Rotation		
Variables (Appendix E- Q27)	Dimension	
	1	2
Commute trips		0.799
Work trips (travelling for work, e.g site visit)		0.814
Leisure trips	0.925	
Shopping	0.882	
Occasional trips (personal or family business)	0.928	
	Flexible trips or non-commute trips	Commute or work trips

APPENDIX K

ONLINE SURVEY: CATREG PLOTS

Factors Affecting the frequency of use of URTPI

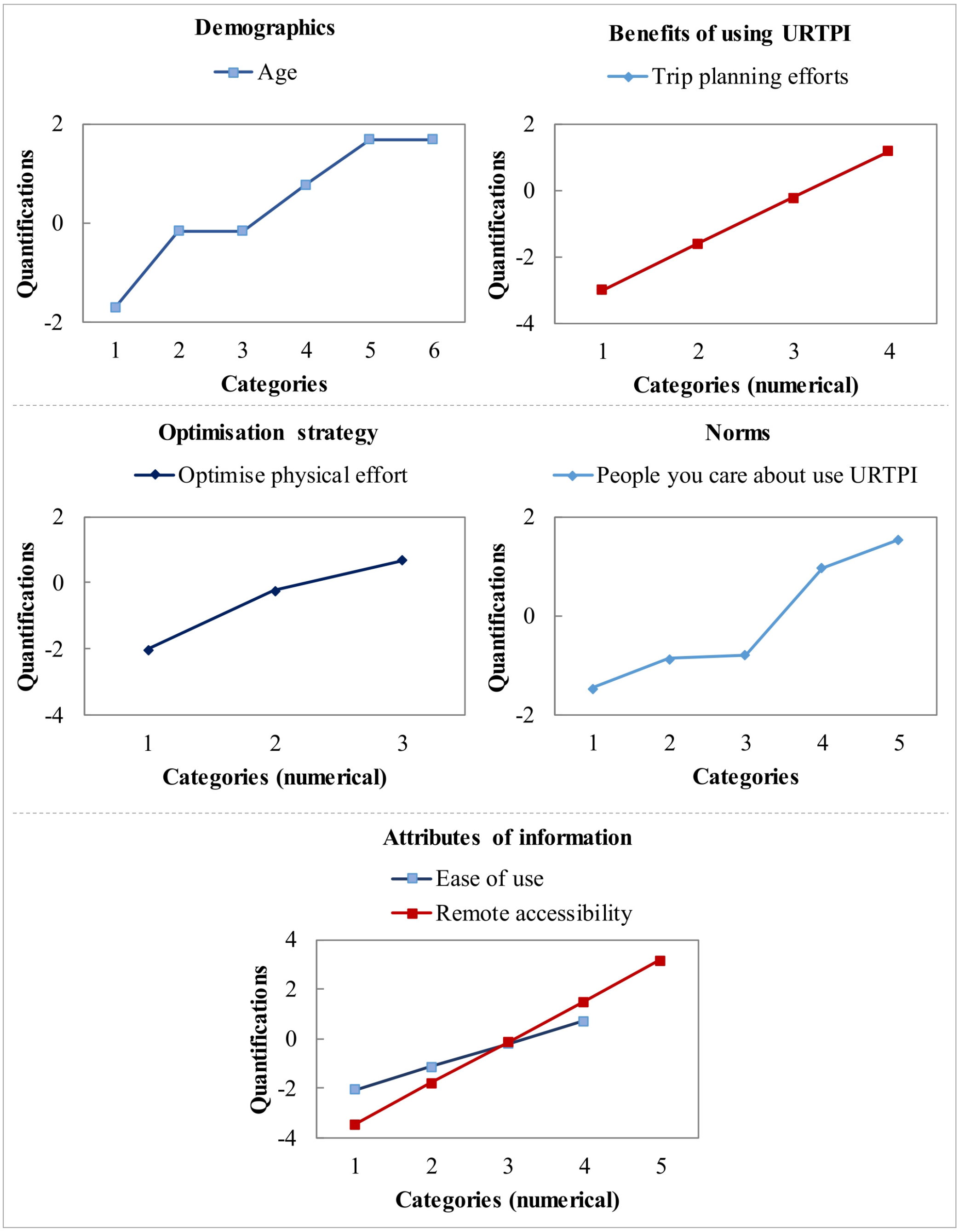


Figure K.1 Factors affecting the frequency of use of URTPI: CATREG plots

Factors Affecting the Importance of Contents of Information

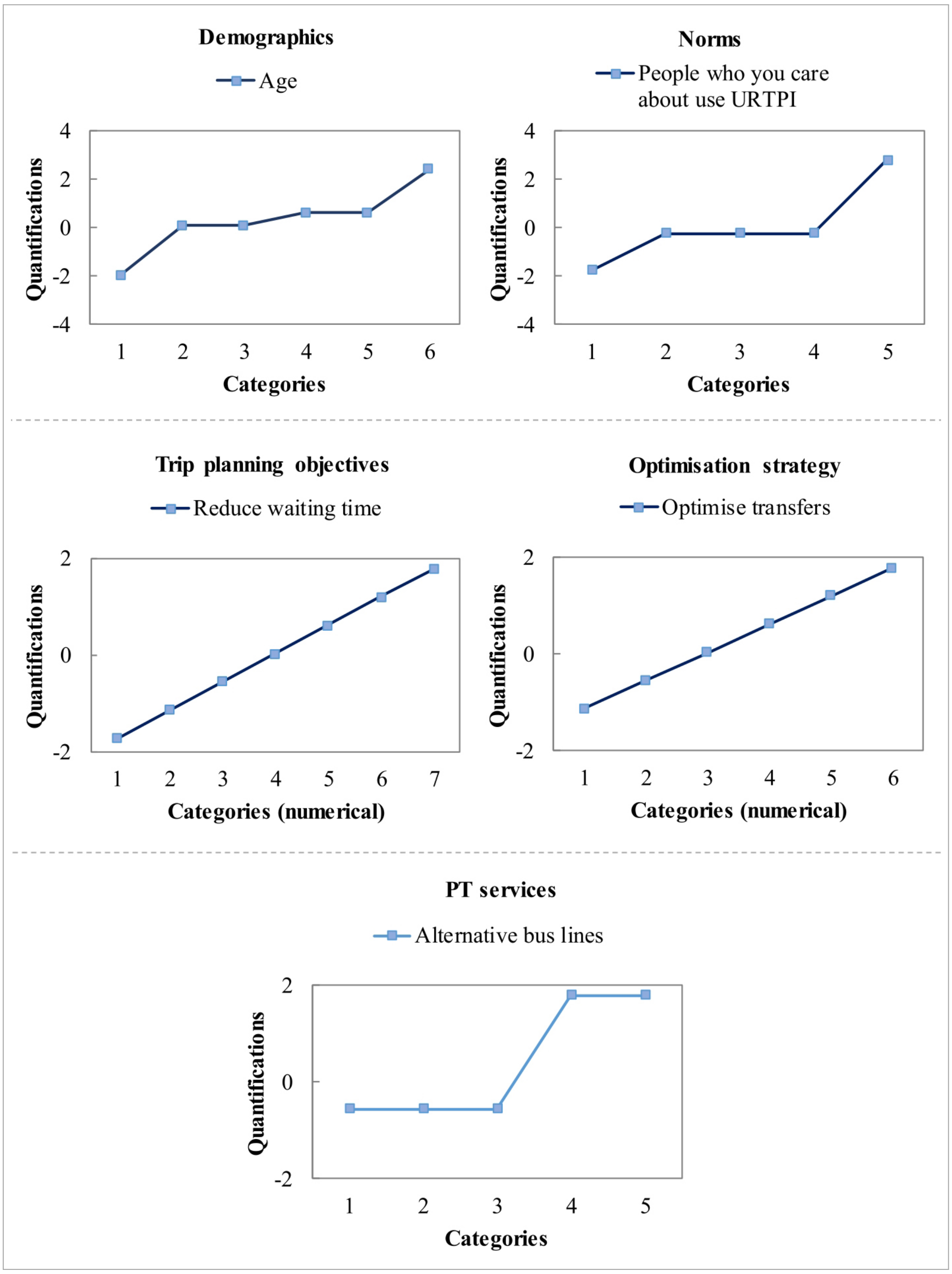


Figure K.2 Factors affecting the importance of *Bus arrival time*: CATREG plots

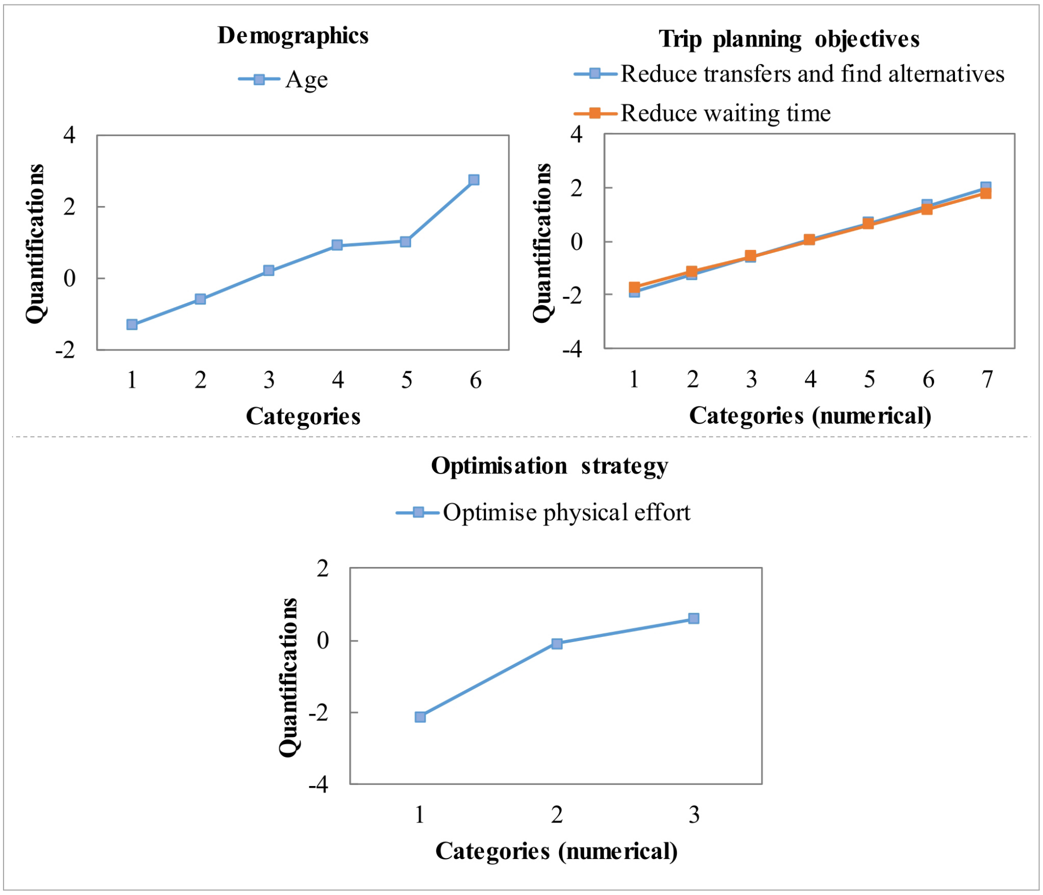


Figure K.3 Factors affecting the importance of *ETA*: CATREG plots

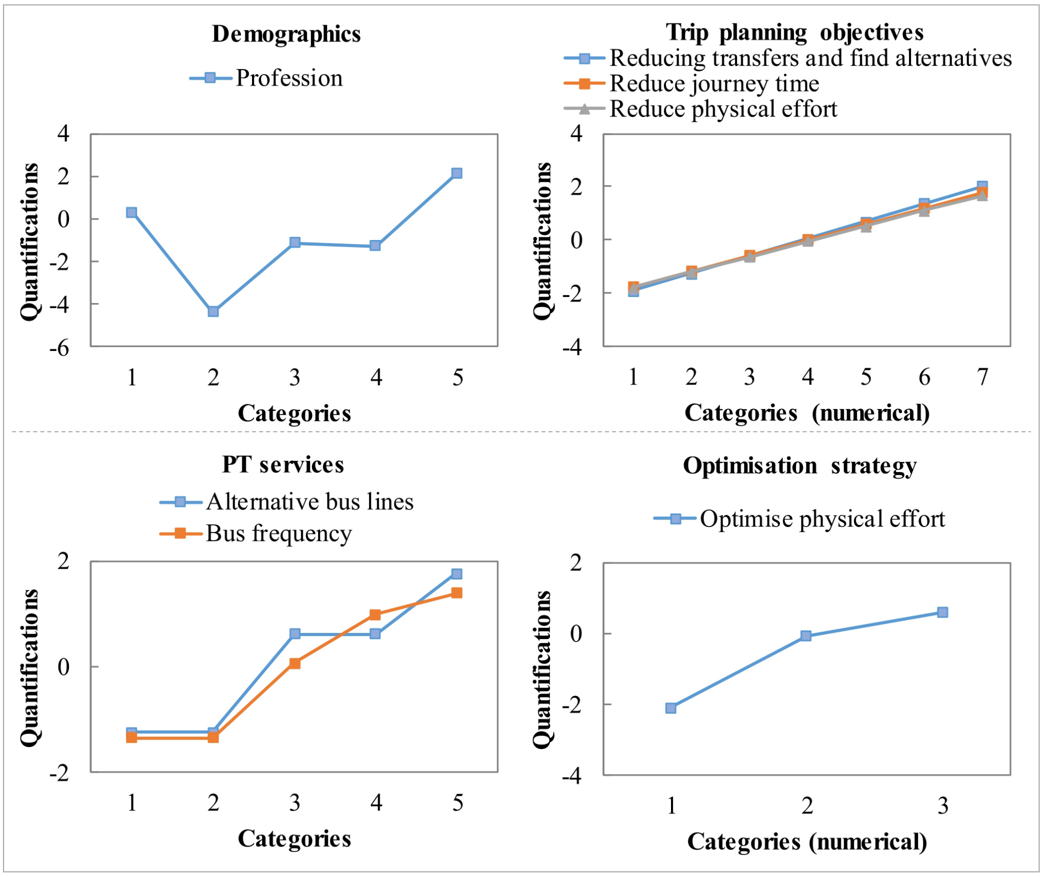


Figure K.4 Factors affecting the importance of *Journey plan*: CATREG plots

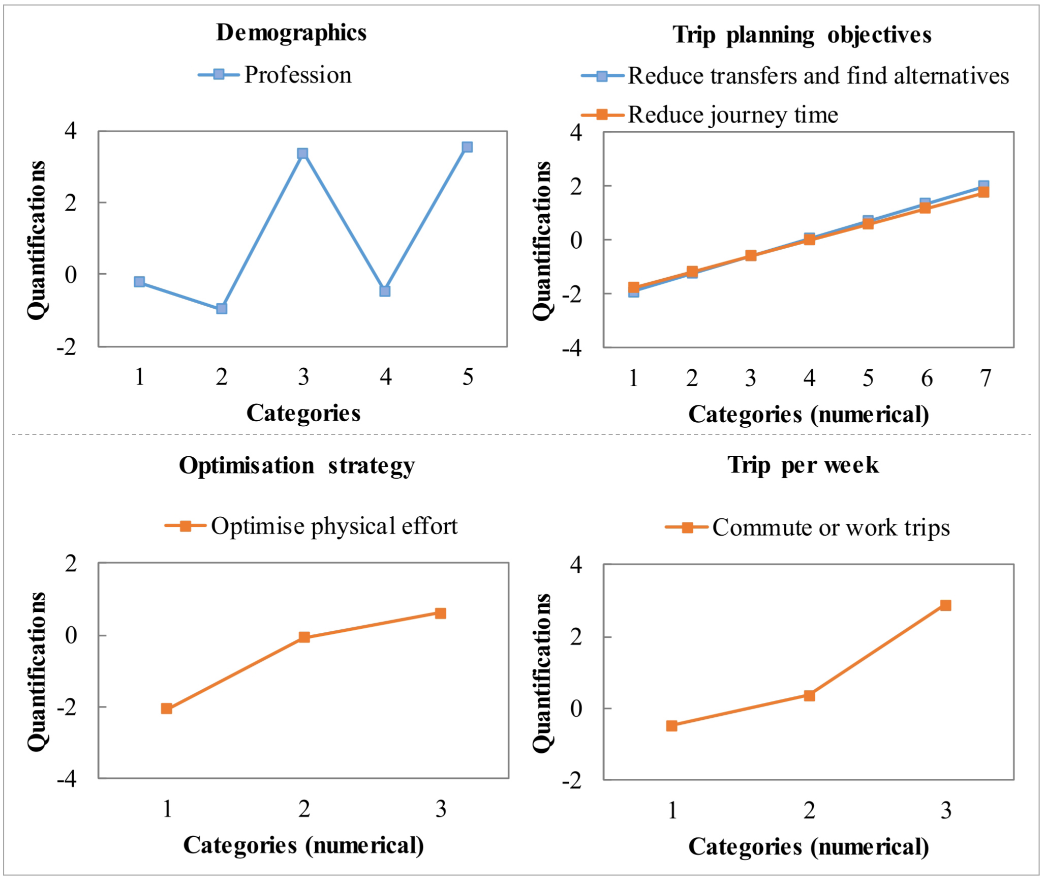


Figure K.5 Factors affecting the importance of *Transfer to other services*

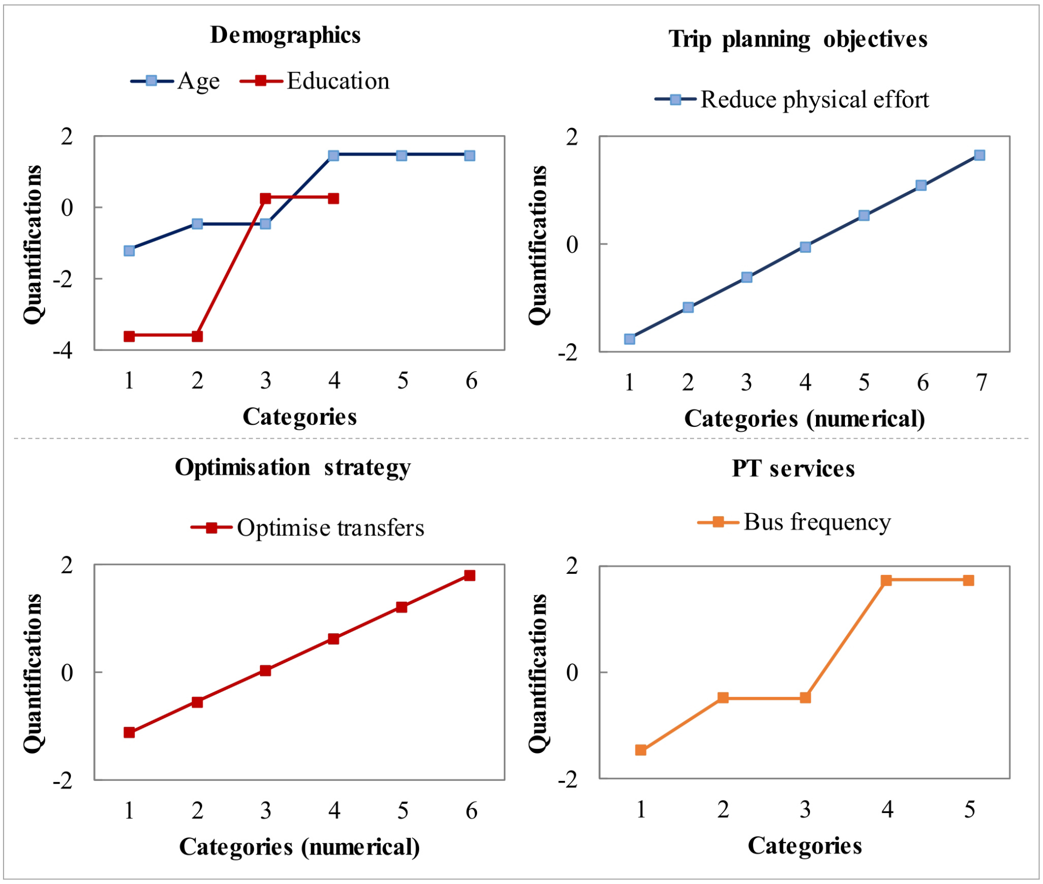


Figure K.6 Factors affecting the importance of *Bus route map*: CATREG plots

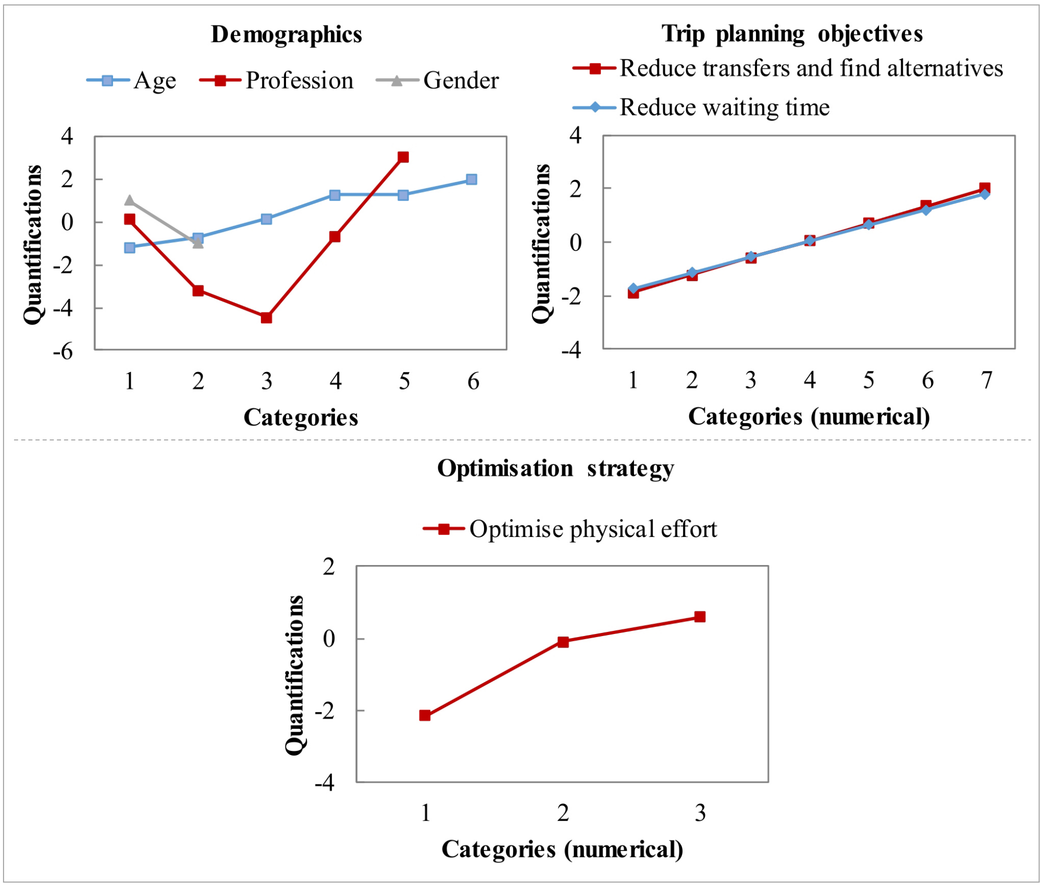


Figure K.7 Factors affecting the importance of *Bus stop location*: CATREG plots

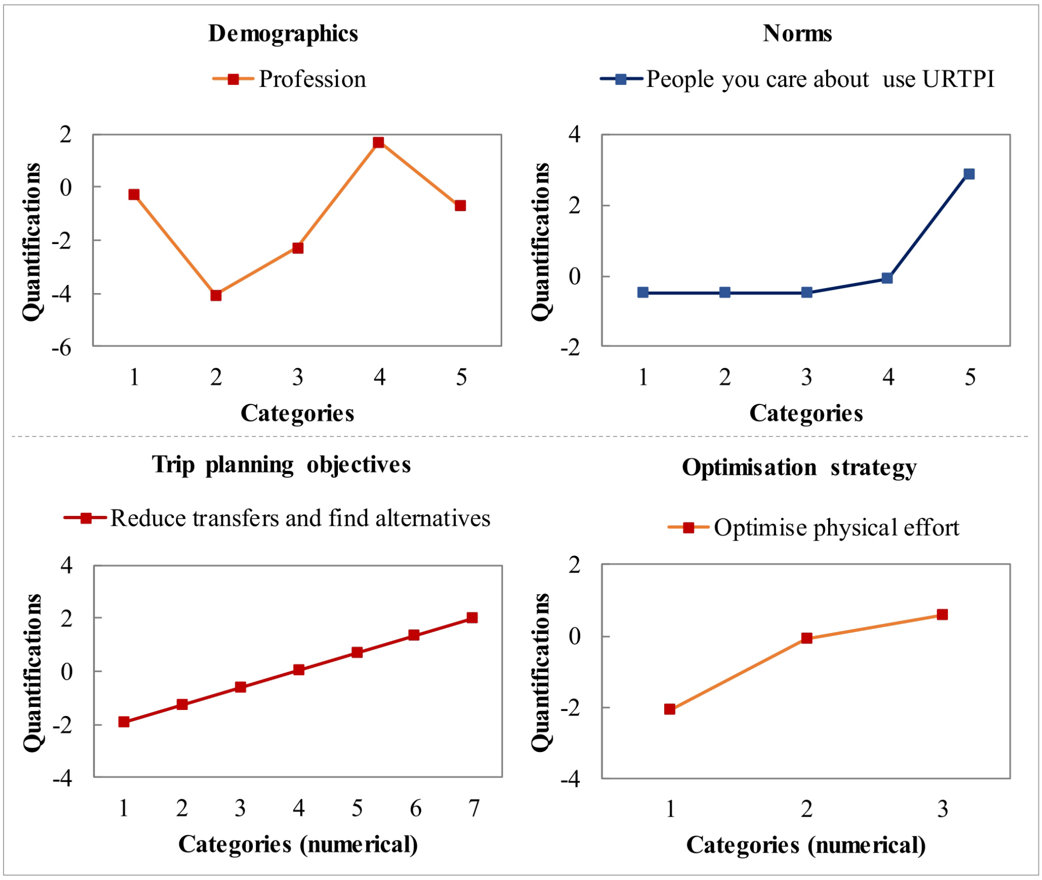


Figure K.8 Factors affecting the importance of *Walking distance*: CATREG plots

Factors Affecting Passengers' Choices

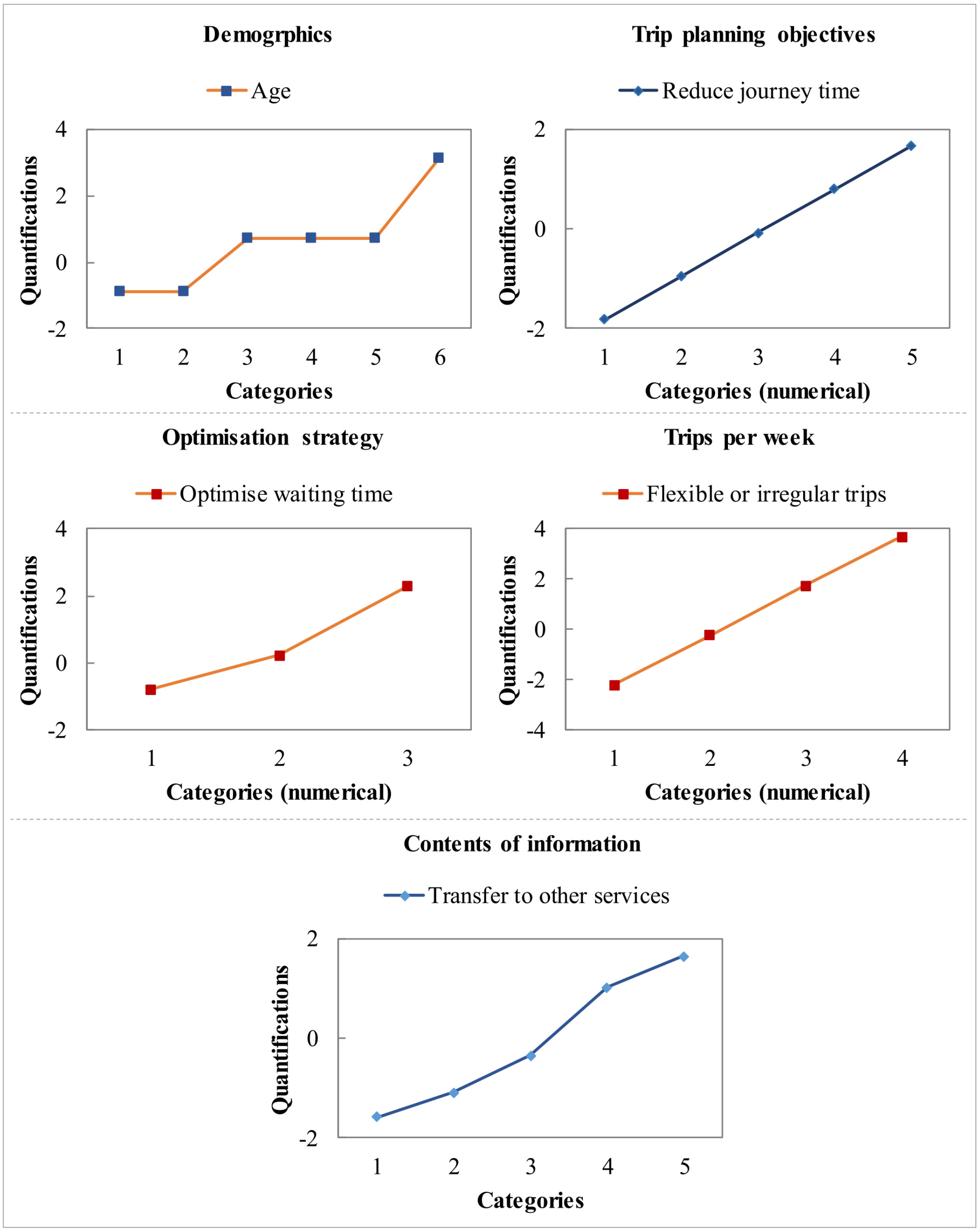


Figure K.9 Factors affecting change of *Departure stop*: CATREG plots

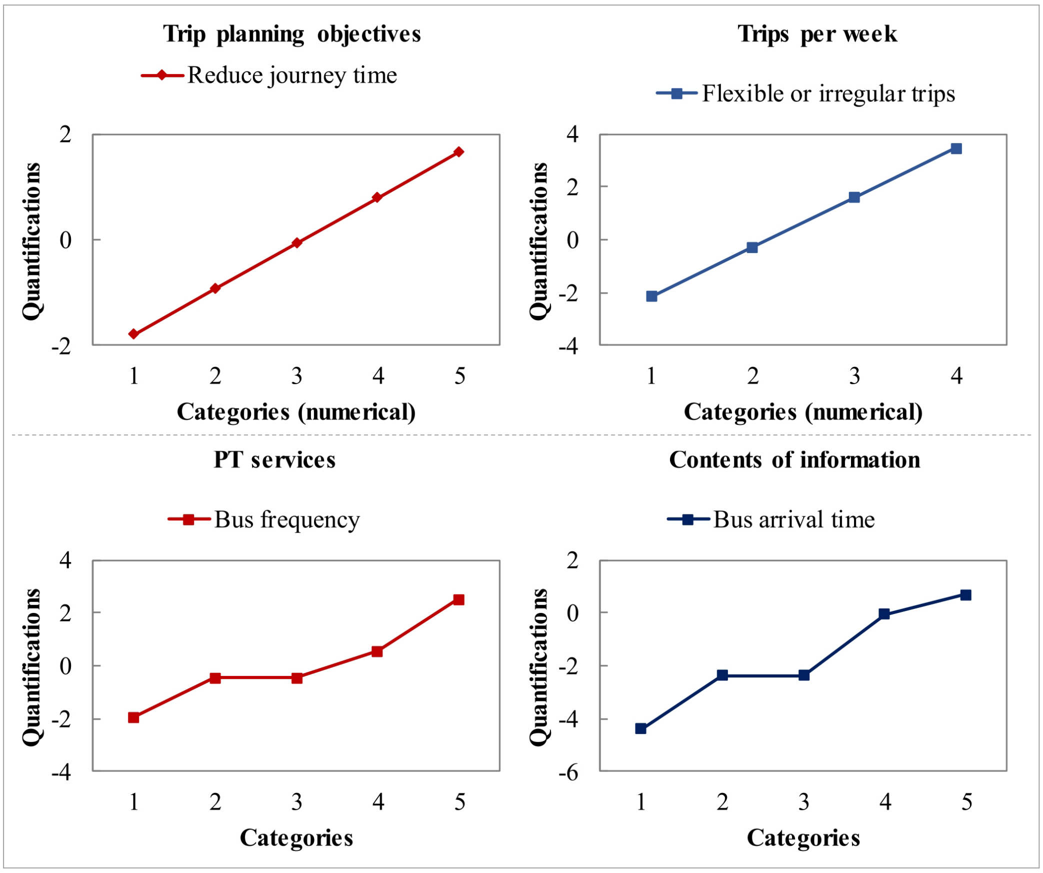


Figure K.10 Factors affecting change in *Time of departure*: CATREG plots

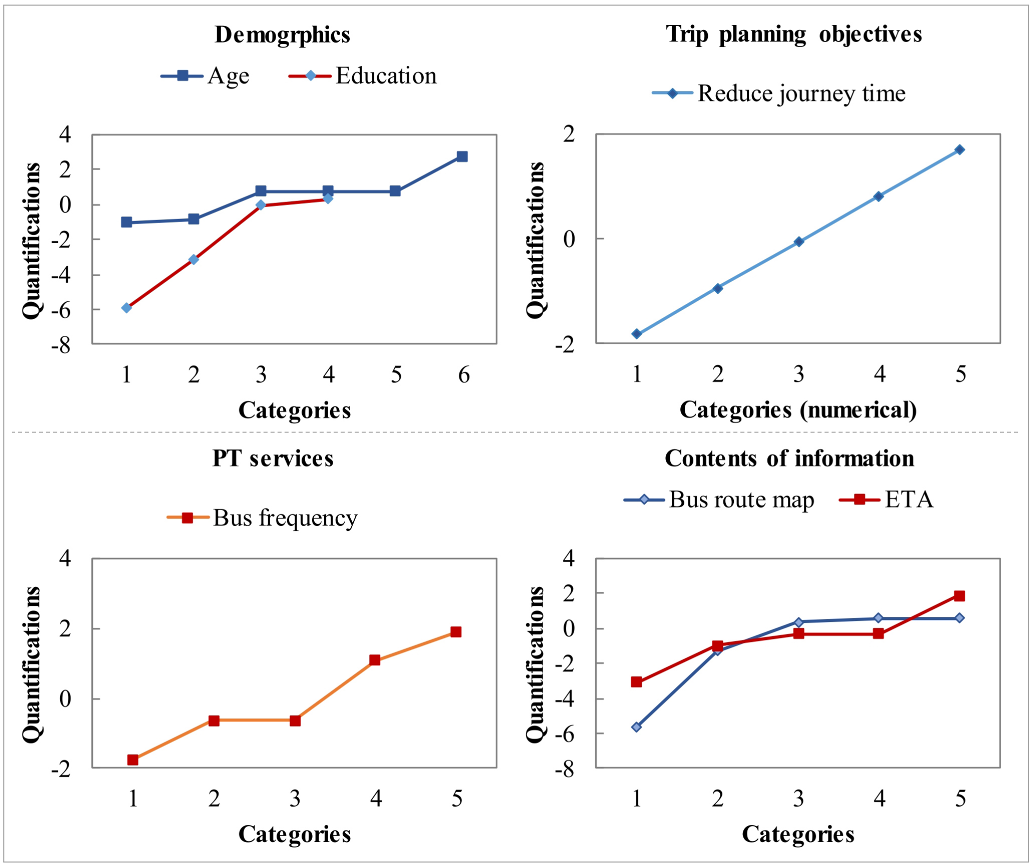


Figure K.11 Factors affecting change of *Bus line*: CATREG plots

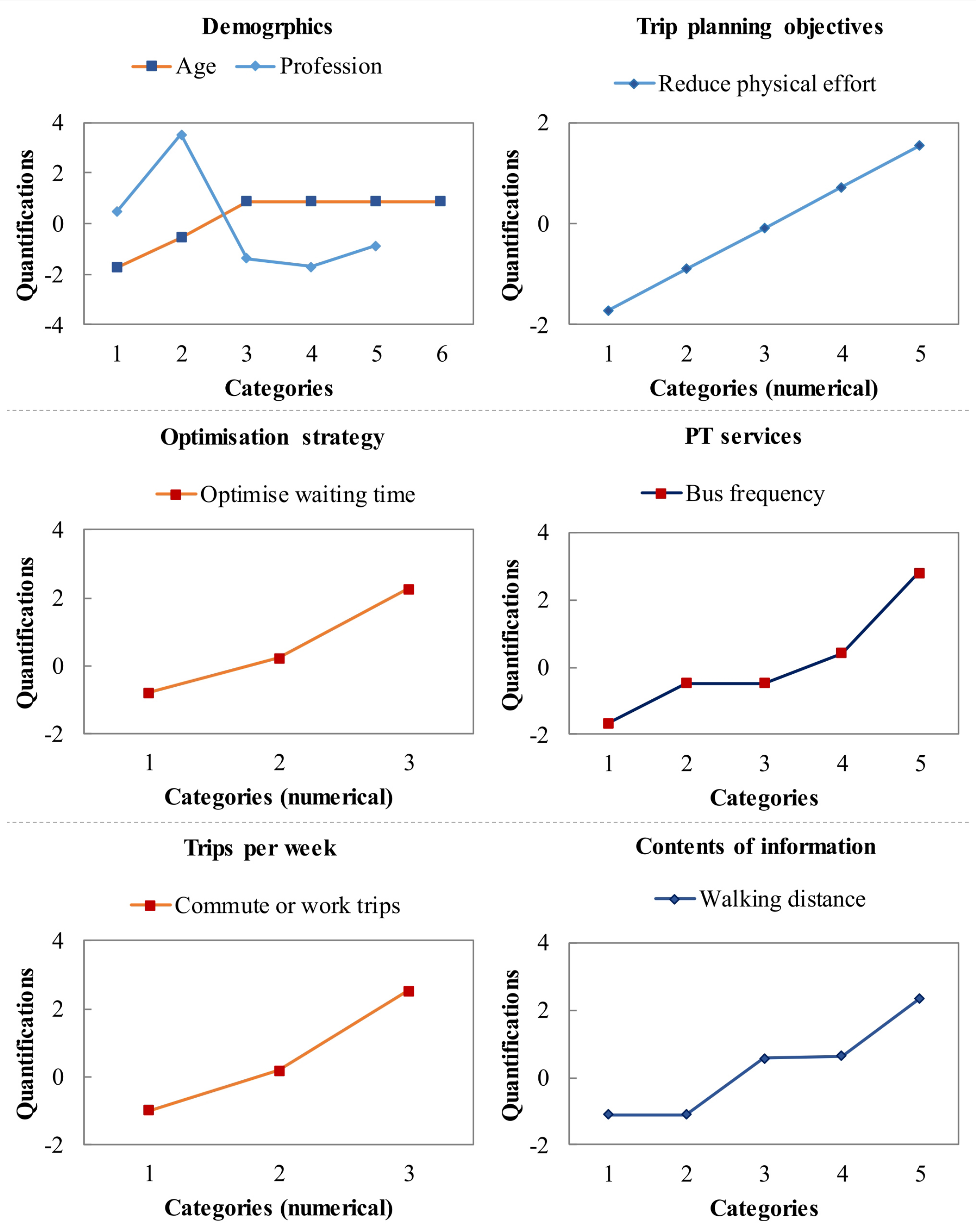


Figure K.12 Factors affecting change of *Alighting stop*: CATREG plots

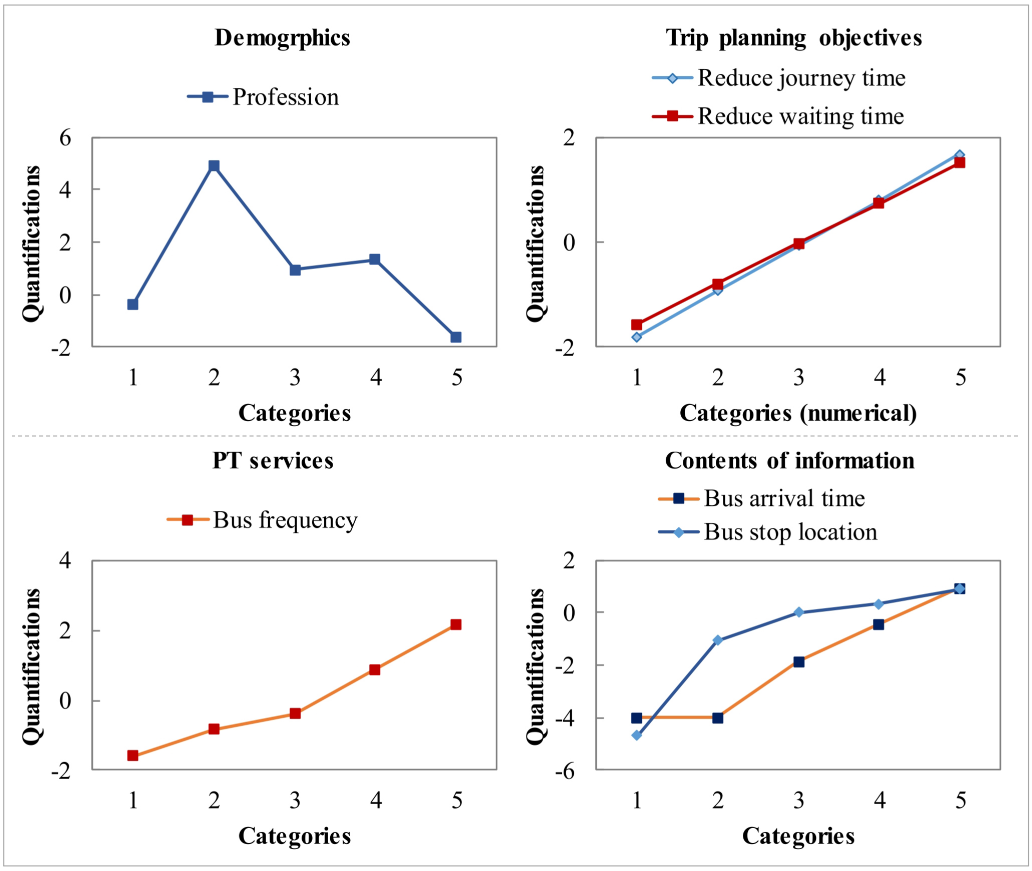


Figure K.13 Factors affecting change of *Boarding time*: CATREG plots